O P E R A T I O N   a n d   S E R V I C E   M A N U A L

MDC–260
Film Deposition Controller

IPN 622800 Rev. E

INFICON

OPERATION and SERVICE MANUAL

MDC-260
Film Deposition Controller

IPN 622800 Rev. E

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Revision D July 2007
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General Safety Warning

⚠️ **WARNING**

All standard safety procedures associated with the safe handling of electrical equipment must be observed. Always disconnect power when working inside the controller. Only properly trained personnel should attempt to service the instrument.

INFICON

**DECLARATION
OF
CONFORMITY**

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

**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:	MDC-260 Thin Film Deposition Controller, including the SO-100 Oscillator Package.
Applicable Directives:	73/23/EEC as amended by 93/68/EEC (LVD)
	89/336/EEC as amended by 93/68/EEC (EMC)
	2002/95/EC (RoHS)
Applicable Standards:	EN 61010-1:2001 (Safety)
	EN 61326-1:1997/A1:1998/A2:2001, Class A: Emissions per Table 3
	Immunity per Table A.1
	Due to the classification of this product it is currently exempt from the RoHS directive.
CE Implementation Date:	October 1, 2007
Authorized Representative:	Duane H. Wright
	Quality Assurance Manager, ISS INFICON Inc.

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

10/01/07

Warranty

INFICON warrants the product to be free of functional defects in material and workmanship and that it will perform in accordance with its published specification for a period of (twenty-four) 24 months.

The foregoing warranty is subject to the condition that the product be properly operated in accordance with instructions provided by INFICON or has not been subjected to improper installation or abuse, misuse, negligence, accident, corrosion, or damage during shipment.

Purchaser's sole and exclusive remedy under the above warranty is limited to, at INFICON's option, repair or replacement of defective equipment or return to purchaser of the original purchase price. Transportation charges must be prepaid and upon examination by INFICON the equipment must be found not to comply with the above warranty. In the event that INFICON elects to refund the purchase price, the equipment shall be the property of INFICON.

This warranty is in lieu of all other warranties, expressed or implied and constitutes fulfillment of all of INFICON's liabilities to the purchaser. INFICON does not warrant that the product can be used for any particular purpose other than that covered by the applicable specifications. INFICON assumes no liability in any event, for consequential damages, for anticipated or lost profits, incidental damage of loss of time or other losses incurred by the purchaser or third party in connection with products covered by this warranty or otherwise.

SAFETY PRECAUTION AND PREPARATION FOR USE

Input Power Requirements
The MDC-260 Thin Film Controller can be set to operate one of the following line voltages: 100, 120, 200, or 240 VAC at line frequency of 50 or 60 Hz. Maximum power consumption is 25 watts. See Section 8.3.3 for instruction on selecting line voltage.

Power Entry Module
The AC (alternating current) power entry module, located in the rear panel of the MDC-260, provides connection to the power source and a protective ground. It also holds the fuses and the voltage selection wheel.

Power Cord

WARNING: *To avoid electrical shock, always connect the power cord to an AC outlet which has a proper protective ground.*

The MDC-260 comes with a detachable, three-wire power cord for connection to a power source with protective ground.

The MDC-260 chassis is connected to the power ground to protect against electrical shock. Always connect to an AC outlet which has a properly connected protective ground. If necessary, or when in doubt, consult a certified electrician.

Grounding
A grounding lug is located on the rear panel, near the power entry module. Use heavy ground wire, wire braid, or copper strap of #12 AWG or larger to connect this grounding lug directly to a facility protective earth ground to provide additional protection against electrical shock.

Line Fuses
There are two 5 x 20 mm fuses mounted inside the power entry module. They are accessible via the snap-in cover. Replace with the correct fuse rating: IEC T Type (Slow), 4/10 A, 250 VAC. Refer to Section 8.3.3 for instruction to replace the fuse.

Power Switch

WARNING: *Do NOT use the power switch as a disconnecting device; disconnect the power cord from the power entry module to fully remove hazardous voltage from inside the MDC-260.*

The power switch is located on the front lower left of the MDC-260. Pressing the switch will toggle the controller on or off. The MDC-260 is off when the LCD and all of the LEDs behind the operating keys are off. However, turning the power switch off does not fully remove the AC power from inside the unit. Always disconnect the power cord from the power entry module to fully remove AC power from inside the unit.

SAFETY TERMS AND SYMBOLS

Terms Used in This Manual

WARNING. *Warning statements identify conditions or practices that could result in personnel injuries or loss of life.*

CAUTION. *Caution statements identify conditions or practices that could result in damage to the MDC-260 or other property.*

NOTE. *Note statements identify a sensitive or irreversible procedure. Proceed with caution.*

Terms Used on the MDC-260

DANGER indicates and injury hazard immediately accessible as you read the marking.

WARNING indicates an injury hazard not immediately accessible as you read the marking.

CAUTION indicates a hazard to the MDC-260 or other property.

Symbols Used on the Product and in the Manual

DANGER
Hazardous Voltage

ATTENTION
Refer to Manual

Protective Ground
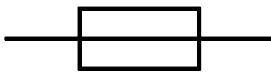
FUSE
Refer to Manual for
Instruction

AC
Alternating Current

POWER
On/Off Switch

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1. GENERAL DESCRIPTION

1.1 PURPOSE

The MDC-260 is a full-featured deposition controller which can provide automatic control of single or multi-layer film deposition in either a production or development environment. The MDC-260 will improve predictability and repeatability of deposited film characteristics through dependable digital control.

The MDC-260 makes programming and operation easy with an easy to use menu-driven user interface and a large graphic LCD for displaying important run-time information and graphs. The plain-English programming interface offers unmatched simplicity and control of all processes, materials, inputs, outputs and actions.

1.2 FEATURES

The MDC-260 incorporates numerous features which are economically justifiable as a result of rapid advances in semiconductor technology and the advent of low cost microprocessors.

1.2.1 AMPLE PROGRAM STORAGE

The MDC-260 is capable of storing up to 10 processes, 250 layer definitions and 8 complete material definitions. Once a program is entered it will be maintained in internal Flash Memory indefinitely (for a minimum of 100 years) without external power.

1.2.2 DYNAMIC MEASUREMENT UPDATE RATE

Measurement is dynamically adjusted from 0.5 to 10 Hz for optimum resolution and control.

1.2.3 SUPERIOR COLOR GRAPHICS DISPLAY

The MDC-260 features a 240x64 pixel color LCD graphics display allowing real-time graphing of important process information such as rate, rate deviation, thickness and power.

1.2.4 PROGRAM SECURITY

To assure the integrity of stored programs, the MDC-260 incorporates view/edit passwords to guard against unauthorized program changes.

1.2.5 DESIGNED FOR UNATTENDED OPERATION

The MDC-260 has been designed for truly automatic operation and toward this end incorporates extensive internal monitoring and overriding abort circuitry to minimize the possibility of damage in the event of a failure or other problem in the total deposition system. In addition there are attention, alert and alarm signals with adjustable volume for trouble and routine operator call.

1.2.6   FAIL SAFE ABORTS

In the event of an MDC-260 failure, as evidenced by unsatisfactory internal checks, the MDC-260 will abort the process and shut off all outputs. In addition to the internal checks, the MDC-260 also provides user enabled aborts on excessive rate control error or crystal failure.

1.2.7   ABORT STATUS RETENTION

In the event that the MDC-260 does abort during the deposition process, pertinent information is stored at the time of abort. More importantly, the process can be easily resumed once the problem is corrected without re-programming.

1.2.8   RUN COMPLETION ON CRYSTAL FAILURE

The extensive monitoring and abort functions are designed to protect the system and/or process from serious and hopefully infrequent malfunctions of the deposition system. A condition which need not cause an abort is the condition of crystal failure. The MDC-260 can be set to abort upon crystal failure or run to completion using a backup crystal or time/power method.

1.2.9   POWERFUL SYSTEM INTERFACE

Fully programmable discrete inputs and outputs permit the MDC-260 to be easily interfaced into deposition systems controlling the most complex processes. Also, source control outputs are fully isolated avoiding ground loop problems. The MDC-260 also supports input from an optical monitor for optical termination of film thickness.

1.2.10   POWER SUPPLY NOISE TOLERANCE

Integral RFI filter and large energy storage capacitors will tolerate high levels of power supply noise and power interruptions of 700 ms or less without effect.

1.2.11   INTERNATIONAL STANDARD POWER CONNECTOR

The power connector is internationally approved and meets IEC (International Electrotechnical Commission) standards. It allows selection of input power voltages ranging from 100 to 240 volts at a frequency of 50 or 60 Hz and includes an integral RFI filter.

1.3   SPECIFICATIONS

1.3.1   MEASUREMENT

Frequency Resolution	0.03 Hz @ 6.0 MHz
Mass Resolution	0.375 ng/cm^2
Thickness Accuracy	0.5% + 1 count
Measurement Update Rate	Dynamically adjusted, 0.5 to 10 Hz
Display Update Rate	10 Hz
Sensor Crystal Frequency	2.5, 3, 5, 6, 9, 10 MHz

1.3.2   DISPLAY

Thickness Display	Autoranging: 0.000 to 999.9 KÅ
Rate Display	Autoranging: 0.0 to 999 Å/sec
Power Display	0.0 to 99.9%
Time Display	0 to 9:59:59 H:MM:SS
Crystal Health	0-99 %
Layer Number	1 to 250
Graphics Display	240X64 Color LCD with CCFL backlighting
Color Schemes	4 built-in color presets

1.3.3   COMMUNICATION

Protocol	USB 1.1
Driver	Microsoft Windows driver included

1.3.4   PROGRAM STORAGE CAPACITY

Process	10 (user definable)
Layer	250 (user definable)
Material	8 (user definable)

1.3.5   PROCESS PARAMETERS

Process Name	12 character string
View/Run Password	4 character string
Edit Password	4 character string
Layer# 1 to 250	Thickness, material name

1.3.6   MATERIAL PARAMETERS

Material Name	10 character string
Sensor #	1 to 2
Crystal #	1 to 16
Source #	1 to 2
Pocket #	1 to 16
Density	0.80 to 99.9 gm/cm^3
Acoustic Impedance	0.50 to 59.9 gm/cm^2 sec
Tooling Factor	10.0 to 499.9%
Proportional Gain	0.00 to 9999
Integral Time Constant	0 to 99.9 sec
Derivative Time Constant	0 to 99.9 sec
Rise to Soak Time	0 to 9:59:59 H:MM:SS
Soak Power	0 to 99%
Soak Time	0 to 9:59:59
Rise to Predeposit Time	0 to 9:59:59
Predeposit Power	0 to 99.9%
Predeposit Time	0 to 9:59:59
Rate Establish Time	0 to 60 sec
Rate Establish Error *	0 to 99.9%
Deposition Rate (#1, #2*, #3*)	00.0 to 999.9 Å/sec
Ramp (#1, #2*) Start Thickness	0 to 100% [100% = Ramp Disabled]
Ramp (#1*, #2*) Stop Thickness	0 to 100%
Time Setpoint	0 to 9:59:59
Ramp to Feed Time	0 to 9:59:59
Feed Power	0 to 99.9%
Feed Time	0 to 9:59:59
Ramp to Idle Time	0 to 9:59:59
Idle Power	0 to 99.9%
Maximum Power	0 to 99.9%
Power Alarm Delay	0 to 99 sec
Minimum Power	0 to 99.9%
Rate Deviation Attention	0 to 99.9%
Rate Deviation Alarm	0 to 99.9%
Rate Deviation Abort	0 to 99.9%
Sample Dwell %	0 to 100%
Sample Period *	0:01:00 to 9:59:59
Crystal Fail	Switch, Time Power, Halt, Abort
Backup Sensor #	1 to 2
Backup Crystal #	1 to 16
Backup Tooling Factor	10.0 to 499.9%
Material Password	4 character string

* These options are made available based on the settings of surrounding parameters, and will not appear if their value is not needed.

The MDC-260 also has a built in material library that contains many common material names along with their density and acoustic impedance values.

1.3.7 INPUT/OUTPUT CAPABILITY

Sensor Inputs	2 BNC inputs
Source Outputs	2 fully isolated, 2.5, 5, 10 volts @ 20 ma. 0.002% resolution
Discrete Inputs	8 fully programmable inputs, user selectable ground true (Passive) or 12 to 120 volt AC/DC (Active).
Discrete Outputs	8 fully programmable outputs, SPST relay, 120VA, 2A max.
Abort Output	1 SPST Relay, 120VA, 2A max.
Remote Power Handset	Front panel, RJH jack
USB 1.1 Communication	USB "B" connectors on both front and rear panel

1.3.8 SENSOR PARAMETERS

Number of Crystals	1 to 16
Shutter Relay Type	Normally open, normally closed, dual, or none
Position Control	Manual, direct, BCD, or individual
Position Drive	Up, down, Fast, inline, single step, or double step
Feedback Type	Individual, BCD, single home, in position, or no feedback
Rotator Delay	0 to 99 sec

1.3.9   SOURCE PARAMETERS

Number of Pockets	1 to 16
Shutter Relay Type	Normally open, normally closed, or none.
Shutter Delay	0.0 to 9.9 sec
Position Control	Manual, direct, BCD, or individual
Position Drive	Up, down, Fast, inline, single step, or double step
Feedback Type	Individual, BCD, single home, in position, or no feedback
Rotator Delay	0 to 99 sec
Source Voltage Range	2.5, 5, 10 volts

1.3.10   UTILITY SETUP PARAMETER

Crystal Frequency	2.5, 3, 5, 6, 9, 10 MHz
Simulate Mode	On/Off
USB Interface Address	1 to 32
Attention Volume	0 to 10
Alert Volume	0 to 10
Alarm Volume	0 to 10

1.3.11   OTHERS

Input Power Requirements	100, 120, 200, 240 VAC; 50/60 Hz; 25 watts
Fuse Rating	IEC T-Type (Slow), 4/10 A, 250 V
Operating Temperature Range	0 to 50°C
Physical Size	Rack-mount configuration (with ears) 10.4" wide x 3.5" high x 9.7" deep Desktop configuration (with feet) 8.5" wide x 4.2" high x 9.7" deep

1.4   ACCESSORIES

The table below lists the most commonly used accessories. Refer to the Price List for more accessories and other products.

Part Number	Description
611200	DCM-250 V2.0
179220	Remote Power Handset
123200-5	SH-102 Sensor Head, cables, and carousel of 10 each 6MHz Gold SC-101 sensor crystals
123213	BSH-150 Single Bakeable Sensor Head with 2-3/4 innch Conflat® Flange.
150212	ASF-140 Adjustable Single Sensor with 1 inch Feedthrough Combo.
124201-4	SO-100 Oscillator with 6" and 10' BNC Cables.
621201	VPLO-6 Vacuum Phase-Lock Oscillator with 6" and 10' BNC Cables.
130200-2	IF-111 Instrument Feedthrough, 1" O-Ring with 1 electrical connector and dual 3/16" water tubes.
130204-2	IF-276 Instrumentation Feedthrough, 2 3/4" Conflat® Flange seal with 1 electrical connector and dual 3/16" water tubes.
150902	SF-120 Combination Sensor Head, Feedthrough, Cables, Crystals and Oscillator.
123204-1	Internal Coax Cable 30".
123204-2	Internal Coax Cable 60".
124202-1	BNC Cable Assembly 10'.
124202-2	BNC Cable Assembly 20'
124204	BNC Cable Assembly 6".
103220	SC-101 Carousel of 10 each 6MHz gold sensor crystals.
103221	SC-102 Carousel of 10 each 6MHz silver sensor crystals.

2. FRONT PANEL DISPLAYS AND CONTROLS

Using the front panel is the most direct method of accessing the MDC-260. Both the programmer and the operator will find it beneficial to become familiar with it.

2.1 GRAPHIC LCD DISPLAY

All programming and status information is shown through the central color LCD. This section lists the available screens. These screens are grouped in three distinctive areas: Programming screens, Graph screen, and Status screens. For detailed descriptions of the different programming and status screens, refer to Section 4 and 5.

2.1.1 PROGRAMMING SCREENS (MENUS)

Pressing the Program key at any time will cause the MDC-260 to return to the main programming mode. In this mode, the user has the ability to make changes to any parameter settings. Upon power up, the LCD display automatically reverts to the last viewed status screen.

2.1.2 RUN-TIME GRAPHS

There are four graphs that may be displayed to show the progress of a deposition process. Pressing the Graph key scrolls through the four available graphs: Rate, Power, Thickness and Rate Deviation. The graphs automatically adjust the time axis as the deposition proceeds.

2.1.3 STATUS SCREENS

Pressing the Status key scrolls through the four available screens of run-time data (Status Screens). Each shows a different aspect of the current process. All of the parameters are updated ten times per second unless the controller is in the Abort mode.

2.1.3.1 MAIN RUN SCREEN

The Main Run Screen is a useful data screen which displays the most pertinent run-time information in large, easy-to-read numbers. The data shown specifically applies to the **active** Source/Sensor combination and the **active** process.

2.1.3.2 SOURCE/SENSOR STATUS SCREEN

The Source/Sensor Status Screen presents run-time data concerning both sources and sensors. Also, from this view, the Pocket #, Sensor # or Crystal # may be changed.

2.1.3.3 INPUT/OUTPUT STATUS SCREEN

The Input/Output Status Screen shows the state of all of the external inputs and output.

2.1.3.4 ACTIVE LAYER PARAMETER UPDATE SCREEN

The Active Layer Parameter Update screen displays a set of parameters of the current active. It allows the user to quickly change these values, if needed, to fine-tune the run, without having to go into the Edit Material Definition screen. This screen is only available during a process.

2.1.3.5 POSITION CONTROL SCREEN

This screen allows the user to easily switch to a desired pocket or crystal in order to replace the material or crystal. The Position Control Screen is only available when the controller is in idle (not in process or abort state).

2.2   OPERATING CONTROLS

Normal operation of the MDC-260 is controlled by three viewing-mode keys (Status, Graph, and Program) and six action keys (Manual, Start, Abort, Reset, Zero and Shutter). Except for Zero, each of the action keys is equipped with an LED to indicate the controller's status.

2.2.1   STATUS KEY

Pressing the Status key will bring up one of the four run-time status screens. Repeatedly pressing the key will cycle through the different status screens. Refer to Section 5 for a detailed description of the viewing modes.

2.2.2   GRAPH KEY
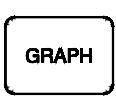
Pressing the Graph key will bring up one of the four run-time graph screens. Repeatedly pressing the key will cycle through the different graph screens. Refer to Section 5 for a detailed description of the viewing modes.

2.2.3   PROGRAM KEY

Pressing the Program key return the controller into Programming Mode, which allows the operator to adjust settings and enter program parameters. The last viewed programming screen will appear immediately (If a programming screen is already shown, this key has no effect.) This key is also used in conjunction with the Up and Down Arrow keys to adjust the contrast of the LCD . If the screen background is too bright, press and hold the Program and the down arrow keys until the text is easy to read. If the screen background is too dark and the text cannot be seen, press and hold the Program and the up arrow keys. Refer to Section 5 for a detailed description of the viewing modes.

2.2.4 MANUAL KEY

This key is used to toggle Manual Mode on and off. A red light behind this key indicates the controller is in manual power control mode. This mode may be selected at any time providing that the controller is not in Abort mode. The Manual mode indicates that the source control voltage output for the active source is being controlled through the Remote Power Handset. (The active source is set by the active material's Source parameter).

In the Manual mode the control voltage remains constant unless incremented up or down by means of the Remote Power Handset. At entry into the Manual mode, the power is left at the last value prior to entry and is thereafter modified only through the Remote Power Handset. Exit from the manual mode is accomplished by means of the Manual or Reset key.

The MDC-260 can also be aborted through the Remote Power Handset. This abort feature is active whether or not MDC-260 is in the manual mode.

2.2.5   START KEY

The Start key starts a process, starts a layer, or resumes an aborted process. A green light behind this key indicates the controller is in process. When this key is pressed the first time a list of stored processes is displayed in the LCD window. You simply scroll the cursor on to the desired process and press Start again to start the process.

2.2.6   ABORT KEY

The Abort key drives the MDC-260 into the Abort mode. All source powers are set to zero and discrete outputs are set to inactive state. A red light behind this key indicates the controller is in the abort mode.

2.2.7   RESET KEY

The Reset key is used to clear the controller from Abort mode and put it into the Ready mode. A yellow light behind this key indicates a Ready mode. The Reset key is inactive during the In Process mode so that a premature exit from the In Process mode requires an abort.

CAUTION: *Once a process is reset, it cannot be resumed. Consequently, don't reset an aborted process if you want to resume it once the problem is cleared.*

2.2.8   ZERO KEY

Pressing the Zero key causes the thickness display to go to zero. This key is active at all times and if pressed during the deposit state will result in a film thicker than that desired by an amount equal to the thickness displayed at the time the display was zeroed.

2.2.9   SHUTTER KEY

This key is used to manually open and close all source shutters. The red light is illuminated when the active source shutter relay is closed. This key is only active when the controller is in the Process Ready mode.

2.2.10   ARROW KEYS

The arrow keys are used to navigate through the programming and setup menu structure. These keys will auto-repeat if they are held down for more than half a second.
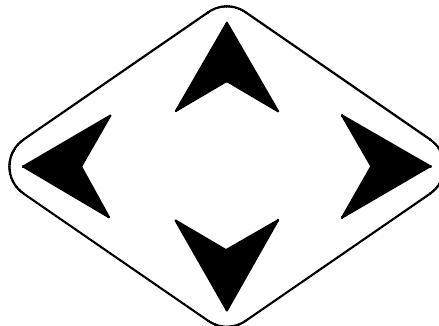
Figure 2-1 Arrow Keys

2.2.11   ALPHANUMERIC KEYPAD

The alphanumeric keyboard is used to edit controller parameters. Refer to Section 4 for details on enter new parameter values
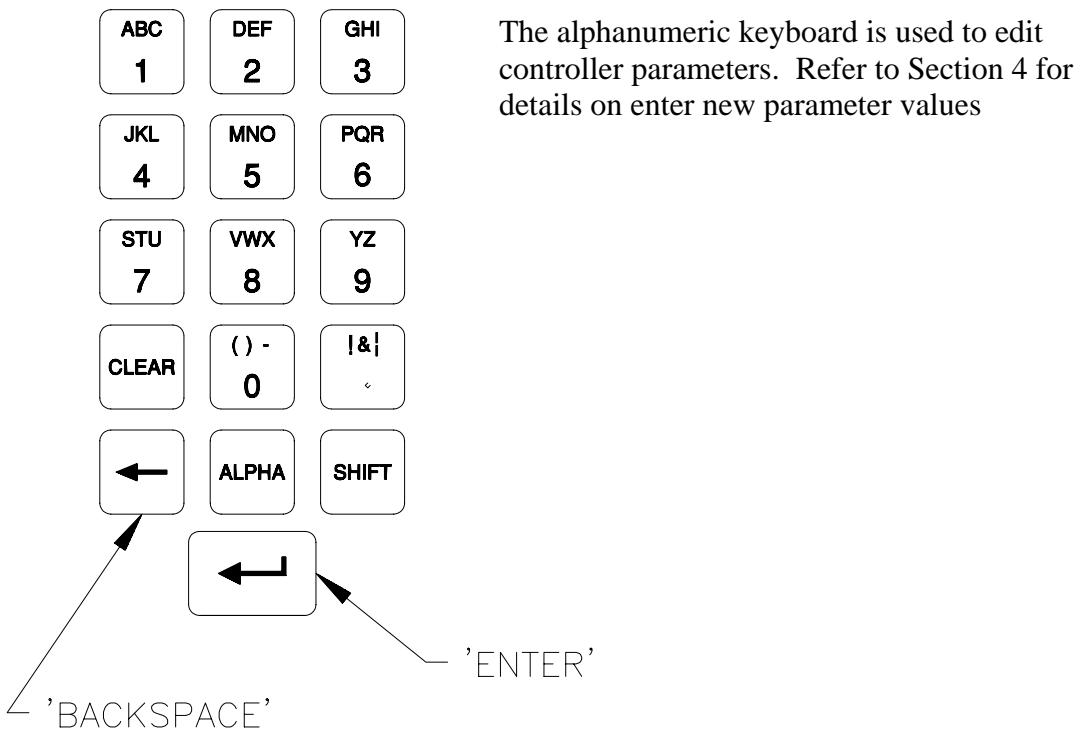
Figure 2-2 Alphanumeric Keypad

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3. BENCH CHECKOUT & INSPECTION

3.1 INSPECTION

Your MDC-260 was released to the carrier in good condition and properly packed. It is essential to all concerned that the contents of the shipment be carefully examined when unpacked to assure that no damage occurred in transit. Check the material received against the packing list to be certain that all elements are accounted for. Items included with your controller are:

> 1 MDC-260 Deposition Controller
> 1 Operation and Service Manual
> 1 Power cord
> 1 Source cable (4 pin mini DIN connector)
> 1 Discrete I/O connector kit (37P D shell)

In addition, you may have ordered one or more of the accessories listed in Section 1.4. If there is evidence of loss or damage:

a) Notify the carrier or the carrier agent to request inspection of the loss or damage claimed.
b) Keep the shipping containers until it is determined whether or not they are needed to return the equipment to INFICON.

3.2 COLD POWER UP

When external power is initially supplied (a "cold" power up), the unit will run a series of tests and initialize all program data. The LCD will show the controller Sign-on screen with its configuration information. See Figure 5-1. The unit will stay in this state until a key is pressed, at which time the LCD display will return to the last viewed screen prior to loss of power.

3.3 WARM POWER UP

Pressing the front-panel "Power" key does not completely remove power from the system, but rather puts the MDC-260 into a power-saving "Stand-by Mode". Pressing the key again wakes up the MDC-260 (a "warm" power up) and resumes whatever operation was in process when the unit was disabled.

3.4 SAMPLE PROGRAM

The sample program listed below is included in the MDC-260 memory at the time of shipment. It can be used to evaluate the controller by running it in Simulate Mode. Follow instructions in Section 4 to navigate through the menu structure. Check the controller parameter values against the sample program for discrepancy and change if necessary. Note also, if the source or sensor configuration has been changed during familiarization with the controller programming, appropriate source and sensor parameter values also need to be retained for the sample program to run correctly.

3.4.1   MATERIAL #1 PARAMETERS

Material Name	Cr
Sensor #	1
Crystal #	1
Source #	1
Pocket #	1
Density	07.20 gm/cm^3
Acoustic Impedance	28.95 gm/cm^2 sec
Tooling Factor	100%
Proportional gain	2400
Integral Time constant	99.9 seconds
Derivative Time constant	0.00 seconds
Rise to Soak Time	0:00:10
Soak Power	5 %
Soak Time	0:00:10
Rise to Predeposit Time	0:00:10
Predeposit Power	9.5 %
Predeposit Time	0:00:05
Rate Establish Time	0 seconds
Deposition Rate #1	10.0 Å/second
Ramp #1 Start Thickness	100 % (No Rate Ramps)
Time Setpoint	0:00:00
Ramp to Feed Time	0:00:05
Feed Power	7 %
Feed Time	0:00:10
Ramp to Idle Time	0
Idle Power	0
Maximum Power	20 %
Power Alarm Delay	5 seconds
Minimum Power	0 %
Rate Deviation Attention	0 %
Rate Deviation Alarm	0 %
Rate Deviation Abort	0 %
Sample Dwell %	100 % (Continuous Sampling)
Crystal Fail	TimePwr
Backup Sensor #	1
Backup Crystal #	1
Backup Tooling Factor	100 %
Material Password	0000

3.4.2 MATERIAL #2 PARAMETERS

Material Name	Au
Sensor #	1
Crystal #	1
Source #	1
Pocket #	2
Density	19.30 gm/cm^3
Acoustic Impedance	23.18 gm/cm^2 sec
Tooling Factor	100 %
Proportional gain	5000
Integral Time constant	99.9 seconds
Derivative Time constant	0.00 seconds
Rise to Soak Time	0:00:05
Soak Power	25 %
Soak Time	0:00:05
Rise to Predeposit Time	0:00:05
Predeposit Power	37.5 %
Predeposit Time	0:00:10
Rate Establish Time	0 sec
Deposition Rate #1	20.0 Å/sec
Ramp #1 Start Thickness	100% (No Rate Ramps)
Time Setpoint	0:00:00
Ramp to Feed Time	0:00:05
Feed Power	10 %
Feed Time	0:00:10
Ramp to Idle Time	0
Idle Power	0
Maximum Power	50 %
Power Alarm Delay	5 seconds
Minimum Power	0 %
Rate Deviation Attention	0 %
Rate Deviation Alert	0 %
Rate Deviation Alarm	0 %
Sample Dwell %	100 % (Continuous Sampling)
Crystal Fail	TimePwr
Backup Sensor #	1
Backup Crystal #	1
Backup Tooling Factor	100 %
Material Password	0000

3.4.3   PROCESS PARAMETERS

Process Name	Layer No.	Thickness	Material
Sample	1	0.400 KÅ	Cr
	2	1.050 KÅ	Au

3.5   SIMULATE OPERATION

Testing the MDC-260 is best accomplished by checking its operation in the Simulate Mode. This mode can be selected by entering the following programming sequence: (Main Menu, Edit System Setup, Edit Utility Setup, Simulate Mode ON). After enabling Simulate Mode, you may run a process in Simulate Mode by pressing the Start key and selecting the process that you want to run.

Simulate Mode is identical to the Normal Mode except that the sensor inputs are simulated. For this reason, entry to the Simulate Mode will switch off the Crystal Failure message if it is flashing. No other difference between the Simulate Mode and the Normal Mode occurs until entry to the Deposit State.

3.6   MANUAL OPERATION

Manual Mode is selected by depressing the Manual key. The LED behind the key will light up indicating the controller is in Manual Mode.

The Manual Mode is identical to the Normal Mode in all respects except that source power for the active source is controlled only through the Remote Power Handset.

The Remote Power Handset has three push buttons (see Figure 3-1). Without any of the buttons depressed, the output power is maintained at its last value. Depressing the "POWER (+)" button will increase the power, depressing the "POWER (-)" button will decrease the power and depressing the "ABORT" button will put the controller into the Abort Mode.

The "ABORT" button on the handset is active whether or not the MDC-260 is in Manual Mode and therefore can be used as a remote "panic button".

The minimum increment by which the power is increased or decreased is 0.1%.
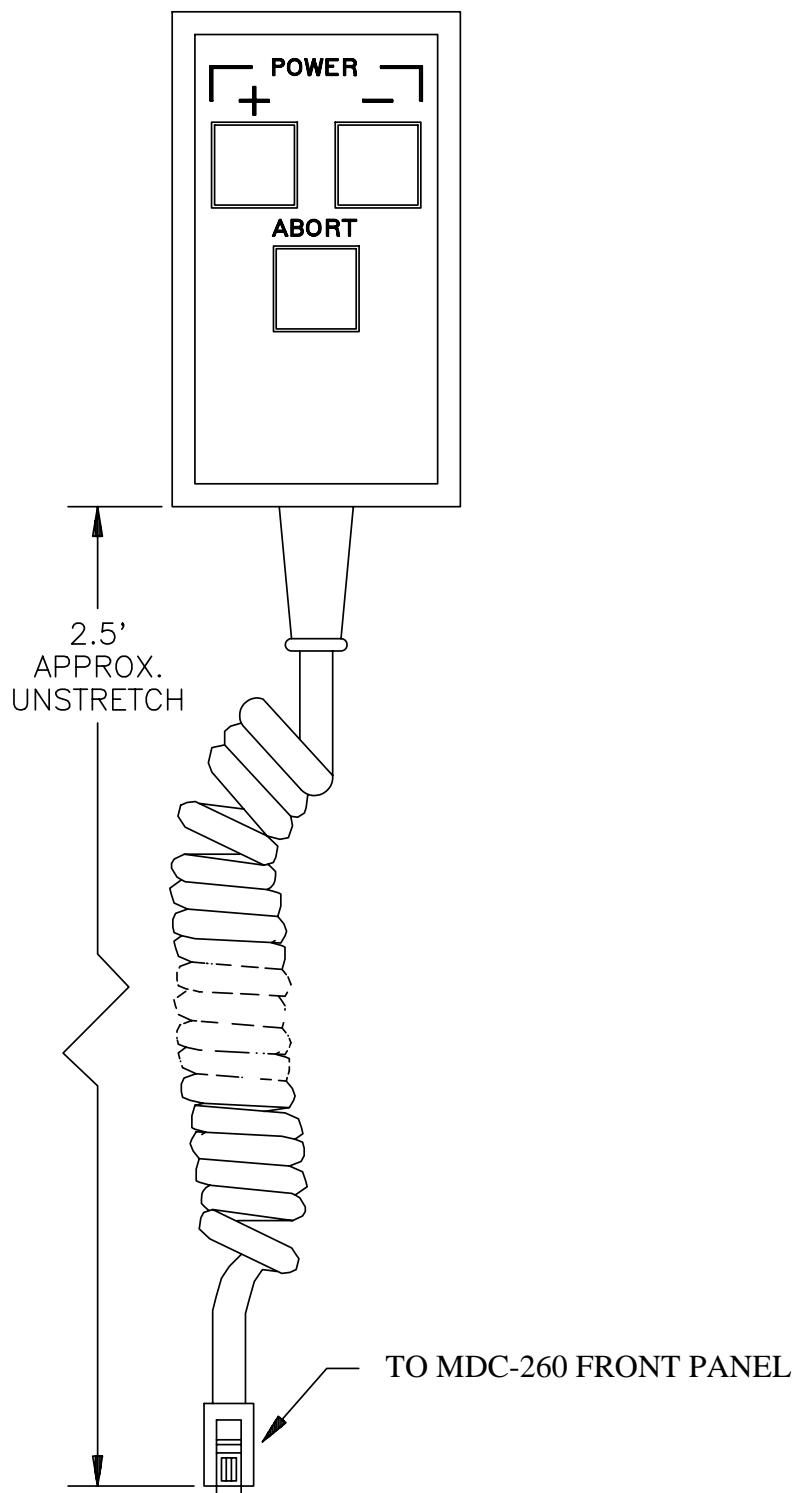
Figure 3-1 Remote Power Handset

4.   PROGRAMMING AND CONTROLLER SETUP

4.1   GENERAL

4.1.1   NAVIGATING THE MENU STRUCTURE

Before attempting to navigate the menu structure of the MDC-260 controller, please refer to Section 2 which provides a brief summary of the front-panel displays and key functions. A graphical menu structure is shown in Figure 16-2. Note that following a power-on ("cold" or "warm"), the LCD will begin at the last screen the unit was displaying when it was turned off.

This may be confusing until the full scope of the controller's capabilities are understood. However, as their names suggest, the Status, Graph and Program keys select the display of status screens, graph screens and programming screens, respectively. Also note that the last viewed screen for each type is remembered and will be displayed the next time that display type is selected.

```
                 Main Menu

          View/Edit Process
          View/Edit Material
          Edit System Setup

```
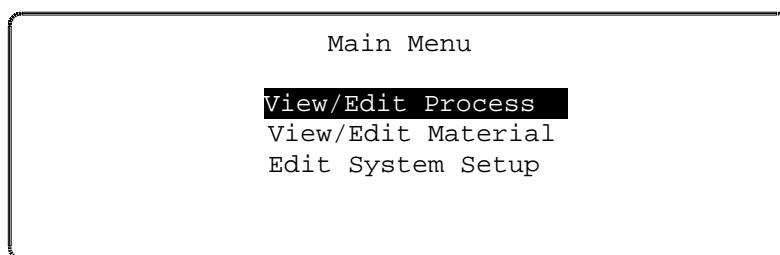
Figure 4-1 The Main Menu

Press the Program key to enter the programming mode. The programming screens can be visualized as a two-dimensional menu format. The Main Menu is visualized at the far left, with an increasing level of detail in the menus to the right. The Left and Right-arrow keys are used to move between menus and columns. The Up and Down-arrow keys are used to scroll through a list of parameters or options in each menu. To select a menu option, highlight it, then press either the Enter key or the Right-arrow key. This will present the next screen associated with the selected option**. Please note that holding the Left arrow key will always bring you back to the Main Menu screen no matter where you are in the menu structure.**

Each of the programming screens is described in detail later in this section.

4.1.2   ENTERING ALPHA CHARACTERS

To enter a name, press the key that contains the letter or character you wish to enter. Next, press the Alpha key to change the number to the first letter of that key. Keep pressing the Alpha key to get the desired letter. Upper/lower case can be toggled by pressing the Shift key. Once the desired letter is achieved, repeat the above procedure and enter the remainder of the name. Note that the 9 key contains characters "Y", "Z", and "space". Use this key to enter a space.

4.1.3 ENTERING TIME PARAMETERS

The MDC-260 expresses time in 24-hour h:mm:ss format. In programming a time parameter, the Decimal '.' key is used to separate hour, minute and second. Hence, 1:45:23 would be entered as "1.45.23" and 0:00:35 entered as "..35", followed by the Enter key.

4.1.4 COPYING AND DELETING

A 'process' is defined by one or more 'layers', and a layer requires a 'material' and a thickness definition. The MDC-260 has the capability of copying and deleting processes, layers, and materials. Except when copying a layer, procedures for copying and deleting a process, a layer and a material are the same. The difference when copying a layer is that layers are pushed-down to make space for the new layer, and move up when a layer is deleted.

To copy a process, position the cursor at the process to be copied, then press the 1 key. Next, move the cursor to the location where the process is to be copied and press Enter. The process will be copied to the new location with the same name. **If there is already a process name at the new location, it will be overwritten.** The copied process should be given a new name to avoid confusion. The same procedure applies when copying a material.

When copying a layer, the copied data will be positioned at the selected layer number. The data of the selected layer, and all following layers, will be pushed down one layer. Example, if a layer is copied onto Layer #4 location, the existing data in Layer #4 will be pushed to Layer #5, Layer #5 to Layer #6, etc., while the copied data is placed in Layer #4.

CAUTION: *Use below instruction carefully as deleted items are not recoverable.*

To delete a process or a material, move the cursor to the item and press the 0 key. A message will pop up asking for verification of the deletion, press 1 to confirm or 0 to cancel the deletion.

4.1.5 PASSWORD PROTECTION

NOTE: *The password protection is only meant to deter unsophisticated users. Be sure to record passwords, because if you forget a password it will not be possible to gain access to the protected item!*

Each Process has a View/Run password and an Edit password. Each Material has an Edit password. The three passwords protect against unauthorized operations. The passwords default to 0000, or no password protection, at the time of shipment. Refer to the descriptions below to set each password.

4.1.5.1 VIEW/RUN PROCESS PASSWORD

The View/Run password is required to view or run a process. To set this password, select View/Edit Process from the Main Menu, select the process from the Select Process screen. Move the cursor onto the View/Run password, type in your password (4-digit string), and then press the Enter key. A message will pop

up asking for verification to change the password. Press 1 to confirm and 0 to cancel the change. Each time you want to view or run this process, you will now be asked to enter the correct password. Note that the Edit Process password takes precedence over the View/Run password. If you know the Edit password, you can also view the process. Once a password other than 0000 has been installed, it will not be displayed unless re-entered.

4.1.5.2 EDIT PROCESS PASSWORD

The Edit process password is required to edit a process. To set this password, select View/Edit Process from the Main Menu, select the process from the Select Process screen. Move the cursor onto the Edit password, type in your password (4-digit string), then press the Enter key. A message will pop up asking for verification to change the password. Press 1 to confirm and 0 to cancel the change. Each time you want to edit this process, you will be asked to enter the correct password. Once a password other than 0000 has been installed, it will not be displayed unless re-entered.

4.1.5.3 EDIT MATERIAL PASSWORD

The Edit material password is required to edit a material. To set this password, select View/Edit Material from the Main Menu, select the material from the Select Material screen. Move the cursor down to the Material Password parameter, the last item in the list, type in your password (4 digit string), then press the Enter key. A message will pop up asking for verification to change the password. Press 1 to confirm and 0 to cancel the change. Each time you want to edit this material, you will be asked to enter the correct password. Once a password other than 0000 has been installed, it will not be displayed unless re-entered.

4.1.6   ADJUSTING LCD DISPLAY CONTRAST

The LCD display contrast can be adjusted by using the Program key in conjunction with the Up-arrow and Down-arrow keys. Hold down the Program key and press the Up-arrow key to increase the contrast. Likewise, hold down the Program key and press the Down-arrow key to decrease the contrast. Continue to adjust the contrast until a clear and comfortable setting is found.

4.1.7   SPECIAL FUNCTION KEY

The number 7 key on the alphanumeric keypad is used as a special function in certain screens. It can be used to toggle the time displayed on the Main Run Screen, or to toggle between thickness and frequency on the Source-Sensor Status Screen.

4.2   GETTING STARTED

This section is intended to help new users quickly program the MDC-260 for basic applications. The section gives the best programming sequence and lists programming examples. See DETAILED PROGRAMMING in section 4.3 for a complete programming description.

4.2.1 UTILITY SETUP

The only critical parameter in the Utility Setup is the Crystal Frequency parameter. This parameter must be set for the specific frequency crystals that you plan to use (2.5, 3.0, 5.0, 6.0, 9.0, 10.0 MHz).

The Simulate Mode parameter may also be useful in the initial setup and testing phase of the MDC-260. Simulate Mode provides a means of simulating deposition on the crystal. This mode is useful for testing the setup of the MDC-260 without having to deposit any material.

If you only are using one MDC-260, leave the USB Interface Address at 01. Numbers greater than 01 are used when multiple MDC-260's are connected to the same system.

4.2.2 SOURCE SETUP

When defining sources or sensors, the MDC-260 will automatically create the inputs and outputs necessary to complete the interface based on the parameter settings. Therefore, once the setup is complete, the user should review the inputs and outputs noting the pin assignments so that the proper connections can be made. Also note that the I/O pin assignments can be changed if necessary in the program input and output screens.

The following two items in the Source Setup are common to almost all types of sources and typically require definition:

Source Shutter - If the source has a shutter to be activated by the MDC-260 then the Shutter Relay Type parameter must be set to either N.O. (normally open) or N.C. (normally closed). The typical setting is N.O. which means that the relay will close to open the shutter.

Once defined, the MDC-260 will create a relay output called "SourceN Shutter" that should be connected to the shutter actuator. The shutter can be tested by pressing the Shutter key with the controller in the Process Ready state. When the red LED in the Shutter key is illuminated then all source shutters should be opened. When the shutter LED is off then all source shutters should be closed.

If the shutter actuator has a significant delay in opening and closing then set the Shutter Delay parameter equal to the delay.

Source Voltage - This parameter must be set to correspond to the input voltage range of the source power supply (0 to 2.5, 5.0 or 10.0 volts).

The settings of the rest of the source parameters are dependent on whether the source has one or more pockets (crucibles) and whether pocket selection is manual or automatic.

Single Pocket Source - If the source has only one pocket (single pocket E-beam gun, filament boat or sputtering source) then the remaining parameters can be left at their default values.

Multiple Pocket Source with Manual Position Control - For manual position control of a multiple pocket source, you need only set the Number of Pockets parameter to the correct number of pockets. Once set, a message will appear at the start of each layer instructing the operator to change Source #N to the required material.

Multiple Pocket Source with Automatic Position Control - There are two parameters requiring definition which are common to all the various types of position control. The first is the Number of Pockets parameter and the second is the Rotator Delay parameter. The Number of Pockets parameter is simply the number of pockets in the source. The Rotator Delay parameter defines the maximum amount of time allowed for the correct pocket to rotate into position. This should be set to the time it takes for the rotator to go from Pocket #1 all the way around to Pocket #1 again.

The settings of the three remaining parameters required for automatic pocket position control depends on the required type of position control and position feedback.

Position Control - The MDC-260 can be setup to either control the pocket position directly by interfacing to the rotator's actuator or indirectly by interfacing to a rotator controller.

Direct Control of Pocket Position - Direct control means that the MDC-260 will control the actuator (rotator motor, pneumatic valve, etc.) directly to get the desired pocket into position. For direct control first set the Control Parameter to Direct then select one of the following drive types and follow the instructions:

a. **Unidirectional Motor Drive -** The rotator drive motor can only turn in one direction. Select Up for the Drive parameter. A relay output will be created called "SourceN Drive Up" that should be connected between the rotator motor and power supply.

b. **Bi-directional Motor Drive -** The rotator motor can turn in either direction. Select Fast for the Drive parameter. Two relay outputs will be created. One called "SourceN Drive Up" and one called "SourceN Drive Dn". With this drive type, the MDC-260 will activate either the drive up or drive down outputs to rotate to the required pocket in the least amount of time.

    c. **Motor Driven Inline Source -** Select Inline for the Drive type parameter. Two relay outputs will be created. One called "SourceN Drive Up" and one called "SourceN Drive Dn". In this case the up output will be activated when going from the greatest pocket to pocket #1.

    d. **Unidirectional Pneumatic Drive -** Select Sngl Step or Dbl Step for the Drive parameter. A relay output will be created called "SourceN Drive Up" that should be connected between the rotator's pneumatic valve and power supply. With Sngl Step, the output will pulse once for one second to increment the rotator one position. With Dbl Step, the output will pulse twice for one second each to increment the rotator one position.

Indirect Control of Pocket Position - Indirect control means that the MDC-260 will indicate the desired pocket position to a pocket rotator controller through position select outputs. The Drive parameter selects between the two following indirect position output formats:

    a. **Individual -** With individual format, one output will be created for each pocket. So, if pocket 2 is the desired pocket, then the output "SourceN Pocket 2" will be true while all the other position outputs will be false.

    b. **BCD -** With BCD format , the MDC-260 will create from one to three outputs based on the number of pockets. For example, an eight pocket source would use three outputs. If pocket one is the desired pocket, all outputs will be false. If pocket four is the desired pocket, outputs one and two will be true and output three will be false.

Position Feedback - The last step in defining automatic control of a multi-pocket source is to select the pocket position feedback type. The MDC-260 has the following five types of position feedback available:

No Feedback - As the name implies, no position feedback is created for this type.

Individual - For this feedback type, one input is created for each pocket position in the source. The inputs are labeled "SourceN Pocket X". All inputs are normally false (open circuit) unless the respective pocket is in position then that input should be true (closed to ground). For example, a six pocket source would use six inputs. If pocket two was in position then all the inputs should be false except the input connected to "SourceN Pocket 2".

Individual position feedback is the most typical feedback type and is recommended if more than one type is available.

BCD - Binary Coded Decimal position feedback. This feedback type uses binary coding to indicate the pocket position. Inputs are numbered most significant bit first. For example, an eight pocket source would use three

inputs. With pocket one in position, all inputs will be false. With poctket four in position, inputs one and two will be true and input three will be false.

Single Home - Single home position feedback. This feedback type uses one input. The input is normally false (open circuit) and should go true (closed to ground) when pocket one is in position.

In Position - In position feedback. This feedback type uses one input. The input is normally false (open circuit) and should go true (closed to ground) when the desired pocket is in position.

4.2.3   SENSOR SETUP

The following examples demonstrate how the MDC-260 is setup to control the four basic types of crystal sensor heads available:

Single Crystal Sensor Head - No sensor parameters need to be changed for a single crystal sensor head.

Single Crystal Sensor Head with Shutter - For a single shuttered sensor head, set the Shutter Relay Type parameter to either N.O. (normally open) or N.C. (normally closed). The typical setting is normally open which means that the relay will close to open the shutter. A relay output called "SensorN Shutter" will be created that should be connected between the sensor shutter actuator and power supply.

Dual Crystal Sensor Head with Shutter - For a dual crystal shuttered sensor head, set the Shutter Relay Type parameter to Dual. A relay output called "DualSnsr1&2 Shtr" will be created that should be connected between the sensor shutter actuator and power supply.

Automatic crystal switching upon failure is enabled in the material menu by setting the Crystal Fail parameter to Switch and the Backup Sensor number to 2. Note that with the dual sensor head you define the sensor number that you would like to use, (or switch too) not the crystal number. The crystal number need only be defined when you are using a multiple crystal sensor head (sensor head with one BNC output and more than one crystal).

Multiple Crystal Sensor Head - The MDC-260 can be setup for either automatic or manual control of multiple crystal sensor heads.

   a. **Manual Crystal Position Control -** For manual crystal position control of a multiple crystal sensor head, set the Number of Crystals parameter to the correct number of crystals. Once set, a message will appear at the start of each layer instructing the operator to change Sensor N to the required crystal number.

   b. **Automatic Crystal Position Control -** There are two parameters requiring definition which are common to all the various types of multiple sensor heads. The first is the Number of Crystals parameter and the second is the Rotator Delay parameter. The Number of

Crystals parameter defines the number of crystals in the sensor head. The Rotator Delay parameter defines the maximum amount of time allowed for the correct crystal to rotate into position. This should be set to the time it takes for the rotator to go from Crystal #1 all the way around to Crystal #1 again.

The settings of the three remaining parameters required for automatic crystal position control depend on the type of position control and position feedback.

Position Control - The MDC-260 can be setup to either control the crystal position directly by interfacing to the rotator's actuator or indirectly by interfacing to a rotator controller.

Direct Control of Pocket Position - Direct control means that the MDC-260 will control the actuator (rotator motor, pneumatic valve, etc.) directly to get the desired crystal into position. For direct control, set the Control Parameter to Direct then select one of the following drive types and follow the instructions:

a. **Unidirectional Motor Drive -** Select Up for the Drive parameter. A relay output will be created called "SensorN Drive Up" that should be connected between the rotator motor and power supply.

b. **Bi-directional Motor Drive -** Select Fast for the Drive parameter. Two relay outputs will be created. One called "SensorN Drive Up" and one called "SensorN Drive Dn". With this drive type, the MDC-260 will activate either the drive up or drive down outputs to get to the required crystal in the least amount of time.

d. **Unidirectional Pneumatic Drive -** Select Sngl Step or Dbl Step for the Drive parameter. A relay output will be created called "SensorN Drive Up" that should be connected between the rotator's pneumatic valve and power supply. With Sngl Step, the output will pulse once for one second to increment the rotator one position. With Dbl Step, the output will pulse twice for one second each to increment the rotator one position.

Indirect Control of Crystal Position - Indirect control means that the MDC-260 will indicate the desired crystal position to a crystal rotator controller through position select outputs. . The Drive parameter selects between the two following indirect position output formats:

a. **Individual -** With individual format, one output will be created for each crystal. So, if crystal 2 is the desired crystal, then the output "SensorN Crystal2" will be true while all the other position outputs will be false.

b. **BCD -** With BCD format , the MDC-260 will create from one to three outputs based on the number of crystals. For example, an eight crystal sensor head will use three outputs. If crystal one is the desired crystal, all outputs will be false. If crystal four is the desired crystal, outputs one and two will be true and output three will be false.

4.2.3.1 EXAMPLE USING THE RSH-600 SIX CRYSTAL SENSOR HEAD

The following is a list of the sensor parameter settings required to control the RSH-600 six crystal sensor head.

Number of Crystals	-	6
Shutter Relay Type	-	None
Control	-	Direct
Drive	-	Sngl Step
Feedback Type	-	Indiv
Rotator Delay	-	30

With the above parameter settings, the MDC-260 will create six position feedback inputs called "SensorN CrystalX" where X ranges from 1 to 6 and one control output called SensorN Drive Up.

The inputs should be connected to the six position feedback pins on the RSH-600 sensor head. Pin #1 of connector J1 on the sensor head should be connected to the "SensorN Crystal1" input on the MDC-260. Pin #2 on the sensor head should be connected to "SensorN Crystal2" on the MDC-260 and so on. Pin #7 on the sensor head should be connected to pin #12 or any of the return pins when using the standard MDC-260 I/O board. When using the MDC-260 Active I/O board then pin #7 of the sensor head should be connected to one side of a 115VAC source. The other side of the 115VAC source should be connected to the other side of the six position feedback inputs on the MDC-260.

One pin from the SensorN Drive Up output should be connected to the 115 VAC voltage source and the other to J1. The remaining pin on J1 should connect to the other side of the 115 VAC power supply. In this configuration, combined with the "single step" drive type, whenever the MDC-260 needs to change crystals it will close the SensorN Drive Up output for one second. This completes the circuit applying the 115 VAC to the RSH-600.

4.2.4   INPUT, OUTPUT AND ACTION SETUP

The MDC-260's inputs, outputs and actions can be used to provide control for, or an interface to all sorts of vacuum system peripherals such as PLC system controllers, substrate heaters, planetary rotators, etc. If your system doesn't require any special interfacing or control then you can skip to the next section.

The following are a few examples of some typical uses for the MDC-260's programmable I/O's and actions.

Optical Monitor Termination - To setup the MDC-260 to terminate the deposit on a signal from an optical monitor, the first step is to program an input that will be connected to an output in the optical monitor. Go to the Program Inputs screen and select a blank input. Name the input "Optical Monitor" for future identification. Note the I/O card and the pin numbers of the input so you can later connect the input to the optical monitor.

Next, go to the Program Actions screen and select any action labeled "No Action". Press the right arrow key with the cursor on the action Name parameter and select the TerminateDeposit action. Move the cursor to the Conditions field and press the 0 key to add a condition. Move the cursor down to the Input condition type, press the right arrow key, move the cursor onto the "Optical Monitor" input and press enter. Press enter again to complete the condition string.

Now, the MDC-260 will terminate the deposit whenever the "Optical Monitor" input is set true by the optical monitor.

Substrate Heat Control - To create an output in the MDC-260 to switch on and off a substrate heat controller, first go to the Program Outputs screen and select a blank output. Name the output "Substrate Heat" for future identification. Note the I/O card number and the pin numbers of the output so you can later connect the output to the substrate heater controller.

Next, move the cursor onto the Conditions field and press the 0 key to add a condition. With the cursor on the State condition type, press the right arrow key and select the state in which you would like the heater to first turn on. If you would like the heater on during more than the one state, then press the 5 key to add an or "|" symbol then press 0 to add the next desired state. Repeat this process until all of the states requiring substrate heat have been added to the condition. For example, if you would like substrate heat to start in the Predeposit Hold state and continue through the Deposit 1 state then your condition string would look like this "Predeposit Hold|Deposit 1".

With the condition string completed, the MDC-260 will set this output true whenever it is in one of the selected states.

4.2.5 DISPLAY SETUP

The only parameter in the Display Setup menu that affects the controller's function is the Pause On Layer Complete parameter. This parameter determines whether or not the controller will pause at the completion of each layer. When set to Yes, the controller will stop at the end of each layer and wait for a Start key press before continuing. When set to No, the controller will immediately go to the next layer.

4.2.6   MATERIAL SETUP

The next step in the initial setup of the controller is to define the materials that you wish to deposit. Because of its many features, the MDC-260 has a long list of material parameters which at first can be overwhelming. Fortunately, the default settings of most parameters are such that the feature they define is disabled when left at the default. This section will list the material parameters typically set for all materials and the parameters which must be set to utilize the different features of the MDC-260. For a detailed description of any material parameter, go to Section 4.3.2.1.

The following is a list of the material parameters that are typically set when defining a new material:

Process Name - If you select a material from the default material library (press the right arrow key from the material name parameter and press enter on the desired material) then the density and acoustic impedance for that material will be entered automatically. If your material is not in the library then you must enter the name, density and acoustic impedance.

Source output and pocket number - Defines the source and pocket number of the source that the material will be deposited from.

Control loop parameters (Proportional Gain, Integral Time, Derivative Time). The default settings for these parameters are a good starting point.

Deposit Rate #1 - Defines the target deposit rate for the material.

Maximum Power - Defines the maximum deposit power for the material.

The above parameters are typically all that are needed to deposit the most basic materials. If no other features are required then the remaining parameters can be neglected. The following is a list of the more specialized features defined by the material parameters. All of the features are disabled by default.

4.2.6.1 POWER RAMPS

Power ramps are used for source material conditioning prior to and after the deposit states. A power ramp is defined by a ramp time, a "ramp-to" power level and a hold time before the next state. There are two power ramps available prior to and one after the deposit states. The first ramp prior to deposit is the Soak and the second is the Predeposit. If only one ramp is needed prior to deposit then you should use the predeposit ramp. The power ramp after the deposit states is called the Feed.

The parameters used to define the three power ramps are as follows:

Soak Power Ramp - Rise to Soak Time, Soak Power and Soak Time

Predeposit Power Ramp - Rise to Predeposit Time, Predeposit Power and Predeposit Time

Feed Power Ramp - Ramp to Feed Time, Feed Power and Feed Time

4.2.6.2 AUTOMATIC CRYSTAL SWITCHING

To enable automatic crystal switching upon failure, set the Backup Sensor, Backup Crystal, and its Tooling Factor parameters to define which Sensor/Crystal to switch to.

4.2.6.3 RATE ESTABLISH

The rate establish feature is used in critical processes where it is important to establish the correct deposition rate prior to opening the source shutter and depositing on the substrates.

⚠️ **NOTE:** *To use this feature, the sensor head must be mounted in such a way that it is in the material vapor stream with the source shutter either opened or closed.*

To enable this feature you must set the Rate Estab. Time to a positive value, then set the Rate Estab. Error parameter. The Rate Establish Time parameter sets the maximum time that the controller will attempt to keep the rate error within the Rate Estab. Error limit for a period of five seconds. If the rate error condition is meet within the allotted time then the controller will enter the deposit state. If not, then the process will be halted and a Rate Establish Error will be displayed.

4.2.6.4 RATE RAMPS

Rate ramping is typically used at the beginning of the deposition to ease the rate up slowly to prevent material spitting. Rate ramping is also used towards the end of the deposition to achieve a more accurate endpoint thickness. By slowing down the rate, the thickness overshoot caused by the delay of the shutter closing is diminished

The MDC-260 has two rate ramps available. A rate ramp is defined by a "Ramp Start" and "Ramp Stop" thickness (expressed as % of total deposit) and the target rate. For example, to setup the MDC-260 to deposit at 20Å/sec for 90% of the layer, then ramp down to 5 Å/sec over the last 10%, you would enter the following material parameters:

Deposit Rate #1 = 20Å/sec
Ramp #1 Start Thk = 90%
Ramp #1 Stop Thk = 100%
Deposit Rate #2 = 5Å/sec

The rate ramps are disabled by default with the Ramp Start and Ramp Stop Thicknesses set to 100% since 100% represents the end of deposition for the layer. The applicable parameters will become available for editing when the start/stop thicknesses are changed from 100%.

4.2.6.5 RATE SAMPLE MODE

The Rate Sample feature is designed for large deposition thicknesses where crystal life is a problem. By sampling the rate periodically to maintain rate control, then closing the sensor shutter with the rate and power level constant, a large deposition thickness can be achieved with one crystal.

To enable the rate sample feature, set the Sample Dwell % parameter to the percentage of time you wish the controller to sample the rate. Then set the Sample Period parameter to adjust how often the rate is sampled. For example, a Sample Period of 0:01:00 (one minute) and a Sample Dwell of 50% will sample the rate for 30 seconds then close the sensor shutter for 30 seconds (assuming it is depositing at the last measured rate). This cycle will repeat every one minute.

4.2.6.6 RATE DEVIATION ACTIONS

The MDC-260 provides three actions that can take place when rate deviation reaches various levels of severity. Each action may be assigned to a rate deviation amount (%). The assignable actions include an attention sound, an alarm sound and a process abort. The attention and alarm sounds are momentarily triggered meaning they will sound when the error is exceeded and clear when within the limit. The process will abort when the "Rate Deviation Abort" level is exceeded, or when the power is at the maximum or minimum power level.

4.2.7   PROCESS SETUP

The final step in the initial setup of the controller is to define the processes that you wish to run. To define a process you should complete the following steps:

1. Select a blank process from the Select Process Screen. Please note that you can also copy and modify a similar process to save time.

2. Enter a process name in the Define Process Screen.

3. Move the cursor onto the layer thickness parameter and enter the desired thickness for the layer.

4. Select a material for the layer by moving the cursor onto the material column, pressing the right arrow key, moving the cursor onto the desired material for the layer and pressing the Enter key.

Repeat steps 3&4 until the process layers are complete.

4.2.8   STARTING A NEW PROCESS

To start a new process, the controller must be in the Process Ready State (You can see the current state of the controller at the top-right corner of any Graph or Status screen). To switch to the Process Ready State, press Abort then Reset. From the Process Ready State, press the Start key, move the cursor onto the desired process and press Start again to start the process. To start a process from a layer other layer #1, press the left arrow key to move the cursor onto the Starting Layer parameter, enter the desired layer number, move back to the desired process and press Start again. Please note that you can also change the process Run Number (provided for your documentation purposes) from the Start Process screen.

4.2.9   RESUMING A PROCESS FROM ABORT OR HALT

To resume an aborted process, first press the start key. A message will appear asking you to press the start key again to resume the process. The process will resume from the layer where the process was aborted starting in either the Rise to

Soak or Rise to Predeposit power states. Once in deposit, the thickness will continue from the last value prior to the abort.

4.3 DETAILED PROGRAMMING

This section covers all of the MDC-260 programming in detail.

4.3.1 VIEW/EDIT PROCESS

Selecting View/Edit Process from the Main Menu will present the Select Process screen to delete, copy, view or edit any one of up to 10 processes.

To select a process for viewing and editing, move the cursor onto the desired process using the Up-arrow and Down-arrow keys, then press the Enter key.

```
Select Process:        01  Cr
                       02  Au
                       03
                       04
                       05
  1   - Copy           06
  0   - Delete         07
  ◄┘  - View/Edit      08                    ↓
```
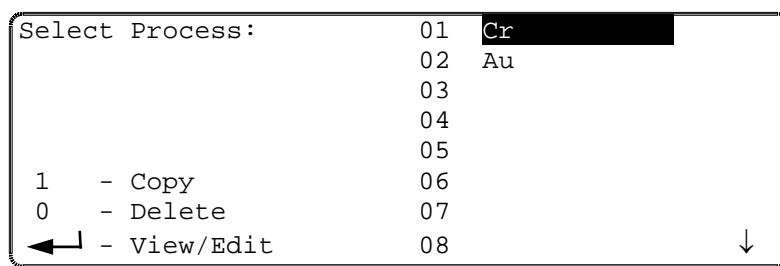
Figure 4-2 Select Process Screen

4.3.1.1 DEFINE A PROCESS

View or Run Password

```
Process Name   Layer# Thickness   Material
Sample            001   0.500     Cr
View/Run  0000    002   1.350     Au
Edit      0000    003   0.000     End Layer
                  004   0.000     End Layer
                  005   0.000     End Layer
                  006   0.000     End Layer
                  007   0.000     End Layer
```

Edit Password

Figure 4-3 Define Process Screen

Selecting a process will bring up the Define Process screen as shown in Figure 4-3. In this screen you enter all of the parameters that define a process. A process consists of a twelve-character name, two levels of passwords and finally a sequence of layers that makeup the process. Each layer consists of a material and the desired thickness for the layer. A process can have from 1 to 250 layers as long as the total number of layers in all the processes is not greater than 250. The following list describes all of the process parameters:

Process Name (twelve character alphanumeric field)

Each process is referenced by a twelve-character alphanumeric process name. You enter a process name using the alphanumeric keypad as described in Section 4.1.2. Please note that the active process name is displayed in the upper left-hand corner of all the status screens.

Edit Password (four character alphanumeric field)

The Edit process password allows you to lock out other users from editing a process unless the correct password is known. To set this password, highlight the Edit password field, type in your password then press the Enter key. A message will pop up asking for verification to change the password. Press "1" to confirm and "0" to cancel the change. Each time you want to edit this process, you will be asked to enter the correct password. Once a password has been entered, this parameter will not be displayed until the password has been entered again.

The default for this parameter is '0000'.

NOTE: *Please note that once the password has been changed, the process cannot be modified unless the correct password is entered so you must remember your passwords!*

View/Run Password (four character alphanumeric field)

The View/Run process password allows you to lock out other users from viewing and/or running a process unless the correct password is known. To set this password, highlight the Edit password field, type in your password then press the Enter key. A message will pop up asking for verification to change the password. Press "1" to confirm and "0" to cancel the change. Each time you want to view or run this process, you will be asked to enter this password. Please note that the view function of this password is ignored if the Edit Password is not set. Once a password has been entered, this parameter will not be displayed until the password has been entered again.

The default for this parameter is '0000'.

NOTE: *Please note that once the password has been changed, the process cannot be modified unless the correct password is entered so you must remember your passwords!*

Layer (001 to 250)

This column shows the layer number in the process. Please note that with the cursors on a layer number you can copy or delete this layer.

Thickness (000.0 to 999.9)

This parameter defines the desired thickness for the layer. The default for this parameter is 0.000 KÅ.

Material

This parameter defines the material for this layer. The layer material is selected from the list of materials defined in View/Edit Material. Therefore, you should define all of the necessary materials for the process before defining the process. See EDIT MATERIAL PASSWORD section 4.3.2.

To select a material, move the cursors to the material parameter for that layer and press the Right-arrow key. The Select Layer Material screen will be displayed as shown below. Scroll to the desired material and press Enter.

The layer material defaults to 'End Layer' meaning this layer marks the end of the process.

```
Select Layer Material      01  Cr
                           02  Au
                           03
                           04
                           05
                           06
                           07
     ←┘    to select material  08
```
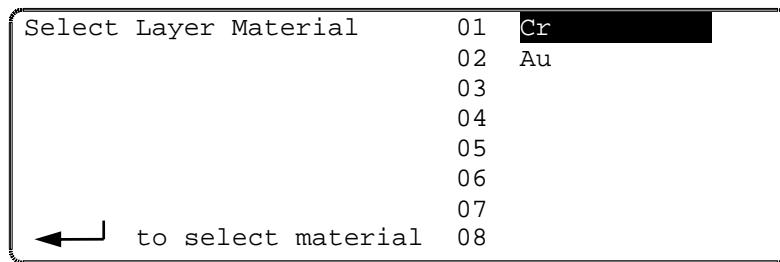
Figure 4-4 Select Layer Material Screen

4.3.2   VIEW/EDIT MATERIAL

From the Main Menu, selecting View/Edit Material will present the Select Material screen shown below.

```
Select Material            01  Cr
                           02  Au
                           03
                           04
                           05
  1   - Copy               06
  0   - Delete             07
  ←┘  - View/Edit          08
```
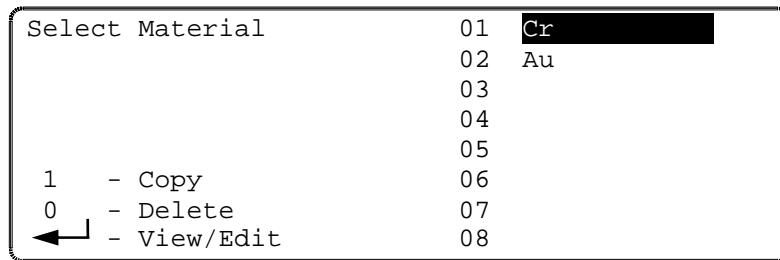
Figure 4-5 Select Material Screen

4.3.2.1 DEFINE A MATERIAL

Selecting a material for viewing and/or editing will present the screen which permits the material to be defined, shows the first page of this screen. In this screen, you define all of the material parameters for the selected material. The material parameters are described in detail below.

```
Material Name:        Cr                Press >
Sensor                1
Crystal               01
Source                1
Pocket                01
Density               07.20       gm/cm^3
Acoustic Impedance    28.95       gm/cm^2/sec
Tooling Factor        100         %           ↓
```
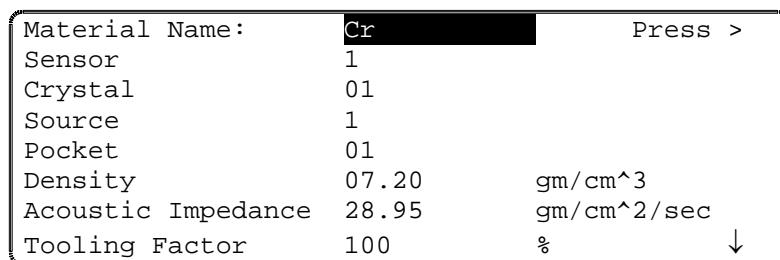
Figure 4-6 Define Material Screen

1. Material Name (A ten character material name)

The material name parameter allows you to either use the keypad to type in a name, or pick a name from the materials already stored in the material library.

To pick a material from the material library, highlight the material parameter and press the Right-arrow key. This will display a complete list of materials that are stored in the MDC-260. To pick a material, highlight that material and press Enter key. Once a material is chosen, the stored values for the density and acoustic impedance for that material are automatically entered into their respective parameters.

2. Sensor# (1 to 2)

This parameter defines the sensor input that will be used for this material. Choose between 1 and 2. The default setting is 1.

3. Crystal# (1 to 16)

This parameter defines the primary crystal used to monitor this material. This parameter cannot be greater than the Number of Crystals parameter in the Sensor Setup screen. The default setting is 1.

4. Source# (1 to 2)

This parameter defines the source output number that will be used for this material. Choose between 1 and 2. The default setting is 1.

5. Pocket# (1 to 16)

This parameter defines the pocket number that contains this material. This parameter cannot be greater than the Number of Pockets parameter in the Source Setup screen. The default setting is 1.

6. Density (0.80 to 99.99 gm/cm^3)

This parameter provides the material density so that the controller can calculate and display the physical film thickness. If the film density is known it should be used. A list of the more commonly used film densities is presented in Table 10-1. As a first approximation, bulk material density can be used in programming. Empirical calibration of this parameter is described in Section 10.5.1.

7. Acoustic Impedance (0.50 to 59.99 gm/cm^2/sec)

This parameter is the acoustic impedance of the material. The acoustic impedance of the deposited film is required by the MDC-260 in order to accurately establish the sensor scale factor when the sensor crystal is heavily loaded. If the acoustic impedance of the film material is known, it can be entered directly in units of 10^5 gm/cm^2 sec. In most cases the acoustic impedance of the bulk material can be used and can be obtained from The Handbook of Physics or other source of acoustic data. The shear wave impedance should be used. The shear wave acoustic impedance can be calculated from the shear modulus or the shear wave velocity and the density by using the following equation:

$$AI = \rho \cdot C = \sqrt{\rho \cdot G}$$

Where:

AI= Acoustic Impedance

ρ= Density (gm/cm^3)

C= Transverse (shear) wave velocity (cm/sec)

G= Shear Modulus (dynes/cm^2).

A list of the acoustic impedance and density of the more commonly deposited materials is presented in Table 10-1 and a technique for empirically determining this parameter is presented in Section 10.5.3.

In many cases and particularly if the sensor crystal is not heavily loaded, sufficient accuracy can be achieved by using the acoustic impedance of quartz which is 8.83 X 10^5 gm/cm^2 sec.

8. Tooling Factor (10.0 to 499.9%)

This parameter is the tooling factor for the average rate and thickness measurements. Typically this parameter is left at the default setting of 100% because each sensor has a tooling factor that is used to compensate for geometric factors in the deposition system which result in a difference between the deposition rate on the substrates and the rate on the sensing crystal. However, this parameter might be used to compensate for any changes in the system that affects all sensor heads equally. To a first approximation the tooling factor can be calculated using the following equation:

$$Tooling\% = \left(\frac{dc}{ds}\right)^2 \cdot 100$$

where:

dc = Distance from source to crystal.

ds = Distance from source to substrate.

The equation above assumes that the angle from normal between the source and sensor and the source and substrate is zero. To account for the angle of the crystal and the substrate, use the following equation:

$$Tooling\% = \left(\frac{dc}{ds}\right)^2 \cdot 100 \cdot \left(\frac{\cos\phi s}{\cos\phi c}\right)$$

where:

dc= Distance from source to crystal.

ds = Distance from source to substrate.

ϕc = The angle of the crystal off of normal from the source.

ϕs = The angle of the substrate off of normal from the source.

This equation assumes the crystal face is perpendicular to the source.

Empirical calibration of the tooling factor is described in Section 10.5.2.

9. Proportional Gain (0 to 9999)

This parameter is the proportional gain factor for the source power control loop. Control loop tuning is covered in Section 6.

10. Integral Time constant (0 to 99.9 sec)

This parameter is the system time constant. Control loop tuning is covered in Section 6.

11. Derivative Time constant (0 to 99.9 sec)

This parameter is the system dead time. Control loop tuning is covered in Section 6.

12. Rise To Soak Time (0 to 9:59:59)

This parameter sets the time interval for the source power to ramp up from zero to the power level set in Soak Power parameter. It should be long enough for the material to have time to reach equilibrium temperature without spitting, or in the case of evaporation sources, protected from unnecessary thermal shock.

13. Soak Power (0.0-99.9%)

This parameter defines the source power level during the Soak state. The Soak Power should be established at a level which will assure that the source material is properly outgassed and prepared for subsequent deposition.

14. Soak Time (0 to 9:59:59)

The Soak Time parameter defines the time duration of the Soak state. It is used in conjunction with the Soak Power to allow the material to fully outgas.

15. Rise To Predeposit (0 to 9:59:59)

This parameter sets the time interval for the source power to ramp from Soak Power level to the Predeposit Power.

16. Predeposit Power (0.0 to 99.9%)

This parameter defines the source power level during the Predeposit state. This should be set as close as possible to the power level required to reach the desired deposition rate. The Manual mode can be used to conveniently determine the Soak and Predeposit power levels of a particular material.

17. Predeposit Time (0 to 9:59:59)

This parameter defines the time duration of the Predeposit state. The Predeposit Time should be established at a value which allows the source material to be brought to the deposit temperature level and stabilized in an orderly manner. Since evaporation will normally occur at the Predeposit power level, too long a

Predeposit Time will result in unnecessary buildup of material on the shutter and unnecessary material loss.

18. Rate Establish Time (0 to 99 seconds)

This parameter defines the time limit of the rate establish state. The Rate Establish state occurs before the deposit state and is used to establish the correct source power before the source shutter is opened. In the rate establish state the crystal shutter is opened, the source shutter is closed, and the controller is controlling source power to achieve the programmed rate within the Rate Establish Error % for a period of 5 seconds. Once the rate has been held within limit for 5 seconds, the controller will go into the deposit state. If the rate error cannot be held within the allowed percentage error for 5 seconds, then the controller will display a Rate Establish Error and the process will be halted.

For the Rate Establish function to work, the sensor must be located somewhere in the vapor stream of the source while the source shutter is closed. The default setting for this parameter is 0, which disables this function.

19. Rate Establish Error % (0 to 99%)

This parameter sets a maximum limit for the rate establish error, which must not be exceeded for a five-second period during the rate establish state, in order for the controller to enter the deposit state.

20. Deposit Rate (#1, #2, #3) (0.0 to 999.9 Å/sec)

Deposition Rate #1 defines the first deposition rate.

Deposition Rates #2 and #3 define the target rate that will follow the prior rate ramp. This rate will continue until either the end of the layer or the beginning of the next rate ramp. These parameters will not be displayed the rate ramps leading up to them are not used (set to 100%).

21. Ramp (#1, #2) Start Thk (0 to 100%)

These parameters set the layer thickness percentage that will trigger the start of the respective rate ramp. The MDC-260 supports two rate ramps. The corresponding "Ramp Stop Thk" parameter sets the layer thickness percentage for the end of the rate ramp. Finally, the next Deposit Rate parameter sets the target deposition rate that the rate ramp will work towards.

Setting any "Ramp Start Thk" parameter to 100% disables that rate ramp.

Note: The ramp parameters can also be used as thickness setpoints for triggering I/O events without actually using the ramping feature. For example, if you wanted to trigger an event after 10% of the layer, your could:

- Set **Ramp #1 Start Thk** to 10%
- Set **Ramp #1 Stop Thk** to 10%
- Set the **Deposit Rate #2** equal to **Deposit Rate #1**.

Then you would use the **Deposit #2 State** condition in the output's or action's condition string that you wanted to trigger.

22. Ramp (#1, #2) Stop Thk (0 to 100%)

These parameters define the layer thickness percentage that will trigger the end of the respective rate ramp. These parameters will not be displayed if their corresponding "Rate Start Thk" parameters are not used (set to 100%).

23. Time Setpoint (0 to 9:59:59)

This parameter defines the time from the start of the layer until the time setpoint event is triggered.

24. Ramp To Feed Time (0 to 9:59:59)

This parameter defines the time allowed for the source power to go from the last deposition power to the Feed Power. The default for this parameter is zero.

25. Feed Power (00.0 to 99.9%)

The Feed Power parameter defines the source power level during the feed state.

26. Feed Time (0 to 9:59:59)

The Feed Time parameter sets the feed time. This parameter can also be used as a delay between the Deposit State and the idle state. The default for this parameter is zero which disables the feed function.

27. Ramp To Idle Time (0 to 9:59:59)

This parameter defines the time allowed for the source power to go from the last deposition power or feed power to the Idle Power. The default for this parameter is zero.

28. Idle Power (00.0 to 99.9%)

This parameter defines the source power after the feed or deposit states until the next Soak or abort state. If the idle power is greater than zero then the next layer using this source and pocket will start from the Predeposit state. If any subsequent layer uses the same source but a different pocket, the idle power will be automatically set to zero.

29. Maximum Power (00.0 to 99.9%)

The maximum power parameter sets the maximum allowable source power for this material. The deposition power will not be allowed to exceed this value.

30. Power Alarm Delay (0 to 99)

This parameter sets the time required for the deposit power to be at Maximum or Minimum power before the alarm will be triggered.

31. Minimum Power (00.0 to 99.9%)

This parameter sets the minimum power level for the minimum power warnings. If the power is at or below this level during a deposit a Minimum Power attention warning will be given. If this condition remains true for longer than the time set by the Power Alarm Delay parameter then a Minimum Power Alert warning will be given.

32. Rate Dev. Attention (00.0 to 99.9%)

The rate deviation attention parameter sets the allowable percent deviation from the deposition rate. If the deposition rate deviates by more than this percentage during the deposition, than a rate deviation attention message will be displayed in the LCD display. The default setting of 00.0% disables this function.

33. Rate Dev. Alarm (00.0 to 99.9%)

This parameter sets the percent deviation from the deposition rate required to trigger a rate deviation alarm. The default setting of 00.0% disables this function.

34. Rate Dev. Abort (00.0 to 99.9%)

The rate deviation abort parameter sets the allowable percent deviation from the deposition rate. If the deposition rate deviates by more than this percentage and the deposit power is at the maximum or minimum power alert level then the process will be aborted. The default setting of 00.0% disables this function.

35. Sample Dwell % (000.0 to 100.0)

The Sample Dwell% parameter establishes the percentage of the Sample Time for which the crystal is being sampled. Rate sampling is used for high deposition thickness where crystal life is a problem. By sampling the rate periodically and setting the power level to establish rate control, then closing the crystal shutter and maintaining the power level, a large deposition thickness can be achieved with one crystal. The primary sensor must have an individual shutter for the rate sample feature. The default for this parameter is 100% which enables sampling at all times.

36. Sample Period (0 to 9:59:59)

The Sample Period parameter defines the sample period. For example, a sample time of 5 minutes and a dwell of 40% will result in the crystal being sampled for 2 minutes, then the crystal shutter is automatically closed for the remaining 3 minutes while the deposition power is kept constant. Please note, once the crystal shutter has opened, there is a 5-second delay for crystal stabilization before measuring. This parameter will not be displayed if the Sample Dwell % parameter is set to 100%.

37. Crystal Fail (Halt, TimePwr, Switch)

This parameter defines the controller's action in the event of a crystal failure. The options are to halt the process, finish the current layer on time-power, or switch to a backup crystal. Use the Enter key to cycle between the options.

38. Backup Sensor # (1 to 2)

This parameter is available when the Crystal Fail parameter (37, above) is set to Switch. This parameter defines the backup sensor input for the backup crystal. For a dual-crystal sensor head, this parameter should be set to "2" assuming Sensor #1 is the primary crystal. However, for multiple-crystal sensor heads, this parameter would be the same value as the Sensor # parameter (2, above) and the Backup Crystal # parameter (39, below) would be set to "2". This is because a multiple-crystal sensor head uses one sensor input to measure any of its crystals while a dual-crystal sensor head uses two sensor inputs to measure either crystal.

39. Backup Crystal # (1 to 16)

This parameter is available when the Crystal Fail parameter (37 above) is set to Switch. This parameter defines the backup crystal number. Note that for a dual-crystal sensor head, this parameter should be set to 1. For a multiple-crystal sensor head, set it to 2.

40. Backup Tooling Factor (10.0% to 499.9%)

This parameter defines the tooling factor for the backup sensor head. Note that for a multiple-crystal sensor head, this parameter should be set to the same value as the [primary] Tooling Factor parameter (8, above).

41. Material Password (4 digit string)

This parameter defines the edit password for the material. If the password is set to anything other than 0000 it will not be displayed, and when you attempt to edit the material you will first be asked to enter the correct password.

4.3.3   SYSTEM SETUP

Choosing the Edit System Setup option from the Main Menu screen will present the System Setup Menu options as shown in Figure 4-7. These options allow for setting up the controller to interface with the vacuum system and are described below.

```
System Setup         Edit Display Setup
                     Program Inputs
                     Program Outputs
                     Program Actions
                     Edit Sensor Setup
                     Edit Source Setup
                     Edit DAC Setup
                     Edit Utility Setup
```
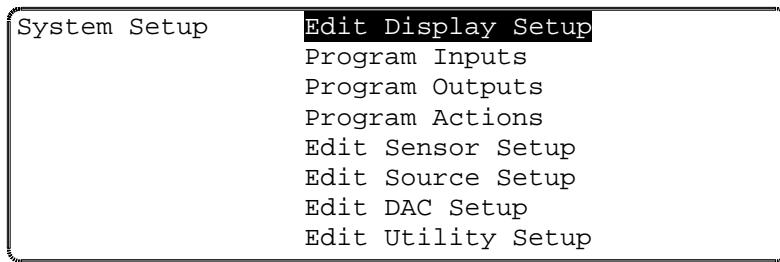
Figure 4-7 System Setup Menu Screen

4.3.3.1 EDIT DISPLAY SETUP

Selecting Edit Display Setup will present the Display Setup screen.

```
                 Display Setup
Pause On Layer Complete             Yes
Display Negatives               Enabled
Thickness Graph Scale           3-digit
Sensor Status                 Thickness
Time Display            Estimated Layer
Rate Graph                     Disabled
Power Graph                     Enabled  ↓
```
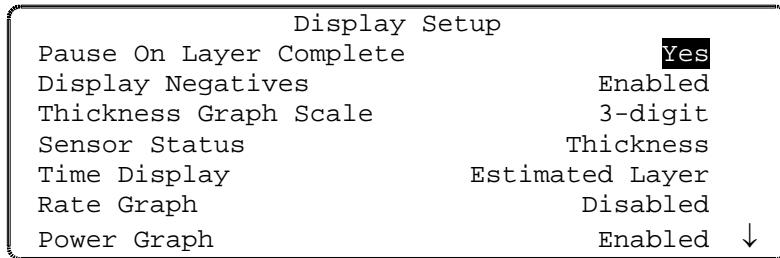
Figure 4-8 Display Setup Screen

1. Pause On Layer Complete (Yes or No)

This parameter determines whether the controller will pause between layers. If this parameter is set to Yes then the controller will stop after completing a layer and wait for a Start key press from the operator. If this parameter is set to No then the controller will automatically increment to the next layer.

2. Display Negatives (Enabled or Disabled)

This parameter defines whether the MDC-260 will display negative rates and thickness or not. If set to disable, the MDC-260 will hold negative values at zero. The default for this parameter is Disabled.

3. Thickness Graph Scale (2-digit, 3-digit)

This parameter defines whether the rightmost 2 or 3 digits of thickness will be graphed effectively setting the graph range at either 100 or 1000Å.

4.   Sensor Status (Thickness, Frequency)

This parameter determines the value displayed in the Sensor Status screen. The available options are sensor Thickness or Frequency. Note that, while in the Source-Sensor Status Screen, Figure 5-8, pressing the "7" key will toggle the sensor display between Thickness and Frequency.

5. Time Display (Estimated State, Layer or Elapsed Process, Layer or State time)

This parameter sets the displayed value in the Time display on the front panel. The choices are estimated state or layer time, or the elapsed process, layer or state time.

6. Rate Graph (Enabled, Disabled)

This parameter defines whether the rate verses time graph is enabled as one of the status screens.

7. Power Graph (Enabled, Disabled)

This parameter defines whether the power verses time graph is enabled as one of the status screens.

8. Thickness Graph (Enabled, Disabled)

This parameter defines whether the thickness verses time graph is enabled as one of the status screens.

9. Rate Dev. Graph (Enabled, Disabled)

This parameter defines whether the rate deviation verses time graph is enabled as one of the status screens.

10. Run Screen (Enabled, Disabled)

This parameter defines whether the Run-Screen is enabled as one of the status screens.

11. Source/Sensor Status (Enabled, Disabled)

This parameter defines whether the source/sensor status screen is enabled as one of the status screens.

12. I/O Status (Enabled, Disabled)

This parameter defines whether the I/O status screen is enabled as one of the status screens.

13. Parameter Screen (Enabled, Disabled)

This parameter defines whether the Parameter screen is enabled as one of the status screens.

14. Color Scheme (Scheme#1 – #4)

This parameter allows the user to toggle between four pre-defined color schemes.

Note: If all status screens are disabled, the **Run-Screen** will be displayed when the Status key is pressed. If all graph screens are disabled, **Rate Vs. Time Graph** will be displayed when the Graph key is pressed.

4.3.3.2 PROGRAM INPUTS

The controller has 'logical' discrete inputs which are used when running a process, and 'physical' discrete inputs at the rear-panel connector pins which can be associated arbitrarily by the user with the logical inputs using the Edit Program Inputs function. By itself a user-defined input has no effect, it can only be useful when its logical state is used as a condition for an internal action, or an external action represented by the state of a discrete output.

The controller provides 8 logical inputs. The 8 logical inputs can be associated with up to 8 physical inputs.

A logical input (1 to 8) can be given a 16-digit name, and can be associated with a physical input by identifying the connector pin number (30 to 37, each of which also has a separate pin for the signal return which is displayed to the right of the Pin#). The input's true level can also be defined for each input. An input defined as High true will be true when the input's voltage is at or above the high level for the particular I/O card installed.

The inputs on the MDC-260 can be configured as either Active or Passive inputs. See Section 8.3.9.1 for instruction.
The Passive inputs are pulled up to 5 volts internally through a 4.7 K OHM resister and are set true, assuming the input's True level is set to Low, by shorting the input pins together. The Active inputs are 12 to 120 volt AC/DC inputs. The Active inputs are set true, assuming the input's true level is set to High, by supplying 12 to 120 volt AC or DC across the input pins.

In the Program Inputs Menu (Main Menu, Edit System Setup, Program Inputs), you will see all of the logical inputs defined. Use the Up-arrow and Down-arrow keys to select a logical input. The Left-arrow and Right-arrow keys select the Input Name, True level and Pin# edit fields. A 16-digit name can be assigned to the logical input. Pressing the Enter key on the True level column will toggle between High or Low true. Any entry less than 30 or greater than 37 will be ignored for the Pin#.

The logical discrete inputs have two categories. One category contains logical inputs that are named and assigned by the user, the other category contains logical inputs that are automatically defined by the controller, such as those required for source and sensor position feedback, and these cannot be changed by the user.

When the controller defines inputs, it selects the blank names remaining in the logical input list and assigns them in sequence to the internally generated functions. For this reason, it is important that unused inputs are left blank, and that there are sufficient inputs for all required functions.

Inputs that are internally defined are discussed further in the source/sensor setup sections. **Table 8-2** lists the input pin numbers.

```
        Input Name        True  Card     Pin-Ret
01   External Start       Low    1       30  12
02   Deposit pressure     High   1       31  13
03   Over Pressure        Low    1       32  14
04   Optical Monitor      Low    1       33  15
05                        Low    1       34  16
06                        Low    1       35  17
07                        Low    1       36  18 ↓
```

Figure 4-9 Program Input Screen

4.3.3.3 PROGRAM OUTPUTS

The controller has 'logical' discrete outputs which are used when running a process, and 'physical' discrete outputs which can be associated arbitrarily by the user with the logical outputs using the Program Outputs function. Each physical discrete output is in the form of a pair of relay contacts assigned to dedicated pins on a controller back-panel connector, and these contacts will close when a the logical discrete output associated with the physical output satisfies a set of conditions defined by the user which are evaluated every 100 ms.

The controller provides 8 logical outputs. The 8 logical outputs can be associated with up to 8 physical outputs. Additionally, the controller has a relay output which is dedicated to the Abort function.

In the Program Outputs Menu (Main Menu, Edit System Setup, Program Outputs), you will see all of the logical outputs defined. Use the Up-arrow and Down-arrow keys to select a logical output. Press Enter or the Right-arrow to edit the name and conditions of that output.

A logical output (1 to 8) can be given a 16-digit name, and can be associated with a physical output by identifying connector pin number (2 to 9, paired with 21 to 28, respectively, for the relay contacts).

The logical discrete outputs have two categories. One category contains logical outputs that are named and assigned by the user, the other category contains logical outputs that are automatically defined by the controller, such as those required for source and sensor rotator controls, and these cannot be changed by the user. These internally defined outputs are indicated by a condition string labeled "Internally Defined"

When the controller defines outputs, it selects the blank names remaining in the logical output list and assigns them in sequence to the internally generated functions. For this reason, it is important that unused outputs are left blank, and that there are sufficient outputs for all required functions. Outputs that are internally defined are discussed further in the source/sensor setup sections.

Table 8-2 lists the output pin numbers.

Two screens are required to program the Discrete outputs. The first screen provides for selecting the output to be programmed, while the second screen provides for the actual programming, including the output name.

Selecting Program Outputs from the System Setup menu will present the Select Output screen.

```
Select Output      01    End of Process
                   02    Wire feed Al
                   03    Layer Complete
                   04    Procs Complete
                   05
                   06
                   07
    ◄┘ – View/Edit 08                              ↓
```
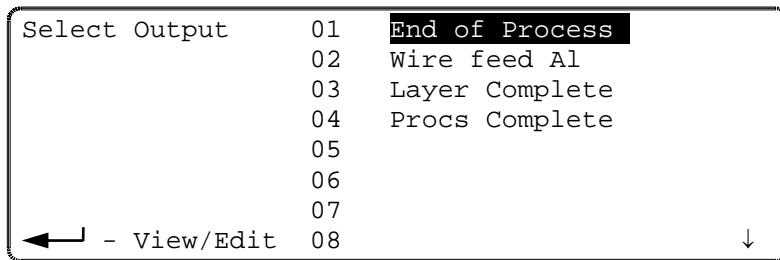
Figure 4-10 Select Output Screen

Selecting an output with the Right-arrow or Enter key will present the screen which permits definition of the output, as shown below.

The Left-arrow, Right-arrow, Up-arrow and Down-arrow keys provide access to the Output Name, card#, pin# and Condition string edit fields. A 16-digit name can be assigned to the logical input. Any entry other than 1 or 2 will be ignored for the card#, as will a pin# less than 2 or greater than 9.

```
                                      Pin#-Return
Output Name  Wire Feed Al             2     21
Conditions   Al & FeedHold



Valid operators: 1=!, 2=(
0=Add condition. ◄┘ to save
```
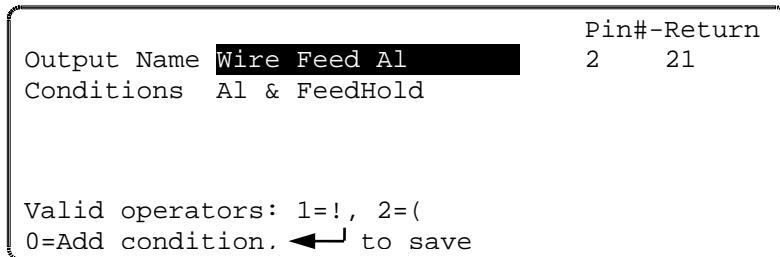
Figure 4-11 Program Output Screen

The output condition string is a logical statement that determines the state of the output. The output relay is closed when the condition string is evaluated as true. Otherwise, the relay is open. Each output condition string is evaluated ten times per second (every 100 milliseconds).

4.3.3.3.1   ENTERING A CONDITION STRING

A condition string comprises one or more individual conditions linked together by the logical operators ! NOT, & AND, | OR and parentheses ( ). Conditions are chosen from a list. To enter a condition string correctly you must follow these rules:

There must be an equal number of closed and open parentheses.

All conditions must be separated by either the & or the | operator.

Condition strings cannot end in an operator.

To enter a condition string, first highlight the condition string field. The second line from the bottom of the screen displays the valid operators and parentheses.

The screen symbols will change depending on the contents of the condition string to the left of the blinking cursor. To select a symbol, press the corresponding key number. In the example displayed, the bottom line tells you that you press the "0" key to select a condition or, the Enter key to finish and validate the string. A blank condition string is evaluated as false.

While entering the condition string, pressing the "0" key will present a screen which has a list of condition types at the left side. For the chosen type, the right-hand side of the screen displays a list of sub-conditions or a number entry field.

Example:

If you move the marker of the left column onto the State condition type, a list of all the possible states will appear in the right column. See Figure 4-12. To select one of the states, press the right arrow key to move the marker to the right column. You then move onto the desired state and press enter. This will return you to the previous screen and add the selected state to the condition string. You can return to the left column without selecting a state by pressing the Left-arrow key.

```
Condition    State          Process Ready
Type         Event          Start Layer
             Input          Change Pocket
             Output         Change Crystal
             Process        Layer Ready
             Material       Soak Rise
             Source         Soak Hold
             Pocket         Predeposit Rise    ↓
```

Figure 4-12 Output Conditions Selection Screen

Example:

If you move the marker of the left column onto the Layer condition type, a number field will appear in the right column. To select layer #5, press the Right-arrow key to highlight the number on the right column. You then type the number 5 and press Enter.

```
Condition    Process
Type:        Material
             Source
             Pocket
             Softnode
             Sensor
             Crystal
             Layer          Number:  005
```

Figure 4-13 Output Conditions Selection - Sub menu

4.3.3.3.2   CONDITION TYPES

States - State conditions are evaluated true whenever the controller is in the respective state. Controller States are:

- Process Ready
- Start Layer
- Change Pocket
- Change Crystal
- Layer Ready
- Soak Rise
- Soak Hold
- Predeposit Rise
- Predeposit Hold
- Establish Rate
- Deposit 1
- Rate Ramp 1
- Deposit 2
- Rate Ramp 2
- Deposit 3
- Ramp To Feed
- Feed
- Ramp To Idle
- Layer Complete
- Process Complete
- Process Resume

Events - Event conditions are evaluated true whenever the respective event is true. Controller Events are:

- Abort
- Halt
- Hold
- Time Power
- Ready
- In Process
- Simulate

- Time Setpoint
- Last Layer
- Crystal Failure
- Crystal Marginal
- Min Rate&Max Pwr
- Max Rate&Min Pwr
- Rate Dev. Alarm
- Rate Est. Error
- Source Fault
- Sensor Fault
- Rate Dev. Alert
- Max. Power Alert
- Min Power Alert
- Rate Dev. Atten.
- Max Power Atten.
- Min Power Atten.

Inputs - Input conditions are represented by the user defined programmable inputs. A condition is either true or false depending on the state of the input. Input conditions are used to indicate the state of something external to the MDC-260. For example, you may want to program the MDC-260 to wait for a certain pressure before starting a deposit. In this case you would create an input called something like "At Pressure" and you would connect this input to a pressure setpoint output of a vacuum gage. Next, you would create a Hold In State action that would cause the MDC-260 to hold in a state prior to deposit until the "At Pressure" input goes true.

Outputs - Output conditions are represented by the user defined programmable outputs. A condition is either true or false depending on the state of the output's total condition string.

Process - The process condition is evaluated true whenever the selected process is the current process.

Material - The material condition is evaluated true whenever the selected material is the current material.

Source (1-2) - The source condition is evaluated true whenever the current source equals the specified source.

Pocket (1-16) - The pocket condition is evaluated true whenever the current pocket equals the specified pocket.

Soft Node (1-8) - Each Soft node defaults to false but can be set to true by a "Set Soft Node" Action. Soft nodes allow the user to link many action condition strings together to trigger another action or output.

Sensor (1-2) - The sensor condition is evaluated true whenever the current sensor equals the specified sensor.

Crystal (1-16) - The crystal condition is evaluated true whenever the current crystal equals the specified crystal.

Layer (1-250) - The layer condition is evaluated true whenever the current layer# equals the specified layer#.

Timer < (1-65,534 seconds) - The MDC-260 has eight internal counters that can be used as conditions to trigger outputs or actions. The timer condition is evaluated true whenever the timer's value is less than the value entered in the timer condition. A timer can be reset to zero using a Start Timer Action. Once reset, a timer will count up to its maximum value and stay there until it is reset again. Timers are typically used to trigger an output for a set amount of time after a certain event or state has occurred. For example, if you wanted to turn on an ion gun for the first 3 minutes of deposition, you would first create an output called "Ion Gun Power" with the condition "!Timer1<1&Timer1<181". This condition says that this output will be true whenever Timer1 is greater than 1 and less than 181 seconds. The next step is to create an action to reset the timer in the state before deposit. Select the "Start Timer #1" action and enter the conditions "Predeposit Hold". The MDC-260 will continually reset timer #1 (set to zero) while it is in the Predeposit Hold state then one second after it enters the deposit state, the "Ion Gun Power" output will go true for 180 seconds or three minutes.

4.3.3.4 PROGRAM ACTIONS

The MDC-260 provides for 8 internal user programmable actions. Internal actions are used to provide special functions at the true evaluation of a condition string. These functions may be such things as terminating a deposit on an input from an optical monitor. Or, sounding an alarm when certain events are true.

To program an action, first select the desired action from the list of eight programmable actions displayed in the Actions screen.

```
Select Action        01  Hold In State
                     02  Step From State
                     03  Sound Attention
                     04  Sound Alert
                     05  Sound Alarm
                     06  No Action
                     07  No Action
  ◄┘ – View/Edit     08  No Action        ↓
```
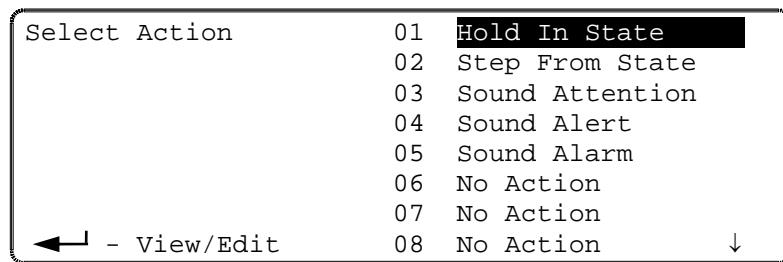
Figure 4-14 Action Selection Screen

Once you have selected the required action, pressing the Right-arrow key will present the screen which permits programming of the action details, and this procedure is similar to the one used for programming discrete outputs.

```
Action Name Hold In State
Conditions




Press > to select action
```

Figure 4-15 Program Action Screen

In this screen you select the predefined action you would like to take and the associated conditions. To specify an action, move the markers onto the action name field and press the Right-arrow key. This will present the Select Defined Action screen.

```
Select Defined Action:  01    No Action
                        02    Manual Power
                        03    Zero Thickness
                        04    Reset Controller
                        05    Abort Process
                        06    Halt Process
                        07    TerminateDeposit
     ⏎ to select action  08    Hold In State    ↓
```
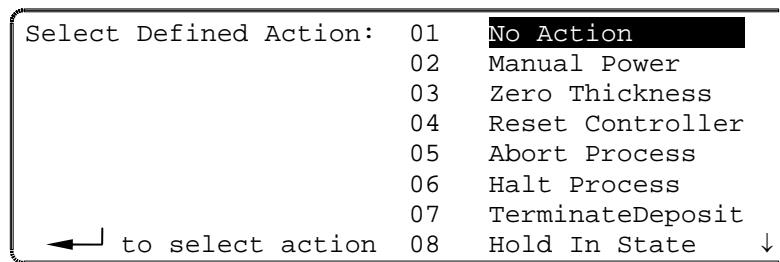
Figure 4-16 Select Defined Action Screen

In this screen you can select a predefined action from the list by moving the cursors onto the desired action and pressing Enter. The following is a list of the predefined actions:

No Action - No action is taken. This is the default setting.

Manual - Functionally identical to pressing Manual key.

Zero - Functionally identical to pressing Zero key.

Reset - Functionally identical to pressing Reset key.

Abort - Functionally identical to pressing Abort key.

Halt - Halts the process, sets active source power to idle, and leaves all other source powers unchanged.

Terminate Deposit - Triggers the final thickness for the deposit state. Action is ignored if state is not a deposit state.

Hold In State - Holds controller in current state.

Step From State - Steps controller to next state.

Sound Attention - Triggers the attention sound and displays the "Attention Action" message in the State/Trouble field in the LCD display.

Sound Alert - Triggers the Alert sound and displays the "Alert Action" message in the State/Trouble field in the LCD display.

Sound Alarm - Triggers the Alarm sound and displays the message "Alarm Action" in the State/Trouble field of the LCD display.

Start Process - Trigger the start of the currently selected process. This action is ignored unless the controller is in the Process Ready state.

Select Process 1-8 - Select process #1-8 as the next process to be started by the Start Process action described above.

Switch Crystals - Toggles between the primary and the backup sensor/crystal combination defined by the active material. The first sensor/crystal will be switched if more than one sensor/crystal combinations are enabled for measurement.

Once the action is selected then you need to establish when the action should take place by defining its condition string. This is covered in the earlier section called Entering a Condition String.

Start Timer 1-8 – Resets the corresponding timer to zero and initiates counting. The timers are used to trigger other actions and/or outputs some time after the triggering event or for a set amount of time. This is a momentary action meaning it only triggers once when evaluated as true. The Start Timer's condition string must be evaluated as false then true to trigger again.

Set Soft Nodes 1-8 – Sets a corresponding soft node. Soft nodes are used in conditions strings to trigger actions or outputs.

Once an action is selected then you need to establish when the action should take place by defining its condition string. This is covered in the earlier section called Entering a Condition String.

4.3.3.5 EDIT SENSOR SETUP

Selecting Edit Sensor Setup will present the Sensor Setup screen shown in Figure 4-17. In this screen you define the sensor parameters that the controller needs to interface to the various types of sensors. Once the sensor setup is complete, the controller will create the necessary inputs and outputs needed to interface to the defined sensors. To define a sensor, first select the sensor number by using the Up-arrow and Down-arrow keys to highlight the desired sensor number. Once selected, the sensor is configured by selecting the appropriate parameters from the right half of the display. Depending on the sensor configuration, some of the unnecessary parameters will be hidden:

```
┌─────────────────────────────────────────────────┐
│ Sensor Setup                                    │
│                   Number of Crystals       06   │
│ Sensor #1         Shutter Relay Type      N.O.  │
│ Sensor #2         Control                Direct │
│                   Drive                      Up │
│                   Feedback Type   No Feedback   │
│                   Rotator Delay(sec)       00   │
│                                                 │
└─────────────────────────────────────────────────┘
```

Figure 4-17 Sensor Setup Screen

1. Number of crystals (1 to 16)

This parameter defines the number of crystals available for that sensor input. For a single sensor head this would be set to one. For a dual sensor head with separate oscillators and sensor connections, this would still be set to one because there is only one crystal for each sensor input. For a multiple rotary type sensor head, this parameter would be set to the number of crystals that the sensor will hold.

2. Shutter Relay type (N.O., N.C., None, Dual)

This parameter defines the shutter relay type used to control the sensor shutter. The following four relay types are available:

N.O. - Relay is normally open and closes to close shutter. For this type, a "SensorN Shutter" output will be created to interface to the shutter actuator.

N.C. - Relay is normally closed and opens to close shutter. For this type, a "SensorN Shutter" output will be created to interface to the shutter actuator.

None - No sensor shutter output is created.

Dual - Select this type for a dual sensor head. For this type, a "Dual Snsr1&2 Shtr" output will be created to interface to the shutter actuator.

3. Control (Manual, Direct, BCD, Indiv)

This parameter defines the type of crystal position control utilized.

Manual, as it implies, means not under control of the MDC-260. Under manual control, the MDC-260 will stop the process upon the completion of the current layer when the next layer requires a different crystal position. A message prompting the operator with the number of the crystal required is displayed in the LCD window. Once the crystal has been changed, the process is resumed by pressing the Start key.

BCD and Indiv are used when control is through an external crystal rotation controller which accepts Binary Coded Decimal inputs or Individual switch closures to select the crystal. The controller creates the number of outputs required to interface with the external controller and set the outputs as required to signal a crystal selection. Note that the BCD value is offset by one to the crystal number. For example, BCD value of 0 selects crystal 1. BCD value of 1 selects crystal 2, and so on.

Direct is used when the actuating device is driven directly. In this case the controller creates one or two outputs, one for each available direction, to drive a motor or solenoid.

4. Drive (Up, Down, Fast, Inline, Sngl Step, Dbl Step)

This parameter defines the drive method or direction for Direct control and only has an effect when Control type is set to Direct. For that reason this parameter will be hidden when the Control type is set to anything other than Direct. The different drive settings are described below.

Up, Down, Fast and Inline - These four settings are typically used with multi-crystal heads that use a motor to rotate the crystals into position. With Up selected, the controller will create one output called "SensorN Drive Up". The MDC-260 will activate this output to increment the sensor head up to the next position. The down selection works the same except the output is called "SensorN Drive Dn". With Fast selected, the controller will create both an up and a down output. The 260 will then determine the fastest direction to the target crystal position by activating the appropriate output. The Inline drive type informs the controller that continuous travel in one direction is not possible. Therefore to get from position 6 to 1, the direction must be down through 5, 4, etc. until 1 is reached.

SnglStep and Dbl Step - Both the SnglStep and Dbl Step settings are typically used with multi-crystal sensor heads that are actuated by pulsing a pneumatic valve. The MDC-260 will create a "SensorX Drive Up" which is either singly or doubly pulsed to sequentially step the sensor head to the next position.

5. Feedback Type (Individual, BCD, Single Home, In Position, No Feedback)

This parameter defines the type of feedback for a multiple sensor head. The three feedback types available are as follows:

Individual - Individual position feedback. This feedback type uses one input for each crystal position in the sensor head. All inputs are normally false (open circuit) unless that crystal is in position then that input is true (closed to ground). For example, a six crystal sensor head would use six inputs. If crystal two was in position then all the inputs would be false except the input connected to feedback position number two.

BCD - Binary Coded Decimal position feedback. This feedback type uses binary coding to indicate which crystal is in position. Inputs are numbered most significant bit first. For example, an eight crystal sensor head would use three inputs. With crystal one in position, all inputs would be false. With crystal four in position, inputs one and two would be true and input three would be false.

Crystal number	Input BCD2	Input BCD1	Input BCD0
1	OPEN	OPEN	OPEN
2	OPEN	OPEN	GND

3	OPEN	GND	OPEN
4	OPEN	GND	GND
5	GND	OPEN	OPEN
6	GND	OPEN	GND
7	GND	GND	OPEN
8	GND	GND	GND

Table 4-1 Table of Input States for BCD Feedback Type

SNGL HOME - Single home position feedback. This feedback type uses one input. The input is normally false (open circuit) and should go true (closed to ground) when crystal one is in position.

IN POSITION - In position feedback. This feedback type uses one input. The input is normally false (open circuit) and should go true (closed to ground) when the desired crystal is in position.

NO FEEDBACK - No crystal position feedback is used.

6. Rotator Delay (0 to 99 seconds)

This parameter serves two different functions. If the feedback type is "None" (Not recommended. See cautions in the Installation section.), this parameter tells the controller how long to wait assuming the crystal is in position. If position feedback is provided, this parameter tells the controller how long it should wait for the crystal to reach its target position before it issues a Sensor Fault message.

4.3.3.6 EDIT SOURCE SETUP

Selecting Edit Source Setup will present the Source Setup screen as shown in Figure 4-18. In this screen you first select the source setup you wish to edit. To select a source, use the Up-arrow and Down-arrow keys, then press the Right-arrow or Enter key to select.
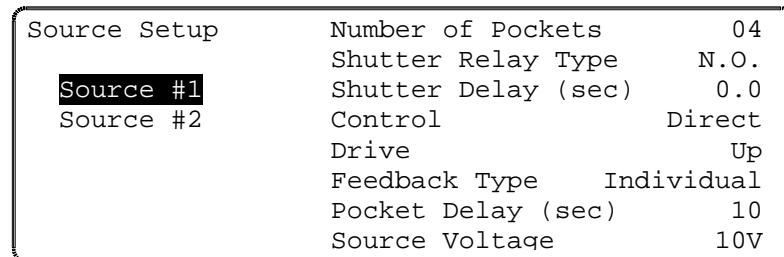
```
Source Setup       Number of Pockets      04
                   Shutter Relay Type    N.O.
Source #1          Shutter Delay (sec)    0.0
Source #2          Control              Direct
                   Drive                    Up
                   Feedback Type    Individual
                   Pocket Delay (sec)      10
                   Source Voltage         10V
```

Figure 4-18 Source Setup Screen

Once selected, the source is configured with the following parameters located on the right side of the display. Depending on the configuration, some of the unnecessary parameters will be hidden:

1. Number of Pockets (1 to 16)

This parameter defines the number of pockets, or crucibles, available for the source. The default value is 1 for a single pocket source.

2. Shutter Relay type (N.O., N.C., None)

This parameter defines the shutter relay type used to control the source shutter. The following three relay types are available:

N.O. - Relay is normally open and closes to close shutter. For this type, a "SourceN Shutter" output will be created to interface to the shutter actuator.

N.C. - Relay is normally closed and opens to close shutter. For this type, a "SourceN Shutter" output will be created to interface to the shutter actuator.

None - No sensor shutter output is created.

3. Shutter Delay (sec) (0.0 to 9.9 seconds)

This parameter should be set to the time it takes for the source shutter to open/close. At the start of the deposition, the controller will delay adjusting the power for this amount of time to allow the shutter to completely open. At the end of deposition, the controller will begin closing the source shutter this much time before the target endpoint thickness is reached so the final thickness should be very close to the target.

4. Control (Manual, Direct, BCD, Indv)

This parameter defines the type of pocket control utilized.

Manual, as it implies, means not under control of the MDC-260. Under manual control, the MDC-260 will stop the process upon the completion of the current layer when the next layer requires a different pocket. A message prompting the operator with the material required is displayed in the LCD window. Once the pocket has been changed, the process is resumed by pressing the Start key.

BCD and Indv are used when control is through an external pocket rotation controller which accepts Binary Coded Decimal inputs or Individual switch closures to select the pocket. The controller creates the number of outputs required to interface with the external controller and sets the outputs as required to signal a pocket change.

Direct is used when the actuating device is driven directly. In this case the controller sets up one or two outputs, one for each available direction, to drive a motor or solenoid.

5. Drive (Up, Down, Fast, Inline, Sngl Step, Dbl Step)

When the Control type is Direct, this parameter defines the drive method or direction. For Sngl Step and Dbl Step drive types, the controller sets up one output which is either singly or doubly pulsed to actuate a solenoid to sequentially step the rotator to the desired position. For Up and Down drive types, the controller sets up one output to control a drive motor which is turned on until the rotator reaches the desired position. For Fast and Inline drive types, the controller sets up a drive up and a drive down output. For the Fast drive type, the controller determines the fastest direction to the target pocket position and turns on the

appropriate output. The Inline drive type informs the controller that continuous travel in one direction is not possible. Therefore to get from position 6 to 1, the direction must be down through 5, 4, etc. until 1 is reached.

The controller creates one or more of the following outputs depending on the type:

> Drive Up
>
> Drive Down
>
> Step

6. Feedback Type (Individual, BCD, Single Home, In Position, No Feedback)

This parameter defines the type of feedback for a multiple pocket source. The three feedback types available are as follows:

Individual   - Individual position feedback. This feedback type uses one input for each pocket position in the source. All inputs are normally false (open circuit) unless the respective pocket is in position then that input is true (closed to ground). For example, a six-pocket source would use six inputs. If pocket two was in position then all the inputs would be false except the input connected to feedback position number two.

BCD   - Binary Coded Decimal position feedback. This feedback type uses binary coding to indicate the pocket position. Inputs are numbered most significant bit first. For example, an eight-pocket source would use three inputs. With pocket one in position, all inputs would be false. With pocket four in position, inputs one and two would be true and input three would be false.

Pocket Number	Input BCD2	Input BCD1	Input BCD0
1	OPEN	OPEN	OPEN
2	OPEN	OPEN	GND
3	OPEN	GND	OPEN
4	OPEN	GND	GND
5	GND	OPEN	OPEN
6	GND	OPEN	GND
7	GND	GND	OPEN
8	GND	GND	GND

Table 4-2 Table of Input States for BCD Feedback Type

SNGL HOME - Single home position feedback. This feedback type uses one input. The input is normally false (open circuit) and should go true (closed to ground) when pocket one is in position.

IN POSITION - In position feedback. This feedback type uses one input. The input is normally false (open circuit) and should go true (closed to ground) when the desired pocket is in position.

NO FEEDBACK - No pocket position feedback is used.

7. Rotator Delay (0 to 99 seconds)

This parameter serves two different functions. If the feedback type is "None" (Not recommended. See cautions in the Installation section) this parameter tells the controller how long to wait, on the assumption the pocket will get into position. If position feedback is provided, this parameter tells the controller how long it should wait for the pocket to reach its target position before it issues a Source Fault message.

8. Source Voltage (2.5V, 5.0V, 10V)

This parameter sets the upper limit of the voltage range for the source control output. The lower limit of the voltage range is always 0. For example, selecting 10V for this parameter sets the source control voltage range from 0 to 10 volts.

4.3.3.7 EDIT UTILITY SETUP

Selecting the Edit Utility Setup from the Edit System Setup menu will present the Utility Setup screen. Figure 4-19 shows the first page of this screen. All parameters are described below.

```
                  Utility Setup
Crystal Frequency      6.0 MHz
Simulate mode          On
Interface address      01   (1-32)
Attention Volume       01   (0-10)
Alert Volume           01   (0-10)
Alarm Volume           01   (0-10)
```

Figure 4-19 Utility Setup screen

1. Crystal Freq. (2.5, 3.0, 5.0, 6.0, 9.0, 10.0 MHz)

This parameter determines the uncoated crystal frequency type for all sensor inputs. The default setting is 6.0 MHz.

2. Simulate Mode (On, Off)

This parameter enables or disables the Simulate mode of the controller. The Simulate mode is used for process testing and differs from the Normal mode only to the extent that the Thickness and Rate displays are derived from a simulated sensor input rather that the actual sensor. While in this mode, the simulated thickness build- up is directly proportional to the displayed power level and independent of actual thickness on the sensor. The Simulate mode allows the total deposit process to be simulated. It also allows the tooling factor, density and acoustic impedance calculations to be conveniently checked and altered at the end of the run, if necessary.

3. USB Interface Address. (1-32)

This parameter sets the controller's computer interface address for the USB interface. This number will be transmitted as a part of all messages sent to and from the MDC-260 from a host computer.

4. Attention Volume (0-10)

This parameter sets the volume of audio attention sound. Attention sounds indicate that the controller is waiting for an operator response or action before continuing the process. A setting of zero disables audio attention sound.

5. Alert Volume (0-10)

This parameter sets the volume of audio alert sound. Alert sounds indicate that a material alert level has been exceeded. A setting of zero disables audio alert sounds.

6. Alarm Volume (0-10)

This parameter sets the volume of audio alarm sound. Alarm sounds indicate that a material alarm level has been exceeded. A setting of zero disables audio alarm sounds.

5.   OPERATING THE MDC-260

5.1   SIGN-ON SCREEN

Upon a power-up, a series of tests are performed on the hardware, all of the
LED's are illuminated, and a Sign-on screen is displayed on the LCD. The user
will be asked to press a key to continue.

```
                    INFICON MDC-260 Software Ver x.x
                    Deposition Controller
                    Serial Number xxxx


                    System Check... OK
        INFICON
                    Press any key to continue.
```
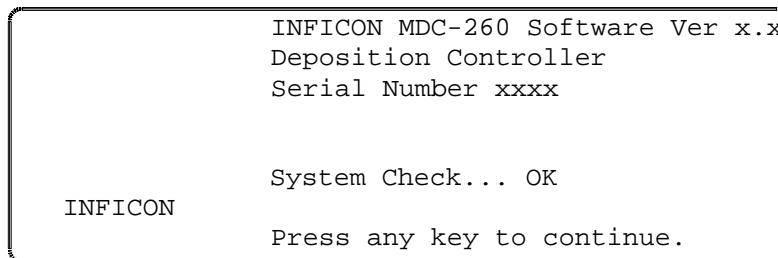
Figure 5-1 Sign-on Screen

After pressing a key, the controller will be put into Abort mode. At this point,
only the red LED behind the Abort key will now be illuminated. The LCD screen
will return the screen that was being displayed when power was last removed.

Pressing the Reset key will put the controller into the Reset (Ready) state in
preparation for a process run.

5.2   STARTING A NEW PROCESS

Pressing the Start key while the controller is in the Reset (Ready) state will
present the screen shown below. A run number is provided to help correlate
process information with a specific process run. The run number can range from
1 to 9999, and is automatically incremented before each new process. At 10,000
the run number will roll over to 1.

```
    Start Process           01 Sample
                            02
    Starting Layer:   001   03
    Run Number    :   0001  04
                            05
                            06
    Press Start to start    07
    or Reset to cancel.     08
```
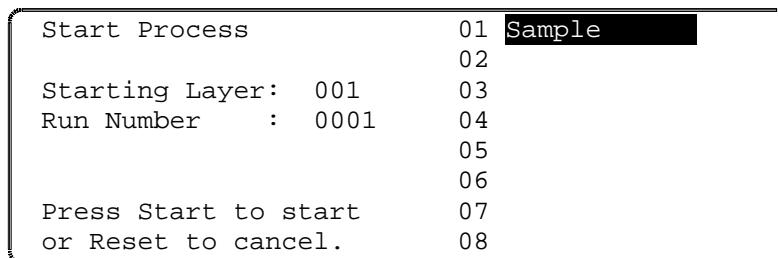
Figure 5-2 Run Process Selection Screen

From this screen you can change the starting layer number or manually assign a
run number, if required. When ready, place the cursor on the desired process
name, which then becomes the 'current' process. To start the process, just press
the Start key again. The controller will then scan the total process definition and

the condition of the system, and if everything appears to be in order, will start the process.

If at this point an error message is presented by the LCD screen, it is likely that there is a problem somewhere with either the system configuration and/or the value of a system parameter which will prevent the process from running correctly. Use the details of the error message as an indication of the corrective action that should be taken. Refer to Section 5.9 for detail explanations of the errors messages. Press the Abort key to abort the process start, then the Reset key, and then make the necessary changes.

5.3   STARTING A NEW LAYER

The Start key is also used to start individual layers when the controller is set up for manual layer sequencing. The controller will prompt the operator to press the Start key to start the next layer.

5.4   RESUMING AN ABORTED OR HALTED PROCESS

The Start key is also used to resume an aborted or halted process. Pressing the Start key while the controller is in abort or halt mode will bring up the following prompt. Note that the green LED behind the Start key is illuminated, indicating that the process can be resumed. Otherwise, the controller has to be reset, and the process has to be started over.

> Press Start to resume process
>
> or Reset to cancel.

Follow the prompt to resume the process.

5.5   GRAPH DISPLAYS

There are four different run time graph screens that can be displayed at any time by pressing the Graph key (providing they have each been enabled in the Edit Display Setup menu). The first key press will bring up the last viewed graph screen, repeatedly pressing the Graph key will cycle through the four graph screens, shown below.
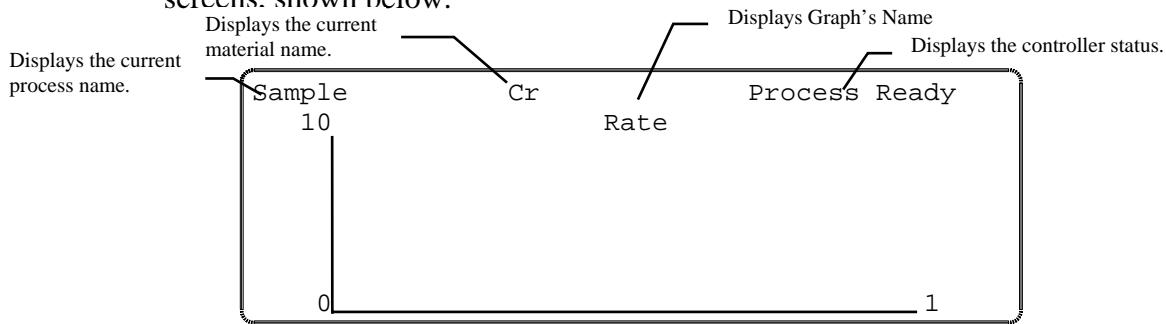
Figure 5-3 Rate vs. Time Graph

```
Sample             Cr              Process Ready
   5                    Rate Dev%

                                                    1


   5
```
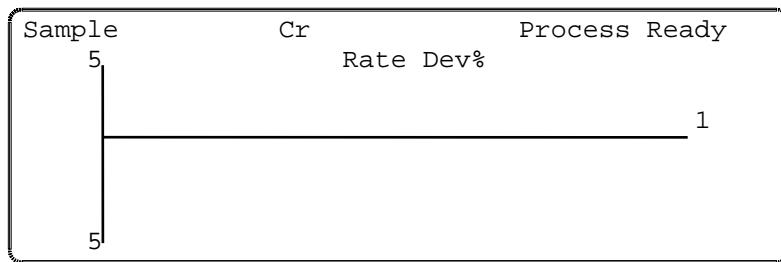
Figure 5-4 Rate Deviation vs. Time Graph

```
Sample             Cr              Process Ready
  999                   Thickness




   0                                                1
```
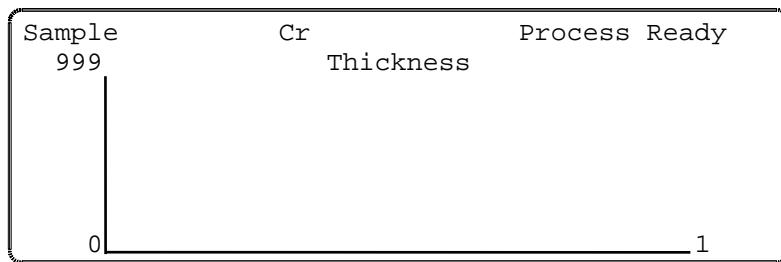
Figure 5-5 Thickness vs. Time Graph

```
Sample             Cr              Process Ready
   10                   Power%




   0                                                1
```
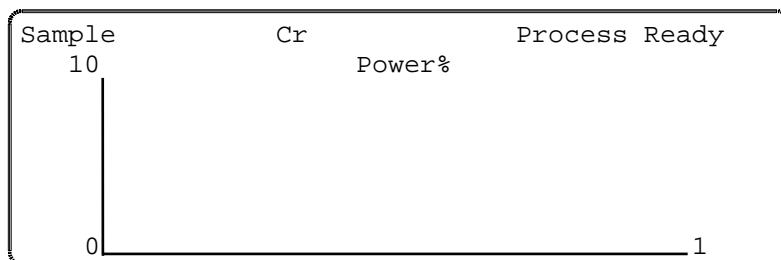
Figure 5-6 Power vs. Time Graph

5.6   STATUS DISPLAYS

There are five run-time status screens that can be displayed by pressing the Status key (providing they have each been enabled in the Edit Display Setup menu). However, only four screens are available at a time, depending on the controller's status. The first key press will bring up the last viewed status screen, repeatedly pressing the Status key will cycle through four of the five status screens, shown below.

5.6.1   MAIN RUN SCREEN

```
Process Name          Au              Process Complete
  Rate Å/Sec        Power %           Thickness KÅ
  3.14             25.0               4.467
   Layer #          Health %          TimeToGo:State
  001               99                1:20:15
```

Figure 5-7 Main Run Screen

The Main Run Screen provides an easy-to-see display of the most critical information.

- The Rate field refers to the rate measured by the active sensor.

- The Power field refers to the power of the active source.

- The Thickness field refers to the cumulative Thickness, as measured by the current sensor

- The Layer field refers to the layer number within the active process.

- The Crystal Health field refers to the health of the active sensor.

- The Time-to-Go field refers to the estimated time remaining or the elapsed time of the current state, layer, or process. Note that the number 7 key can be used to toggle between the time modes.

5.6.2   SOURCE-SENSOR STATUS SCREEN

```
Sample        Ag                    Process Ready
Source    Pocket      Power
  1*        01        00.0%
  2         --        00.0%

Sensor    Crystal     Health    Rate      Thickness
  1*        01        99%       00.0         0.000
  2         --        00%       00.0         0.000
```

Figure 5-8 Source-Sensor Status Screen

The Source/Sensor Status screen displays the status of the two sensors and sources including the crystal or pocket position, source power, crystal health, each sensor's deposition rate and thickness or frequency. You select either sensor thickness or frequency in the Edit Display Setup Menu by setting the Sensor Status parameter. Active sources and the active sensors are indicated with a "*" next to the number. A failed sensor/crystal is indicated by "--" in the Health field.

5.6.3   I/O STATUS SCREEN

```
Sample            Cr                  Process Ready
      Input          State       Output       State
01 Source1 BCD 0      F    Source1 BCD 0        F
02 Source1 BCD 1      T    Source1 BCD 1        T
03                    F    Source1 Shutter      F
04                    F                         F
05                    F                         F
06                    F                         F
```

Figure 5-9 I/O Status Screen

The I/O Status screen indicates the state of all the MDC-260's inputs and outputs.
Please note that you can use the arrow keys to scroll up and down the I/O listing.

5.6.4   ACTIVE LAYER PARAMETER UPDATE SCREEN

```
Sample            Cr               Predeposit Hold
        Active Layer Parameter Update
Sensor        1           Soak Pwr          25.0
Crystal       01          Predep. Pwr       32.0
Thickness     1.500       Max Pwr           55.0
Rate #1       010.0       Prop. Gain        1000
Rate #2       000.0       Int. Time         99.9
Rate #3       000.0       Deriv. Time       00.0
```

Figure 5-10 Active Layer Parameter Update Screen

The Active Layer Parameter Update screen displays a set of parameters of the
current active layer as shown in Figure 5-10. It allows the user to quickly change
these values, if needed, to fine-tune the run, without having to go into the Edit
Material Definition screen. To change a value, use the arrow keys to move the
cursor to highlight it, punch in the new value and press Enter. Note that values
changed in this screen will be written back to the material definition. Note that
this screen is only available during a process.

5.6.5   POSITION CONTROL SCREEN

```
Sample            Cr                  Process Ready
              Position Control

                    Command   Actual   Health
Source 1 Pocket:                 01      N/A
Source 2 Pocket:                 --      N/A
Sensor 1 Crystal:                --      99%
Sensor 2 Crystal:                --      00%
```

Figure 5-11 Position Control Screen

The Position Control Screen is only available when the controller is in idle (not in process or abort state). It allows the user to easily switch to a desired pocket or crystal in order to replace the material or crystal.

To command a new pocket position, highlight the command field of the corresponding source. Punch in the desired pocket number. Once the desired pocket position is reached, it will be displayed in the Actual [position] field, if feedback is provided.

Likewise, to command a new crystal position, highlight the command field of the corresponding sensor. Punch in the desired crystal number. Once the desired crystal position is reached, it will be displayed in the Actual [position] field, if feedback is provided. The Crystal Health of that crystal will also be displayed in the Health field.

5.7   MODES

Modes are conditions that the controller can occupy. Some modes are indicated by the LED's behind the operating keys. Other modes are displayed in the top right hand corner of the status display (Refer to Figure 5-3). These controller modes are described below.

5.7.1   PROCESS READY

The Process Ready Mode indicates the MDC-260 has been reset and is awaiting a Start key press. The yellow LED behind the Reset key, when illuminated, indicates that the controller is in Process Ready Mode.

5.7.2   ABORT

The Abort mode is indicated by a red LED behind the Abort key as well as the flashing of all of the numeric LED displays. In Abort Mode all displays and operating keys, with the exception of the Start and Reset keys, are inoperative. All source control outputs are forced to zero, the Abort relay is closed and all discrete outputs are forced to open circuit. In addition, if the controller initiated the abort then the condition which caused the abort will be displayed in the top right hand corner of the LCD display. Exit from Abort Mode requires either a Reset or Start key press. See also Section 5.4 for resuming an aborted process. Refer to Table 5-1 for conditions that can cause an abort.

5.7.3   HALT (SOFT ABORT)

In Halt all I/O is frozen. If power is above Soak level, it is ramped down to Soak at the Predeposit ramp rate. If Power is at or below the Soak level it is held constant. The user has the option to resume from Halt or press Reset and start over. See also Section 5.4 for resuming a halted process. Refer to Table 5-1 for conditions that can cause the process to halt.

5.7.4   IN PROCESS

The green LED behind the Start key indicates the controller is in the In-Process Mode.

5.7.5   NOT SAMPLING

This mode indicates that the sensor crystal is shuttered from the source and that the deposition rate is established using the last power level. Sampling mode is set by two material parameters, Sample Dwell % and Sample Period. Refer to Section 4.3.2.1 # 35 and # 36 for a description of Sample Mode.

5.7.6   PROCESS COMPLETE

This mode indicates that the selected process has run to completion. A Process Complete message is displayed in the top right hand corner of the status display. In addition, an attention warning will sound. The controller remains in this mode until a reset signal puts it into the Process Ready mode.

5.7.7   MANUAL

This mode is indicated by the red LED behind the Manual key. In this mode the control voltage output is controlled through the Remote Power Handset. For a detailed description of this mode, refer to Section 3.6.

5.7.8   SIMULATE

This mode simulates rate and thickness build-up by simulating the sensor input rather than the actual sensor. Refer to Section 3.5 for more information on the Simulate Mode.

5.8   STATES

Figure 5-12 shows the different states that make up a complete deposition cycle, such as Rise to Soak, Rise to Predeposit, etc. The controller moves from state to state as the deposition progresses.

5.9   TROUBLE, ERROR AND WARNING MESSAGES

"Troubles" are controller conditions which in most case are indicative of problems or errors, but may be just warnings. These messages are displayed in the top right hand corner of the status screen (See Figure 5-3). When trouble messages are displayed, the status banner at the top of the screen turns red.

In addition, there are three levels of audible warnings associated with the trouble conditions, Attention, Alert and Alarm. * Sound will clear when the condition clears.

Table 5-1 lists the messages and warning levels. The list is arranged in descending order of priority. In the event that more than one warning level is triggered, the higher level has priority. An asterisk (*) in the Clear column indicates the warning sound will clear when the condition clears. Any key press will also clear the sound. The action column indicates if any action is taken by the controller as a result of the trouble.

Messages	Warning		
	Type	**Clear**	**Action**
Min Rate&Max Power	Alarm		Abort
Max Rate&Min Power	Alarm		Abort
System Setup memory corrupted	Alarm		Halt
Process memory corrupted	Alarm		Halt
Material memory corrupted	Alarm		Halt
Rate Est. Error	Alarm		Halt
Crystal Failure	Alarm/Attn	NO/*	Halt
Source Fault	Alarm		Halt
Sensor Fault	Alarm		Halt
No Snsrs Enabled	Alarm		Halt
Time Power	Alarm		Time/Power
Rate Dev. Alarm	Alarm	*	
Alarm Action	Alarm		
Crystal Marginal	Alert/Attn	NO/*	
Rate Dev. Alert	Alert	*	
Max power Alert	Alert	*	
Min power Alert	Alert	*	
Alert Action	Alert	*	
Xtal Fail Switch	Attention		Crystal Switch
Xtal Mrgn Switch	Attention		Crystal Switch
Rate Dev. Atten	Attention	*	
Max power	Attention	*	
Min power	Attention	*	
Change source # X to (material name) and press Start to continue.	Attention		Hold
Change sensor # X to crystal # X and press Start to continue.	Attention		Hold
Attention Action	Attention	*	
Press Start to resume process.	N/A		
Start to continue.	Attention	*	Hold

* Sound will clear when the condition clears.
Table 5-1 Trouble Conditions and Warnings

5.9.1   DESCRIPTION

The messages in the above table are described below.

5.9.1.1   MIN RATE&MAX POWER

This message indicates that the output power is at the maximum power level set by the Maximum Power parameter and the rate deviation is below the limit value set in the Rate Dev. Alarm parameter. When this happens, the controller will go into the Abort mode and the Alarm will sound.

5.9.1.2   MAX RATE&MIN POWER

This message indicates that the output power is at the minimum power level set by the Minimum Power parameter, and the rate deviation is above the limit value set by the Rate Dev. Abort parameter. When this happens, the controller will go in Abort mode and the Alarm warning will sound.

5.9.1.3   SYSTEM SETUP MEMORY CORRUPTED

The integrity of the System Setup Memory has changed since the last time a system parameter was modified. Each one of the sub menus and its parameters has to be checked and corrected as necessary to fix this problem.

5.9.1.4   PROCESS MEMORY CORRUPTED

The integrity of the selected process has been changed since last time the process was modified. Each one of the process parameters has to be checked and corrected as necessary to fix this problem.

5.9.1.5   MATERIAL MEMORY CORRUPTED

The integrity of the selected material has been changed since last time the material was modified. Each one of the material parameters has to be checked and corrected as necessary to fix this problem.

5.9.1.6   RATE EST. ERROR

The controller is unable to establish the programmed rate within the time specified in the Rate Establish Time parameter. The rate is considered established when it stays within the Rate Establish Error % for 5 seconds.

5.9.1.7   CRYSTAL FAILURE

This condition indicates lack of a valid signal from the sensor, and generally results from a failed crystal but may also indicate problems in the crystal mounting or the interconnection between the sensor and the controller. If the primary crystal fails and the process is not in deposit state, the Attention warning will sound. If the backup crystal fails and the process is not in the deposit state, the alarm will sound and the process will be halted.

5.9.1.8   SOURCE FAULT

This condition indicates that the correct source pocket position feedback has not been achieved within the time set by the Rotator Delay parameter (Source Setup Menu).

5.9.1.9   SENSOR FAULT

This condition indicates that the correct crystal position feedback has not been achieved within the time set by the Rotator Delay parameter (Sensor Setup Menu).

5.9.1.10   NO SENSORS ENABLED

This condition indicates that no sensors were enabled for measurement of this material.

5.9.1.11   TIME POWER

This message is displayed when the controller is completing the current layer based on the last power and rate. This occurs in the event of a crystal failure without a backup.

5.9.1.12   RATE DEV. ALARM

The deposition rate error is greater than the rate deviation value set in the Rate Deviation Alarm parameter.

5.9.1.13   ALARM ACTION

This message indicates the Alarm sound was initiated by an internal action.

5.9.1.14   CRYSTAL MARGINAL

The sensor crystal in use is poor in quality. If the crystal is the backup one, the Alert warning will sound when the process is in deposit state. If the primary crystal is in poor quality then the Attention will sound.

5.9.1.15   RATE DEV. ALERT

The deposition rate deviation is greater than the value set in the Rate Deviation Alert parameter.

5.9.1.16   MAX POWER ALERT

Indicates that the power output level has been at the Maximum Power level longer than the time period set in the Power Alert Delay parameter.

5.9.1.17   MIN POWER ALERT

Indicates that the power output level has been at or below the Minimum Power level longer than the time period set in the Power Alert Delay parameter.

5.9.1.18   ALERT ACTION

This message indicates the Alert sound was initiated by an internal action.

5.9.1.19   XTAL FAIL SWITCH

This message indicates the primary crystal has failed and the sensor input has been switched to the backup crystal. In addition, the Attention warning sounds. Press any key to clear the sound.

5.9.1.20   XTAL MRGN SWITCH

This message indicates the primary crystal is marginal and the sensor input has been switched to the backup crystal. In addition, the Attention warning sounds. Press any key to clear the sound.

5.9.1.21   RATE DEV. ATTEN

The deposition rate deviation error is greater than the value set in the Rate Deviation Attention parameter.

5.9.1.22   MAXIMUM POWER

The output power is being limited by the value set in the Maximum Power parameter.

5.9.1.23   MINIMUM POWER

The output power is at or below the minimum power set by the Minimum Power parameter.

5.9.1.24   CHANGE POCKET...

Prompts the operator to switch the source pocket to the correct position. The process will be on hold until the Start key is pressed. There is no message if the Control parameter is set to Auto (Source Setup Menu).

5.9.1.25   CHANGE CRYSTAL...

Prompts the operator to switch the sensor to the correct crystal position. The process will be on hold until the Start key is pressed. There is no message if the Control parameter is set to Auto (Sensor Setup Menu).

5.9.1.26   ATTENTION ACTION

This message indicates the Alert sound was initiated by an internal action.

5.9.1.27   PRESS START TO RESUME PROCESS

This message comes up when the controller is aborted during a process. After the abort condition is removed, the operator may press the Start key to resume the process. To cancel from resuming the process, press Reset key.
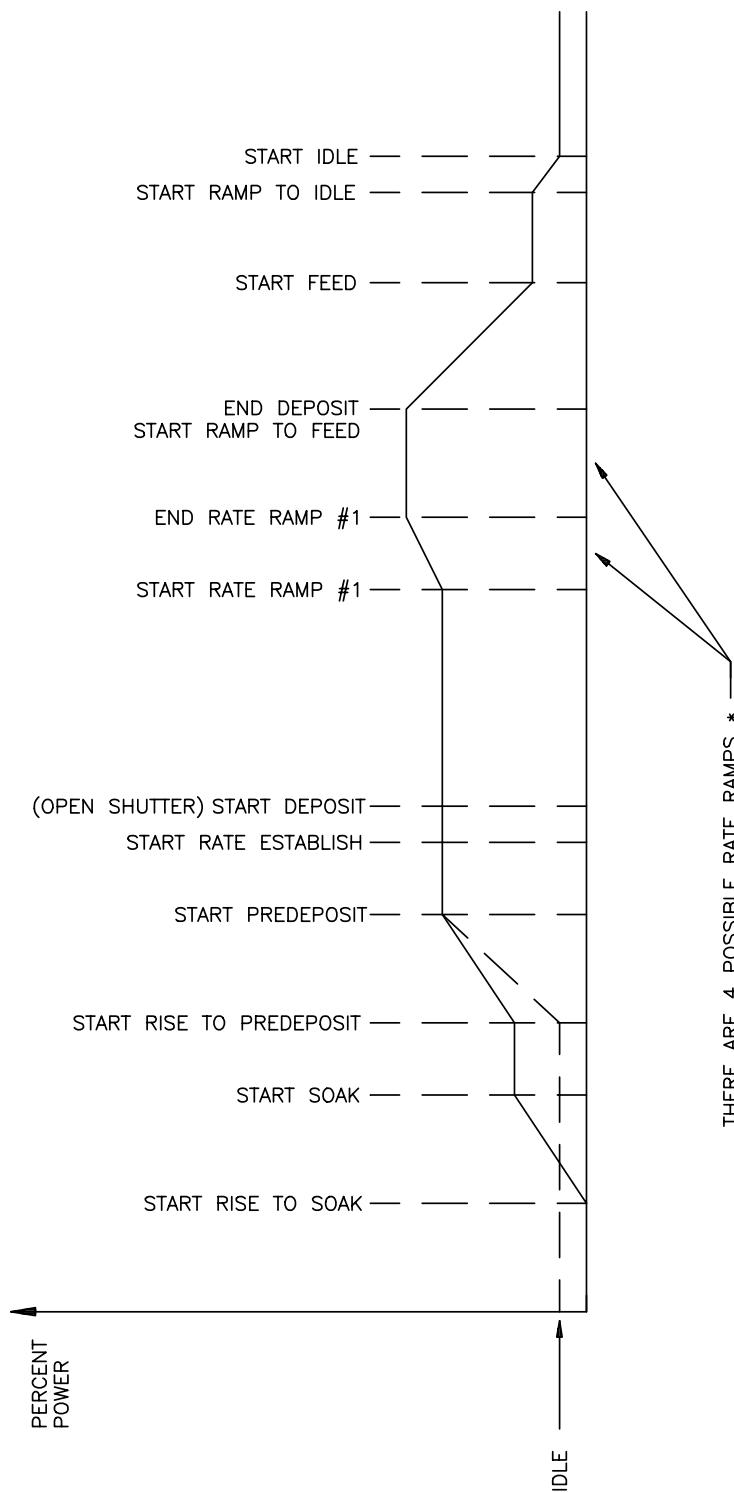
Figure 5-12 Typical Process Profile

6.   TUNING THE MDC-260 CONTROL LOOP

6.1   CONTROL LOOP BASICS

If evaporation rate were a function of source power alone, a rate controller would not be necessary. One would establish the power required achieving the desired rate, set the power at that point and that would be that. In control system parlance, this is called "Open Loop" control.

Unfortunately, evaporation rate is a function of many variables. With E-gun sources, rate is affected by material level, water-cooling temperature, beam position, sweep pattern, etc. With filaments and boats, rate is affected by material level, boat or filament condition, power line voltage, power losses in cables, connections, transformers, switches, etc. Even when sputtering under the conditions of constant power and constant pressure, rate is affected by target condition.

So, if we want to achieve a known and constant rate, we need a rate controller. The rate controller compares the measured rate with the desired rate and attempts to keep them equal by adjusting the command signal to the power supply. This is called "Closed Loop" or feedback control.

The most common example of feedback control is a car and driver. The car is the "Plant". It is controlled by pedal pressure and steering wheel angle. Its output is direction and speed. The driver is the "Controller". The driver monitors the direction and speed and adjusts pedal pressure and steering wheel angle to achieve the direction and speed he/she desires.   If we hold the controls steady and close our eyes, no feedback, then our control is open loop. If the road is very straight and there is no wind, "no disturbances to the plant", we can sometimes stay on the road for a pretty good distance. If the road is rolling or we have a good crosswind, the time we can stay on the road in open loop control can be pretty short indeed.

If the controller is slow and sluggish, i.e. a drunk driver, the difference between the desired speed and direction can be very different from the speed and direction desired. The driver can be all over the road, speeding up, slowing down, etc.

If the controller's gain is too high, typical of a young person's first driving experience, the response to an error is both slow and too great and the car careens from one side of the road to the other. This control "System" would normally go completely unstable and crash if control were not assumed by a different controller.

In the case of a young driver with a little more experience under his/her belt, the response speed has improved but the gain is still a little high. The vehicle stays pretty well in control but there is a lot of steering wheel action. We say this controller is "oversteering".

When we go from one vehicle to another, especially if the vehicles are very different in size or weight, we find that we must really concentrate on our driving at first. That is because we are learning the characteristics of the "Plant". As

soon as we've learned them, we know what we have to do to correct for errors and we are back in good control.   In other words the controller must compensate for the characteristics or the "Plant".

6.2   CONTROL LOOPS APPLIED TO VACUUM DEPOSITION

In the deposition control loop the vacuum system and evaporation supply make up the plant. The output, deposition rate, is controlled by the source control voltage which establishes the source power. If all plants were the same we could predefine the characteristics of the controller for optimum control. Unfortunately, plants vary widely, in their gain, linearity, response, noise and drift.

The question we are going to address here is how the controller adjusts the source control voltage, the "command signal".   The MDC utilizes a type 1-control loop. A type 1 control loop does not require a continuous error to achieve a non-zero control voltage.

Many controllers utilize a type 0 control loop. In this type of loop the source control voltage output is determined by multiplying the rate error by the Proportional gain. For any given non-zero output the error required to achieve, the necessary output is inversely proportional the to gain. High gain, low error, low gain, high error. This would seem to call for high gain. Unfortunately, the higher the gain results in higher chance of instability. We may go unstable before we get the error down to where we want it.

In the MDC, the proportional gain parameter sets the rate at which the control voltage changes in response to an error signal. Any error in the rate causes the source control voltage to ramp to a new value. When the source control voltage increases or decreases to the correct value, the value required to achieve the desired rate, the error goes to zero and the output remains constant.

The Derivative Time constant is utilized to compensate for slow sources such as boats and induction heated sources. Like a large truck, these sources take time to get up to speed and to stop. The Derivative Time constant looks at the rate of change of the error. If the error is decreasing rapidly we better take our foot off the gas or we are going to overshoot our target. If the error is decreasing, but decreasing very slowly, we need to goose it to get up to speed.   The Derivative Time constant instructs the controller on how much attention to pay to the rate of change of the error.   A value of zero tells the controller to ignore the rate of change of the error. A large value tells the controller that this source is slow and is going to be hard to get going and hard to stop. So if the rate starts to fall off, give it power, or if we're quickly approaching the target, begin to decrease the power.

The Integral Time constant is used to keep the thickness profile on schedule. We may have no rate error right now, so if we were not concerned about the thickness profile, we would be happy and leave everything as it is. However if we are trying to stay on a thickness profile, stay on schedule as it were, we may want to speed up or slow down a little bit to make up for previously lost, or gained time. For example, suppose our desired speed is 50 mph and that's the speed we are traveling. However we've been traveling for exactly an hour and we've only

gone 48 miles because of some traffic earlier on. Our Integral error is 2 miles. If we want to get back on schedule we need to speed up a bit.   If schedule is very important to us, we will speed up a lot to get back on schedule fast. If schedule is not important at all we will maintain our speed. The Integral Time constant instructs the controller on how much attention to pay to the schedule. If we don't care what happened in the past and we want zero rate error right now, we don't want any Integral feedback. To accomplish that we set the Integral Time constant to its maximum value, which tells the controller to ignore any past error unless it lasts for a very long time.

6.3   ESTABLISHING MDC-260 CONTROL LOOP PARAMETERS

As explained above, the MDC utilizes three control loop parameters referred to as PID parameters; Proportional gain, Integral Time constant and Derivative Time constant to provide for optimization of the control loop. The MDC provides default values for each of these parameters.

Parameter	Minimum value	Maximum value	Default value
Proportional gain	1	9999	1000
Integral time constant, sec.	0	99.9	99.9
Derivative time constant sec.	0	99.9	0.0

Table 6-1 Default and Range for PID Parameters

The following table lists some recommended PID values for different types of deposition sources. These values represent a good starting point and in some cases may not need to be further modified.

Parameter	Electron Beam Gun	Filament Boat
Proportional gain	2000	600
Integral time constant, sec.	99.9	99.9
Derivative time constant sec.	25.0	75.0

Table 6-2 Suggested PID Starting Values for Different Sources

In the MDC-260, the PID parameters are defined at the material level because different materials often require different PID settings even though they may be deposited from the same source. Therefore it is usually necessary to establish the PID parameters for every each material and deposition source.

The first step in setting the PID parameters for a new material or source is to enter the recommended starting values listed above. Be sure and choose the PID values for the type of source you're using. Next, create a dummy process with the first layer set for the new material. Start and abort the dummy process to load the new material as the active material. You should now see the material's name in the top line of any Status Screen. Next, open the shutter and put the MDC-260 in the

manual power mode and adjust the source power using the remote handset to establish the power ramp parameters. Set the Predeposit Power level at or slightly below the power needed to get the desired deposition rate.

With the power ramp parameters defined, the next step is to start the dummy process to see how well the MDC-260 controls the rate. If the rate is too high or low when the shutter opens then make a note to go back and adjust the Predeposit Power level. Watch the rate graph and the power display. If the rate is different from the target rate then you should see the MDC-260 adjust the power attempting to achieve the target rate. If the rate is close to the target, then you should temporarily change the rate to see how the MDC-260 reacts. Ideally the MDC-260 will adjust the power so that the rate goes right to the target rate without overshooting it. If it does then no further adjustments are necessary.

If it seems like the MDC-260 is reacting too slowly, press the Program key to get back to the material screen and increase the Proportional Gain parameter. Begin with changes of about 10 to 20%. Changes of this magnitude are a good starting point because they are large enough to show the effect of the parameter and small enough that you won't greatly overshoot the ideal setting. Remember that too much Proportional Gain will make the system unstable and too little will make the MDC-260 slow to react. An unstable system is evident by the rate oscillating around the target value. A general rule of thumb is the faster the source, the larger the Proportional Gain. And conversely, the slower the source the smaller the Proportional Gain.

With the Proportional Gain at an acceptable value, the next step is to adjust the Derivative Time if necessary. Disturb the system again by changing the target rate. Watch the rate graph as the rate approaches the target. If the rate overshoots the target then increase the Derivative Time and change the target rate again to see the effect. Repeat these steps slowly increasing the Derivative Time until the rate goes right to the target without overshoot.

In very slow systems such as large filament boats, the Proportional Gain parameter may have to be set so low to maintain stability where the rate smoothly levels off but remains below the target value. In this case you will need to adjust the Integral Time parameter. This parameter works in reverse meaning the smaller the value the larger the effect. So, slightly decrease this parameter then watch the rate graph. The rate should ramp up to the target without overshoot. If the ramp takes too long then slowly decrease the Integral Time again and repeat these steps until you are satisfied with the control.

7.   INPUT/OUTPUT CHARACTERISTICS

The following section describes the electrical characteristics of the MDC-260 inputs and outputs. All outputs are updated and inputs are sampled every 100 msec. In order to insure immunity to transients, inputs are not considered to have changed until the same input state is obtained on two successive input samples.

For this reason all input signals must have a minimum duration of at least 0.2 sec. Input signals lasting less than 100 msec. will be ignored while signals lasting between 100 and 200 msec. may or may not be recognized.

7.1   SOURCE CONTROL VOLTAGE OUTPUT

For maximum noise immunity, each two-terminal control voltage output pair is isolated from controller ground. Either terminal can be grounded within the user system, so the output can provide either a negative or positive output voltage range. In the event that the receiving equipment has an isolated input, one of the two lines should be grounded to avoid excessive voltage buildup on the otherwise isolated circuitry.

The voltage output range can be programmed (see Source Setup) for 2.5, 5.0 or 10 volts full scale. The output impedance is nominally 100 ohms. The outputs are short circuit protected with short circuit current limited to between 20 and 40 milliamps, though the outputs should not be short-circuited for long periods. The schematic appears in Figure 7-4.

CAUTION: *To avoid damage to the instrument, do NOT allow long term shorting of any of the source output which may cause excessive temperature rise in the isolated power supply.*

7.2   SENSOR INPUT

The sensor oscillator is connected through a single coaxial cable. Sensor ground is common with the MDC-260 ground. Power to the sensor oscillator is carried on the center conductor of the coaxial cable. Power is supplied from the MDC-260 internal 5-volt supply through a 50-ohm resistor which accomplishes the dual function of properly terminating the 50-ohm coaxial cable and providing short circuit protection. The sensor buffer circuit is shown schematically in Figure 7-4.

7.3   DISCRETE OUTPUTS

Each Discrete Output is an isolated, independent, normally open relay output connected to one pin pair on the output connector. Each output contact is rated for 120 VA, 2A maximum. See **Table 8-2** for pin signal assignments.

7.4   DISCRETE INPUTS

The inputs can be set to accept one of the two input types, "Passive" or "Active". They are selectable through the internal DIP switches (See Section 8.3.9.1).

The Passive inputs are activated by shorting the input's pins together. The inputs are internally pulled up to 5 volt through a 4.7 Kohm resistor and incorporate a 10-millisecond filter to enhance noise immunity and provide protection from a momentary short. The Passive input circuit is shown in Figure 7-1.

The Active inputs are activated by supplying 12 to 120 volt AC or DC across the input pins. The inputs incorporate a 10 millisecond filter to enhance noise immunity and provide protection from a momentary short. The Active input circuit is shown in Figure 7-2.

Pin assignments are shown in **Table 8-2**.
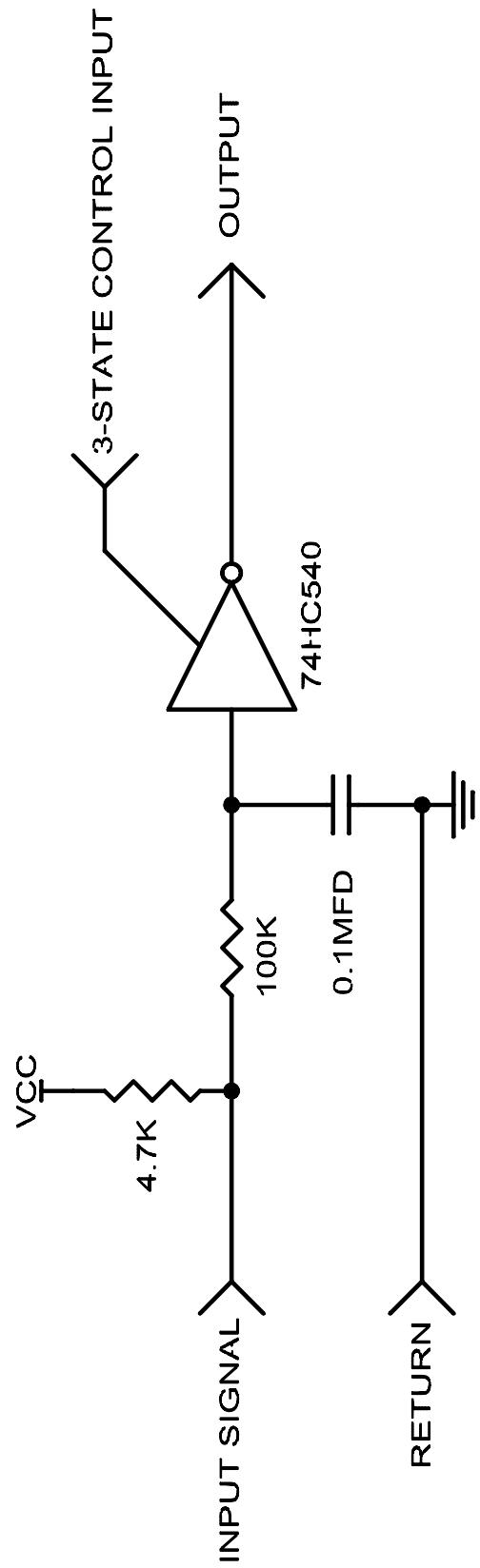
Figure 7-1 Passive Input Buffer circuit
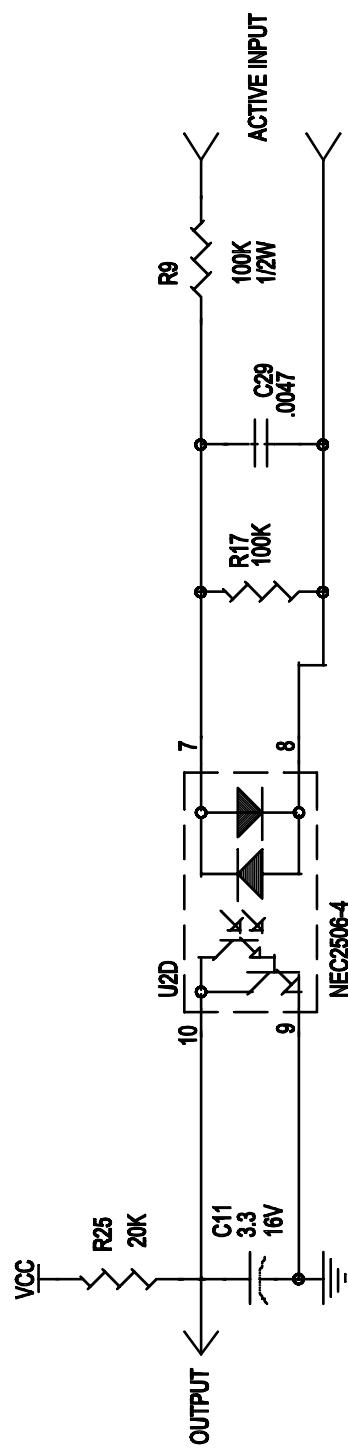
Figure 7-2 Active Input Buffer Circuit
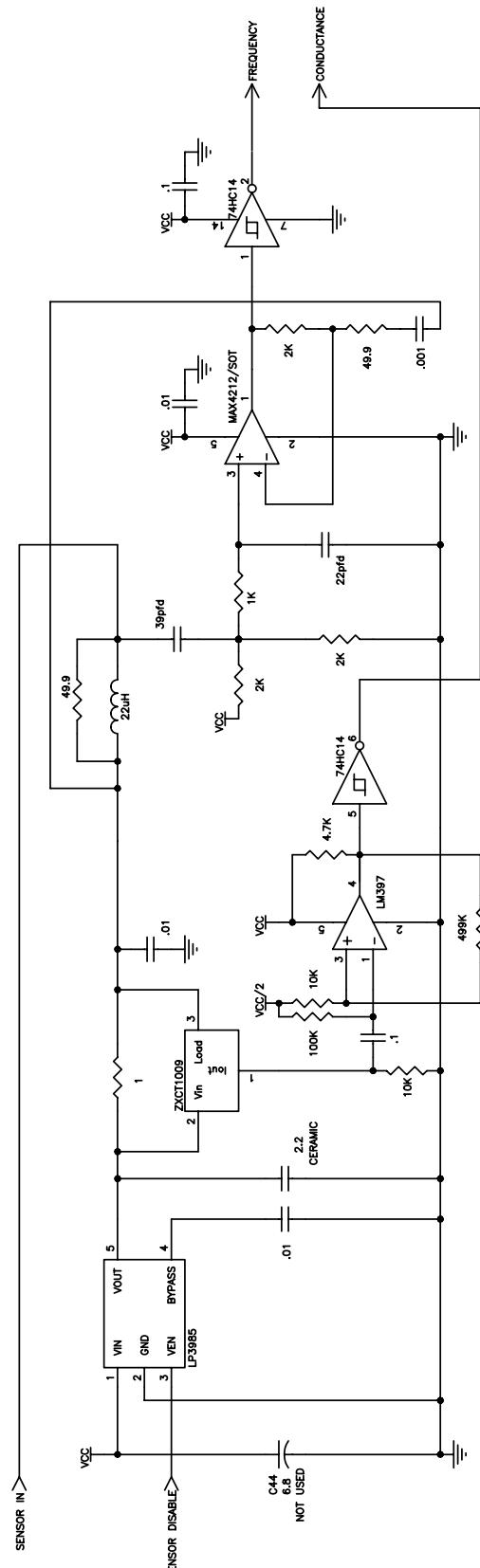
Figure 7-3 Sensor Input Buffer circuit
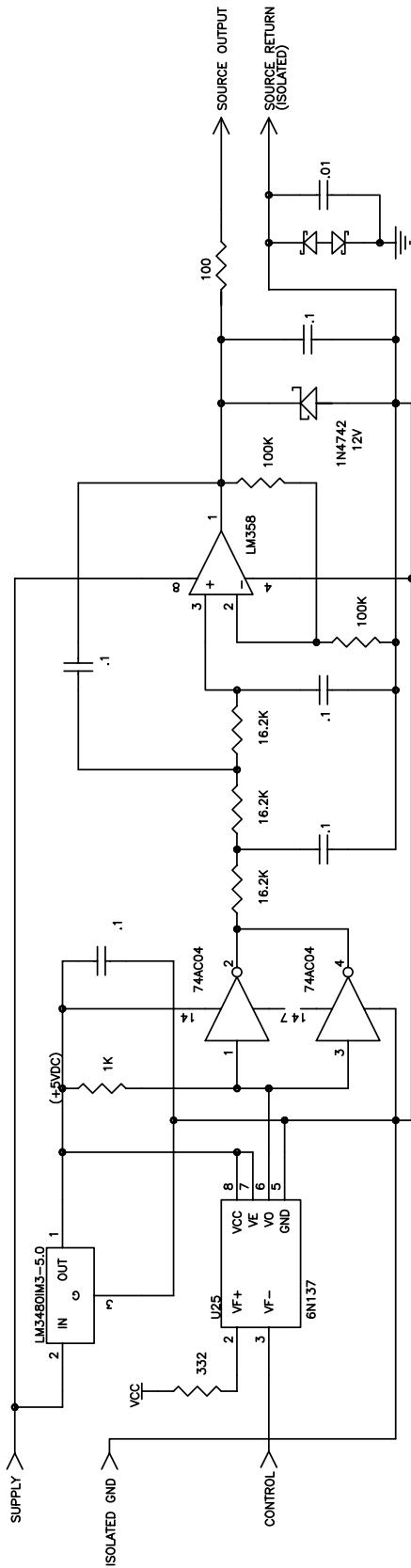
Figure 7-4 Source Output Driver circuit

8. CONTROLLER INSTALLATION

8.1 MOUNTING

The MDC-260 is intended for either rack mounting or desktop usage. When rack mounting, it should be mounted at approximately eye level for maximum operating ease. If the MDC-260 is mounted in a rack containing other heat generating equipment, care should be taken that there is adequate ventilation to assure that the ambient temperature does not exceed the MDC-260's ambient temperature rating.

8.2 PROPER GROUNDING

The MDC-260 was designed for maximum noise immunity and in most cases will require no special grounding precautions. In the event that noise sensitivity is noted in unusually noisy environments, more attention to proper grounding may be required. It is important that the rack in which the MDC-260 is mounted is tightly grounded to the vacuum station. This grounding is best accomplished by a multipoint mechanical connection through the structure itself or through grounding straps. Grounding straps should be as wide as practicable, preferably a 1" wide copper sheet or braid.

A small diameter copper conductor does not create an effective ground.

Although the D.C. resistance measured with such a connection may be low, the inductance can be high allowing rapidly changing currents to create large potential differences over the length of the ground wire. Multiple current paths significantly reduce the inductance, and since the inductance of a conductor is inversely proportional to it's radius, wide straps will have the lowest inductance.

In particularly noisy environments it is desirable to ground the MDC-260 to the rack frame, or other good ground, by means of a grounding strap connected to the grounding lug provided on the rear panel.

8.3 EXTERNAL CONNECTIONS

Most external connections are made through the rear panel (See Figure 8-4). The Remote Power Handset connector and a temporary USB connection are, however, located on the front panel (Figure 8-3).

8.3.1 POWER ENTRY MODULE

The power entry module is an internationally approved type. It provides connection to the power source and a protective ground. Two fuse holders, voltage selection wheel and RFI filter are part of the power receptacle assembly. The power plug must be removed to change the fuses or the voltage selection wheel position.

8.3.2 POWER CORD

WARNING: *To avoid electrical shock, always connect the power cord to an AC outlet which has a proper protective ground.*

The MDC-260 comes with a detachable, three-wire power cord for connection to a power source with protective ground.
The MDC-260 chassis is connected to the power ground to protect against electrical shock. Always connect to an AC outlet which has a properly connected protective ground. If necessary, or when in doubt, consult a certified electrician.

8.3.3 LINE VOLTAGE SELECTION AND FUSE REPLACEMENT

The voltage selection is preset at the factory to your requested line input voltage. However, the following nominal input voltages can be selected: 100, 120, 220, 240. For a 230 volt supply voltage, the 240 volt option should be used. The two line fuses are IEC T Type (Slow), 4/10 A, 250 VAC. To change the line voltage or to replace the fuses, refer to Figure 8-1 and follow the steps below.
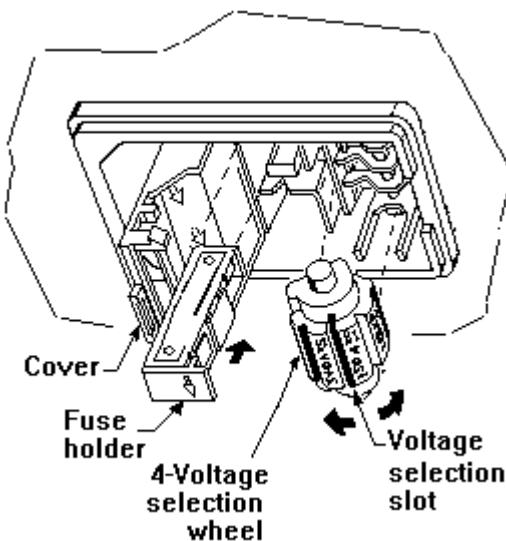
Figure 8-1 Power Entry Module

WARNING: *To avoid electrical shock or personal injury, disconnect the power cord before opening the cover on the power entry module.*

1. Disconnect the power cord from the power entry module.
2. Using a medium flat-tip screwdriver or similar tool, open the cover on the power module exposing the two fuses and the voltage selection wheel.

3. Insert the tool into the voltage selection slot and remove the wheel from the module.

4. Select the desired voltage. Replace the wheel back into the module.

5. If fuse replacement is needed, pull out the fuse holders. Check and replace fuse(s) with the correct type. Replace the fuse holders back into the module.

6. Close the module cover, making sure the selected voltage shows through the window.

8.3.4 GROUND LUG

Use heavy ground wire, wire braid, or copper strap of #12 AWG or larger to connect this grounding lug directly to a facility protective earth ground to provide additional protection against electrical shock. In particularly noisy environments the MDC-260 should be grounded to the instrument rack, or other good ground, by means of the grounding lug in the rear panel. (See Figure 8-4).

8.3.5 REMOTE POWER HANDSET

Figure 8-3 shows the location of the receptacle into which the Remote Power Handset is plugged.

8.3.6 SENSOR INTERFACE

The MDC-260 sensor interface is a 50-Ohm coax cable terminated with BNC connectors [similar to AMP 225395-1 (plug) and AMP 225396-1 (jack)]. The BNC jacks on the rear panel mate with a sensor oscillator.

8.3.7 SOURCE INTERFACE

The MDC-260 source interface is a 4-pin, circular mini DIN connector [equivalent to CINCH MDSS-4S]. The pin layout is defined in Figure 8-5 and

Table 8-1 supplies pin signal assignments.

8.3.8 USB COMMUNICATION

CAUTION: *The interface is designed only for one connection at a time. Do NOT attempt to connect both front and back USB ports to host computers.*

There are two USB "B" Type connectors on the MDC-260, one is located on the front and the other is in the back of the unit. They are both label "USB".

8.3.9 DISCRETE INPUT/OUTPUT

The MDC-260 communicates to external devices and logic controllers through the Discrete Input/Output D37P connector. When configured as "Passive", an input is asserted by shorting the desired input pin pair (the inputs are internally pulled-up to 5V through a 4.7 KΩ resistor). When configured as "Active", an input is asserted by supplying a 12- to 120-volt AC or DC signal to the desired input pin. Each discrete output is a relay that is closed when certain internal conditions are met. Refer to Section 4.3.3.2 and 4.3.3.3 for I/O programming instructions.

8.3.9.1 CONFIGURING INPUT TYPE

CAUTION: *To avoid damage to the instrument, verify the input type prior to making connections.*

Each individual input can be configured as either passive or active type by setting the two internal DIP switch array, SW1 and SW2. Refer to Section 8.5 and Figure 8-9 to remove the controller cover and locate the switches.
Each position of SW1 and SW2 are used as pairs. Both have to be set ON or OFF. ON selects passive type input and OFF selects active type input. The example on Figure 8-2 shows Input 1 through 4 are set for passive type, and Input 5 through 8 are set for active type.
Use the form in Section 14.4 to record the input type settings for future reference.
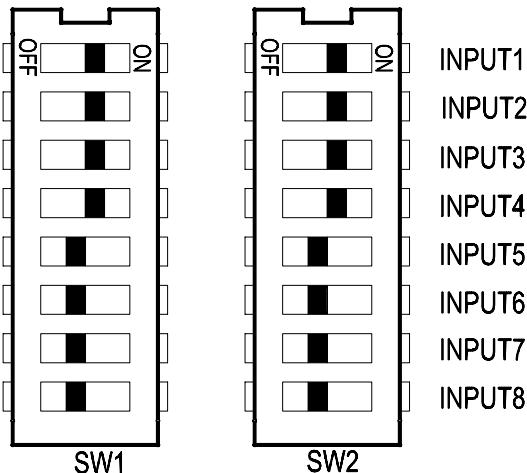
Figure 8-2 Input Type Selection Switches

8.4   POWER SWITCH

WARNING: *Do NOT use the power switch as a disconnecting device; disconnect the power cord from the power entry module to fully remove hazardous voltage from inside the controller.*

The power switch is located on the front lower left of the MDC-260. Pressing the switch will toggle the controller on or off. The MDC-260 is off when the LCD and all of the LEDs behind the operating keys are off. However, turning the power switch off does not fully remove the AC power from inside the unit. Always disconnect the power cord from the power entry module to fully remove AC power from inside the unit.

8.5   CONTROLLER COVER REMOVAL

WARNING: *Under no circumstances should the controller cover be removed without first removing the line voltage cord, as dangerous voltages are present inside the case.*

WARNING: *The controller contains no user serviceable parts. Only trained technician should attempt to service it.*

CAUTION: *To prevent damage to internal components by means of electrostatic discharge (ESD), wear a grounded anti-static wrist strap.*

Five screws located on the top of the unit and 1 screw on the rear panel secures the cover of the Monitor. Remove the 6 screws, and slide the top cover toward the rear.

To reinstall the cover, slide it into the groove created by the front and side panels, then replace the screws.

WARNING: *To avoid electrical shock or personal injury, do not operate the controller without its cover installed in place.*
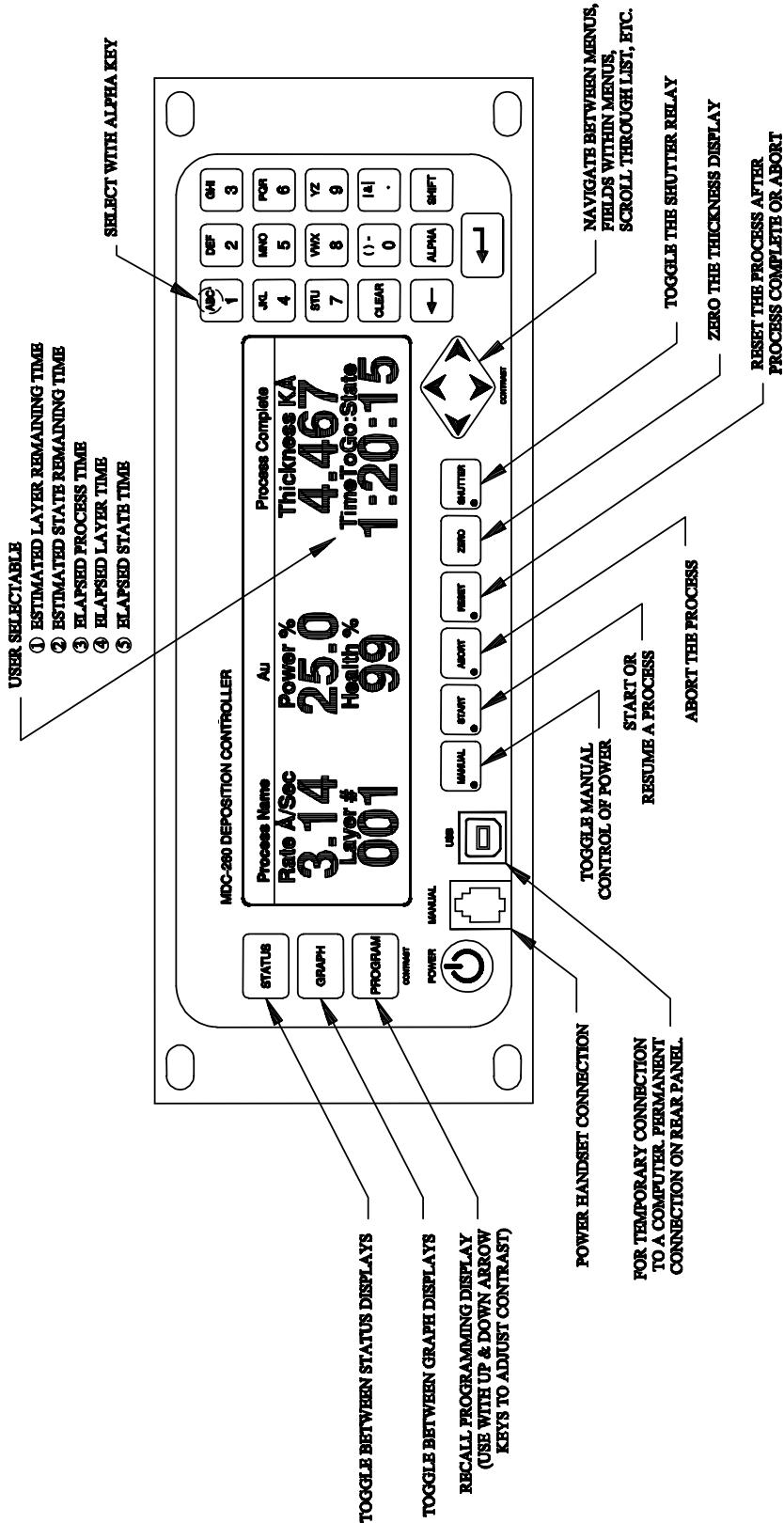
Figure 8-3 MDC-260 Front Panel
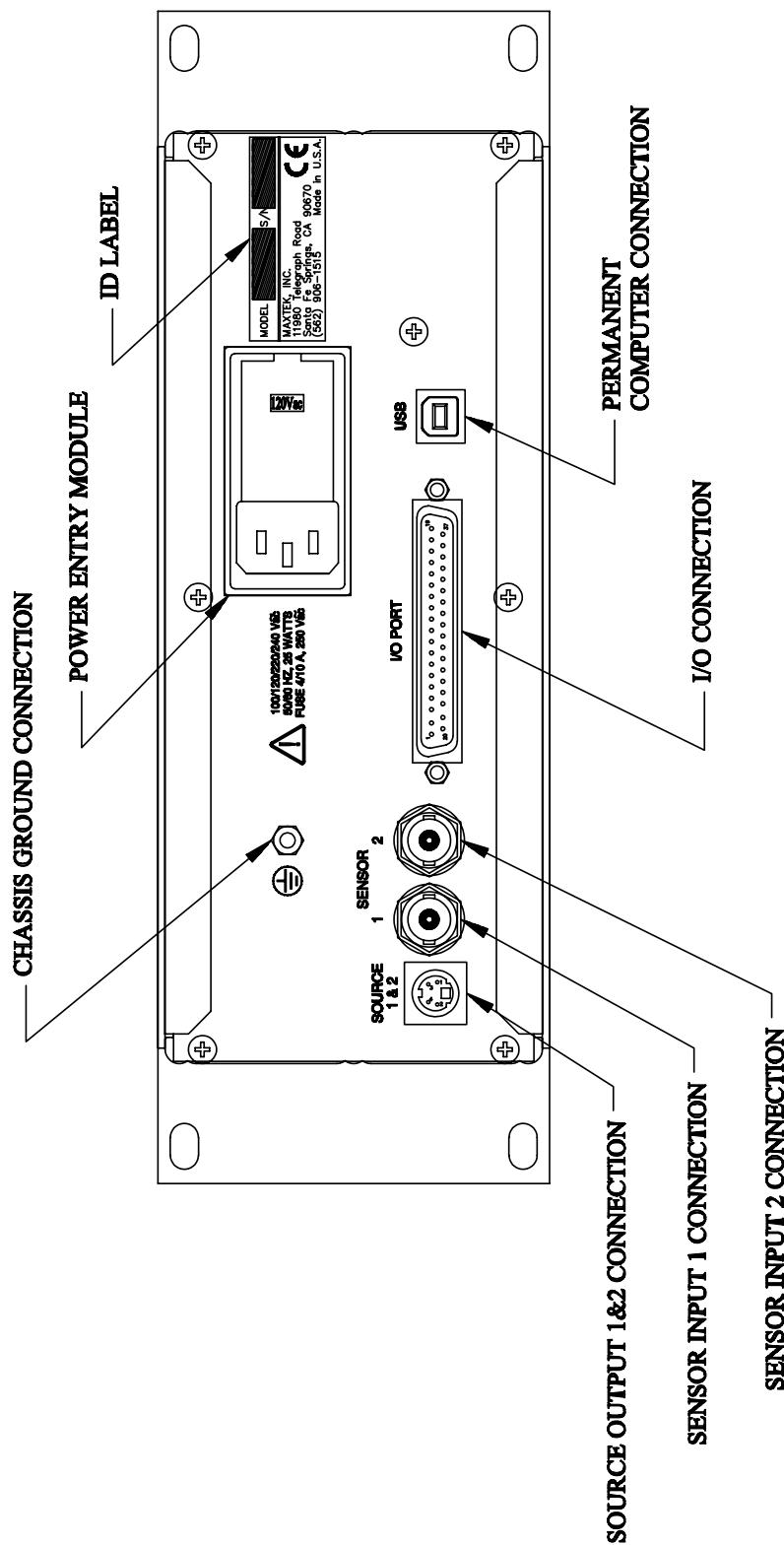
Figure 8-4 MDC-260 Rear Panel
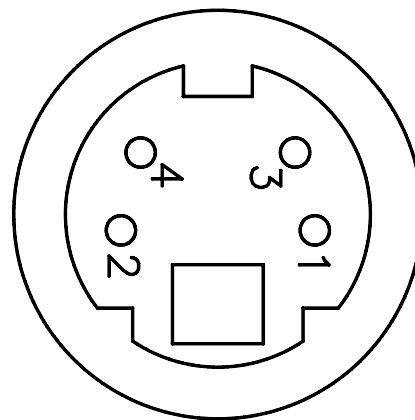
Figure 8-5 Source Socket Connector Pin Out

| Pin | Signal | |
Number	**Source-Sensor Bd #1**	**Source-Sensor Bd #2**
1	Source #2 Control Voltage	Source #4 Control Voltage
2	Source #2 Return	Source #4 Return
3	Source #1 Return	Source #3 Return
4	Source #1 Control Voltage	Source #3 Control Voltage

Table 8-1 Source Control System Interface Connector Pin Assignments
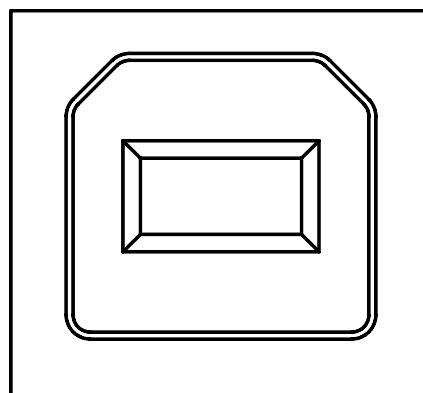
Figure 8-6 USB "B" Type Socket Front and Rear Panel Connector
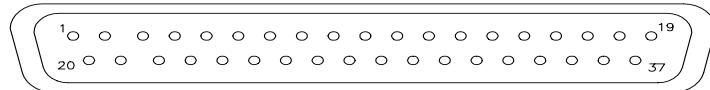
Figure 8-7 D37P Discrete I/O plug connector

Pin Number	Function
1, 20	Abort output
2, 21, 11	Output 1 (Common, N.O., N.C.)
3, 22, 29	Output 2 (Common, N.O., N.C.)
4, 23	Output 3
5, 24	Output 4
6, 25	Output 5
7, 26	Output 6
8, 27	Output 7
9, 28	Output 8
30	Input 1
12	Input 1 Return
31	Input 2
13	Input 2 Return
32	Input 3
14	Input 3 Return
33	Input 4
15	Input 4 Return
34	Input 5
16	Input 5 Return
35	Input 6
17	Input 6 Return
36	Input 7
18	Input 7 Return
37	Input 8
19	Input 8 Return

Table 8-2 Discrete I/O System Interface Connector Pin Assignments

PIN 1 ⎯⎯⎯   ⎯⎯⎯ PIN 4
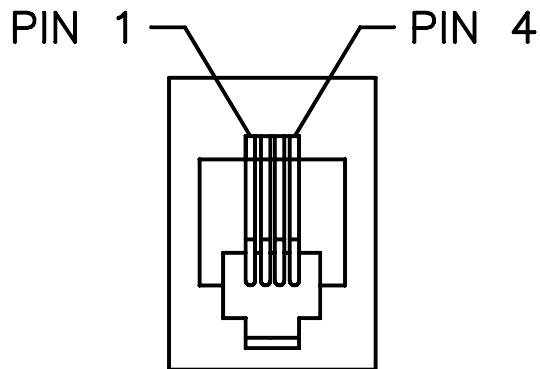
Figure 8-8 Front Panel Manual Power Connector

Pin Number	Signal
1	Decrease
2	GND
3	Abort
4	Increase

Table 8-3 Front Panel Manual Power Connector Pin Assignments

SW1 & SW2, USE TO SET INPUT TYPE
(PASSIVE OR ACTIVE)
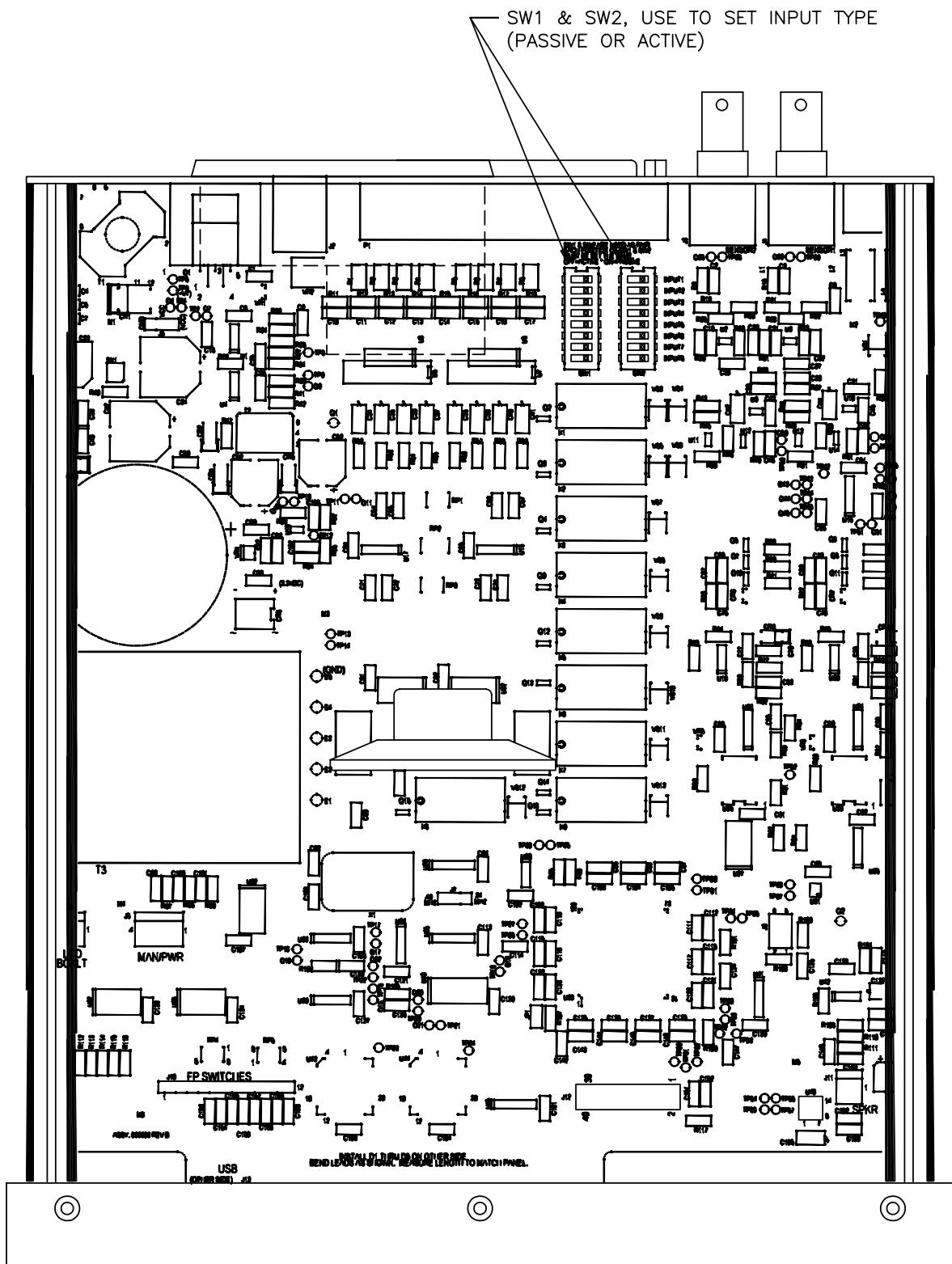
Figure 8-9 MDC-260 Top View (Cover Removed)

IMPORTANT!
RECOMMENDED GROUNDING METHOD

Bolt copper strap to ground lug of the MDC-260.

MDC—260 CONTROLLER REAR PANEL

Star washers are recommended to be used between the front panel mounting angles and the rack. The star washers will cut through the paint providing four additional ground points between the MDC and the instrument rack.

System Grounding Point Bolt copper straps to clean, bare metal.

Copper straps should be as wide as practical, preferably a 1'' wide copper sheet or braid.

Building Floor

Grounding Rods, 6 ft. apart copper-clad steel, ¾" dia. X 8 ft. (minimum)

1. As shown, sink two grounding rods into the earth approximately six feet apart. Locate these rods as close as possible to the vacuum cabinet.

2. Measure the resistance between the rods. If the resistance is greater than 3 Ohms, consult an Electrician specializing in grounding systems. If the resistance is 3 Ohms or less, connect a length of copper grounding strap to the system's central grounding point, which should be somewhere on the vacuum system.

3. Silver solder the other end of this grounding strap to the rods. Do not rely on mechanical connections.

Figure 8-10 Recommended Grounding Method

9.   SYSTEM INSTALLATION

9.1   SENSOR HEAD DESCRIPTION

The sensor head is designed for simple installation and easy crystal replacement. It consists of two parts; a water-cooled gold-plated 304 stainless steel housing which is permanently positioned in the vacuum system, and a quickly removable gold plated 304 stainless steel crystal holder which snaps into the housing. The crystal holder accommodates an industry standard 0.550" diameter crystal.

This design provides several convenient features in performance and use. The crystal holder is thermally shielded by the water-cooled housing insuring excellent crystal performance in temperature environments up to 300°C. The sensor may be baked out with no water-cooling to temperatures up to 250°C.

The exposed crystal electrode is fully grounded to effectively eliminate problems due to free electrons and RF interference.

The crystal holder is easily removed and installed even in awkward locations in the vacuum system. Once removed from the housing the crystal is still retained in the crystal holder by a snap on retainer. The crystal can be easily replaced without tools at a more convenient place, such as a clean bench.

The housing is provided with four tapped (4-40) holes for convenient mounting, 1/8" diameter X 5" long inlet and outlet water cooling tubes, and a coaxial connector (See Figure 9-6). The electrical connection to an instrumentation feedthrough is made with a 30" coaxial cable. Both ends of the cable terminate with standard Microdot® S-50 type connectors. Cable lengths up to 60" are available upon request.

9.2   SENSOR HEAD INSTALLATION

The sensor head can be installed in any appropriate location in the vacuum chamber, preferably more than 10 inches from the evaporation source. It can be supported by its integral mounting bracket furnished with two #4-40 tapped holes. The internal (vacuum) cable, supplied with the sensor kit, connects the sensor head to the dual water/electrical feedthrough, to which the oscillator is attached. The cable length from sensor head to feedthrough connection should not exceed 60 inches. Shield the sensor cable in the most expedient way possible to protect it from radiation heat released from the evaporation source or the substrate heater.

The water-cooling tube connects to the feedthrough by brazing or vacuum couplings. If necessary, both cable and water lines may be wrapped in aluminum foil to extend their useful life. The mounting tabs may be used to install a radiation shield to specifically protect the Microdot® connector and cable at its attachment point to the head.

Water-cooling of the sensor head should always be provided except during short depositions at low temperatures. In all cases, head operating temperature should not exceed 100°C. Sufficient cooling for thermal environment to 300°C can be provided by approximately 0.2-gpm water flow.

Use a shutter to shield the sensor during initial soak periods to protect the crystal from any sputtering that may occur. If a small droplet of molten material hits the crystal, the crystal may be damaged and oscillation may cease.

9.3   SENSOR OSCILLATORS

There are two sensor oscillators that may be used with the MDC-260, namely the SO-100 and the VPLO-6. Both oscillators are designed to work with industry standard 6-megahertz sensor crystals. Each oscillator is supplied with a 6" coaxial cable and a 10' coaxial cable. The 6" cable interconnects the oscillator and the feedthrough. The 10' cable interconnects the oscillator and the MDC-260. This single coaxial cable provides both power for the oscillator and the signal output for the controller. Cables of other lengths are available upon request for replacing the 10' cable.

9.3.1   SO-100 OSCILLATOR

The SO-100 sensor oscillator, Figure 9-3, is a simple, economical oscillator unit designed to work with most simple metal film deposition processes. It contains no intelligent.

9.3.2   VPLO-6 OSCILLATOR

The VPLO-6 sensor oscillator, Figure 9-4, has the phase lock loop technology incorporated in its design. This allows the sensor crystals to achieve their maximum life span. It also helps the rate stability in controlling the most complex deposition processes. In addition, it has built-in intelligent that make troubleshooting of installation problems effortless.

9.3.3   INSTALLATION

Connect one end of the 10-foot oscillator cable to the BNC connector on the appropriate sensor input at the rear of the MDC-260. Connect the other end of the cable to the oscillator with the arrow pointed toward the sensor head. The oscillator connects to the feedthrough leading into the vacuum chamber using a 6 in. cable.

⚠ **CAUTION:** *Always use the cables supplied by INFICON to make the connections. Failure to make these connections properly will result in the impedance mismatch of the oscillator circuit.*

9.4   INSTRUMENTATION FEEDTHROUGH

A 1 inch diameter, O-Ring sealed feedthrough (IF-111, Figure 9-5) or a 2-3/4 inch Conflat® flange seal are available with 1/8 inch source and return water cooling lines, and internal and external coaxial cable connectors. Base plate thickness up to one inch can be accommodated.

RF interference and free electrons are effectively shielded from the signal connector through the use of fully closed coaxial cable connections. A standard coaxial cable with a Microdot® S-50 connector mates the internal feedthrough

connector to the sensor head. The feedthrough has a standard BNC connector for the coaxial connection to the sensor oscillator.

9.5   SENSOR CRYSTAL REPLACEMENT

The Next Generation Cool Drawer™ simplifies the replacement of the sensor crystal. However, since the system relies on the sensor crystal to perform accurate measurements, care must be taken to maintain the cleanliness of the crystal during installation. Please read the following Section 9.5.1 and 9.5.2 before attempting to replace the crystal.

Removal and replacement of sensor crystals should be performed in a clean environment. An isolated clean workbench is recommended for crystal replacement.

9.5.1   CRYSTAL CARE AND HANDLING

It is essential that a sensor crystal is clean and free of contamination that undermine the quality of the crystal inducing errors in the measurements or shortening its useful life. The following guidelines are recommended for general handling of the sensor crystals.

♦   Keep the crystals in a clean environment. Store them in their original package until use.

♦   Never handle the crystals with bare hands.

♦   Always use plastic tweezers around the edge of the crystal during handling.

♦   Do not touch the center of a sensor crystal, as any oil, dirt, dust, or scratches will quickly degrade the quality of the crystal.

♦   When using a chemical agent to clean the crystal, ensure that the crystal electrode material(s) will not be damaged by the chemical.

♦   Never use cleaner that will etch the quartz surface.

♦   Always rinse with deionized water, or another appropriate pure liquid, before drying the crystal.

♦   Always use a flow of dry, oil-free, non-reactive gas (e.g. filtered nitrogen) to blow-dry the crystal. It is better to chase liquid off the crystal than to let it evaporate off the crystal.

♦   Never wipe the crystal – even soft, lint-free cloth will scratch the crystal.

♦   When handling the drawer always hold it by the edges to avoid touching the crystal surface.

9.5.2   CRYSTAL REPLACEMENT PROCEDURE

1. Using your thump and index fingers, gently squeeze the sides of the retainer at mid section then lift it up, away from the drawer, as shown in Figure 9-1.
2. Holding the drawer by the handle and turn it up side 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 9-2.

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 9-2. Never push down (or pull up) on the contact spring, doing so may permanently damage it.

5. Inspect the whole assembly. The retainer should lie evenly and engage the drawer at all of the four corners.

Contact spring
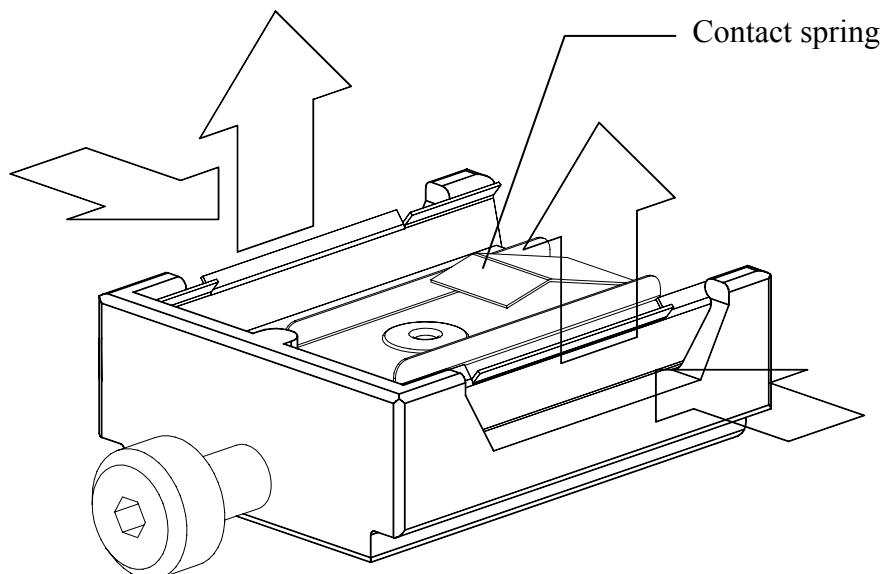
Figure 9-1 Removing the Crystal Retainer

Retainer

Crystal

Orientation
Notch

Handle

Drawer
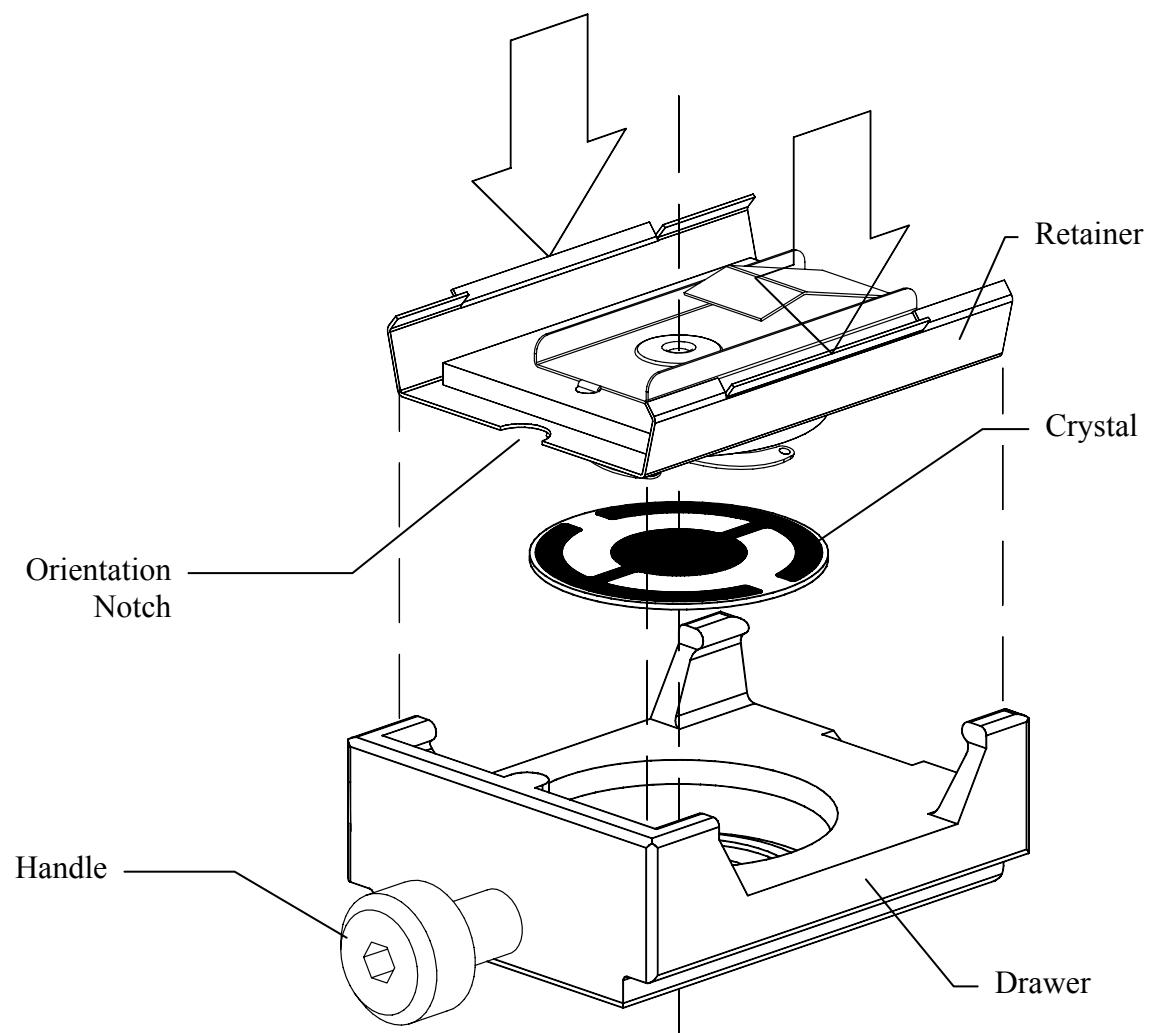
Figure 9-2 Installing the Sensor Crystal

9.6 TYPICAL SYSTEM INSTALLATION

A typical system installation is shown in Figure 9-7. Installation can vary depending on the application
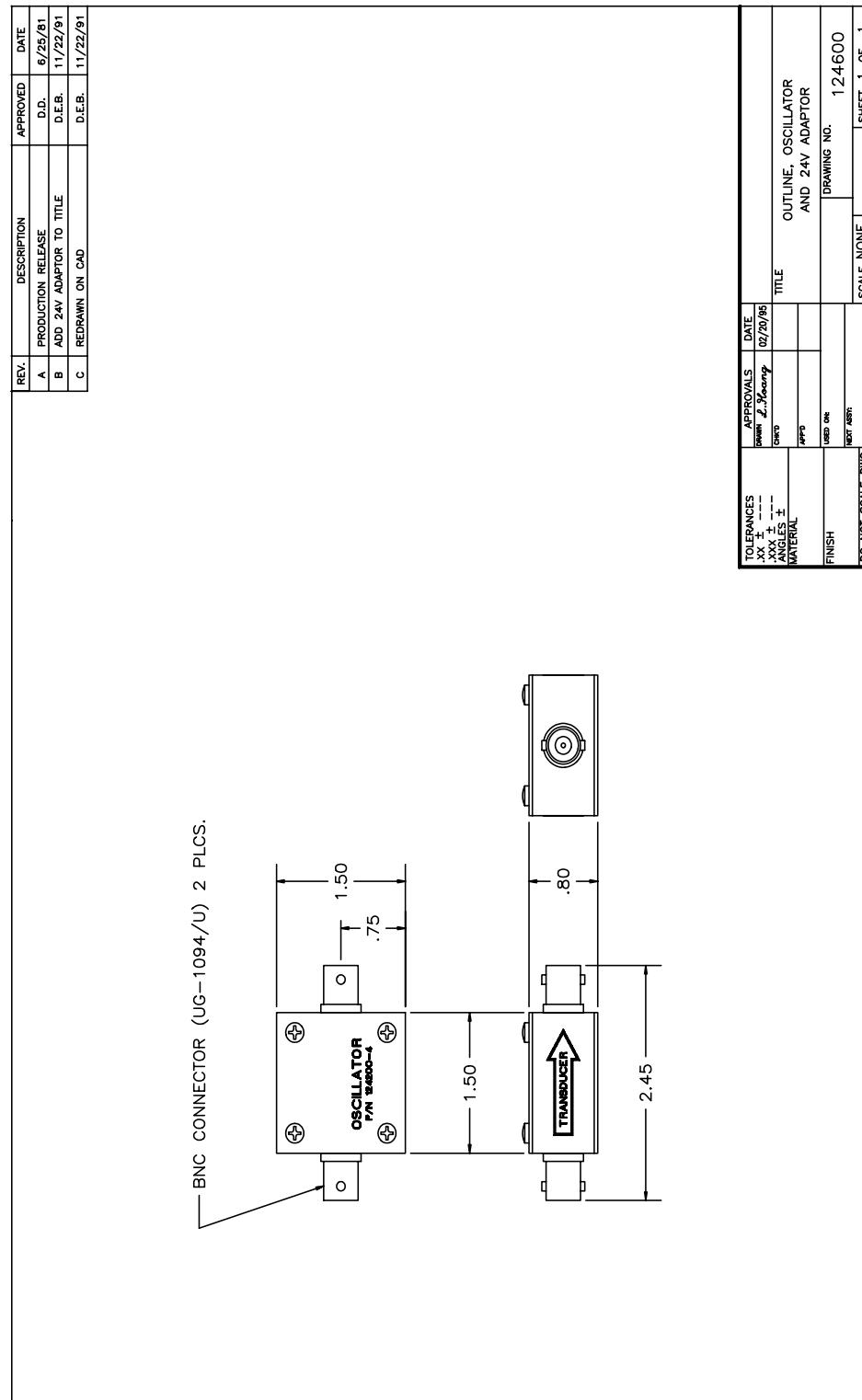
Figure 9-3 SO-100 Sensor Oscillator Outline
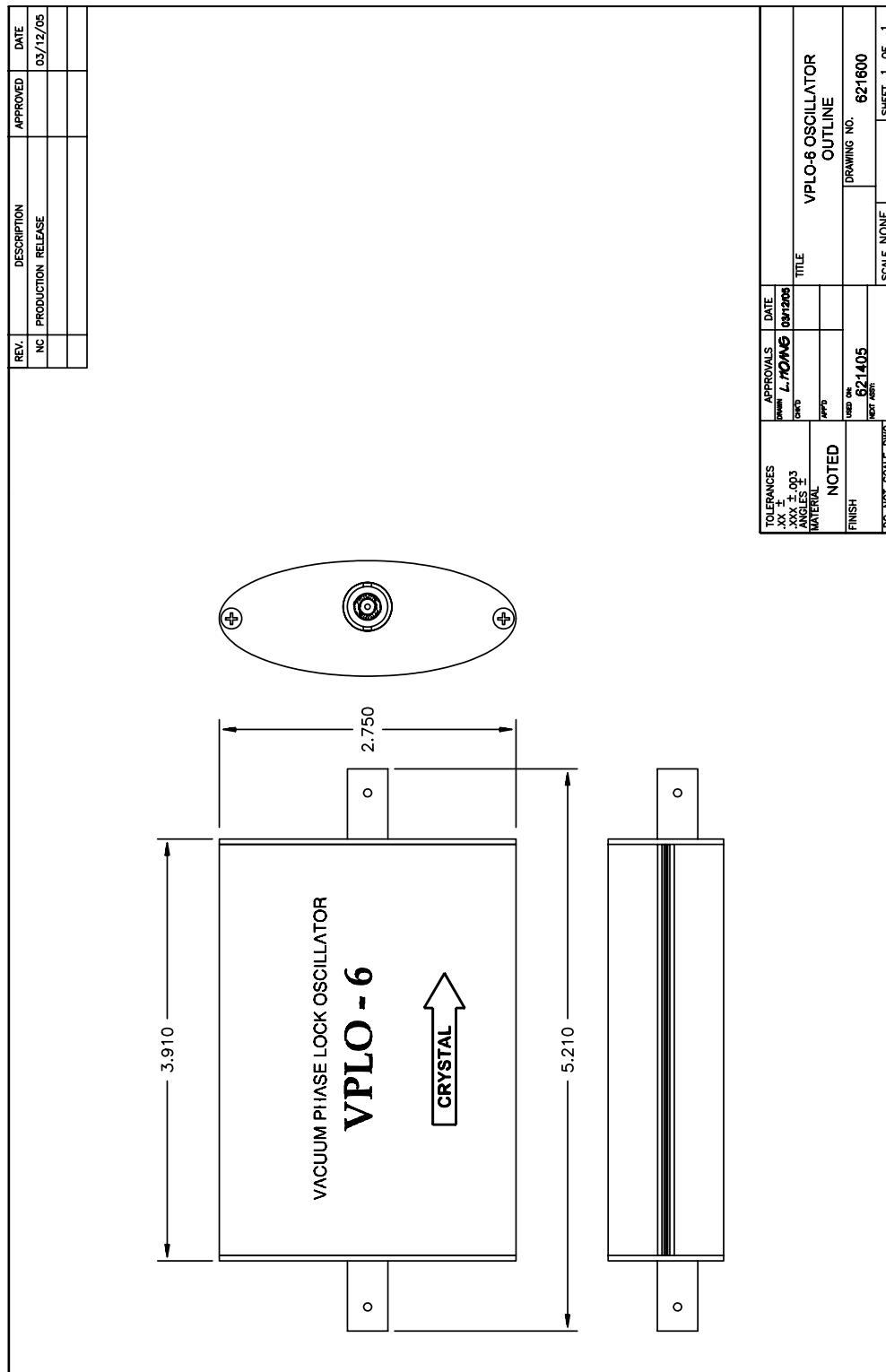
Figure 9-4 VPLO-6 Sensor Oscillator Outline

NOTE:
1. ALL PARTS ARE TYPE 304 CRES EXCEPT BNC CONNECTOR.

O-RING #122 (VITON)

WASHER 2.0"[5.1] OD X 1.0"[2.5] ID X .062"[0.16] THK

NUT 1-14 UNS X .55"[1.4] THK

BNC CONNECTOR (UG-1094/U)

TUBE .189"[0.48] O.D. (2) PLCS

MICORDOT S-50 TYPE CONNECTOR

7.00±.12

1.63

1.00

.38

5.00±.12

(MAX. BASE PLATE THICKNESS)

1.50
HEX

REV.   DESCRIPTION   APPROVED   DATE
A   PRODUCTION RELEASE   D.D.   05/14/81

APPROVALS   DATE
DRAWN L. Young   2/22/95
CHK'D
APP'D

USED ON:
NEXT ASSY:

TOLERANCES
.XX ± .03
.XXX ± ---
ANGLES ±
MATERIAL

FINISH

DO NOT SCALE DWG.

TITLE
OUTLINE, IF-111
1" O-RING INSTRUMENTATION F/T

DRAWING NO.   130605

SCALE NONE   SHEET 1 OF 1

Figure 9-5 IF-111 Instrumentation Feedthrough Outline
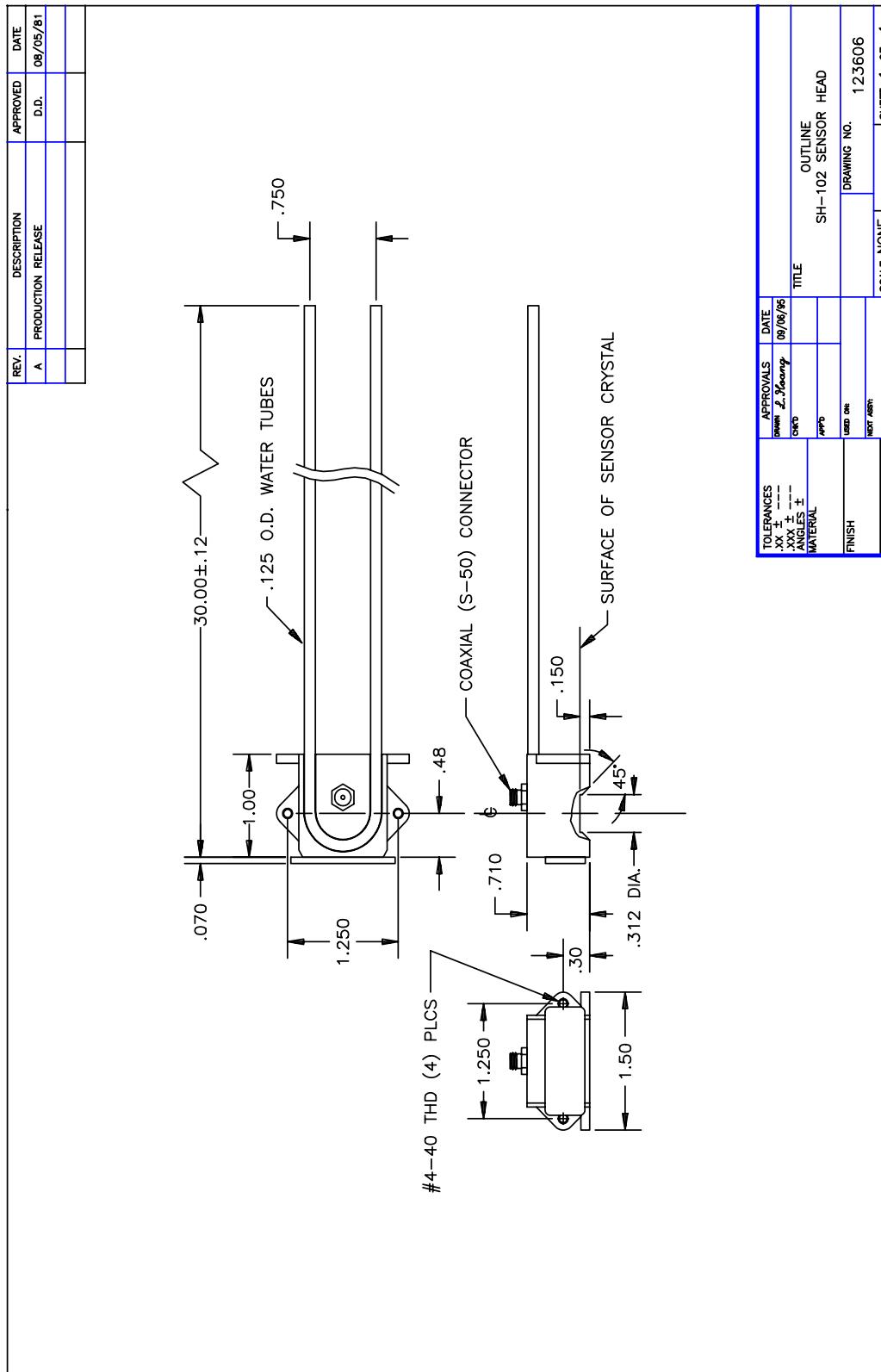
Figure 9-6 SH-102 Sensor Head Outline
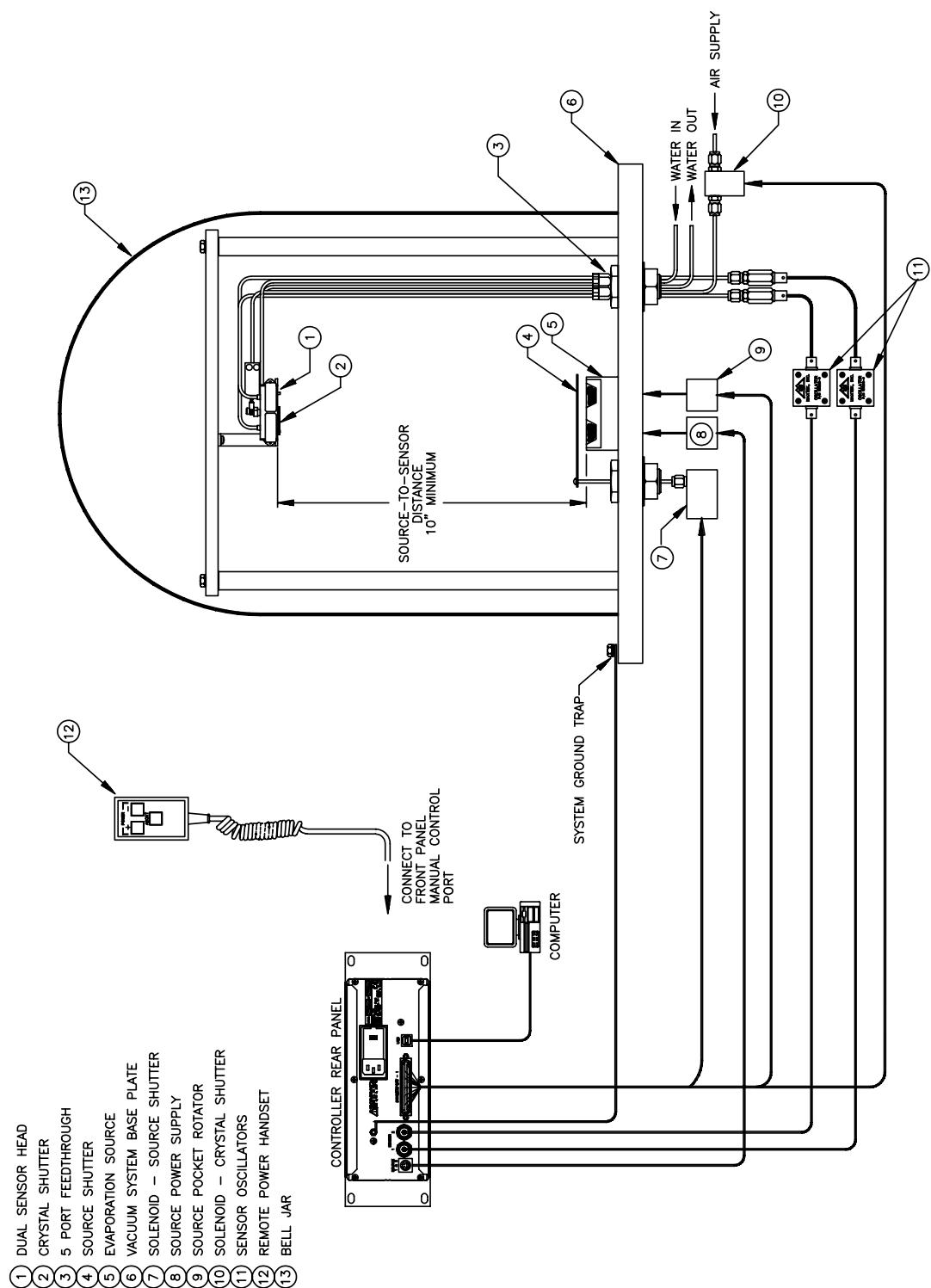
Figure 9-7 Typical System Installation

10.   THEORY OF OPERATION

10.1   BASIC MEASUREMENT

The MDC-260 uses a quartz crystal as the basic transducing element. The quartz crystal itself is a flat circular plate approximately 0.55 in. (1.40 cm) in diameter and 0.011-0.013 in. (28-33mm) thick for 6 and 5 MHz. The crystal thickness is inversely proportional to the crystal frequency. The crystal is excited into mechanical motion by means of an external oscillator. The unloaded crystal vibrates in the thickness shear mode at approximately the frequency of the specified crystal. The frequency at which the quartz crystal oscillates is lowered by the addition of material to its surface.

10.2   FILM THICKNESS CALCULATION

Early investigators noted that if one assumed that the addition of material to the surface produced the same effect as the addition of an equal mass of quartz, the following equation could be used to relate the film thickness to the change in crystal frequency.

$$TK_f = \frac{N_q \cdot \rho_q}{\rho_f \cdot f^2}\left(f_q - f\right) \qquad (1)$$

where:

N_q= Frequency constant for an "AT" cut quartz crystal vibrating in thickness shear (Hz x cm).

N_q = 1.668 x 10^5 Hz x cm.

ρ_q = Density of quartz g/cm^3.

f_q = Resonant frequency of uncoated crystal.

f = Resonant frequency of loaded crystal.

Tk_f = Film thickness.

ρ_f = Density of film g/cm^3 .

This equation proved to be adequate in most cases, however, note that the constant of proportionality is not actually constant because the equation contains the crystal frequency which of course changes as the film builds up. Because the achievable frequency change was small enough, the change in scale factor fell within acceptable limits.

Improvements in sensor crystals and oscillator circuits resulted in a significant increase in achievable frequency shift. Low cost integrated digital circuits became available allowing a significant increase in basic instrument accuracy. As a result of the above two factors, the frequency squared term in the scale factor became a significant limitation on the measurement accuracy.

If the period of oscillation is measured rather than the frequency, 1/period can be substituted for frequency resulting in the following equation.

$$TK_f = \frac{N_q \cdot \rho_q}{\rho_f} \left(\tau - \tau_q \right) \qquad\qquad (2)$$

where:

$\tau =$ Period of loaded crystal (sec.)

$\tau_q =$ Period of uncoated crystal (sec.)

Note: Units of are cm/sec.

Note that the constant of proportionality in this equation is constant. This approach was demonstrated to be a significant improvement over frequency measurement and was widely adopted.

The original assumption that the addition of a foreign material to the surface of the crystal produced the same effect as that of the addition of an equal mass of quartz was of course, questionable and indeed work with crystals heavily loaded with certain materials showed significant and predictable deviation between the actual measured film thickness and that predicted by equation 2. Analysis of the loaded crystal as a one dimensional composite resonator of quartz and the deposited film led to the equation below:

$$TK_f = \left(\frac{\rho_q}{\rho_f} \right) \cdot N_q \cdot \left(\frac{\tau}{\pi R_z} \right) \cdot \arctan\left[R_z \tan \pi \left(\frac{\tau - \tau_q}{\tau} \right) \right] \qquad\qquad (3)$$

where:
R_z is referred to as the Acoustic Impedance Ratio and is obtained by dividing the acoustic impedance of quartz by the acoustic impedance of the deposited film.

This equation introduces another term into the relationship which is the ratio of the acoustic impedance of quartz to the acoustic impedance of the deposited film. The acoustic impedance is that associated with the transmission of a shear wave

in the material. Note that if the acoustic impedance ratio is equal to one, quartz on quartz, equation 3 reduces to equation 2.

Although the above equation still involves a number of simplifying assumptions, its ability to accurately predict the film thickness of most commonly deposited materials has been demonstrated.

The use of microprocessors allows an equation as complex as equation 3 to be solved economically and the above equation is implemented in the MDC-260.

The basic measurement is period, which can be thought of as a measurement of equivalent quartz mass.

The actual film mass on the crystal is then found by applying the acoustic impedance correction factor.

At the beginning of the deposit, or when the thickness indication is zeroed, the initial equivalent quartz mass and the initial corrected film mass are stored. For each subsequent measurement the new corrected total film mass is calculated, and the film mass deposited since the start of deposit is determined by subtracting the initial corrected film mass from the total corrected film mass.

The film thickness on the crystal is calculated by dividing by the film mass by the film density.

The film thickness on the substrates is then calculated by multiplying the film thickness on the crystal by a tooling factor.

If the acoustic impedance parameter is changed following a deposition both the total and the initial film masses are recalculated. This allows the effect of the changed parameter value to be immediately displayed and provides a relatively straightforward method of empirically determining the acoustic impedance if it is not available. See section 10.5.3.

10.3   SENSOR CRYSTAL

An essential part of the MDC-260 system is the sensor crystal. A good understanding of its behavior will help minimizing unnecessary problems, and ensure proper and reproducible measurements. Refer to Section 9.5.1 and read the following sections carefully to get a full understanding of the sensor crystal.

10.3.1 CRYSTAL HEALTH

The crystal health is calculated and displayed in two different ways, depending on which sensor oscillator is used. If the SO-100 was used, the Crystal Health is displayed as a percentage, which decreases from a value of 99% for an uncoated crystal blank to 0 at a total deposited aerial mass of 25 mg/cm^2. This value corresponds to a crystal frequency shift of approximately 1.5 MHz, or an aluminum thickness of 925 KÅ. Because the crystal health is determined from the calculated film mass, the Acoustic Impedance parameter will affect the displayed crystal health.

10.3.2 CRYSTAL STABILITY

A sensor crystal cannot distinguish the difference between a frequency shift due to deposited material or that due to other disturbances. Thus any extraneous factors, other than the deposited mass, which may cause the quartz crystal to change its resonant frequency, must be properly controlled. Factors that can influence the stability of a sensor crystal are categorized as follows:

♦ The crystal itself: Improper design, localized stress, damage to the crystal

♦ The crystal holder: Improper seating of the crystal, large mechanical coupling between the crystal and the holder

♦ Thermal input: Radiation from evaporation source, radiation from substrate heater, bombardment by charge particles, energy released by condensates

♦ Stress: Thermal stress, stress release in the deposited materials

Other factors that can affect stability are humidity, shock, vibration and change in pressure. Controlling those conditions is a must to insure accurate measurements.

10.3.3 TEMPERATURE COEFFICIENT OF THE CRYSTAL

The temperature coefficient of quartz crystals is normally specified in units of parts per million per degree of temperature change. A one part per million change in frequency of the sensing crystal corresponds to an indicated thickness change of approximately 7.4 Å for a material with a density of 1.0 gm/cm³. For Aluminum with a density of 2.7 gm/cm³, this is equivalent to approximately 2.7Å. This intrinsic dependence of resonance frequency of a sensor crystal on temperature is generally small in applications in gas phase when operating at or near its "turn-around-point". The "turn-around-point" is where the temperature coefficient of the crystal is zero. That is, there is no change in resonance frequency due to a change in the temperature of the crystal at the turnaround point. INFICON vacuum crystals are optimized for operating temperature of 70ºC. These crystals have very good temperature stability when operating close to their specified temperature.

Over the temperature range of 20° to 100° C, the worst case temperature coefficient is equivalent to approximately 2 Å of Al per degree C of crystal temperature change. However, because the temperature coefficient is not constant, the worst case drift in indicated thickness over a crystal temperature range of 20° to 100° C, is approximately ± 100 Å of Al.

The typical worst-case drift in indicated thickness over the range of 20° to 100° C (68° to 212° F) is on the order of 50 Å. The indicated thickness drift may be either positive or negative depending on the actual operating temperature and the actual crystal cut.

Once the turnaround point is exceeded, the temperature coefficient will always be negative with respect to indicated thickness (positive with respect to frequency change). That is, as the temperature of the crystal continues to increase, the indicated thickness will slowly decrease even though the actual thickness is constant.

The temperature induced drift is reversible, which means that, even if the temperature of the crystal is allowed to increase drastically during deposition, as long as the temperature of the crystal is allowed to return to its pre-deposition temperature the resulting indicated thickness will contain no error due to crystal temperature.

There is, however, an upper limit above which the temperature of the crystal should not be allowed to climb. Quartz has a Curie temperature of about 573° C (1063° F). At the Curie temperature the crystallographic structure changes and the quartz loses its piezoelectric nature. The process is irreversible and the structure which supports piezoelectric behavior does not return when the temperature is brought back below the Curie temperature. The crystal is thus irreversibly damaged once the Curie temperature is reached.

The Curie temperature can be significantly lowered by stress so the maximum crystal temperature should be kept well below the 573° C limit.

10.3.4 CRYSTAL LIFE EXPECTANCY

It is difficult to predict the useful life of a crystal since it depends on many factors. Some of these factors are:

- The quality of the quartz

- The amount of deposited material

- The stress generated in the crystal due to deposited material

- The acoustic losses in the deposited material

- The design of the oscillator circuitry

Other aspects that affect the crystal life include the type of the deposited material, spitting of source material resulting in non- uniform films, film flakes that landed on the crystal's active area, and of course, physical damage to the crystal such as chipping, cracking, or peeling of the electrode, etc.

In general, a sensor crystal can be used until its frequency drops to about 50% of its uncoated value. However, for the reasons stated above, crystal failures often occur well before that.

The sensor crystals are considered expendable. However, a crystal may be reused. In applications where a film is deposited, the crystal can be stripped using a chemical etchant. Care must be taken so only the deposited material is stripped and not the crystal electrodes. The amount of times that a crystal can be reused greatly depends on its condition after each use or stripping. Needless to say, careful handling and cleaning of the crystal is required to maximize its re-usability. INFICON does not recommend reusing the crystal once it failed. It is up to the user to weigh the cost benefit of reusing the crystal versus jeopardizing a production run to a might-be-marginal crystal.

Noisy or erratic measurement indicates that the crystal is about to fail. It might even be difficult to obtain a stable baseline. Visually, traces of consumption and wear can often be seen on the crystal surface. Edges of the sensor crystal might

become cracked and the deposited film, even the electrode, starts to show scratches and tears.

In order to establish the point at which the crystal should be changed, several trial runs should be made to determine the point at which the crystal fails and subsequent crystals should then be replaced well in advance of this point.

10.3.5 CRYSTAL ELECTRODE TYPE RECOMMENDATION

There are generally three film deposition categories, low stress, high stress, and dielectric films. Recommended crystal electrode types for each category are explained below.

Low Stress Films: Gold electrode crystals are recommended for deposition of low stress materials like aluminum, copper, gold, silver, etc. These materials generally soft and produce very little or no tensile stress. You can also use silver or aluminum electrode crystals for these materials.

High Stress Films: Materials like chromium, inconel, molybdenum, nickel, nickel-chrome, zirconium, titanium, etc., will produce high stress films. These films often "pull" on the crystal's sensing electrode surface, which may sometimes alter its oscillation, creating rate noise, oscillation failure, etc. We recommend that silver electrode crystals to be used for these films. The silver electrode surface yields and absorbs the stress on the quartz. Aluminum electrode crystals are also recommended for these materials.

Dielectric Films: Aluminum electrode crystals are recommended for use in deposition of dielectric materials like aluminum oxide, magnesium fluoride, silicon monoxide and dioxide, titanium dioxide, thorium fluoride, etc. However, the trick is to get these materials to stick to the aluminum electrode. Usually, heating up the crystal (and the substrates) would dramatically enhance the adhesion.

10.4   RATE CALCULATION

The deposition rate for each sensor is calculated by dividing the change in the measured thickness by the time between measurements. The rate is then filtered by a three pole digital filter to filter out quantizing and sampling noise introduced by the discrete time, digital nature of the measurement process. The above filter has an effective time constant of about 2 seconds. Following a step the displayed rate will settle to 95% of the final value in 5 sec. The individual sensor rates are displayed in the Source/Sensor status screen.

If only one sensor is enabled for measurement, then the displayed rate is the measured rate for only that sensor. If multiple sensors are enabled for measurement, then the displayed rate is the weighted average of all of the sensors enabled for measurement.

10.5   EMPIRICAL CALIBRATION

For many film materials the film density and acoustic impedance is known to sufficient accuracy that the values can be used directly, and empirical calibration

of these parameters is not necessary. A library of material names, density and acoustic impedance of the more commonly deposited materials is stored in the MDC-260 memory. These materials are also listed in Table 10-1.

If the values of the density and acoustic impedance are not known they can be calibrated empirically as described below.

Calibration requires the establishment of the film density, the tooling factor and the acoustic impedance in this order. If the approximate value of the parameters is known they should be used initially. If the acoustic impedance is not known use the value 8.83, the value for quartz.

10.5.1 FILM DENSITY

Establishing the film density can be accomplished by depositing a trial film on several test substrates placed around and as close as possible to the sensor crystal and in the same plane. The trial deposition should be thick enough to allow an independent measurement of the film on the test substrates to be made with adequate precision using an optical interferometer or surface-measuring device.

When making the trial deposition, use a fresh crystal and remember to write down the final thickness reading displayed by the MDC-260, as this will be needed in the calculation. If the acoustic impedance parameter has been accurately established previously, a fresh crystal is not required.

Determine the average film thickness on the test substrates and use the following equation to calculate the material's density:

Density = (Displayed Thickness/Average Measured Thickness) * Density(test)

Where Density(test) is the density parameter setting used during the calibration run.

Once the calibration procedure is complete, the programmed film density is correct for this particular film.

10.5.2 TOOLING FACTOR

Having established the film density, the material and the sensor tooling factors should be established next. For the MDC-260, it is typical to keep the material tooling factor equal to 100% and only use the sensor tooling factors to compensate for geometric factors in the deposition system which result in a difference between the deposition rate on the substrates and the rate on the sensing crystal. This way, each sensor's individual rate, as displayed in the Source/Sensor Status Screen, will represent the rate on the substrates. This will make it easy to identify any changes in the vapor distribution since all sensors should display the same rate once calibrated.

To do the sensor calibration, place several test substrates at representative locations in the deposition fixture and change the crystals in the sensors head or heads that you wish to calibrate for this material. Go to the material selection menu and select the material you wish to calibrate. Set the material conditioning parameters as well as the desired deposition rate if not set already. Also, enter the

Configure Sensors parameters to select which sensors will be used to measure this material.

Next, scroll down to Calibrate Sensors and press the right arrow key to get to the Calibrate Sensors screen. Enter the desired calibration thickness and press the Start key to start the calibration run. The calibration thickness should as thick or thicker as you're actual coatings.

Once started, the MDC-260 will condition the source as programmed, open the source shutter and deposit until the calibration thickness is reached as displayed in the main thickness display.

Once the calibration run is complete, determine the average film thickness on the test substrates by using an alternate measurement device such as a surface profilometer. Enter the measured substrate thickness in the Measured Thickness field in the Calibration Screen and press Enter. The MDC-260 will calculate the new tooling factors for all sensors enabled during calibration. The new sensor tooling factors will be displayed in the NewTlng field in the calibration screen. The MDC-260 will then ask the user if the new tooling factors should be saved.

10.5.3 ACOUSTIC IMPEDANCE

Establishment of the acoustic impedance requires that the crystal be heavily loaded. Continue to deposit on the sensor crystal until the crystal health approaches 50% or until the crystal is approaching the end of its useful life. Deposit another trial run as above but this time use the manual power mode instead of the automatic mode. Measure the average film thickness on the test substrates and this adjust the acoustic impedance parameter up or down to bring the displayed thickness into agreement with the measured thickness. This calibrates the acoustic impedance parameter.

The MDC-260 is now fully calibrated for the film in question and should produce consistent and accurate films.

Table 10-1 Material Density and Acoustic Impedance Value

Material	Symbol	Density (mg/cm²)	Impedance (10⁵ gm/cm²sec)
Aluminum	Al	2.70	8.17
Aluminum Antimonide	AlSb	4.36	*
Aluminum Carbide	Al_4C_3	2.36	*
Aluminum Fluoride	AlF_3	3.07	*
Aluminum Nitride	AlN	3.26	*
Aluminum Oxide	Al_2O_3	3.97	26.28
Antimony	Sb	6.62	11.49
Arsenic	As	5.73	9.14
Arsenic Selenide	As_2Se_3	4.75	*
Barium	Ba	3.5	4.20
Barium Fluoride	BaF_2	4.87	11.13
Barium Nitrate	BaN_2O_6	3.24	7.00
Barium Oxide	BaO	5.72	*
Beryllium	Be	1.85	16.26
Beryllium Fluoride	BeF_2	1.99	*
Beryllium Oxide	BeO	3.01	*
Bismuth	Bi	9.8	11.18
Bismuth Fluoride	BiF_3	5.32	*
Bismuth Oxide	Bi_2O_3	8.90	*
Bismuth Selenide	Bi_2Se_3	6.82	*
Bismuth Telluride	Bi_2Te_3	7.70	*
Boron	B	2.54	22.70
Boron Carbide	B_4C	2.37	*
Boron Nitride	BN	1.86	*
Boron Oxide	B_2O_3	1.82	*
Cadmium	Cd	8.64	12.95
Cadmium Fluoride	CdF_2	6.64	*
Cadmium Oxide	CdO	8.15	*
Cadmium Selenide	CdSe	5.81	*
Cadmium Sulfide	CdS	4.83	8.66
Cadmium Telluride	CdTe	5.85	9.01
Calcium	Ca	1.55	3.37
Calcium Fluoride	CaF_2	3.18	11.39
Calcium Sulfate	$CaSO_4$	2.96	8.87
Calcium Titanate	$CaTiO_3$	4.10	*
Carbon (Diamond)	C	3.52	40.14
Carbon (Graphite)	C	2.25	2.71
Cerium	Ce	6.78	*
Cesium	Cs	1.87	*
Cesium Chloride	CsCl	3.99	6.31
Cesium Sulfate	Cs_2SO_4	4.24	7.29

Chromium	Cr	7.20	28.95
Chromium Boride	CrB	6.17	*
Chromium Carbide	Cr_3C_3	6.68	*
Cobalt	Co	8.71	25.74
Cobalt Oxide	CoO	6.44	21.43
Copper	Cu	8.93	20.21
Copper (I) Sulfide (alpha)	Cu_2S	5.6	12.80
Copper (I) Sulfide (beta)	Cu_2S	5.8	13.18
Copper (II) Sulfide	CuS	4.6	10.77
Copper Oxide	Cu_2O	6.00	*
Dysprosium	Dy	8.54	14.72
Erbium	Er	9.05	11.93
Erbium Oxide	Er_2O_3	8.64	*
Europium	Eu	5.244	*
Gadolinium	Gd	7.89	13.18
Gallium	Ga	5.93	14.89
Gallium Antimonide	GaSb	5.60	*
Gallium Arsenide	GaAs	5.31	5.55
Gallium Nitride	GaN	6.10	*
Germanium	Ge	5.35	17.11
Germanium Nitride	Ge_3N_2	5.20	*
Germanium Oxide	GeO_2	6.24	*
Germanium Telluride	GeTe	6.20	*
Gold	Au	19.30	23.18
Hafnium	Hf	13.09	24.53
Hafnium Carbide	HfC	12.20	*
Hafnium Nitride	HfN	13.80	*
Hafnium Oxide	HfO_2	9.68	*
Holnium	Ho	8.8	15.2
Holnium Oxide	Ho_2O_3	8.41	*
Indium	In	7.30	10.50
Indium Antimonide	InSb	5.76	11.48
Indium Arsenide	InAs	5.70	*
Indium Selenide	In_2Se_3	5.70	*
Indium Telluride	In_2Te_3	5.80	*
Iridium	Ir	22.40	68.45
Iron	Fe	7.86	25.30
Iron Sulfide	FeS	4.84	*
Lanthanum	La	6.17	9.59
Lead	Pb	11.30	7.81
Lead Chloride	$PbCl_2$	5.85	*
Lead Fluoride	PbF_2	8.24	13.36
Lead Oxide	PbO	9.53	*
Lead Selenide	PbSe	8.10	*
Lead Sulfide	PbS	7.50	15.60

Lead Telluride	PbTe	8.16	13.56
Lithium	Li	0.53	1.50
Lithium Bromide	LiBr	3.47	7.18
Lithium Fluoride	LiF	2.64	11.41
Lithium Niobate	$LiNbO_3$	4.70	19.07
Magnesium	Mg	1.74	5.48
Magnesium Aluminate	$MgAl_2O_4$	3.60	*
Magnesium Fluoride	MgF_2	3.0	13.86
Magnesium Oxide	MgO	3.58	21.48
Manganese	Mn	7.20	23.42
Manganese (II) Sulfide	MnS	3.99	9.39
Manganese Oxide	MnO	5.39	18.91
Mercury	Hg	13.46	11.93
Molybdenum	Mo	10.20	34.36
Molybdenum Boride	MoB_2	7.12	*
Molybdenum Carbide	Mo_2C	9.18	*
Nickel	Ni	8.91	26.68
Nickel Oxide	NiO	7.45	*
Niobium	Nb	8.57	17.91
Niobium Boride	NbB_2	6.97	*
Niobium Carbide	NbC	7.82	*
Niobium Nitride	NbN	8.40	*
Palladium	Pd	12.00	24.73
Palladium Oxide	PdO	8.31	*
Platinum	Pt	21.40	36.04
Platinum Oxide	PtO_2	10.20	*
Potassium	K	0.86	0.87
Potassium Bromide	KBr	2.75	4.67
Potassium Chloride	KCl	1.98	4.31
Potassium Fluoride	KF	2.48	*
Rhenium	Re	21.04	58.87
Rhodium	Rh	12.41	42.05
Rubidium	Rb	1.53	3.48
Ruthenium	Ru	12.36	48.51
Samarium	Sm	7.54	9.92
Samarium Oxide	Sm_2O_3	7.43	*
Scandium	Sc	3.0	9.70
Scandium Oxide	Sc_2O_3	3.86	*
Selenium	Se	4.82	10.22
Silicon	Si	2.32	12.40
Silicon (II) Oxide	SiO	2.13	10.15
Silicon Dioxide (fused quartz)	SiO_2	2.2	8.25
Silver	Ag	10.50	16.69
Silver Bromide	AgBr	6.47	7.48
Silver Chloride	AgCl	5.56	6.69

Sodium	Na	0.97	1.84
Sodium Bromide	NaBr	3.20	*
Sodium Chloride	NaCl	2.17	5.62
Sodium Fluoride	NaF	2.56	9.31
Sodium Nitrate	$NaNO_3$	2.27	7.40
Strontium	Sr	2.620	*
Strontium Fluoride	SrF_2	4.28	12.15
Strontium Oxide	SrO	4.99	17.08
Sulphur	S	2.07	3.86
Tantalum	Ta	16.60	33.70
Tantalum (IV) Oxide	Ta_2O_5	8.2	29.43
Tantalum Carbide	TaC	13.90	*
Tantalum Nitride	TaN	16.30	*
Tellurium	Te	6.25	9.81
Tellurium Oxide	TeO_2	5.99	10.24
Terbium	Tb	8.27	13.38
Thallium	Tl	11.85	5.70
Thallium Chloride	TlCl	7.00	*
Thorium	Th	11.69	18.24
Thorium Dioxide	ThO_2	9.86	31.09
Tin	Sn	7.30	12.20
Tin Oxide	SnO_2	6.95	*
Tin Selenide	SnSe	6.18	*
Tin Sulfide	SnS	5.08	*
Tin Telluride	SnTe	6.44	*
Titanium	Ti	4.50	14.06
Titanium (IV) Oxide	TiO_2	4.26	22.07
Titanium Boride	TiB_2	4.50	*
Titanium Carbide	TiC	4.93	*
Titanium Nitride	TiN	5.43	*
Tungsten	W	19.30	54.17
Tungsten Boride	WB_2	10.77	*
Tungsten Carbide	WC	15.60	58.48
Uranium	U	18.70	37.10
Uranium Dioxide	UO_2	10.97	30.87
Uranium Oxide	U_4O_9	10.97	25.38
Vanadium	V	5.96	16.66
Vanadium Boride	VB_2	5.10	*
Vanadium Carbide	VC	5.77	*
Vanadium Dioxide	VO_2	4.34	*
Vanadium Nitride	VN	6.13	*
Ytterbium	Yb	6.98	7.81
Ytterbium Oxide	Yb_2O_3	9.17	*
Yttrium	Y	4.34	10.57
Yttrium Oxide	Y_2O_3	5.01	*

Zinc	Zn	7.04	17.18
Zinc Antimonide	Zn_3Sb_2	6.30	*
Zinc Fluoride	ZnF_2	4.95	*
Zinc Oxide	ZnO	5.61	15.88
Zinc Selenide	ZnS	5.26	12.23
Zinc Sulfide	ZnS	4.09	11.39
Zinc Telluride	ZnTe	6.34	11.47
Zirconium	Zr	6.51	14.72
Zirconium Boride	ZrB_2	6.08	*
Zirconium Carbide	ZrC	6.73	33.45
Zirconium Nitride	ZrN	7.09	*
Zirconium Oxide	ZrO_2	5.60	*

* Denotes the acoustic impedance value for the material has not been yet established. Use the quartz AI value of 8.83.

11.   COMPUTER INTERFACE

11.1   GENERAL

The MDC-260 Deposition Controller features two USB sockets (front and rear) for remote access and monitoring from a personal computer. The DCM-250 Deposition Control Manager software may be used for general control of and logging run-time data from the MDC-260 or a custom software solution may be developed to provide a more project-specific control and/or monitoring environment. This section provides details on setting up and using the MDC-260's USB interface for such a solution.

CAUTION: *The interface is designed only for one connection at a time. Do NOT attempt to connect both USB ports simultaneously.*

The MDC-260 does not support USB hosting capabilities, and therefore cannot be interfaced with devices such as portable USB memory cartridges. It may only be connected to a personal computer or other device that functions as a USB host.

The first step to communicating with the MDC-260 is to establish a "link" between the target MDC-260 and the host [computer]. The DCM-250 (version 2.0 or later) setup program installs the MDC-260 Deposition Controller Driver Set and a host API (Application Program Interface) provided in the form of a Windows Dynamic Link Library, SiUSBXp.DLL (see Section 11.2 - Host API Functions). This DLL communicates with the MDC-260 via the Driver Set and the operating system's USB stack.

Once the link is established, the next step is to issue a command to the MDC-260, using the host APIs *SI_Write* function. After receiving a complete message, the MDC-260 responds with a confirmation message (Section 11.5 - TRANSMISSION RECEIPT) followed by any data that your command requested. Section 11.3 - PROTOCOL details these commands and their usage.

11.2   HOST API FUNCTIONS

The following is a list of the host API functions:

SI_GetNumDevices() - Returns the number of MDC-260s connected to the host

SI_GetProductString () - Returns the USB descriptor for a given MDC-260

SI_Open () – "Opens" an MDC-260 and returns a handle

SI_Close() - Cancels pending IO and "closes" an MDC-260

SI_Read() - Reads a block of data from an MDC-260

SI_Write() - Writes a block of data to an MDC-260

SI_SetTimeouts() - Sets read and write block timeouts

SI_GetTimeouts () - Gets read and write block timeouts

SI_SetBaudRate() - Sets the specified Baud Rate

In general, communication with the MDC-260 is initiated by making a call to *SI_GetNumDevices*. This call will return the number of MDC-260s currently connected the host. This number is then used as a range when calling *SI_GetProductString* to build a list of MDC-260 serial numbers or description strings.

To access an MDC-260, it must first be "opened" by a call to *SI_Open* using an index determined from the call to *SI_GetNumDevices*. The *SI_Open* function will return a handle to the MDC-260 that is to be used in all subsequent accesses. Data I/O is performed using the *SI_Write* and *SI_Read* functions. When I/O operations are complete, the MDC-260 is "closed" by a call to *SI_Close*.

Below is a detailed look at each of the host API functions:

SI_GetNumDevices

Description: This function returns the number of MDC-260s currently connected to the host.

Prototype: `SI_STATUS SI_GetNumDevices (LPDWORD NumDevices)`

Parameters: **1.** *NumDevices* – Address of a DWORD variable that will contain the number of MDC-260s connected on return.

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or SI_DEVICE_NOT_FOUND (0xFF) or SI_INVALID_PARAMETER (0x01)

SI_GetProductString

Description: This function returns a NULL terminated serial number (S/N) string or product description string for the MDC-260 specified by an index passed in DeviceNum. The index for the first MDC-260 is 0 and the last one is the value returned by *SI_GetNumDevices* – 1.

Prototype:
```
SI_STATUS SI_GetProductString (DWORD
DeviceNum, LPVOID DeviceString, DWORD
Options)
```

Parameters: **1.** *DeviceNum* – Index of the MDC-260 for which the product description string or serial number is desired.
2. *DeviceString* – Variable of type **SI_DEVICE_STRING** which will contain a NULL terminated descriptor or serial number string on return.
3. *Options* – DWORD containing flags to determine if DeviceString contains a serial number, Vendor ID or Product ID string.

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or
SI_DEVICE_NOT_FOUND (0xFF) or
SI_INVALID_PARAMETER (0x06)

Other Constants   SI_RETURN_SERIAL_NUMBER (0x00)
SI_RETURN_DESCRIPTION (0x01)
SI_RETURN_LINK_NAME (0x02)
SI_RETURN_VID (0x03)
SI_RETURN_PID (0x04)

SI_Open

Description: "Opens" an MDC-260 (using device number as returned by *SI_GetNumDevices*) and returns a handle to be used for subsequent accesses.

Prototype:
```
SI_STATUS SI_Open (DWORD DeviceNum, Handle
*Handle)
```

Parameters: **1.** *DeviceNum* – MDC-260 index. 0 for the first device, 1 for the 2nd, etc.

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or
SI_DEVICE_NOT_FOUND (0xFF) or
SI_INVALID_PARAMETER (0x06)

SI_Close

Description: Closes an "open" MDC-260 using the handle provided by SI_Open and sets the handle to INVALID_HANDLE_VALUE.

Prototype: `SI_STATUS SI_Close (HANDLE& Handle)`

Parameters: **1.** *Handle* – Handle to the MDC-260 to "close" as returned by SI_Open (passed by reference).

Return Value: SI_STATUS   =   SI_SUCCESS or (0x00)
                                SI_INVALID_HANDLE (0x01)

SI_Read

Description: Reads the specified number of bytes into the specified buffer and retrieves the number of bytes read. Given valid input parameters, this function is blocking until the specified number of bytes become available or a timeout occurs (see *SI_SetTimeouts*)

      NOTE: If timeouts are set to zero this function is not blocking and will immediately return the current number of bytes available in the MDC-260 driver buffer. This may be less than the requested number of bytes (zero bytes if there is no data available), so make sure to check the read size return values in this scenario.

Prototype: `SI_STATUS SI_Read (HANDLE Handle, LPVOID Buffer, DWORD NumBytesToRead, DWORD *NumBytesReturned)`

Parameters: **1.** *Handle* – Handle to the MDC-260 as returned by *SI_Open*.
2. *Buffer* – Address of a character buffer to be filled with read data.
3. *NumBytesToRead* – Number of bytes to read from the MDC-260 into the buffer.
4. *NumBytesReturned* – Address of a DWORD which will contain the number of bytes actually read into the buffer on return.

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or
                                SI_INVALID_REQUEST_LENGTH
                                    (0xFF)
                                SI_INVALID_PARAMETER (0x06) or
                                SI_RX_QUEUE_NOT_READY (0x03) or
                                SI_INVALID_HANDLE (0x01) or
                                SI_READ_TIMED_OUT (0x0d)

SI_Write

Description: Writes the specified number of bytes from the specified buffer to the MDC-260. Given valid parameters, this function is blocking until the write is successful, fails or a timeout occurs. The write is successful when the MDC-260 has accepted all of the data. If the write fails or a timeout occurs, SI_WRITE_ERROR is returned.

Prototype:
```
SI_STATUS SI_Write (HANDLE Handle, LPVOID
Buffer, DWORD NumBytesToWrite, DWORD
*NumBytesWritten)
```

Parameters: **1.** *Handle* – Handle to the MDC-260 to write as returned by *SI_Open*.
2. *Buffer* – Address of a character buffer of data to be sent to the MDC-260.
3. *NumBytesToWrite* – Number of bytes to write to the MDC-260.
4. *NumBytesWritten* – Address of DWORD which will contain the number of bytes actually written to the MDC-260.

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or
SI_WRITE_ERROR (0x04) or
SI_INVALID_REQUEST_LENGTH
(0x07)
SI_INVALID_PARAMETER (0x06) or
SI_INVALID_HANDLE (0x01)

SI_SetTimeouts

Description: Sets the read and write timeouts.

Prototype:
```
SI_STATUS SI_SetTimeouts (DWORD
ReadTimeout, DWORD WriteTimeout)
```

Parameters: **1.** *ReadTimeout* – *SI_Read* operation timeout (in milliseconds).
2. *WriteTimeout* – *SI_Write* operation timeout (in milliseconds).

Return Value: SI_STATUS   =   SI_SUCCESS (0x00)

SI_GetTimeouts

Description: Returns the current read and write timeouts.

Prototype: `SI_STATUS SI_GetTimeouts (LPDWORD ReadTimeout, LPDWORD WriteTimeout)`

Parameters: **1.** *ReadTimeout – SI_Read* operation timeout (in milliseconds).
2. *WriteTimeout – SI_Write* operation timeout (in milliseconds).

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or
SI_INVALID_PARAMETER (0x06)

SI_SetBaudRate

Description: Sets the BAUD Rate at which your operating system will communicate with the MDC-260.

NOTE: The MDC-260 communicates at 128,000 bits/second (BAUD rate).

Prototype: `SI_STATUS SI_SetBaudRate (HANDLE Handle, DWORD dwBaudRate)`

Parameters: **1.** *Handle* – Handle to the MDC-260 as returned by *SI_Open*.
2. *dwBaudRate* – A DWORD value specifying the BAUD rate to set.

Return Value: SI_STATUS   =   SI_SUCCESS (0x00) or
SI_INVALID_BAUDRATE (0x09) or
SI_INVALID_HANDLE (0x01)

11.3   PROTOCOL

Once you have established a connection to the MDC-260, the next step is to actually exchange data with it. All communications between the host and the MDC-260 are in the form of message character strings with the following format (shown in decimal and hexadecimal):

	Header		Interface Address	Instruction Code	Length	Message Data (0 - 249 bytes)	Checksum
Dec	255	254	1...32	253	0...249	xx, xx, xx, etc.	0...255
Hex	FF	FE	01...20	FD	00...F9	xx, xx, xx, etc.	00...FF

- **Header (2 bytes):** Indicates the beginning of a new message.
- **Interface Address (1 byte)**: Defines which MDC-260 should receive and respond to the message, or which MDC-260 the message originated from. The USB Interface Address may range from 0 to 32 (set via Edit System Setup, Edit Utility Setup, USB Interface Address). An address of zero will be received by all controllers present on the bus
- **Instruction Code (1 byte):** Indicates what type of message is being sent or responded to.
- **Message Length (1 byte):** Indicates the amount of data being transmitted in the message. This does not include the header, interface address, instruction code, the length byte itself or the checksum.
- **Message Data (0 – 249 bytes):** The data, if any, being sent to or from the controller. Because of the upper limit of 249 bytes, it is possible that certain instructions will take multiple messages to complete their task.
- **Checksum (1 byte):** To ensure the integrity of the data sent, a checksum is calculated and attached to every message sent to or from the controller. It only applies to the instruction code byte, message length byte and the message bytes. The checksum is the compliment of the one byte sum of all bytes from, and including, the instruction code to the end of the message. If the one byte sum of all these bytes is added to the checksum, the result should equal 255. If the sum of all bytes occupies more than one byte, a single byte checksum can be generated using the expression: checksum=!(Sum MOD 256), i.e. the checksum is the complement of the remainder byte which results from dividing the sum of all bytes by 256.

11.4   DATA TYPES

There are three data types stored in the MDC-260: one byte, two byte, and three byte parameters. All data types are stored as integers in binary format with the most significant byte first. The one byte data types are either ASCII characters, numeric values (0-255), or 8 bit registers. Some of the multiple byte data types

are decimal values stored as integers. To convert these values to their decimal equivalent, use the following equation:

Decimal Value = (Integer Value)/(10*DP)

where DP is the value's decimal point position. The decimal point positions for all the parameters are constant and are given in tables along with the parameters' range.

11.5   TRANSMISSION RECEIPT

Immediately after receiving a complete message, the MDC-260 will transmit a short "Transmission Receipt" to the host computer. It indicates:
- That a message was received (specified by the "Message Received" Code = 253)
- Which controller received the message (specified by its USB Interface Address)
- What instruction code was received (specified by the Instruction Code)
- The outcome of the transmission (specified by the Receive Code)

The transmission receipt has the following format, shown in decimal and hexadecimal:

	Header		**Interface Address**	**"Message Received"**	**Length**	**Instruction Code**	**Receive Code**	**Checksum**
Dec	255	254	(1–32)	253	2	(0–40)	(0–8)	(0–255)
Hex	FF	FE	(01–20)	FD	02	(00–28)	(00–08)	(00–FF)

The following table shows a list of possible Receive Codes:

Receive Code	**Description**
0	Message Received O.K.
1	Invalid Checksum
2	Invalid Instruction Code
3	Invalid Message Length
4	Parameter(s) Out of Range
5	Invalid Message
6	Process Undefined – Can't Add Layer
7	Insufficient Layer Space - Can't Add Layer

11.6   TRANSMITTING AND RECEIVEING MESSAGES

Whenever the MDC-260 receives a message, it will automatically send a receipt that confirms it received the message, as described above. If the message instructs the controller to take action or contains data to program the controller with, the appropriate action is taken immediately. If the message instructs the

controller to transmit data back to the host computer, an additional message is sent immediately after the receipt. The format of these messages is the same as messages sent to the controller.

The tables in the Instruction Summary show the order that data is expected by the controller or, conversely, the order that the data will be sent from the controller. The title of each action is seen from the point of view of the MDC-260. A "Send a Process" command will prompt the MDC-260 to transmit a message to the host computer containing parameter data for a particular process. A "Receive a Process" command will command the MDC-260 to receive data from the host computer containing parameters for a process, and will overwrite the existing data for that process.

11.7   INSTRUCTION SUMMARY

Instruction Code	Description
0	Remote Keypress Activation of Controller
1	Send Controller System Information
2	Send Utility Parameters
3	Receive utility parameters
4	[Not Supported]
5	[Not Supported]
6	Send a Material
7	Receive a Material
8	Send Material List
9	Send Number of Undefined Layers
10	Send a Process
11	Receive a Process
12	Delete a Process
13	Send a Process Layer
14	Insert a Process Layer
15	Replace a Process Layer
16	Delete a Process Layer
17	Send a Process List
18	Send Source Setup
19	Receive Source Setup
20	Send Sensor Setup
21	Receive Sensor Setup
22	Send Input Setup
23	Receive Input Setup
24	Send Output Setup
25	Receive Output Setup
26	Send Action Setup
27	Receive Action Setup
28	Send controller Status
29	Start Process
30	Send Run-Time Values
31	Start Automatic Data Logging
32	[Internal Command]
33	Set Active Source Power
34	[Internal Command]
35	[Internal Command]
36	[Not Supported]
37	[Not Supported]
38	Initiate Remote Action
39	Send Individual Run-time Value Command
40	Enable/Disable the Front Panel Keyboard

11.8   INSTRUCTION DESCRIPTIONS

The following section describes all of the valid instructions and shows examples of how they are used. Each example is show in decimal [Dec] and hexadecimal [Hex]. Each successful command will immediately prompt the MDC-260 to send a transmission receipt, as described previously. If the message asked the MDC-260 to transmit data back to the host computer, an example of that data is also shown. Assumptions about the status of the MDC-260's parameter data are explicitly stated.

In parameter data tables, entries in **bold** represent the factory default values. In the instruction examples, entries in **bold** represent variable fields that may change depending on the data transmitted. If a checksum is provided in the example, it will need to be re-calculated if any of the variable data changes.

Note: All examples assume the target controller's USB Interface Address is 01.

Code #00: Remote Keypress Activation of Controller

Description: Simulates a physical keypress of the MDC-260's front panel keypad. The valid key codes are shown in the following table:

Remote Activation Code	Description
1	START key
2	ABORT key
4	RESET key
8	SHUTTER key
16	MANUAL key
32	PROGRAM key
64	GRAPH key
128	ZERO key

Format/Example:
- To simulate a "Zero" keypress (Activation Code = 8), transmit:

	Header		Interface Address	Instruction Code	Length	Key Code (Data)	Checksum
Dec	255	254	**1**	0	1	**8**	**246**
Hex	FF	FE	**01**	00	01	**08**	**F6**

Response:
- The controller will respond with the normal transmission receipt.

Code #01: Send System Information

Description: Instructs the controller to transmit the hardware and software version numbers to the host computer. The following is a description of the data transmitted:

Name	Length (bytes)	Message
Model and Software Version	34	INFICON MDC-260 Software Ver. X.Xx
Total: 34 Data Bytes		

Format/Example:
- To instruct the controller to send the system information, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	1	0	**254**
Hex	FF	FE	**01**	01	00	**FE**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Instruction Code	Length	34 Data Bytes	Checksum
Dec	255	254	**1**	1	34	**(data)**	**(checksum)**
Hex	FF	FE	**01**	01	22	**(data)**	**(checksum)**

(data): ASCII bytes for "INFICON MDC-260 Software Ver. X.Xx ", with blank spaces filling in any unused bytes.
(checksum): The checksum from the instruction code through the last data byte.

Code #02: Send Utility Parameters

Description: Instructs the controller to send the utility parameters to the host computer. The following is a description of the data transmitted.

Prm#	Parameter Name	Length (bytes)	Values (decimal)
1	Pause on Layer Complete	1	4 = No, **5 = Yes**
2	Negative Thickness Enable	1	**6 = Enabled**, 7 = Disabled
3	Thickness Graph Scale	1	8 = 2 Digit, **9 = 3 Digit**
4	Sensor Status Select	1	**10 = Thickness**, 11 = Frequency
5	Time To Go Display	1	12 = Estimated Layer, **13 = Estimated State,** 14 = Elapsed Process, 15 = Elapsed Layer, 16 = Elapsed State
6	Rate Graph	1	**6 = Enabled**, 7 = Disabled
7	Power Graph	1	**6 = Enabled**, 7 = Disabled
8	Thickness Graph	1	**6 = Enabled**, 7 = Disabled
9	Rate Deviation Graph	1	**6 = Enabled**, 7 = Disabled
10	Source/Sensor Status	1	**6 = Enabled**, 7 = Disabled
11	I/O Status	1	**6 = Enabled**, 7 = Disabled
12	Crystal Frequency	1	39 = 2.5 MHz, 40 = 3.0 MHz, 41 = 5.0 MHz, **42 = 6.0 MHz**, 43 = 9.0 MHz, 44 = 10.0 MHz
13	Simulate Mode	1	**45 = Off**, 46 = On
14	USB Interface Address	1	**01**, 02, 03 ... 32
15	Attention Volume	1	0, **1**, 2, 3 ... 10
16	Alert Volume	1	0, **1**, 2, 3 ... 10
17	Alarm Volume	1	0, **1**, 2, 3 ... 10
18	Starting Layer Number	1	0, **1**, 2, 3 ... 10
Total: 18 Data Bytes			

Format/Example:

- To instruct the controller to send the utility parameters, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	2	0	**253**
Hex	FF	FE	**01**	02	00	**FD**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Instruction Code	Length	18 Data Bytes	Checksum
Dec	255	254	**1**	2	18	**(data)**	**(checksum)**
Hex	FF	FE	**01**	02	12	**(data)**	**(checksum)**

(data): The 18 utility values, as shown in the utility data table above.
(checksum): The checksum from the instruction code through the last data byte.

Code #03: Receive Utility Parameters

Description: Instructs the controller to enter all the incoming utility parameters into memory. Use the table from Code #02 to construct a message to set the utility parameters to your desired settings.

Format/Example:
- To re-program the controller with custom utility parameters, transmit:

	Header		Interface Address	Instruction Code	Length	18 Data Bytes	Checksum
Dec	255	254	**1**	3	18	**(data)**	**(checksum)**
Hex	FF	FE	**01**	03	12	**(data)**	**(checksum)**

(data): The 18 utility values, as shown in the utility data table above.
(checksum): The checksum from the instruction code through the last data byte.

Response:
- The controller will respond with the normal transmission receipt.

Code #04: Not Supported

Description: Instruction Code #04 is not supported by the MDC-260. Attempting to issue it to the controller will result in an "Invalid Instruction Code" error in the message receipt.

Code #05: Not Supported

Description: Instruction Code #05 is not supported by the MDC-260. Attempting to issue it to the controller will result in an "Invalid Instruction Code" error in the message receipt.

<u>**Code #06: Send a Material**</u>

Description: Instructs the controller to send all the material parameters for
Material #N to the host computer. A description of the material parameter list is in
the table below: (Default values are in **bold**):

Parameter name	Length (bytes)	Byte Offset	Dec. Pt. Pos	Values (decimal)	Units
Material Name	10	0	*	[8 ASCII Bytes]	ASCII
Sensor #	1	10	*	**1**, 2	None
Crystal #	1	11	*	**1**, 2, 3...16	None
Source #	1	12	*	**1**, 2	None
Pocket #	1	13	*	**1**, 2, 3...16	None
Rate Establish Time	1	14	*	**0**, 1, 2...99	Seconds
Rate Start Thickness #1	1	15	1	**0**...9999	0.1 Å/Sec
Rate Start Thickness #2	1	16	1	**0**...9999	0.1 Å/Sec
Rate Stop Thickness #1	1	17	1	**0**...9999	0.1 Å/Sec
Rate Stop Thickness #2	1	18	1	**0**...9999	0.1 Å/Sec
Power Alarm Delay	1	19	*	**0** ... 99	Seconds
Sample Dwell %	1	20	*	0, 1, 2...**100**	%
Crystal Fail (Action)	1	21	*	0 = Switch **1 = TimePwr** 2 = Halt 3 = Abort	None
Backup Sensor #	1	22	*	**1**, 2	None
Backup Crystal #	1	23	*	**1**, 2, 3...16	None
Density	2	24	2	80...**100**...9999	0.01 gm/cm³
Acoustic Impedence	2	26	2	400...**883**...5999	0.01 gm/cm²/sec
Tooling Factor	2	28	1	100...**1000**...4999	0.1%
Proportional Gain	2	30	*	1...**1000**...9999	None
Integral Time	2	32	1	0...**999**	0.1 Seconds
Derivative Time	2	34	1	**0**...999	0.1 Seconds
Rise to Soak Time	2	36	*	**0**...35999	Seconds
Soak Power	2	38	1	**0**...999	0.1%
Soak Time	2	40	*	**0**...35999	Seconds
Rise to Predeposit Time	2	42	*	**0**...35999	Seconds
Predeposit Power	2	44	1	**0**...999	0.1%
Predeposit Time	2	46	*	**0**...35999	Seconds
Rate Establish Error	2	48	1	**0**...999	0.1%
Deposit Rate #1	2	50	1	**0**...9999	0.1 Å/Sec

Deposit Rate #2	2	52	1	**0**...9999	0.1 Å/Sec
Deposit Rate #3	2	54	1	**0**...9999	0.1 Å/Sec
Time Setpoint	2	56	*	**0**...35999	Seconds
Ramp to Feed Time	2	58	*	**0**...35999	Seconds
Feed Power	2	60	1	**0**...999	0.1%
Feed Time	2	62	*	**0**...35999	Seconds
Ramp to Idle Time	2	64	*	**0**...35999	Seconds
Idle power	2	66	1	**0**...999	0.1%
Maximum Power	2	68	1	0...**999**	0.1%
Minimum Power	2	70	1	**0**...999	0.1%
Rate Deviation: Attn	2	72	1	**0**...999	0.1%
Rate Deviation: Alarm	2	74	1	**0**...999	0.1%
Rate Deviation: Abort	2	76	1	**0**...999	0.1%
Sample Dwell Period	2	78	*	**0**...35999	Seconds
Backup Tooling Factor	2	80	1	**100**...4999	0.1%
Material Password	4	82	*	[4 ASCII Bytes]	ASCII

Total: 86 Data Bytes

* - Indicates decimal point position is not applicable.

Format/Example:
- To instruct the controller to send the parameters for Material #4, transmit:

	Header		Interface Address	Instruction Code	Length	Material #N (one byte)	Checksum
Dec	255	254	**1**	6	1	**4**	**244**
Hex	FF	FE	**01**	06	1	**04**	**F4**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	Material #N (one byte)	86 Data Bytes	Checksum
Dec	255	254	**1**	6	87	**4**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	06	57	**04**	**(data)**	**(checksum)**

(data): The 86 material parameter data bytes, as shown in the utility data table above.
(checksum): The checksum from the instruction code through the last data byte.

Code #07: Receive a Material

Description: Instructs the controller to enter all the incoming material parameters for Material #N into memory. Use the table from Code #06 to construct a message to set Material #N's parameters to your desired settings.

Format/Example:
- To re-program Material 4 in the controller with custom parameters, transmit:

	Header		Interface Address	Inst. Code	Length	Material #N (one byte)	86 Data Bytes	Checksum
Dec	255	254	**1**	7	87	**4**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	07	57	**04**	**(data)**	**(checksum)**

(data): The 86 material parameter data bytes, as shown in the utility data table above.
(checksum): The checksum from the instruction code through the last data byte.

Response:
- The controller will respond with the normal transmission receipt.

Code #08: Send Material List

Description: Instructs the controller to send a list of all material names in the order that they are stored in the controller. The material list consists of eight 10-character material names.

Format/Example:
- To instruct the controller to send the material list, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	8	0	**245**
Hex	FF	FE	**01**	08	00	**F5**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	80 Data Bytes	Checksum
Dec	255	254	**1**	8	80	**(data)**	**(checksum)**
Hex	FF	FE	**01**	08	50	**(data)**	**(checksum)**

(data): The 80 data bytes represent the eight material names in ASCII.
(checksum): The checksum from the instruction code through the last data byte.

Code #09: Send Number of Undefined Layers

Description: Instructs the controller to send the number of undefined layers to the host computer.

Format/Example:
- To instruct the controller to send the number of undefined layers, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	9	0	**246**
Hex	FF	FE	**01**	09	00	**F6**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	1 Data Byte	Checksum
Dec	255	254	**1**	9	1	**(data)**	**(checksum)**
Hex	FF	FE	**01**	09	1	**(data)**	**(checksum)**

(data): A one-byte value representing the number of undefined layers (0-250)
(checksum): The checksum from the instruction code through the last data byte.

Code #10: Send Process

Description: Instructs the controller to send all the process parameters for Process #N to the host computer. A description of the process parameter list is as follows:

Parameter Name	Length (bytes)	Dec. Pt. Position	Range	Units
Process name	12	*	Characters	None
Edit Password	4	*	Characters	None
View/Run Password	4	*	Characters	None
Number of Layers	1	*	0...250	None
Total: 21 Data Bytes				

Following this general information about Process #N, one or more messages are transmitted describing all of the layer data for the layers included in the process are transmitted. Because the MDC-260's message size is limited to 249 data bytes, it may take up to five messages to transmit all of the layer data (depending on how many layers are included in the process). Each message will contain between one (1) and sixty (60) layers. For example, if the process contains the maximum number of layers (250), the controller will send the layer data in five messages. The first four messages will have 60 layers and the last message will have 10 layers. The format of each layer messages is as follows:

Parameter Name	Length (bytes)	Dec. Pt. Position	Range	Units
Layer #N Thickness	3	3	0...999900	Å
Layer #N Material #	1	*	1...8	None
Total: 4 Data Bytes per Layer				

Format/Example:
- To instruct the controller to send the parameters for Process #5, transmit:

	Header		Interface Address	Instruction Code	Length	Process #N (one byte)	Checksum
Dec	255	254	**1**	10	1	**5**	**239**
Hex	FF	FE	**01**	0A	01	**05**	**EF**

Response:

- In addition to the normal transmission receipt, the controller will respond with several messages. The first message describes the general information about Process #N, and has the following format:

	Header		Interface Address	Inst. Code	Length (bytes)	Process #N (one byte)	21 Data Bytes	Checksum
Dec	255	254	**1**	10	22	**N**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	0A	16	**N**	**(data)**	**(checksum)**

(data): The 21 data bytes representing the general information about Process #N.
(checksum): The checksum from the instruction code through the last data byte.

- After the general information message is transmitted, the controller will send between one (1) and five (5) messages containing information about each layer. Up to sixty (60) layers can be transmitted in each message. Each of these messages has the following format:

	Header		Interface Address	Inst. Code	Length (bytes)	Message Number	Data Bytes	Checksum
Dec	255	254	**1**	10	**(length)**	**(1...5)**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	0A	**(length)**	**(1...5)**	**(data)**	**(checksum)**

(length): The number of data bytes, including the Message Number, in this message.
(data): Layer data for up to 60 layers (4 bytes of data per layer).
(checksum): The checksum from the instruction code through the last data byte.

Code #11: Receive Process

Description: Instructs the controller to enter the incoming parameters of Process #N into memory. Use the first table from Code #10 to construct a message to set Process #N's parameters to your desired settings.

Format/Example:

- To re-program Process #5 in the controller with custom parameters, transmit:

	Header		Interface Address	Inst. Code	Length (bytes)	Process #N (one byte)	21 Data Bytes	Checksum
Dec	255	254	**1**	11	22	**5**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	0B	16	**05**	**(data)**	**(checksum)**

(data): The 21 data bytes representing the general information about Process #N.
(checksum): The checksum from the instruction code through the last data byte.

Response:
- The controller will respond with the normal transmission receipt.

NOTE: To modify process layers, you must use the following instructions codes:
- **Code #12: Delete Process**
- **Code #14: Insert Process Layer**
- **Code #15: Replace Process Layer**

Code #12: Delete Process

Description: Instructs the controller to delete Process #N and its associated layers.

Format/Example:
- To delete Process #4 in the controller, transmit:

	Header		Interface Address	Inst. Code	Length (bytes)	Process #N (one byte)	Checksum
Dec	255	254	**1**	12	1	**4**	**238**
Hex	FF	FE	**01**	0C	01	**04**	**EE**

Response:
- The controller will respond with the normal transmission receipt.

Code #13: Send Process Layer

Description: Instructs the controller to send the process layer parameters for Process #N, Layer #Y to the host computer. A description of the process layer parameter list is as follows:

Parameter Name	Length (bytes)	Decimal Pt. Position	Range	Units
Layer #N Thickness	3	3	0...999900	Å
Layer #N Material #	1	*	1...8	None
Total: 4 Data Bytes per Layer				

Format/Example:
- To instruct the controller to send the data for a Process #6, Layer #2, transmit:

	Header		Interface Address	Inst. Code	Length (bytes)	Process #N (one byte)	Layer #Y (one byte)	Checksum
Dec	255	254	**1**	13	2	**6**	**2**	**232**
Hex	FF	FE	**01**	0D	02	**06**	**02**	**E8**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Int. Addr.	Inst. Code	Len.	Process #	Layer #	4 Data Bytes	Checksum
Dec	255	254	**1**	13	6	**N**	**Y**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	0D	06	**N**	**Y**	**(data)**	**(checksum)**

(data): The requested layer information, as described in the table above (4 bytes).
(checksum): The checksum from the instruction code through the last data byte.

Code #14: Insert Process Layer

Description: Instructs the controller to insert the incoming layer parameters of Process #N in front of Layer #Y, effectively adding the layer to the process. A description of the insert process layer parameter list is as follows:

Parameter Name	Length (bytes)	Decimal Pt. Position	Range	Units
Layer #N Thickness	3	3	0...999900	Å
Layer #N Material #	1	*	1...8	None
Total: 4 Data Bytes per Layer				

Format/Example:

- To instruct the controller to insert a layer right in front of Layer #Y in Process #N, transmit:

	Header		Int. Addr.	Inst. Code	Len.	Process #	Layer #	4 Data Bytes	Checksum
Dec	255	254	**1**	14	6	**N**	**Y**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	0E	06	**N**	**Y**	**(data)**	**(checksum)**

(data): The layer parameter information, as described in the table above (4 bytes).
(checksum): The checksum from the instruction code through the last data byte.

Response:

- The controller will respond with the normal transmission receipt.
- If all of the layers are defined then the controller will respond with an "Insufficient Layer Space" error (Receive Code #7).

Code #15: Replace Process Layer

Description: Instructs the controller to enter the incoming process layer parameters into Process #N, Layer #Y. The format is identical to that of Code #14: Insert Process Layer. The only difference between the two instructions is that, in this case, the process layers are not shifted to make room for the incoming layer.

Format/Example:

- To instruct the controller to replace Layer #Y in Process #N, transmit:

	Header		Int. Addr.	Inst. Code	Len.	Process #	Layer #	4 Data Bytes	Checksum
Dec	255	254	**1**	15	6	**N**	**Y**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	0F	06	**N**	**Y**	**(data)**	**(checksum)**

(data): The layer parameter information, as described in the table above (4 bytes).
(checksum): The checksum of the entire message, excluding the checksum itse

Response:

- The controller will respond with the normal transmission receipt.
- If you attempt to write to an undefined process the controller will respond with a "Process Not Defined" error (Receive Code #6). To define a process, use the Receive Process instruction (Code #11).

Code #16: Delete Process Layer

Description: Instructs the controller to delete Layer #Y from Process #N.

Format/Example:
- To instruct the controller to delete Layer #5 in Process #3, transmit:

	Header		Int. Addr.	Inst. Code	Len.	Process #	Layer #	Checksum
Dec	255	254	**1**	16	6	**3**	**5**	**227**
Hex	FF	FE	**01**	10	06	**03**	**05**	**E3**

Response:
- The controller will respond with the normal transmission receipt.
- If you attempt to delete a layer from an undefined process, or if you attempt to delete an undefined layer in a process the controller will respond with a "Parameter(s) Out of Range" error (Receive Code #4).

Code #17: Send Process List

Description: Instructs the controller to send all process names in the order that they are stored in the controller. The process list consists of ten 12-character process names.

Format/Example:
- To instruct the controller to send the process list, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	17	0	**238**
Hex	FF	FE	**01**	11	00	**EE**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	120 Data Bytes	Checksum
Dec	255	254	**1**	17	120	**(data)**	**(checksum)**
Hex	FF	FE	**01**	11	78	**(data)**	**(checksum)**

(data): The 120 data bytes represent the ten process names in ASCII.
(checksum): The checksum from the instruction code through the last data byte.

Code #18: Send Source Setup

Description: Instructs the controller to send the source setup parameter list for all sources. A description of the source parameter list for each source is as follows:

Parameter Name	Length (bytes)	Decimal Pt. Position	Values	Units
Number of Pockets	1	*	**1**...16	None
Shutter Relay Type	1	*	17 = Normally open, 18 = Normally closed, **19 = None**	None
Control	1	*	21 = Direct, 22 = BCD, 23 = Indiv, **24 = Manual**	None
Drive	1	*	**25 = Up,** 26 = Down, 27 = Fast, 28 = Inline, 29 = Sngl Step, 30 = Dbl Step	None
Feedback Type	1	*	31 = Individual, 32 = BCD, 33 = Single Home, 34 = In Position, **35 = No Feedback**	
Pocket Indexer Delay	1	*	**0**...99	Seconds
Source Voltage Range	1	*	36 = 2.5V, 37 = 5.0V, **38 = 10V**	Volts
Shutter Delay	2	1	**0**...99 (LSB first)	.1 sec
Total: 9 Data Bytes				

There are two sources with 9 bytes per source for a total of 18 bytes. All 18 bytes are sent in the same message starting with source #1.

Format/Example:

- To instruct the controller to send the source setup parameter list, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	18	0	**239**
Hex	FF	FE	**01**	12	00	**EF**

Response:

- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	18 Data Bytes	Checksum
Dec	255	254	**1**	18	18	**(data)**	**(checksum)**
Hex	FF	FE	**01**	12	12	**(data)**	**(checksum)**

(data): The 18 data bytes represent the configuration parameters of both sources.
(checksum): The checksum from the instruction code through the last data byte.

Code #19: Receive Source Setup

Description: Instructs the controller to enter the incoming source setup parameters into memory. Use the table from Code #18 to construct a message to set the source parameters to your desired settings.

Format/Example:

- To re-program the controller with custom source parameters, transmit:

	Header		Interface Address	Instruction Code	Length	18 Data Bytes	Checksum
Dec	255	254	**1**	19	18	**(data)**	**(checksum)**
Hex	FF	FE	**01**	13	12	**(data)**	**(checksum)**

(data): The 18 utility values, as shown in the utility data table above.
(checksum): The checksum from the instruction code through the last data byte.

Response:

- The controller will respond with the normal transmission receipt.

Code #20: Send Sensor Setup

Description: Instructs the controller to send the sensor setup parameter list for all sensors. A description of the sensor parameter list is as follows:

Parameter Name	Length (bytes)	Decimal Pt. Position	Values	Units
Number of crystals	1	*	**1**...16	None
Shutter Relay Type	1	*	17 = Normally open, 18 = Normally closed, **19 = None**, 20 = Dual	None
Control	1	*	21 = Direct, 22 = BCD, 23 = Indiv, **24 = Manual**	None
Drive	1	*	**25 = Up**, 26 = Down, 27 = Fast, 28 = Inline, 29 = Sngl Step, 30 = Dbl Step	None
Feedback Type	1	*	31 = Individual, 32 = BCD, 33 = Single Home, 34 = In Position, **35 = No Feedback**	None
Pocket Indexer Delay	1	*	**0**...99	Seconds
Total: 6 Data Bytes				

There are two sensors with 6 bytes per sensor for a total of 12 bytes. All 12 bytes are sent in the same message starting with sensor #1.

Format/Example:

- To instruct the controller to send the sensor setup parameter list, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	20	0	**235**
Hex	FF	FE	**01**	14	00	**EB**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	12 Data Bytes	Checksum
Dec	255	254	**1**	20	**12**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	14	**0C**	**(data)**	**(checksum)**

(data): The 12 data bytes represent the configuration parameters of both sensors.
(checksum): The checksum from the instruction code through the last data byte.

Code #21: Receive Sensor Setup

Description: Instructs the controller to enter the incoming sensor setup parameters into memory. Use the table from Code #20 to construct a message to set the sensor parameters to your desired settings.

Format/Example:
- To re-program the controller with custom sensor parameters, transmit:

	Header		Interface Address	Instruction Code	Length	12 Data Bytes	Checksum
Dec	255	254	**1**	21	12	**(data)**	**(checksum)**
Hex	FF	FE	**01**	15	0C	**(data)**	**(checksum)**

(data): The 12 utility values, as shown in the utility data table above.
(checksum): The checksum from the instruction code through the last data byte.

Response:
- The controller will respond with the normal transmission receipt.

Code #22: Send Input Setup

Description: Instructs the controller to send the Input parameter list for Input #N.
A description of the Input parameter list is as follows:

Parameter Name	Length (bytes)	Allowable Range
Name	16	All ASCII Characters
Type *	2	0...65535 (LSB first)
True Level	1	0 = Low, 1 = High
Input Pin#	1	30...37
Total: 20 Data Bytes		

* The Type parameter defines whether the input is undefined, user defined, or internally defined. 0 = Undefined 65,535 = user defined. All other values indicated internally defined inputs created by the MDC for source pocket and sensor crystal position control. When clearing an input you must set the Type = 0 (00 hex). When defining an input you must set the type = 65535 (FF hex). Internal types should only be set by the MDC.

Format/Example:
- To instruct the controller to send the parameter list for Input #4, transmit:

	Header		Interface Address	Instruction Code	Length	Input #N (1-8)	Checksum
Dec	255	254	**1**	22	1	**4**	**228**
Hex	FF	FE	**01**	16	01	**04**	**E4**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	Input #N (1-8)	20 Data Bytes	Checksum
Dec	255	254	**1**	22	**21**	**4**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	16	**15**	**04**	**(data)**	**(checksum)**

(data): The 20 data bytes represent the configuration parameters the selected Input.
(checksum): The checksum from the instruction code through the last data byte.

Code #23: Receive Input Setup
Description: Instructs the controller to enter the incoming Input parameters for Input #N into memory. Use the table from Code #22 to construct a message to set the parameters for Input #N to your desired settings.

Format/Example:
- To re-program Input #N with custom parameters, transmit:

	Header		Interface Address	Inst. Code	Length	Input #N (1-8)	20 Data Bytes	Checksum
Dec	255	254	**1**	22	**21**	**4**	(data)	(checksum)
Hex	FF	FE	**01**	16	**15**	**04**	(data)	(checksum)

(data): The 20 data bytes represent the configuration parameters the selected Input.
(checksum): The checksum from the instruction code through the last data byte.

Response:
- The controller will respond with the normal transmission receipt.

Code #24: Send Output Setup
Description: Instructs the controller to send the Output parameter list for Output #N. A description of the Output parameter list is as follows:

Parameter Name	Length (bytes)	Allowable Range
Name	16	All ASCII Characters
Type *	2	0 – 65535 (LSB first)
Condition String **	24	! | & ( )
Output Pin#	1	2-9
Total: 43 Data Bytes		

* The Type parameter defines whether the input is undefined, user defined, or internally defined. 0 = Undefined 65,535 = user defined. All other values indicated internally defined inputs created by the MDC for source pocket and sensor crystal position control. When clearing an input you must set the Type = 0 (00 hex). When defining an input you must set the type = 65535 (FF hex). Internal types should only be set by the MDC.

** The condition string is described in the program I/O section of the manual. The allowable characters are ! \| & ( ). The individual conditions are represented by numbers. The conditions are 1, 2, or 3 bytes each. The first byte is the condition number. The second and third byte, if any, are the sub-condition number. The allowable conditions are listed in the table following the example.

Format/Example:

- To instruct the controller to send the parameter list for Output #2, transmit:

-

	Header		Interface Address	Instruction Code	Length	Output #N (1-8)	Checksum
Dec	255	254	**1**	24	1	**2**	**228**
Hex	FF	FE	**01**	18	01	**02**	**E4**

Response:

- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	Output #N (1-8)	43 Data Bytes	Checksum
Dec	255	254	**1**	22	**44**	2	**(data)**	**(checksum)**
Hex	FF	FE	**01**	16	**2C**	**02**	**(data)**	**(checksum)**

(data): The 43 data bytes represent the configuration parameters the selected Output.

(checksum): The checksum from the instruction code through the last data byte.

Allowable Conditions for Output Programming

Condition Name	Condition Number	Sub-condition Range
Controller State	128	1...22
Input	129	1...8
Output	130	1...8
Process	131	1...10
Material	132	1...8
Source	133	1...2
Pocket	134	1...16
Sensor	135	1...2
Softnode	136	1...8
Crystal	137	1...16
Layer	138	1...250 (two bytes, MSB first)
Timer #1-8	139-146	1...9999 (two bytes, MSB first)
Abort	147	Not Used
Halt	148	Not Used
Hold	149	Not Used
Time Power	150	Not Used
Ready	151	Not Used
In Process	152	Not Used
Simulate	153	Not Used
Time Setpoint	154	Not Used
Last Layer	155	Not Used
Crystal Failure	156	Not Used
Crystal Marginal	157	Not Used
Min Rate&Max Pwr	158	Not Used
Max Rate&Min Pwr	159	Not Used
Rate Dev. Alarm	160	Not Used
Rate Establish Error	161	Not Used
Source Fault	162	Not Used
Sensor Fault	163	Not Used
Rate Deviation Alert	164	Not Used
Max Power Alert	165	Not Used
Min Power Alert	166	Not Used
Rate Deviation Attention	167	Not Used
Max Power Attention	168	Not Used
Min Power Attention	169	Not Used
Manual Power	170	Not Used

All condition strings must be terminated with a null (zero).

Code #25: Receive Output Setup

Description: Instructs the controller to enter the incoming parameters for Output #N into memory. Use the table from Code #24 to construct a message to set the parameters for Output #N to your desired settings.

Format/Example:
- To re-program Output #N with custom parameters, transmit:

	Header		Interface Address	Inst. Code	Length	Output #N (1-8)	43 Data Bytes	Checksum
Dec	255	254	**1**	22	**44**	**2**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	16	**2C**	**02**	**(data)**	**(checksum)**

(data): The 43 data bytes represent the configuration parameters the selected Output.
(checksum): The checksum from the instruction code through the last data byte.

Response:
- The controller will respond with the normal transmission receipt.

Code #26: Send Action Setup

Description: Instructs the controller to send the parameter list for Action #N. A description of the Action parameter list is as follows:

Parameter Name	Length (bytes)	Allowable Range
Action Type	1	0...37
Condition String	24	! | & ( )
Total: 25 Data Bytes		

Format/Example:
- To instruct the controller to send the parameter list for Action #5, transmit:

	Header		Interface Address	Instruction Code	Length	Action #N (1-8)	Checksum
Dec	255	254	**1**	26	1	**5**	**223**
Hex	FF	FE	**01**	1A	01	**05**	**DF**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	Action #N (1-8)	25 Data Bytes	Checksum
Dec	255	254	**1**	26	**26**	**5**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1A	**1A**	**05**	**(data)**	**(checksum)**

(data): The 25 data bytes represent the configuration parameters the selected Action.

(checksum): The checksum from the instruction code through the last data byte.

The action type defines the action that will be taken when the condition is evaluated as true. The following table contains the list of possible actions.

Action Name	Action Type
No Action	1
Manual Power	2
Zero Thickness	3
Reset Process	4
Abort Process	5
Halt Process	6
Terminate Deposit	7
Hold In State	8
Step From State	9
Sound Attention	10
Sound Alert	11
Sound Alarm	12
Start Process	13
Select Process 1-8	14...21
Switch Crystals	22
Start Timer #1-8	23...30
Set Softnode #1-8	31...38

Code #27: Receive Action Setup

Description: Instructs the controller to enter the incoming parameters for Action #N into memory. Use the table from Code #26 to construct a message to set the parameters for Action #N to your desired settings.

Format/Example:

- To re-program Action #N with custom parameters, transmit:

	Header		Interface Address	Inst. Code	Length	Action #N (1-8)	25 Data Bytes	Checksum
Dec	255	254	**1**	27	**26**	**5**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1B	**1A**	**05**	**(data)**	**(checksum)**

(data): The 25 data bytes represent the configuration parameters the selected Action.
(checksum): The checksum from the instruction code through the last data byte.

Response:

- The controller will respond with the normal transmission receipt.

Code #28: Send Controller Status

Description: Instructs the controller to send the controller status data list.

Format/Example:
- To instruct the controller to send the controller status data list, transmit:

	Header		Interface Address	Instruction Code	Length	Checksum
Dec	255	254	**1**	28	0	**228**
Hex	FF	FE	**01**	1C	00	**E4**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	24 Data Bytes	Checksum
Dec	255	254	**1**	28	**24**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1C	**18**	**(data)**	**(checksum)**

(data): The 24 data bytes represent the controller status data list.
(checksum): The checksum from the instruction code through the last data byte.

A description of the controller status data list is as follows:

Parameter Name	Length (bytes)	Values
Controller State	1	1 = Process ready 2 = Start layer 3 = Change pocket 4 = Change crystal 5 = Layer ready 6 = Soak rise 7 = Soak hold 8 = Rise to Predeposit 9 = Predeposit hold 10 = Establish rate 11 = Shutter Delay 12 = Deposit #1 13 = Rate ramp #1 14 = Deposit #2 15 = Rate ramp #2

		16 = Deposit #3
		17 = Ramp to feed
		18 = Feed hold
		19 = Ramp to idle
		20 = Layer complete
		21 = Process complete
		22 = Process resume
Abort Process Errors	1	Bit 6 = Max Rate&Min Pwr
		Bit 7 = Min Rate&Max Pwr
Alarm 1 Errors	1	Bit 0 = Action Setup Corrupted
		Bit 1 =Output Setup Corrupted
		Bit 2 = Input Setup Corrupted
		Bit 3 = Crystal Fail, Process Halted
		Bit 4 = Rate Establish Error
		Bit 5 = Active Layer Corrupted
		Bit 6 = Active Process Corrupted
		Bit 7 = System Setup Corrupted
Alarm 2 Errors	1	Bit 1 = No Sensor Enabled for Material
		Bit 2 = Halt Process Action
		Bit 3 = Sound Alarm Action
		Bit 4 = Rate Deviation Alarm
		Bit 5 = Crystal Fail, Time Power Mode
		Bit 6 = Sensor Fault
		Bit 7 = Source Fault

Alert Errors	1	Bit 3 = Sound Alert Action Bit 4 = Minimum Power Alert Bit 5 = Maximum Power Alert Bit 6 = Rate Deviation Alert Bit 7 = Crystal Marginal&Deposit
Attention 1 Errors	1	Bit 0 = Process Complete Bit 1 = Minimum Power Attention Bit 2 = Maximum Power Attention Bit 3 = Rate Deviation Attention Bit 4 = Crystal Marginal&!In Process Bit 5 = Crystal Fail&! In Process Bit 6 = Crystal Marginal&In Process, Switch Bit 7 = Crystal Fail&In Process, Switch
Attention 2 Errors	1	Bit 1 = Sensor Calibration Done Bit 2 = Not Sampling (Sample Mode) Bit 3 = Manual Crystal Change Bit 4 = Resume Process Bit 5 = Sound Attention Bit 6 = Manual Pocket Change Bit 7 = Pause on Layer Complete
Discrete Input Register 1	1	Bit 0 = Input #1, ...8 (0=False, 1=True)
Discrete Output Register 1	1	Bit 0 = Output #1, ...8 (0=False, 1=True)
Controller Status 1	1	bit 0 = Ready Mode bit 1 = Manual Mode bit 2 = Time Power Mode bit 3 = Hold Mode bit 4 = Halt Mode bit 5 = Abort Mode bit 6 = Power Control Mode bit 7 = In Process
Controller Status 2	1	bit 0 = Resume Process bit 1 = Simulate Mode bit 5 = Material Time Setpoint bit 6 = Backup Sensor Active bit 7 = Last Layer Of Process
Source #1-2 Pocket Position	1x2	(1-16)
Source #1-2 Power	2x2	(0-4000), Power=99.9%*N/4000
Sensor #1-2 Crystal Position	1x2	(1-16)
Sensor #1-2 Crystal Health	2x2	(0.0-99.9)%
Total: 24 Data Bytes		

Code #29: Start Process

Description: Instructs the controller to start Process #N starting from Layer #Y.

Format/Example:
- To instruct the controller to start Process #6 starting from Layer #30, transmit:

	Header		Interface Address	Inst. Code	Length	Process #N (1-10)	Layer #Y (1-99)	Checksum
Dec	255	254	**1**	29	**2**	**6**	**30**	
Hex	FF	FE	**01**	1D	**02**	**06**	**1E**	

Response:
- The controller will respond with the normal transmission receipt.

Code #30: Send Run-Time Values

Description: Instructs the controller to send the run-time value list. A description of the run-time value list follows the example.

Format/Example:
- To instruct the controller to send the run-time value list, transmit:

	Header		Interface Address	Inst. Code	Length	Checksum
Dec	255	254	**1**	30	**0**	**225**
Hex	FF	FE	**01**	1E	**00**	**E1**

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		Interface Address	Inst. Code	Length	103 Data Bytes	Checksum
Dec	255	254	**1**	30	**103**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1E	**67**	**(data)**	**(checksum)**

(data): The 103 data bytes represent the run-time value list.
(checksum): The checksum from the instruction code through the last data byte.

#	Value Description	Length	Format	Units
1	Power	4	String	%
2	Average Thickness	5	String	KA
3	Average Rate	4	String	Å/sec
4	Active Crystal Health	2	String	%
5	Layer number	3	String	N/A
6	Rate deviation	4	String	%
7	Active process number	1	String (1...10)	N/A
8	Active material number	1	String (1...8)	N/A
9	Active source number	1	String (1...2)	N/A
10	Sensor #1 Rate	4	String	Å/sec
11	Sensor #2 Rate	4	String	Å/sec
12	Sensor #1 Thickness	5	String	KÅ
13	Sensor #2 Thickness	5	String	KÅ
14	Sensor #1 Crystal Position	1	String (1...160)	N/A
15	Sensor #2 Crystal Position	1	String (1...160)	N/A
16	Sensor #1 Crystal Strength	4	String (0.0...99.9)	%
17	Sensor #2 Crystal Strength	4	String (0.0...99.9)	%
18	Source #1 Pocket Position	1	String (1...16)	N/A
19	Source #2 Pocket Position	1	String (1...16)	N/A
20	Layer Time To Go	7	String	h:mm:ss
21	State Time To Go	7	String	h:mm:ss
22	Elapsed Process Time	7	String	h:mm:ss
23	Elapsed Layer Time	7	String	h:mm:ss
24	Elapsed State Time	7	String	h:mm:ss
25	Source #1 Status	1	Bit 0: Shutter Bit 1: Rotator Drv Up Bit 2: Rotator Drv Down	N/A
26	Source #2 Status	1	Bit 0: Shutter Bit 1: Rotator Drv Up Bit 2: Rotator Drv Down	N/A
27	Sensor #1 Status	1	Bit 0: Shutter Bit 1: Rotator Drv Up Bit 2: Rotator Drv Down Bit 3: Enabled Bit 5: Failed	N/A
28	Sensor #2 Status	1	Bit 0: Shutter Bit 1: Rotator Drv Up Bit 2: Rotator Drv Down Bit 3: Enabled Bit 5: Failed	N/A

29	Controller State	1	Binary (0...25)	N/A
30	Abort Process Errors	1	Bit 6: Max Rate/Min Pwr Bit 7: Min Rate/Max Pwr	N/A
31	Alarm 1 Errors	1	Bit 0: Action Setup Corrupted Bit 1: Output Setup Corrupted Bit 2: Input Setup Corrupted Bit 3: Crystal Fail, Process Halted Bit 4: Rate Establish Error Bit 5: Active Layer Corrupted Bit 6: Active Process Corrupted Bit 7: System Setup Corrupted	N/A
32	Alarm 2 Errors	1	Bit 1: No Sensor Enabled for Material Bit 2 = Halt Process Action Bit 3 = Sound Alarm Action Bit 4 = Rate Deviation Alarm Bit 5 = Crystal Fail/Time Power Mode Bit 6 = Sensor Fault Bit 7 = Source Fault	N/A
33	Alert Errors	1	Bit 3 = Sound Alert Action Bit 4 = Minimum Power Alert Bit 5 = Maximum Power Alert Bit 6 = Rate Deviation Alert Bit 7 = Crystal Marginal & Deposit	N/A
34	Attention 1 Errors	1	Bit 0 = Process Complete Bit 1 = Minimum Power Attention Bit 2 = Maximum Power Attention Bit 3 = Rate Deviation Attention Bit 4 = Xtal Marginal&!In Process Bit 5 = Xtal Fail&!In Process Bit 6 = Xtal Marginal&In Proc., Switch Bit 7 = Xtal Fail&In Proc., Switch	N/A

35	Attention 2 Errors	1	Bit 1 = Sensor Calibration Done Bit 2 = Not Sampling (Sample Mode) Bit 3 = Manual Crystal Change Bit 4 = Resume Process Bit 5 = Sound Attention Bit 6 = Manual Pocket Change Bit 7 = Pause on Layer Complete	N/A
36	Controller Status 1	1	bit 0 = Ready Mode bit 1 = Manual Mode bit 2 = Time Power Mode bit 3 = Hold Mode bit 4 = Halt Mode bit 5 = Abort Mode bit 6 = Power Control Mode bit 7 = In Process	N/A
37	Controller Status 2	1	bit 0 = Resume Process bit 1 = Simulate Mode bit 5 = Material Time Setpoint bit 6 = Backup Sensor Active bit 7 = Last Layer Of Process	
Total: 103 Data Bytes				

Code #31: Initiate Automatic Data Logging

Description: This operation allows the computer to setup the MDC-260 to automatically output selected run-time values to the computer port every 100 milliseconds. The values to be sent are determined when this instruction is issued. Each value can be selected to be sent by setting its corresponding bit = 1. All values with a bit setting = 0 will not be sent.

The run-time values available to be sent are the same as in Code #30. The difference is that this instruction allows you to select which values to send and once selected, the values are sent automatically until the next "Initiate Automatic Data Logging" instruction or the controller power is removed.

Format/Example:
- To instruct the controller to initiate automatic data logging, transmit:

	Header		Interface Address	Inst. Code	Length	5 Data Bytes	Checksum
Dec	255	254	**1**	31	**5**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1F	**05**	**(data)**	**(checksum)**

(data): The 5 data bytes represent the selection bits determining what values to send. **(checksum):** The checksum from the instruction code through the last data byte.

- To instruct the controller to stop sending data, transmit:

	Header		Interface Address	Inst. Code	Length	5 Data Bytes	Checksum
Dec	255	254	**1**	31	**5**	**0, 0, 0, 0, 0**	
Hex	FF	FE	**01**	1F	**05**	**00, 00, 00, 00, 00**	

Byte #	Bit #	Description	Length(bytes)	Format	Units
1	0	Power	4	String	%
	1	Thickness	5	String	KÅ
	2	Deposition rate	4	String	Å/sec
	3	Crystal health	2	String	%
	4	Layer number	3	String	None
	5	Rate deviation	4	String	%
	6	Active Process	2	String	
	7	Active Material	2	String	
2	0	Active Source	1	String	
	1	Sensor #1 Rate	4	String	Å/sec
	2	Sensor #2 Rate	4	String	Å/sec
	3	Sensor #1 Thickness	5	String	KÅ
	4	Sensor #2 Thickness	5	String	KÅ
	5	Sensors #1-6 Crystal Position	6	String	
	6	Sensor #1 Strength	4	String	%
	7	Sensor #2 Strength	4	String	%
3	0	Sources #1-2 Pocket Position	4	String	
	1	Layer Time To Go	7	String	h:mm:ss
	2	State Time To Go	7	String	h:mm:ss
	3	Elapsed Process Time	7	String	h:mm:ss
	4	Elapsed Layer Time	7	String	h:mm:ss
	5	Elapsed State Time	7	String	h:mm:ss
	6	Sources #1-2 Status bits	2		
	7	Sensors #1-2 Status bits	2		
4	0	Controller State	1	Binary	
	1	Trouble Flags	6		
	2	Controller Status	2		
	3	Unused	0		
5	0-7	Unused	0		
Total: 5 Data Bytes					

All string values are in ASCII format including decimal points and colons where needed. See send run-time values (Code #30) above for details on the source/sensors status, controller trouble and controller mode bits.

Response:
- The controller will respond with the normal transmission receipt.
- Every 100 milliseconds, the controller will send a message including all of the selected run-time values in the following format:

	Header		Interface Address	Inst. Code	Length	Data Bytes	Checksum
Dec	255	254	**1**	31	**(length)**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1F	**(length)**	**(data)**	**(checksum)**

(length): The sum of all lengths, in bytes, of all the requested data (see table).
(data): The requested data, in ASCII characters. The data is always presented in the order shown in the table above, with data not requested left out.
(checksum): The checksum from the instruction code through the last data byte.

Code #32: Internal Command

Description: Instruction Code #32 is used by the software interface package and is not designed for external interfacing.

Code #33: Set Active Source Power

Description: Instructs the controller to enter the incoming source power value into the active source power. This command only works if the controller is in the manual power control mode. A description of the manual power parameter list is as follows:

Parameter Name	Length (bytes)	Allowable Range
Source Power	2	(0-999) units are 0.1%
Total: 2 Data Bytes		

Format/Example:
- To set the active source power to 50% (500 dec = 1F4 hex), transmit:

	Header		Interface Address	Inst. Code	Length	2 Data Bytes (Source Pwr)		Checksum
Dec	255	254	**1**	33	**2**	1	244	231
Hex	FF	FE	**01**	21	**02**	1	F4	E7

Response:
- The controller will respond with the normal transmission receipt.

Code #34: Internal Command

Description: Instruction Code #32 is used by the software interface package and is not designed for external interfacing.

Code #35: Internal Command

Description: Instruction Code #32 is used by the software interface package and is not designed for external interfacing.

Code #36: Not Supported

Description: Instruction Code #36 is not supported by the MDC-260. Attempting to issue it to the controller will result in an "Invalid Instruction Code" error in the message receipt.

Code #37: Not Supported

Description: Instruction Code #37 is not supported by the MDC-260. Attempting to issue it to the controller will result in an "Invalid Instruction Code" error in the message receipt.

Code #38: Remote Activation of Controller

Description: This instruction initiates a remote action. The possible actions are shown in the following table:

Remote Action Code	Description	Action Trigger Type
0	Sound Alarm Action	Momentary
1	Sound Alert Action	Momentary
2	Sound Attention Action	Momentary
3	Step From State Action	One Shot
6	Clear Hold in State Action	Continuous
5	Set Hold in State Action	Continuous
6	Terminate Deposit Action	One Shot
7	Halt Process Action	One Shot
8	Switch Crystals	One Shot

All the momentary actions trigger the action for a 100-millisecond period for each message received. The one shot actions trigger the action once for each message received. For example, sending one step from state message would cause the controller to step into the next state one time. The continuous actions trigger that action indefinitely. So the set hold in state action will cause the controller to hold in the current state until the clear hold in state action is received and the exit state condition is meet.

Format/Example:

- To initiate a Terminate Deposit action, transmit:

	Header		Interface Address	Inst. Code	Length	Remote Action Code	Checksum
Dec	255	254	1	38	1	6	210

Hex	FF	FE	**01**	26	**01**	**06**	**D2**

Response:
- The controller will respond with the normal transmission receipt.

Code #39: Send a Run-Time Value

Description: Instructs the controller to send one run-time value base on the Value Code received. The table of run-time values can be found in the description for Code #30.

Format/Example:
- To instruct the controller to send the current Layer Number, transmit:

	Header		**Interface Address**	**Inst. Code**	**Length**	**Run-Time Value**	**Checksum**
Dec	255	254	**1**	39	**1**	**4**	
Hex	FF	FE	**01**		**01**	**04**	

Response:
- In addition to the normal transmission receipt, the controller will respond with:

	Header		**Interface Address**	**Inst. Code**	**Length**	**Data Bytes**	**Checksum**
Dec	255	254	**1**	30	**(length)**	**(data)**	**(checksum)**
Hex	FF	FE	**01**	1E	**(length)**	**(data)**	**(checksum)**

(length): The length of the single run-time value to be sent by the controller.
(data): The requested data value, in ASCII characters.
(checksum): The checksum from the instruction code through the last data byte.

Code #40: Enable/Disable the Front Panel Keyboard

Description: Instructs the controller to either enable or disable the MDC-260's front panel keys based on the value received. A value of 255 (FF hex) disables the keys. Any other value will enable the keys.

Format/Example:
- To instruct the controller to disable the front panel keyboard, transmit:

	Header		Interface Address	Inst. Code	Length	Data Byte	Checksum
Dec	255	254	**1**	40	**1**	**255**	
Hex	FF	FE	**01**	28	**01**	**FF**	

Response:
- The controller will respond with the normal transmission receipt.

12.   REPAIR AND MAINTENANCE

12.1   HANDLING PRECAUTIONS

Integrated Circuits (I.C.'s) can be damaged by static discharge into their inputs. This static discharge is the same phenomenon that produces the unpleasant shock when one grabs a doorknob after walking across a carpet. The likelihood of static buildup is proportional to the dryness of the air and can be particularly troublesome in cold, dry climates, or hot desert climates.

⚠ **CAUTION:** *To prevent damage to internal components by means of electrostatic discharge (ESD), wear a grounded anti-static wrist strap.*

In order to minimize the chance of discharging body charge into the I.C. inputs, always handle circuit boards by the edge, avoiding contact with the connector area. When moving a board from one surface or work area to another surface or work area, always personally touch the new surface or location before laying down or inserting the board so that you, the board, and the surface, or equipment, are all at the same potential. It is wise in dry climates to minimize the amount of movement when handling or replacing I.C.'s in circuit boards. When handing a circuit board or I.C. to another person, always touch the person first.

Wood or paper surfaces are the most forgiving surfaces to work on. Plastic should be avoided. Metal is O.K. as long as the metal is always touched with the hand prior to laying down the I.C.'s or circuit boards.

P.C. boards or I.C.'s should never be placed in plastic bags unless they are of the conductive plastic type intended for this use. These bags are typically black or pink and are normally labeled as conductive or anti-static. If no conductive plastic bags are available, boards or I.C.'s can be wrapped in paper, and then placed in plastic bags or shipping bags.

If the above precautions are observed, the chance of damage will be minimal and no problems should be encountered.

12.2   MAINTENANCE PHILOSOPHY

The MDC-260 was designed around a maintenance-free philosophy. There are no serviceable components inside the unit. Field repair at the component level is not recommended and indeed can void the warranty. The following sections are intended primarily as an aid in understanding the operation of the MDC-260 and to help in isolating problems external to the unit.

12.3   TROUBLE SHOOTING AIDS

The following table describes possible problems that could occur when interfacing the controller with a vacuum system. With each symptom is a list of probable causes and suggested remedy.

Symptom	Possible Cause	Remedy
Unit blows line fuse.	a) Line voltage selection wheel is not installed to agree with line voltage being used.	a) Change line voltage selection. Refer to Section 8.3.3
	b) Incorrect fuse size or type.	b) Replace with correct fuse size (or type). See Section 8.3.3
	c) Shorted rectifiers in power supply area.	c) Return unit to manufacturer for repair.
	d) Shorted transformer or filter capacitor.	d) Return unit to manufacturer for repair.
Front Panel display never illuminates.	a) Blown fuse.	a) Replace with correct fuse size (or type). See Section 8.3.3
	b) Loose connections between LCD and main board.	b) Check and secure LCD backlight connector to main board J6. Check and secure LCD data lines cable to main board J12.
	c) Faulty clock generator (High Speed Clock)	c) Return unit to manufacturer for repair.
LCD display shows a blank blue screen.	a) Contrast level is set too low.	a) Adjust contrast (Sec 4.1.6)
	b) Bad LCD display.	b) Return unit to manufacturer for repair.
LCD display shows a bright "white" screen.	a) Contrast level is set too high.	a) Adjust contrast (Sec 4.1.6)
	b) Bad LCD display.	b) Return unit to manufacturer for repair.
"Crystal Failure" message flashes with selected sensor properly connected.	a) Defective cable or cables.	a) Replace cable(s)
	b) Defective or overloaded sensor crystal.	b) Replace crystal with a new one.
	c) Oscillator unit connected in the wrong direction.	c) Reverse the connections.
	d) Bad Oscillator unit.	d) Replace with a new oscillator.
	e) Improper cable length	e)
No control voltage while monitoring output of selected Source.	a) Improperly wired cable, or shorted wires.	a) Verify the cable connection against Figure 13-1. Also, check for electrical shorts.
Front panel control keys non- functional.	a) Defective membrane keys	b) Contact manufacturer.
	b) Loose connections between the membrane keys and the main board.	b) Check and secure membrane connector to main board J10.

The unit fails to activate externally controlled devices (Shutters, solenoids, etc.)	a) Improperly wired cable, or shorted wires.	a) Verify the cable connection against Table 8-2 and Figure 8-7. Also, check for electrical shorts.
	b) Mismatch in programmed output and the physical wiring.	b) Verify and revise the output to match the physical wiring. See Sec 4.3.3.3
	c) Faulty Relay	c) Return unit to manufacturer for repair.
Unable to remotely control the unit via Discrete I/O inputs.	a) Improperly wired cable, or shorted wires	a) Verify the cable connection against Table 8-2 and Figure 8-7. Also, check for electrical shorts.
	b) Mismatch in the programmed input and the physical wiring.	b) Verify and revise the input to match the physical wiring. See Sec 4.3.3.2
	c) The selected input type doesn't match the input type.	c) Refer to Section 8.3.9.1. Verify and select the correct type of input.
	d) The selected input logic doesn't match the input logic	d) See Section 4.3.3.2. Verify and select the correct logic.
Unable to manually control the source power through the Remote Power Handset.	a) Controller is not in Manual mode.	a) Press Manual key to set manual mode.
	b) Controller is in Abort mode.	b) Press Reset, then Manual key to set manual mode.
	c) Faulty Remote Power Handset.	c) Replace with new Remote Power Handset.
	d) Loose connection from the Manual Control connector to the Main bd.	d) Check and secure front panel Manual connector to main board J8.

For further assistance, see Support at www.inficon.com.

12.4   RETURNING THE MDC-260 TO THE FACTORY

If there is a need to return your controller to the factory, please call INFICON to obtain a Returned Merchandise Authorization Number (RMA#). This number is required prior to returning your controller to the factory. You are required to show this RMA number on your shipping document. It will help us track and ensure proper actions will be made to your controller.

13.   APPENDIX A – MATING CABLE COLOR CODES

Pin Number	Color	Signal
1	Black	Source 2 or 4 control
2	Green	Source 2 or 4 return
3	Red	Source 1 or 3 return
4	Brown or White ***	Source 1 or 3 control

*** Note: This color code varies depending on the manufacturer. It is coded BROWN in a 4-conductor cable and WHITE in a 7-conductor cable.
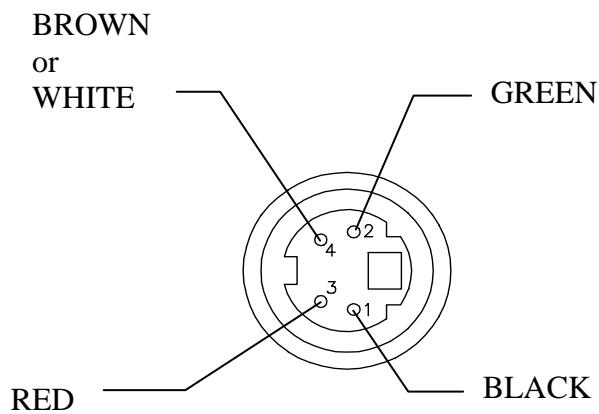
Figure 13-1 Plug Pin Out - Source Cable Connector

14. APPENDIX B – PARAMETER TEMPLATES

The following pages are blank templates, provided to manually archive the MDC-260's parameters. Please feel free to photocopy these pages and use them to store parameter information.

14.1   MATERIAL

Material Number	
Material Name	
Sensor #	
Crystal #	
Source #	
Pocket #	
Density	
Acoustic Impedance	
Tooling Factor	
Proportional Gain	
Integral Time Constant	
Derivative Time Constant	
Rise to Soak Time	
Soak Power	
Soak Time	
Rise to Predeposit Time	
Predeposit Power	
Predeposit Time	
Rate Establish Time	
Rate Establish Error	
Deposition Rate 1	
Deposition Rate 2	
Deposition Rate 3	
Rate Start Thickness 1	
Rate Start Thickness 2	
Rate Stop Thickness 1	
Rate Stop Thickness 1	
Time Setpoint	
Ramp to Feed Time	
Feed Power	
Feed Time	
Ramp to Idle Time	
Idle Power	

MATERIAL CONT'D

Maximum Power	
Max Power Alarm Delay	
Minimum Power	
Rate Deviation Attention	
Rate Deviation Alarm	
Rate Deviation Abort	
Sample Dwell %	
Sample Period	
Crystal Fail	
Backup Sensor #	
Backup Crystal #	
Backup Tooling Factor	
Material Password	

14.2   PROCESS

Page ___ of ___	
Process Number	
Process Name	
Edit password	
Run/View password	

Layer #	Material Thickness (kÅ)	Material Name

SYSTEM:_____ ENTERED BY:_____ APPROVED BY:_____ DATE:_____

14.3   DISPLAY SETUP

Pause On Layer Complete	☐ Yes ☐ No
Display Negatives	☐ Enabled ☐ Disabled
Thickness Graph Scale	☐ 2 Digit ☐ 3 Digit
Time To Go Display	☐ Estimated State ☐ Elapsed Process ☐ Elapsed Layer ☐ Elapsed State ☐ Estimated Layer
Rate Graph	☐ Enabled ☐ Disabled
Power Graph	☐ Enabled ☐ Disabled
Thickness Graph	☐ Enabled ☐ Disabled
Source/Sensor Status	☐ Enabled ☐ Disabled
Rate Dev. Graph	☐ Enabled ☐ Disabled
Source/Sensor Status	☐ Enabled ☐ Disabled
I/O Status	☐ Enabled ☐ Disabled
Color Scheme	☐ Scheme #1 ☐ Scheme #2 ☐ Scheme #3 ☐ Scheme #4

SYSTEM:_____   ENTERED BY:_____   APPROVED BY:_____   DATE:_____

14.4 INPUTS

Input #	Input Name	True Logic	Type	Pin #	Return Pin #
1		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
2		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
3		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
4		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
5		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
6		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
7		☐ LOW ☐ HIGH	☐ Passive ☐ Active		
8		☐ LOW ☐ HIGH	☐ Passive ☐ Active		

SYSTEM:_____ ENTERED BY:_____ APPROVED BY:_____ DATE:_____

14.5   OUTPUTS

Output #	Output Name	Conditions	Pin #	Return Pin #
1				
2				
3				
4				
5				
6				
7				
8				

SYSTEM:_____   ENTERED BY:_____   APPROVED BY:_____   DATE:_____

14.6   ACTIONS

Output #	Action Name	Conditions
1		
2		
3		
4		
5		
6		
7		
8		

14.7   SENSOR SETUP

Sensor #	☐ 1	☐ 2		
Number of Crystals	☐ 1	☐ 2	☐ 3	☐ 4
	☐ 5	☐ 6	☐ 7	☐ 8
	☐ 9	☐ 10	☐ 11	☐ 12
	☐ 13	☐ 14	☐ 15	☐ 16
Shutter Relay Type	☐ N.O. ☐ N.C. ☐ DUAL			
Control	☐ MANUAL ☐ DIRECT ☐ BCD ☐ INDIV.			
Drive	☐ UP ☐ DOWN ☐ FAST ☐ INLINE ☐ SNGL STEP ☐ DBL STEP			
Feedback Type	☐ NO FEEDBACK ☐ INDIVIDUAL ☐ BCD ☐ SINGLE HOME ☐ IN POSITION			
Rotator Delay (sec)				

14.8   SOURCE SETUP

Source #	☐ 1	☐ 2		
Number of Pockets	☐ 1	☐ 2	☐ 3	☐ 4
	☐ 5	☐ 6	☐ 7	☐ 8
	☐ 9	☐ 10	☐ 11	☐ 12
	☐ 13	☐ 14	☐ 15	☐ 16
Shutter Relay Type	☐ N.O. ☐ N.C. ☐ None			
Shutter Delay (sec)				
Control	☐ MANUAL ☐ DIRECT ☐ BCD ☐ INDIV.			
Drive	☐ UP ☐ DOWN ☐ FAST ☐ INLINE ☐ SNGL STEP ☐ DBL STEP			
Feedback Type	☐ NO FEEDBACK ☐ INDIVIDUAL ☐ BCD ☐ SINGLE HOME ☐ IN POSITION			
Rotator Delay (sec)				
Source Voltage	☐ 2.5V ☐ 5V ☐ 10V			

SYSTEM:_____   ENTERED BY:_____   APPROVED BY:_____   DATE:_____

14.9   UTILITY SETUP

Crystal Frequency (MHz)	□ 2.5 □ 3.0 □ 5.0 □6.0 □9.0 □10.0
Simulate Mode	□ On □ Off
USB Interface Address (1-32)	
Attention Volume (0-10)	
Alert Volume (0-10)	
Alarm Volume (0-10)	

SYSTEM:_____ ENTERED BY:_____ APPROVED BY:_____ DATE:_____

15. INDEX

16.   MENU MAPS

Figure 16-1 Map of Status and Graph Screens

Figure 16-2 Map of Programming Menu Screens