Denton Infinity 22 E-beam Standard Operating Procedures for Electron beam Evaporation

Coral name: **E-beam Evap 1**
Model: Infinity 22
Location: CNST NanoFab, Building 215, Room B104

Overview

- This tool is a dual e-beam/thermal evaporator. The present instructions refer only to the e-beam evaporation process (6-pocket electron gun source, or "source 1"). Source 2 is a dual thermal evaporation source and is covered under a separate manual.

- These instructions are divided into three parts:

  - automatic operation using an existing process and material
  - creation of a process and a new material
  - manual operation using the hand-held remote control.

- The system is equipped with an electron gun containing 6 pockets, each 25cc in capacity. The pockets are referred to as Source 1-Pocket 1, Source 1-Pocket 2,…, Source 1-Pocket 6.

- Refer to the following five figures showing the five graphical user interface (GUI) screens needed to do a run:

  Fig. 1 Overview (starting screen; accessed by closing the Auto Control screen)
  Fig. 2 Auto Control (accessed from Overview)
  Fig. 3 Deposition Configuration (accessed from Auto Control)
  Fig. 4 E-beam control
  Fig. 5 Heat and rotation Control

- The color code for all the GUI screens is the following:
  Green: ON or Satisfied
  Red: OFF or Not Satisfied

Special Notes and Restrictions

- You must be qualified by super user to use this tool
- This tool is reserved for the following metals: Au, Ag, Cu, Ni, Cr, Al, Ti, Fe, Co, W. Evaporation of materials other than these requires prior authorization from Nanofab staff.
- When you are done with your work, **always leave the chamber under vacuum**. Minimize the time the chamber is left at atmosphere.
- ***Note of caution***: the electrical power required to obtain a stable evaporation depends not only on the material but also on the exact type of boat or crucible you are using. Do not run an automatic process stored in the Telemark 860 controller unless you are sure it is the right one for your evaporation. The first time you are using either a new material and/or crucible liner, always do a test run using the remote control and write

down the adequate times and power levels. You can then create a new material and process in the 860 for your purpose.

- All seven interlock indicators on the Overview screen (Fig. 1) should be green when you get to the machine. If not, notify Nanofab staff member. Do not proceed any further with the machine.
- The cryopump temperature indicator should read 7-9K. If not, notify Nanofab staff member. Do not proceed any further with the machine.

I. Automatic Operation

1. Vent chamber

In the Overview screen (Fig. 1), press Auto Control (light blue, bottom right). This brings up the Autocontrol screen (Fig. 2). Press Auto, top left in System Control box. The tab turns from red to green. Press Auto Vent; the tab turns green, showing "running". Press Close. This brings back the Overview screen. It will take ~ 4 min. for the chamber to come to atmosphere. Open door.

2. Load material and wafer and pump-down

Press Manual. Press E-beam Control. Open shutter. Take note of the positions of your source materials: pockets 1 to 6. You can view each pocket by enabling the crucible motor and incrementing the crucible number (Fig. 4). Close shutter. Place wafer in dome. Close and latch door.
Press Close. On the Overview screen, press Auto Control (light blue, bottom right). On the Auto Control screen, press Auto (top left), press Auto Pump.

3. Deposition

- Press Deposition Configuration (Fig. 3). Enter the following:
  - Process start pressure: 3.0E-6 Torr. It will take ~ 15 minutes to reach this base pressure from atmosphere.
  - Rotation setpoint in percent of maximum speed (typ. 25%)
  - Heat: toggle "selected/not selected". If selected, enter Heat Setpoint in °C
  - Press Close
- High Voltage Power Supply cabinet: turn on High Voltage and Control circuit breakers (up position)
- On the Telemark TT-10/15 Control, turn key to ON to enable the high voltage power supply.
- Switch Telemark Sweep Power Supply Controller to ON
- Set Telemark Sweep Select to AUTO (sweep #1 is automatically selected in this automatic deposition mode)
- Select process on Telemark 860 controller as follows:
  - Deselect Manual (green light goes off)
  - Press Reset
  - Press Start. This brings up the Start Process screen

- Select process using the up and down arrows
- From the Auto Control screen, press Autodeposition
- You may press Status repeatedly on the 860 to view graphs of rate, rate deviation, thickness, power and source and sensor status as the deposition progresses.

- Once the process is completed, the beeper will sound. Press Program to turn it off.
- Press Autovent to bring the chamber to atmosphere
- Remove your wafer, latch door and press Autopump.
- ***Fill out Runlog sheet in logbook***

II. Programming the 860 Controller and Menu Structure

1. 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 seen 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. 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, align the cursors with the option, then press either the Enter or Right-arrow key. This will present the next screen associated with the selected option. You can always hold down the Left-arrow key to go back to the Main Menu.

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. Its 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 number 9 key contains characters Y, Z and “space”. Use this key to enter a space.

3. Entering Time Parameters

The model 860 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. Copying and Deleting

A “process” is defined by one or more “layers”, and a layer requires a “material” and a thickness definition. The model 860 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 number 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 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.

5. Password protection

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 password default is 0000, or no password protection. Refer to the description below to set each password**. Be sure to record passwords because if you forget a password it will not be possible to gain access to the protected item!**

5.1 View/Run Process Password

The View/Run password is required to 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), 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.

5.2 Edit Process Password

The Edit Process password is required to edit a process. To set this password, select View/Edit 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 now be asked to enter the correct password. Once a password other than 0000 has been installed, it will not be displayed unless re-entered.

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 now be asked to enter the correct password. Once a password other than 0000 has been installed, it will not be displayed unless re-entered.

6. Process

6.1 Setup

A "process" is a deposition recipe specifying the desired *layers and thicknesses* using pre-defined "materials". All the other deposition parameters are entered under "materials". To define a process, you should complete the following steps:
a) From Main Menu, select View/Edit Process. Select a blank process from the Select Process screen. Note that you can also copy and modify a similar process to save time.
b) Enter a process name in the Define Process screen (twelve characters alphanumeric). **Examples of process names are Al 1, Ti 2, Cr 4, etc. where the number refers to the pocket number where the material is placed.**
c) Move the cursor onto the layer thickness parameter and enter the desired thickness for the layer.
d) 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.
e) Repeat steps c and d until the process layers are complete.

6.2 Start

To start a new process, the controller must be in the Process Ready state. If not, press Abort then Reset. From the Ready state, press the Start key, move the cursor onto the desired process and press Start again to start the process.

6.3 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.

7. Material

7.1 Basic Parameters

The model 860 has a long list of material parameters (a total of 50) that need to be defined for each material, which can be overwhelming at first. 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 the materials and the parameters which must be set to utilize the different features of the 860 controller. For a detailed description of any material parameter, refer to Section 4.3.2.1 of the Telemark Model 860 Controller Manual.
The following is a list of parameters that are typically set when defining a new material:

1. Material 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. **Try to use the same name for the material as for the process. For instance, Al 1 is Aluminum in pocket 1, Ti 2 is Titanium in pocket 2, etc. This way will reduce the possibility of mix-ups.**

2. Sensor input and crystal number – Defines the sensor and crystal number of the sensor which will be used to monitor this material

3. Source output and pocket number – Defines the source and pocket number that the material will be deposited from.

4. Tooling factor – Used to correlate the controller's rate and thickness readings with those actually measured on the substrates. This parameter is determined empirically. **For the present configuration/positions of the source and crystal, the tooling factor is 136%.**

5. Control loop parameters (Proportional gain, Integral time and Derivative time) – The default settings for these parameters are a good starting point.
    - Proportional gain: 1800
    - Integral time: 99.9
    - Derivative time: 25

Refer to the 860 manual for further information.

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

7. Maximum power – Defines the maximum deposit power for the material. It is used as a safety feature to prevent overheating or thermal runaway which would damage either the source or the chamber.

7.2 Specialized Parameters

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 materials parameters. All of these features are disabled by default.

7.2.1 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.

7.2.2 Automatic crystal switching

To enable automatic crystal switching upon failure, set the crystal fail parameter to Switch then set the Backup Sensor, Backup Tooling and Backup Crystal parameters.

7.2.3 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 model 860 has four rate ramps available. A rate ramp is defined by its Ramp Start and ramp Stop Thicknesses and the final rate. The rate ramps are disabled by default with the Ramp Start and Ramp Stop Thicknesses set to 999.9.

III. Operation Using the Remote Power Handset

The remote control is typically used when depositing a new material to empirically determine the power values needed to melt the material and obtain given evaporation rates. These values can then become parts of a new material and process for subsequent automatic operation.

- Vent chamber, load wafer and material, pump down as described under "Automatic Operation".
- In Overview, go to Auto Control/Deposition Configuration (Fig. 3)
  - Toggle Heat ON/OFF. If Heat is to be ON, select Temperature Setpoint
  - Toggle Rotation ON; enter speed in % of maximum (typically 25%)
  - Select Process Start Pressure as 3.0E-6 Torr
  - Press Close
- On the Telemark TT-10/15 Control, turn key to ON

- Wait for the process start pressure to be reached (approx. 15 minutes). In Overview, set System Control to Manual. Then press E-beam control (upper right, blue button). Refer to Fig. 4.
  - Sweep select: 1, 2, 3 or 4
  - Crucible control: rotate to desired pocket 1, 2, 3, 4, 5 or 6 by pressing Crucible # and Enable
  - Control mode: Remote
  - Rotation: 25 % and ON
  - Shutter: OFF
  - System enable
    - System Power ON (green)
    - Reset
    - HV Power ON (green)
    - Emission ON (green)

- On the Telemark controller, select a process using with the following sequence of keystrokes.

  - Reset
  - Manual (green light ON)
  - Start (brings up the Start Process screen)
  - Arrow up/down to desired process
  - Start
  - Abort
  - Reset
  - Manual

- Start increasing the power using the hand-held remote control. A reasonable ramp rate is typically one click (0.1%) per second to progressively heat the source.

- When you get to 5% power, stop increasing and check the sweep pattern to make sure the electron beam is ***centered and sweeping the source without encroaching on the copper hearth***. There are two ways to choose a seep pattern:

  - Set the Telemark Sweep Select to AUTO and select the sweep on the touch screen 1, 2, 3 or 4, or
  - Set the Telemark Sweep Select to Manual and select the sweep using the rotary switch
  - Look at the source and adjust the position, frequency and amplitude of the sweep.

  Note: For each sweep, you can choose either a triangle or spiral pattern

- When you reach 11% power, ***check the sweep pattern again*** and readjust if needed

- Open shutter. It is preferable to open the shutter when some metal is already evaporating (i.e. at predeposit power). If you don't know, 15% is a good default value.

- Keep increasing power until the desired deposition rate is achieved. As an example, for Al, 17% power yields 0.1Å/s and 21.5% yields 1.0Å/s. Note that the exact power level will vary with the sweep pattern.

- When the desired thickness is attained, close the shutter and decrease power to zero

- On E-beam Control GUI screen, press:

  - Rotation OFF
  - Emission OFF
  - HV Power OFF
  - System Power OFF
  - Crucible Motor STOP

- Make sure chamber temperature is below 60°C before venting

.

- Vent chamber: Go to the Auto Control screen, press Auto, then press Autovent.
- Remove your wafer, latch door and press Autopump.
- ***Fill out runlog sheet in logbook***.

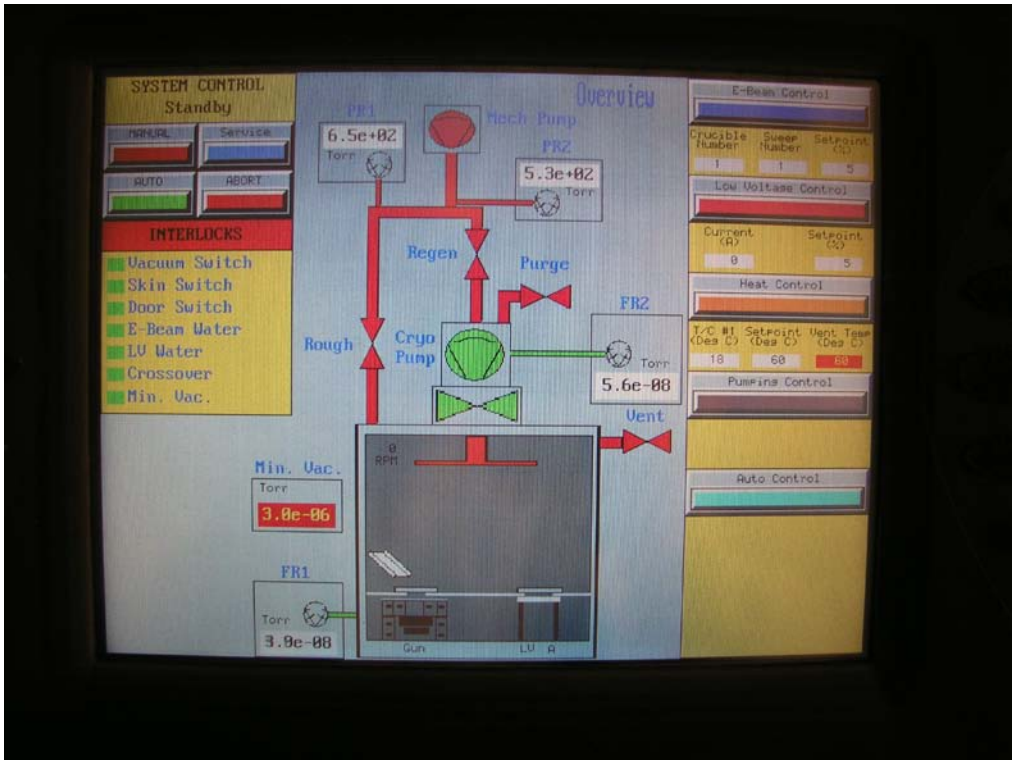

Figure 1 Overview screen

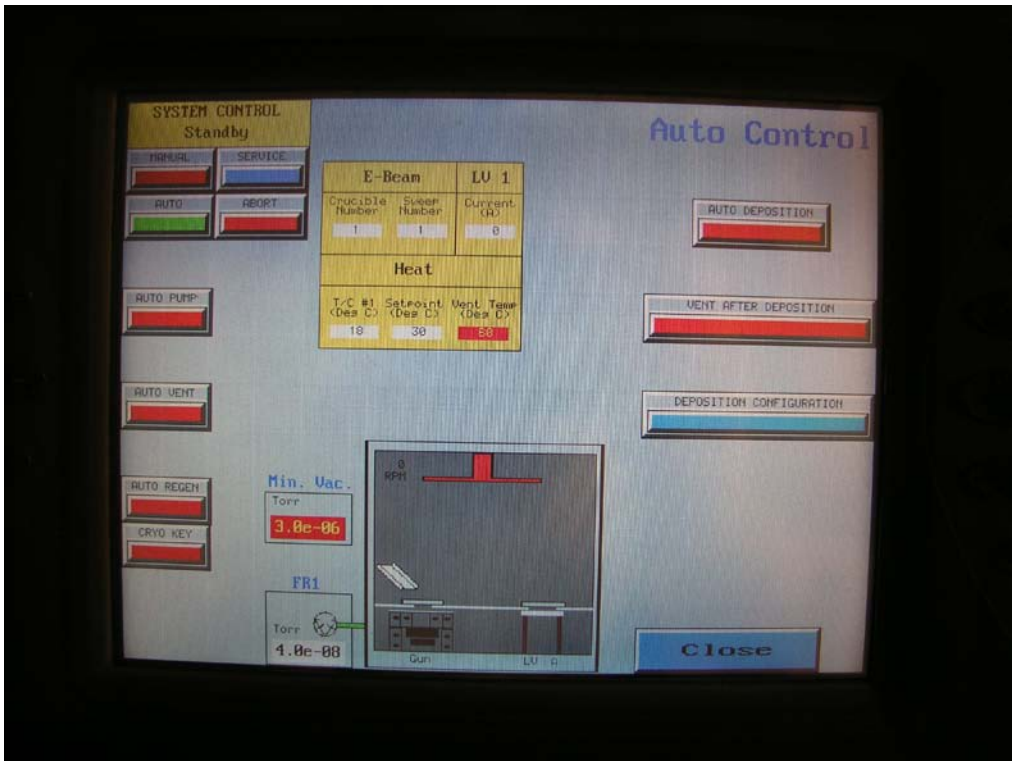

Figure 2 Auto Control Screen

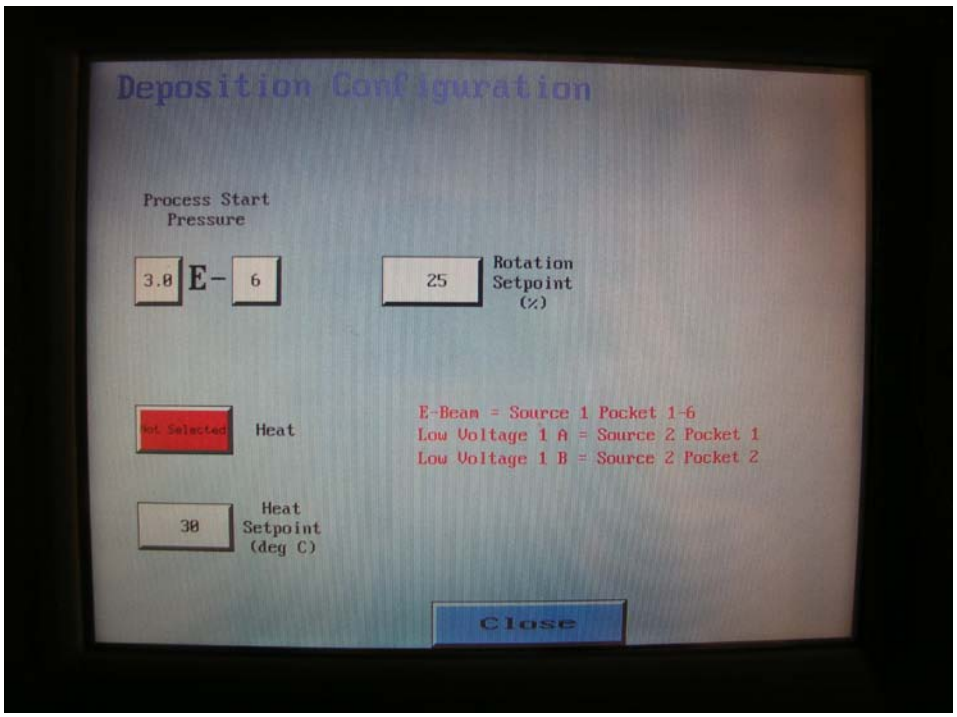

Figure 3 Deposition Configuration

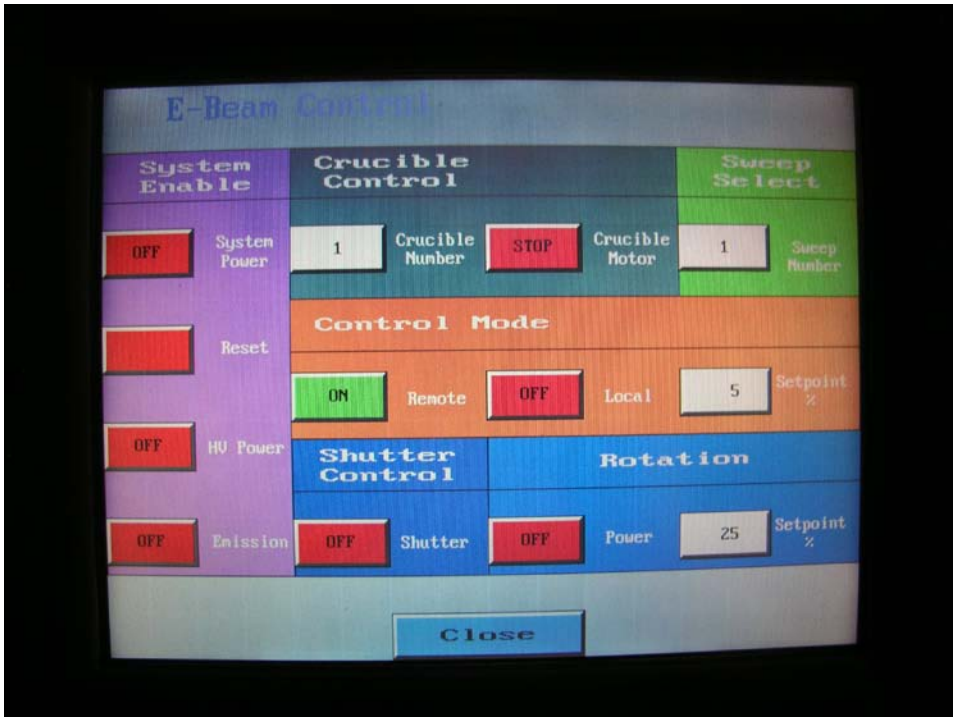

Figure 4 Electron beam source control

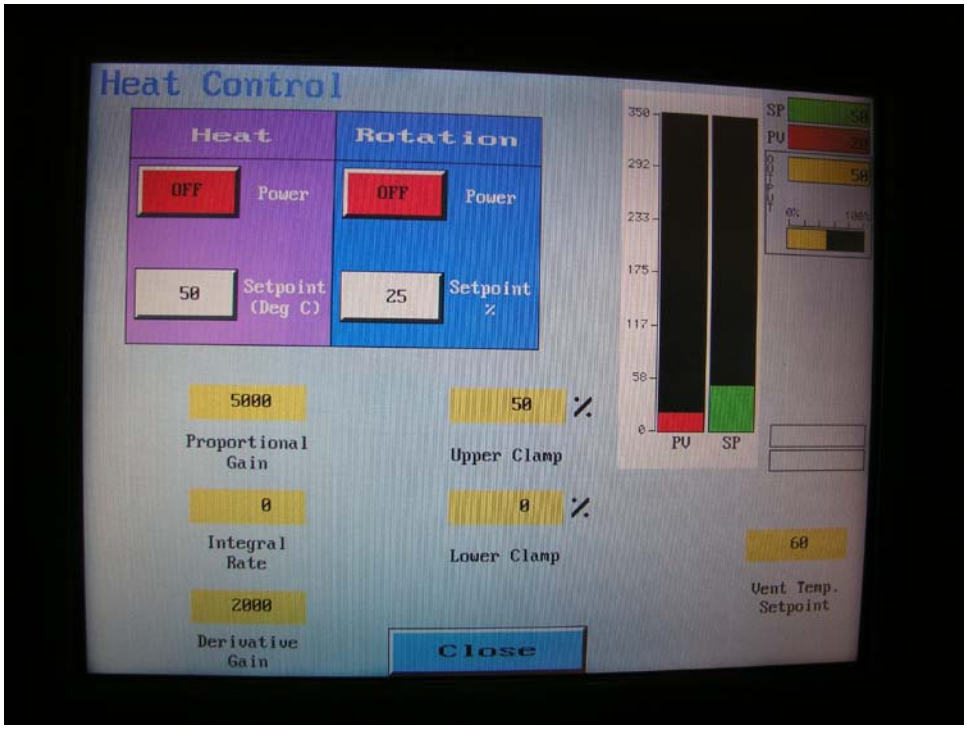

Figure 5 Heat and Rotation control