

# Trovato Evaporator Software

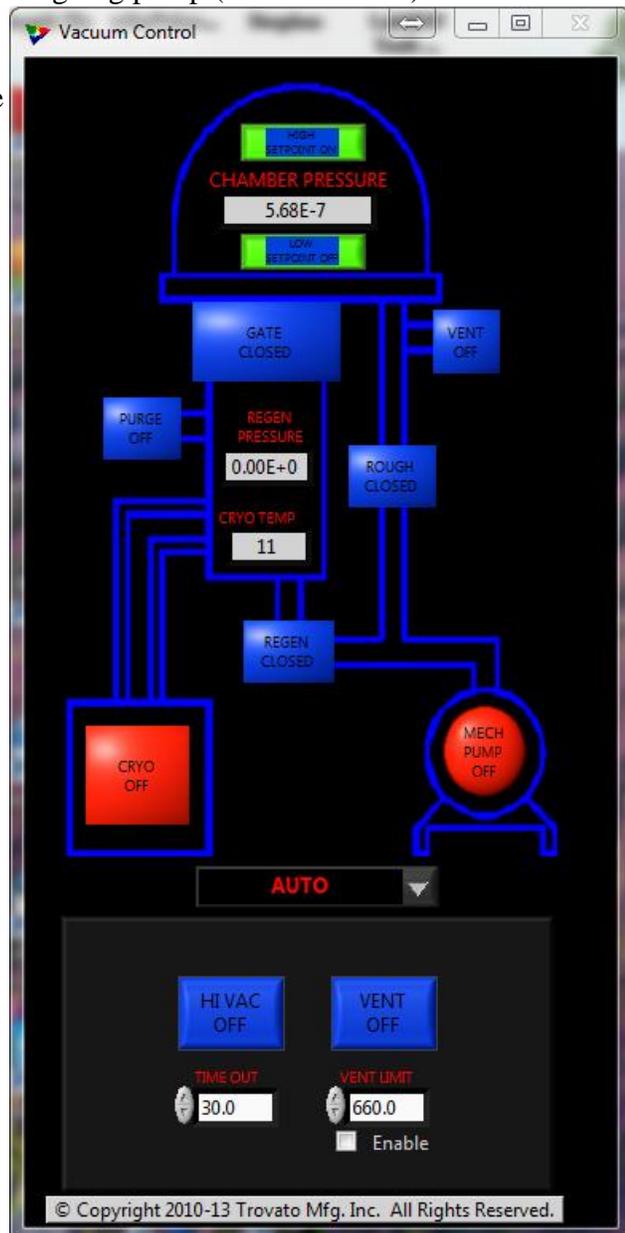
When the software for the Trovato Evaporator is launched there are four components: the Main Panel, Fixture Control, Turbo Control, and Labjack I/O Control.

## Cryo-Pump Control

Cryo-pump control is used to sequence the pump stack components to put the chamber under vacuum or to vent the system to atmospheric pressure.

### AUTO Mode

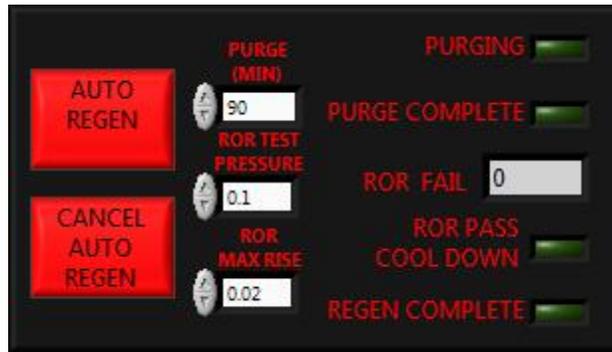
- Start-up Sequence - The pump-down sequence is started by pressing the Hi Vac On/Off button. This will start the roughing pump (MECH PUMP). When the Time Out (30 Sec) has expired for evacuating the roughing line the Rough Valve will open to the chamber. The CHAMBER PRESSURE will begin to drop. When the chamber pressure drops below 300 mTorr the HIGH SETPOINT indicator will turn from Red to Green. When chamber pressure drops below 200 mTorr the LOW SEPOINT indicator will turn from Red to Green. At this time the Rough Valve will close, the Roughing Pump (MECH PUMP) will turn off, and the GATE VALVE is commanded to open. When the gate is fully open the GATE OPEN/CLOSED indicator will turn from Blue to Green. The Chamber is now exposed to the Cryo array and the pressure will continue dropping.
- Vent Sequence – To start the vent sequence, the Gate must be closed. Pressing the HI VAC ON/OFF button will cause the Gate Valve to close. When the Gate is fully closed the GATE OPEN/CLOSED indicator will turn from Green to Blue. At this time the VENT ON/OFF button will be enabled. Actuating the VENT ON/OFF button will start



the vent sequence. If the Ion Gauge is on, a relay will open to turn off the filament and protect the Ion Gauge. After a brief delay, (~8 seconds) the Vent Valve is opened and vent gas is allowed to flow into the chamber. By setting a VENT LIMIT to a pressure (in Torr) and selecting Enable the vent valve will automatically close upon reaching the final pressure. Be sure the VENT LIMIT value is less than atmosphere, as the vent gas will continue to be expelled because the chamber pressure will never rise much above atmosphere. If the VENT LIMIT is not enable the operator must select the VENT ON/OFF button again to stop the flow of the vent gas.

### REGEN Mode

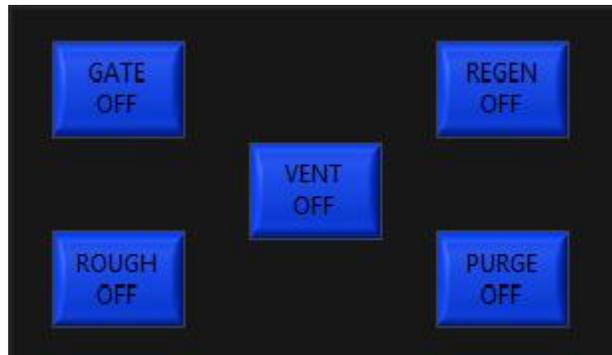
The REGEN Mode panel is used to automatically regenerate the cryo vacuum. Pressing the AUTO REGEN button will start the regeneration sequence. The sequence may be stopped by pressing the CANCEL AUTO REGEN button. Values can be entered for the PURGE time, ROR TEST PRESSURE, and ROR MAX RISE. As steps in the sequence are completed Indicators on the panel will change from Dark Green to Bright Green.



### MANUAL Mode

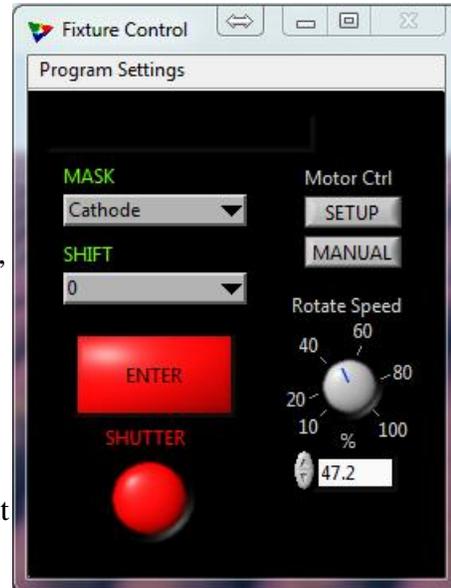
Great care should be taken while in MANUAL Mode. Opening a valve at an inappropriate time can cause the cryo-pump to lose containment, which will then necessitate the regeneration of the cyro. This process can take several hours.

- GATE ON/OFF – Opens and closes the Gate Valve.
- REGEN ON/OFF – Opens and closes the Regen Valve for the cryo-pump.
- VENT ON/OFF – Opens and closes the Vent Valve.
- ROUGH ON/OFF – Opens and closes the Roughing Valve.
- PURGE ON/OFF – Opens and closes the Purge Valve for the cryo-pump.
- MECH PUMP ON/OFF – Turns on or off the Roughing Pump.



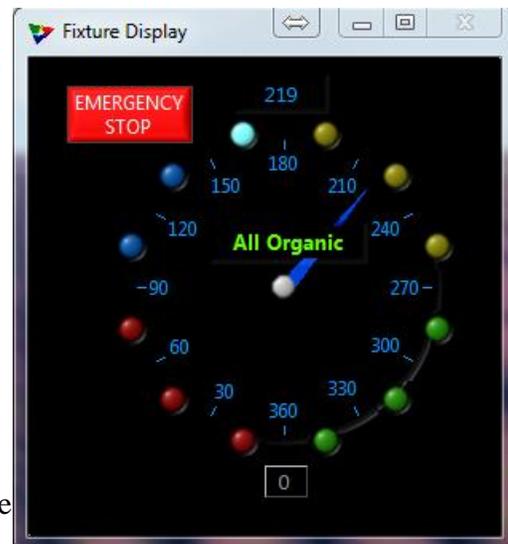
## Fixture Control

Fixture Control is used to control mask changing, substrate shutter, and the rotation of the fixture. The MASK selection control is used to select the desired mask that will be used. The selections include Cathode, All Organic, and the variant selection such as Organic 1, Organic 2, etc. The Cathode and All Organic mask expose all of the substrates to the deposition process. The variant mask, such as Organic 1 will only expose substrate 1 to the deposition process. There is a variant selection for each of the substrates in the fixture. The SHIFT selection control is set the final resting position in the chamber in degrees, with 0 degrees being the front of the chamber by the door. There is a User selection that allows the operator to set a desired position in a number entry control that will appear just above the SHIFT selection box when User is selected. There is a Rotate selection for rotating the fixture during process. The Rotate Speed knob sets the motor speed 0% through 100%. The Shift cycle is started by pressing the ENTER button at which time the button will turn green. All SHIFT selections except Rotate will stop automatically when the shift is complete at which time the button will turn red. When Rotate is selected the rotation is started and stop by pressing the ENTER. While the fixture is rotating the button turns green. The shutter is opened and closed with the SHUTTER button. The button is red when the shutter is closed and green when the shutter is open. The SETUP button launches the Motor Control setup dialog box. The MANUAL button launches the Motor Control manual mode dialog box.



## Fixture Display

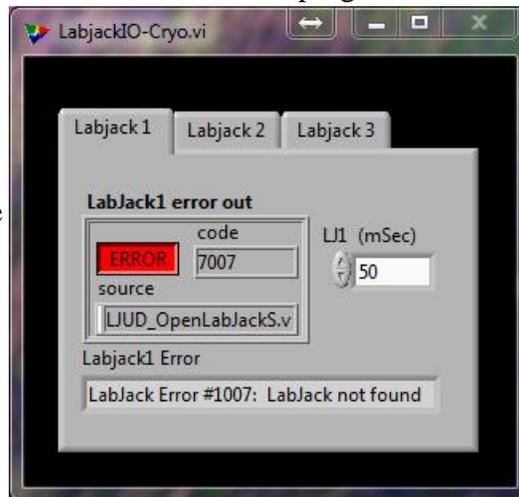
The Fixture Display program provides operator feedback for the various functions of the machine fixturing. The EMERGENCY STOP button immediately stops motor rotation when pressed and the button turns dark red. The button must be pressed again in order for the motor to be operated again. Be aware that if EMERGENCY STOP is pressed in the middle of a SHIFT cycle the fixture control program may lose track of the sequence of shifting and the fixture will have to be reset by the operator which may involve opening the chamber. The LEDs that are arranged in a circle around the rotational control represent the sources and their location in the chamber. The colors for the LEDs are grouped by power supply and the colors may be set using the Power Supply Info dialog discussed later. Moving the mouse/cursor over top of an LED will cause a Tip String to be displayed that will



give the source name and the material, if any, that is assigned to the source. The ordinate numbers arranged in a circle around the circular control represent the command positions that are available using the SHIFT selection box on the Fixture Control program.

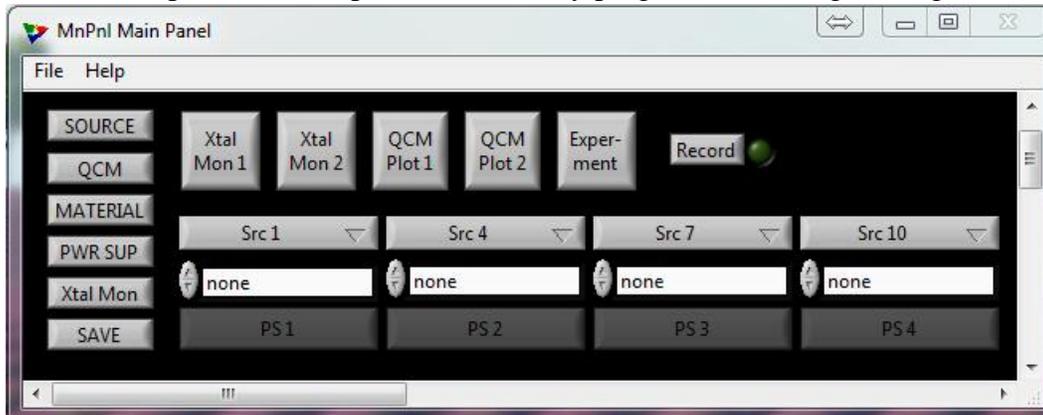
### Labjack I/O Control

The Labjack control program is used to monitor the USB connections with the input/output controllers. The picture to the right shows an error on Labjack 1 indicating that the USB cable is disconnected.



### Trovato Main Panel

The Main Panel is the “launch pad” for other parts of the application. It is also the access point for the system configuration database. The medium-sized rectangular buttons on the left of the window launch the database dialogs. The large square buttons launch the crystal monitor, plotter, and experiment directory programs. The long rectangular buttons



along the bottom of the window select sources with the current materials and launch the power supply control program. The Record button controls logging for the whole system. There are several programs that record data for the system: Cryo Control, Power Supply Control, Crystal Monitor, Fixture Control, Experiment Control, and the Annotator. The Annotator is note taking program that will be discussed later.

### Database Dialog Boxes

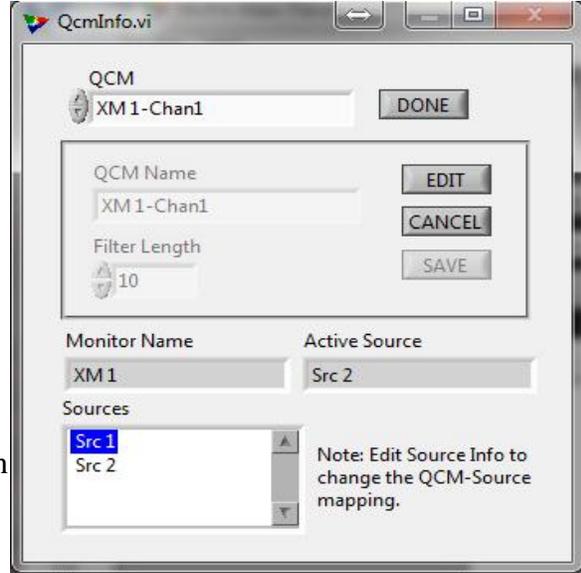
There are some general guidelines that apply to the database dialog boxes. When first opened, the database item is in read-only mode. This allows for a quick and simple view of the data being displayed. To make changes to the data the EDIT button must be pressed to activate Edit mode. When editing is complete, pressing the SAVE button will

save the changed data to the database. Press the CANCEL button to discard the changes and restore the original data. Pressing either the SAVE or CANCEL buttons transitions the dialog back to read-only mode. Pressing the DONE button closes the dialog box.

### QCM Info

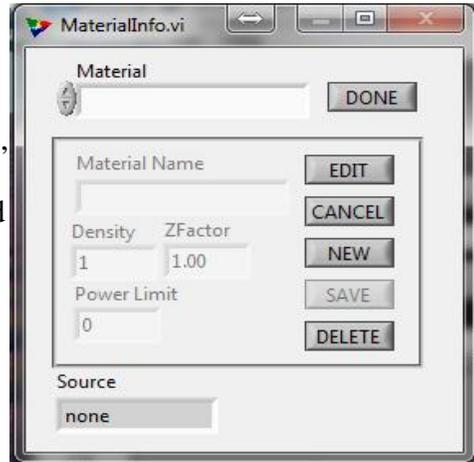
The Quartz Crystal Micro-balance (QCM) dialog is used to build a description of the relationship between the crystal, the crystal reader, the material, and the source heater. The following functions can be accomplished in Edit mode:

1. The QCM Name can be set. There is no limit to the length of the name, but a practical display limit is approximately 24 characters.
2. The Filter Length is the number of samples that are averaged together in a moving average to generate a stable rate value for use with the power supply controller. The Filter Length can also be changed from the Power Supply Controller. The sample time/rate is set on the Crystal Monitor controller window. The sample time/rate multiplied by the length gives the actual filter time constant. For example, if the crystal monitor is updating every 1000 mSec and the Filter Length is 10, the filter constant is 10,000 mSec or 10 seconds.



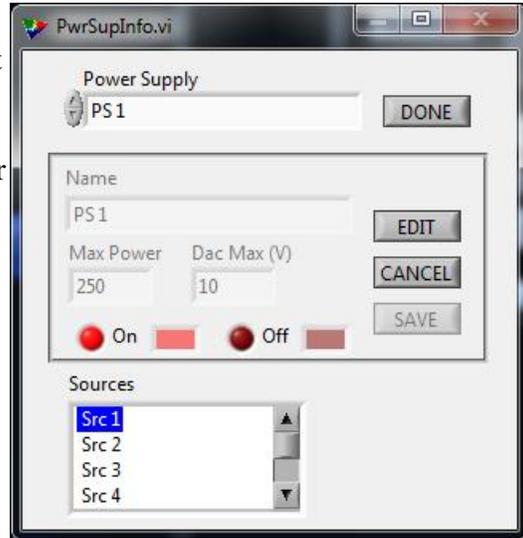
### Material Info

The Material Info dialog is used to set the parameters for calculating the material thickness during deposition. In Edit mode, the Material Name, Density, ZFactor, and Power Limit can be set. The Power Limit is the Max Current in Amps that should be used by the Power Supply Controller for this material. This value can be overridden at process time in the power supply control program.



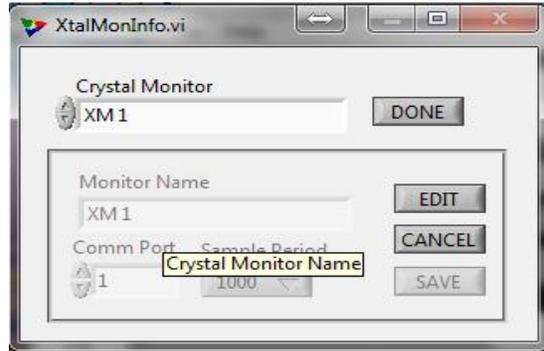
### PwrSupInfo (Power Supply Info)

This dialog is used to set the parameters for a particular Power Supply. This information is set at the factory. Several indicators in the system are color coded. Those include: the source LEDs on the Fixture Display window, the plotter lines and rate indicators on the QCM Plotter windows, and the name, power indicator, and rate indicator on the Power Supply window. Those color can be customized with this dialog.



### XtalMonInfo (Crystal Monitor Info)

This dialog is used to set the Comm Port and the default Update Rate for the Crystal Monitor. The Comm Port should be left set to the factory default. The Update Rate is the time in milliseconds between samples of the crystal. This can also be changed on the Crystal Monitor control panel.



### Save

This button forces the database files to be written to disk, which is generally done on a periodic basis anyway. This feature just provides the added safety of being sure the data is written to disk.

### Crystal Monitor

The Xtal Mon button launches the Crystal Monitor control panel. This panel controls the Trovato 4-channel crystal monitor and performs the QCM calculations for those channels. The Lifex (where x is 1-4) is a simple lifetime calculation of the percentage of frequency with 6MHz being 100% and 5MHz being 0%. It



is generally recommended that crystals with a life percentage less than 80% be replaced. The green OK1-OK4 LEDs are a quick indicator that a crystal is reading properly. The LED shows green when a crystal is reading properly and red when it is not reading properly. Sample Update selects the time in milliseconds between channel samples. All 4 channels are sampled simultaneously. If the Raw Data is not updating on a regular basis pressing the green ON next to the Sample Update selector will interrupt the sampling and enable the Init button. Pressing the Init button will initialize the communication channel to re-establish communications with the crystal monitor.

## QCM Plotter

The QCM Plotter button launches the Plotter control panel. This panel provides a visual display of the deposition rate of up to 4 QCM channels. The SELECT button allows the operator to select any active QCM or None for any of the channels. The displayed rate

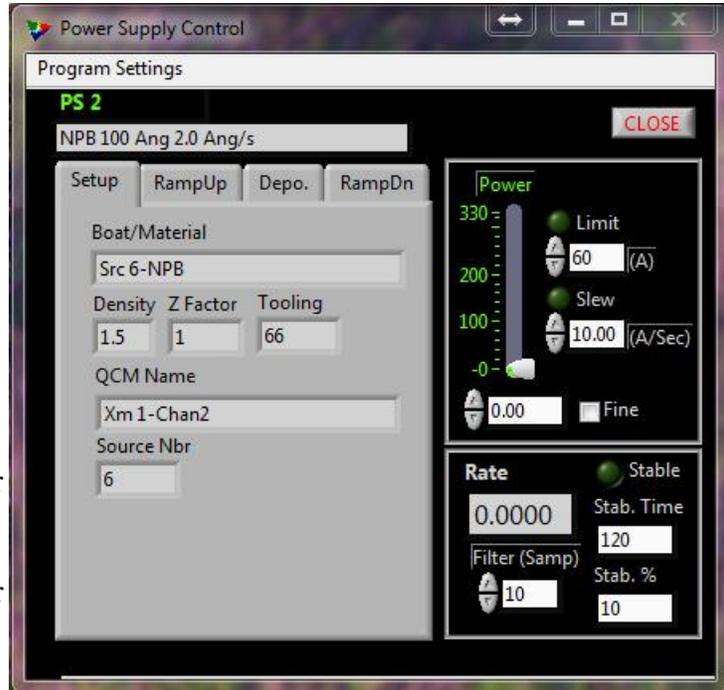


can either be RAW or FILTERED data. The display can be scaled using the menu select box located above the chart. Named settings can be created using the Program menu selections: Load, Save, Save As, Delete, and Rename. Load will read in the parameters that were saved previously. Save will save the new values to the current setting name. Save As will create a new setting with the name selected by the user. Delete will delete the settings from the list. Rename allows the user to change the name of a saved setting.

## PS 1 and PS 2

The PS 1 and PS 2 buttons launch the control panels for Power Supply 1 and Power Supply 2 respectively. The following description will use PS 1, but the operation of PS 2 will be the same. The source, and thus the material that will be used for a deposition with a power supply, is selected on the Main Panel. If your system is equipped with a High Current Switch (HCS), launching the power supply window activates the appropriate HCS for the selected source. The desired settings can be selected from the main panel. The desired settings may also be selected from the Program Settings menu. As with the QCM Plotter, the Program Settings menu has the following selections: Load, Save, Save As, Delete, and Rename.

The right-hand portion of the Power Supply Control panel contains controls that are used through-out the evaporation process. The Power control bar is used to monitor and control the electrical current (in Amps) that is being directed to the source. The Power level is shown as a green bar. Under certain conditions, a red bar will indicate that requested current has exceeded the Material Power Limit and/or Slew limit. The LED above the Limit control indicates that the Material Power Limit is being exceeded when bright red. The LED above the Slew control indicates that the



Slew rate limit is being exceeded when bright red. The Slew limit controls how quickly the power is allowed to change in A/Sec (amps per second). Slew control can be very important while under PID control to prevent wild swings in current due to crystal or material misbehavior. The Increment/Decrement button for the Power control will normally bump the Power Up/Down by 0.1 amps. Selecting the Fine check-box changes that increment to 0.05 amps. The Rate indicator shows the FILTERED deposition rate. The Filter (Samp) control overrides the Filter Length as originally defined by the QCM database dialog. There is a Stable LED that indicates that the rate has stabilized as defined by the Stab. Time and Stab % controls. Stab. Time defines the amount of time that the rate remains in a band of plus or minus Stab. % of the programmed Target Rate. The left hand side of the screen contains a tab control with tabs that corresponds with the various phases of the deposition process. Those phases being material Setup, power Ramp Up (pre-conditioning), Deposition, and power Ramp Down (post-conditioning).

### Setup

The above diagram highlights the Setup tab which is an information screen that shows the selections that have been made for the deposition process. It shows source, material, and QCM information that is being used in the process.

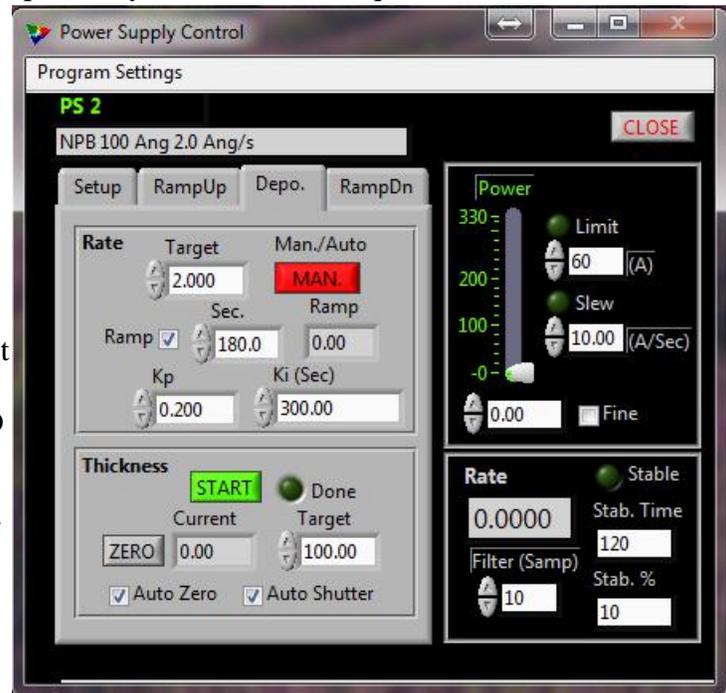
## Ramp Up

The Ramp Up tab is used as an automated ramp-soak sequence to slowly bring a boat up to evaporation temperature. One ramp stage is default, with two Soak and another Ramp cycle being optional. The first ramp starts at the current Power level and then incrementally ramps to the Power 1 setting in the amount of time indicated in the Seconds control. The Done LEDs next to the Seconds controls show bright green to indicate that a particular phase is complete. A check in the Soak 1 check-box indicates that Soak cycle is to commence at the conclusion of the first ramp.

A Soak cycle merely holds the Power at a given level for the number of Soak 1 Seconds indicated. A check in the Ramp 2 check-box indicates that a second ramp cycle will commence upon completion of Soak 1 if selected or Ramp 1 if Soak 1 is not selected. Ramp 2 will increase/decrease power from Power 1 to Power 2 over the time indicated in the Ramp 2 Seconds control. A check in the Soak 2 check-box indicates that Soak 2 will commence when the previous active cycle is completed. Pressing the Start button begins the programmed sequence of ramp/soak cycles. Once the sequence is started it can be stopped at any time by the red STOP button.

## Depo.

The Depo. (Deposition) tab is used for automatic control of rate and deposition thickness. This tab is organized into two sections: one for Rate and the other for Thickness. The Target control located in the Rate section is the target rate for PID control. The Man./Auto button switches between MAN. (Manual) and AUTO control of the Power. The output of the power supply is under PID (Proportional, Integral, and Differential) control when



AUTO is selected. The Ramp check-box indicates the selection of a Rate Ramp during which the Rate commanded for the PID loop will be ramped from the current Rate to the Target rate for the time indicated in the Sec. (seconds) Control. The Ramp control displays the Rate being commanded to the PID loop while the Rate Ramp is in progress.  $K_p$  is the gain for the proportional component of the PID loop.  $K_p$  can be considered as the band of Angstroms per second which is dominated by proportional gain.  $K_i$  is the gain for the integral component of the PID loop.  $K_i$  can be considered the time in seconds over which the rate is adjusted for long term error. A  $K_i$  value of zero would normally cause a divide by zero error, but in our case we have used this value to indicate that  $K_i$  is not to be used and the control loop will be purely proportional. Trovato Mfg. Inc. has chosen not to implement the differential portion of the PID control.

In the Thickness section of the tab, the Zero button is used to set the Current thickness to zero. The Auto Zero check-box indicates that the Thickness will set to zero when the START button is pressed. The button then changes to a red STOP button. The Auto Shutter check-box indicates that the substrate Shutter will Open when the START button is pressed. If the operator has not pressed the STOP button when the Current thickness reaches the Target thickness then: the Done LED will show bright green, the STOP button will be automatically actuated, and the substrate Shutter will close, if the Auto Shutter check-box is selected. The operator may override the position shutter at any time by pressing the SUBSTRATE SHUTTER button on the Fixture Control window.

### RampDn

The Ramp Down tab ramps the power down from the current level to zero power during the time listed in the Seconds control.



## **Trovato System Mapping**

The process control portion of the Trovato Evaporator system is designed to be material-centric. The pieces that work together to provide process control are the Material information, the QCM feedback from inside the chamber, and the evaporation hardware consisting of power supply, high current switch, and source. The material is mapped to a source using the source information dialog. The power settings can be thought of as material characterizations. These parameters will vary according to materials, with sometimes drastically different parameters for metals versus organic materials.

Best Practices for System Configuration may include the following:

1. Define the materials that will be used in all phases of the deposition process.
2. Decide the material locations in the chamber, i.e. in which source in the chamber will the material reside. This will help in defining the electrical switch and power supply mapping that must take place during setup for the process.
3. Define the mapping for the QCMs to the sources in the chamber. This is mostly a physical process of positioning the crystal heads so that they have an unobstructed “view” of the desired sources, while also avoiding any “view” of undesired sources. Then define which crystal a source will use for feedback on the Source Info dialog. (This is often done at the factory, but can be modified by the customer.)
4. Start the Crystal Monitor program and verify that the connected channels are reading appropriately.
5. On the Main Panel select the material to be used for deposition and the Settings (or characterization) and start the Power Supply program. The selected QCM, high current switch, and material info will be displayed on the Setup Tab.
6. Select the active QCM channel(s) for the QCM Plotter. The plotter is a very important tool for the researcher to understand how the materials are reacting to the current being supplied by the power supply. An individual channel may be viewed alone for clarity, or multiple channels may be monitored to understand any interactions that may occur between materials in adjacent boats or to monitor materials being deposited on another. When there is cross-talk or material being deposited on another crystal this can lead to degradation or loss of accuracy of that crystal. Again, proper naming of settings are encouraged.