Operation and Maintenance Manual

AERES®
Integrated Software

ANGSTROM®
ENGINEERING
Your Thin Film Partner

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Hazards and Safety

Safety of operators is a top priority for Angstrom Engineering®. Users should be aware of common hazards and safety considerations when operating their Angstrom Engineering® thin-film deposition system. This section details the most common hazards as well as common safety measures that are integrated into every Angstrom system.

High Voltage

High Voltage warning label used on Angstrom Engineering® systems

Potentially fatal high voltages (208 or 380 volts depending on region) can be accessed inside the electrical cabinet. As a result, warning labels are affixed to the cabinet access panel. Main power must be disconnected before accessing the electrical cabinet. Please consult Angstrom Engineering® before performing any maintenance or troubleshooting inside the electrical cabinet.

Electron Beam Power Supply

If the system is equipped with an electron beam evaporation system, its power supply can produce up to 10 kV DC. This voltage level is potentially fatal.

NOTE: If the system is equipped with an electron beam evaporation system, please consult its manual, included in electronic format, in addition to this manual for important operator safety information. All operators must review the safety information in this document before attempting to operate the system. The power supply must be grounded appropriately to ensure the safe operation of the system. Please consult with Angstrom Engineering® before altering or servicing any ground connections.

The high voltage power supply is mounted in the system frame and warning labels have been applied to the cabinet exterior panels to warn of the presence of potentially lethal voltages. If any work is required inside the cabinet, it is necessary that the main system input power disconnect be open. Please consult Angstrom Engineering® before performing any electrical work within the cabinet.

Various interlocks have been implemented to ensure operator safety. The high voltage power supply input power is interrupted when the chamber door is opened. A number of water and vacuum interlocks must also be closed in order for the power supply output to be enabled.

Tampering with, overriding, or otherwise altering any interlock or safety device voids all warranties, and endangers both the health and safety of the system operators.

High Temperature

High Temperature warning label used on Angstrom Engineering® systems

Thin film deposition can be performed at temperatures in excess of 1600°C. As a result, the sources and substrate holders may remain hot long after venting. Users must use extreme caution and allow sufficient cooling time before handling the sources or the substrate holders post-deposition.

Interlocks

Magnetic interlocks found on chamber doors

The deposition chamber is protected from damage by a safety interlock on the chamber door. The interlocks on the chamber door are magnetic (non-contact) read heads that sense a coded magnetic actuator. The interlocks are connected to a safety relay designed to drop all power to devices in the chamber when the door opened. Tampering with these chamber door interlocks is forbidden.

Pinch Points

Air cylinders, motors, and moving parts used by the system are located at the top of the deposition chamber. These are mechanical hazards ranging in severity from pinch points; crush points; and high-torque, rotating parts. Stay clear of these devices and components during operation.

Material Safety

All materials intended to be used in the system must have their Safety Data Sheet (SDS) available to system operators. Some materials do not adhere well to the inside surfaces of the chamber and may form a fine dust when the chamber door is opened. If this is the case, additional safety measures to those needed for the bulk materials may be required. For example, respiratory safety measures, personal protective equipment, protection from ignition sources, or other hazard-reduction measures may be necessary.

Maintenance Mode

NOTE: Maintenance mode is only available on certain system configurations.

Maintenance mode allows service personnel to override safety interlocks (e.g. door safety switches or proximity switches) and maintain the supply of pneumatic air and electrical power to system components, including those used to maintain vacuum pressures in the system. This creates potential hazards.

Maintenance personnel should use extreme caution when performing maintenance or troubleshooting while in maintenance mode. It is recommended to turn off electrical power and interrupt the supply of pneumatic air when performing maintenance inside the chamber.

Maintenance mode is activated by means of a keyed switch. It is recommended that the key be removed from the switch and stored in a secure location except when maintenance is being performed.

Additionally, the opening of a vacuum chamber door will normally trigger the automatic closing of the chamber vent valve during a vent process. However, with maintenance mode active, the door interlock will be bypassed. Therefore, if the vent timer is set too high, or if the vent valve is opened by the user on the System Overrides page, the venting gas could flow continuously into the environment outside of the chamber, creating an asphyxiation hazard. Users must ensure that the vent valve is turned off while the door is open in maintenance mode.

System Basics

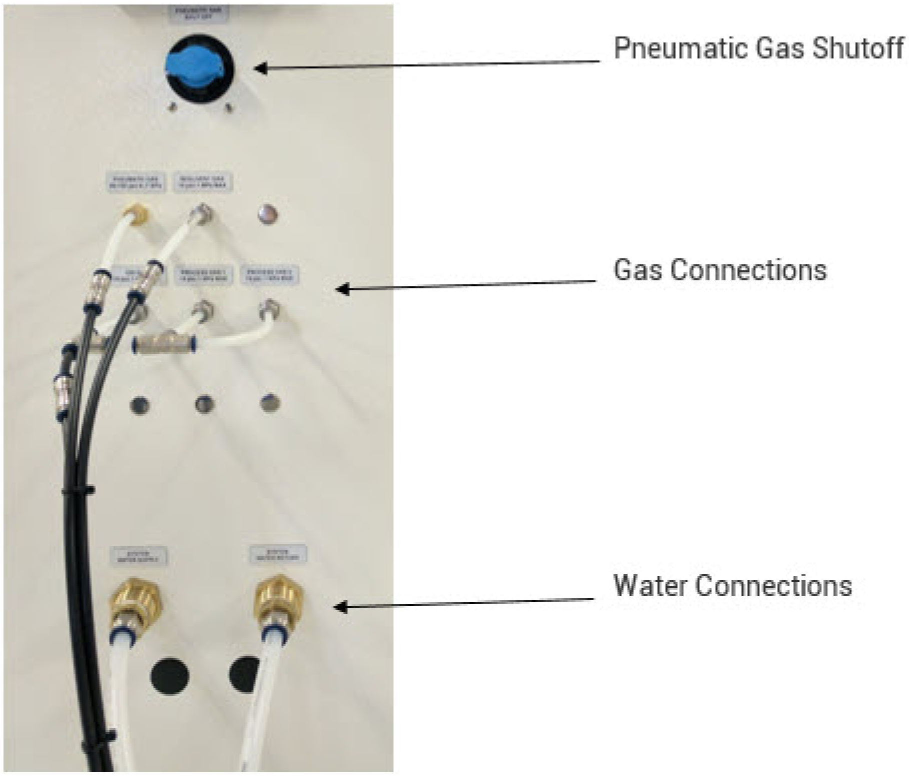
This chapter covers aspects of the physical deposition system, including power and fluid connections, loading sources and QCMs, and starting up the system.

System Utilities Overview

To operate the deposition system, and utilize its full potential, the appropriate utilities (power, water and gasses) need to be connected and must meet the specification outlined in the Installation Requirements document (supplied separately). These connections are made on the system utility panel. Panel configurations and layouts will vary depending on system components.

Fluid Connections

An example of the fluid utility panel is shown below:



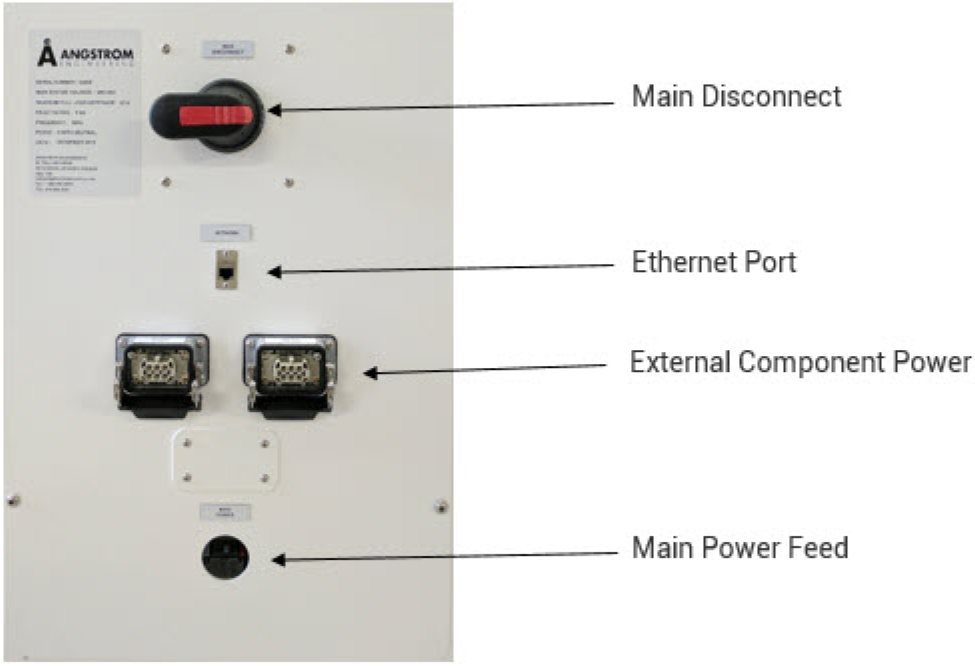
Pneumatic Gas Shutoff - Central shutoff for pneumatic gas (compressed air). Releases all pneumatic pressure when in the off position.

Gas Connections - Connections for pneumatic gas, vent/purge gas and process gasses.

Water Connections - Connections for system cooling water. Can include secondary connections to external components (e.g. compressor).

Power Connections

An example of the electrical utility panel is shown below:



Main Disconnect - Main power switch for the system.

Ethernet Port - Connection to local network and internet (required for remote support).

External Component Power - Outlets to supply power to external components (rough pumps, compressors, chillers, etc.).

Main Power Feed - Inlet for facilities main power cable into system frame.

System Start-Up and Shut-Down

To start-up the deposition system:

1. Turn the main disconnect switch to ON and reset the emergency stop
2. Turn on the system computer and the monitor (the system control software should start up automatically when the computer is booted)
   - On systems without a rack-mounted computer, the computer and monitor will power on automatically when the main disconnect is switched on
3. Login to the software (the software will be in Operator mode by default)
4. If equipped with a cryo pump, a regeneration may be required (supervisor login is required to perform a regeneration)
5. Address and clear any alarms by navigating to the Alarms screen and resetting faults
6. The system is now ready for loading materials, substrates, and running processes

To shut-down the deposition system:

1. Save all current work on the PC
2. Shut down the PC
3. Turn the main disconnect switch to OFF

Replacing QCM Sensors

The QCM sensor crystals deteriorate with use. Once they reach the end of their useful life (typically no lower than 80% remaining to ensure acceptable level of specimen accuracy), the sensors will need to be replaced.

To replace a QCM crystal sensor:

1. Pull the crystal retaining disc from the crystal head
2. Push the old crystal out through the front-side
3. Place a new crystal in the retaining disc with the fully-plated side facing down
4. Gently push down on the crystal so that it is firmly in place
5. Push the retaining disc back into the sensor head until it snaps into place

6. Reset the error on the Sensors Page in Aeres®

7. Verify the frequency reading and remaining life

Loading Sources

Select the relevant source based on your system configuration and follow the steps to load new material in the system.

Resistive Source

1. Loosen the two wing-nut screws on each copper post
2. Slide the copper clamp pieces backwards
3. Place desired boat onto copper posts (in the case of a covered boat, material should be loaded prior to this step)
4. Lift clamping pieces and slide back onto the edge of the boat
5. Tighten wingnut screws such that boat is held firmly in place. Set-screws on the rear of each copper clamp piece should also be adjusted so clamp is level and has good contact with the boat's top surface (e.g. flash evaporator boats)
6. Load material into the boat

Radak® Source

1. Remove outer furnace cover by turning counter-clockwise until loose, then lifting out
2. Remove crucible
3. Add desired material (and liner, if applicable) to crucible up to maximum of:
   - 1 cc for Radak® I
   - 10 cc for Radak® II
4. Place crucible back into furnace
5. Add or remove radiation baffle if needed (baffle in for applications applying T>600°C)
6. Reinstall source cover

Electron Beam Source

1. Navigate to the Load Materials page in Aeres® and select the eBeam source
2. Rotate the hearth to the desired source
3. Insert appropriate liner/crucible for material to be deposited (if applicable)
4. Add the desired material to the crucible/hearth
   - For materials that form a melt, only fill to half or two-thirds capacity
   - For materials that do not form a melt, crucible can be just below full capacity

Sputter Source

1. Remove water-cooled baffle or chimney debris shield (if equipped)
2. Unscrew and remove anode shield
3. Unscrew and remove target clamping ring
4. Place thermal transfer media or apply thermal paste onto cathode
5. Place target onto cathode
6. Screw the target clamping ring back on until tight, taking extra care not to cross thread (risk of damaging copper threads)
7. Screw on anode shield and adjust height such that the gap between the anode shield and target clamp matches the thickness of the spacer tool provided
8. Adjust outer lock-nut such that anode shield is held firmly at this height
9. Remount water-cooled baffle or chimney debris shield (if equipped)

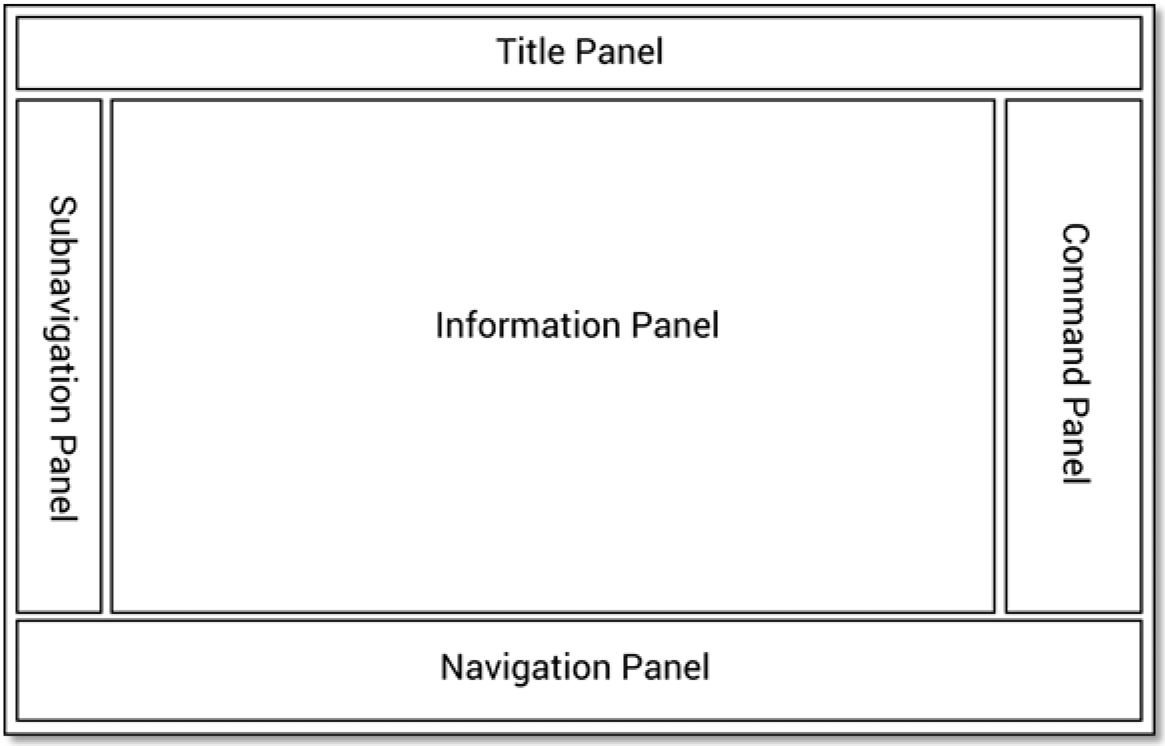
AERES® Overview

Angstrom Engineering® systems are powered by AERES®, a proprietary software system that directly controls all aspects of the deposition process, including the logging of all process data. Through AERES®, the user will be able to control aspects of the system required for operation. This UI is where recipes will be built and run.

NOTE: The description of the user interface in this manual includes machine component renderings and deposition chamber components that may not accurately reflect the tooling and/or functionality of your machine. Descriptions are included for general explanation of the AERES® software functionality. If in doubt, contact Angstrom Engineering Inc.

HMI General Layout

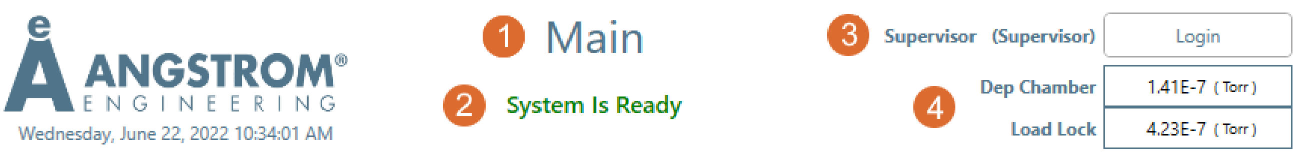
The HMI (human-machine interface) allows you to control the deposition chamber. It is divided into five main panels as illustrated below:



Schematic Layout of the HMI in Aeres®

Title Panel

The title panel is located at the top of the HMI. It is displayed at all times, regardless of the page selected. It is broken into several subcomponents, which are described below.



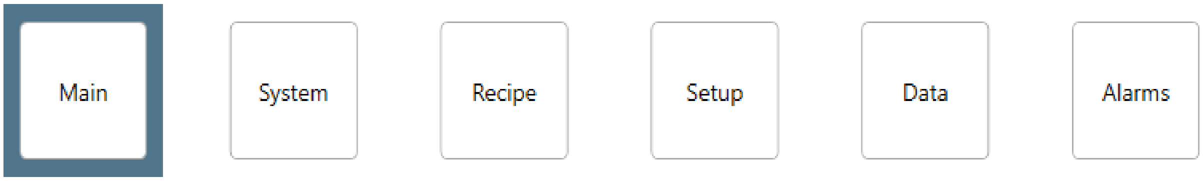
Aeres® Title Panel subcomponents

1. **Current View Name** - Displays the name of the currently selected page.
2. **Message Area** - Serves two purposes:

- Displays the current system status. The system status provides color-coded messages in green (normal), yellow (warning or attention is required), and red (faulted). The system status messages are structured to assist the user in transitioning from system start-up to the running of Recipes.
- Provides a quick method to view and acknowledge fault messages; when a fault message is present, the operator may acknowledge the fault by pressing the "Acknowledge" button found in the message area.

3. **Login** - Allows users tiered level access to certain features on the system. Users can log into their accounts using the "Login" button and entering their user name and password. Account creation and group access levels can be edited on the User Management page.
4. **Pressure** - Displays the current pressure of the chamber(s).
   - **Dep Chamber** - Displays the main chamber pressure of the system, as measured by a vacuum gauge with a span covering the full range of system pressures. If more than one chamber is present, this will be indicated here.
   - **Load Lock** - Displays the pressure of the Load Lock chamber (if installed), as measured by a vacuum gauge with a span covering the full range of the system.
   - **Process Pressure** - If installed, the monitoring of high-precision, high-accuracy measurements for the chamber pressure are displayed here.

AERES® Navigation Panel



AERES® Navigation Panel for Standard Configurations

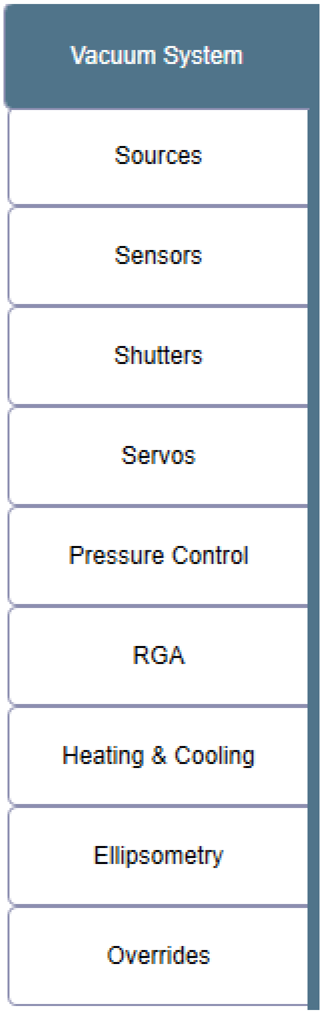
The Navigation Panel is located at the bottom of the HMI and allows the user to select different screens of the deposition system. It is displayed at all times, regardless of the screen selected. Each screen contains one or multiple pages that group together features with similar functionality. The screen currently selected will be highlighted in blue and the screen title will be displayed in the Title Panel. If a system warning exists, the Alarms navigation button will be highlighted in yellow. Alternatively, if a system fault exists, the Alarms button will be highlighted in red until it is resolved.

Standard Navigation Page Options:

1. **Main** - Used to load and run process recipes and to select the materials that have been manually loaded into the deposition sources by the operator.
2. **System** - Provides access to automated and/or manual controls for:
   - Vacuum System
   - Sources
   - Sensors
   - Shutters
   - Servo
   - Pressure Control
   - Heating & Cooling
   - Overrides
3. **Recipe** - Used to build, edit, and save deposition recipes.
4. **Setup** - Allows the viewing and editing of:
   - Setpoints
   - Materials
   - Gases
   - User Management
   - Tooling Factor
   - Rate Control
   - Pressure Control
5. **Data** - Allows user to record data in real time or load and review previously recorded data.
6. **Alarms** - Displays all active alarms and system history. Navigate to this page once active alarms are resolved, and click the acknowledge button to clear them.

Sub-Navigation Panel

The Sub-Navigation Panel is located on the left side of the HMI. It contains all the sub-pages available in the currently selected page. The current selection is highlighted in blue. An example from the System page is shown below.



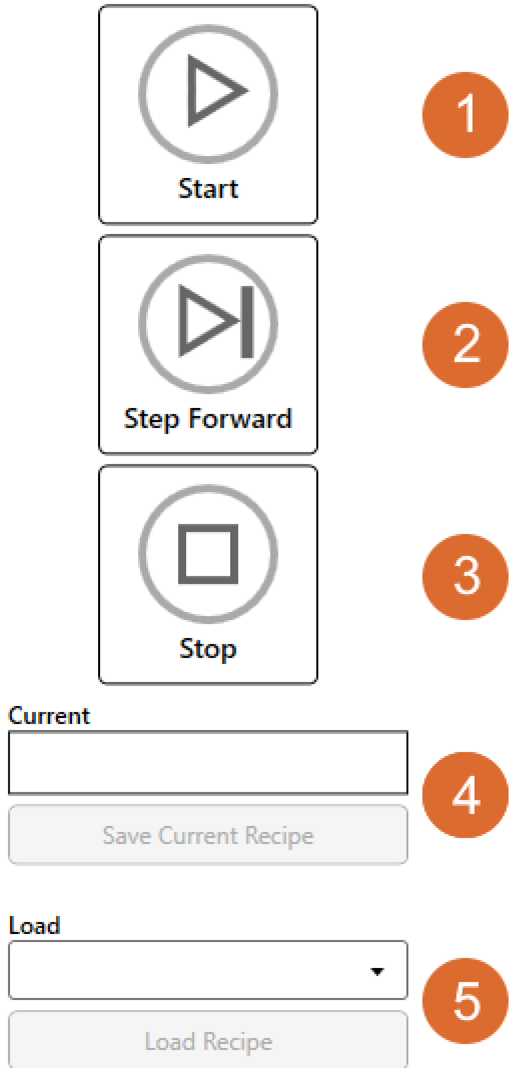
Sub-Navigation panel from the System Page.

Main Screen

In AERES® configurations, the Main Screen is divided into two sub-pages: the Load Materials Page, and the Process Page. These pages allow the user to register the deposition materials present in the system with AERES®, and to monitor and control deposition recipes.

Command Panel

The Command Panel shown is always shown on the Main screen, and has the following elements:



Aeres® Command Panel

1. **Start Button** - Starts the currently loaded recipe.

2. **Step Forward Button** - Moves a running recipe into its next step. This is only enabled when a source is in manual control mode.

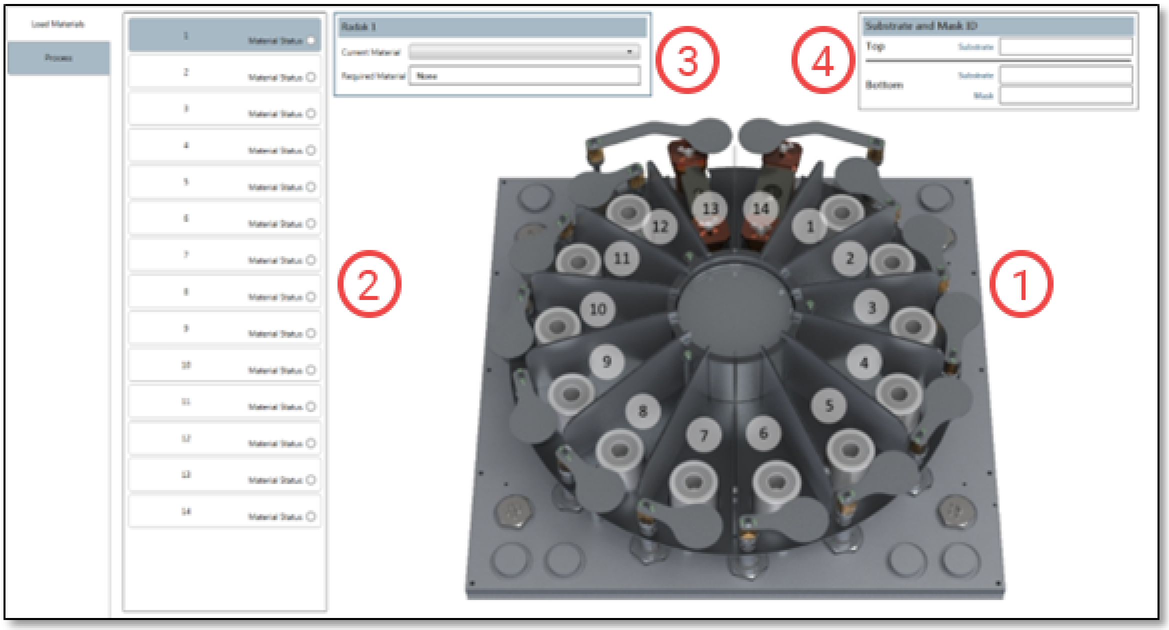
3. **Stop** - Stops (aborts) the recipe that is currently running.

4. **Current Recipe Display** - Displays the name of the recipe that is currently loaded into Aeres®. If any parameters in the recipe have been changed by the user since it was loaded, a yellow exclamation symbol will appear here, and the message area will warn that "Recipe parameters have changed since the recipe was loaded". Furthermore, the "Save Current Recipe" button will become active and clicking it will allow the user to save the modified recipe under a different name or overwrite the existing recipe.

5. **Load Recipe Display** - Clicking the dropdown will allow browsing for a recipe file. Once a file is selected, the "Load Recipe" button will become active, and clicking it will load the selected recipe into Aeres®.

Load Materials Page

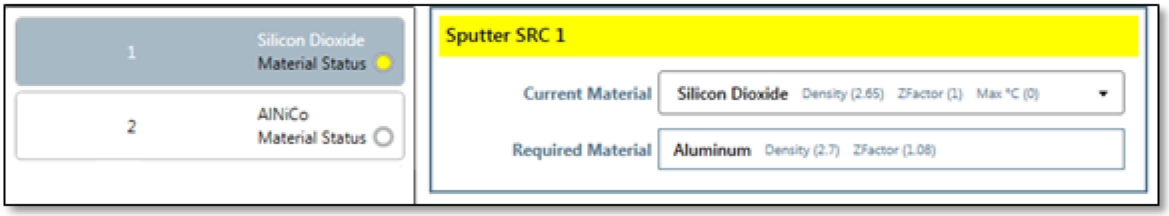
The layout of information panel when the Load Materials page is selected is shown below:



An Example of the Load Materials Page in Aeres®

1. **Source Layout Image** - A rendering of the source layout in the deposition chamber, with each source numbered.

2. **Source List** - A list of all sources in the system. This displays the material loaded into the source, and an indicator for the "Material Status", which shows whether the material in the source and the material required by a loaded process match. The status indicator is green when the materials match, and yellow in case of a mismatch. An example of this, on an Angstrom system equipped with an RF sputter source.

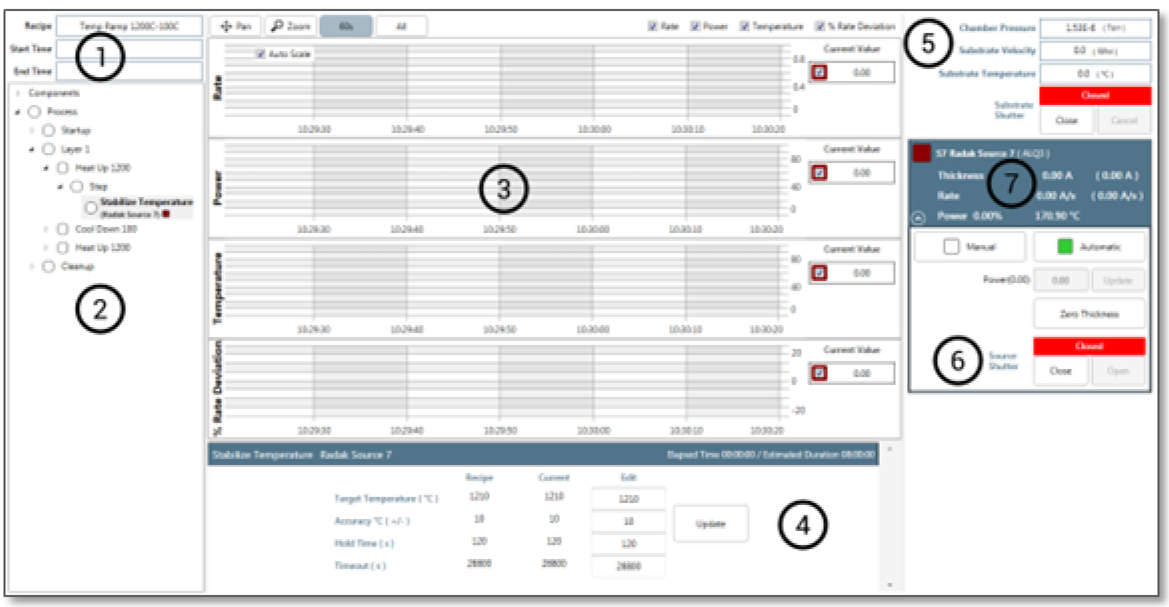


A mismatch between the loaded material and Aeres® recipe requirement

3. **Selected Source Panel** - Allows the user to input into Aeres® (by a drop-down menu) the material that is currently loaded into the selected source. If a recipe is currently loaded into Aeres®, the material required by that recipe is also shown.

Process Page

The Process page allows the user to control all aspects of the deposition process. The layout of the Process page is shown, and a description of each of its elements is given below.



Structure of the Process Page, providing real-time monitoring of the deposition

1. **Process Details** - Displays the current recipe name, its start time and end time, and any substrate ID and mask ID information associated with the process to be run.

2. **Recipe Tree** - Displays the full structure of the recipe, showing all of its components, layers, phases, steps and actions.

3. **Graphs** - Graphs of the deposition rate, output power, source temperature and rate deviation from the setpoint value, all as a function of time. Each graph can be toggled on or off and scaled using the mouse. When multiple series are present on the same graph, the visibility of each series can be toggled on or off.

4. **Action Parameters** - When a recipe action in the recipe tree is selected, its parameters are shown. Certain recipe actions (depending on the system configuration) can be changed while a recipe is running by entering a new value in the "Edit" field and clicking "Update". Of these actions, some can only have their parameters altered prior to their execution in the recipe, while others may altered during the recipe action.

5. **Chamber Info** - Displays information relevant to the deposition chamber, such as the current chamber pressure, the substrate rotational speed, and the substrate temperature.

6. **Substrate Shutter Control** - Displays the current state of the substrate shutter and allows the user to override any currently running recipe to keep the shutter closed.

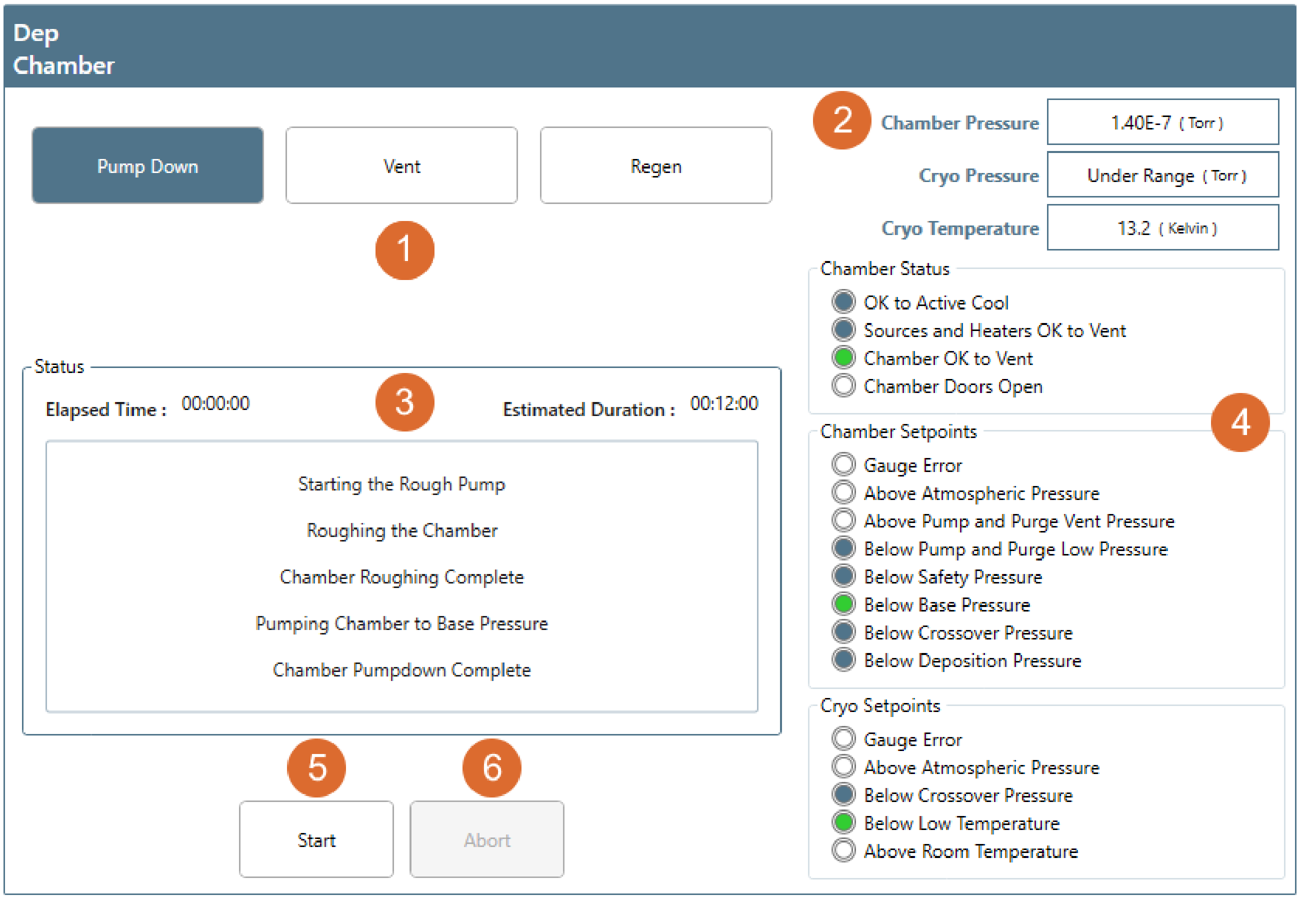
7. **Source Control** - Each source that is used in the current layer of the active process has a panel in this area. Each panel displays the deposition rate, the deposited thickness and the output power for that source. The panel can be expanded to allow the user to toggle between automatic and manual power control modes, to "zero" the deposited thickness measured by the quartz crystal monitor, and to override the source's shutter to "closed" (if installed).

System Screen

The System Screen provides more advanced control over individual system components. Through the sub-navigation panel, different pages can be selected to access controls for subsets of the system's components. The following sections describe the pages typically found in the System Screen.

Vacuum System Page

The Vacuum System page provides the ability to run any predefined vacuum system sequences. These are usually the chamber pump down and vent sequences, as well as cryogenic pump regeneration sequences (if any are installed). The layout of the information panel on the Vacuum System page is shown.



The Vacuum System Page in Aeres® showing automated system routines and system status information

1. **Sequence Selection Buttons** - This area contains a selection button for the available sequences: Pump Down, Vent and "Regen" (for cryogenic pump regeneration, if any are installed on the system).

2. **Gauge Readings** - Displays the values measured by pressure and temperature gauges in the vacuum system. This can include the vacuum chamber pressure, the cryogenic pump temperature and pressure, high-accuracy process pressure measurements, etc.

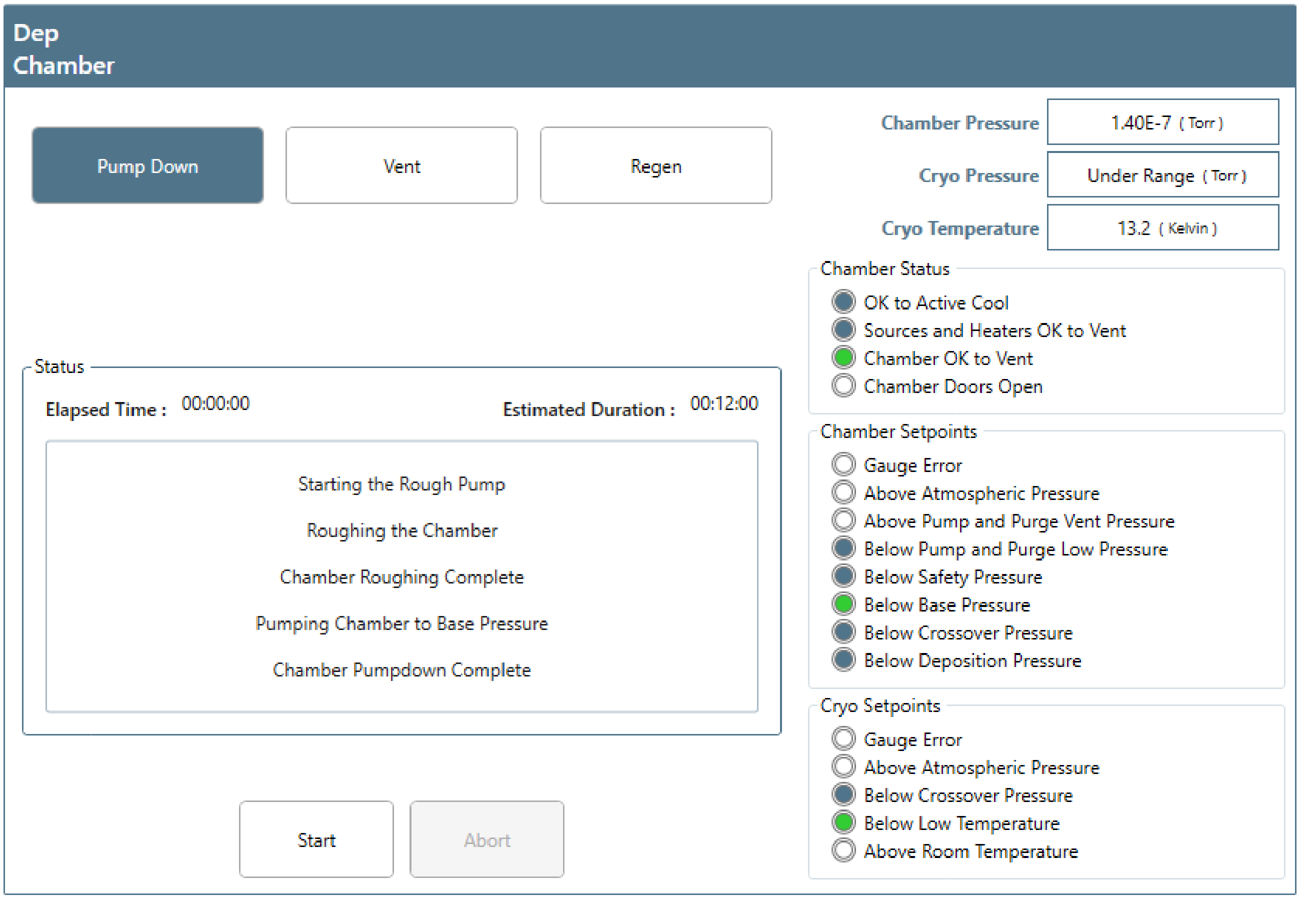
3. **Sequence Status** - This shows a list of the steps in the selected sequence, with the active step highlighted if the sequence is running. It also displays the elapsed time and estimated duration of the sequence and allows the user to toggle certain optional portions of a sequence on/off (such as pump and purge during a vent sequence).

4. **System Status and Interlock Indicators** - This area shows the status of all interlocks related to the operation of the vacuum system sequences, grouped according to the system components to which the status or interlock corresponds.

5. **Start Button** - Clicking this button will start the selected sequence.

6. **Abort** - Aborts any active sequence.

Pump Down



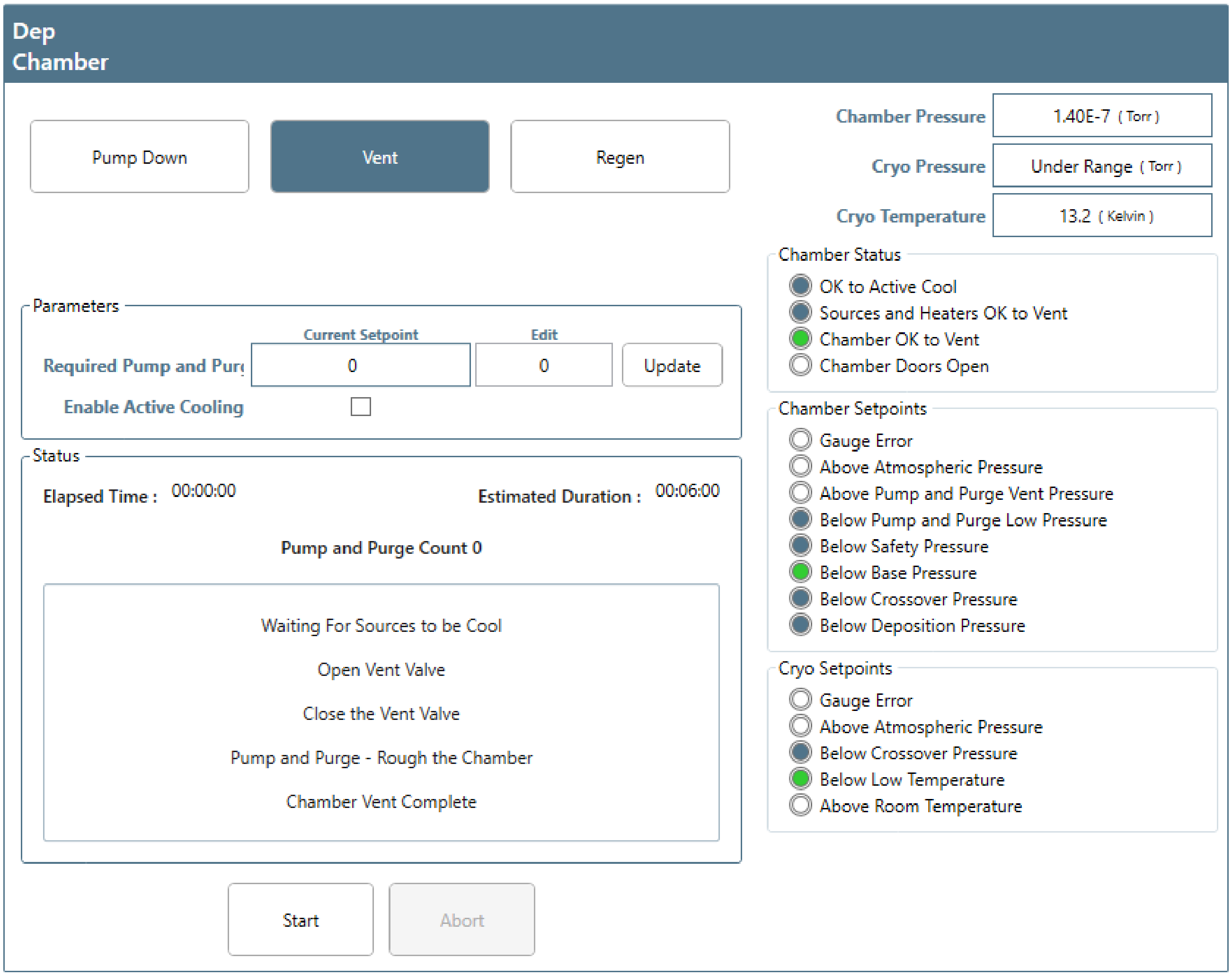
Aeres® automated pump down sequence, the current action will be highlighted in green

When the option is selected, the status box on the page will update to show the steps for the pump down sequence. If all the required interlocks are met, clicking the start button will initiate the sequence and move through the displayed steps. The sequence steps will vary depending on the exact system configuration. The main variation in configuration is the type of high-vacuum pump used (Turbo pump or Cryo pump).

On a system equipped with a cryo pump, the typical pump down sequence will pump the chamber down to the crossover pressure using the rough pump. Once this pressure is achieved, the rough valve is closed and the cryo gate valve is opened. The system then waits for the Base Pressure to be achieved to complete the sequence.

On a system equipped with turbo pump, the sequence will typically start the rough pump and turbo pump simultaneously. The rotational speed of the turbo pump is monitored until it achieves its set speed. After which, the system waits for Base Pressure as with the cryo pump.

Vent



Aeres® automated vent sequence, the current action will be highlighted in green

As with the pump down sequence, the vent sequence steps are displayed in the status box when the sequence is selected. Additionally, there is a Parameters box that provides access to optional features of the sequence such as Pump and Purge and Active Cooling.

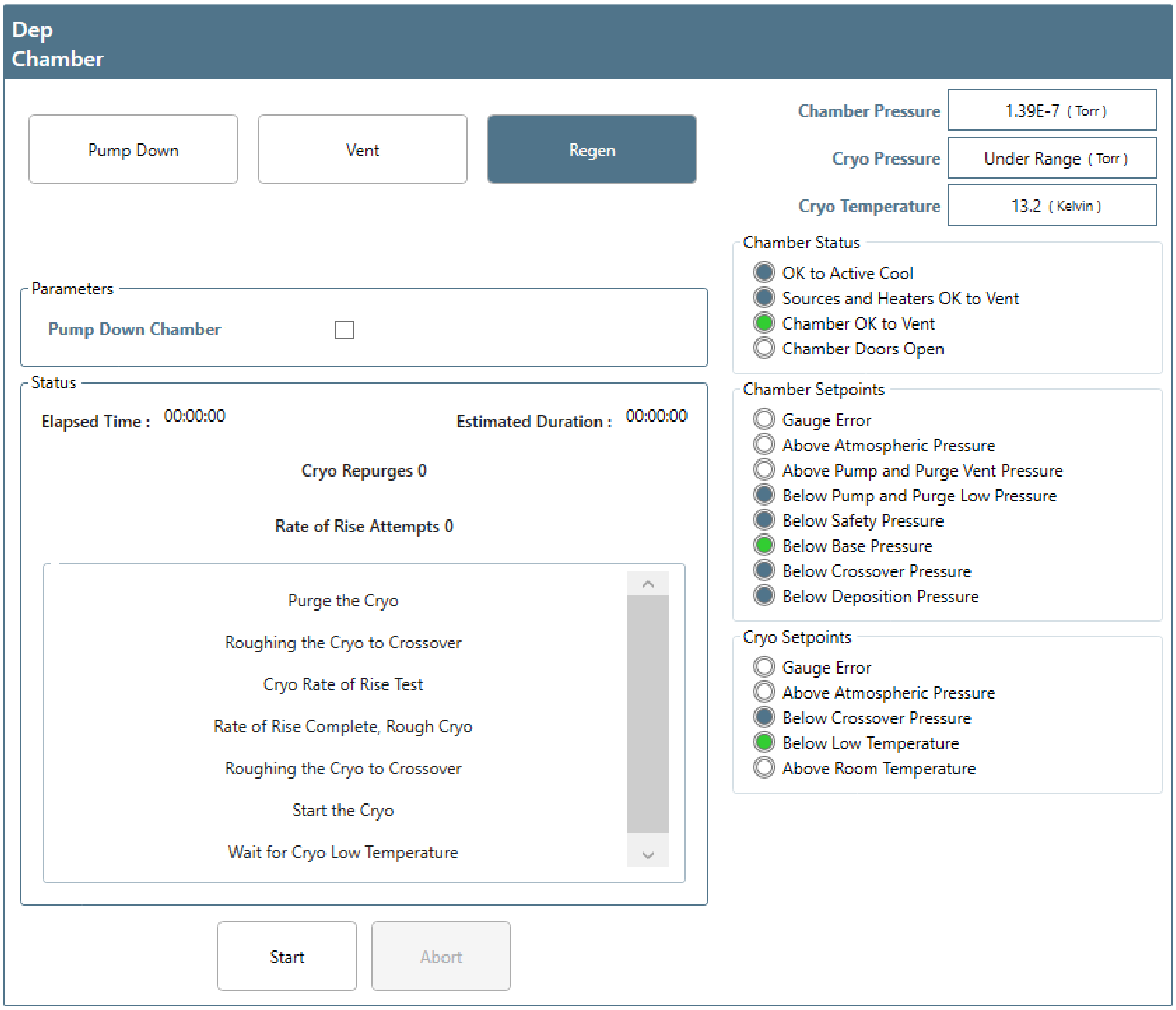
The basic vent sequence will first stop (turbo) or isolate (cryo/turbo) the high-vacuum pump, then open the chamber vent valve for the duration of the Max Chamber Vent Duration or until the chamber door is opened.

If a number greater than 0 is entered in the Pump and Purge Cycles field, the sequence will refill the chamber with vent gas up to the Pump and Purge Vent Pressure setpoint, then pump it down to the Pump and Purge Low Pressure setpoint for the specified number of cycles. On completion, the vent sequence continues as normal. This is typically performed to purge out any potentially harmful gases/vapors that may be in the chamber through the pump before the chamber door is opened.

When Active Cooling is selected, the system behaves in a similar fashion as Pump and Purge but will remain at the Vent Pressure for the duration of the Active Cooling Delay Time Setpoint during each cycle. This is done while monitoring the temperature of any components with thermocouple feedback. The sequence is repeated as many times as necessary such that the chamber is not completely vented until all components are below a safe temperature.

It is recommended to never expose the Radak® source filament to air when above 100°C, the system must allow the sources to cool below that point before completely venting to room pressure. This can take a very long time if left to occur under vacuum. The goal of Active Cooling is to accelerate the cooling of the source, so the chamber can be opened sooner. When enabled, the system will wait until all sources are below 400°C, then vent up to a target high pressure using nitrogen. The system will hold at this pressure for a set time to allow convection to aid in the cooling of the source, then pump down to a low pressure target using the rough pump. The cycle is then repeated using fresh gas until all sources are below 100°C, and the system is then allowed to completely vent to room pressure.

Regen Cryo



Aeres® automated regen sequence, the current action will be highlighted in green

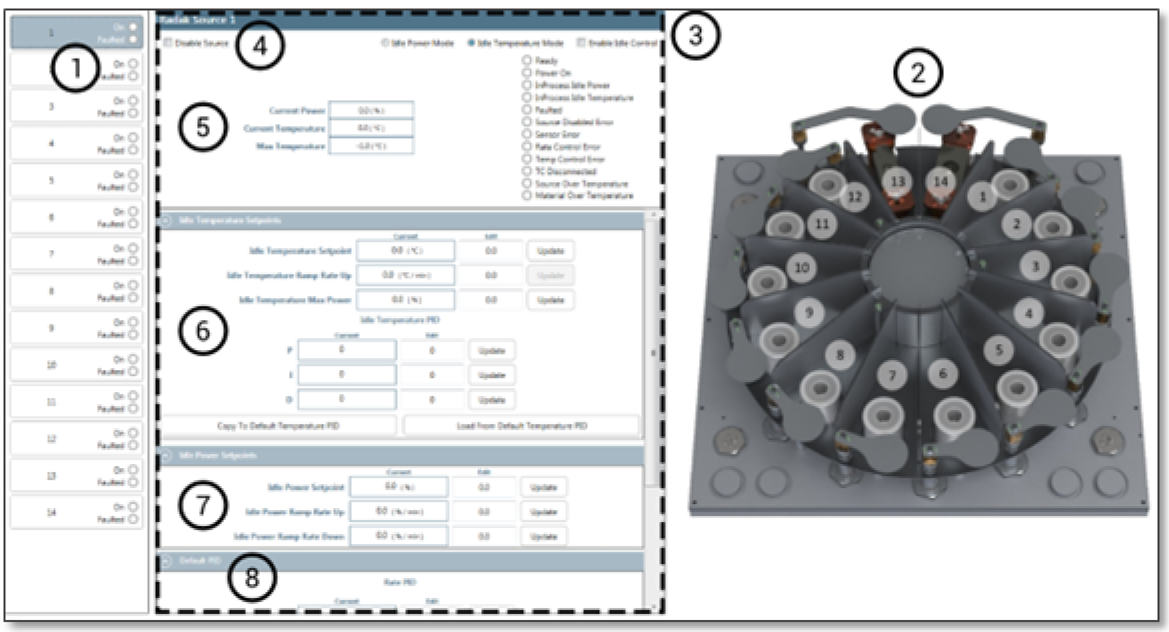
The Regen Cryo sequence is used to regenerate the pumping capacity of the cryo pump and then start the pump. This can be performed if the temperature of the cryo is above the recovery temperature set-point and the cryo pump is off, or when it is believed a cryo regeneration is required. The sequence can be started while the cryo pump is running or when it is off. For most systems regeneration may be required every three to six months. If sputter processes are performed in the chamber then the regeneration interval may be more frequent due to the increased gas load to the cryo pump.

The status box will show the sequence steps as with the previous sequences. Here, the cryo pump is purged with an inert gas (usually nitrogen) until the duration of the Minimum Purge Time setpoint has elapsed, and the pump temperature is above the Cryo Pump Room Temperature setpoint. The system then attempts to pump down to the Cryo Pump Crossover Pressure setpoint. If this setpoint is not achieved, the cryo pump is re-purged briefly, then pumped again. This cycle is repeated until the crossover pressure is achieved. A rate of rise test is then performed on the pump. If the test is not completed under the required criteria (rate of rise < 10 mTorr/min), the pump and purge cycle above is repeated until the rate of rise test produces satisfactory results. Once the test is completed, the cryo is pumped down to the crossover pressure once more, then the pump and helium compressor are both activated to begin cooling the helium. The regen sequence is completed when the temperature of the cryo pump is below the Cryo Pump Low Temperature setpoint.

An additional option available here is to select the Pump Down Chamber when Complete check-box. This will simply start the pump down sequence upon completion of the regen sequence.

Sources Page

This page contains a control panel for each individual deposition source in the system, an example of which is shown. Each panel displays information about the source and allows editing of a variety of source operation parameters.



The Sources System Page in Aeres®, showing a list of all available deposition sources and control information

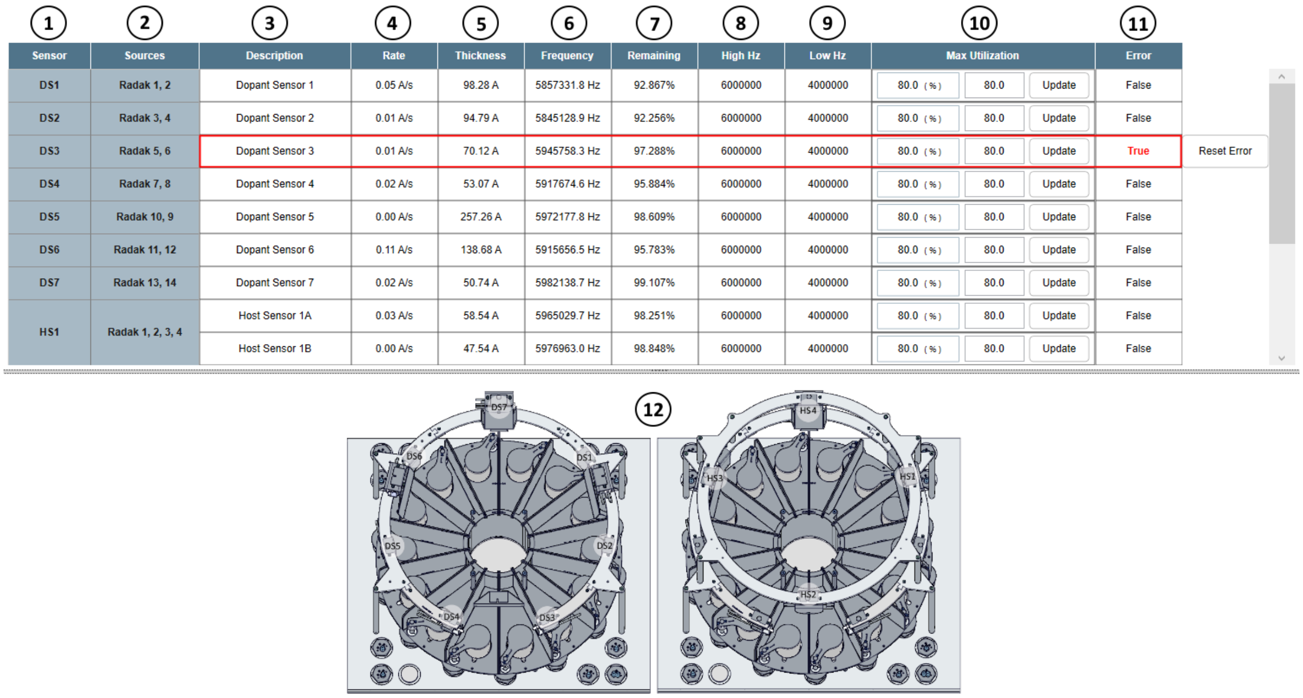
1. **Source List** - A list of all sources in the system.
2. **Source Layout Image** - A rendering of the source layout in the deposition chamber, with each source numbered.
3. **Source Control Panel** - When a source is selected from the source list, the control panel displays information and allows for editing of parameters related to the selected source.
4. **Source Name** - Displays the name of the source.
5. **Source Information Panel** - Displays information relating to the selected source, including the current power applied, the current source temperature, and several source statuses; the source can also be enabled/disabled on this panel.
   - **Disable Source**: When selected power cannot be applied to the source. Faults and errors are ignored when the source is disabled, allowing process recipes that do not use the selected source to be run.
   - **Enable Idle Control**: When selected power will be applied to the source according to either the Idle Temperature Setpoints or Idle Power Setpoints, as chosen by the user.
   - **Source Status Indicators**: Color-coded indicators which feedback the status of the source, including potential faults and errors.
   - **Current Power**: Displayed as a percentage of the maximum power that can be applied to the currently selected source.
   - **Current Temperature**: Displays the temperature of the currently selected source (if applicable).
   - **Max Temperature**: Displays the maximum temperature allowed for the currently selected source. Any source temperature higher than this value will result in a fault and power will no longer be supplied to the source.
6. **Idle Temperature Setpoints** - Parameters relevant to the Idle Temperature Control mode are input and displayed here (for Radak® sources only). Idle Temperature is a user-defined temperature that you can set a source to remain at when not actively being used in a process.
   - **Idle Temperature Setpoint**: The temperature setpoint at which the selected source will be controlled using the Idle Temperature PID controller.

- **Idle Temperature Ramp Rate Up**: The maximum rate at which the temperature of the source will increase in Idle Temperature Mode.
- **Idle Temperature Max Power**: The maximum power (as a percentage of the maximum power that can be applied to the source) that will be applied to the source in Idle Temperature Mode.
- **Idle Temperature PID**: Provides access to the proportional, integral, and derivative control parameters used to maintain the source at the Idle Temperature Setpoint.
- **Copy to Default Temperature PID**: Clicking this button will update the Default Temperature PID values with the current Idle Temperature PID values.
- **Load from Default Temperature PID**: Clicking this button will replace the Idle Temperature PID values listed with those from the Default Temperature PID.

7. **Idle Power Setpoints** - Parameters relevant to the Idle Power Control mode are input and displayed here. Idle Power is a user-defined power level that you can set a source to remain at when not actively being used in a process.
   - **Idle Power Setpoint**: The power setpoint that will be supplied to the selected source.
   - **Idle Power Ramp Rate Up**: The rate at which power will be applied to the selected source when the current power is less than the Idle Power Setpoint.
   - **Idle Power Ramp Rate Down**: The rate at which power will be applied to the selected source when the current power is greater than the Idle Power Setpoint.
8. **Default PID** - Depending on the source selected, there will be one or two sections: Rate PID and Temperature PID (for Radak® sources only).
   - **Max Rate**: The value entered here will limit the maximum deposition rate from this source during recipes (this option may not be available on all systems).
   - **Rate PID**: Displays and allows editing of the default PID control parameters used to control the deposition rate in rate-controlled recipe actions (e.g. Deposit Rate).
   - **Temperature PID**: Displays and allows editing of the default PID control parameters used to control the temperature of Radak® and other sources equipped with temperature sensors.

Sensors Page

The Sensors page, allows the user to view the status of all sensors in the deposition system.



Sensor	Sources	Description	Rate	Thickness	Frequency	Remaining	High Hz	Low Hz	Max Utilization			Error	
DS1	Radak 1, 2	Dopant Sensor 1	0.05 A/s	98.28 A	5857331.8 Hz	92.867%	6000000	4000000	80.0 (%)	80.0	Update	False	
DS2	Radak 3, 4	Dopant Sensor 2	0.01 A/s	94.79 A	5845128.9 Hz	92.256%	6000000	4000000	80.0 (%)	80.0	Update	False	
DS3	Radak 5, 6	Dopant Sensor 3	0.01 A/s	70.12 A	5945758.3 Hz	97.288%	6000000	4000000	80.0 (%)	80.0	Update	True	Reset Error
DS4	Radak 7, 8	Dopant Sensor 4	0.02 A/s	53.07 A	5917674.6 Hz	95.884%	6000000	4000000	80.0 (%)	80.0	Update	False	
DS5	Radak 10, 9	Dopant Sensor 5	0.00 A/s	257.26 A	5972177.8 Hz	98.609%	6000000	4000000	80.0 (%)	80.0	Update	False	
DS6	Radak 11, 12	Dopant Sensor 6	0.11 A/s	138.68 A	5915656.5 Hz	95.783%	6000000	4000000	80.0 (%)	80.0	Update	False	
DS7	Radak 13, 14	Dopant Sensor 7	0.02 A/s	50.74 A	5982138.7 Hz	99.107%	6000000	4000000	80.0 (%)	80.0	Update	False	
HS1	Radak 1, 2, 3, 4	Host Sensor 1A	0.03 A/s	58.54 A	5965029.7 Hz	98.251%	6000000	4000000	80.0 (%)	80.0	Update	False	
		Host Sensor 1B	0.00 A/s	47.54 A	5976963.0 Hz	98.848%	6000000	4000000	80.0 (%)	80.0	Update	False	

An example of the Sensors Page in Aeres®. In the above, three sensors are reporting an error

1. **Sensor** - The functional name of the sensor or sensor grouping.
2. **Sources** - The sensor will capture deposition rates for these sources.
3. **Description** - The description of the sensor.
4. **Rate** - The current rate being measured by the sensor.
5. **Thickness** - Displays the accumulated thickness measured by the sensor since it was last zeroed.
6. **Frequency** - Displays the current oscillation frequency of the quartz crystal.
7. **Remaining** - Displays the crystal lifetime remaining, calculated as the percentage of range defined by the high and low operating frequency.
8. **High Hz** - The upper limit of crystal operating frequency.
9. **Low Hz** - The lower limit of crystal operating frequency.

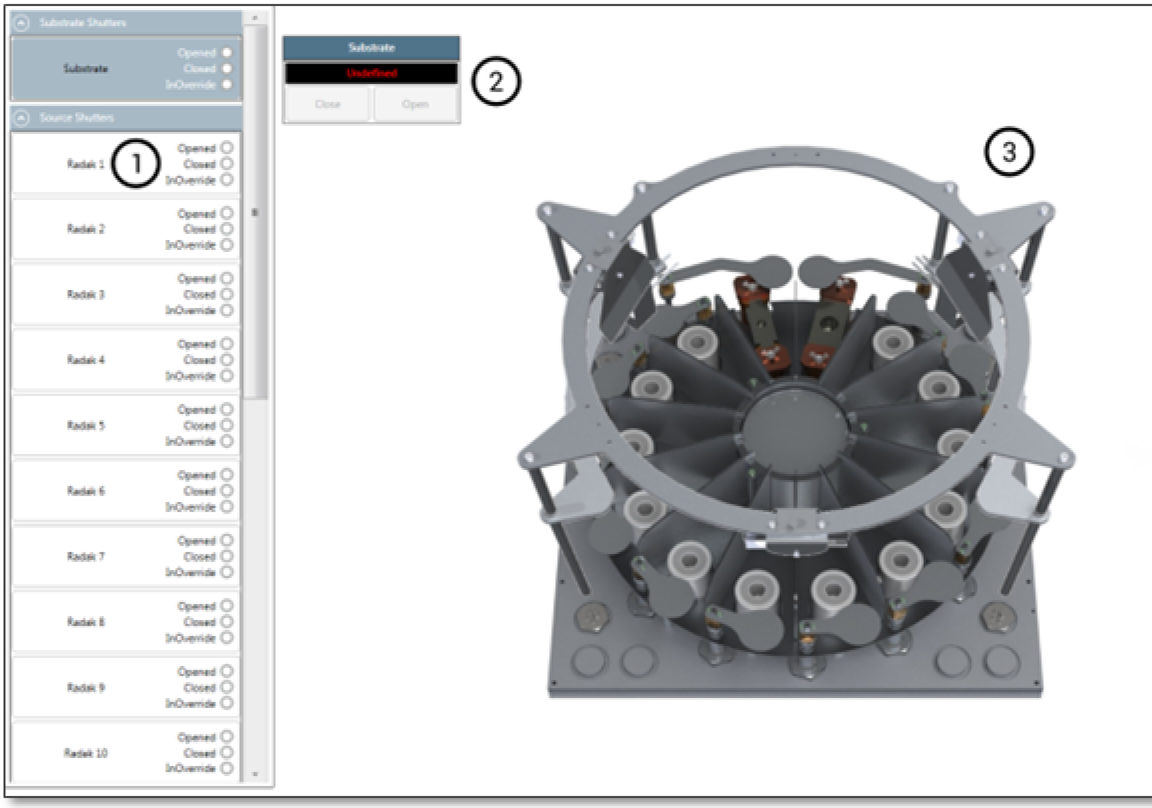
10. **Max utilization** - This is a user-customizable setpoint for the maximum usable crystal lifetime. When the crystal lifetime remaining has decreased by this amount, a warning will be displayed that the crystal has no remaining life. Similarly, a warning will also be given when the crystal nears the end of its maximum utilization. Typically, this value is set to 20% to allow for acceptable levels of measurement accuracy. Some sensor configurations (Dual Sensors and Rotary Sensors) will automatically switch to the next crystal when one runs out of utilization.

11. **Error** - Displays "True" or "False" to indicate if the crystal is faulted. In the event of a fault, a reset button will appear to allow the user to reset the fault after the issue is corrected.

12. **Sensor Layout Image** - A render of the deposition chamber showing and labeling all sensors.

Shutters Page

The Shutters page allows the user to view and manually control the positions of all shutters in the deposition chamber. Note that when running a Process, the user will be unable to manually control shutters from this page. A typical layout is shown below.



The status of all System Shutters under the control of Aeres® are shown in the Shutters Page

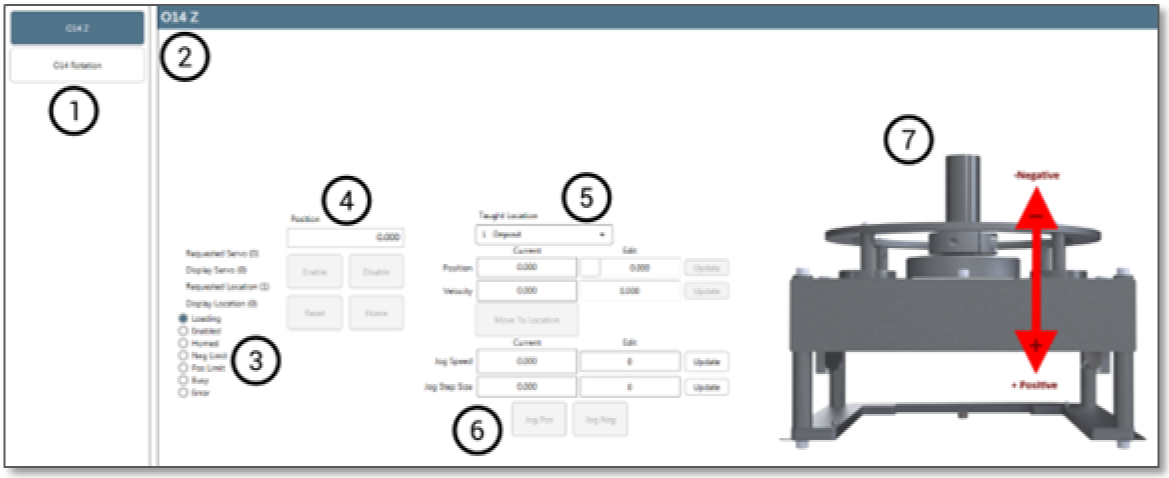
1. **Shutter List** - A list of all shutters in the deposition chamber, grouped by their function (e.g. substrate, source, etc.). Each entry has indicators to show whether the shutter is opened, closed, or "In Override".

2. **Selected Shutter Panel** - When a shutter is selected from the list, it can be toggled to its open or closed state from this panel. If toggled away from its default position, the shutter will be marked as "In Override".

3. **Shutter Layout Image** - A rendered image of the inside of the chamber, showing the position of all shutters.

Servo Page

If servo motors are used to actuate system components, then the Servo page allows the user to view and modify their settings.



Servo Motors are Used in Aeres® to Move System Components Through a Full Range of Motions

1. **Servo List** - A list of all available servo motors in the system that can be manipulated.
2. **Servo Name** - Displays the name of the servo selected from the list.
3. **Status** - A set of predefined indicators for the selected servo, showing its status or position in the system.
4. **Main Control** - Displays the current position of the servo. For users with sufficient privileges, the selected servo motor has the following control buttons active:
    - **Disable** - Clicking this button prevents any control command from being sent to the selected servo.
    - **Enable** - Clicking this button returns the servo motor to its enabled state.
    - **Reset** - Allows the user to reset any error condition present on the selected servo.

- **Home** - Clicking this button commands the servo to run through its full range of motion and mechanically re-establish its starting or "home" position. Caution must be used when homing servos; the user must ensure that the servo's range of motion is not blocked by any external objects, system components that have been put into an override state, or any other set of conditions that would otherwise result in the servo colliding with an object.

  Note: Clicking the home button on some servo drives (such as eBeam indexer and pellet feeders) will set the current position to zero instead of re-establishing the factory "home" position.

5. **Taught Locations** - In this area, the user is presented with controls to choose between the predefined servo locations needed to automate motion in the deposition system and (with sufficient user privileges) is given the ability to modify them.

   - **Taught Location** - Provides a drop-down menu from which the predefined position to be taught can be selected.
   - **Position** - This is the distance, measured in mm or degrees from the home position, that the servo motor will move when an automated routine or the user requests movement to the selected Taught Location.
   - **Velocity** - This allows the user to specify the speed (in mm/s or degrees/s) at which the servo motor will move to the selected Taught Location. Note that it is possible to specify different speeds for movement to each Taught Location.
   - **Move to Location** - Clicking this button will allow the user to move the servo motor to the selected Taught Location. The user must ensure that the servo motor will not collide its attached parts with any objects in the system before clicking this button.

6. **Jog Control** - These controls allow the user to move ("jog") the servo motor to any position within its range of motion. Normally, these controls will only be used by Angstrom Engineering® technicians to set-up automated routines, but access is provided in Aeres® so that experienced users have full control over the components of their deposition system. When using these controls, it is recommended that small step sizes be used to prevent possible crashes with other system components.

   - **Jog Speed** - This specifies the speed (in mm/s or degrees/s) at which the servo motor will move when actuated.

- **Jog Step Size** - This specifies the distance from the home position (in mm or degrees) that the servo will move when actuated.
- **Jog Pos** - Clicking this button will actuate the servo motor in the positive direction by the specified Jog Step Size and at the specified Jog Speed.
- **Jog Neg** - Clicking this button will actuate the servo motor in the negative direction by the specified Jog Step Size and at the specified Jog Speed.

7. **Servo-Controlled System Component** - This shows an annotated rendering of the system component controlled by the selected servo motor, indicating the positive and negative directions of travel.

Heaters Page

This page will be available for systems equipped with heating elements other than those present in deposition sources, such as substrate/stage heaters, annealing heaters or wall bakeout heaters. Like the Sources Page, the user can view and edit the status of the heater(s) in the system. An example of the Heaters Page layout is shown.

The Heaters Page provides the Aeres® user with access to temperature and power controls

1. **Heater List** - If there are multiple heaters installed in the system, they will appear here. Selecting a heater will display its information and settings.

2. **Heater Name** - Displays name of the selected heater.

3. **Heater Information Panel** - Displays information relating to the selected heater.

   - **Disable Heater** - No power can be applied to the selected heater when this is enabled. Faults and errors are ignored by Aeres® when the heater is disabled, allowing process recipes that do not use the selected heater to be run.

   - **Current Power** - Displays the power currently being applied to the selected heater, as a percentage of the maximum power.

- **Current Temperature** - Displays the current temperature of the component that the heater has been designed to heat (for example, the substrate holder). Aeres®' unique calibration system displays the steady-state temperature of the component, based on the system's reference thermocouple. During its automatic temperature calibration routine, Aeres® determines an array of values to accurately control and determine the component's temperature, ensuring that deposition substrates are at the specified temperature.

- **Reference TC** - Displayed when the user has sufficient privileges, this is the actual temperature of the system's reference thermocouple.

- **Calibration TC** - Displayed when the user has sufficient privileges, this is the temperature of the thermocouple used to calibrate the temperature of the heated system component. "Error" will be displayed if the thermocouple is disconnected.

- **Calibrate** - Clicking this button will initiate the automatic temperature calibration routine for the selected heater. Please note that, depending on the system configuration, temperature calibrations can take a number of days of continuous operation. Also note that initiating a calibration on a calibrated system (as indicated by the status indicator) will erase all previously stored values. Should your system need re-calibration, please contact Angstrom Engineering® to ensure your existing calibration is appropriately backed-up.

- **Abort** - Clicking this button will abort the temperature calibration in progress, but all data collected up until this point will be retained. When the calibration routine is restarted (by clicking again on the "Calibrate" button), Aeres® will return to its calibration from the point where the calibration was last stopped. Calibration routines can be stopped and restarted an unlimited number of times, until the calibration is complete. This allows users to calibrate their system over a number of downtime periods (for example, overnight), in the event that an uninterrupted time period is not available.

- **Max Temperature** - This allows the user to specify the maximum Current Temperature value allowed for the heater. Should this temperature be reached at any point during operation, power will cease being applied to the heater, and a system fault will be issued.

- **Idle Power Mode / Idle Temperature Mode** - Specifies whether the selected heater will be maintained in Idle Power Mode or Idle Temperature Mode when Idle Control Mode is enabled (see below).

- **Enable Idle Control** - When enabled, the selected source will be powered in either Idle Power Mode or Idle Temperature Mode, as above.
- **Source Status Indicators** - Provides color-coded indicators of the status of the source, including potential faults and errors.
- **Ready** - The selected heater is ready to be powered.
- **Power On** - Power is currently being applied to the selected heater.
- **Faulted** - A fault is preventing power from being applied to the selected heater. In the event of unknown or persistent faults, please contact Angstrom Engineering®.
- **Fault (Heater Disabled)** - Displayed when the selected heater has been disabled by the user.
- **Warning (High Temperature)** - This indicator illuminates as a warning that the selected heater, or nearby components, are near the maximum temperature allowed.
- **Temp Control Error** - Illuminates to indicate an issue with the PID controller maintaining the temperature setpoint. Please contact Angstrom Engineering® if you encounter this error.
- **TC Disconnected** - Indicates a disconnected or broken thermocouple for the selected heater.
- **Substrate Over Temperature** - Illuminates when the heater temperature has risen above its maximum temperature value, which will return a system fault. This fault must be acknowledged to allow the system to return to operation.
- **Temperature Differential Error** - Please contact Angstrom Engineering® if you encounter this error.
- **Calibration TC Disconnected** - Indicates that the system's calibration thermocouple has been disconnected.
- **Calibrating** - Illuminates when the system is performing a calibration.
- **Calibrated** - Illuminates to indicate that a calibration has been successfully completed and is being used to calculate the Current Temperature of the heated component.
- **Calibration Error** - Indicates that an error was encountered during the calibration routine. Please contact Angstrom Engineering® for assistance with this error.

4. **Idle Temperature Setpoints** - This allows the user to specify additional parameters for controlling the selected heater in Idle Temperature Mode. A range of parameters for the PID controller on the selected heater are automatically determined during Aeres®' calibration, and, according to the input Idle Temperature Setpoint, are loaded automatically by Aeres® to provide optimal control of the heated component.

   - **Idle Temperature Max Power** - This allows the user to specify a maximum power (expressed as a percentage of the maximum power that can be applied) that will be applied to the selected heater in Idle Temperature Mode. Note that setting this value too low may prevent the heater from reaching its setpoint value.

   - **Idle Temperature Setpoint** - The setpoint temperature for the heater, when Idle Temperature Mode is enabled.

   - **Idle Temperature Ramp Rate Up** - Allows the user to specify a maximum rate of change in the temperature of the selected heater (in °C/min) during heating. This can be used to limit thermal shocks to susceptible materials.

5. **Idle Power Setpoints** - Provides control over the power settings for the selected heater when in Idle Power Mode.

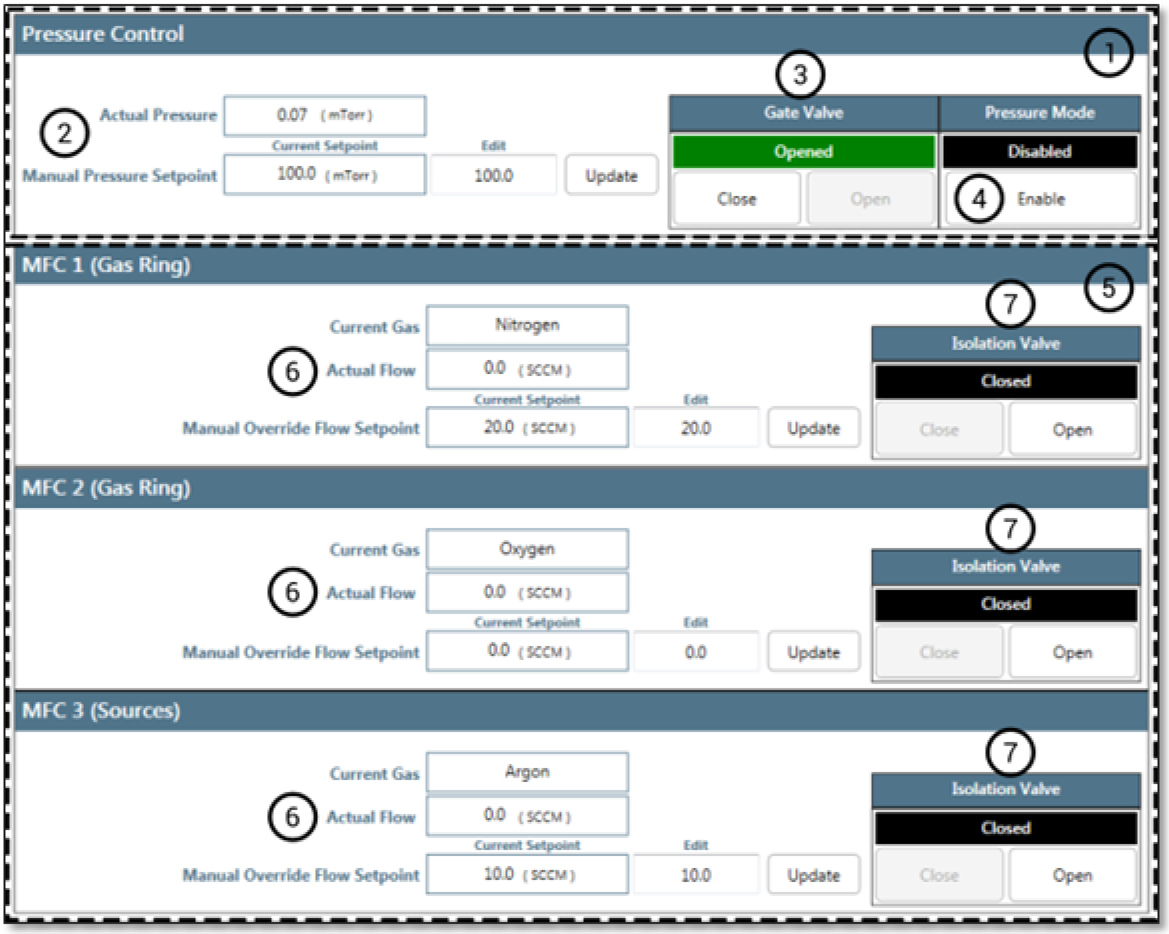
   - **Idle Power Setpoint** - The power setpoint, expressed as a percentage of the maximum heater power.

   - **Idle Power Ramp Rate Up** - This allows the user to specify the rate (in %/min) at which power will be applied to the heater when increasing power to the Idle Power Setpoint.

   - **Idle Power Ramp Rate Down** - This allows the user to specify the rate (in %/min) at which power will be reduced to the heater when Aeres® decreases power to the Idle Power Setpoint.

Pressure Control Page

If the system is equipped with process gas flow and/or pressure control, this page will be available. Here, the user can manually toggle process gas isolation valves open and closed, set mass flow controller (MFC) flow rates, toggle the control mode of the pressure control valve and set the chamber pressure. A typical layout of the Pressure Control page is shown.



The Pressure Control Page in Aeres® allows complete control over process gas flow rates and total system pressure

1. **Pressure Control** - This panel provides the user control of the pressure within the system. The controls and indicators in this panel differ from those in the Vaccum System Page in that the pressure of the system is regulated by an automatic control valve on the system's vacuum pump, whose controller monitors the system pressure using a high-precision, high-accuracy pressure gauge that has been specified according to the deposition process requirements.

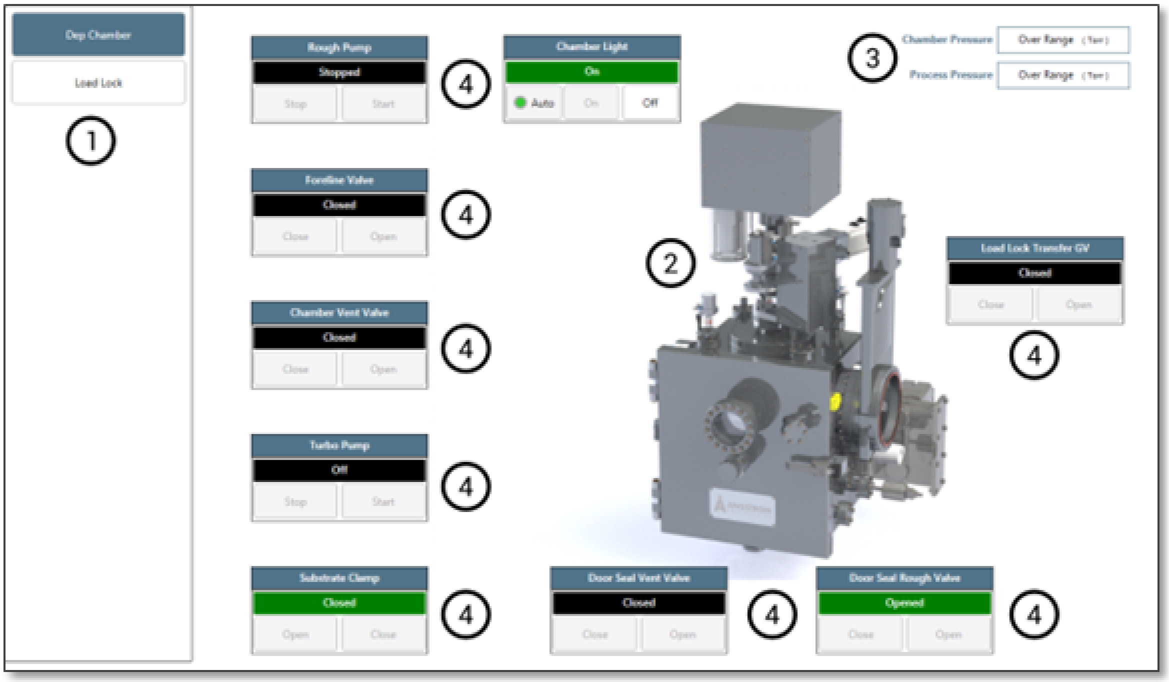
2. **Pressure**

- **Actual Pressure** - Displays the system pressure as measured by a high-precision process pressure gauge. Note that this vacuum gauge has a specified accuracy range particular to the system's configuration; chamber pressure values outside of this range may not correspond to Chamber Pressure measurements.
- **Manual Pressure Setpoint** - Here, the user can define the pressure setpoint at which the system will be held when Pressure Mode is enabled.

3. **Gate Valve Controls** - Similar to the Overrides page, this provides a status indicator and controls to open and close the control valve that throttles the effective pumping speed of the vacuum pump. When Pressure Mode is enabled, opening the gate valve using these controls will also take the valve out of pressure control mode.
4. **Pressure Mode Enable** - Clicking this button will enable the adaptive pressure control of the chamber pressure, as measured by the process pressure gauge for the Manual Pressure Setpoint. Pressure Mode is only available when a recipe is not running in Aeres®. Also note that, to maintain the system at a pressure above Base Pressure, Pressure Mode requires that at least one process gas is flowing into the chamber. To exit Pressure Mode, click on the "Open" button in the Gate Valve Controls.
5. **MFC Controls** - For each mass flow controller installed in the system, a window will be shown to allow the user to manually regulate the flow of its process gas.
6. **MFC Flow Rates** - Here, the following information and controls are displayed.
   - **Current Gas** - Displays the gas for which the MFC is configured to regulate, as per the Gases Setup Screen
   - **Actual Flow** - Displays the current flow rate of gas through the MFC, in standard cubic centimeters per minute
   - **Manual Override Flow Setpoint** - Allows the user to enter the mass flow setpoint (in sccm) that will be regulated by the MFC once the Isolation Valve is opened
7. **Isolation Valve Controls** - Similar to controls found on the Overrides page, the user can toggle the isolation valve to open or close the flow of the indicated process gas. When the Isolation Valve is opened, the flow rate through the MFC will be regulated at the Manual Override Flow Setpoint.

Overrides Page

The Overrides Page provides the user with the ability to override the position or state of system components not otherwise controlled on other system screen pages, such as pumps, valves, and clamps.



The Overrides Page in Aeres® allows the user to see the state of components that do not have their own dedicated system screen

1. **Chamber List** - If the system is equipped with multiple chambers or a load lock, selection between the overrides page for each chamber can be done from this list.

2. **Chamber Image** - A rendered image of the selected system chamber.

3. **Gauge Readings** - Here, the output from pressure gauges and other indicators attached to the selected chamber are displayed.

4. **Override Controls** - The name of each Aeres®-controlled component attached to the selected chamber is displayed, with its corresponding status indicator and override control. If the user does not have sufficient privileges to override the component, or if safety interlocks are preventing the component from changing its state, the buttons to change the component's state will be inactive (greyed-out).

Your system may include, but is not limited to, the following overrides:

Beacon - Controls the color indicated by the beacon light attached to the system.

Chamber Light - Allows for manually turning the light inside the chamber on or off. "Auto" allows Aeres® to control it for specific actions (transfer).

Cryo Pump - Turns the Helium compressor and cold head power on or off.

Cryo Purge Valve - Opens or closes the valve connected to the purge gas port on the utilities panel. Flows the connected gas into the cryo pump, this is done automatically during a Regen process.

Door Seal Rough Valve - Opens the valve allowing the rough pump to create a vacuum seal for the chamber door, keeping it closed.

Door Seal Vent Valve - Opens the valve to allow vent gas into the door seal, allowing the user to open the door after a process.

Foreline Valve - In Turbo pump systems, this valve is open when the Turbo pump is on since the Rough pump will back the Turbo pump during operation. In Cryo pump systems, this valve is opened to pump the Cryo chamber to crossover pressure during a Regen cycle. It is then closed and the Cryo pump is started.

Gate Valve - Valve between the chamber and Cryo or Turbo pump, depending on system configuration. Open when the chamber is being pumped down. Closed when venting the system.

Pellet Feeder - Allows user to manually swing the pellet feeder over the source and Dispense material then swing away to clear.

Rough Pump - Allows for manually turning the rough pump on or off. Required for pumping chamber to crossover pressure.

Rough Valve - Opens or closes the valve connecting the rough pump to the chamber.

Sputter Purge Valve - For systems equipped with a Hollow Cathode, this will empty the water in the cooling loop allowing for replacement of the target. The water is expelled from the indicated port on the utilities panel. Failure to do this before a target swap will result in the chamber being filled with water.

Substrate Clamp - Opens and closes the clamp for performing substrate transfer on systems with thermally controlled substrates.

Substrate Z-Stage - Allows for manual raising and lowering of the Z-Stage for systems using proximity sensors for positions (not present on servo driven stages).

Swing-in Sensor - Allows user to manually actuate the sensor in or out.

Transfer Valve - Opens or closes the valve between chambers, for systems with transfer capabilities.

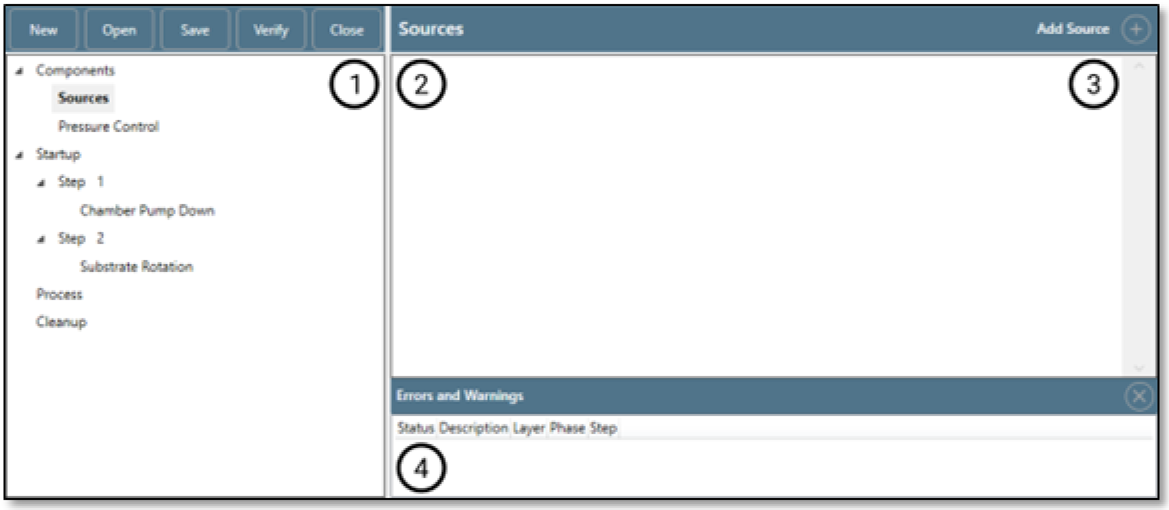
Turbo Pump - Allows for manually turning the Turbo pump on or off.

Vent Valve - Opens or closes the valve connecting the chamber to the vent gas connected at the utility panel.

Recipe Screen

For AERES® systems, the recipe screen will contain the "Process Builder" page. Deposition recipes (.rcp files) are used to control the deposition of one or more thin-film layers on a substrate, all within a single deposition chamber.

Process Builder Page



The layout of the recipe screen in Aeres®

1. **Recipe Tree** - The overall structure of a new or currently open Aeres® recipe is shown in this panel with collapsible Layers, Phases, and Steps. Only one recipe can be open at any time in the recipe screen. Standard file operations are always displayed at the top of the recipe tree.

    - **New** - This will close the currently loaded recipe without saving it and open a new recipe.
    - **Open** - Clicking this button will open a standard dialogue box to navigate the computer's directory structure to open an existing .rcp recipe file.
    - **Save** - This button always functions as a "Save s" button and will open a standard dialogue box to save the currently open recipe. On saving, a check on the structure and settings of the recipe will be performed. If errors or possible problems with the recipe are found, the Errors and Warnings window will open automatically and the user will be asked to confirm that the recipe be saved.
    - **Verify** - Clicking this button will perform a check on the structure and settings of the currently open recipe and open the Errors and Warnings window.
    - **Close** - Clicking this button will close the currently open recipe without saving any changes.

2. **Edit Window** - The Edit Window will show the contents of any Layer, Phase, Step, or recipe action selected from the recipe tree, allowing the user to edit these components of the Aeres® recipe.

3. **Recipe Addition** - The label on the plus (+) button will change contextually, allowing the user to add commands and structures to the component of the Aeres® recipe currently selected in the recipe tree and displayed in the Edit Window.

4. **Errors and Warnings** - This window displays when the "Verify" button has been clicked, or when the user attempts to save an Aeres® recipe containing errors or potentially problematic commands. Here, the status of the recipe issue ("warning" for issues which may cause undesired recipe behavior and "error" for issues that will prevent a recipe from running), a description of the issue, and its location (layer, phase, and step) will be displayed. This allows the user to assess any problems with the recipe at a glance and decide on the corrective action required (if any, as in the case of warnings where the issue triggering the warning is intentional).

Setup Screen

The Setup Screen provides the user with access to a series of pages used to configure Aeres®' interaction with the deposition system. The setpoints for various pressure, temperature, timer, and counter values used in the deposition process can be set, as well as the material properties for deposition source materials and process gases.

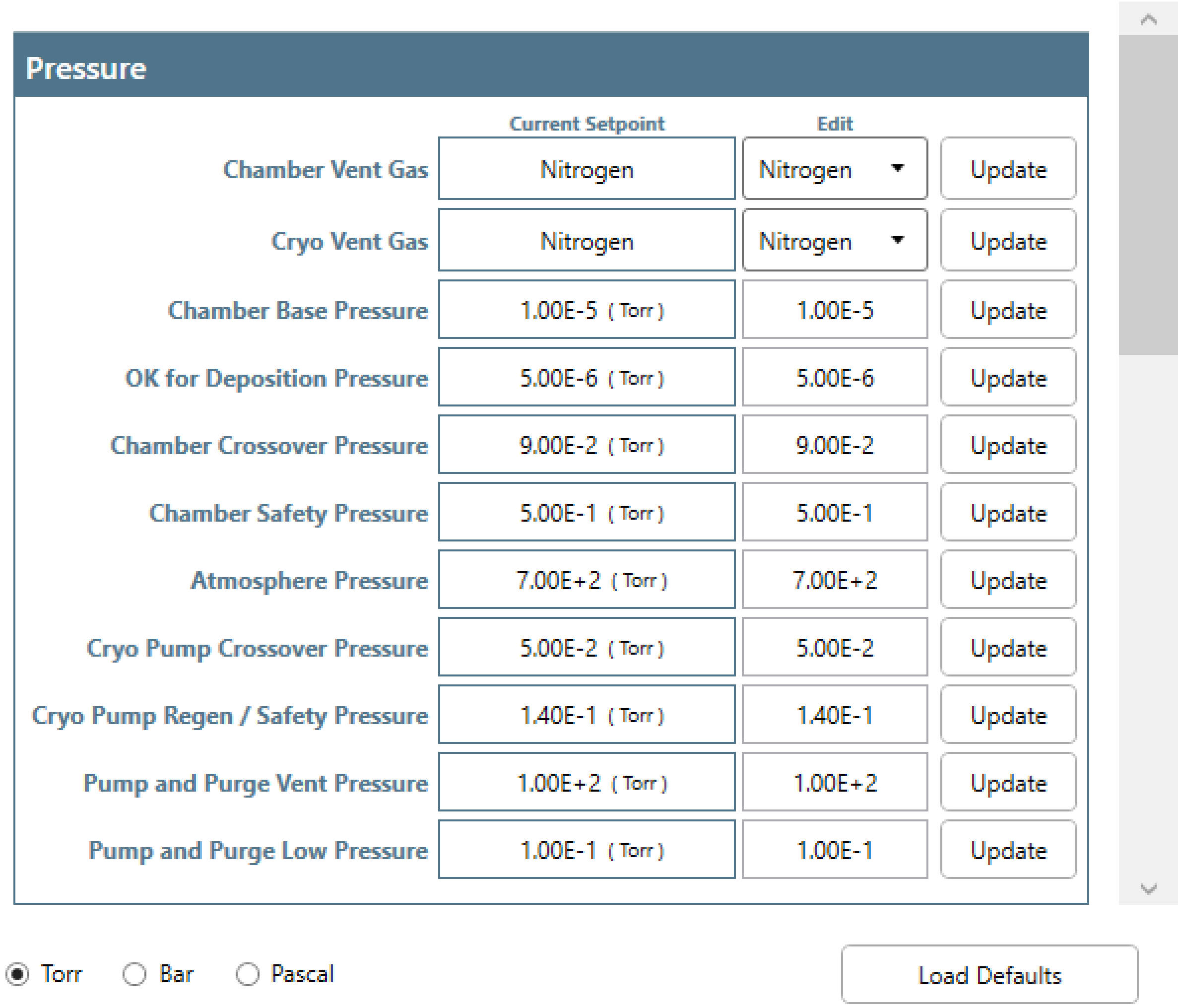
Setpoints

System setpoints, including those for pressure, temperature and timers/counters can be viewed and customized on the Setpoints Page. The definition of these setpoints, and descriptions of their interactions with Aeres® processes is given in this section.

Modifications can be made to setpoint values by entering the desired value into the **Edit** window and clicking the "Update" button. Changes will be reflected in the **Current Setpoint** column.

Pressure Setpoints

Setpoints used to control pressure related aspects of the system.



The Pressure window displays the current setpoint values and allows the ability to edit them

Chamber Vent Gas - Select the gas used for venting the chamber from the drop-down menu.

Cryo Vent Gas - Select the gas used for venting / purging the Cryo pump from the drop-down menu.

Chamber Base Pressure - The chamber Base Pressure setpoint is triggered from the chamber gauge module. This pressure setpoint must be achieved during the initial pump down along with the OK for Deposition Pressure before deposition can be executed. Note that after the Chamber Base Pressure setpoint has been achieved the OK for Deposition Pressure is used as the gating setpoint for subsequent depositions.

OK for Deposition Pressure - The OK for Deposition Pressure setpoint is a user defined pressure that must be achieved before a deposition can start. Unlike the chamber Base Pressure setpoint this pressure must be achieved before each deposition process is started whereas the chamber Base Pressure setpoint is only reached once during the initial pump down. Note that after the setpoint has been achieved it is ignored during deposition, allowing for pressure fluctuations from out-gassing materials, and partial pressures during a sputter operation (if applicable).

Chamber Crossover Pressure - The Chamber Crossover Pressure setpoint is triggered from the chamber gauge. This is the pressure that the rough pump must achieve in manual operation, or during a chamber pump down sequence, before the gate valve to the cryo pump can be opened for high vacuum pump down.

Chamber Safety Pressure - The Chamber Safety Pressure setpoint is triggered from the chamber gauge. This setpoint is not active until the chamber achieves the Chamber Base Pressure setpoint. Then, if the pressure in the chamber ever rises to this setpoint, the cryo gate valve closes automatically to protect the cryo pump, and a fault appears on the system screen. This setpoint must be higher in pressure than the Chamber Crossover Pressure setpoint.

Atmosphere Pressure - The Atmosphere Pressure setpoint is used to identify when the system is up to atmospheric pressure.

Cryo Pump Crossover Pressure - The Cryo Pump Crossover Pressure setpoint is the pressure the rough pump must reach on the cryo pump gauge before the compressor can be started. Once the setpoint is achieved it is ignored because the pressure will typically rise before decreasing as the cryo cools to operating temperature. As the pump cools to base temperature, the pressure will drop and the gauge will eventually feedback "Under Range".

Cryo Pump Regen / Safety Pressure - The "Cryo Pump Regen Pressure" setpoint is a user defined setpoint; this is the pressure that a cryo pump cannot exceed while below the "Cryo Pump Recovery Temperature" and also acts as the cryo safety pressure. If the cryo pump is running and this pressure is achieved with the gate valve open, the system triggers closure of the gate valve and the cryo pump is turned off. This pressure setpoint must be higher than the Cryo Pump Crossover Pressure setpoint. Also, when exceeded, an alarm message appears.

Pump and Purge Vent Pressure - This is the pressure to which the chamber will vent to during pump and purge cycles, as well as Active Cooling cycles.

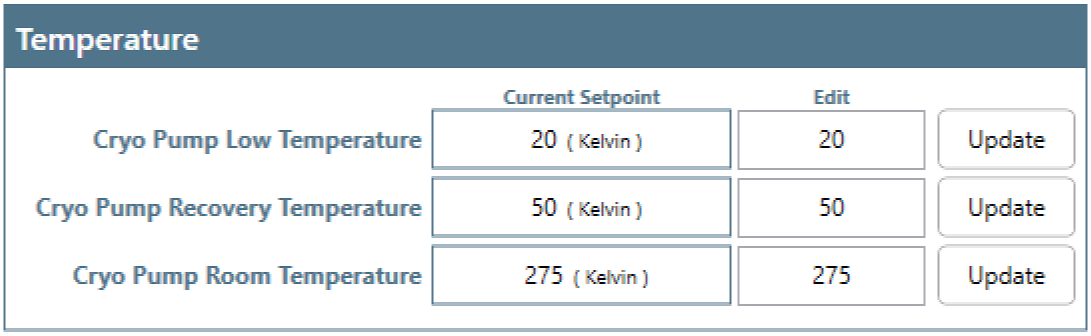
Pump and Purge Low Pressure - This is the pressure to which the chamber will pump down to during pump and purge cycles, as well as Active Cooling cycles.

Units Selection - Select the units (Torr, Bar or Pascal) to display pressure setpoints and readings in.

Load Defaults - Overwrites any existing modifications to setpoint values with factory settings.

Temperature Setpoints

Setpoints used to control temperature aspects of the system.



The Temperature window displays current setpoint values as they relate to the system.

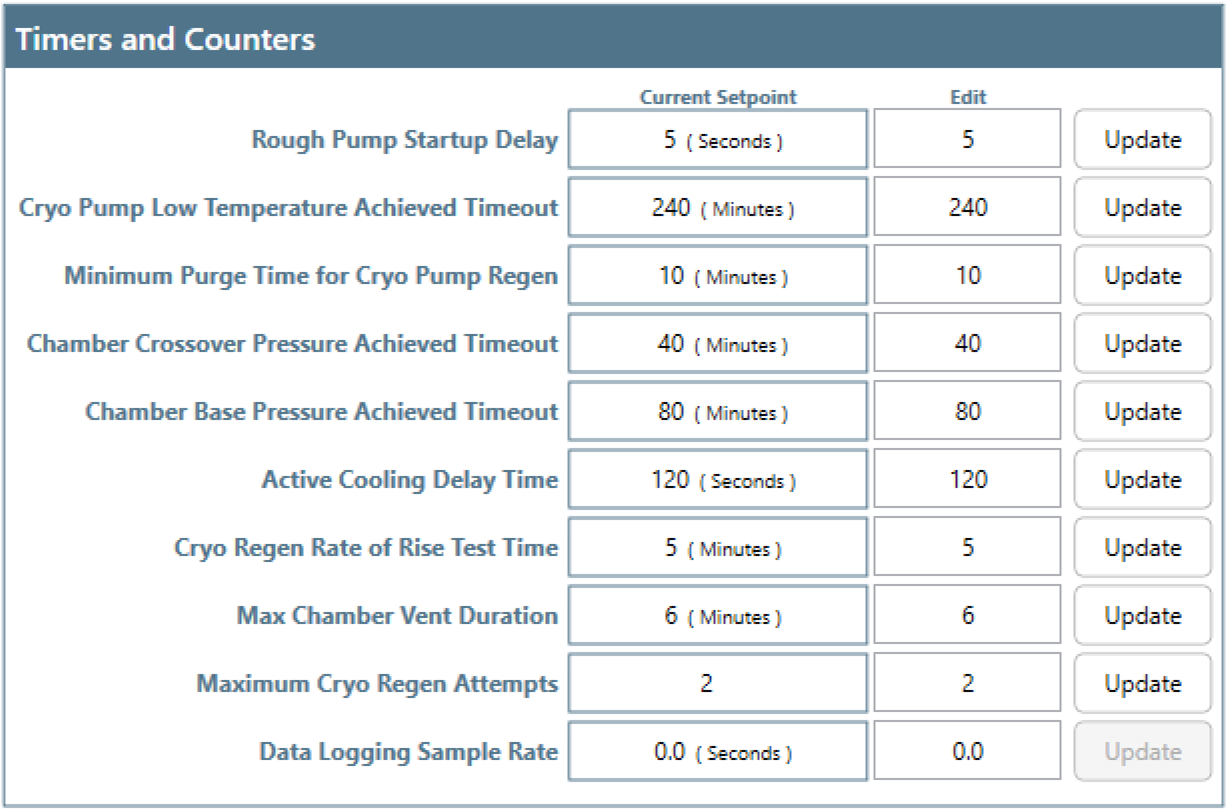
Cryo Pump Low Temperature - The Cryo Pump Low Temperature setpoint is read from an analog output signal from the temperature monitor. During a chamber pump down sequence, this setpoint is used to determine if the cryo has achieved low temperature and is able to continue with the process.

Cryo Pump Recovery Temperature - The Cryo Pump Recovery Temperature setpoint is read from an analog output signal from the temperature monitor. Once the low temperature setpoint of the cryo pump has been reached, the cryo pump is able to recover (in the event of a power failure, for example) provided the temperature remains below this value. The setpoint is also utilized for manual control. If the temperature of the cryo pump is above this setpoint and below the room temperature setpoint for any reason the cryo pump should be regenerated.

Cryo Pump Room Temperature - The Cryo Pump Room Temperature setpoint is read from an analog output signal from the temperature monitor. The setpoint is used in automatic sequences to flag that the cryo is warm enough for trapped species to desorb from its sorbent inner surfaces. If the cryo pump temperature is between the recovery and room temperature setpoints the cryo must be regenerated.

Timers and Counters Setpoints

Setpoints used to control the timers and counters used in Aeres® automated functions.



The Timers and Counters window displays the current setpoint values used in Aeres® automatic sequences

Rough Pump Startup Delay - This timer represents the delay before starting the rough pump and opening the chamber rough valve or the cryo/turbo pump foreline valve during an automated sequence. This is to prevent the rough pump from quickly switching between tasks before it is safe to do so.

Cryo Pump Low Temperature Achieved Timeout - This timer represents the maximum allowable time for the cryo pump to reach the low temperature setpoint defined by the user.

Minimum Purge Time for Cryo Pump Regen - When executing a regeneration sequence, the cryo pump will be purged for this minimum amount of time, or until the cryo pump reaches the room temperature setpoint if not within the minimum purge time.

Chamber Crossover Pressure Achieved Timeout - This timer will trigger a fault if the chamber does not reach the crossover pressure set in the pressure setpoints in the allotted time.

Chamber Base Pressure Achieved Timeout - This timer represents the maximum allowable time to achieve the Chamber Base Pressure setpoint during an automated sequence.

Active Cooling Delay Time - This timer changes the delay period before beginning another pump and purge cycle when the Active Cooling feature is selected on the vent page.

Cryo Regen Rate of Rise Test Time - During the regeneration sequence, after achieving the Cryo Pump Crossover Pressure, the rate of rise is tested to ensure the pressure is sufficiently stable to begin running the helium circuit. This setpoint defines the duration of the rate of rise test.

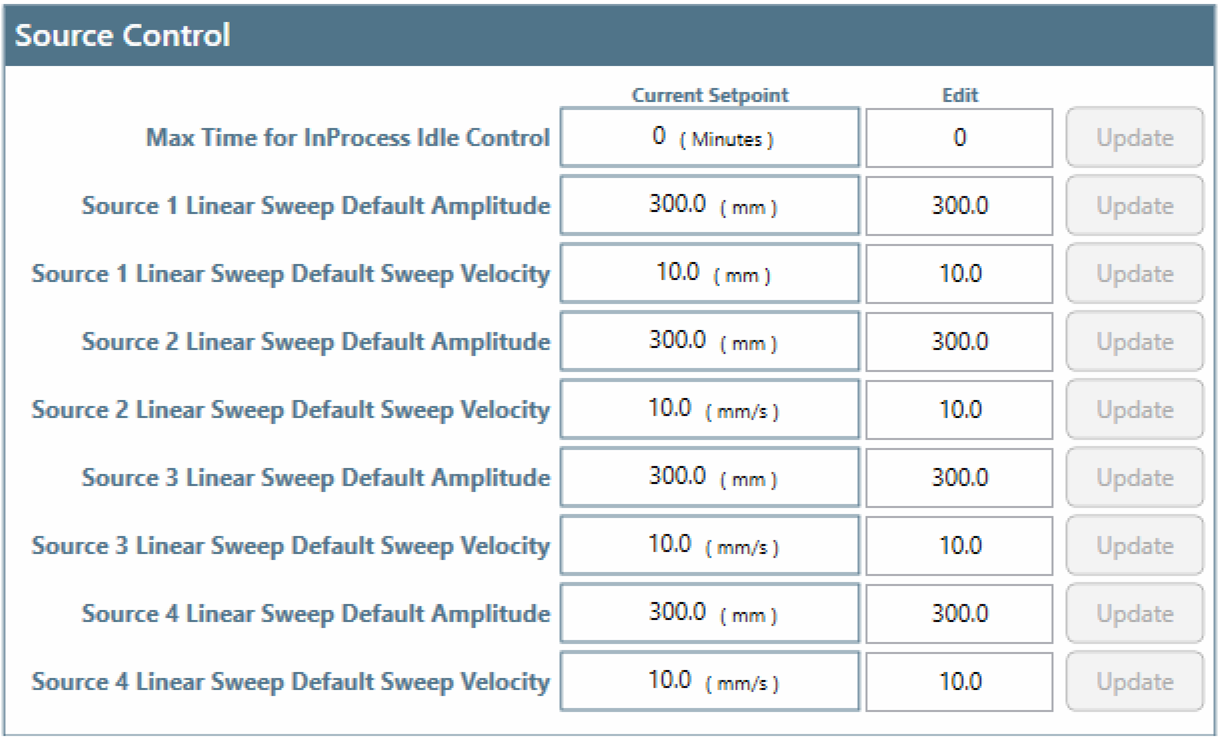
Maximum Chamber Vent Duration - This timer determines the maximum time the vent valve will remain open during a chamber vent sequence.

Maximum Cryo Regen Attempts - This determines the maximum number of times the system will attempt to regenerate the cryo pump if it fails to pass the rate of rise test.

Data Logging Sample Rate - Selects the interval at which Aeres® will record data points during a process.

Linear Sputter Setpoints

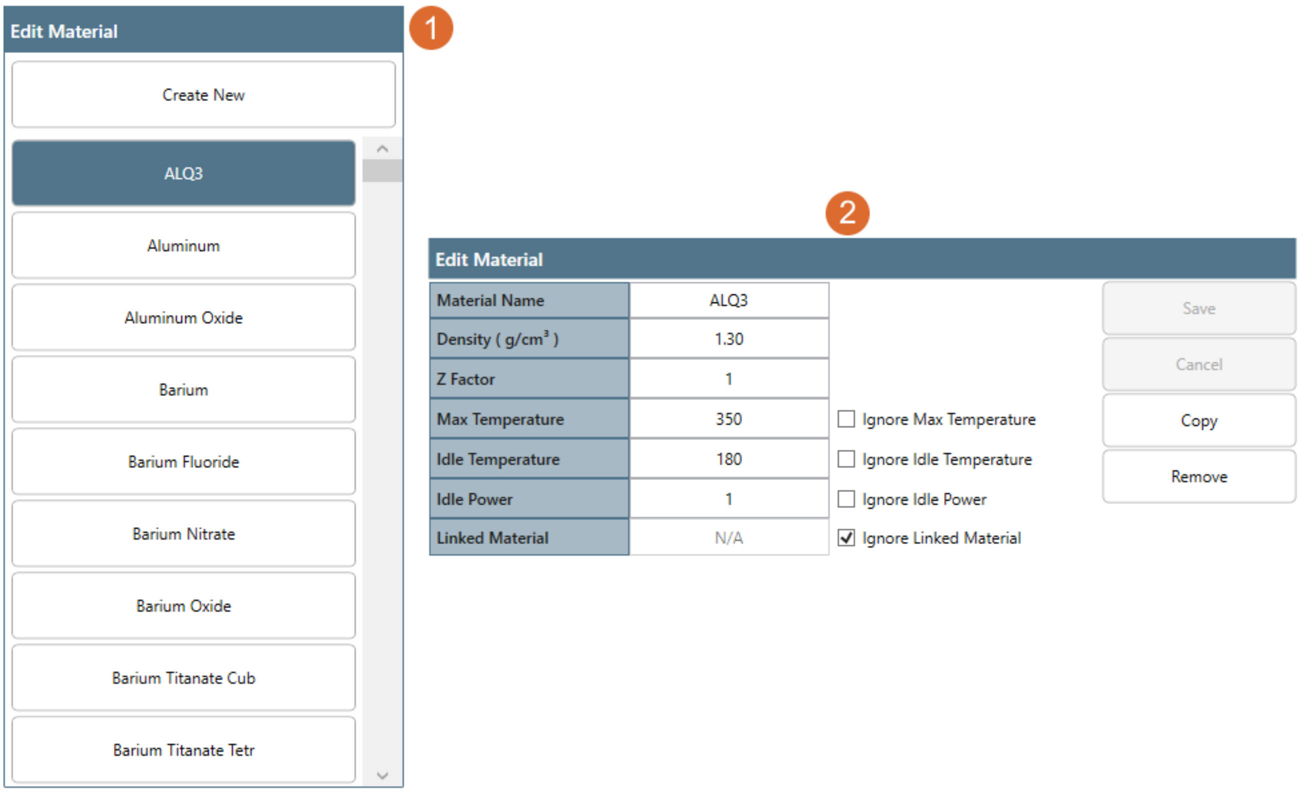
Linear Sputter Setpoints are a subset of the Setpoints Page and specific to systems equipped with linear sputter sources. The setpoints define the length and velocity of the substrate sweep. The amplitude (sweep length) is defined as the distance from the centre of the chamber to the farthest point the substrate travels in one direction (parallel to the pass). The total travel of the substrate in the chamber will be 2x the sweep length.



The Linear Sputter Setpoints can be edited and updated in this screen

Materials Page

The Materials Page allows the user to create and edit the properties of materials used within the deposition system.



The Materials Page in Aeres® with listed material data

1. **Materials List** - A list of all materials in the database.

   Create New - Clicking this button allows the user to create a new database entry. The values to be entered will appear in the adjacent window.

2. **Edit Materials Window** - New materials can be created here, and existing entries edited by clicking on their entry in the Materials List. When a material is selected, its properties are displayed.

   - **Name** - The name of the material as displayed by Aeres® anywhere it is used in the system.
   - **Density** - The density of the material in g/cm^3.

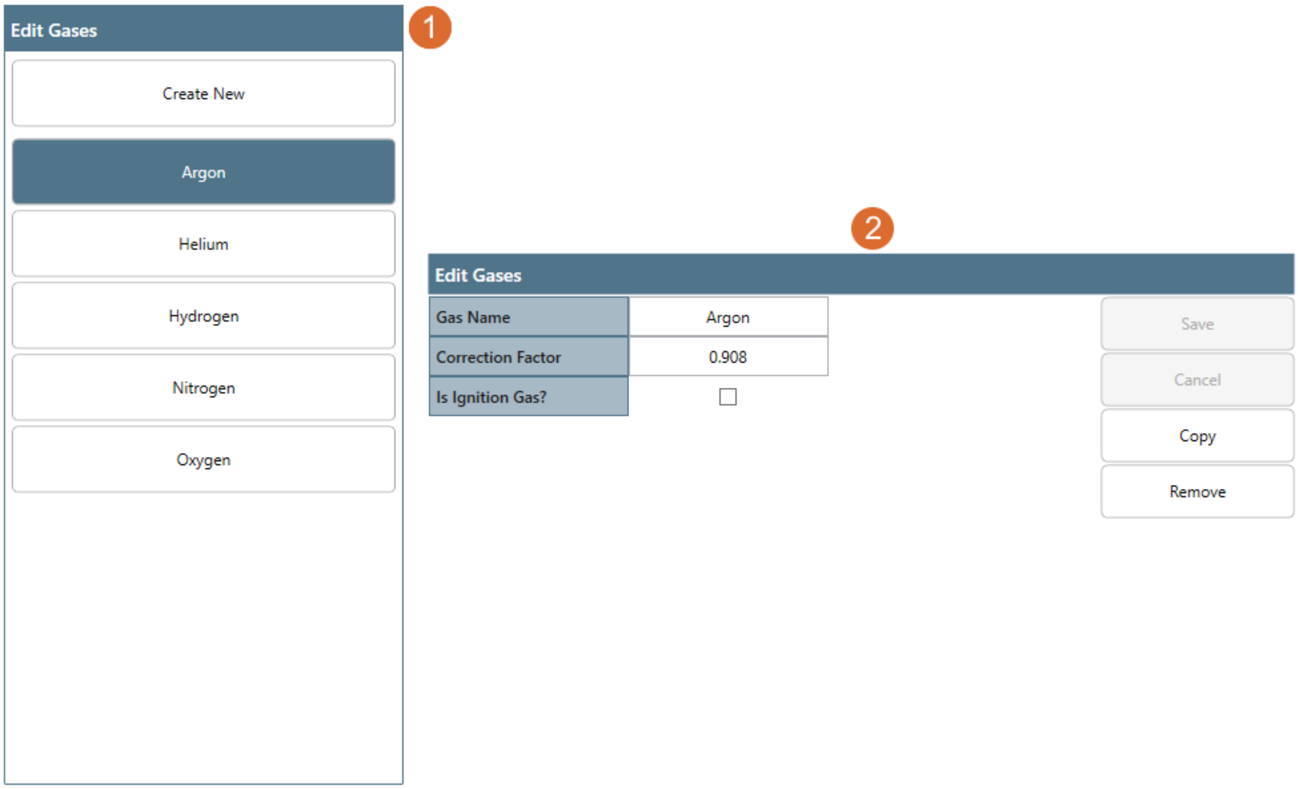
- **Z-Factor** - The Z-Factor is used by all quartz crystal microbalance sensors in the system to determine the thickness of the material deposited. This value is used to match the acoustic impedance of the deposited material (Zm) to the acoustic impedance of the quartz crystal (Zq) that is used to measure film thickness. With this factor the thickness and rate that is measured from the quartz crystal is more accurate.
- **Max Temperature** - The value input here will automatically set the Maximum Temperature of a deposition source; this value will dictate operational parameters when the selected material is registered with Aeres® in the Load Materials Page. This automatic setting of the maximum temperature can be prevented by clicking the Ignore Max Temperature checkbox.
- **Idle Temperature** - The value input here will automatically set the Idle Temperature Setpoint of a deposition source; this value will dictate operational parameters when the selected material is registered with Aeres® in the Load Materials Page. This automatic setting of the Idle Temperature Setpoint can be prevented by clicking the Ignore Idle Temperature checkbox.
- **Idle Power** - Entering a value here will set the Idle Power Setpoint of a source when the selected material is loaded into it. This automatic setting of the Idle Power Setpoint can be prevented by clicking the Ignore Idle Power checkbox.
- **Linked Material** - Used to define a source material that is different than the deposited material for reactive processes. This feature allows for running recipes with a reactive deposition material (e.g. TiN or TiO_2) that do not match the loaded material on the load materials page, as long as the linked material (e.g. Ti) for the deposition material is populated on the load materials page instead.

Entry Control Buttons - Clicking these buttons will execute the following actions.

- **Save** - Clicking this button will write any changes that were made to the database entry. Note that if changes to the Source or Material are made, and this corresponds to an already-existing entry, then the values in that entry will be overwritten.
- **Cancel** - Discards any changes made to the database entry.
- **Copy** - Clicking this button creates a temporary database entry based on the currently selected record that can be used as a template for a new entry.
- **Remove** - Clicking this button will remove the currently selected record from the database.

Gases Page

The Gases Page allows the user to edit the gases used by the system, including their material properties.



The Gases Page used to configure Aeres® for the connected process gases

1. **Gas List** - A list of all gases in the database.

   Create New - Clicking this button allows the user to create a new database entry. The values to be entered will appear in the adjacent window.

2. **Gas Editing Window** - New gases can be created here. When a gas is selected from the Gas List, the following parameters are displayed:

   - **Gas Name** - The name of the gas as displayed anywhere it is used in Aeres®.

   - **Correction Factor** - The correction factor for the selected gas when being used with an MFC calibrated for a different gas. Please contact Angstrom Engineering® for assistance if you are unsure which correction factor to use for new gases, gas mixtures, or the gas for which the system's MFCs were originally calibrated.

- **Is Ignition Gas?** - Selecting this box will allow the selected gas to be used as an ignition gas for sputtering processes. This box must be selected for the selected gas to work with the "pressure bump" feature of the Process Pressure recipe action.

Entry Control Buttons - Clicking these buttons will execute the following actions.

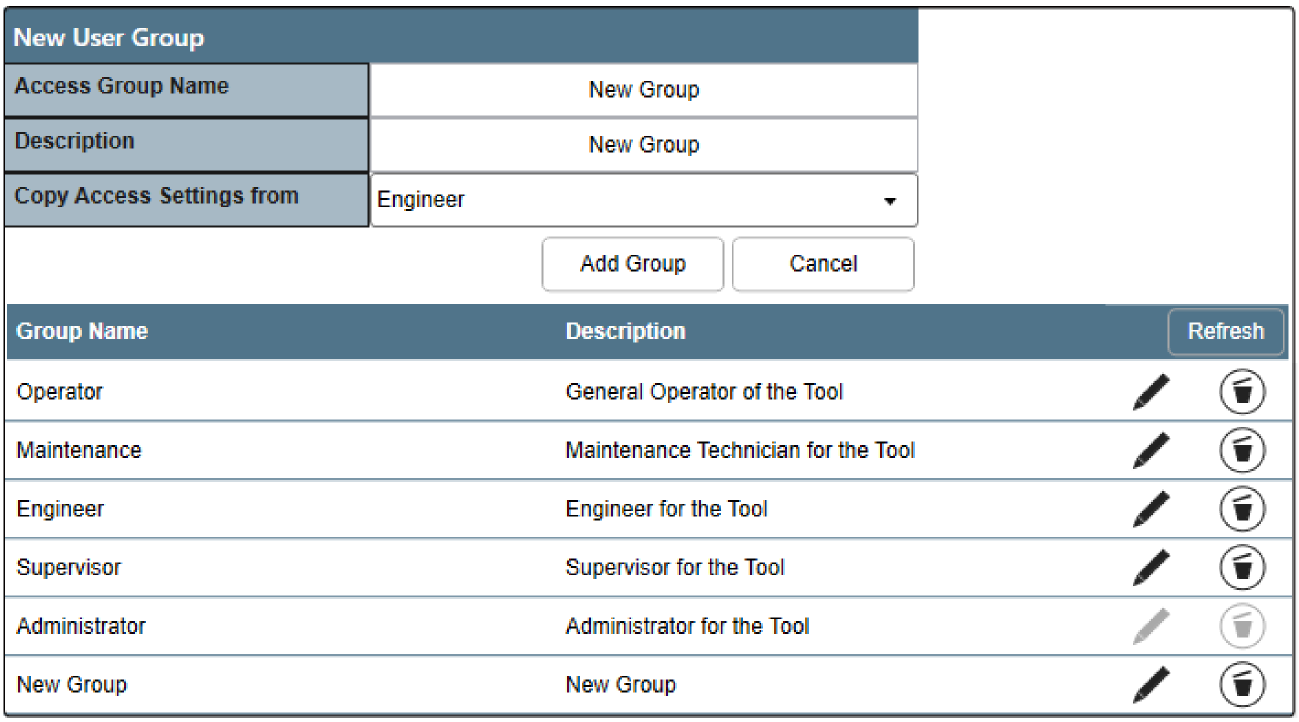
- **Save** - Clicking this button will write any changes that were made to the database entry. Note that if changes to the Source or Material are made, and this corresponds to an already-existing entry, then the values in that entry will be overwritten.
- **Cancel** - Discards any changes made to the database entry.
- **Copy** - Clicking this button creates a temporary database entry based on the currently selected record that can be used as a template for a new entry.
- **Remove** - Clicking this button will remove the currently selected record from the database.

User Management

Aeres® provides customization options for restricting user access to various features on the system. There are 3 sections within the "User Management" page; "Groups", "Features", and "Users". Each group can be configured to allow or restrict access to particular features of the system. One or more users can be assigned to any of the available groups depending on which features they require access to.

Groups

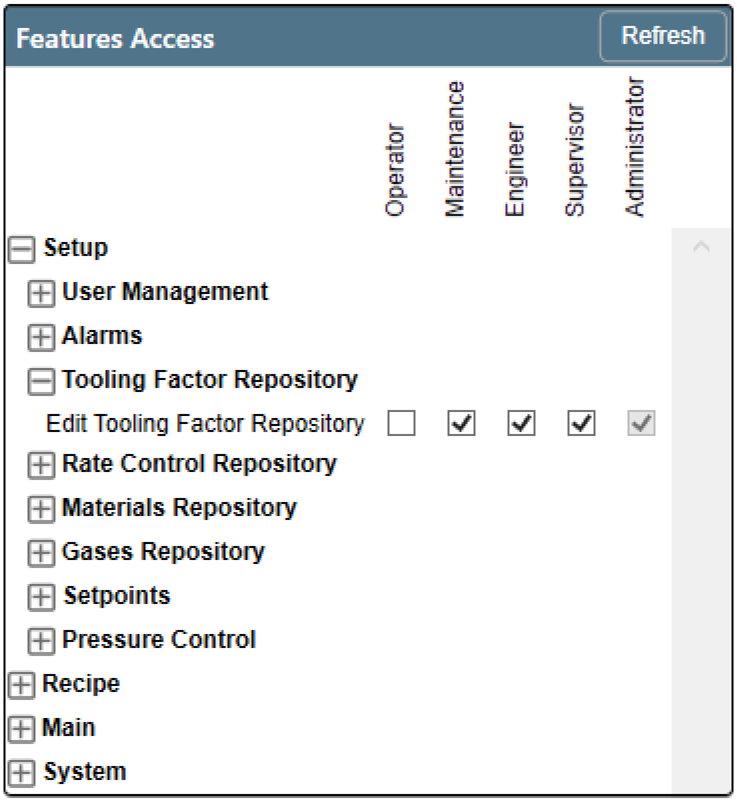
Allows for the addition and editing of new user groups. Aeres® has 5 access groups by default (Operator, Maintenance, Engineer, Supervisor, and Administrator). To add a new group, enter the new group information in the subsequent rows and then click the "Add Group" button to populate the groups list.



Adding new user groups to Aeres®

Features

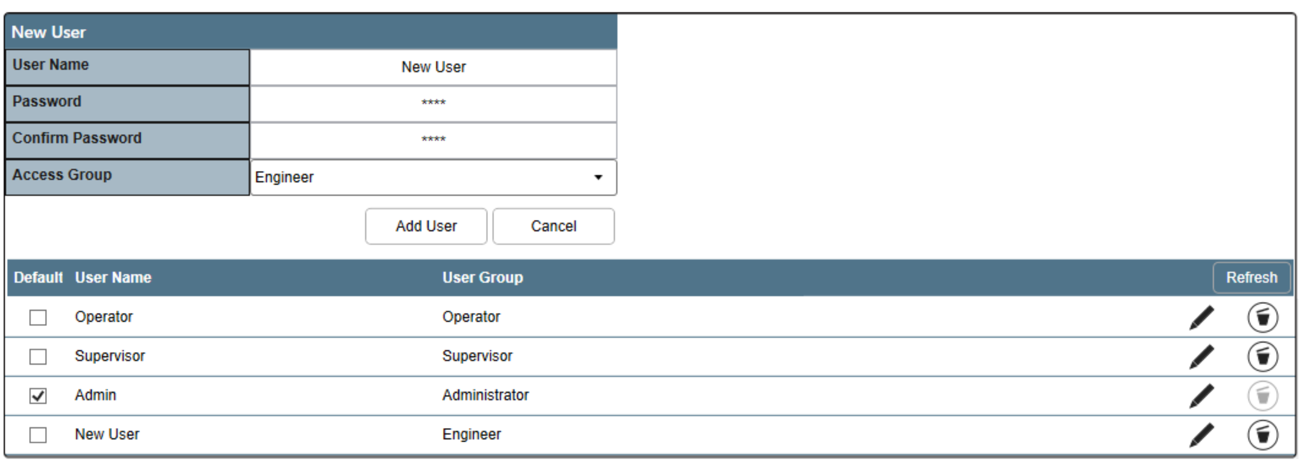
System features are categorized based on the page where they can be found within Aeres®. Expanding each category will reveal these features. System features can be toggled for each access group using the check boxes. Users within the Administrator group will be able to change the features accessible to all other groups.



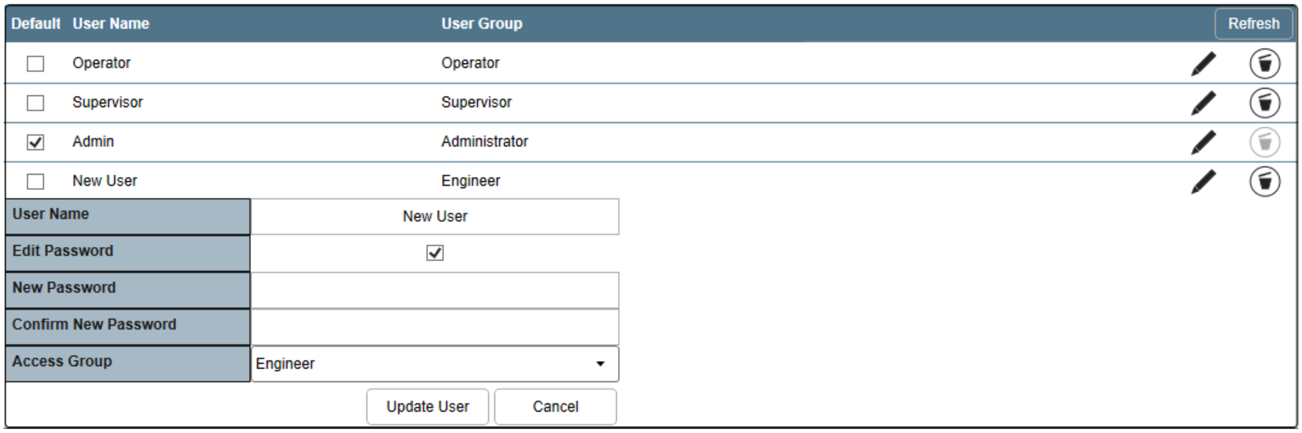
Setup feature access for user groups

Users

Allows for the addition, editing, removal, and group assignment of users. Aeres® has 3 default user accounts (Operator, Supervisor, and Admin), which can be removed once the user database is populated with at least one Administrator level user. Enter the new user information in the subsequent rows and then click the "Add User" button to populate the user accounts list.



Adding new user accounts in Aeres®



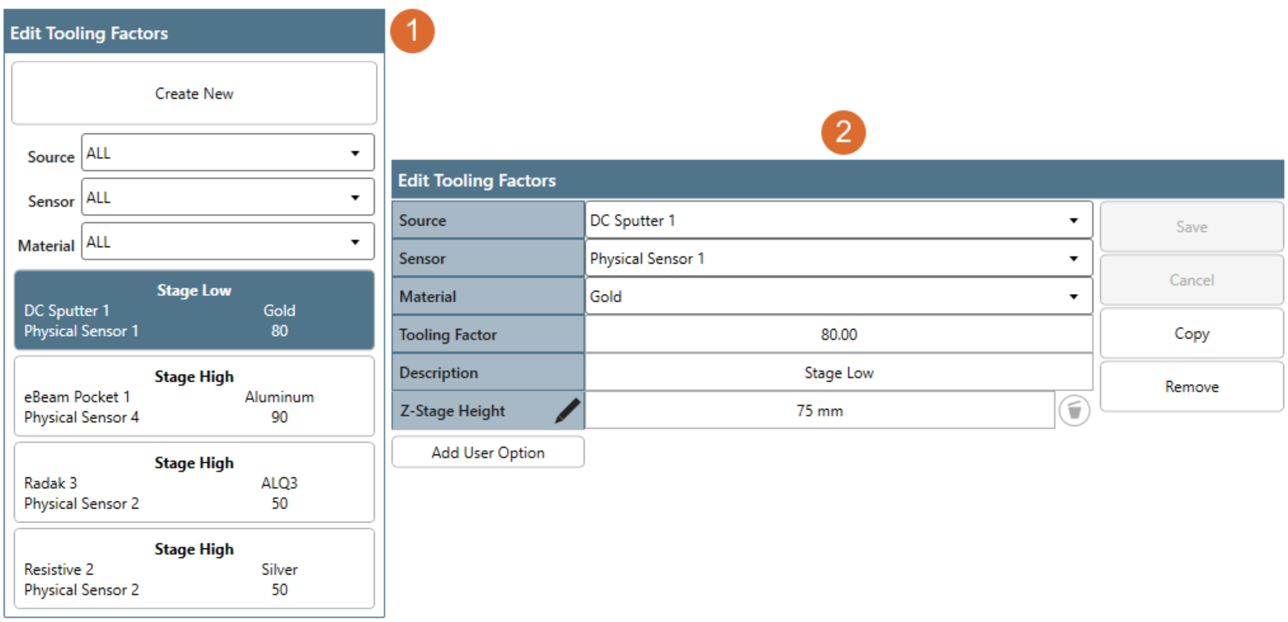
Editing user accounts in Aeres®

Tooling Factor

The Tooling Factors Page is a database of all tooling factor values saved in Aeres®. These can be accessed by the user when configuring sources in Aeres® recipes. Tooling Factor values relate the thickness of material that the sensor sees to the thickness of material measured on the substrate. A new tooling factor can be calculated by:

$$New\ Tooling\ Factor = \frac{Measured\ Thickness}{Target\ Thickness} \times Original\ Tooling\ Factor$$

All values in the database must be entered manually by the user on this page. Also note that Tooling Factor values are source, sensor, and material specific, unless specified for "ANY" source, sensor, or material.



Tooling Factor Database with user stored entries

1. **Tooling Factor Database Entries** - Listed here are all entries in the tooling factor database, organized by source name, sensor name, and material.

   Create New - Clicking this button allows the user to create a new database entry. The values to be entered will appear in the adjacent window.

   Database Entry Filters - Selecting values from these drop-down menus allows the user to view only database entries corresponding to the selected source, sensor, and material.

2. **Edit Tooling Factor Window** - The values of the Tooling Factor database entries are edited in this window.

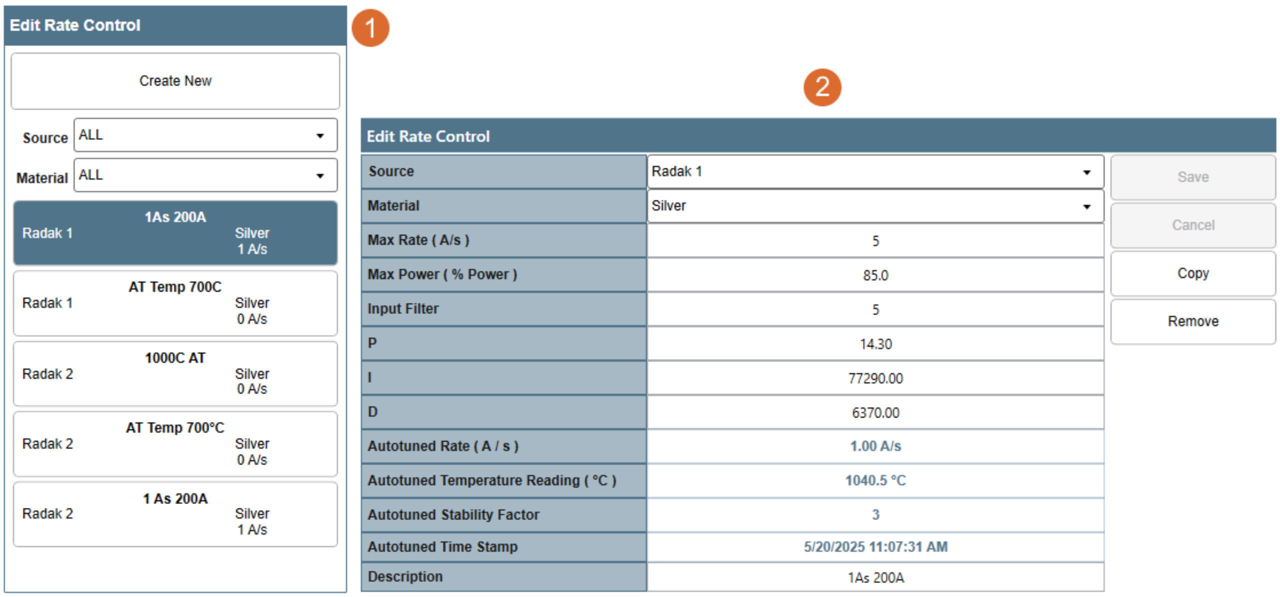
    - **Source** - This drop-down menu allows the selection of the deposition source to which the database entry will be associated.
    - **Sensor** - This drop-down menu allows the selection of the sensor to which the database entry will be associated.
    - **Material** - This drop-down menu allows the selection of the material to which the database entry will be associated.
    - **Tooling Factor** - Clicking on this entry allows the user to enter the numerical value for the Tooling Factor for this database entry.
    - **Description** - Here, the user can enter any notes or additional information that are to be attached to this database entry.
    - **User Option** - This allows the user to input additional criteria for the tooling factor, in this example the deposition height is specified.

Entry Control Buttons - Clicking these buttons will execute the following actions.

- **Save** - Clicking this button will write any changes that were made to the database entry. Note that if changes to the Source or Material are made, and this corresponds to an already-existing entry, then the values in that entry will be overwritten.
- **Cancel** - Discards any changes made to the database entry.
- **Copy** - Clicking this button creates a temporary database entry based on the currently selected record that can be used as a template for a new entry.
- **Remove** - Clicking this button will remove the currently selected record from the database.

Rate Control Database

The Rate Control DB Page is a database of all PID values saved in Aeres®, which can be accessed by the user when configuring sources in Aeres® recipes (please refer to the section Source Configuration: General Notes). PID values in the database can be either user-entered or generated automatically from the Autotune recipe action. Note that Rate Control Database entries are source and material specific, unless specified for "ANY" source or material.



Rate Control Database with user stored entries

1. **Rate Control Database Entries** - This lists all entries saved in the PID Rate Control database, organized by source name, material corresponding to those PID values, and the deposition rate at which those PID values were obtained during autotuning (this value will be 0 for manually entered database entries).

   Create New - Clicking this button allows the user to create a new database entry. The values to be entered will appear in the adjacent window.

   Database Entry Filters - Selecting values from these drop-down menus allows the user to view only database entries corresponding to the selected source, sensor, and material.

2. **Edit Rate Control Window** - The values of Rate Control Database entries are edited in this window.

   - **Source** - This drop-down menu allows the selection of the deposition source to which the database entry will be associated.

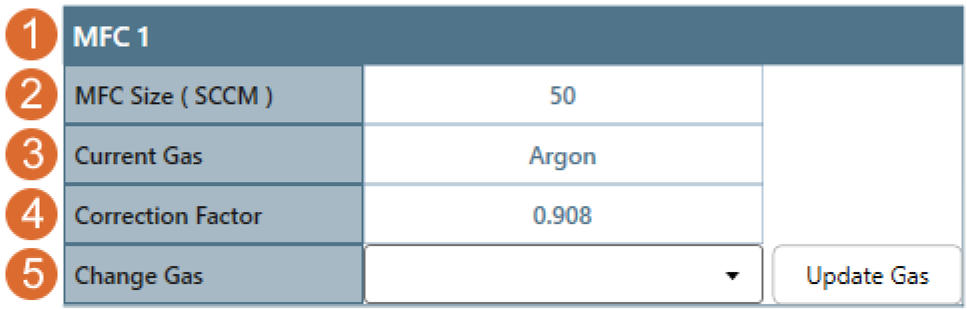
- **Material** - This drop-down menu allows the selection of the material to which the database entry will be associated.
- **Max Rate** - This entry allows the user to specify the maximum rate at which the material will be deposited from the source selected in the database entry. This allows the user to specify maximum deposition rates that will be recipe-specific.
- **Max Power** - This is the maximum power (expressed as a percentage of the power limit of the source) that will be applied to the selected source when this database entry is used to configure a source in an Aeres® recipe.
- **Input Filter** - This is the size of the moving average Input Filter that will be used to sample the deposition rate in the system for this database entry.
- **PID** - Values for the proportional, integral, and derivative constants used to control the deposition rate from the database entry's source and material.
- **Autotuned Rate** - The rate at which PID controller values were obtained when autotuning the controller. If the database entry was manually entered, this displayed value will be "0".
- **Autotuned Temperature Reading** - This is the temperature at which PID values were obtained during autotuning. Please note that this only pertains to Radak® sources and other sources equipped with temperature feedback.
- **Autotuned Stability Factor** - The Stability Factor used for autotuning. See the Autotune recipe action for more details.
- **Autotuned Time Stamp** - Indicates when the Autotune parameters were collected, through using the Autotune recipe action.
- **Description** - The user can enter any notes or additional information for this database entry.

Entry Control Buttons - Clicking these buttons will execute the following actions.

- **Save** - Clicking this button will write any changes that were made to the database entry. Note that if changes to the Source or Material are made, and this corresponds to an already-existing entry, then the values in that entry will be overwritten.
- **Cancel** - Discards any changes made to the database entry.
- **Copy** - Clicking this button creates a temporary database entry based on the currently selected record that can be used as a template for a new entry.
- **Remove** - Clicking this button will remove the currently selected record from the database.

Pressure Control Page

The Pressure Control Page on the Setup Screen allows the user to view the size of any MFCs installed in the system and select which gas is connected to each. The layout of the Pressure Control Page is shown.



The Pressure Control Page tells Aeres® which process gas is connected to a given MFC

1. **MFC Number/Description** - Identifies the MFC corresponding to the values displayed in the window.

2. **MFC Size** - The capacity (maximum flow rate) of the MFC, in sccm.

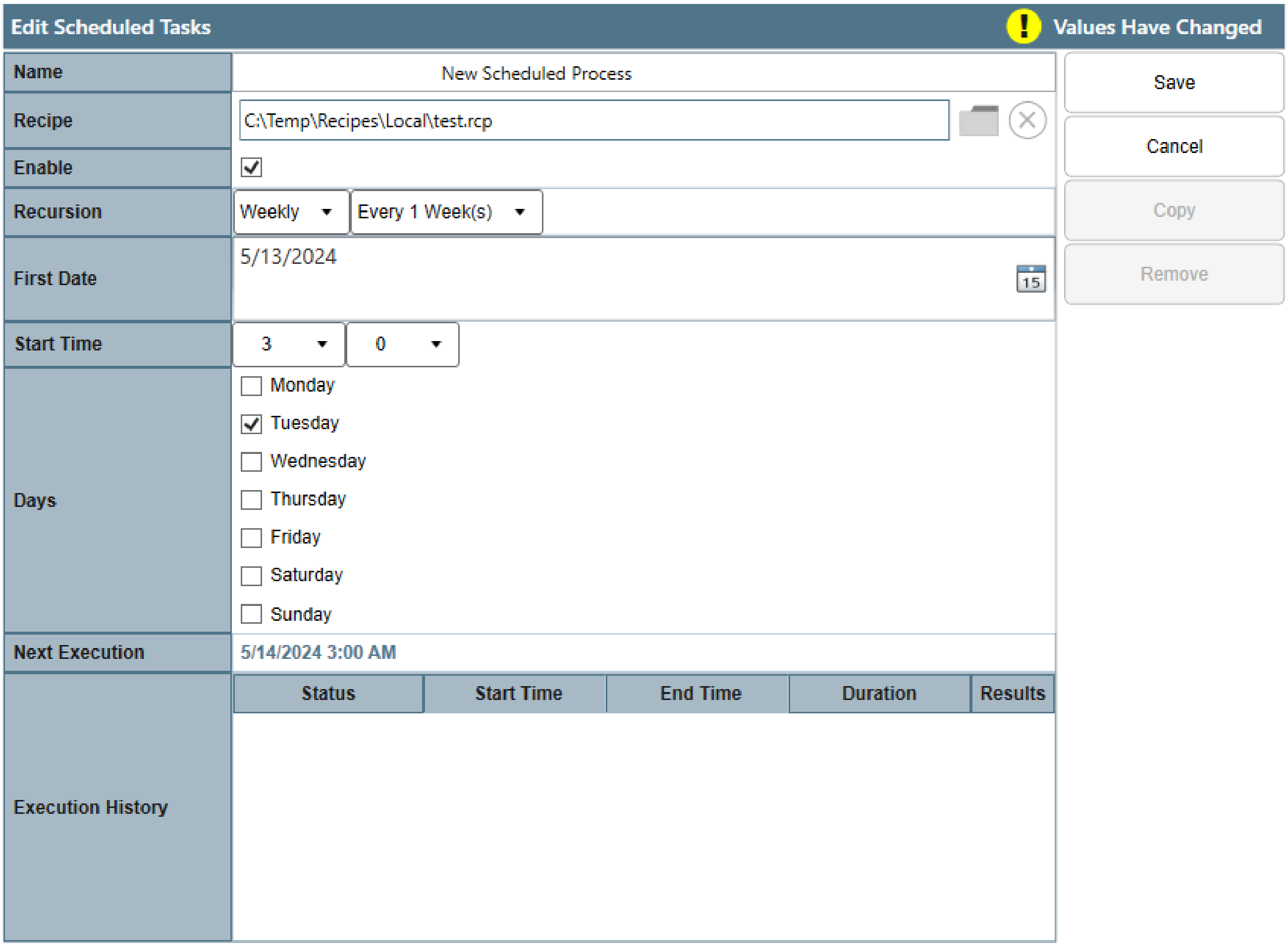
3. **Current Gas** - The gas currently registered with Aeres® as connected to the selected MFC.

4. **Correction Factor** - The correction factor currently being used by Aeres® to calculate the flow rate of gas through the MFC. If the gas connected to the MFC matches the gas for which it was calibrated, this value will be 1.00.

5. **Change Gas** - This drop-down menu allows the user to select a gas from the database displayed on the Gases Page. Clicking the "Update Gas" button updates Aeres® to set the Current Gas to that selected in the Change Gas field.

Process Scheduling

Aeres® allows the user to schedule premade recipes to run automatically at a specific time of day and day of the week. This feature is found under “Setup > Process Scheduling”.



New Scheduled Tasks in Aeres®

Name: The name of the scheduled task.

Recipe: The recipe that will run when the scheduled task is enabled.

Enable: When selected, the task will run at the next day and time selected. When unselected, the task will not run.

Recursion: The time interval that the task will re-occur.

First Date: The first day that the task will run.

Start Time: The time that the scheduled task will run.

Days: The days of the week the scheduled task will run.

Next Execution: The next scheduled run for the task.

Execution History: A list of the past runs of the scheduled task.

Once saved, the scheduled task will appear underneath the “Overview” tab on the left navigation panel where it can be edited further if required. The "Overview" tab will show all of the scheduled tasks, enabled or disabled, as shown below:

Scheduled Processes					
Name	Recipe Path	Enabled	Next Execution	Repeating	Last Execution
New Scheduled Process	C:\Temp\Recipes\Local\test.rcp	☑	5/18/2024 8:00 AM	Weekly	○

Overview of Tasks in Aeres®

Data

Aeres® offers users two different ways to view and record data; either by monitoring a system variable in real time, or by viewing past process log data.

Data Logging

Every deposition process will automatically generate a data log of all variables relating to the process including chamber pressure, the power applied to sources, deposition rates, etc.

A data log for each completed process is stored in D:\Angstrom Engineering\Logs in a sub-folder named with the recipe file name followed by a date and time stamp. This sub-folder will also contain two recipe files; one tagged as Original, which is the recipe as loaded, and another tagged as Complete which captures any changes made to the recipe during the run (updated setpoints, timers, PID parameters, etc).

Real Time Data Viewer

The Real Time Data Viewer allows the user to view and save data from a user-defined list of variables when running the system. Use the plus (+) icon next to a variable to add it to the chart.. Click the green play button to start the live plot, then press the "Start Recording" button to begin saving the data. Sampling time can be changed to reduce file size of recorded data, and recording time can be changed to stop the recording.

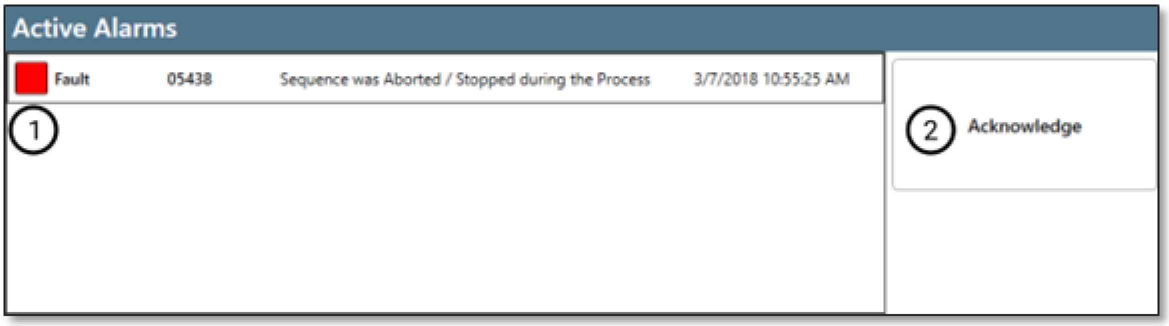
Data Viewer

This page allows the user to load previously recorded data logs, either from recipe data logging or from the real time data viewer logs. Click the "Load File" button and select the file you wish to view. Use the plus (+) icon next to a variable to add it to the chart. Variables added to the chart can be plotted with different colours and axis settings.

Alarms Screen

The Alarm Screen in Aeres® displays all warnings and alarms in the deposition system as well as relevant information associated with that alarm (including descriptions, timestamps, and error codes).

Active Alarms



Aeres® Alarms Screen Shows a List of All Active Alarms, Including Faults and Warnings

1. **Active Alarms List**

   When an alarm is triggered, any automated process is stopped, a red banner appears on the Title Panel, and the alarm is displayed in the Active Alarms list with a description of the error.

2. **Acknowledge Button**

   To clear an alarm, the user must resolve the issue that triggered the alarm, and then click the Acknowledge button on the Alarms screen or on the Title Panel.

System History

The system history page displays all past alarms and warnings which have occurred, with respective timestamps. It also displays other system information, such as recipes that have been completed and/or aborted.

Deposition Processes and Aeres® Recipes

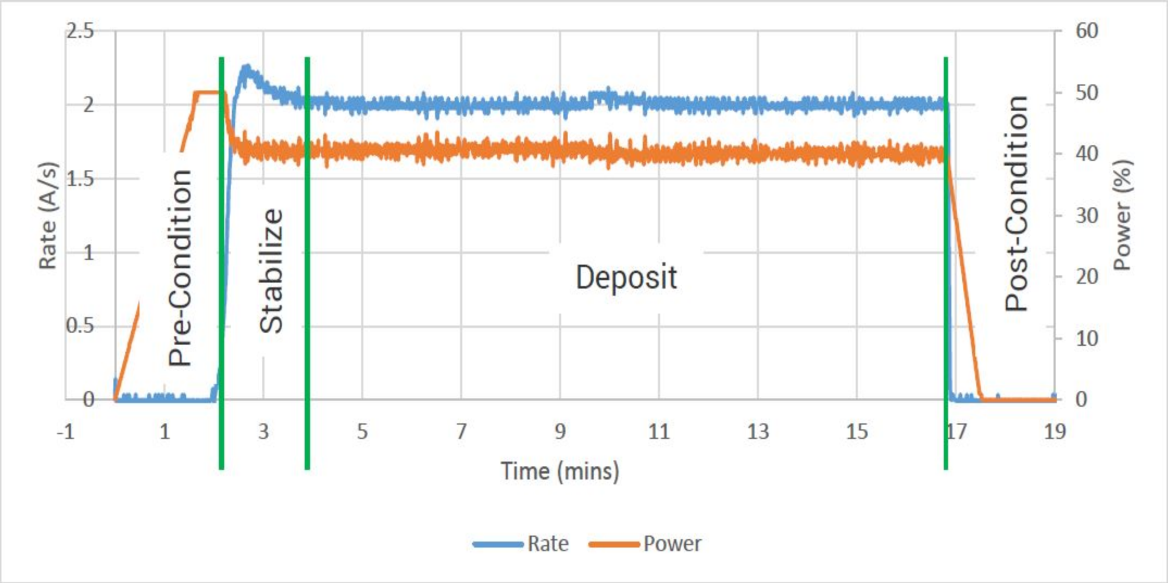
Almost all thin-film vacuum deposition processes share common features and modes of operation. By unifying the creation of thin-film deposition recipes around these commonalities in one intuitive user interface, Aeres® aggregates the control and data logging of all its system components. Developed with powerful features to execute complex depositions, but designed for every user, Aeres® recipes ensure repeatability, accuracy, and control.

The next sections introduce thin-film deposition concepts and how they are integrated into Aeres® recipes. Every recipe action is described, followed by a step-by-step guide on how to create an Aeres® recipe. After reading this chapter, the user should be familiar with all of the recipe actions as they relate to the components of their Angstrom Engineering® system and be able to confidently build and save their own recipes before proceeding to system operation.

Thin-Film Vacuum Deposition Basics

The most basic form of thin-film vacuum deposition processes is a single-layer deposition. The goal of any deposition is to deposit the desired material onto a substrate in a controlled manner, but in most cases, this cannot be achieved instantaneously. Distinct phases in the deposition process are consequently required, and it is the management of these phases for which Aeres® is designed.

A schematic of the four most commonly encountered phases of any deposition process is shown.



Data Logged by Aeres® Showing The Four Most-Commonly Encountered Phases in Vacuum Thin-Film Deposition Processes.

Typically, in the first phase of the process (pre-condition), the deposition source containing the deposition material is gradually brought to its operating setpoints. The intent of this phase is usually to minimize any thermal or electrical stress on system components by allowing time for heat transfer in the parts. This can involve gradual increases to the power, temperature, current, or voltage, and may be done at either the pressure at which the deposition is to be performed, or another temporary pressure. The deposition substrate is not exposed to the source in this phase (i.e. the substrate shutter and/or source shutters are closed) and any deposition rate sensors may be similarly shielded (if sensor shutters are installed).

In the stabilization phase of deposition, the deposition source, vacuum chamber, and any other process equipment are held at their operating setpoints, with the sensor now exposed to the deposition source (again, if sensor shutters are installed) and the substrate remaining unexposed. The rate of deposition is measured using the sensor and allowed to stabilize. Once a stability criterion has been satisfied (e.g. a fixed period or a maximum percentage deviation in a fixed timeframe), the process then moves to its deposition phase.

During the deposition phase, the substrate is now exposed to the material flux from the deposition source. Deposition rate measurements from the sensor are integrated over time to give a cumulative measure of the deposited film thickness, as measured from the time the substrate was exposed to the deposition source. Once the desired thickness has been deposited, the material flux from the deposition source to the substrate is then blocked (or, in some systems, the substrate itself is removed from the material flux). With the single-layer deposition now complete, the deposition proceeds to the final phase: post-condition.

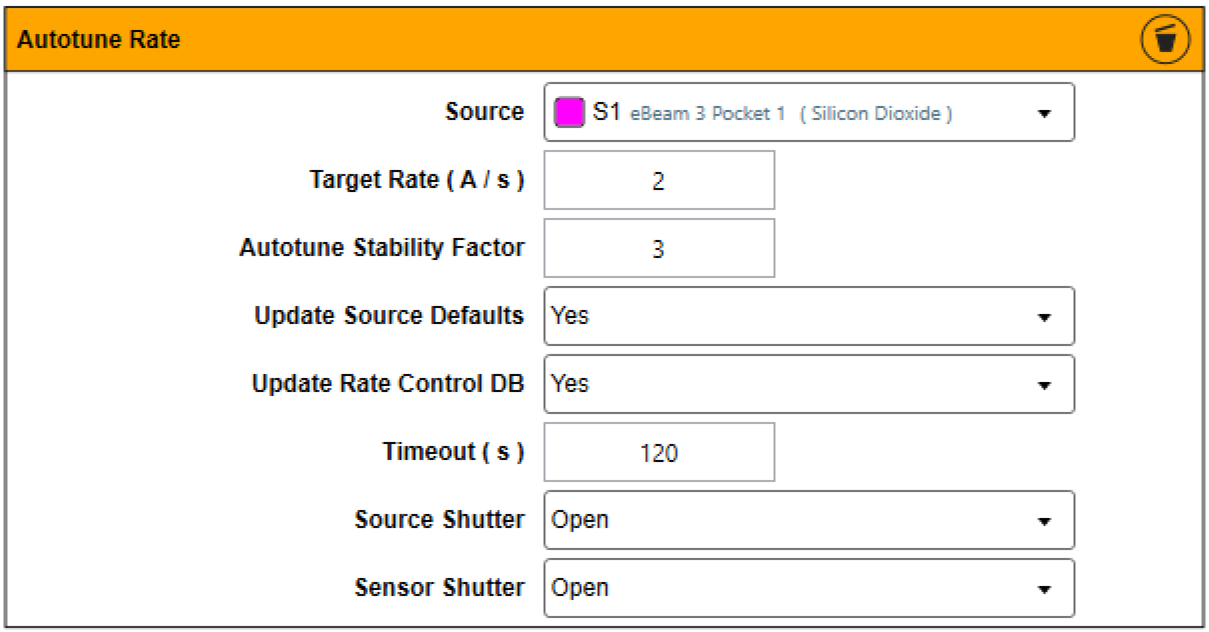
Post-conditioning is used to bring the deposition source, any remaining deposition material, and other system components safely back to their idle states before running subsequent depositions. Like the pre-condition phase, the operating points of system components (e.g. temperature and power levels) are gradually reduced to minimize any strain caused by sudden changes in operating conditions and consequently increase the lifetime of components.

Recipe Actions

When building a recipe there are many different actions which can happen sequentially or simultaneously. This section details what each action performs and what their respective parameters control.

Autotune Rate

Initiates a process to determine PID values for controlling a source at a specified deposition rate. Calculated values can be stored in the Rate Control Database.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Rate (Å/s): Enter the deposition rate to collect the PID values for.

Autotune Stability Factor: Determines whether the tuning favors aggressiveness or stability in reaching and maintaining the desired setpoint. 1 is most aggressive, 10 is most stable. 3 is the default setting.

Update Default: Select if the new PID values will be written to the source as default PID values found on the Sources Page.

Update Rate Control DB: Select if the new PID values will be written to the Rate Control Database entry selected in the Source Configuration. Typically, this is desired behavior.

Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions. This should be open to obtain proper rate values.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement. This should be open to obtain proper rate values.

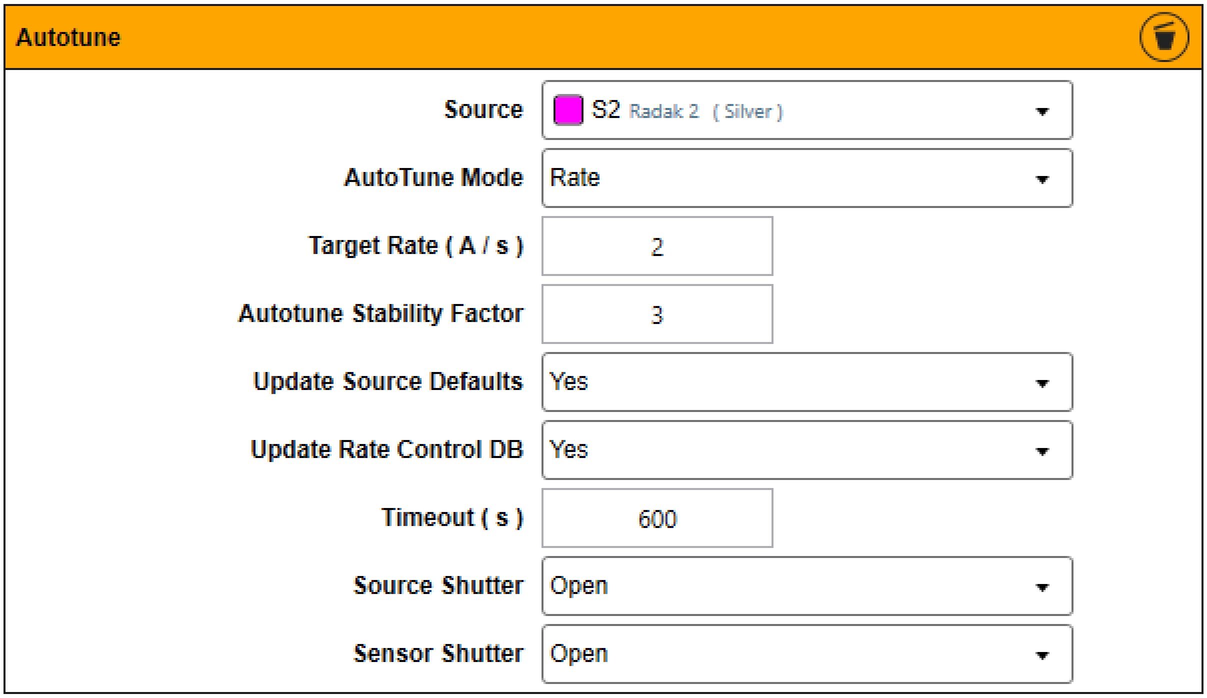
A PID loop is a feedback mechanism commonly used in industrial control systems. A PID loop continuously calculates an error value as the difference between a desired setpoint and a measured process variable. The P value accounts for present values of the error. For example, if the error is large and positive, the control output will also be large and positive. The I value accounts for past values of the error. For example, if the current output is not sufficiently strong, error will accumulate over time, and the controller will respond by applying a stronger action. The D value accounts for possible future values of the error, based on its current rate of change.

For a process to be controlled based on the rate reading from the quartz crystal sensor, the software needs to have PID values to minimize the deviation between the current rate and the target rate. PID values are used to drive the power to achieve control at a certain rate. The Aeres®software includes an autotuning feature that allows the system to generate the PID values automatically.

During the autotune action, the system drives the source power to the Max Power that was defined in the recipe (or rate control database) for that particular source until the rate overshoots the target by a certain amount. At this point, the power is set to 0% until the rate decreases below the target by a certain amount. During this time, the system observes the rate changes in response to the power and PID values are derived from it. The power on/power off is cycled two or three times and then the system will have PID values for that source. These PID values are saved to the source page and/or the rate control database if the options for updating them are selected, otherwise the PID values will be used for the current process only.

Autotune

Initiates a process to determine PID values for controlling a source at a specified rate or temperature.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Autotune Mode: Select to Autotune rate or temperature (only for Radak® sources).

Target Rate (Å/s): Enter the deposition rate to collect the PID values for.

Target Temperature (°C): Enter the temperature to collect the PID values for.

Autotune Stability Factor: Determines whether the tuning favors aggressiveness or stability in reaching and maintaining the desired setpoint. 1 is most aggressive, 10 is most stable. 3 is the default setting.

Update Default: Select if the new PID values will be written to the source as default PID values found on the Sources page.

Update Rate Control DB: Select if the new PID values will be written to the Rate Control Database entry selected in the Source Configuration. Typically, this is desired behavior.

Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions. This should be open to obtain proper rate values.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement. This should be open to obtain proper rate values.

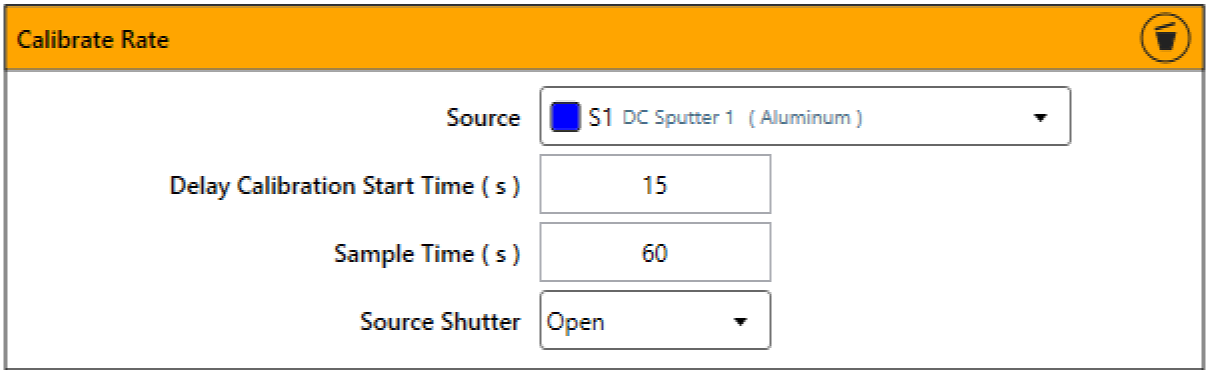
A PID loop is a feedback mechanism commonly used in industrial control systems. A PID loop continuously calculates an error value as the difference between a desired setpoint and a measured process variable. The P value accounts for present values of the error. For example, if the error is large and positive, the control output will also be large and positive. The I value accounts for past values of the error. For example, if the current output is not sufficiently strong, error will accumulate over time, and the controller will respond by applying a stronger action. The D value accounts for possible future values of the error, based on its current rate (or temperature) of change.

For a process to be controlled by the rate reading from the quartz crystal, or the temperature reading from the thermocouple, the software needs to have PID values to minimize the deviation between the current rate (or temperature) and the target rate (or temperature). PID values are used to drive the power to achieve control at a certain rate (or temperature). The Aeres® software includes an autotuning feature that allows the system to generate the PID values automatically.

During the autotune action, the system drives the source power to the Max Power that was defined in the recipe (or rate control database) for that particular source until the rate (or temperature) overshoots the target by a certain amount. At this point, the power is set to 0% until the rate (or temperature) decreases below the target by a certain amount. During this time, the system observes the rate (or temperature) changes in response to the power and PID values are derived from it. The power on/power off is cycled two or three times and then the system will have PID values for that source. These PID values are saved to the Sources page and/or the rate control database if the options for updating them are selected, otherwise the PID values will be used for the current process only.

Calibrate Rate

If the system is equipped with a swing-in calibration sensor, this action moves the sensor above the source and allows Aeres® to collect deposition rate data which can be used in a subsequent Deposit Calibrated Rate step. This action is typically used for sputtering sources. Substrate shutters should remain closed when executing this action.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

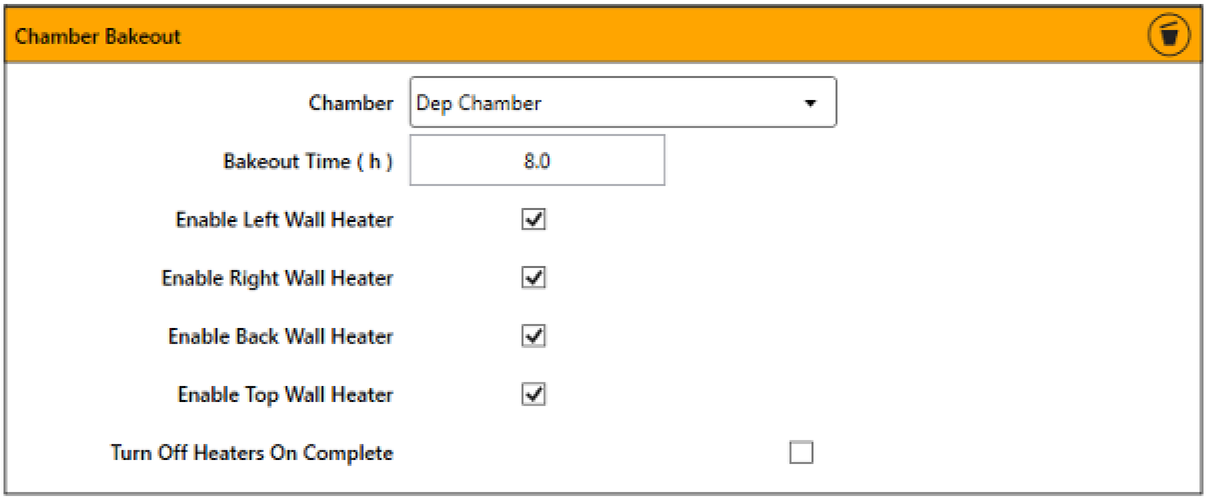
Delay Calibration Start Time (s): Adds a time delay before rate data is collected. Allows time for the swing-in sensor to move into position and rate data to stabilize.

Sample Time (s): Specifies the amount of time the deposition rate data will be collected. The average deposition rate during this time will be used in the Deposit Calibrated Rate action.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions. This should be open to collect an accurate rate measurement.

Chamber Bakeout

If the system is equipped with wall heaters, this action will run the heaters at a temperature set within the Aeres® Configurator for a specified amount of hours. This temperature is set to the safe-to-touch limits of the external chamber walls, typically 60 °C. This action is typically used to remove contaminants within the chamber or accelerate any out-gassing within the chamber to assist in reaching a vacuum pressure specification.



Chamber: Select the chamber to bakeout.

Bakeout Time (h): Duration of the bakeout in hours.

Enable Left Wall Heater: When selected, the left wall heater will be used during the chamber bakeout.

Enable Right Wall Heater: When selected, the right wall heater will be used during the chamber bakeout.

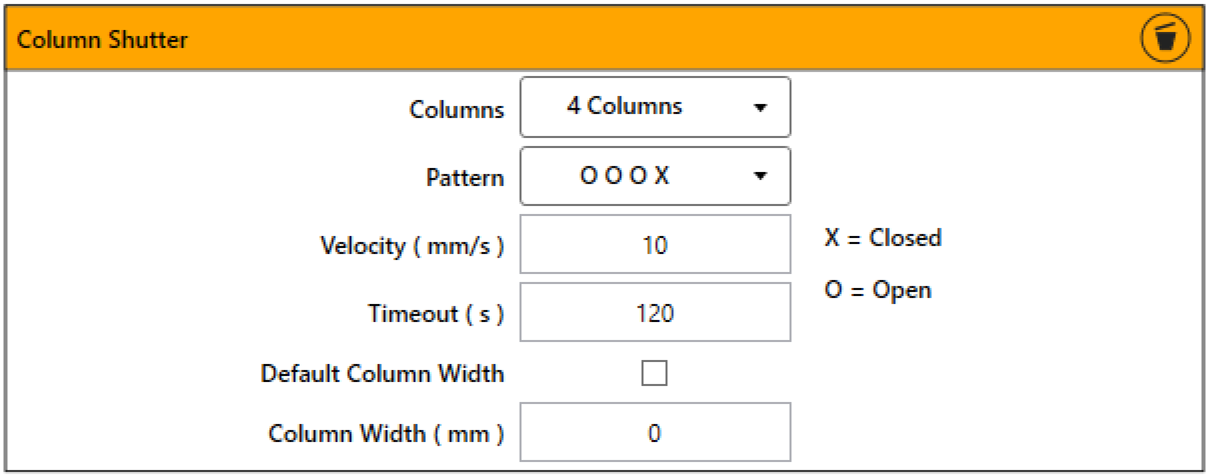
Enable Back Wall Heater: When selected, the back wall heater will be used during the chamber bakeout.

Enable Top Wall Heater: When selected, the top wall heater will be used during the chamber bakeout.

Turn Off Heaters On Complete: When selected, this will turn off the wall heaters once the bakeout time has elapsed. If this is not selected, the selected wall heaters will remain on until the process has completed.

Column Shutter

Moves the combinatorial/column shutters to form a selected pattern within the defined column width, moving at a defined velocity. This action is used to partially shutter the substrate holder/stage to deposit either a gradient film or selectively deposit certain areas of the substrate holder.



Columns: Defines the total number of columns to which the pattern is applied. This variable can be selected from a drop-down menu, with pre-defined options for the system.

Pattern: Defines the column pattern - the final position of the shutter blades are ultimately defined by the Pattern, Columns (number of columns), and Column Width. Pattern options can be selected from a drop-down menu and includes all permutations of a given number of columns. O = open/exposed, X = closed/shuttered.

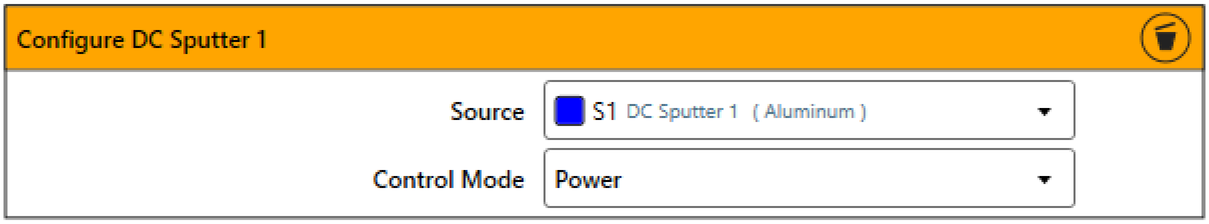
Velocity (mm/s): Defines the velocity of the shutter blades when moving to a selected pattern, in mm per second.

Timeout (s): Defines the time limit for the action to be executed. Shutter blades should reach their final position, as defined by Columns, Pattern and Column Width, before timeout is reached.

Default Column Width: Select to use the default column width as defined by the Total Width setpoint in the System > Setpoints section of Aeres®, or deselect to define a custom **Column Width**, in mm.

Configure DC Supply

On systems equipped with a DC power supply, this action configures the control parameters of the source. This action is required if using a DC sputter source later in the process.

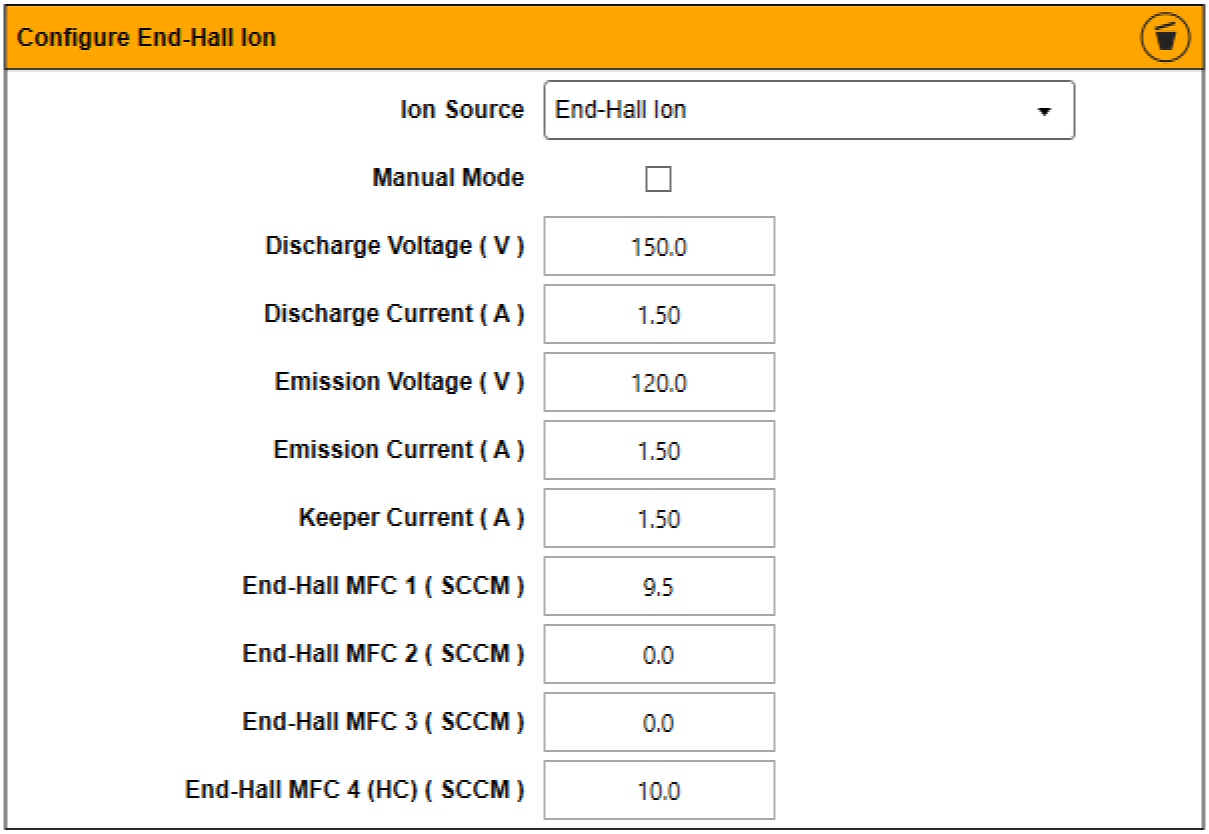


Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Control Mode: Selects whether the source is to be controlled by power, voltage, or current. For general sputtering processes, power should be selected.

Configure End-Hall HC Ion Source

If the system is equipped with an end-hall hollow cathode ion source, this action will configure the control parameters for ion assisted deposition, or ion etching processes. This action is required if an Enable Ion Source action is used later in the process.



Ion Source: Selects which ion source to configure within the chamber.

Manual Mode: When selected, this will fix all gas flow rates other than the hollow cathode gas flow. Used for reactive sputtering when the reactive gas is supplied from the ion source. Note that the discharge current will float in this mode.

Discharge Voltage (V): The voltage (in volts) provided to the anode of the end-hall ion source. This is directly related to the ion beam energy.

Discharge Current (A): The current (in amps) provided to the anode of the end-hall ion source. This is directly related to the ion beam current.

Emission Voltage (V): The voltage (in volts) provided to the hollow cathode after ignition to control the emitted electrons.

Emission Current (A): The emitted electron current (in amps) provided by the hollow cathode neutralizer.

Keeper Current (A): The current (in amps) that is provided to the hollow cathode source to ignite the hollow cathode.

End-Hall MFC 1 (SCCM): The gas flow rate for MFC channel 1 on the ion source controller.

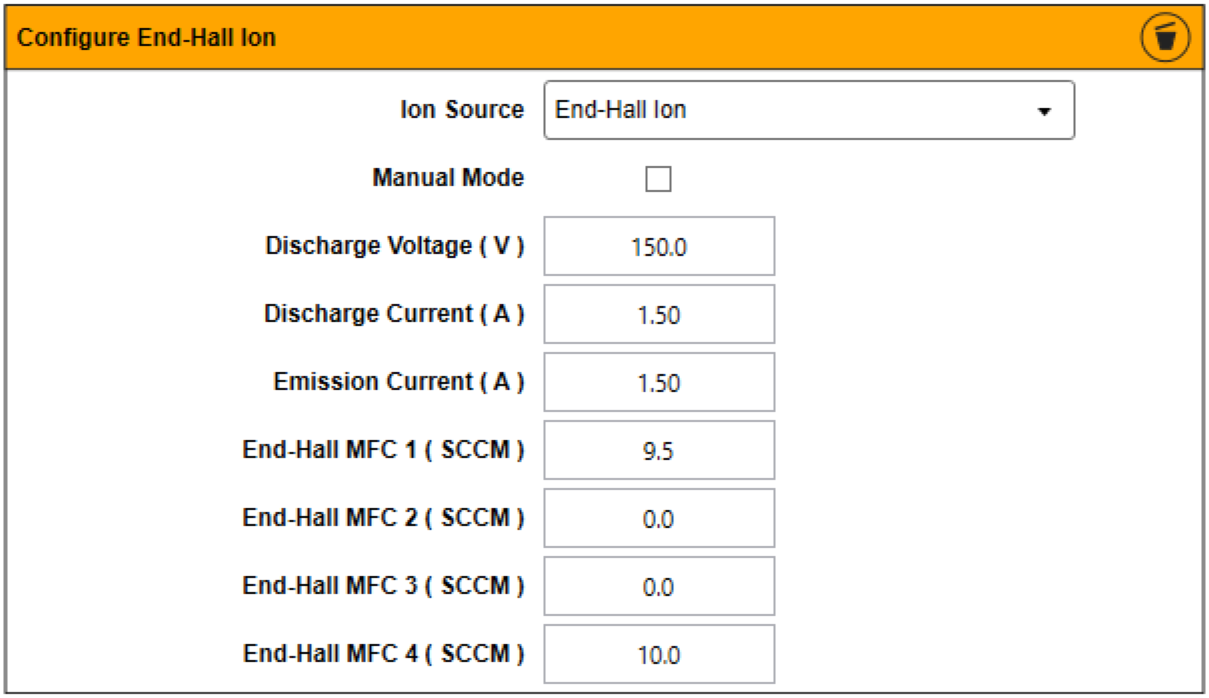
End-Hall MFC 2 (SCCM): The gas flow rate for MFC channel 2 on the ion source controller.

End-Hall MFC 3 (SCCM): The gas flow rate for MFC channel 3 on the ion source controller.

End-Hall MFC 4 (HC) (SCCM): The gas flow rate for MFC channel 4 on the ion source controller. This channel is reserved for the hollow cathode.

Configure End-Hall Ion Source

If the system is equipped with an end-hall ion source, this action will configure the control parameters for ion assisted deposition, or ion etching processes. This action is required if an Enable Ion Source action is used later in the process.



Ion Source: Selects which ion source to configure within the chamber.

Manual Mode: When selected, this will fix all gas flow rates other than the hollow cathode gas flow. Used for reactive sputtering when the reactive gas is supplied from the ion source. Note that the discharge current will float in this mode.

Discharge Voltage (V): The voltage (in volts) provided to the anode of the end-hall ion source. This is directly related to the ion beam energy.

Discharge Current (A): The current (in amps) provided to the anode of the end-hall ion source. This is directly related to the ion beam current.

Emission Current (A): The emitted electron current (in amps) provided by the neutralizer filament.

End-Hall MFC 1 (SCCM): The gas flow rate for MFC channel 1 on the ion source controller.

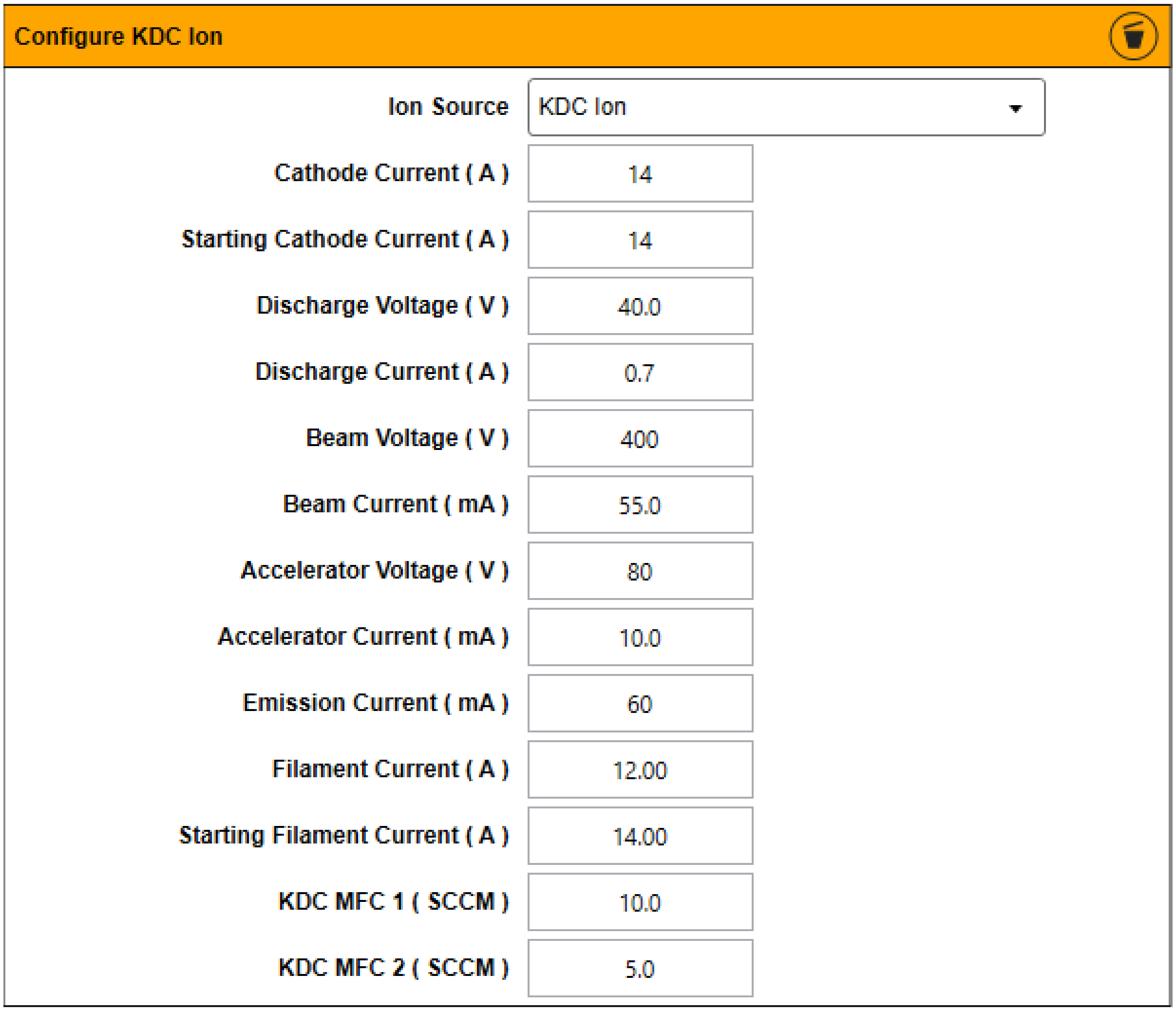
End-Hall MFC 2 (SCCM): The gas flow rate for MFC channel 2 on the ion source controller.

End-Hall MFC 3 (SCCM): The gas flow rate for MFC channel 3 on the ion source controller.

End-Hall MFC 4 (SCCM): The gas flow rate for MFC channel 4 on the ion source controller.

Configure KDC Ion Source

If the system is equipped with a KDC ion source, this action will configure the control parameters for ion assisted deposition, or ion etching processes. This action is required if an Ion Beam Discharge or Enable Ion Source action is used later in the process.



Ion Source: Selects which ion source to configure within the chamber.

Cathode Current (A): The current (in amps) provided to the cathode filament of the KDC ion source during the beam enable step.

Starting Cathode Current (A): The current (in amps) provided to the cathode filament of the KDC ion source during the discharge step.

Discharge Voltage (V): The voltage (in volts) provided to the discharge surface of the KDC ion source.

Discharge Current (A): The current (in amps) provided to the discharge surface of the KDC ion source.

Beam Voltage (V): The voltage (in volts) of the ion beam. This is directly related to ion beam energy.

Beam Current (mA): The current (in milliamps) of the ion beam.

Accelerator Voltage (V): The voltage (in volts) provided to the accelerator grid. This value must be set to a minimum of 20 percent of the beam voltage.

Accelerator Current (mA): The current (in milliamps) expected between the accelerator grids. This should be a low value (10s of mA). Higher values indicate shorting between the grids.

Emission Current (mA): The emitted electron current (in milliamps) provided by the neutralizer filament.

Filament Current (A): The current (in amps) provided to the neutralizer filament during the beam enable step.

Starting Filament Current (A): The current (in amps) provided to the neutralizer filament during the discharge step.

KDC MFC 1 (SCCM): The gas flow rate for MFC channel 1 on the ion source controller.

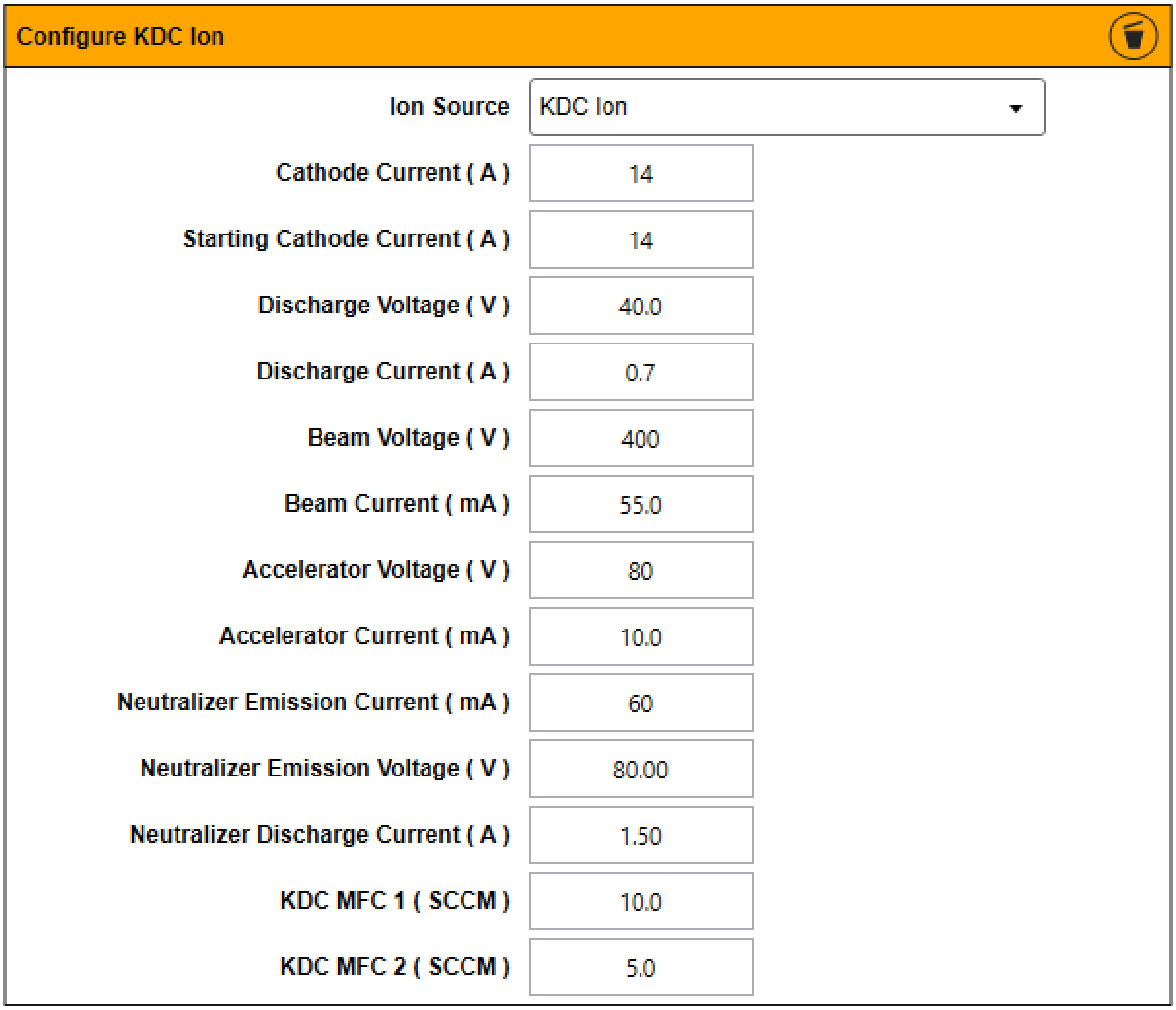
KDC MFC 2 (SCCM): The gas flow rate for MFC channel 2 on the ion source controller.

KDC MFC 3 (SCCM): The gas flow rate for MFC channel 3 on the ion source controller.

KDC MFC 4 (SCCM): The gas flow rate for MFC channel 4 on the ion source controller.

Configure KDC LFN Ion Source

If the system is equipped with a KDC LFN ion source, this action will configure the control parameters for ion assisted deposition, or ion etching processes. This action is required if an Ion Beam Discharge or Enable Ion Source action is used later in the process.



Ion Source: Selects which ion source to configure within the chamber.

Cathode Current (A): The current (in amps) provided to the cathode filament of the KDC ion source during the beam enable step.

Starting Cathode Current (A): The current (in amps) provided to the cathode filament of the KDC ion source during the discharge step.

Discharge Voltage (V): The voltage (in volts) provided to the discharge surface of the KDC ion source.

Discharge Current (A): The current (in amps) provided to the discharge surface of the KDC ion source.

Beam Voltage (V): The voltage (in volts) of the ion beam. This is directly related to ion beam energy.

Beam Current (mA): The current (in milliamps) of the ion beam.

Accelerator Voltage (V): The voltage (in volts) provided to the accelerator grid. This value must be set to a minimum of 20 percent of the beam voltage.

Accelerator Current (mA): The current (in milliamps) expected between the accelerator grids. This should be a low value (10s of mA). Higher values indicate shorting between the grids.

Neutralizer Emission Current (mA): The emitted electron current (in milliamps) provided by the LFN.

Neutralizer Emission Voltage (V): The voltage (in volts) provided to the LFN filament during the emission.

Neutralizer Discharge Current (A): The current (in amps) provided to the LFN filament during the emission.

KDC MFC 1 (SCCM): The gas flow rate for MFC channel 1 on the ion source controller.

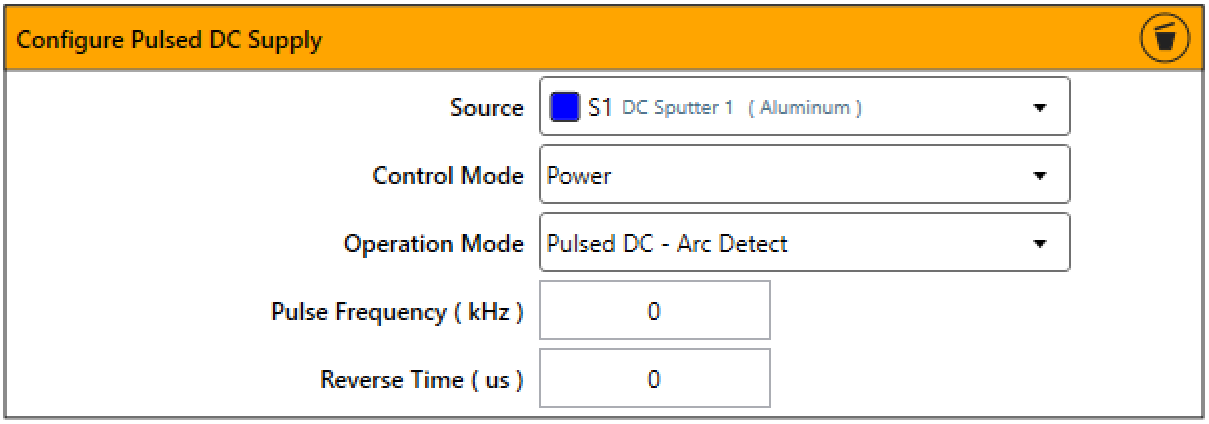
KDC MFC 2 (SCCM): The gas flow rate for MFC channel 2 on the ion source controller.

KDC MFC 3 (SCCM): The gas flow rate for MFC channel 3 on the ion source controller.

KDC MFC 4 (SCCM): The gas flow rate for MFC channel 4 on the ion source controller. MFC 4 is specifically dedicated for the LFN and must be used for all processes.

Configure Pulsed DC Supply

On systems equipped with a pulsed DC power supply, this action configures the control parameters of the power supply for sputtering processes. This action is required if using a pulsed DC sputter source later in the process.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Control Mode: Selects whether the source is to be controlled by power, voltage, or current. For general sputtering processes, power should be selected. For reactive sputtering processes, current should be selected.

Operation Mode: Configure the DC power supply to operate in pulsed DC or continuous DC mode. Additionally, the arc detection routine is selected.

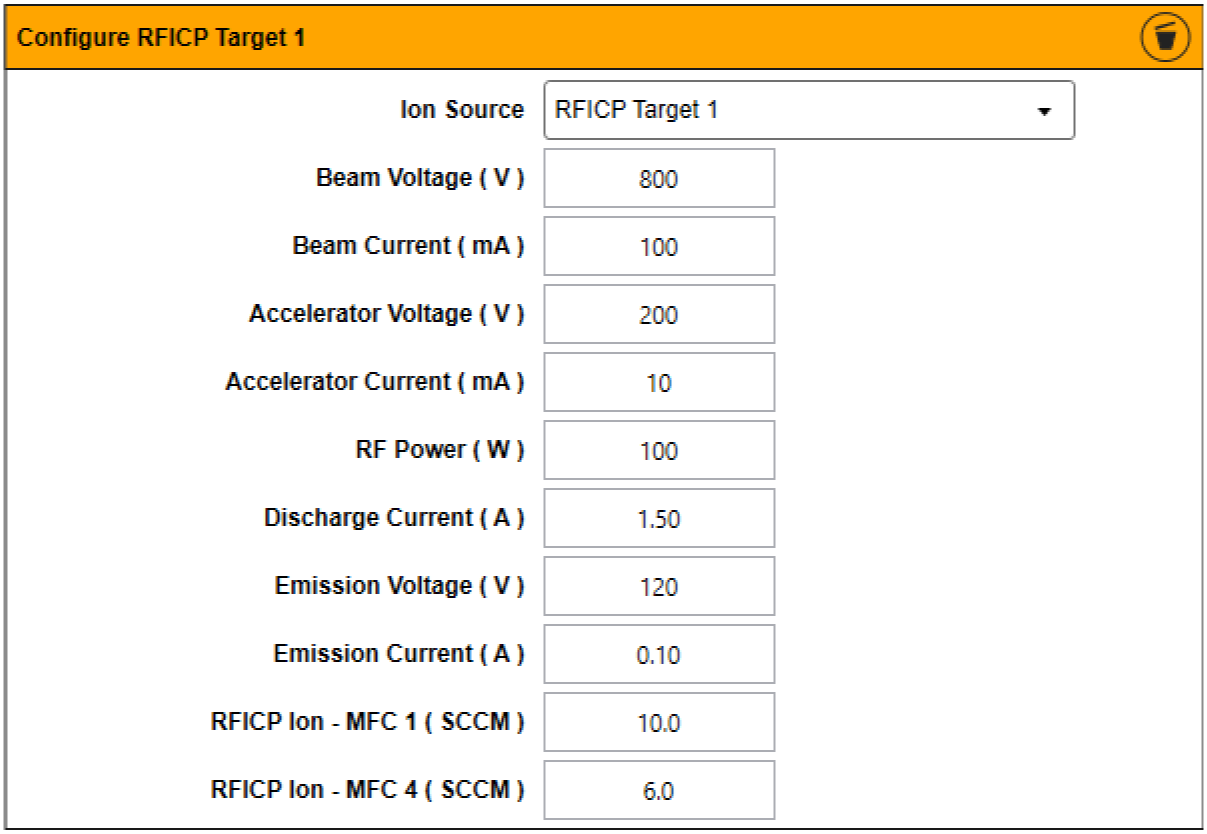
- **Arc Detect:** Arc quench engages only when a Hard Arc is detected (recommended).
- **Spark Detect:** Arc quench engages when a Hard Arc or a Spark is detected.

Pulse Frequency (kHz): Enter the frequency of pulses from the DC power supply (2 - 100 kHz). A recommended starting value is 20 kHz, adjust as needed.

Reverse Time (us): Enter the reverse pulse duration between pulses from the DC power supply (1 - 10 us). A recommended starting value is 3 us, adjust as needed.

Configure RFICP Ion Source

If the system is equipped with a RFICP ion source, this action will configure the control parameters for ion beam sputtering, or ion etching processes. This action is required if an Ion Beam Discharge or Enable Ion Source action is used later in the process.



Ion Source: Selects which ion source to configure within the chamber.

Beam Voltage (V): The voltage (in volts) of the ion beam. This is directly related to ion beam energy.

Beam Current (mA): The current (in milliamps) of the ion beam.

Accelerator Voltage (V): The voltage (in volts) provided to the accelerator grid. This value must be set to a minimum of 20 percent of the beam voltage.

Accelerator Current (mA): The current (in milliamps) expected between the accelerator grids. This should be a low value (10s of mA). Higher values indicate shorting between the grids.

RF Power (W): The starting RF power (in watts) for the discharge. This value is auto-regulated by the controller to provide the desired beam current.

Discharge Current (A): The current (in amps) provided to the LFN filament during the emission.

Emission Voltage (V): The voltage (in volts) provided to the LFN filament during the emission.

Emission Current (mA): The emitted electron current (in milliamps) provided by the LFN.

RFICP MFC 1 (SCCM): The gas flow rate for MFC channel 1 on the ion source controller.

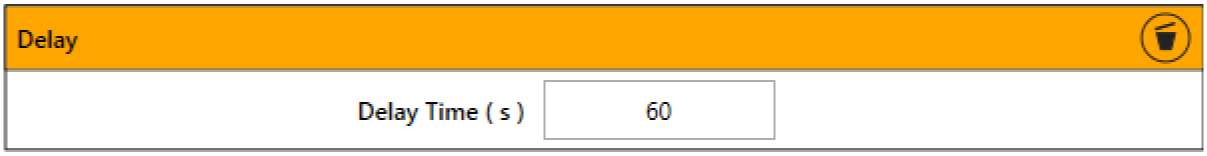
RFICP MFC 2 (SCCM): The gas flow rate for MFC channel 2 on the ion source controller.

RFICP MFC 3 (SCCM): The gas flow rate for MFC channel 3 on the ion source controller.

RFICP MFC 4 (SCCM): The gas flow rate for MFC channel 4 on the ion source controller. MFC 4 is specifically dedicated for the LFN and must be used for all processes.

Delay

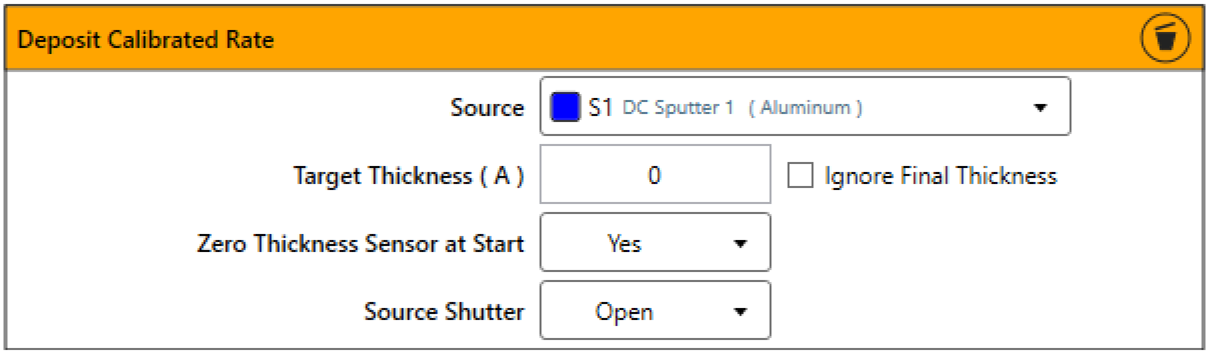
Adds a simple time delay to the process.



Delay Time (s): The length of time (in seconds) before the action is complete.

Deposit Calibrated Rate

When this recipe action is used after Calibrate Rate action, Aeres® will automatically adjust the deposition time based on the rate sampled previously to satisfy the thickness parameter.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Thickness (Å): The desired film thickness (in angstroms) required to complete the action.

Ignore Final Thickness: The source will maintain constant power for the duration of all other actions within the “Step”.

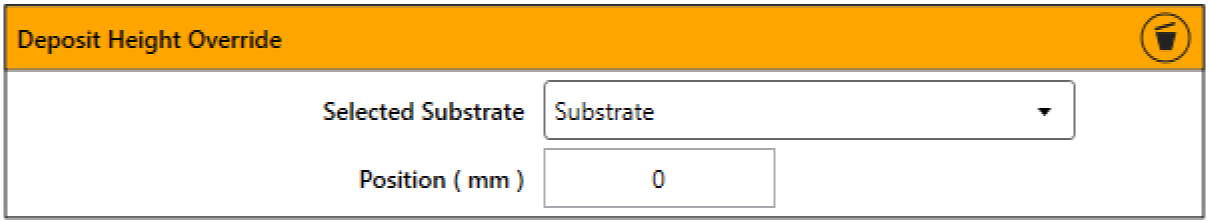
Zero Thickness Sensor at Start: If “Yes,” then the thickness accumulated on the sensor during the process up to this point will be reset to 0.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions. During deposit phases this should be open.

Deposit Height Override

Manually set the deposition height of the stage. Stage must be equipped with a Servo motor. Allows the user to go to a specified height rather than the default taught deposition height.

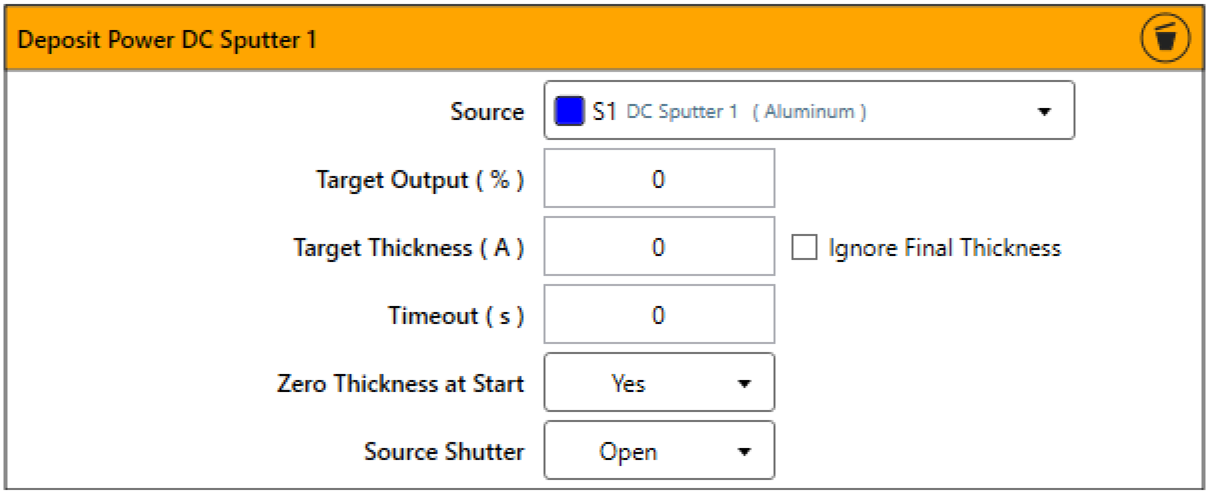
Note: This action does NOT move the stage, rather it updates the taught location for "Deposit Height" on the Servos > Z-Stage Servos page. The stage will only move to the defined position during the deposit phase once the substrate shutters have opened. This action MUST be added before the deposit phase.



Position (mm): The setpoint in millimeters for the servo stage position.

Deposit Power

The selected source will run at a constant power until a user specified thickness (or timeout) is reached. Substrate shutters should be open for this deposit action.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Power (%): The power setpoint that the system will maintain during the action. This is expressed as a percentage of the total output power available to the source.

Target Thickness (Å): The desired film thickness (in angstroms) required to complete the action.

Ignore Final Thickness: The source will maintain constant power for the duration of all other actions within the “Step”.

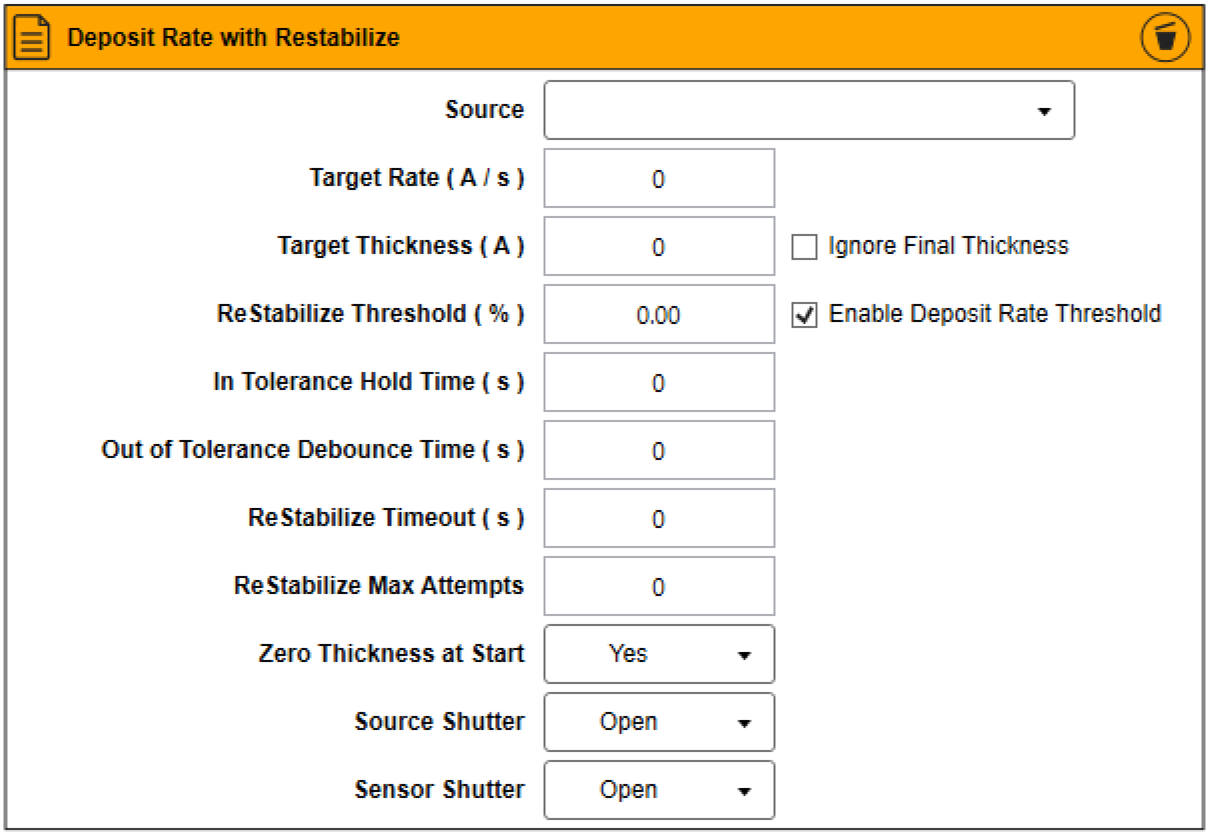
Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Zero Thickness at Start: If “Yes,” then the thickness accumulated on the sensor during the process up to this point will be reset to 0. This is recommended if the substrate has been shuttered from material up to this point. Selecting “No” means the thickness accumulated on the sensor thus far will be counted towards the Target Thickness parameter.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Deposit Rate with Restabilize

Power will be controlled to the source to maintain the target rate using the PID values loaded from the "Source Configuration" window. The action is completed once the target thickness has been reached. If the Target Rate falls outside of the ReStabilize Threshold, the substrate shutters will close until the rate is back within the threshold.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Rate (A/s): Enter the desired deposition rate.

Target Thickness (A): The desired film thickness (in angstroms) required to complete the action.

ReStabilize Threshold (%): The deposition rate tolerance expressed as a +/- percent deviation of the Target Rate. If the deposition rate falls outside of this threshold, the substrate shutters will close until the rate is back within the threshold, and the In Tolerance Hold Time has elapsed.

In Tolerance Hold Time (s): The amount of time to hold within the ReStabilize Threshold before re-opening the substrate shutters and continuing the deposition.

Out of Tolerance Debounce Time (s): The specified time before closing the substrate shutters and attempting to restabilize if the rate falls outside of the ReStabilize Threshold.

ReStabilize Timeout (s): The maximum amount of time (in seconds) for the rate to restabilize. If the rate does not restabilize within this time, the process will fault.

ReStabilize Max Attempts: The total number of attempts the rate will try and restabilize. If the rate falls outside of the ReStabilize Threshold more than the allowed attempts, the process will fault.

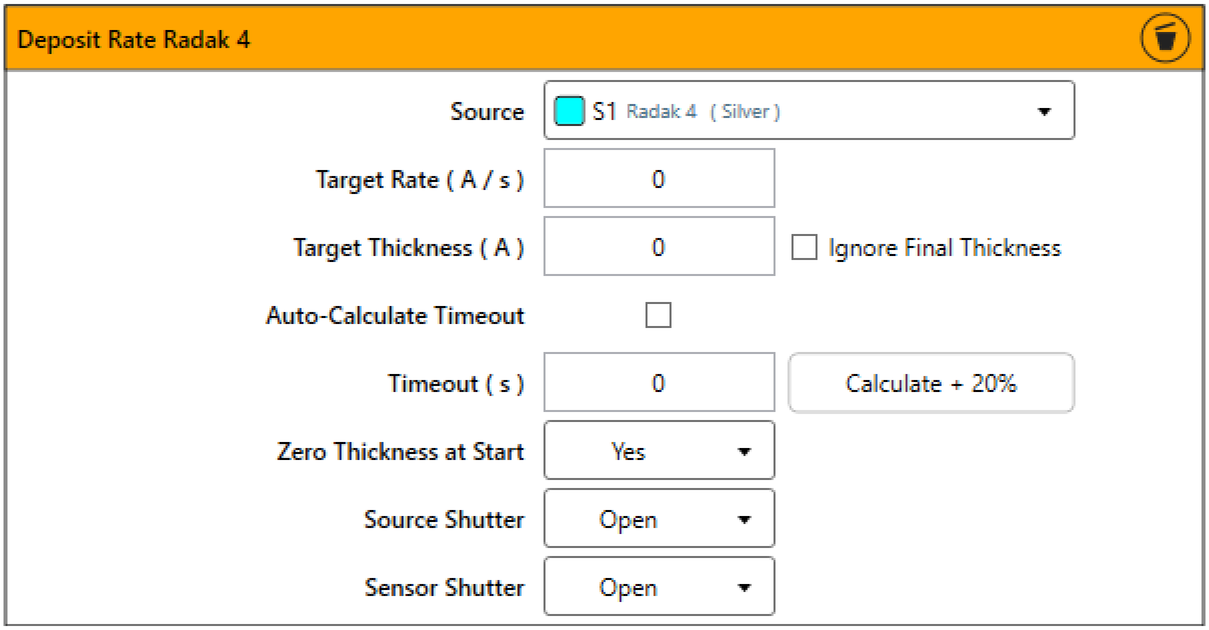
Zero Thickness at Start: If "Yes," then the thickness accumulated on the sensor during the process up to this point will be reset to 0. This is recommended if the substrate has been shuttered from material up to this point. Selecting "No" means the thickness accumulated on the sensor thus far will be counted towards the Target Thickness parameter.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close. This should be open for deposit actions. This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement. This should be open to obtain an accurate thickness measurement.

Deposit Rate

Power will be controlled to the source to maintain the target rate using the PID values loaded from the "Source Configuration" window. The action is completed once the target thickness has been reached.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Rate (Å/s): Enter the desired rate to deposit at.

Target Thickness (Å): The desired film thickness (in angstroms) required to complete the action.

Ignore Final Thickness: The source will maintain constant rate for the duration of all other actions within the "Step".

Auto-Calculate Timeout: Checking the box will automatically adjust the timeout to be 20% longer than estimated.

Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Calculate + 20%: Adds 20% onto the expected duration of the deposition based on the target thickness and rate.

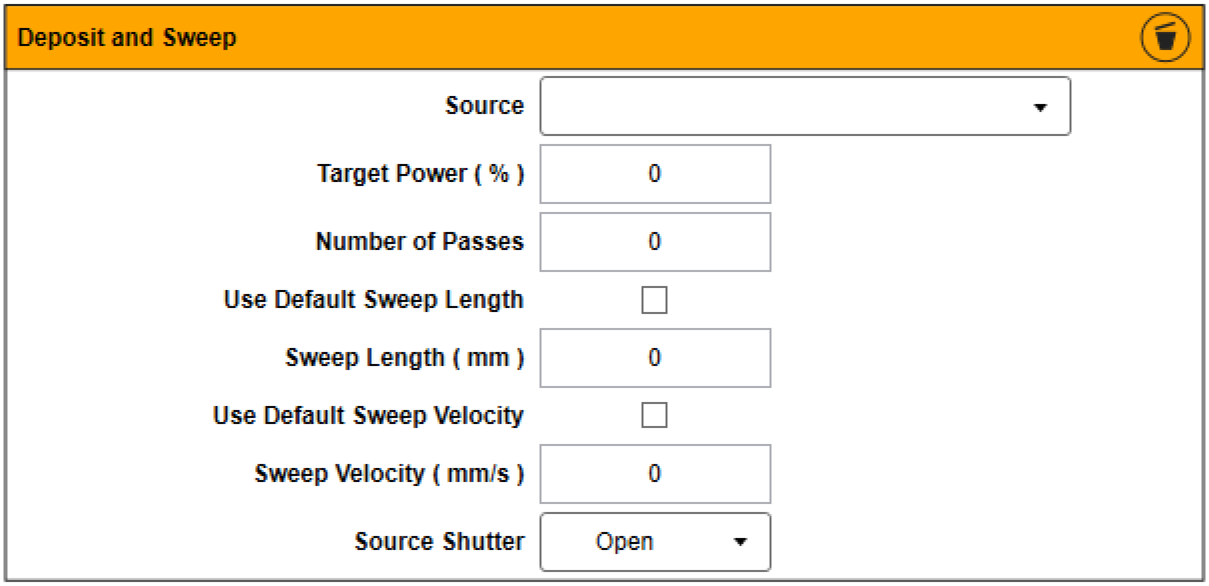
Zero Thickness at Start: If “Yes,” then the thickness accumulated on the sensor during the process up to this point will be reset to 0. This is recommended if the substrate has been shuttered from material up to this point. Selecting “No” means the thickness accumulated on the sensor thus far will be counted towards the Target Thickness parameter.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions. This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement. This should be open to obtain an accurate thickness measurement.

Deposit and Sweep

This action is specific to systems equipped with a linear sputter chamber where the substrate raster scans (sweeps) over the sputter source during deposition.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Power (%): The power setpoint that the system will maintain during the action. This is expressed as a percentage of the total output power available to the source.

Number of Passes: Defines the total number of sweeps the substrate holder will perform during the action.

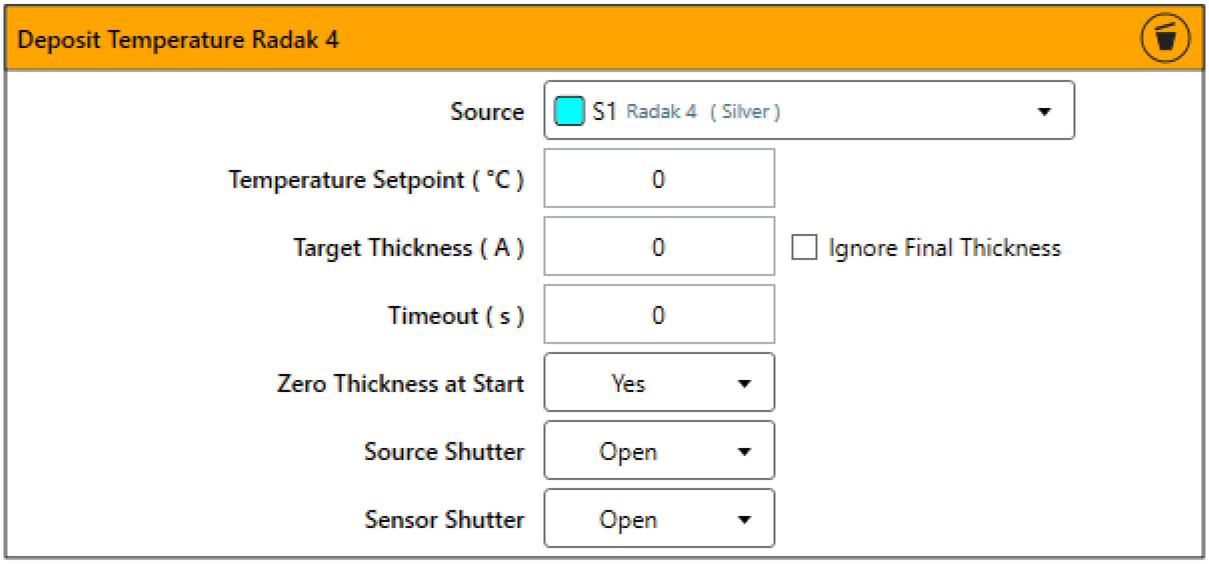
Use Default Sweep Length: When selected, the sweep length will be defined using the default value from the Linear Sputter Setpoints page. If unselected, the **Sweep Length (mm)** will be input and defined directly in the action.

Use Default Sweep Velocity: When selected, the sweep velocity will be defined using the default value from the Linear Sputter Setpoints page. If unselected, the **Sweep Velocity (mm/s)** will be input and defined directly in the action.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Deposit Temperature

The selected source will maintain the temperature setpoint until the thickness condition (or timeout) is reached. This action is suitable for sources that have temperature feedback (e.g. Radak® sources). Often used for evaporating organics that are sensitive to temperature. Substrate shutters should be open for deposit phases.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Temperature Setpoint (°C): The temperature in degrees Celsius that the source will maintain. The source will use the PID values loaded from the Rate Control database that were obtained from the Autotune (temperature) action.

Target Thickness (Å): The desired film thickness (in angstroms) required to complete the action.

Ignore Final Thickness: The source will maintain constant temperature for the duration of all other actions within the “Step”.

Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Zero Thickness at Start: If “Yes,” then the thickness accumulated on the sensor during the process up to this point will be reset to 0. This is recommended if the substrate has been shuttered from material up to this point. Selecting “No” means the thickness accumulated on the sensor thus far will be counted towards the Target Thickness parameter.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

EBeam Sweep Override

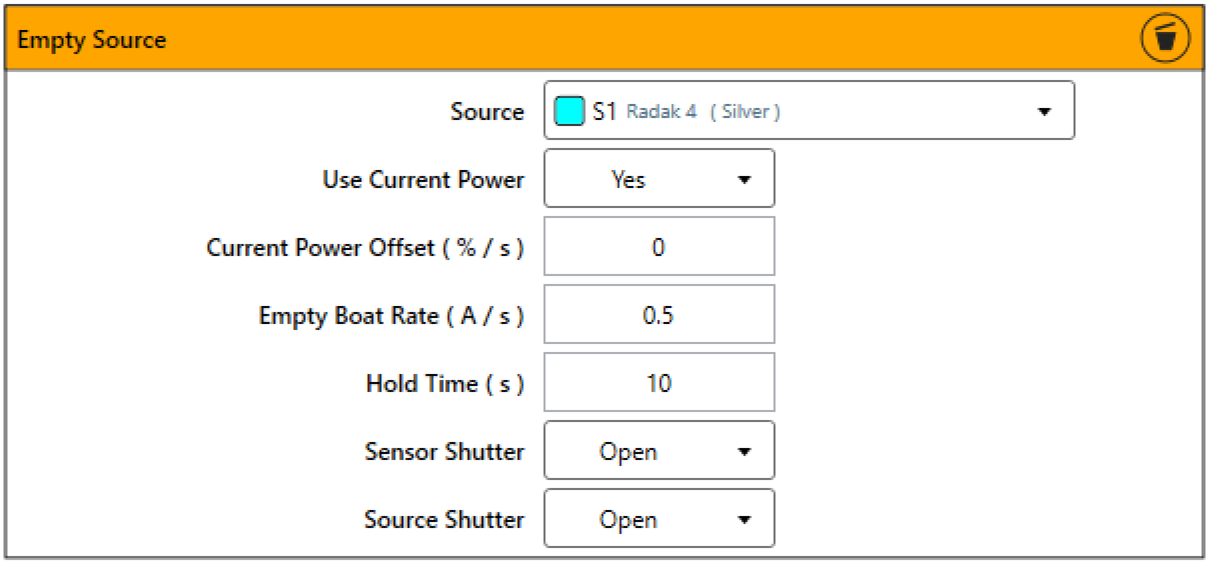
Allows user to change the sweep pattern that was configured in the "Components > Source" section of the recipe for the eBeam source. Once this action is reached in the process, the Sweep Controller will change the sweep pattern to the new sweep pattern number selected.

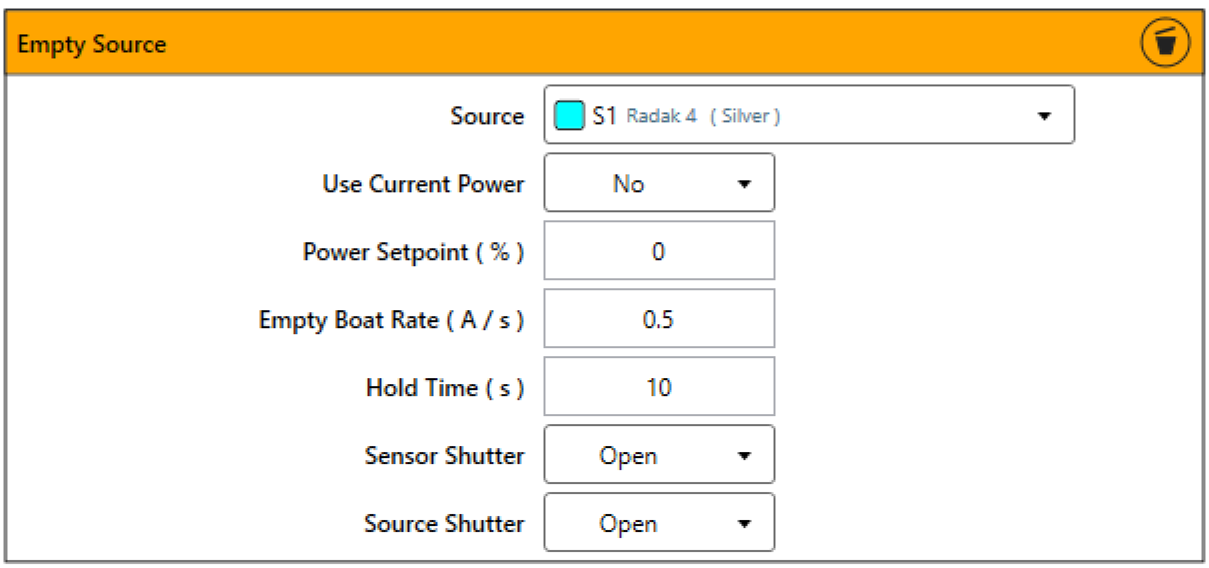
Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Selected Sweep: This number corresponds with the pattern number on the sweep controller.

Empty Source

Used to evaporate remaining material from a Resistive or Radak® source. Maintains a fixed power until the measured rate falls below the user setpoint. Substrate shutters should be closed during this action.





Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Use Current Power: Selecting "Yes" will maintain the last power setting. Selecting "No" allows user to enter a desired power setpoint.

Current Power Offset (If Yes): Input a power offset value to be applied on the last power setting.

Power Setpoint (If No): Input the desired fixed power setpoint for the source to maintain. Expressed as a percentage of total output power available to the source.

Empty Boat Rate (A/s): The measured rate below which the source is considered empty. If reached the action will be considered complete.

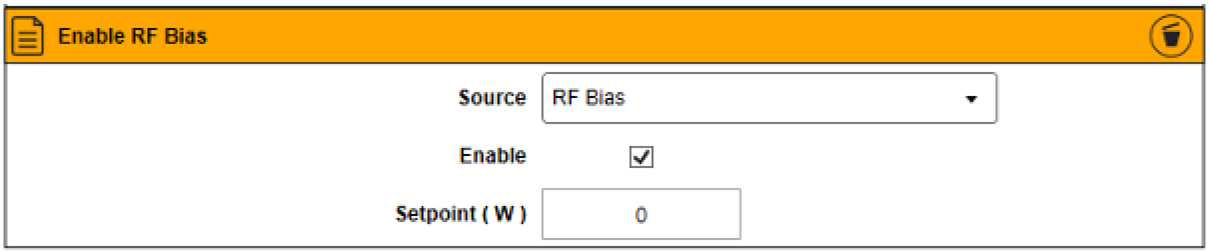
Hold Time: The amount of time the system will maintain the target value before completing the action.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Enable Plasma Source

Used to enable or disable a plasma source within the chamber, and set the source to a specified power.



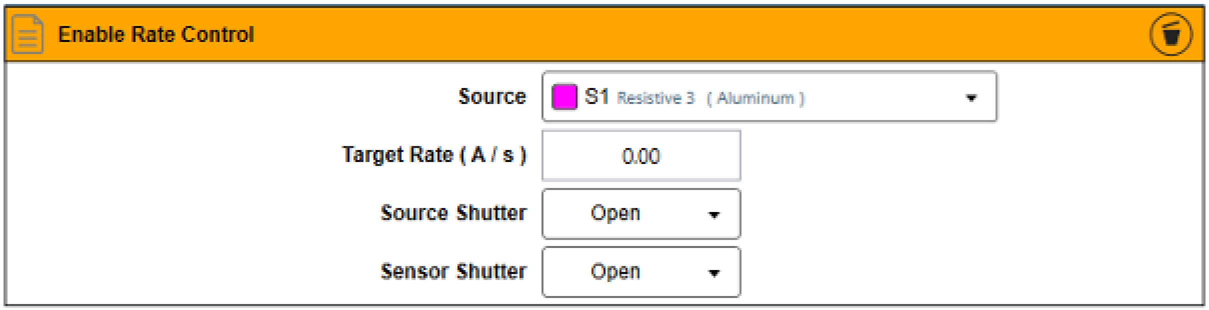
Source: Selects the source for this action.

Enable: If selected, the plasma source will be enabled. If unselected, the plasma source will turn off.

Setpoint (W): The power of the plasma source during operation (in Watts).

Enable Rate Control

Used to hold a source at a target rate.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

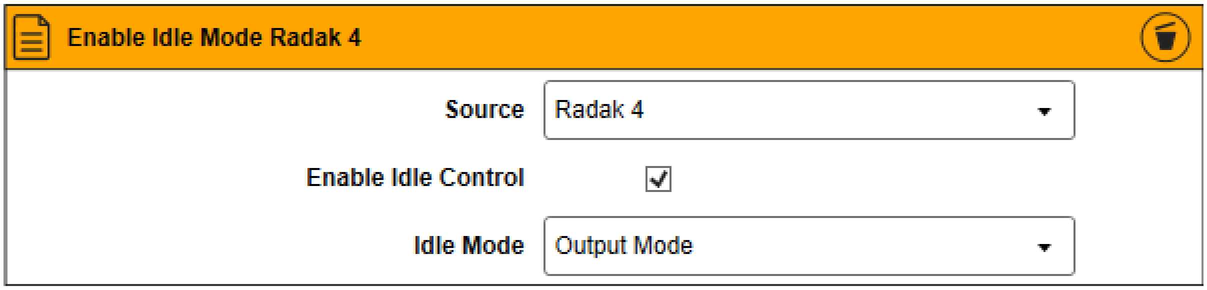
Target Rate (A/s): The rate at which the source will be held.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close. This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Enable Source Idle

Enable or disable a source in Idle Temperature or Idle Power mode. The source does not need to be added to the "Components > Source" section in the recipe editor to appear in the drop down list as long as it has idle control capability. The idle parameters from the “System > Sources” page will be used.



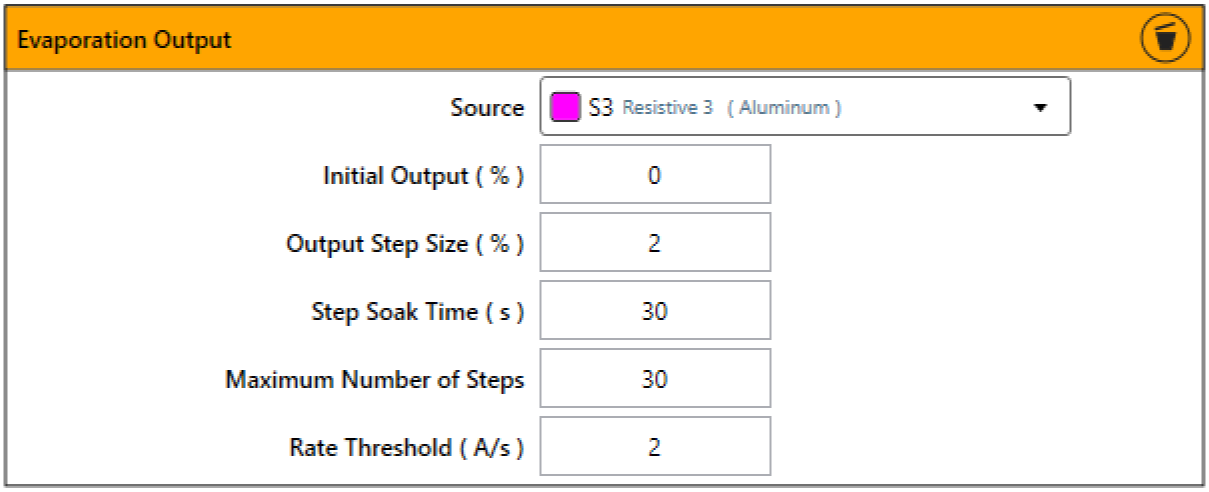
Source: Selects the source for this action.

Enable Idle Control: If selected, idle control will be enabled using the selected mode in the “Idle Mode” drop down list.

Idle Mode: Choose either Temperature Mode or Output Mode. The options available depend on the source type.

Evaporation Output

Operates a selected source beginning at a set initial output power, increasing the output by a defined step size value for a defined soak time (per step), until a threshold rate is achieved or the maximum number of steps has been exceeded. This action is used to determine the percent of total available output power at which a material begins to evaporate.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Initial Output (%): Defines the initial output power to be applied to the selected source, expressed as a percentage of the total output power available to the source.

Output Step Size (%): Defines the incremental step in output power to be applied to the selected source, expressed as a percentage of the total output power available to the source.

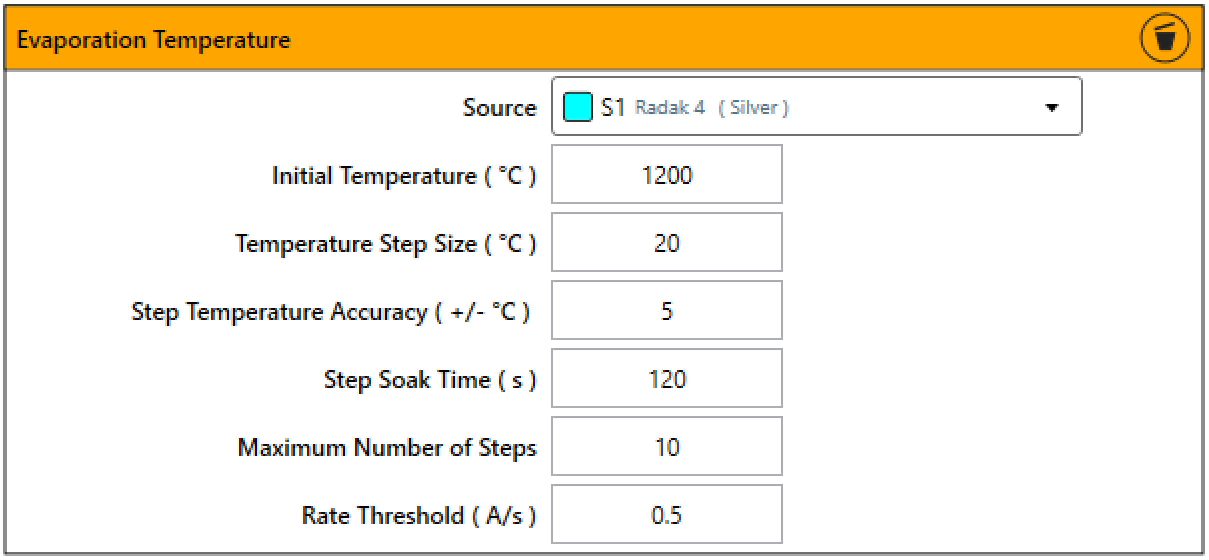
Step Soak Time (s): Defines the amount of time to hold the output power at a static value for each increment (step) in output, in seconds (s).

Maximum Number of Steps: The maximum number of steps allowed. If the rate does not reach the threshold within the maximum allotted steps, the process will fault after the final soak period.

Rate Threshold (Å/s): The target rate threshold for the action, in angstroms per second (Å/s). The action will be completed when this threshold is reached.

Evaporation Temperature

Operates a selected Radak® source beginning at a set initial temperature, increasing the temperature by a defined step size value until a threshold rate is achieved or the maximum number of steps has been exceeded. This action is used to determine the temperature at which a material begins to evaporate.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list. This action can only be used with Radak® sources (e.g. sources with temperature feedback).

Initial Temperature (°C): Defines the initial temperature to be applied to the selected source, in units of degrees Celsius.

Temperature Step Size (°C): Defines the incremental step in temperature to be applied to the selected source, in units of degrees Celsius.

Step Temperature Accuracy (+/- °C): Defines the accuracy window for each increment (step) in temperature, in degrees Celsius. A step is considered to have reached its target when temperature is within the window bound by the +/- accuracy that is defined.

Step Soak Time (s): Defines the amount of time to hold the temperature at each increment (within the bounds of the +/- accuracy defined), in seconds.

Maximum Number of Steps: The maximum number of steps allowed. If the rate does not reach the threshold within the maximum allotted steps, the process will fault after the final soak period.

Rate Threshold (Å/s): The target rate threshold for the action, in angstroms per second (Å/s). The action will be completed when this threshold is reached.

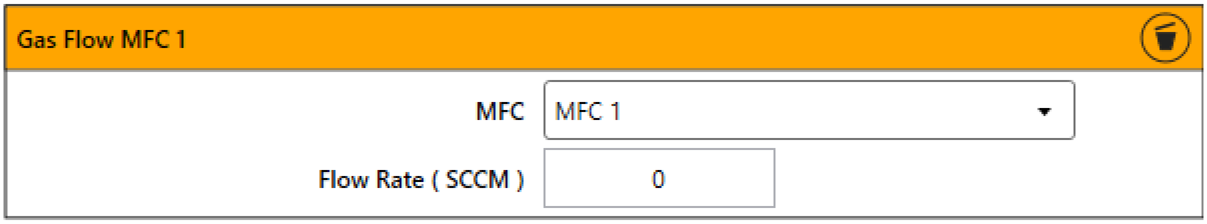
Execute Subroutine

When subroutines are enabled in Aeres®, this action will allow the user to jump to a specific subroutine during a recipe. See Subroutines section for more details.

Subroutine Name: The name of the subroutine to execute.

Gas Flow

Flows gas into the chamber at a user specified flow setpoint. System must be equipped with an MFC.



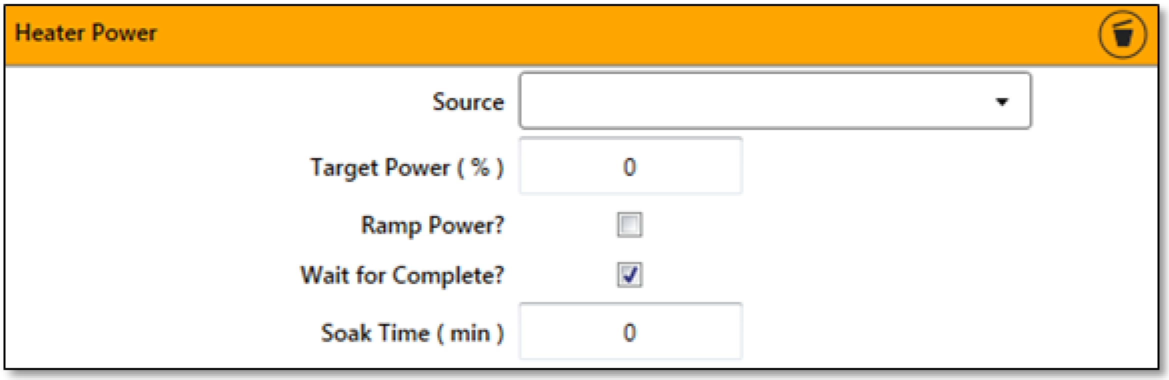
MFC: Select the MFC to flow gas from. MFC must first be added in the Components > Pressure Control section of the recipe.

Flow Rate: Specify the desired flow rate of process gas.

Heater Power

Note: This is a legacy action. Refer to "Heating & Cooling Power Control" for the newest action.

Sets the substrate heater to a fixed power for the remainder of the layer.



Source: Selects the heater for this action.

Target Power (%): The power setpoint that the system will maintain during the action. This is expressed as a percentage of the total output power available to the source.

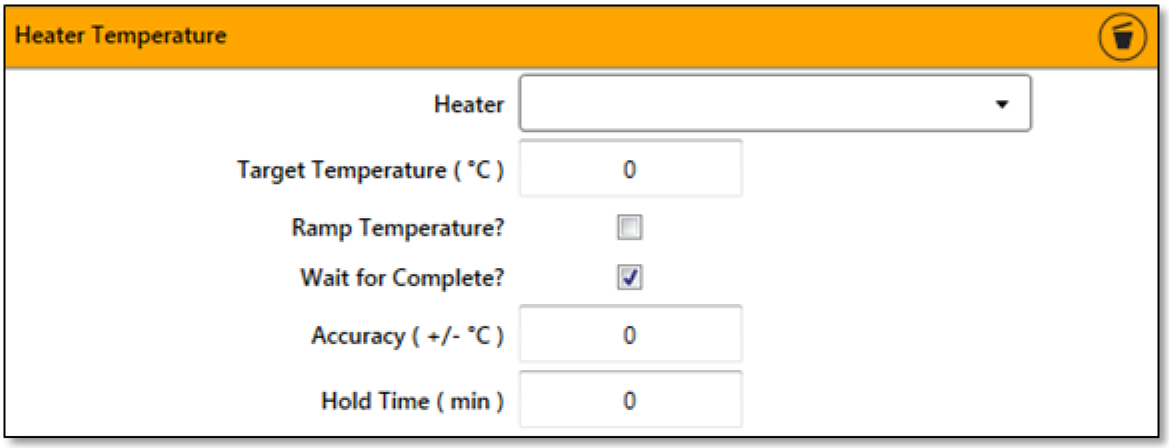
Ramp Power?: If selected, the user can define a ramp rate to achieve the selected target power.

Wait for Complete?: If selected, **Soak Time (min)** will become an available field. The action will complete when the selected power is achieved and the soak time has elapsed. Otherwise, the heater will continue to operate at its target power until the process is complete.

Heater Temperature

Note: This is a legacy action. Refer to “Heating & Cooling Temperature Control” for the newest action.

Sets the substrate heater to a fixed temperature for the remainder of the process.



Heater: Selects the heater for this action.

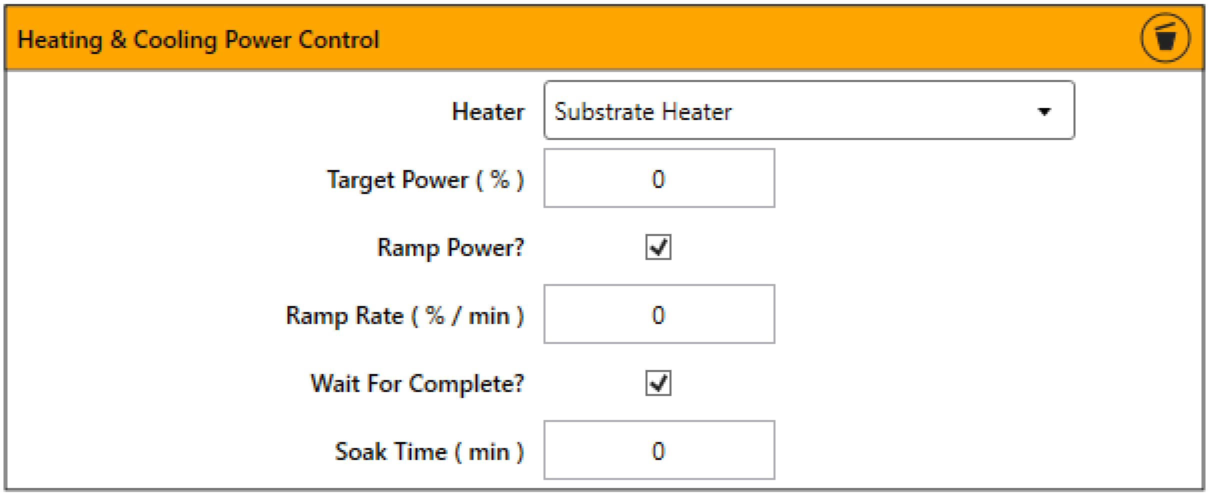
Target Temperature (°C): The temperature in degrees Celsius that the heater will maintain.

Ramp Temperature?: If selected, the user can define the ramp rate to achieve the selected target temperature.

Wait for Complete?: If selected, **Accuracy (+/- °C)** and **Hold Time (min)** will become available fields. The action will complete when the selected temperature is maintained within the defined accuracy for the set hold time. Afterwards, the heater will continue to operate at its target temperature until the process is complete.

Heating & Cooling Power Control

Applies a constant output power to the selected heater. Power is expressed as a percentage of the total available power. This action can be used for substrate heater elements, but should not be used for fluid cooled substrates.



Heater: Selects the heater for this action.

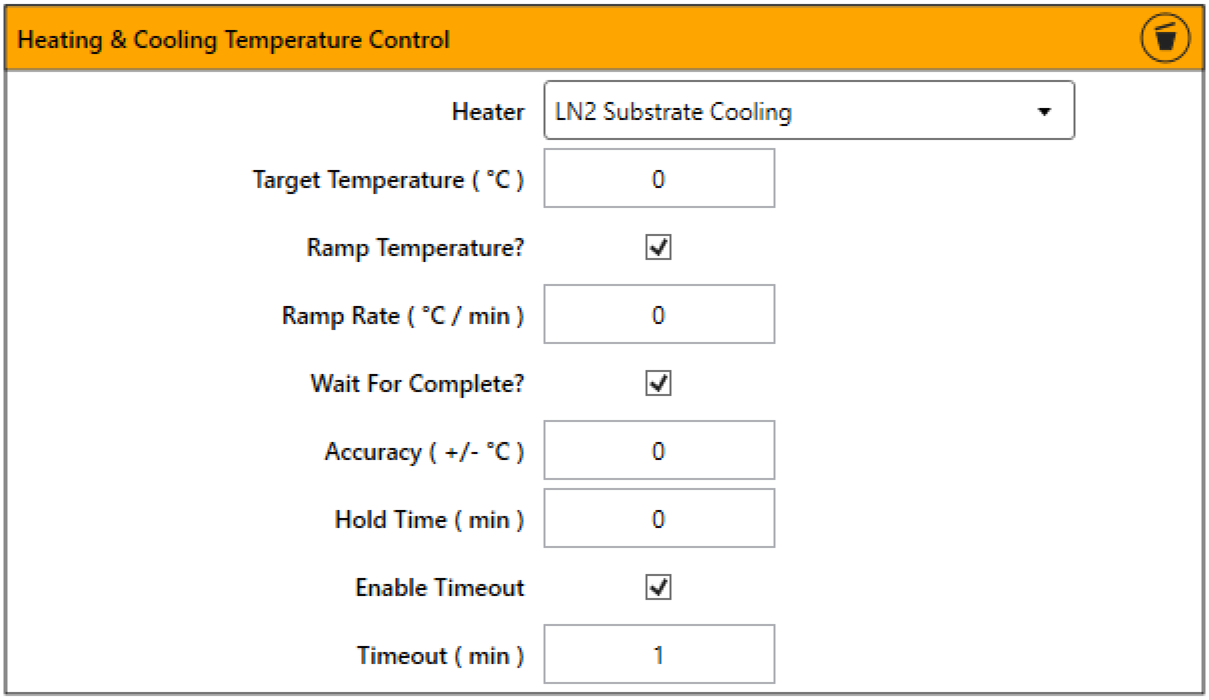
Target Power (%): The power setpoint that the system will maintain during the action. This is expressed as a percentage of the total output power available to the source.

Ramp Power?: If selected, the user can define a ramp rate to achieve the selected target power.

Wait for Complete?: If selected, **Soak Time (min)** will become an available field. The action will complete when the selected power is achieved and the soak time has elapsed. Otherwise, the heater will continue to operate at its target power until the process is complete.

Heating & Cooling Temperature Control

The system will control the selected Heater to achieve the specified temperature. Can be used for heaters or fluid cooled stages with temperature feedback.



Heater: Selects the heater for this action.

Target Temperature (°C): The temperature in degrees Celsius that the heater will maintain.

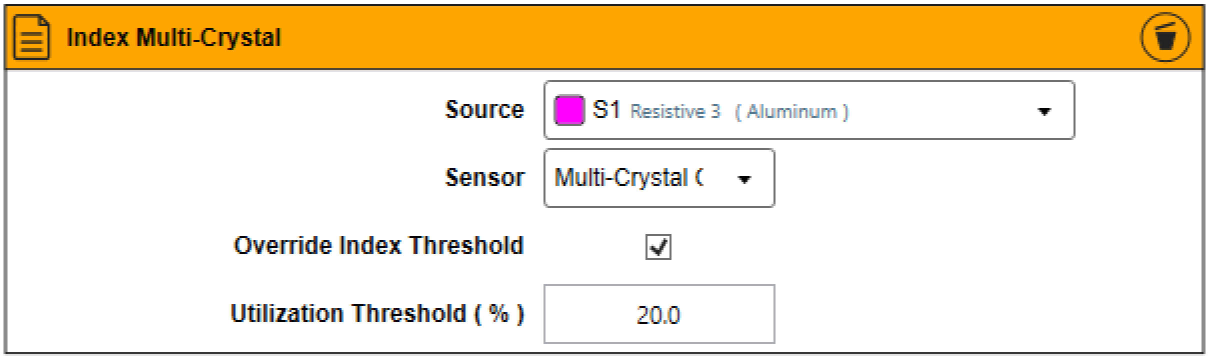
Ramp Temperature?: If selected, the user can define the **Ramp Rate (°C/min)** to achieve the selected target temperature. Not applicable for fluid cooled substrates.

Wait for Complete?: If selected, **Accuracy (+/- °C)** and **Hold Time (min)** will become available fields. The action will complete when the selected temperature is maintained within the defined accuracy for the set hold time. Otherwise, the heater will continue to operate at its target temperature until the process is complete.

Enable Timeout: If selected, a **Timeout (min)** parameter can be applied. If the system is unable to reach the Target Temperature range within this time, then the process will fault.

Index Multi-Crystal

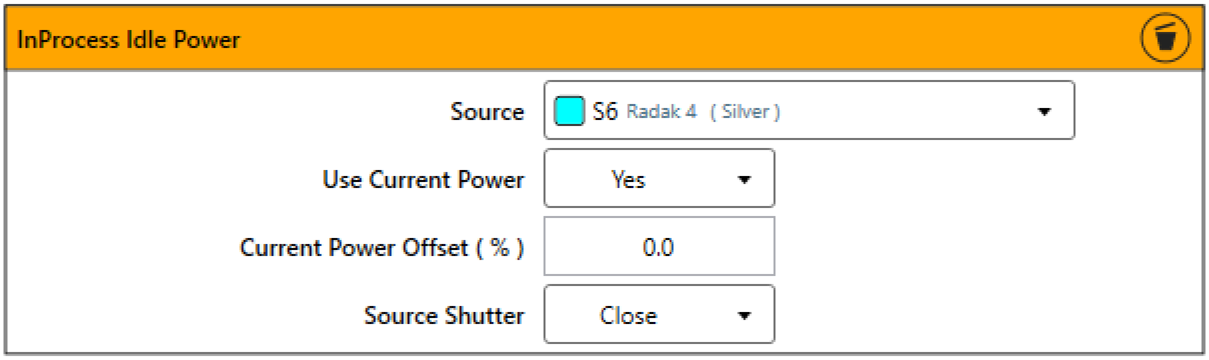
The system will index to the next crystal on a rotary Multi-Crystal QCM sensor.

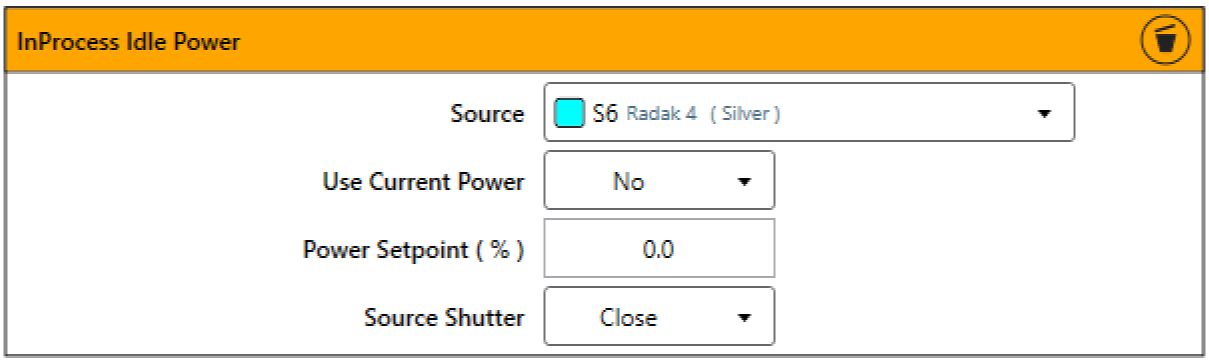


Sensor: Selects the QCM sensor that should be indexed. Note that it must be a Multi-Crystal QCM sensor.

InProcess Idle Power

Applies a fixed power setpoint to the selected source for the remainder of the process.





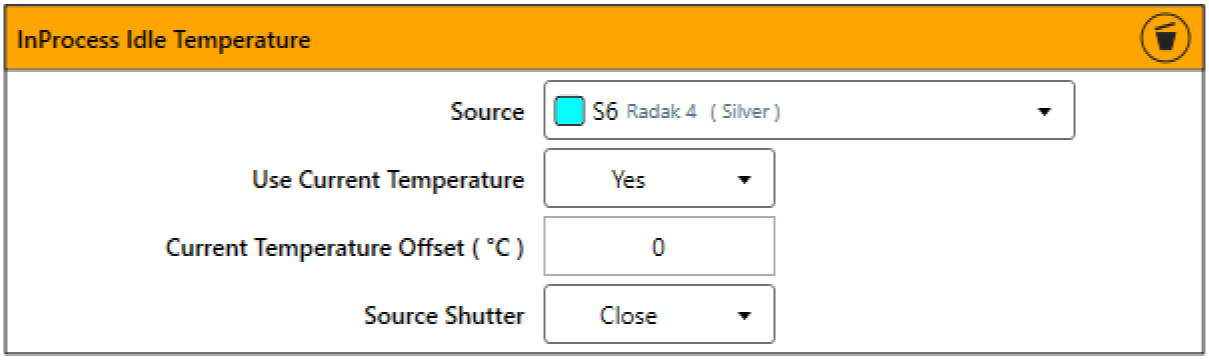
Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

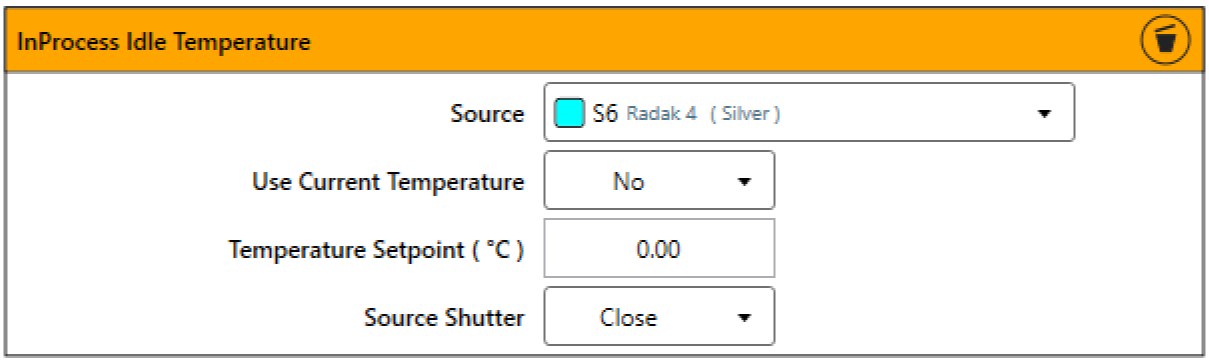
Use Current Power: Selects if the power currently applied to the source is used for this action. If "Yes", then a **Current Power Offset (%)** can be applied. If "No", a **Power Setpoint (%)** can be entered to set the Idle Power.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.

InProcess Idle Temperature

Applies a fixed temperature setpoint to the selected source for the remainder of the process.





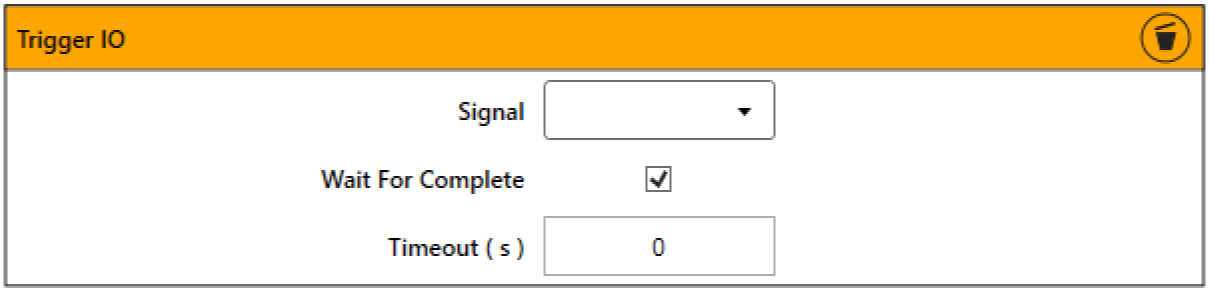
Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Use Current Temperature: Selects if the current temperature of the source is used for this action. If "Yes", then a **Current Temperature Offset (°C)** can be applied. If "No", a **Temperature Setpoint (°C)** can be entered to set the Idle Temperature.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.

Trigger

This recipe action will trigger unique system features such as raising and lowering non-servo z-stages.



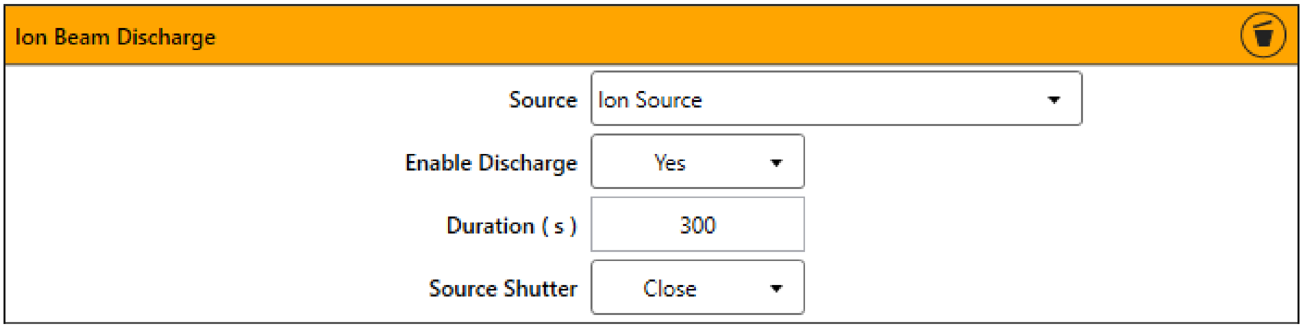
Signal: Selects an action to be initiated.

Wait for Complete: If selected, a **Timeout (s)** can be defined. This recipe step will wait until the triggered action is complete before moving to the next step. If unselected, the recipe will proceed to the next step without waiting for the triggered action to complete.

Timeout (s): The maximum duration (in seconds) that this action will run if Wait for Complete is selected. If this time has elapsed, the process will fault.

Ion Beam Discharge

This recipe action will turn on or off the discharge of a gridded ion source that has been configured in the recipe.



Source: Selects the source for this action.

Enable Discharge: If "Yes," this recipe action will turn on the ion source discharge. If "No," this recipe action will turn off the ion source discharge.

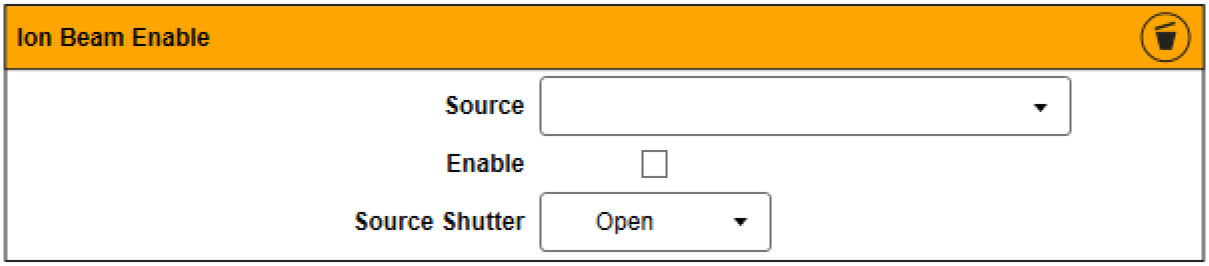
Duration (s): The amount of time (in seconds) the discharge will run.

Source Shutter: Select whether the source shutter (if equipped) needs to open or close.

Ion Beam Enable

Note: This is a legacy action. Refer to “Enable Ion Source” for the newest action.

This recipe action will enable the beam of the ion source that is selected within the action. A "Configure Ion Source" recipe action must be used in a prior step to set the parameters that the ion source will use during the recipe. Typically, an "Ion Beam Discharge" action is also required to ignite the source prior to enabling the beam.



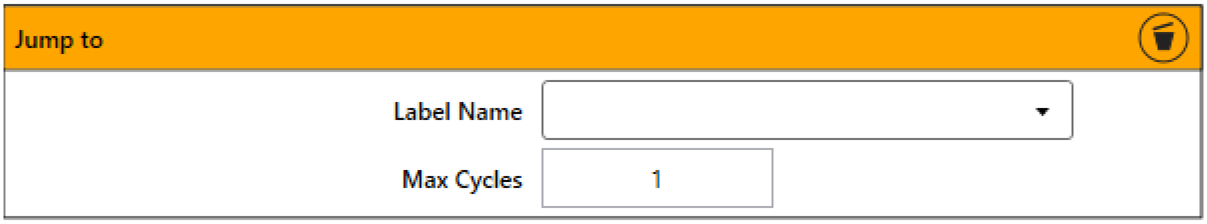
Ion Source: Selects the ion source to use during the recipe.

Enable: If selected, the ion beam will turn on until this action is encountered again with this option disabled.

Source Shutter: Sets the ion source shutter to be opened or closed.

Jump to Label

Must be used in conjunction with the "Label" recipe action. Once the "Jump to Label" action is reached in the recipe, the process will loop back to where the defined label is located in the recipe and repeat all actions that follow. The number of cycles can be set, determining how many loops are to be performed. Once the cycles are reached, the Jump to Label action is complete and the process will carry on with any remaining actions that exist outside of the loop.

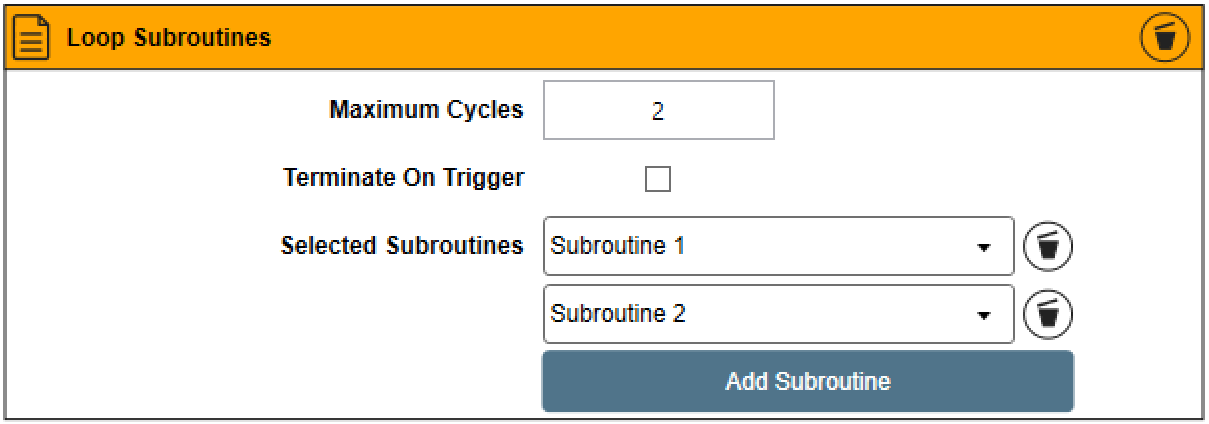


Label

Provides a point in the recipe that can be looped back to. This action gets tagged with a user defined name. Its position in the recipe will determine where the Jump to Label action loops back to. Requires the use of the Jump to Label action.

Loop Subroutines

When subroutines are enabled in Aeres®, this action allows users to cycle through multiple subroutines in a specified order for a set number of cycles. See Subroutines section for more details.



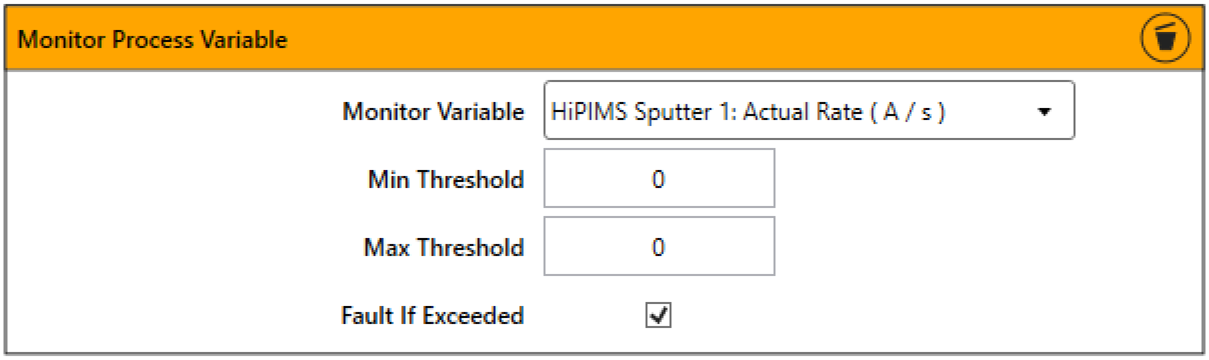
Maximum Cycles: Defines the number of times the selected subroutine order will loop.

Terminate on Trigger: Applicable on select systems equipped with components that can output a termination trigger. If enabled, this will interrupt and terminate the loop prematurely if a trigger is detected. If no trigger is detected, the loop will terminate based on the "Maximum Cycles" parameter.

Selected Subroutines: Specifies the subroutine(s) to be executed. The loop will cycle through the subroutines in the order listed, from top to bottom. Subroutines must be created in the subroutine section before they can be selected from the drop-down list. Additional subroutines can be added to the loop using the "Add Subroutine" button.

Monitor Process Variable

Monitors a process variable, and will fault or give a warning if it exceeds the threshold values. Examples of variables that could be monitored: deposition rate (Å/s), substrate temperature (°C), and chamber pressure (Torr).



Monitor Variable: Selects the variable to be monitored.

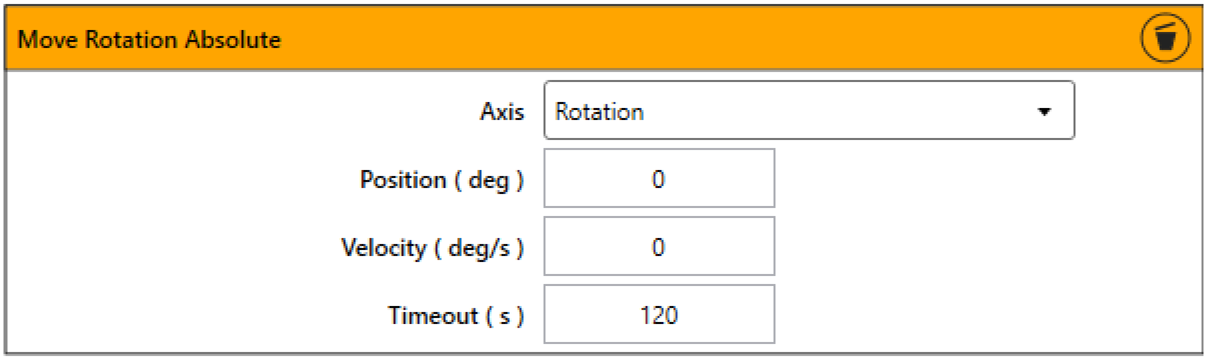
Min Threshold: Defines the lower limit of the variable being monitored.

Max Threshold: Defines the higher limit of the variable being monitored.

Fault If Exceeded: If selected, the system will fault if a threshold is reached. If not, this action will provide a warning feedback to the user. For example, if the monitored variable is detected outside of the thresholds defined, a warning message will appear in a banner. The recipe will not be interrupted by the warning and will carry on.

Move Absolute

Moves a servo motor to a specified position.



Axis: Selects which servo motor to control.

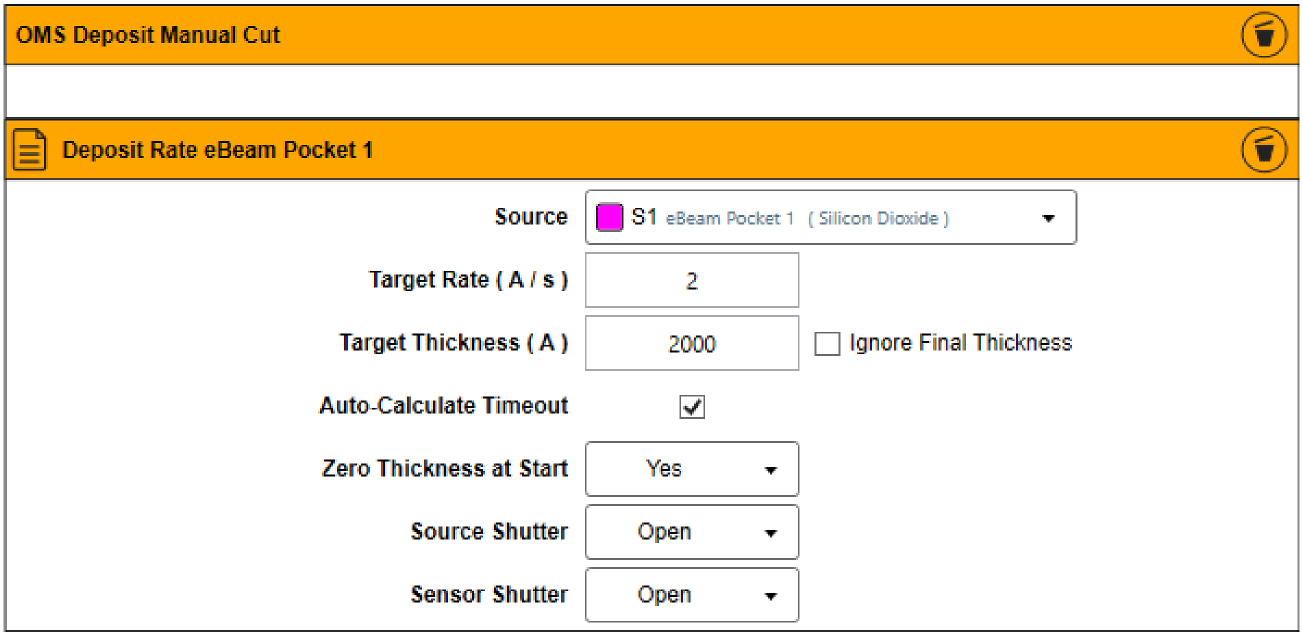
Position: The setpoint that the servo motor will drive to. Units depend on which Axis is selected. Degrees for rotational/tilt motors and millimeters for linear motors.

Velocity: How fast the servo motor will move to the setpoint. Units depend on the Axis selected.

Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

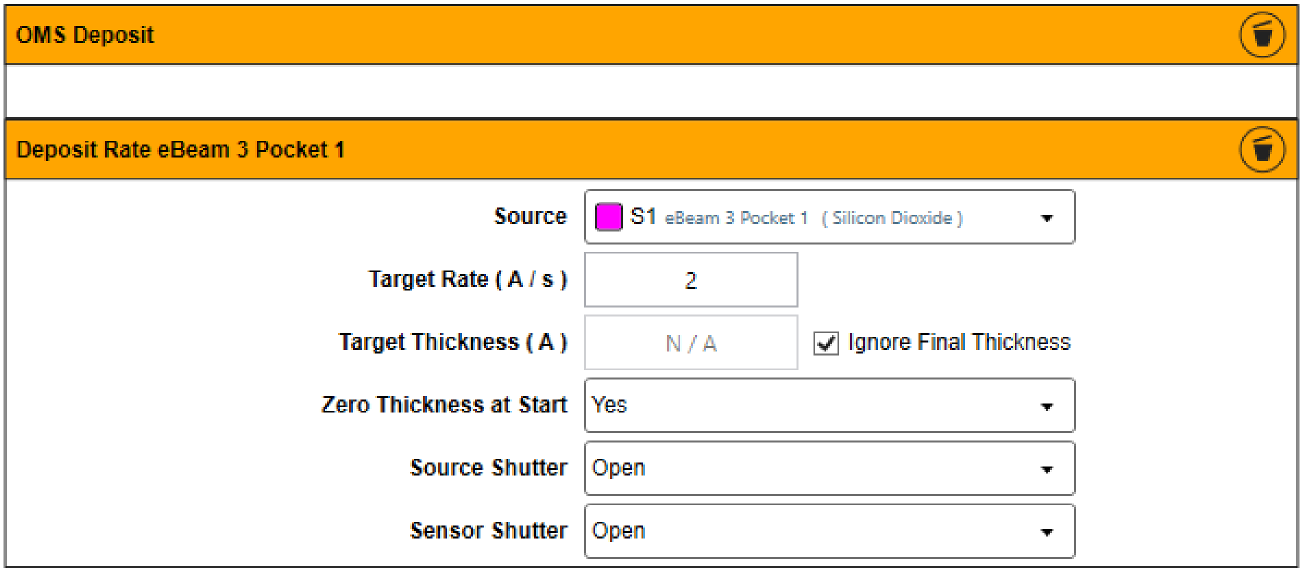
OMS Deposit Manual Cut

This action communicates with the OMS software to allow the deposition to be controlled by Aeres®, such as with the QCM sensor. This action must be in the same step as a deposit action so that the associated deposit action will control the final thickness. The layer that this action is being used for in the OMS project must be setup for manual cut and not for optical cut to work correctly.



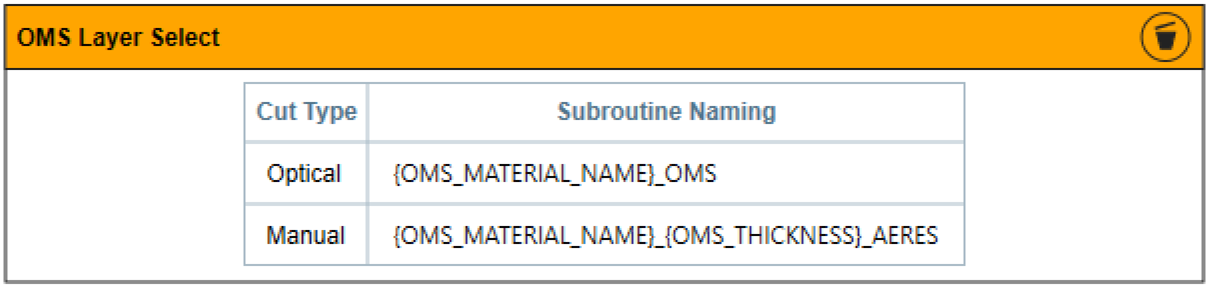
OMS Deposit

This action communicates with the OMS software to allow the deposition thickness to be controlled by the optical monitoring system rather than by the Aeres® deposit action. This action must be in the same step as a deposit action with the **Ignore Final Thickness** checkbox selected so that the associated deposit action will complete automatically once the OMS software has measured the target thickness defined in the OMS project. The layer that this action is being used for in the OMS project must be setup for optical cut and not for manual cut to work correctly.



OMS Layer Select

This action is used to begin the OMS calibration routine and select the layer that will be deposited next within the sequence of layers in the OMS project. This action should be located in the process section of the recipe below the OMS Load Project action, and allows communication between Aeres® and the OMS software to ensure the sequence of layers is deposited in the correct order.


OMS Layer Select

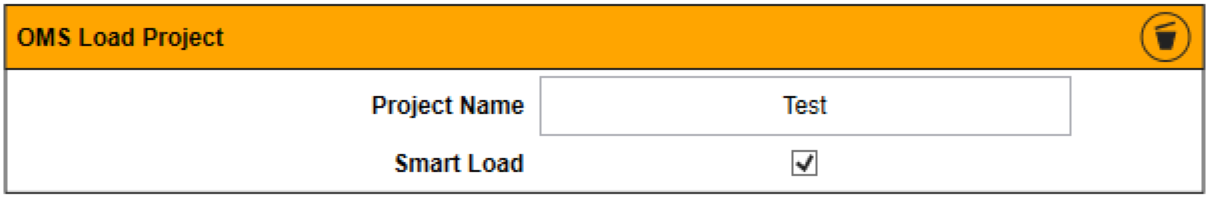
Cut Type	Subroutine Naming
Optical	{OMS_MATERIAL_NAME}_OMS
Manual	{OMS_MATERIAL_NAME}_{OMS_THICKNESS}_AERES

In order for the OMS software to select the correct material and process to run in Aeres®, a subroutine must exist in the Subroutines section of the Aeres® recipe that has the following naming convention:

- For any layer in the OMS project that is intended to be cut using the optical monitor, the associated subroutine must have the name “MATERIAL_OMS” where the material name of the OMS project layer is followed by “_OMS”.
- For any layer in the OMS project that is intended to be cut using feedback from the Aeres® control system (e.g. QCM sensor), the associated subroutine must have the name “MATERIAL_THICKNESS_AERES” where the material name of the OMS project layer is followed by the thickness of the layer in nanometers followed by “_AERES”.

OMS Load Project

This action loads the desired OMS project into the OMS software.

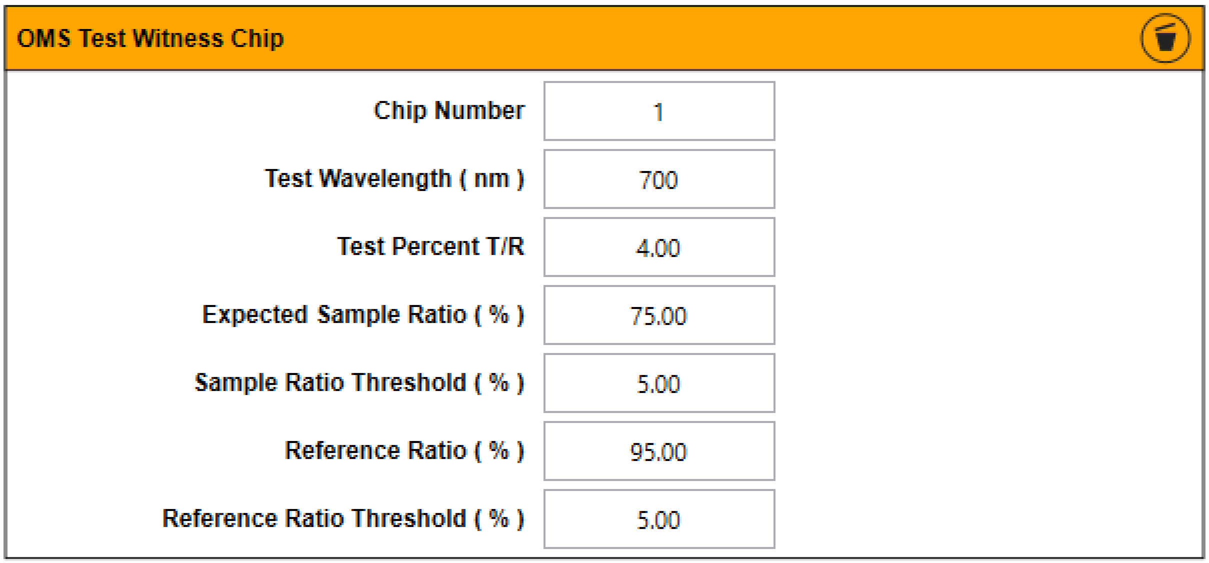


Project Name: The exact file name of the associated OMS project.

Smart Load: Checking this box will allow the process to continue from the first undeposited layer upon restart in the event that the process was aborted or faulted between layers, instead of from the beginning of the OMS project.

OMS Test Witness Chip

This action can be used on tools with integrated optical monitoring systems (OMS) to verify the state of the witness glasses before running a deposition. This will determine which glasses are appropriate to use and which ones to skip. This action will index the glass changer to the commanded witness glass location, measure the signal strength on the witness glass, display the results of the test, and then update the “Witness Glass Conditions” panel in the Setup > Setpoints page of Aeres® accordingly. When running a deposition process that uses the OMS to terminate layers, the system will only use witness glass index locations that are set to “Usable” in the Setpoints page.



Chip Number: Index number of the witness glass according to glass changer assembly.

Test Wavelength (nm): Wavelength in nm that the witness glass will be checked with.

Test Percent T/R: Ideal reflected / transmitted signal strength base on witness glass material (e.g. 4% reflection on back-side roughened glass, 92% transmission on double-side polished glass).

Expected Sample Ratio (%): The expected ratio of the measured reflected / transmitted signal to the ideal signal strength (accounts for losses in the optical path).

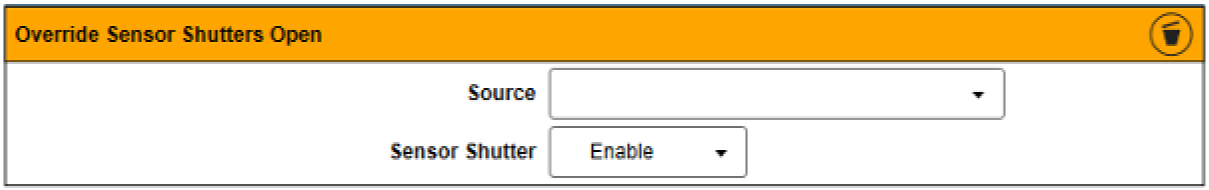
Sample Ratio Threshold (%): The threshold range for an acceptable reflected signal strength (i.e. 10% threshold at an expected sample ratio of 70% would allow for a sample to pass the test if the signal strength is between 60%-80%).

Reference Ratio (%): The expected ratio of the reference signal to the full-strength signal of the light source (should be close to 100% for a new bulb).

Reference Ratio Threshold (%): The threshold range for an acceptable reference signal strength (used to determine if the light source is operating correctly, a 5% threshold at an expected reference ratio of 95% would allow for a sample to pass the test if the signal strength is between 90%-100%).

Override Sensor Shutters Open

This action will force the selected sensor shutter open until it is disabled or the process layer has completed.

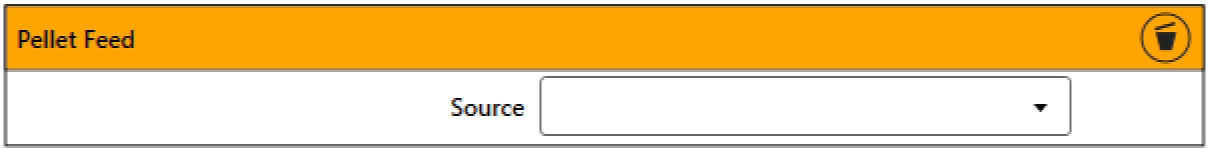


Source: The source that the sensor is observing.

Sensor Shutter: Selecting “Enable” will force the sensor shutter open. Selecting “Disable” will cancel the override and other actions in the recipe will revert back to controlling the shutter.

Pellet Feeder

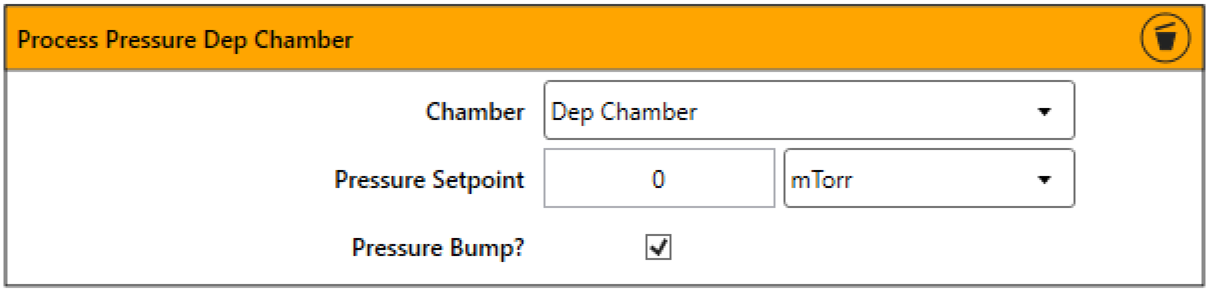
Index the pellet feeder to the next position, unloading material into the respective source.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Process Pressure

Available on systems equipped with motorized gate valves, a process pressure gauge, and an MFC. Used to specify the pressure for the process. The Process Pressure action must be used in combination with the Gas Flow action to introduce gas into the chamber at a fixed flow rate.



Chamber: Selects the chamber in which to control the process pressure.

Pressure Setpoint: Defines the target process pressure and its units (mTorr or Torr). Setpoints of 3-5 mTorr are typical values for sputtering processes. Adjust based on process requirements.

Pressure Bump: If selected, the process pressure will momentarily be increased to 20 mTorr at the beginning of the action and settle back down to the defined setpoint. This feature can be used to assist with plasma ignition. Use this action in combination with the Gas Flow and Ramp Power actions to ignite a plasma on a sputter source.

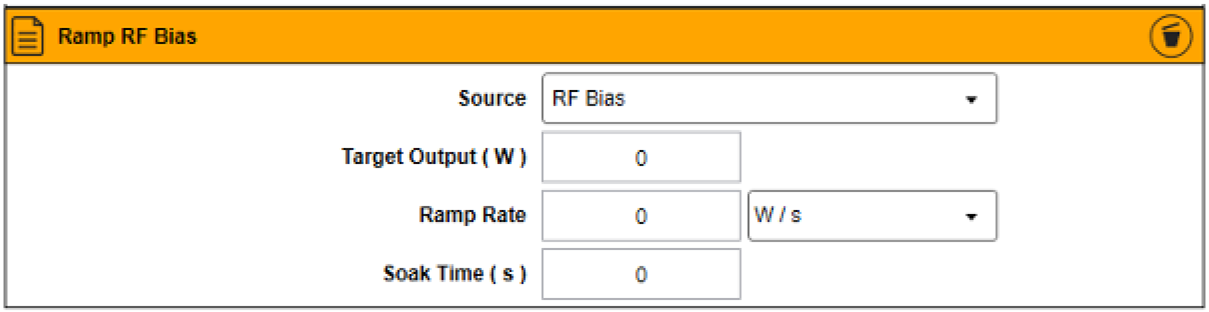
Chamber Pump Down

Initiates an automated pump down sequence for the selected chamber. See "System > Vacuum System Page" for more details on the automated pumping sequence. This action is required if a recipe is started from atmosphere. Adding a Pump Down action at the end of a layer will automatically stop all gas flow and prevent unexpected faults from eBeam or ion sources to occur for exceeding the safety pressures.

Chamber: Select the chamber to pump down.

Ramp Plasma Source

Used to ramp the power of a plasma source within the chamber to a targeted power.



Source: Selects the source for this action.

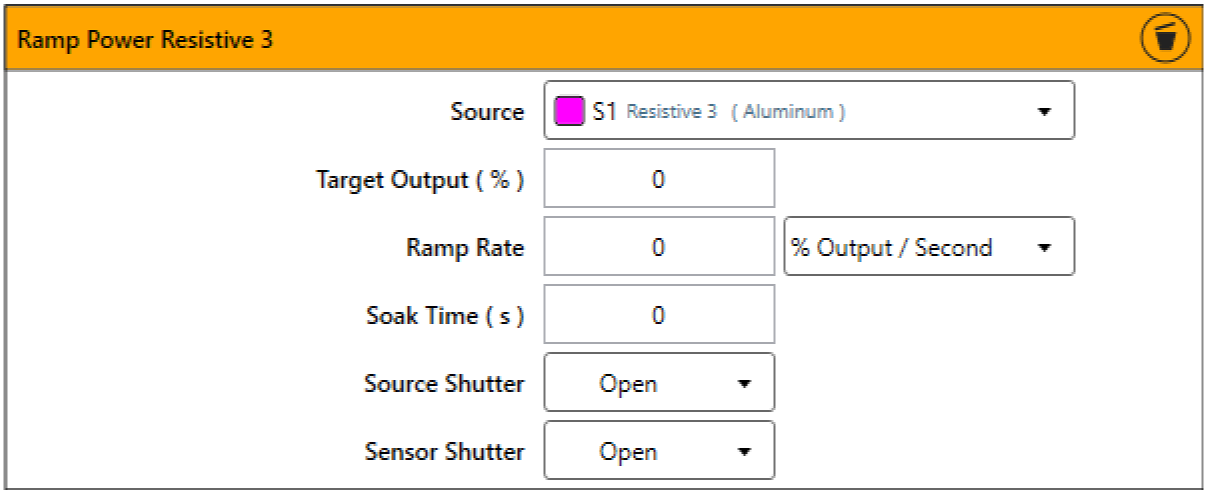
Target Output (W): The targeted power of the plasma source during operation (in Watts).

Ramp Rate: The rate at which the power of the plasma source will increase until the "Target Power (W)" is reached.

Soak Time (s): The amount of time (in seconds) that the plasma source will be held at the "Target Output (W)" until the process continues to the next step.

Ramp Power

Changes the output power at a defined ramp rate until the target setpoint is reached. Used for eBeam, Resistive, and Sputtering sources during ramp up and ramp down of the source.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Output (%): The output power that the source will ramp to. Expressed as a percentage of the total available source power.

Ramp Rate: Defines the rate of change in power to reach the defined Target Output. Units may be selected in percent power per minute or percent power per second from the drop-down selection.

Soak Time (s): Determines how long (in seconds) the system will maintain the Target Output setpoint once it is reached.

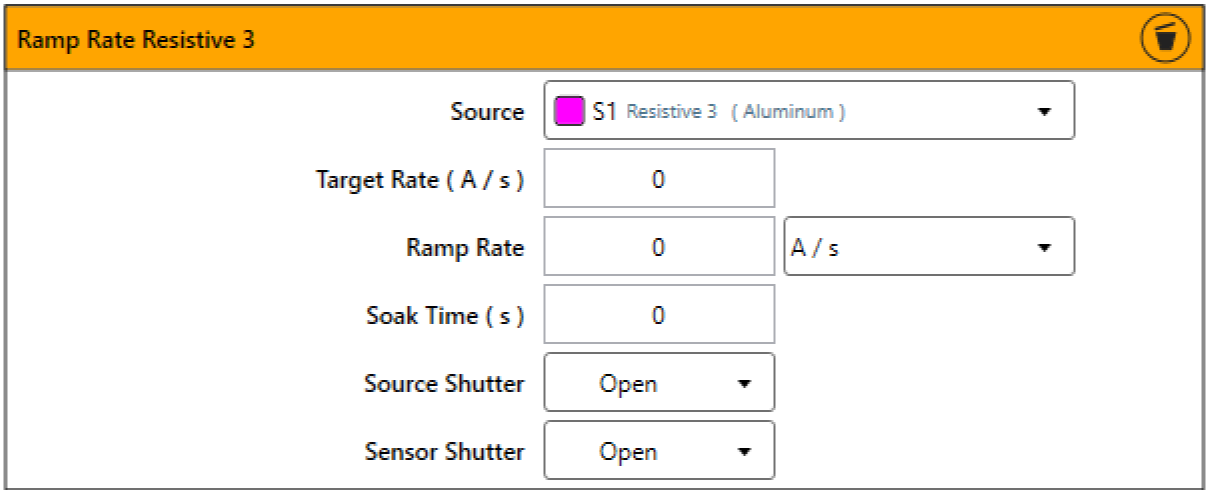
Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Ramp Rate

Note: This is a legacy action. Refer to "Stabilize Rate" for the revised action.

Ramps the deposition rate to a new rate.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Rate (Å/s): Enter the target deposition rate (in Angstroms per second). It is recommended for the defined Target Rate to match the Autotuned Rate from the Rate Control Database entry selected in the "Components > Sources" section of this recipe.

Ramp Rate: The acceleration rate at which the deposition rate is ramped.

Soak Time (s): Time (in seconds) that the rate will remain at the target setpoint after it is achieved.

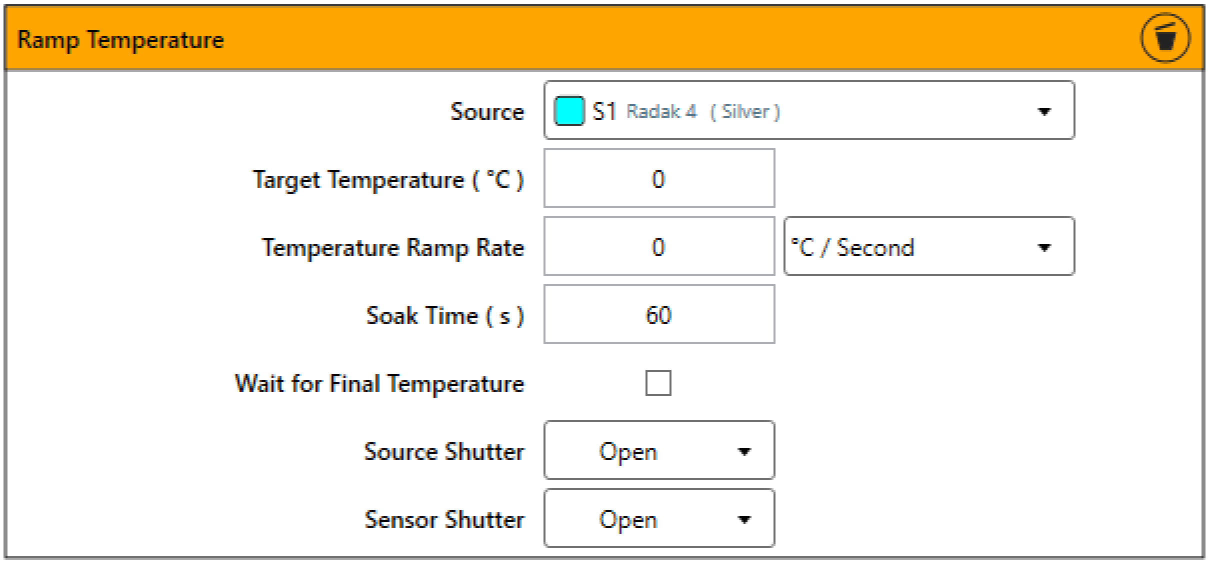
Source Shutter: Selects whether the source shutter (if equipped) needs to open or close. This should be open for deposit actions.

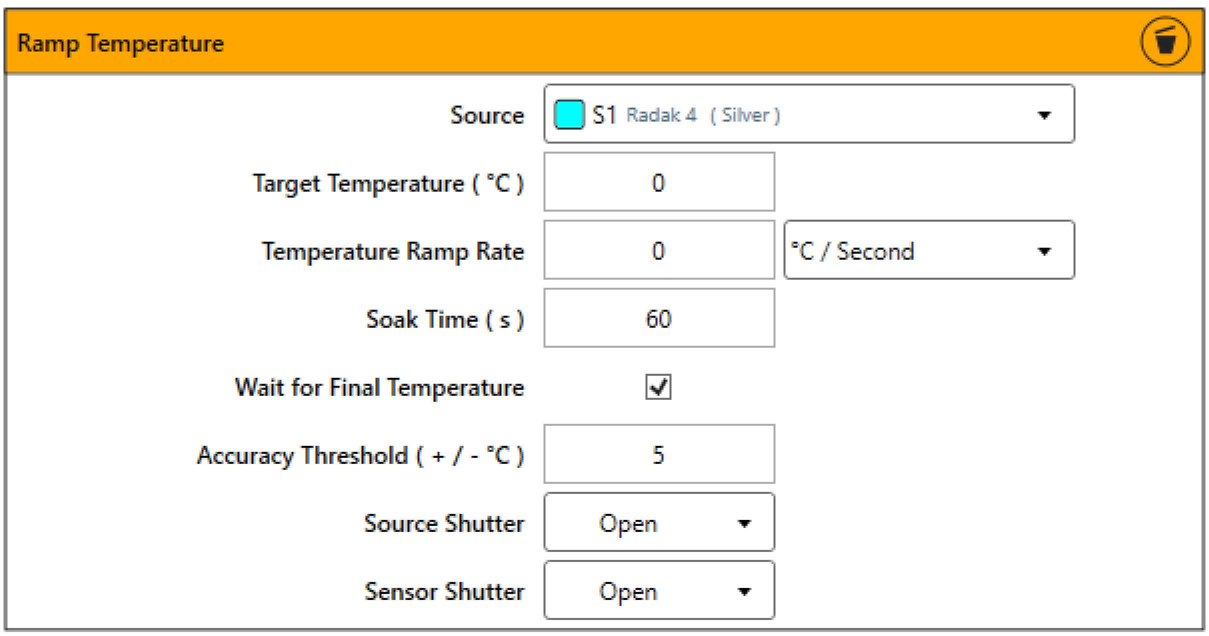
Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Ramp Temperature

Note: This is a legacy action. Refer to "Stabilize Temperature" for the revised action.

This recipe action changes the power supplied to the source to reach the temperature setpoint. It is used for Radak® sources in precondition phases to warm up the source and material.





Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Temperature (°C): The temperature (in degrees Celsius) that the source will attempt to reach.

Temperature Ramp Rate: The desired rate of change of the source temperature in degrees Celsius per second or degrees Celsius per minute depending on the drop-down selection. Controls how fast the source will reach the Target Temperature.

Soak Time (s): Determines how long (in seconds) the system will maintain the Target Temperature setpoint once it is reached.

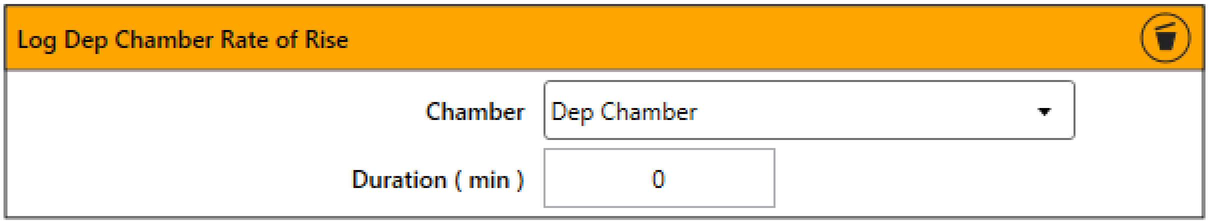
Wait for Final Temperature: If selected, an additional option for **Accuracy Threshold (+/- C)** of the Target Temperature will be available. The action will complete if the source temperature is within this range.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Log Chamber Rate of Rise

Performs an automated sequence to close gate valves and monitor chamber pressure. A log file is generated and chamber pressure can be analyzed to determine leak back rates.



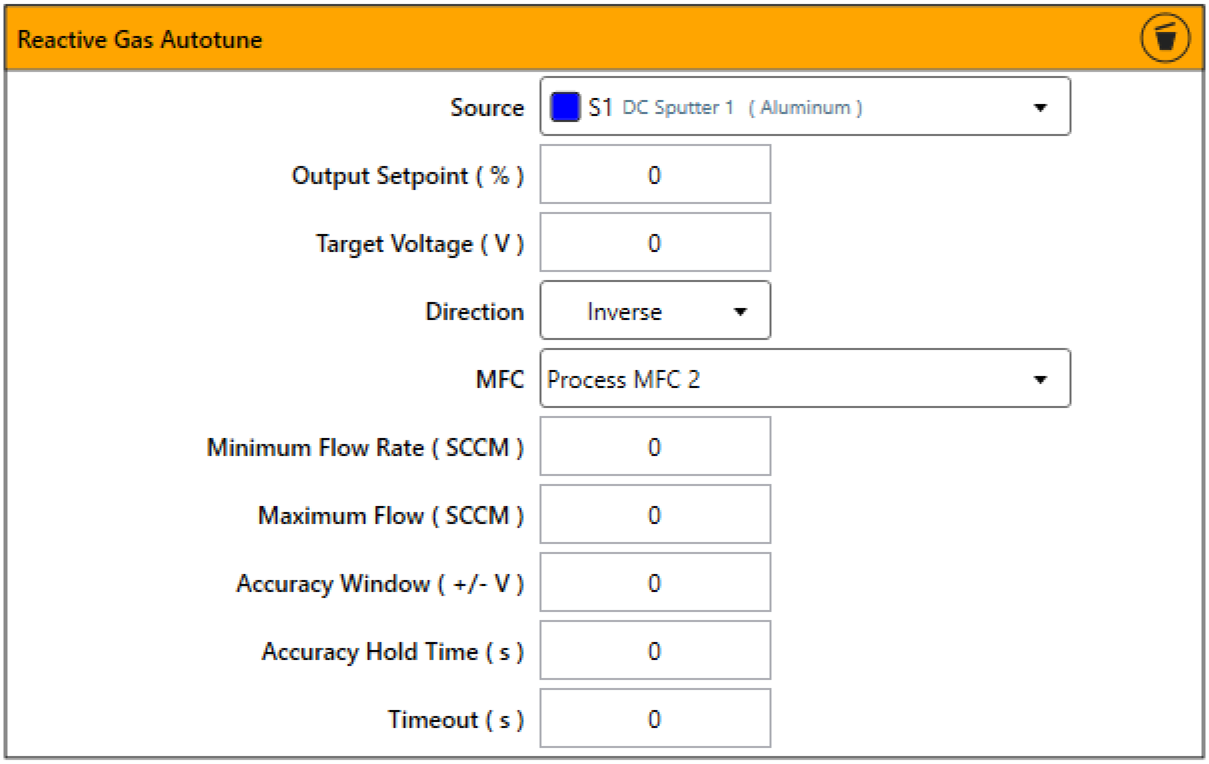
Chamber: Select the chamber to perform the rate of rise test on. When initiated, the gate valve(s) on the chamber will close and chamber pressure will be logged.

Duration (min): The length of time that the system will perform the rate of rise test. Typically, this is 30 minutes.

Reactive Gas Autotune

This recipe action experimentally obtains the PID values required to control the reactive gas MFC flow to maintain the target voltage. Once this action is used, the PID control of the reactive gas flow will be maintained until another recipe action alters the reactive gas flow. This action should be used directly before the deposit phase of a reactive sputtering process. The source should be operated in "Current" mode, see Configure Pulsed DC Supply. A constant non-reactive gas flow (e.g. Ar) should be maintained during this action (same value used during the Reactive Gas Ladder).

Before using this action, a recipe containing a Reactive Gas Ladder action should be completed to obtain the values required.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Output Setpoint (%): The percent of available current that the sputter source will maintain during the action. Note that power and voltage will change as the target becomes poisoned. This should be the same value used in the previous Reactive Gas Ladder recipe.

Target Voltage (V): The sputter source voltage that the source should maintain. This value should be approximately 60-85% of the voltage towards the poisoned state from the metallic state. Adjust as needed for the desired film stoichiometry.

- For example, if the metallic voltage is 500 V and the poisoned voltage is 400 V, then a Target Voltage of 425 V would correspond to 75% of the voltage swing. If the metallic voltage is 500 V and the poisoned voltage is 600 V, then a Target Voltage of 575 V would correspond to 75% of the voltage swing.

Direction: If the voltage increases with an increase in reactive gas flow, then select Direct. If the voltage decreases with an increase in reactive gas flow, then select Inverse.

Minimum Flow Rate (SCCM): A reactive gas flow that allows the poisoned target to fully return to the metallic state. Based on the downwards Reactive Gas Ladder.

Maximum Flow Rate (SCCM): A reactive gas flow that is able to fully poison the target from the metallic state. Based on the upwards Reactive Gas Ladder.

Accuracy Window (+/- V): The range around the Target Voltage that the PID control will consider to be acceptably stable.

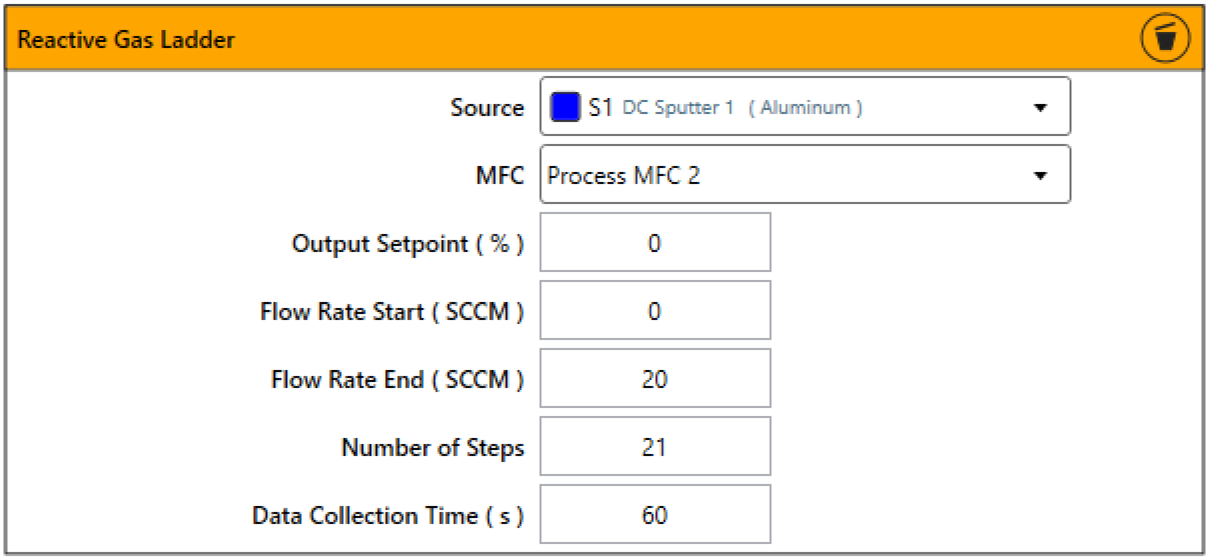
Accuracy Hold Time (s): The duration in seconds that the system must maintain the Target Voltage within the Accuracy Window before the action is completed.

Timeout (s): The total time the system will attempt to stabilize at the Target Voltage. If exceeded, the process will fault.

Refer to Deposition Processes > Reactive Sputtering for more details about this process.

Reactive Gas Ladder

For reactive sputtering processes, this action will step the reactive gas flow up or down at user defined intervals. A log should be taken of the sputter source voltage so that the change in voltage due to target poisoning can be monitored. This will determine the flow required to reach the poisoned state. The source should be operated in "Current" mode, see Configure Pulsed DC Supply. A constant non-reactive gas flow (e.g. Ar) should be maintained during this action.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

MFC: Selects the reactive gas MFC (e.g. O2, N2). This must be initially configured in the "Components > Pressure Control" section.

Output Setpoint (%): The percent of available current that the sputter source will maintain during the action. Note that power and voltage will change as the target becomes poisoned.

Flow Rate Start (SCCM): The starting reactive gas MFC flow.

Flow Rate End (SCCM): The final reactive gas MFC flow.

Number of Steps: The total number of steps between the starting flow and ending flow. Intermediate flow setpoints will be automatically calculated to be equidistant from each other.

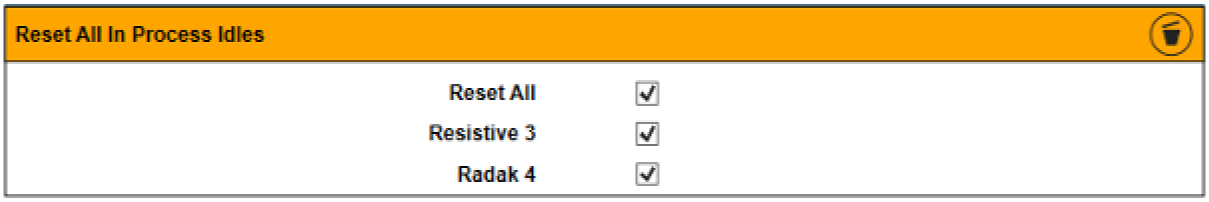
Data Collection Time (s): The duration in seconds that the system will maintain the MFC flow at each step.

It is recommended to use this action twice and reverse the starting and ending MFC flow to obtain a gas ladder stepping down as well. For example, the first gas ladder could start at 0 sccm and end at 20 sccm. Then, a second gas ladder can be performed immediately afterwards, starting at 20 sccm and ending at 0 sccm. This will determine the flow rate required to return to the metallic state. See Reactive Gas Autotune for using the values collected during the Reactive Gas Ladders from the DC sputter voltage and MFC flow graphs.

Refer to Deposition "Processes > Reactive Sputtering" for more details about this process.

Reset All InProcess Idles

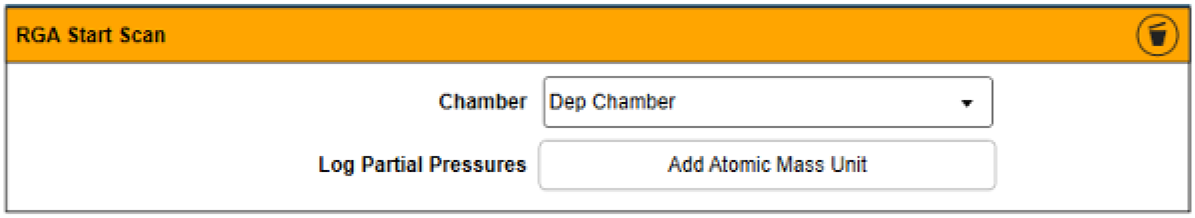
Resets any selected idling sources that have used the "InProcess Idle Power" or "InProcess Idle Temperature" actions previously in the recipe. This will return the source to the same state it was prior to starting the recipe, including idling via the System > Sources page.

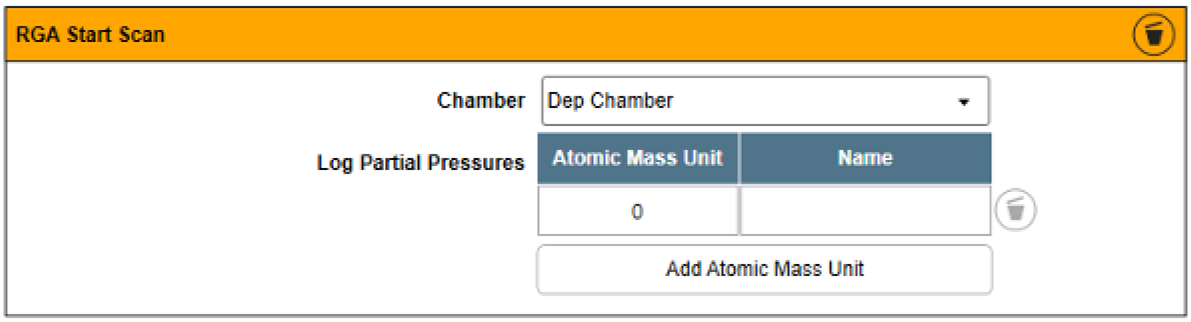


Reset All: Selects all sources that the system can idle, and resets their idle values. When deselected, sources can be selected and reset individually.

RGA Start Scan

Starts an RGA scan on the selected chamber.





Chamber: Select the chamber to start the RGA scan.

Log Partial Pressures: A button to add the Atomic Mass Unit and custom Name of the partial pressure species to be logged.

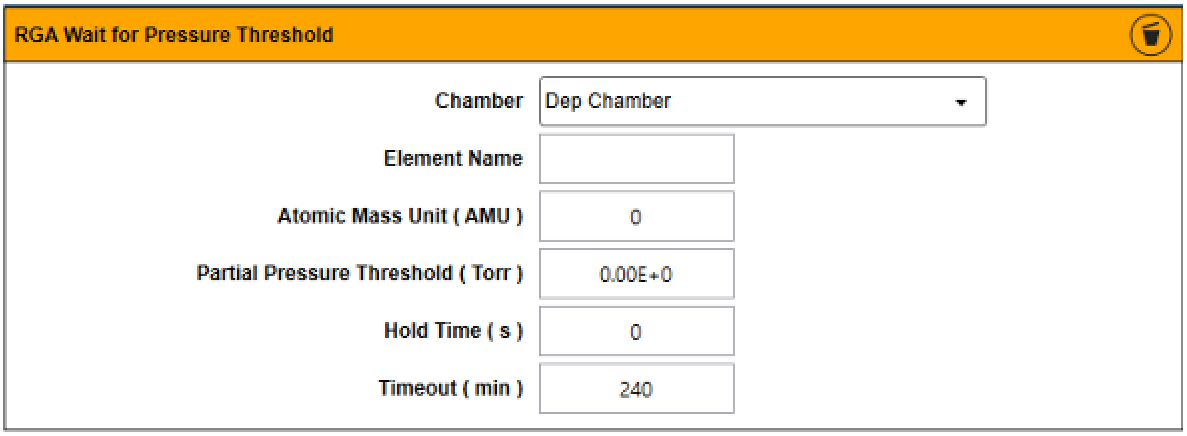
RGA Stop Scan

Stops an active RGA scan on the selected chamber.

Chamber: Select which chamber to stop the RGA scan.

RGA Wait for Pressure Threshold

The RGA partial pressure of a selected chamber and gas species will be monitored until a pressure threshold is reached. The action is considered completed when the threshold is achieved and held for a defined period of time.



Chamber: Selects which chamber to monitor the RGA partial pressure.

Element Name: The gas species that the user would like to track within the chamber environment.

Atomic Mass Unit (AMU): The atomic mass (in AMU) of the gas species.

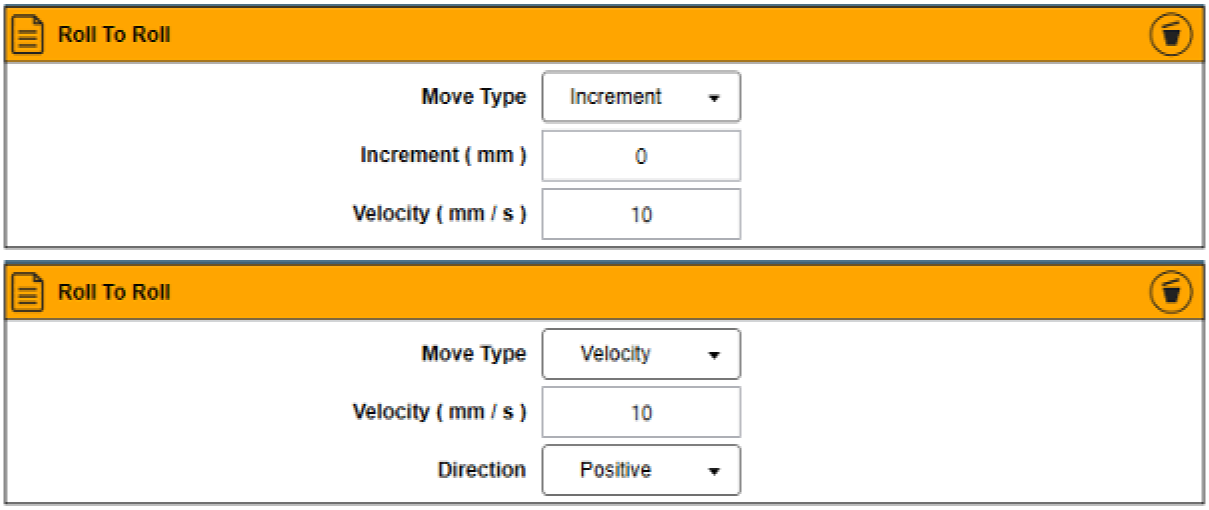
Partial Pressure Threshold (Torr): When the partial pressure of the gas species falls beneath this threshold, the Hold Time will be activated.

Hold Time (s): The duration (in seconds) that the partial pressure must be below the Partial Pressure Threshold for the action to be considered complete.

Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Roll To Roll

This recipe action will allow the user to increment the roll to roll system by a specified distance and speed, or roll at a selected speed in a specified direction.



Move Type: A drop down menu to select the type of roll to roll move that the user wants to use in the recipe. The two options are increment or velocity.

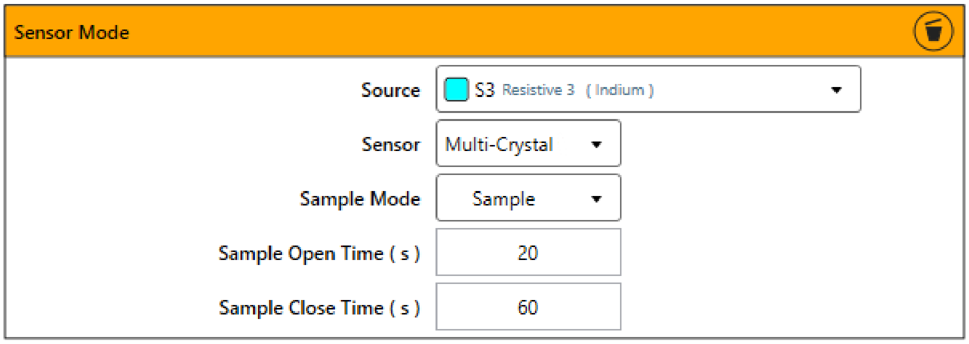
Increment (mm): Defines the distance that the user would like the roll to move, in millimeters.

Velocity (mm/s): Defines the positive or negative speed of the roll, in millimeters per second.

Direction: A drop down menu that defines the direction in which the user wants the roll to move. The two options are positive or negative.

Sensor Mode

This action allows for rate sampling in order to preserve crystal life for thick depositions. Must be used in conjunction with a sensor equipped with a shutter. The sensor shutter opens and closes at specified intervals.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Sensor: Selects the QCM sensor that is linked to the Source.

Sensor Mode:

- **Standard:** No sampling, sensor is exposed to the source at all times
- **Sampling:** Allows user to control the intervals at which the sensor is exposed to the source

Sample Open Time (s): The duration in seconds that the sensor shutter will be open, allowing the system to collect rate data from the QCM.

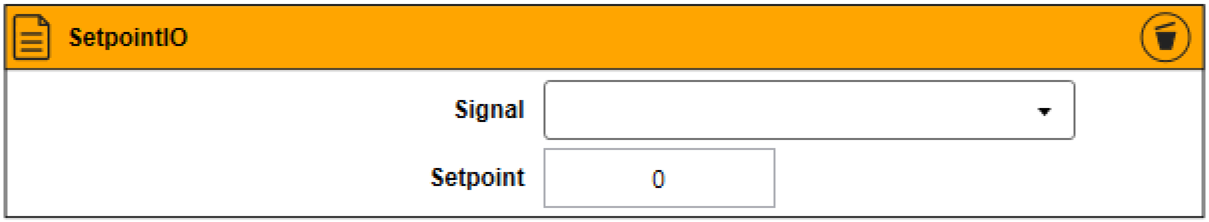
Sample Close Time (s): The duration in seconds that the sensor shutter will be closed, preventing deposition on the QCM.

The sample open and close times will depend on how stable the deposition rate is at a given power for the material. During the Sample Close Time, the system will maintain a constant power based on the last power reached during the Sample Open Time. Close times that are too long may result in deposition rate instability. Open times that are too short may not allow enough time for the system to stabilize the rate again.

This action is intended to be used alongside the Deposit Rate action. Rate Sampling should not be used during the Autotune action.

Setpoint

This recipe action will send setpoints to an external device that is not integrated with other recipe actions.

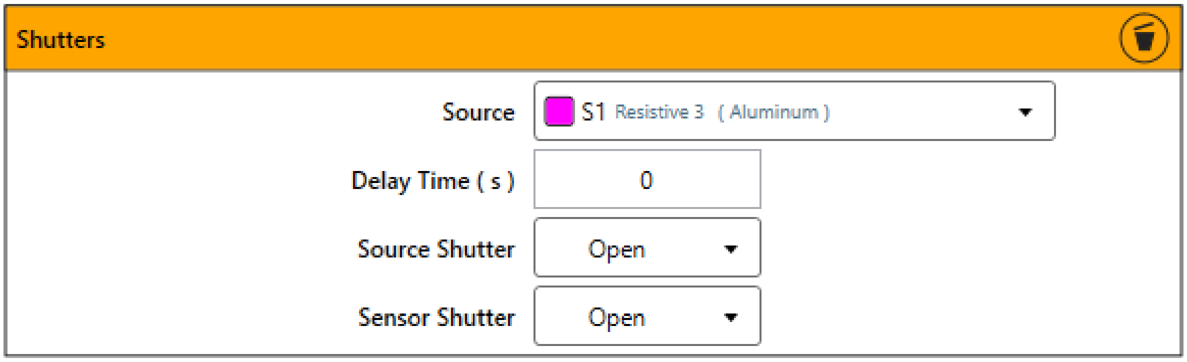


Signal: Selects the parameter on the external device.

Setpoint: Value that will be sent to the external device parameter.

Shutters

Used to open or close a source shutter while incorporating a time delay before proceeding.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Delay Time (s): Time (in seconds) before the shutter is actuated.

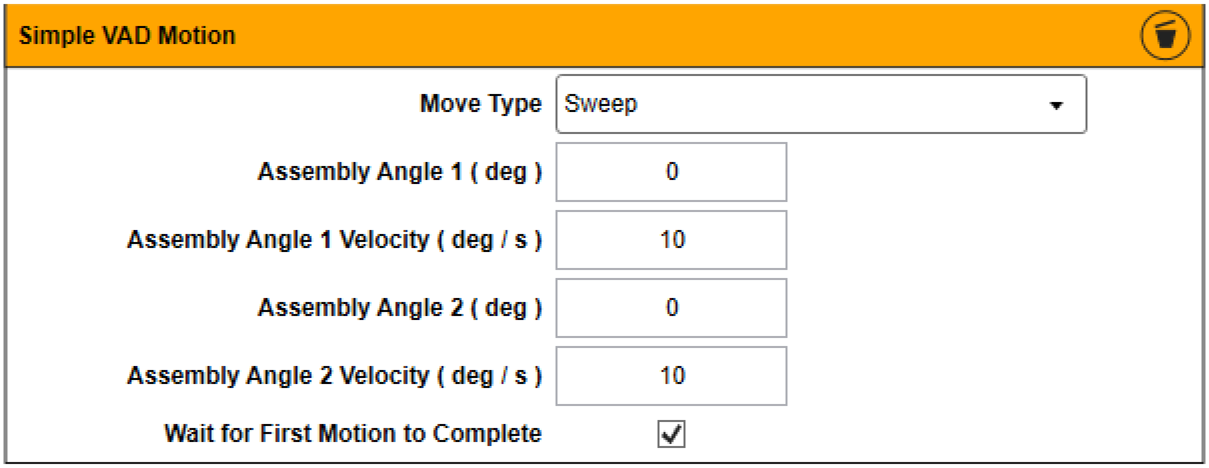
Source Shutter: Selects whether the source shutter needs to open or close.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close.

Simple VAD Motion

Note: This is a legacy action. Refer to "VAD Motion" for the newest action.

If the tool is equipped with a VAD stage, this action will control the tilt angle and tilt velocity of the stage.



Move Type: Selects the movement pattern of the VAD stage. If Absolute is selected, the stage will move to the required angle and hold for the rest of the process. If Sweep is selected, the stage will move back and forth between the two required angles for the rest of the process.

Assembly Angle 1 (deg): The initial tilt angle (in degrees) of the stage. Typically, 0 deg is when the substrate is parallel with the chamber baseplate.

Assembly Angle 1 Velocity (deg/s): The tilt velocity (in degrees per second) to reach Assembly Angle 1.

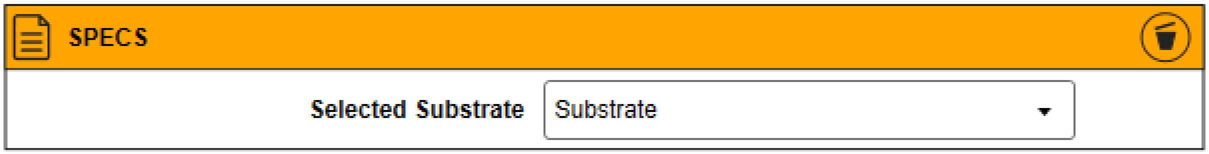
Assembly Angle 2 (deg): If Sweep is selected as the Move Type, this will be the secondary tilt angle (in degrees) of the stage. The stage will tilt back and forth between this angle and Assembly Angle 1.

Assembly Angle 2 Velocity (deg/s): The tilt velocity (in degrees per second) to reach Assembly Angle 2.

Wait for First Motion to Complete: When selected, this will wait for the initial tilt to Assembly Angle 1 to be completed before continuing on to the next step of the process. When unselected, the process will move to the next step during the initial tilt to Assembly Angle 1.

SPECS

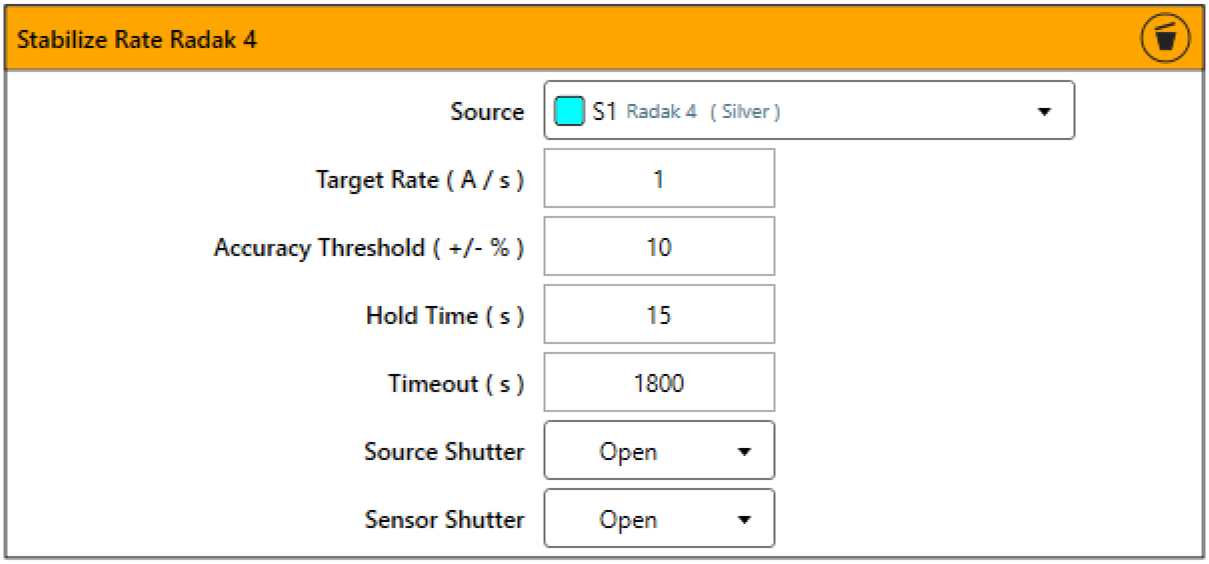
SPECS prodigy is a data acquisition and experimental control software package which uses electron spectroscopy. This action will give control of a process cell to the SPECS Prodigy software so that it can perform its experiments, execute move commands, and give control back to Aeres® when SPECS is complete.



Selected Substrate: Selects the substrate to perform SPECS on.

Stabilize Rate

This recipe action adjusts output power to the selected source, using the PID values stored in the database for this material and source combination, to reach the defined Target Rate. Used for eBeam, Resistive, and Radak® sources, prior to a deposit phase.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Rate (Å/s): Enter the target deposition rate (in Angstroms per second). It is recommended for the defined Target Rate to match the Autotuned Rate from the Rate Control Database entry selected in the "Components > Sources" section of this recipe.

Accuracy Threshold (+/- %): Defines the accuracy window of the Target Rate. Expressed as a percentage of the Target Rate.

Hold Time (s): The duration (in seconds) that the rate must be within the Accuracy Threshold for the action to be considered complete.

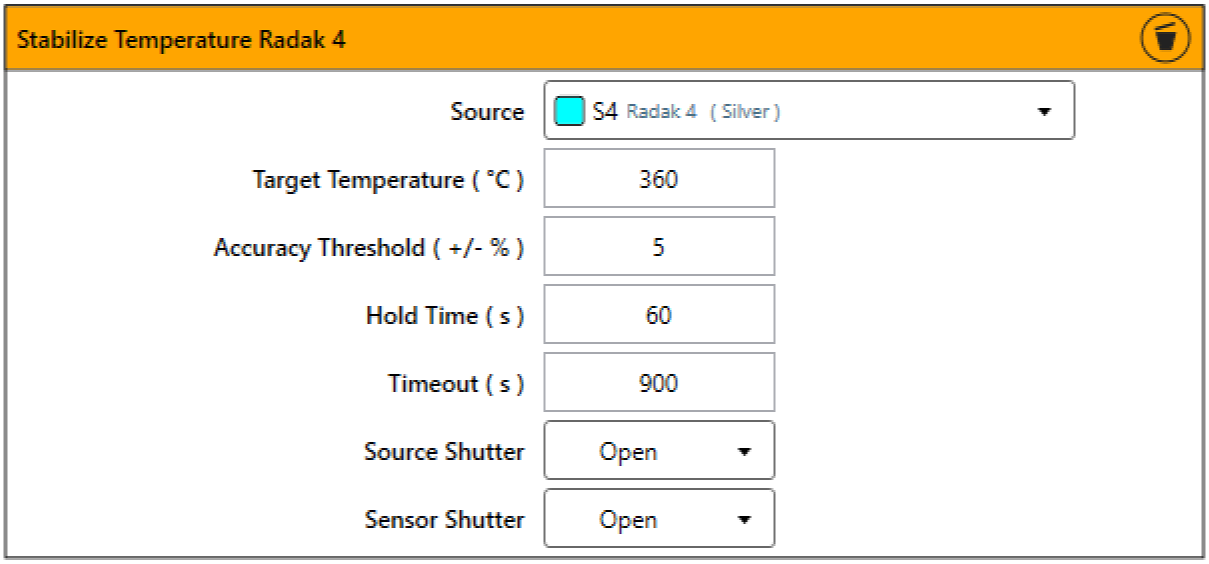
Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close. This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Stabilize Temperature

Source power will be adjusted to reach or maintain the Target Temperature. Should be used after an Autotune Temperature action with an identical or similar temperature setpoint has been run with the source. Typically used with Radak® sources to precondition a thermosensitive material, such as organic materials, which require fine temperature control. Only available for sources with temperature feedback.



Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Temperature (°C): The temperature in degrees Celsius that the source will target. The source will use the PID values loaded from the Rate Control database that were obtained from the Autotune (temperature) action.

Accuracy Threshold (+/- %): Defines the accuracy window of the Target Temperature. Expressed as a percentage of the Target Temperature.

Hold Time (s): The duration (in seconds) that the temperature must be within the Accuracy Threshold for the action to be considered complete.

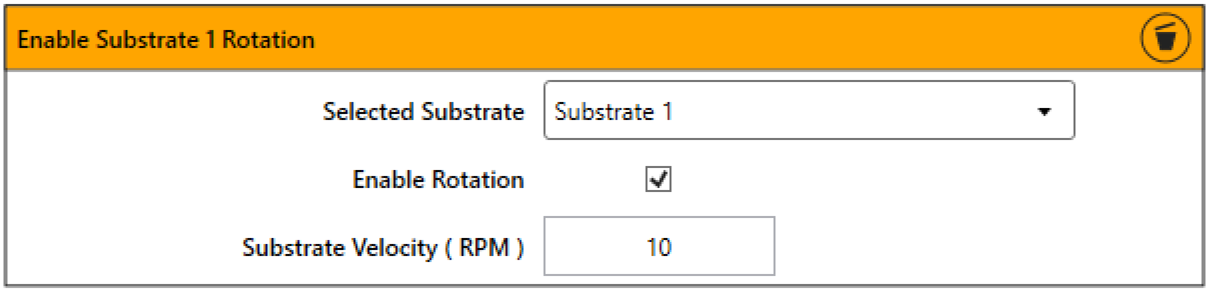
Timeout (s): The maximum duration (in seconds) that this action will run. If this time has elapsed, the process will fault.

Source Shutter: Selects whether the source shutter (if equipped) needs to open or close.This should be open for deposit actions.

Sensor Shutter: Selects whether the sensor shutter (if equipped) needs to open or close. This should be open for accurate rate measurement.

Substrate Rotation

This action is used to define the substrate rotation velocity during a deposition process. The velocity will be maintained for the duration of the process, unless changed by adding another Substrate Rotation action in the recipe.

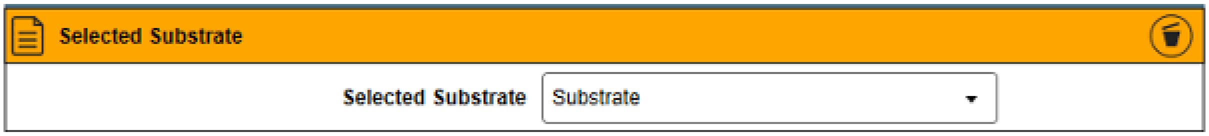


Enable Rotation: If selected, will allow the stage to rotate at the defined velocity. If not, no rotation will occur.

Substrate Velocity (RPM): The rotation speed in revolutions per minute.

Substrate Select

For systems equipped with multiple substrates in the same chamber, this action will allow the user to select which substrate to use for the process.



Selected Substrate: A drop down menu to select the substrate to be used in the process.

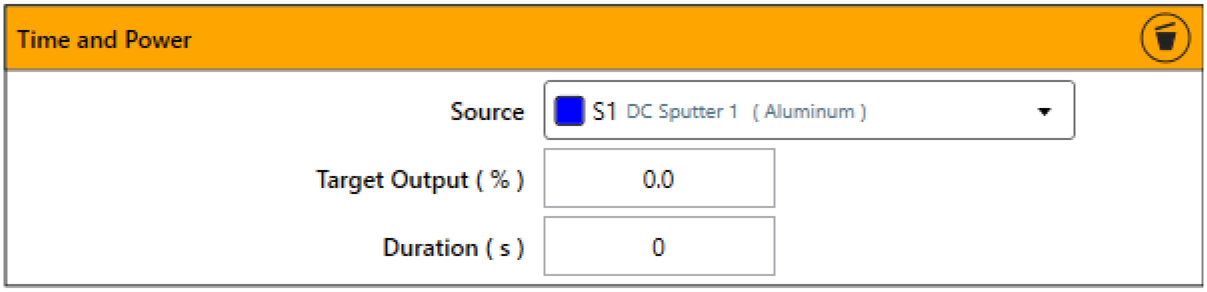
Ti-Sub Pump

Activates the titanium sublimation pump for the specified number of cycles.

Number of Cycles: The number of sublimation cycles to be run.

Time and Power

Maintains a source power setpoint for a specified duration. Typically used for sputtering processes where a Calibration Sensor is not used.



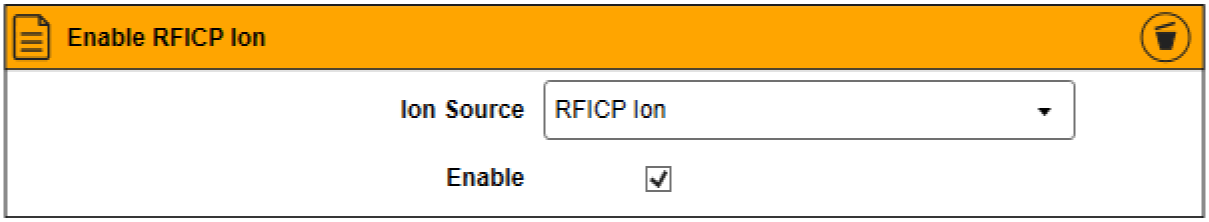
Source: Selects the source for this action. The source must have been added to the "Components > Source" section in the recipe editor to appear in the drop down list.

Target Output (%): A percentage of the total available source output power.

Duration (s): The length of time (in seconds) that the system will hold the source Target Output. The action is complete when the duration is achieved.

Enable Ion Source

This recipe action will enable the beam of the ion source that is selected within the action. A "Configure Ion Source" recipe action must be used in a prior step to set the parameters that the ion source will use during the recipe. Typically, an "Ion Beam Discharge" action is also required to ignite the source prior to enabling the beam.

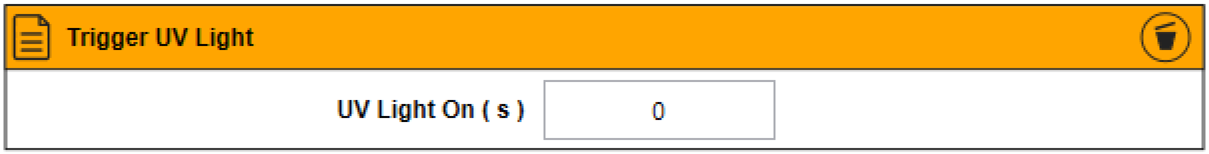


Ion Source: Selects the ion source to use during the recipe.

Enable: If selected, the ion beam will turn on until this action is encountered again with this option disabled.

Trigger UV Light

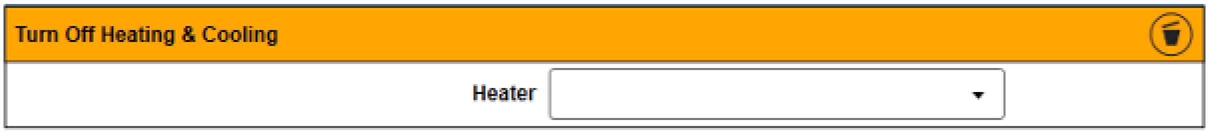
If a UV light is installed in the chamber, this action will turn the light on for a specified amount of time, and then turn it off. This is typically used for ozone generation while supplying oxygen to the chamber.



UV Light On (s): The amount of time (in seconds) the UV light will remain on.

Turn Off Heating & Cooling

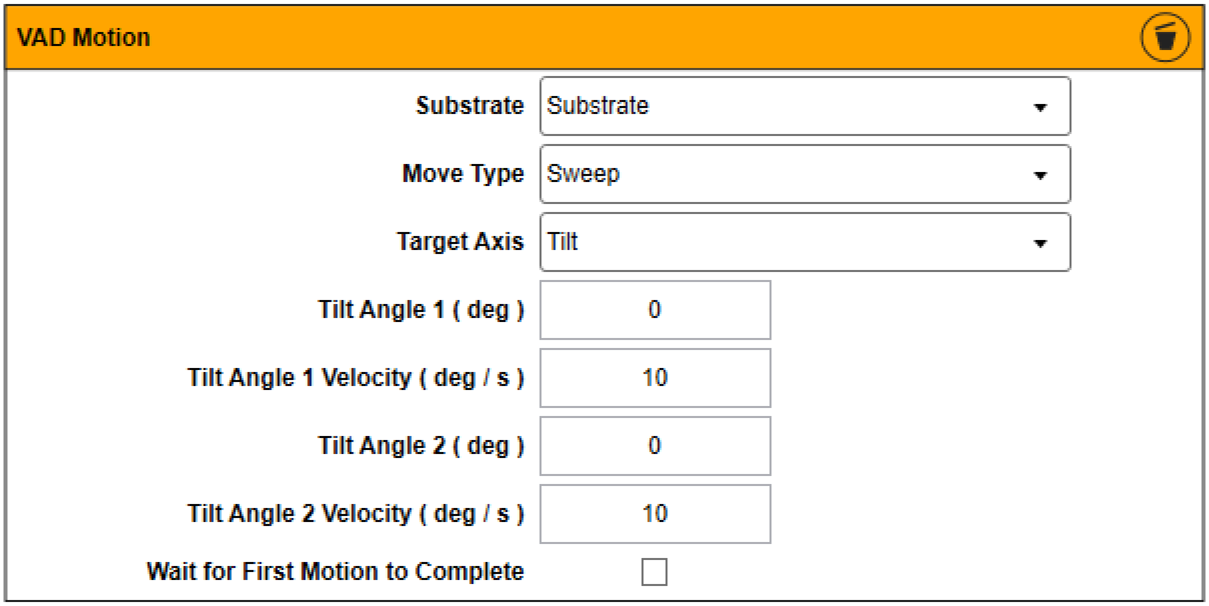
If the system is equipped with substrate heating and/or cooling, and is being used in the process, this action will allow the user to turn off the heating and/or cooling for the remainder of the process.



Heater: Selects the heater for this action.

VAD Motion

If the tool is equipped with a VAD stage, this action will control the tilt angle and tilt velocity of the stage.



Substrate: Select the substrate to be used.

Move Type: Selects the movement pattern of the VAD stage. Options include Absolute, Absolute with Backlash Correction, Azimuthal Advance, Helix, Polygon, Relative, Sweep and Zig Zag.

Target Axis: Select the axis to apply the Move Type. Options include Substrate Rotation, Substrate Tilt, or Both.

Note: The following parameters apply to the Absolute and Sweep Move Types. Updated descriptions for all Move Types will be added in a future version of the manual.

Tilt Angle 1 (deg): The initial tilt angle (in degrees) of the stage. Typically, 0 deg is when the substrate is parallel with the chamber baseplate.

Tilt Angle 1 Velocity (deg/s): The tilt velocity (in degrees per second) to reach Assembly Angle 1.

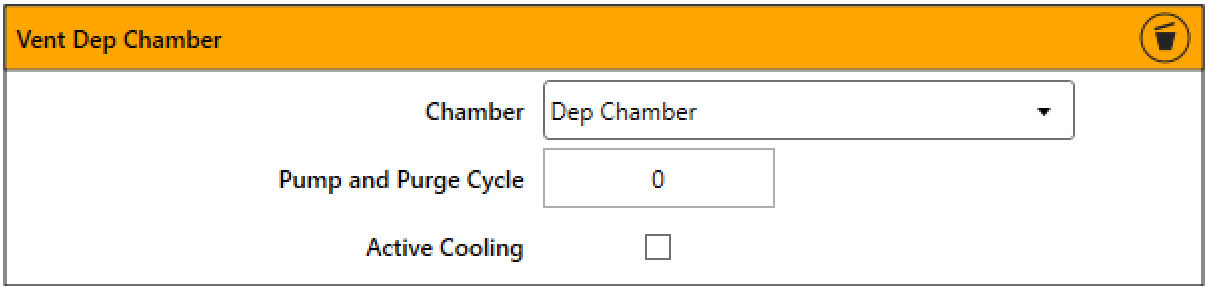
Tilt Angle 2 (deg): If Sweep is selected as the Move Type, this will be the secondary tilt angle (in degrees) of the stage. The stage will tilt back and forth between this angle and Assembly Angle 1.

Tilt Angle 2 Velocity (deg/s): The tilt velocity (in degrees per second) to reach Assembly Angle 2.

Wait for First Motion to Complete: When selected, this will wait for the initial tilt to Assembly Angle 1 to be completed before continuing on to the next step of the process. When unselected, the process will move to the next step during the initial tilt to Assembly Angle 1.

Chamber Vent

Initiates an automated vent sequence for the selected chamber. See "System > Vacuum System Page" for more details on the automated vent sequence.



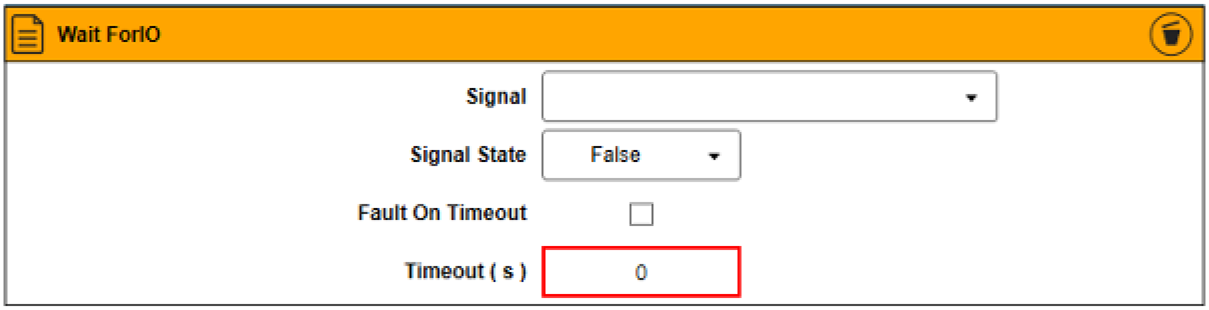
Chamber: Selects the chamber to be vented.

Pump and Purge Cycle: Specify how many times the chamber should be pumped and subsequently purged with venting gas (e.g. nitrogen) before fully venting to atmosphere.

Active Cooling: If selected, Pump and Purge cycles will be performed until temperature controlled stages/sources are below safe venting temperatures (typically 100 °C). This speeds up the cool down process.

Wait for IO

This recipe action will wait for a specified IO signal from a non-standard external device before continuing the process.



Signal: The signal from the external device.

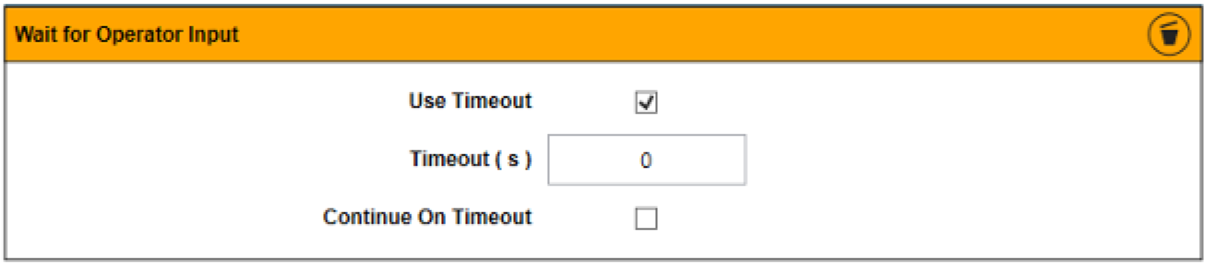
Signal State: A true or false criteria depending on if the user wants to continue the process on an active or inactive signal.

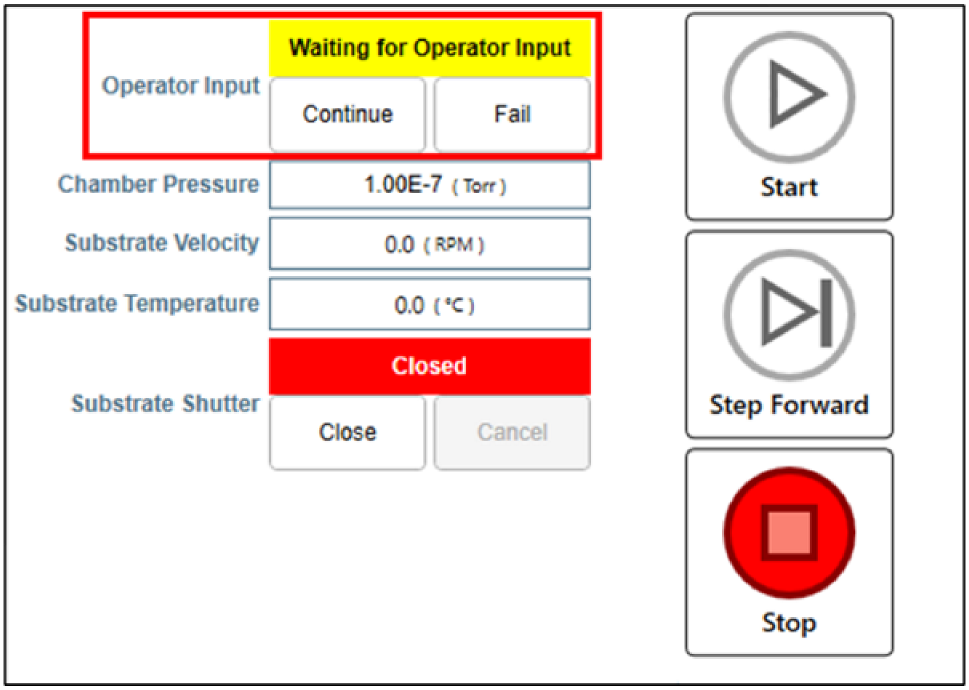
Fault On Timeout: If the desired signal state is not met before the "Timeout (s)" elapses, the process will fault.

Timeout (s): The time (in seconds) before the process continues to the next step, or faults if "Fault On Timeout" is selected.

Wait for Operator Input

This recipe action will wait for the user's input to continue running the process. On the process page, a dialogue box will appear in the top right corner of the page providing the option to continue the process, or fault the process.





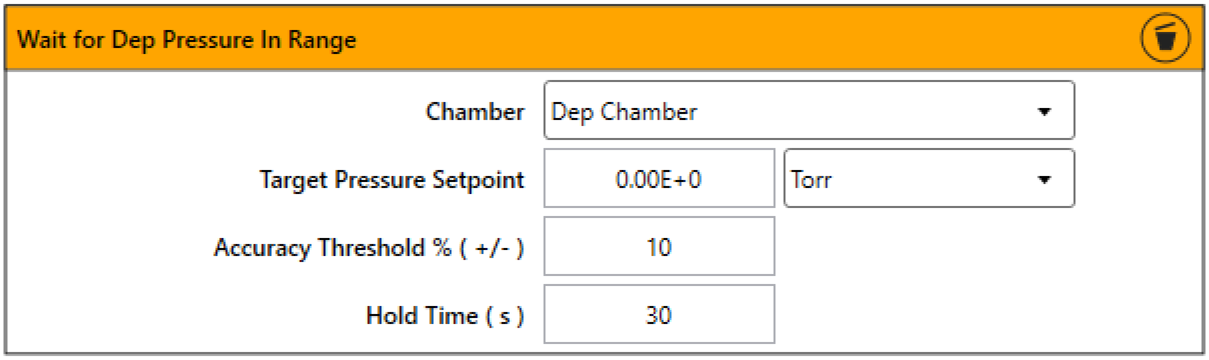
Use Timeout: When selected, this will allow the user to input a time (in seconds) when the recipe will either fault, or continue onto the next step. If selected, the "Timeout (s)" and "Continue On Timeout" parameters will appear.

Timeout (s): The elapsed time before the recipe will fault if the operator has not selected "Continue On Timeout".

Continue On Timeout: When selected, this will allow the process to continue without operator input after the "Timeout (s)" has elapsed.

Wait for Chamber Pressure in Range

This recipe action will monitor the selected chamber pressure until it is within a specified range for a defined period of time.



Chamber: Selects which chamber to monitor pressure.

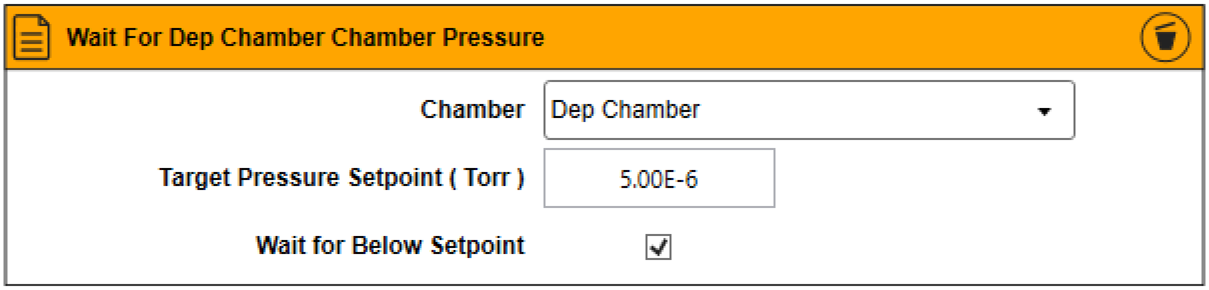
Target Pressure Setpoint: The pressure that the system must reach before this action will be completed. The drop-down selection specifies whether the units are Torr or mTorr.

Accuracy Threshold % (+/-): Determines the acceptable pressure range as a percentage of the Target Pressure Setpoint.

Hold Time (s): The duration that the chamber pressure must be within the specified Accuracy Threshold before the action will be completed.

Wait for Chamber Pressure

The chamber pressure of a selected chamber will be monitored until a specified Target Chamber Pressure is reached. The action is considered completed when the defined setpoint is achieved.



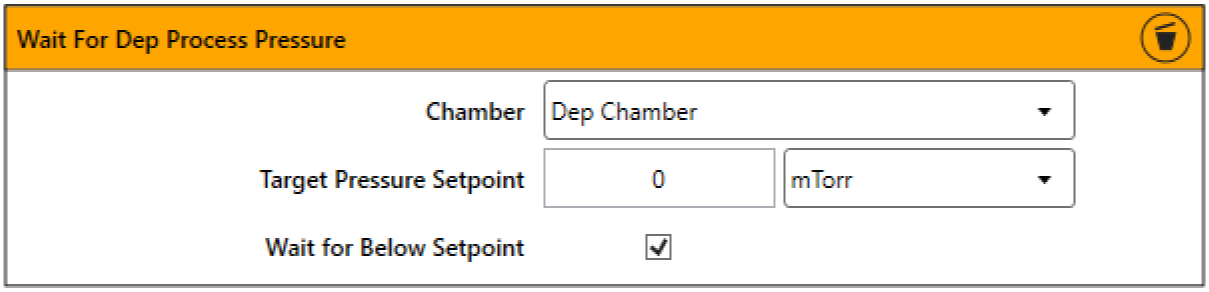
Chamber: Selects which chamber to monitor pressure.

Target Pressure Setpoint: The pressure to be reached in the selected chamber for this action to be completed. Units will depend on the selected units in the Setup > Setpoints page.

Wait for Below Setpoint: If selected, pressure must be below the setpoint before the action is complete. If deselected, pressure must be above the setpoint before the action is complete.

Wait for Process Pressure

Waits until the process pressure in the selected chamber reaches the defined setpoint. A process gauge must be present on the chamber to use this action. A Gas Flow action must be used with this action.



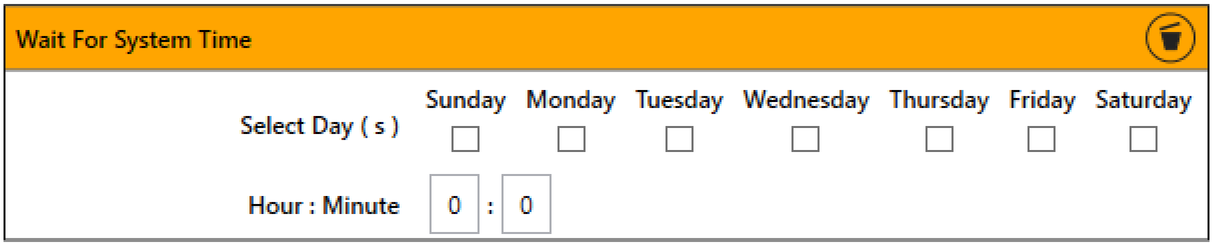
Chamber: Selects which chamber to monitor pressure.

Target Pressure Setpoint: The pressure that the system must reach before this action will be completed. The drop-down selection specifies whether the units are Torr or mTorr.

Wait for Below Setpoint: If selected, pressure must be below the setpoint before the action is complete. If deselected, pressure must be above the setpoint before the action is complete.

Wait for System Time

This recipe action will wait for the computer's system time to match the specified time before completing.



Aeres® Recipe Structures

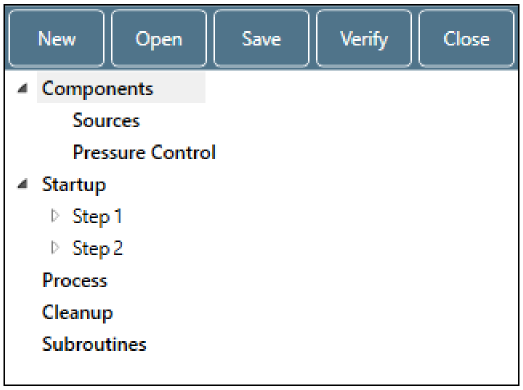
The recipe structure in Aeres® liberates users from the constraints of traditional deposition control software. In Aeres®, users are free to create recipes with as many phases as required to deposit the desired configuration of thin films on their substrates. Aeres® recipes are easily populated with recipe actions, whereas traditional thin-film deposition control software can limit users to only four predefined phases for a single-layer deposition, and users are forced to define their process requirements within the constraints of those definitions.

In the next few sections, the overall structure of Aeres® recipes are described in detail. Every Aeres® recipe has the same basic constituents, which are executed sequentially to create the deposition recipe. Within each section, the user may add any available options to configure and control their system. Each of the following parts contains a list of these options, hyperlinked to the relevant manual section, and so the reader is encouraged to use this part of the Aeres® manual as an electronic reference. Please note that, depending on the factory configuration of the Angstrom Engineering® system, not all recipe actions may be available.

Recipes have five sections:

1. Components
2. Startup
3. Process
4. Cleanup
5. Subroutines

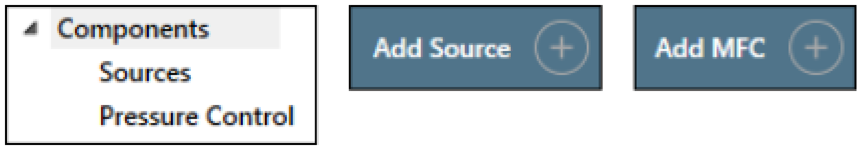
These sections are shown in the recipe tree of any newly created or open recipe on the Aeres® Process Builder Page. An example of a newly created recipe tree is shown , with each section described in the following.



An Aeres® recipe tree showing the four sections of a new Aeres® recipe

Components

In the components section, all sources and mass flow controllers (MFCs) to be used in the deposition recipe must be selected and configured. To add a deposition source or mass flow controller to the recipe, select "Sources" or "Pressure Control" from the recipe tree and then click the recipe addition button (+) in the upper-right corner of the Process Builder Page.



Contextual selection of components. The recipe addition that is displayed when the following items are selected in the recipe tree are: a drop-down menu when the "Components" item is selected (Left), a plus (+) button to add deposition sources when "Sources" is selected (Middle), and a plus (+) button to add mass flow controllers when "Pressure Control" is selected.

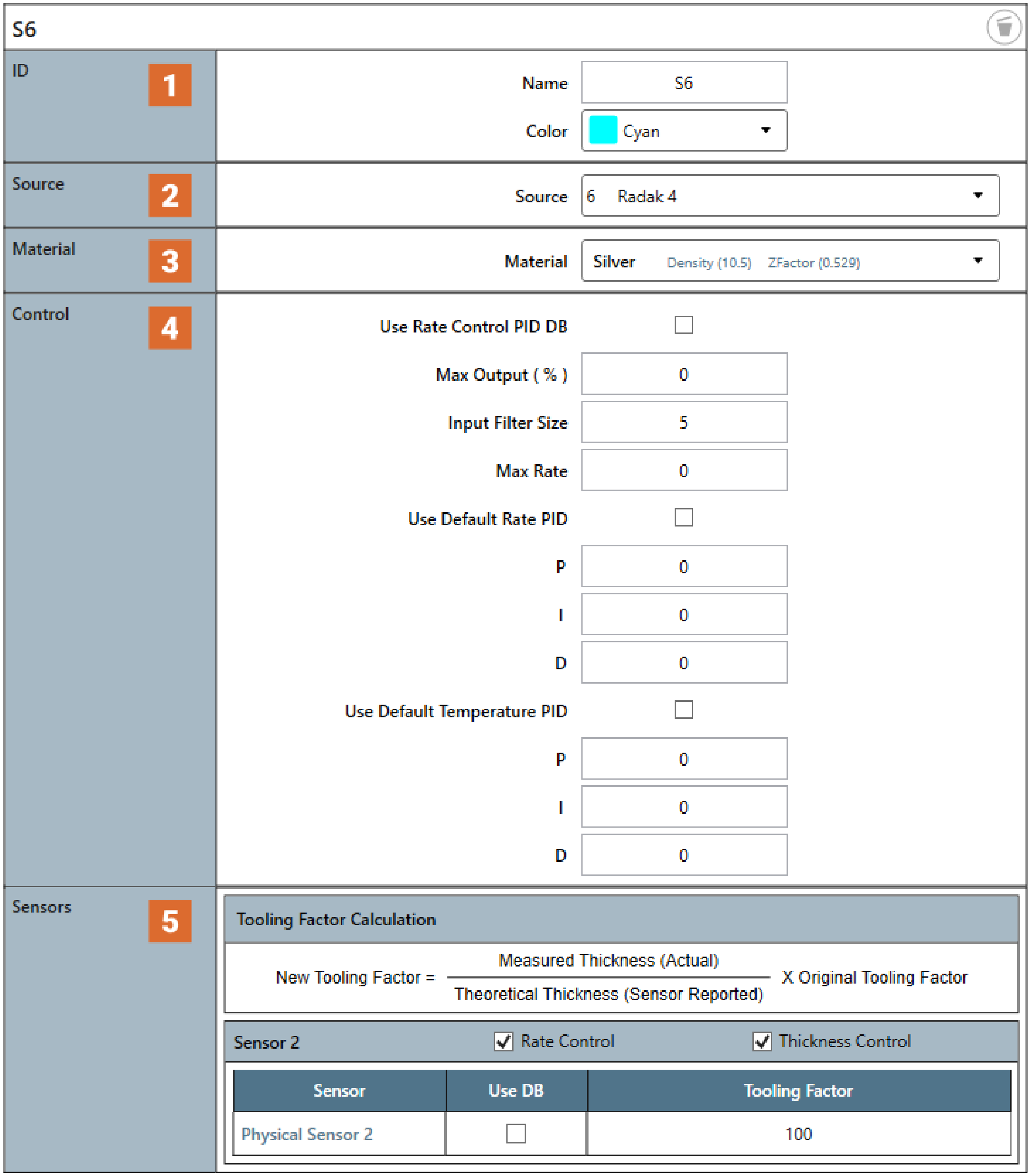
The component configuration windows for deposition sources and mass flow controllers are described in the next few paragraphs.

Source Configuration: General Notes

The Source Configuration window allows users to quickly populate and modify the control parameters of deposition sources to be used in an Aeres® recipe. These values will be saved with the recipe, which allows users to build a collection of recipes with control parameters tailored to each deposition to be performed.

The configuration of sources in Aeres® recipes share similar features. A general overview of the configuration options available is presented in this section, followed by sections describing parameters or operating conditions that are specific to common deposition sources found in Angstrom Engineering® systems.

An example of the Source Configuration window, which will be referred to for common configuration options in this section, is shown.



An Example of the Source Configuration Window for a Radak® Source, which allows users to specify the control parameters and material to be used in the recipe for the selected source.

1. **ID:** Shows information relating to the identification of the source.

   Name: The user can enter a descriptive name for the deposition source, which will be used in the recipe.

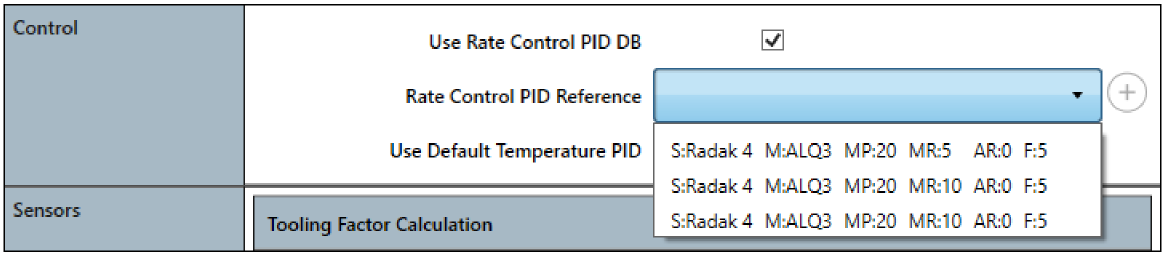
   Color: This drop-down menu allows the user to select a color for the deposition source, which will be used to plot data for the source on the Process Page. In multi-layer and co-deposition recipes, assigning contrasting colors to each source allows the user to quickly identify the data associated with each deposition source.

2. **Source:** This drop-down menu allows the user to select the source(s) to be used in the recipe.

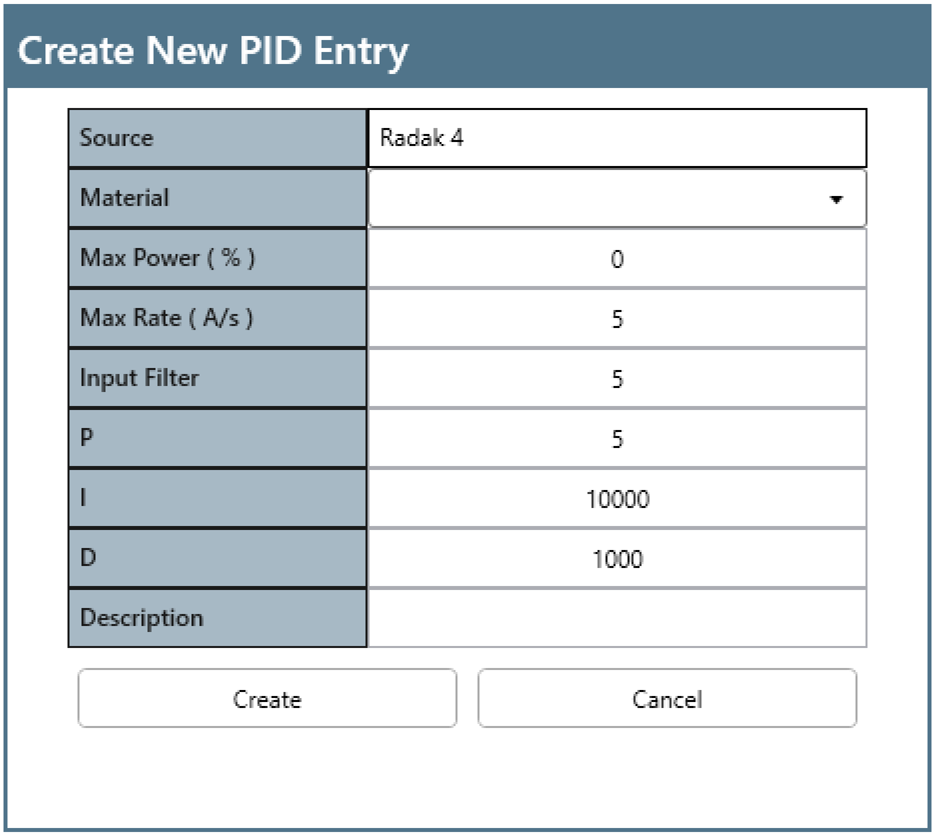
3. **Material:** In this drop-down menu, the material to be used by the recipe in the source selected above is chosen from the Materials Database. For a recipe to run, all materials specified as loaded into the selected sources must match with the materials and sources registered in the Load Materials Page. If this is not the case, Aeres® will notify the user of a materials mismatch between the recipe and the current system state and will not run the recipe. This prevents depositions from being run with incorrect materials, reducing waste and downtime.

4. **Control:** In this section, users specify the operating and control parameters of the source within the recipe. If installed, database values can be read and used in the recipe, or users may specify parameters unique to the recipe being created. The options available in this section are:

   - **Use Rate Control PID DB:** If this box is selected, then each time this recipe is run, rate control parameters are imported directly from the Rate Control Database (if installed). Upon selecting this box, the user will be presented with a drop-down menu, and can select from a summary of each rate-control entry for the current source in the Rate Control Database. Clicking "Create New" will present the user with a window to create a new database entry. Once a new entry is created, the user will then be able to select it from the drop-down menu for use in the current recipe and would be available for use in other recipes that are created/edited. For further details, please consult the Rate Control Database section.



Selecting the "Use Rate Control PID DB" option presents the user with a drop-down menu listing the Rate Control Database entries available to control the rate of deposition from the source being configured in the currently open recipe. The database entry parameters summarized in the drop-down menu are the Source (S), Material (M), Maximum Power (MP), Maximum Rate (MR), the rate at which Autotuned PID values were generated (AR), and the Input Filter size (F).



When the "Use Rate Control PID DB" box is selected, entries for the Rate Control Database can be generated within the Process Builder Page, and then selected for use in the recipe currently being generated.

If not using a Rate Control PID DB entry, the user will have to set the following values manually:

- **Max Power (%):** Corresponds to the maximum power (expressed as a percentage of the factory-configured maximum power) that can be applied to the source.
- **Max Rate:** Corresponds to the maximum allowed rate during the process. Exceeding this rate will throw a fault when running the recipe.
- **Input Filter:** Determines how many data points are used in a rolling average that is then fed into the PID loop. Filtering helps reduce the impact of signal noise on the control loop.

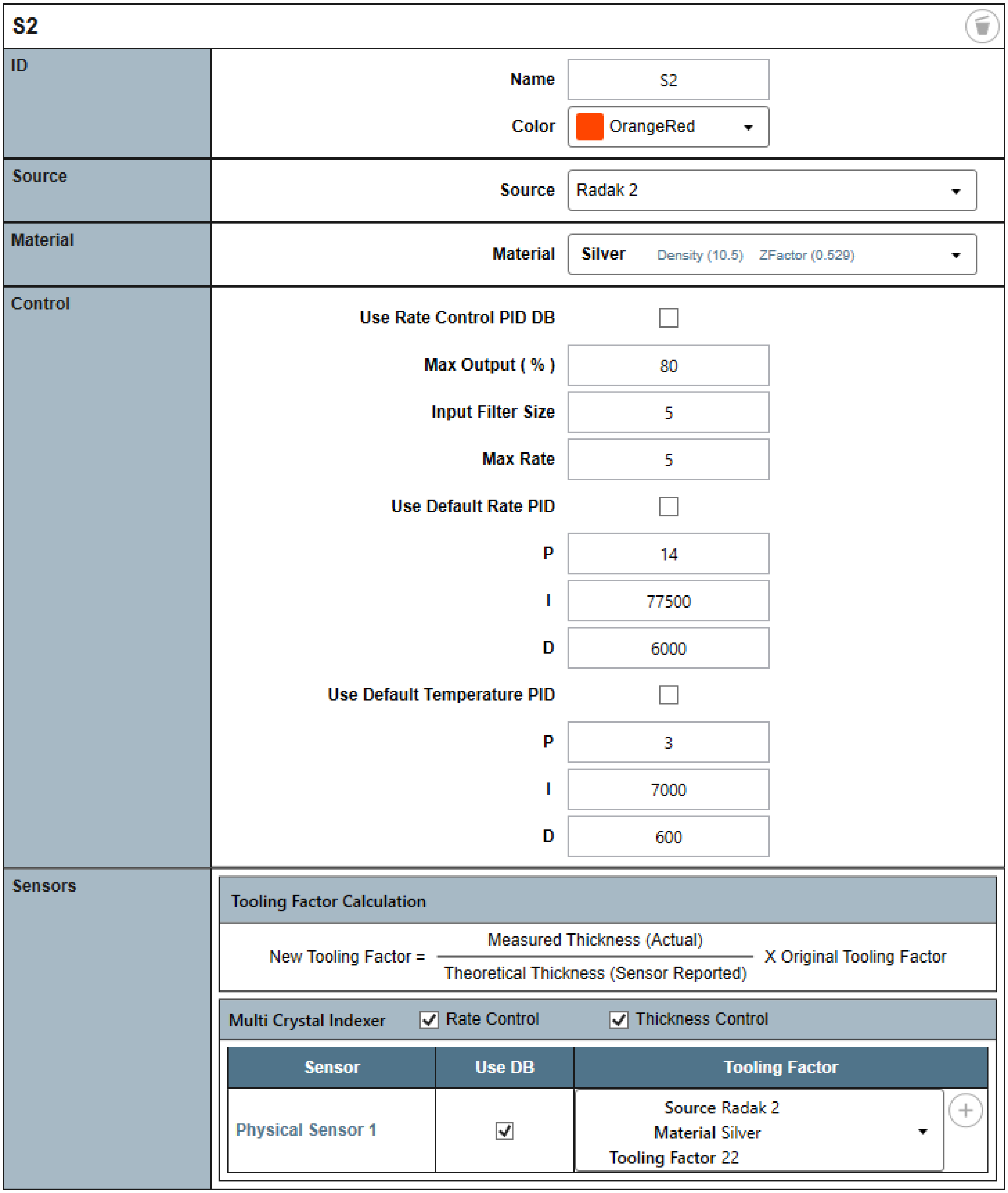
- **PID:** These fields allow the user to enter values for the proportional, integral, and derivative parameters for PID control of the deposition rate from the selected source.
- **Use Default Rate PID:** If this box is selected, then Aeres® will use the Default Rate PID parameters entered on the Sources Page to control the rate of deposition from the source being configured. If left unselected, then the user must enter P, I, and D values for the rate control PID loop in the recipe.

5. **Sensors:** The sensor(s) available for the selected source will be displayed here, with the following options.

- **Rate Control:** If this box is selected, Aeres® will use this sensor to control the rate of deposition from a source during the execution of the recipe. If multiple sensors are selected for rate control, Aeres® will use the average of the sensor measurements to control the deposition rate.
- **Thickness Control:** If this box is selected, then Aeres® will use this sensor to control the thickness of the material deposited on the substrate. If multiple sensors are selected for thickness control, Aeres® will use the average of the sensor measurements to control the thickness of deposited material.
- **Use DB:** For systems with Tooling Factor Database enabled, the user can select this option to automatically populate the recipe with the system's Tooling Factor for the current sensor-material-source combination in the recipe being created.
- **Tooling Factor:** This is the Tooling Factor that is applied for the selected sensor, material, and source in the recipe. If the "Use DB" option is left unselected, the user can select this text box and manually enter the Tooling Factor to be applied in the recipe.
- **Freq Correction:** Selecting this box will enable frequency correction for this sensor (if installed on the deposition system). Frequency correction allows for higher accuracy in the deposition of organic layers but requires process configuration and calibration. Please contact Angstrom Engineering® for further details.

Source Configuration: Radak®

Since Radak® sources are equipped with integrated thermocouples, their configuration comes with a set of temperature control options not included for other deposition source types. These options, which are used to regulate the crucible temperature in the Radak® source, are described below. For a description of the other configuration options on these sources, see Source Configuration: General Notes.

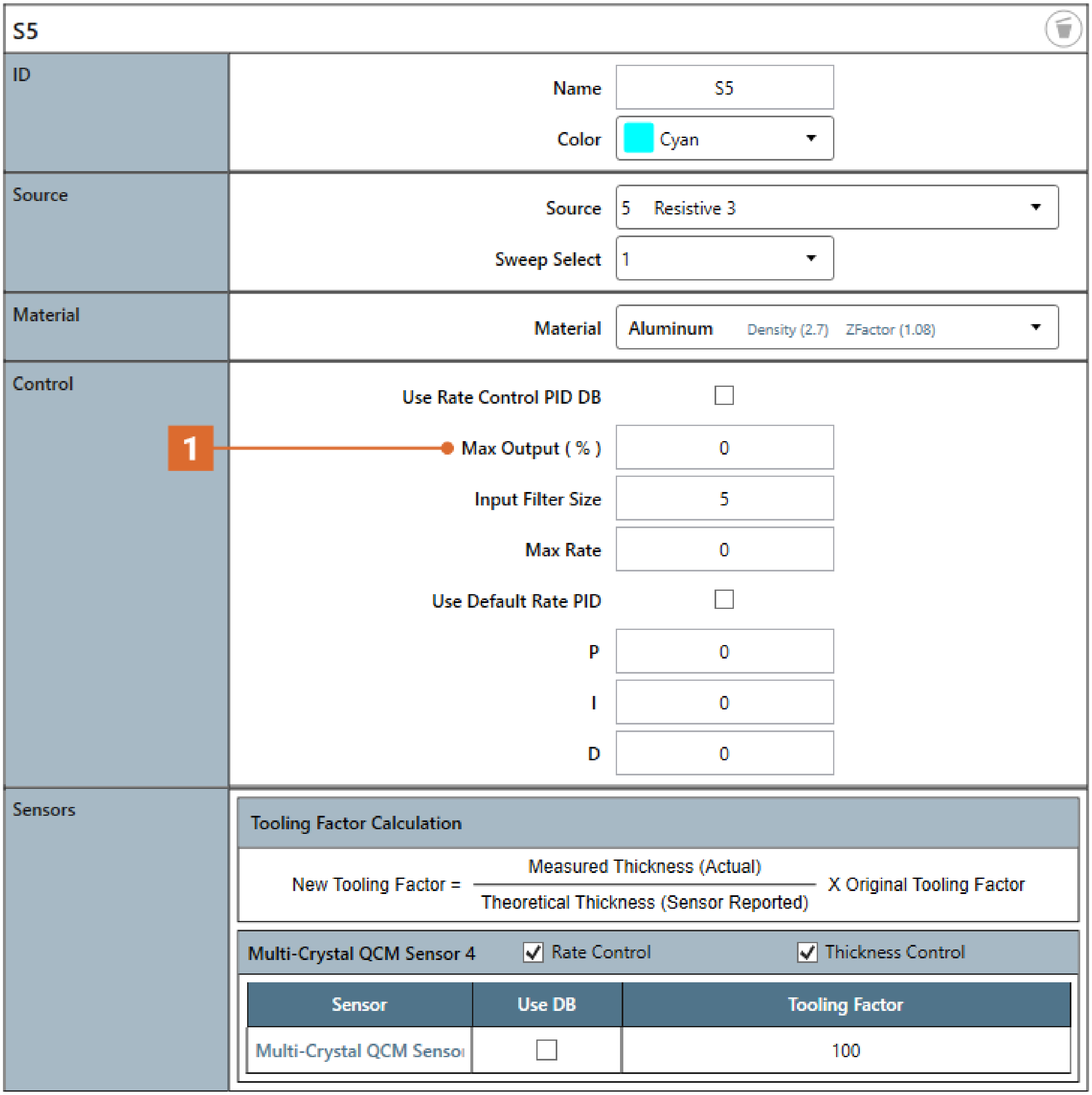


- **Max Output (%):** This is the maximum power that will be output to the Radak® source during recipe execution. For details on the maximum temperature limits, see the Sources Page and Materials DB Page.

- **Use Default Rate PID:** Selecting this box will trigger Aeres® to use the Default Rate PID parameter values as defined on the Sources Page each time this recipe is executed.
- **Use Default Temperature PID:** Similar to PID rate control, selecting this box will trigger Aeres® to use the Default Temperature PID parameter values as defined on the Sources Page each time this recipe is executed.
- **PID:** These fields allow the user to enter values for the P, I, and D parameters for PID control of the temperature of the selected Radak® source in the currently open recipe, provided the user leaves the "Use Default Temperature PID" box unselected.

Source Configuration: Resistive

The configuration of this type of source in Aeres® is straightforward, with all options covered in section Source Configuration: General Notes. An example of the resistive source Configuration Window is shown below. Other notes on Source Configuration parameters specific to resistive deposition sources are detailed below.



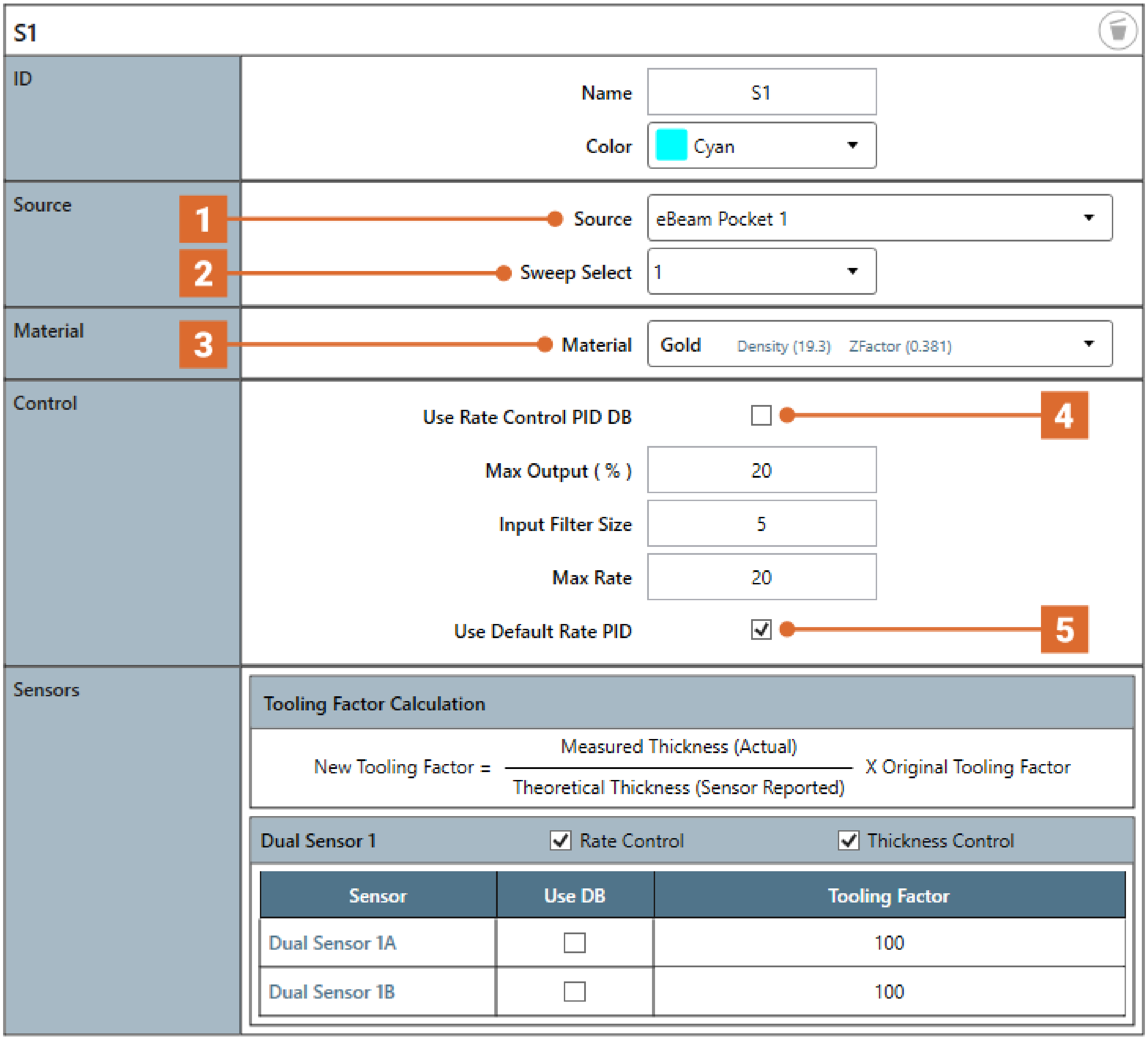
An Example of The Source Configuration Window for Resistive Sources.

1. **Max Output (%):** For resistive deposition sources, this corresponds to the maximum power (expressed as a percentage of the factory-configured maximum power) that can be applied to the source.

Source Configuration: eBeam

In terms of their configuration in an Aeres® recipe, electron beam deposition sources differ from other sources in that each e-beam source has multiple pockets that can contain different materials. Aeres® treats each pocket in an e-beam source as a separate source, thus the user must create and configure a separate e-beam source in their recipe for each material pocket that is to be used for deposition. For example, if two materials are to be deposited from two different pockets in the same e-beam source, then the user would add two sources to their Aeres® recipe: one "source" for the first pocket, and another "source" for the second (even though there is only one e-beam deposition source physically installed in the system). Each of these virtual sources in the recipe is then configured in an e-beam Source Configuration Window, an example of which is shown below.

This gives users the most flexibility in the use of their e-beam deposition source in Aeres® recipes, since each pocket and each material can be configured with their own deposition settings. Other notes on the configuration of e-beam sources in the Source Configuration window are detailed below.



Electron-Beam Deposition Source Configuration in an Aeres® recipe

1. **Source:** This drop-down menu allows the user to select which pocket on the e-beam source will be used for deposition.

2. **Sweep Select:** This drop-down menu specifies the predefined pattern through which the electron beam will be moved to heat the pocket material. For details on the sweep patterns available, please consult the user manual of the electron beam controller installed in your Angstrom Engineering® system.

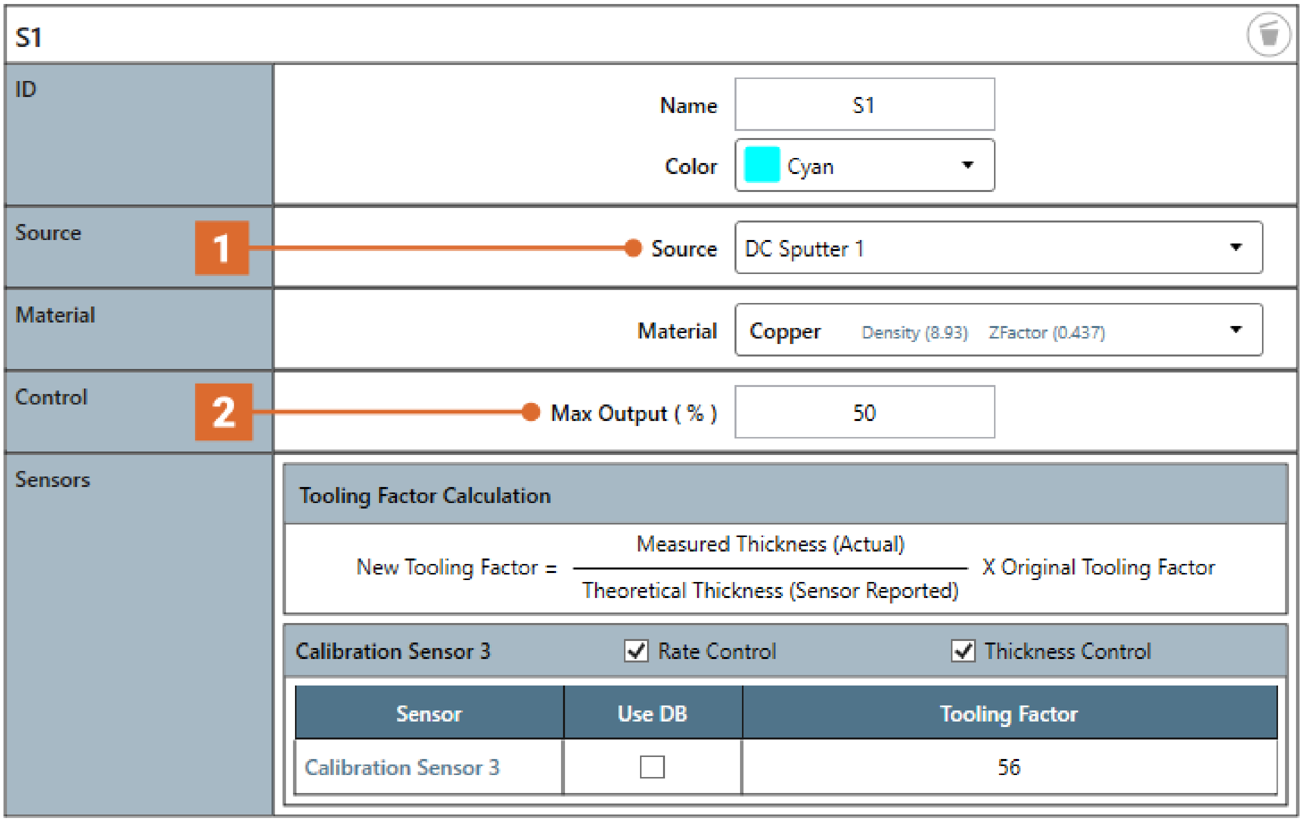
3. **Material:** This drop down menu allows the user to select the material they are depositing from the selected pocket.

4. **Use Rate Control PID DB:** Checking this allows the user to load Max Power, Max Rate, Input Filter, and PID values that have been Autotuned to the desired rate. These values are overwritten if there is a Autotune step in the recipe. Refer to Source Configuration for more information.

5. **Use Default Rate PID:** Checking this allows the user to load the Default source PID values found on the Sources Page. Refer to Source Configuration for more information.

Source Configuration: DC and Pulsed-DC Sputtering

Since DC and pulsed-DC sputter sources have multiple control modes (e.g. regulation of current, voltage, or power), the user should consult the recipe actions Configure DC Supply and Configure Pulsed DC Supply to understand how these recipe actions interact with the Max Power (%) setting in the Source Configuration window. Presented below are details on the configuration of DC and Pulsed-DC sputter sources in Aeres®.



The Source Configuration Window for DC and Pulsed-DC Sputter Power Supplies.

1. **Source:** This drop-down menu allows the user to select which sputter source will be supplied with DC/pulsed-DC power when used as a deposition source in the currently open recipe. Note that for systems with multiple sputter sources and shared power supplies, not all sputter sources may be available for use with DC and/or pulsed-DC power. This depends on the factory configuration of the system.

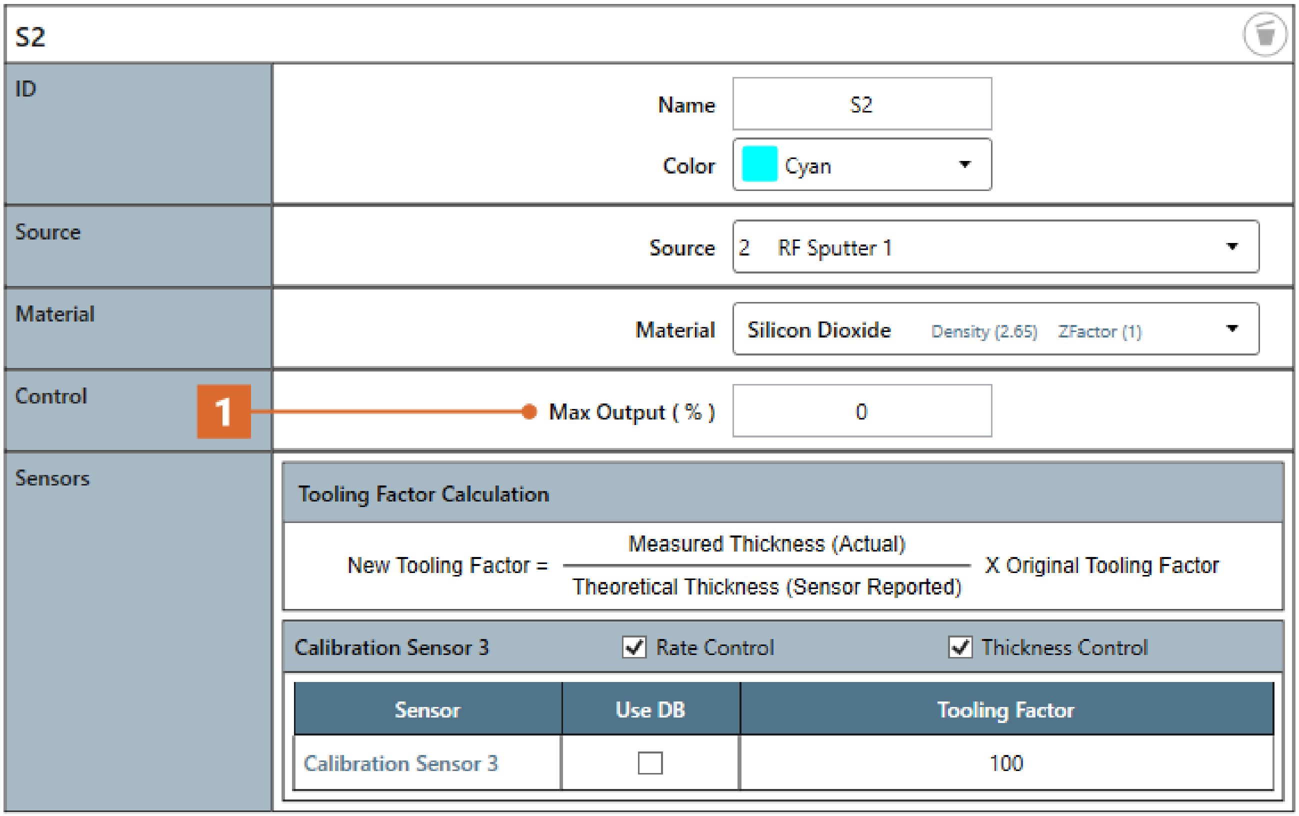
2. **Max Output (%):** This is the maximum current, voltage or power output from the DC or pulsed-DC power supply that will be supplied to the sputter source, expressed as a percentage of the power supply's full-scale value.

The regulation mode of the power supply (current, voltage, or power) is determined by the last Configure DC Supply or Configure Pulsed DC Supply recipe action that was run in the recipe. If neither of these recipe actions is used in a recipe, the default regulation mode for DC power supplies and pulsed-DC power supplies is current control. The value for Max Power (%) for a configured source is fixed during a recipe, regardless of any changes made to the power supply regulation mode during a recipe. For example, if in a recipe, a source with a DC power supply is set in the Source Configuration window with Max Power (%) = 50%, then until the Configure DC Supply or Configure Pulsed DC Supply recipe action is executed, that source will be run with current regulation where the maximum supplied current will be equal to 50% of the full-scale output of the DC power supply. If the Configure DC Supply recipe action is then used to put the source into voltage regulation mode, the maximum voltage that the DC power supply will output will be 50% of its full-scale voltage output. Before running any sputter target in a source, be sure to calculate its maximum operating power, and do not exceed this value during operation. This can be calculated from the target material's maximum recommended power density, thickness, and the nominal size of the target. Most targets in DC and pulsed-DC sputtering have maximum power densities of 100 W/in^2, with nominal operating power densities around 70 W/in^2. However, sputter targets with low thermal conductivities, thick sputter targets, or oxide/nitride targets may only be able to sustain sputtering plasmas at low power densities. Generally, most users obtain their optimal deposition rates well below their sputter materials maximum power densities.

The remaining options in the DC and Pulsed-DC Configuration window are covered in Source Configuration: General Notes.

Source Configuration: RF

RF power supplies, both for sputtering and plasma cleaning/etching, are regulated in power control mode. A sample of the Source Configuration window for RF power supplies is shown below.



The Source Configuration Window for RF Power Supplies.

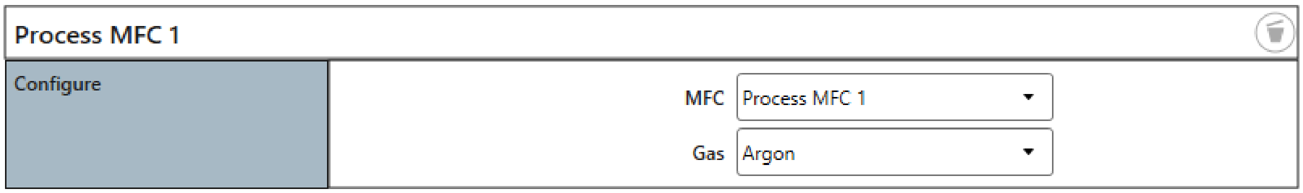
1. **Max Output (%):** This is the maximum forward power that Aeres® will allow to be output by the RF power supply, expressed as a percentage of the power supply's maximum power rating.

All Angstrom Engineering® systems are supplied with automatic matching networks to minimize the amount of RF power reflected from the process, and these are factory-tested to ensure robust operation. Similarly, all RF power supplies in Angstrom Engineering® systems have voltage standing wave ratio protection to cope with any reflected power resulting from processes outside of the system's normal operation. For RF sputtering applications, be sure to calculate the maximum operating power of any target material before applying RF power. The maximum operating power can be calculated from the target material's maximum recommended power density, thickness, and the nominal size of the target. Most targets in RF sputtering have maximum power densities of 35 W/in^2, with nominal operating power densities around 20-25 W/in^2. However, sputter targets with low thermal conductivities, thick sputter targets, or oxide/nitride targets may only be able to sustain sputtering plasmas at lower power densities. This is particularly true for bonded sputter targets. Generally, most users obtain their optimal deposition rates well below their sputter materials maximum power densities.

The remaining options in the RF Source Configuration window are covered in Source Configuration: General Notes.

Pressure Control Configuration: MFC

The Pressure Control Configuration window allows the user to select which mass flow controllers will be used in their recipe, and the corresponding gases that must be used with the selected MFCs. At the start of any recipe's execution, Aeres® will perform a check to ensure the gases registered on the Pressure Control Page match those required by the recipe and warn the user in the event of a mismatch. The configuration options are as follows.



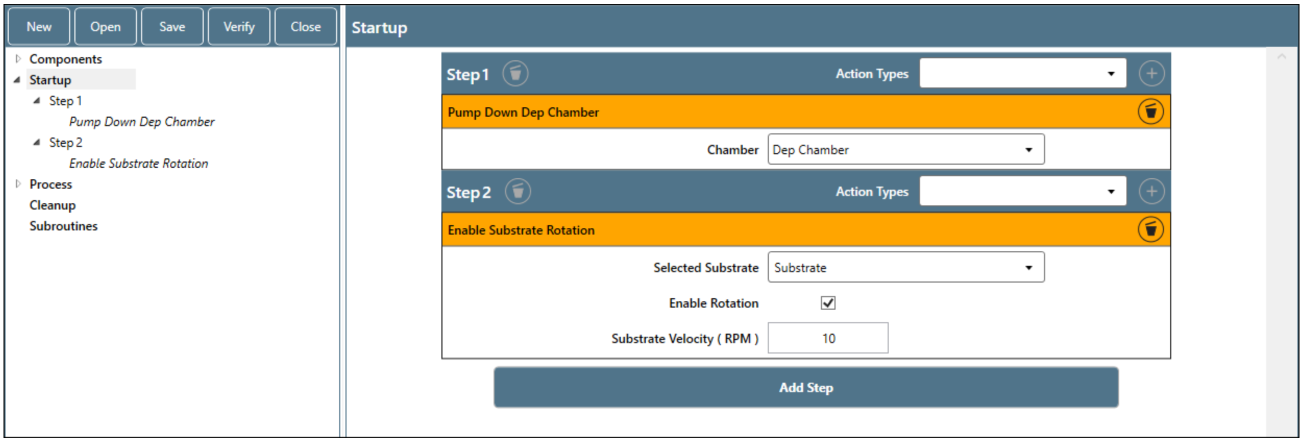
The Pressure Control Configuration window specifies the combination of Mass Flow Controller(s) and gas(es) to be used in the recipe

- **MFC** - The user specifies the mass flow controller to be used in the recipe.
- **Gas** - The user selects the gas that will be regulated by the selected MFC.

Startup

The Startup section of an Aeres® recipe is used to execute recipe actions that must take place before any processing of the sample occurs. These typically correspond to actions relating to the pressure within the system and the setting of initial conditions. Every new recipe is automatically populated with two Steps, Chamber Pump Down and Substrate Rotation, since these actions are common to most recipes.

The Steps in the Startup section of a recipe will be executed sequentially by Aeres®. When multiple recipe actions exist within a Step, these actions will be run simultaneously while that Step is active.



The recipe tree of a newly created recipe is automatically populated with two Steps: Chamber Pump Down and Substrate Rotation

Process

The process section of an Aeres® recipe is where all actions needed to perform a deposition are carried out. The user has the most flexibility in this recipe section and can create recipes that are limited only by the physical constraints of their system.

Within the process section, there are four, nested levels:

1. Layers
2. Phases
3. Steps
4. Recipe actions

Every recipe can contain as many layers, phases, steps, and recipe actions as necessary to achieve the final objective. These levels are described in more detail below.

When creating a recipe in the process section, there are four rules to follow:

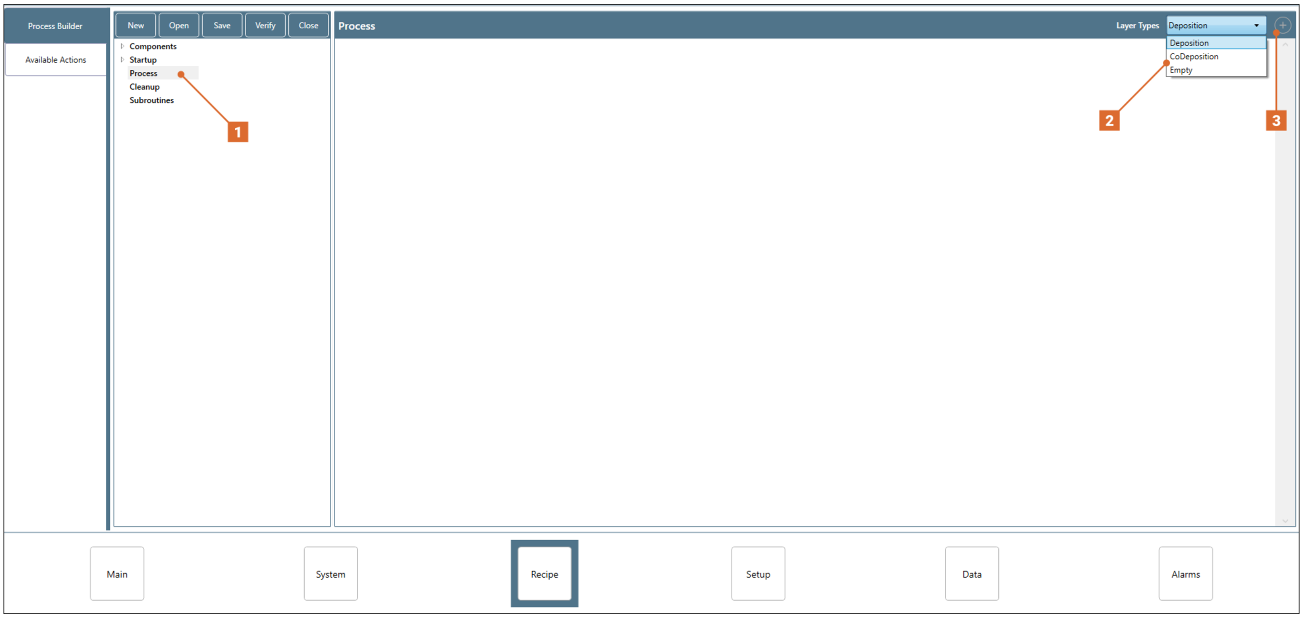
1. Layers, phases, steps, and recipe actions are preformed sequentially.
2. All recipe actions within a step are performed simultaneously.
3. Recipe actions are contained within steps, steps are contained within phases, and phases are contained within layers.
4. Layers, phases, and steps must not be empty.

Layers

Each layer in a recipe is intended to represent a physical layer in a thin-film deposition process. When a Llayer is being executed, the Process Page will graphically display information for only the sources used in that active layer and its phases.

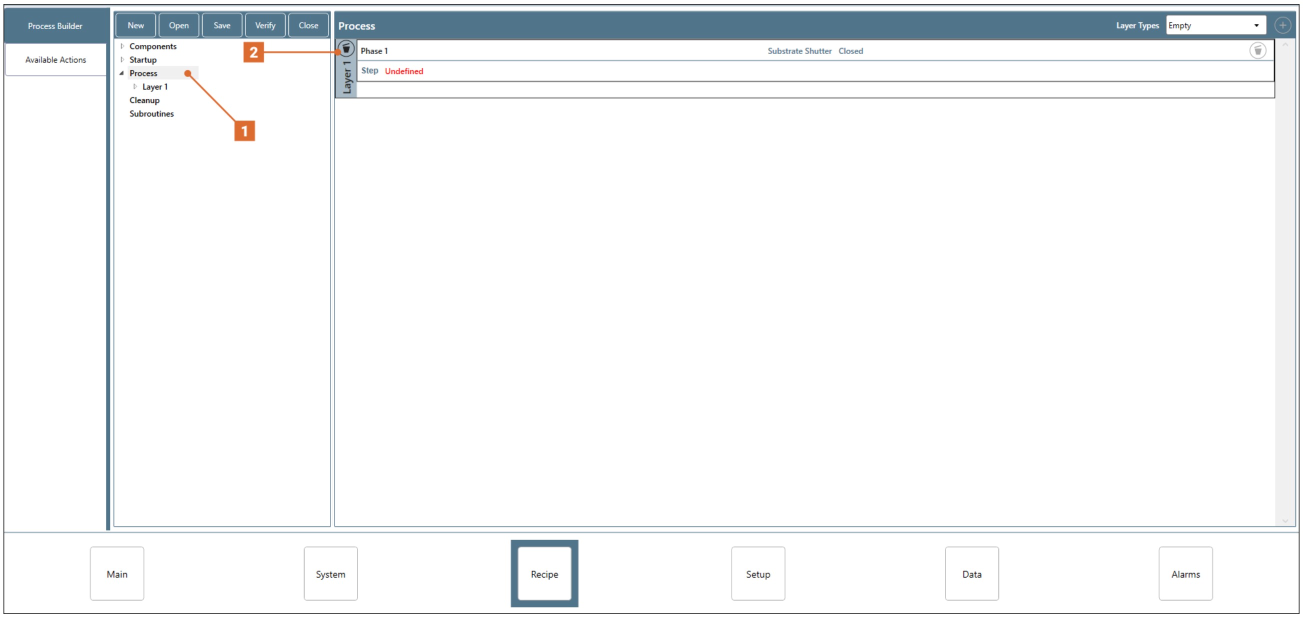
Layers can be named by the user by clicking on the name of the layer in the recipe tree, then entering a new name in the text box in the edit window.

To add a Layer within the Process Section:



1. Ensure the process section is selected in the recipe tree.
2. From the drop-down menu "Layer Types," select the layer to be added.
   - **Deposition** - Provides a preconfigured layer with four phases (Precondition, Stabilize, Deposit, and PostCondition) that can be easily customized for use with one source.
   - **CoDeposition** - Provides a preconfigured layer with four phases, as above, but with additional steps for easy customization of deposition from two sources running simultaneously.
   - **Empty** - Provides an empty layer that can be populated with phases.
3. Click the plus (+) button.

To delete a Layer from the Process Section:



1. Ensure that the process section is selected in the recipe tree.
2. Click the trash can icon of the layer's summary in the edit window. This layer, and all of its phases, steps, and recipe actions will be immediately removed from the recipe.

Phases

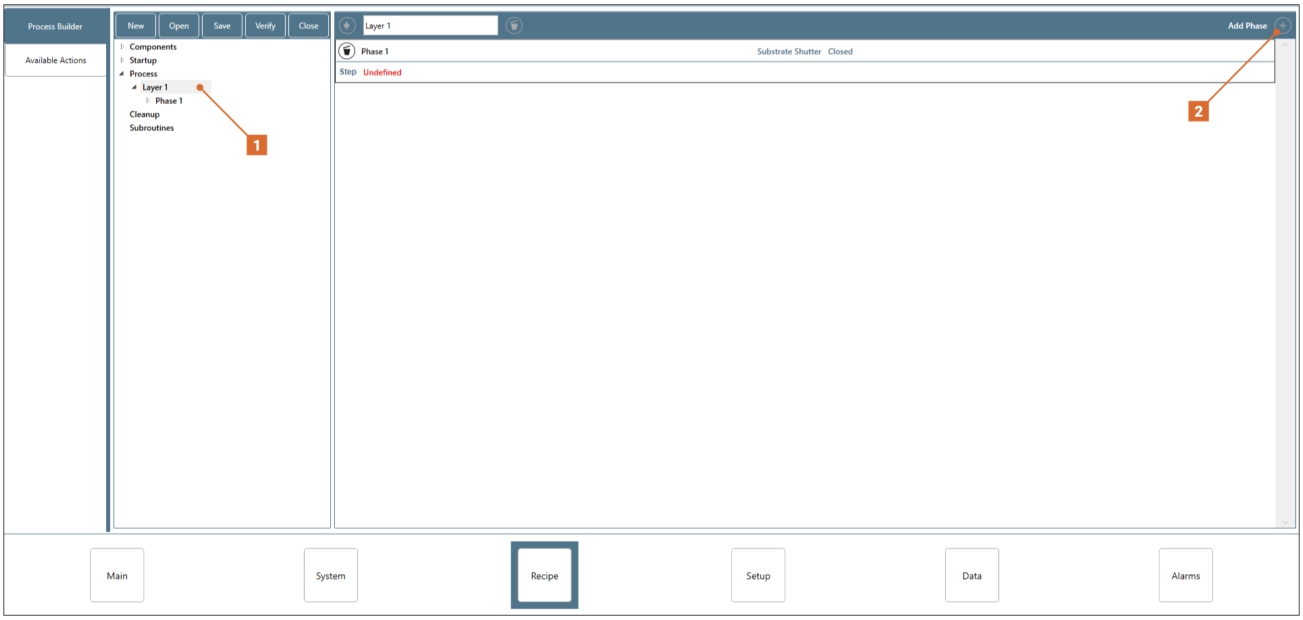
Each phase in a layer is used to conceptually group all steps needed to complete a layer. For example, one phase could be used to group all steps necessary to precondition a material, then the next phase could group all steps needed to stabilize a rate for deposition, the next step could be used to deposit the material of interest, etc.

Each phase in a layer will contain a series of steps that will be executed sequentially. In each phase, the substrate shutter can be set as either open or closed.

When a recipe is running, the Process Page will place a marker on its graphs to indicate that a new phase has been started.

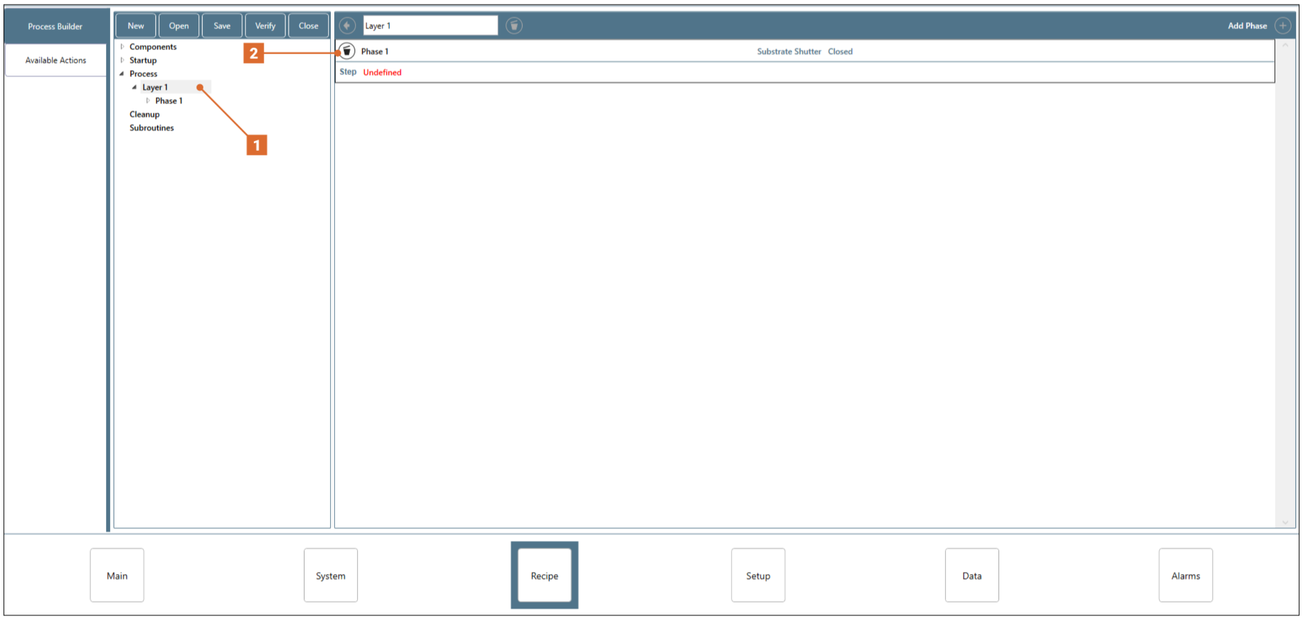
To rename a phase, click on the name of the phase in the recipe tree, then enter a new name in the text box of the edit window.

To add a phase within a layer:



1. Ensure the layer to which the phase is to be added is selected in the recipe tree.
2. Click the plus (+) button next to "Add Phase".

To delete a phase within a layer:



1. Ensure the layer from which the phase is to be deleted is selected in the recipe tree.
2. Click the trash-can icon of the phase's summary in the edit window. This phase, and all of its steps and recipe actions will be immediately removed from the recipe.

Recipe Actions

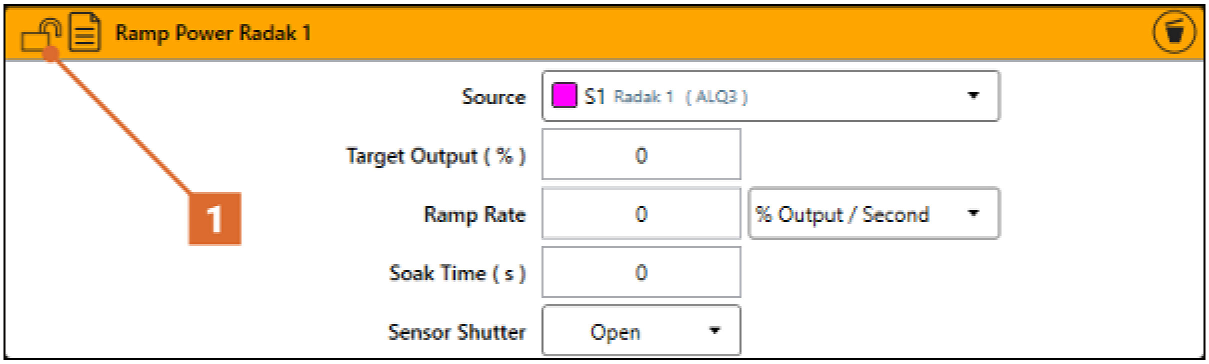
Recipe actions are the fundamental actions that allow the user to control the system. All recipe actions are grouped within steps in the recipe. Depending on the factory configuration of the system, not all recipe actions may be available to the user. They are available for addition in the process section of a recipe. Descriptions of each action are available in the recipe actions section.

Recipe Action Access Control

Locking enables recipe creators to restrict specific user groups from modifying loaded recipe parameters on the "Process" page. Certain recipe action parameters can be set to non-editable, ensuring that users executing the recipe can only modify unlocked values during a process.

How to Use Locking

1. Create a new recipe or load an existing one in the recipe editor.
2. If an action allows for its parameters to be locked, the locking icon will appear on the top ribbon of the action.



- The locking icon has 3 different states:

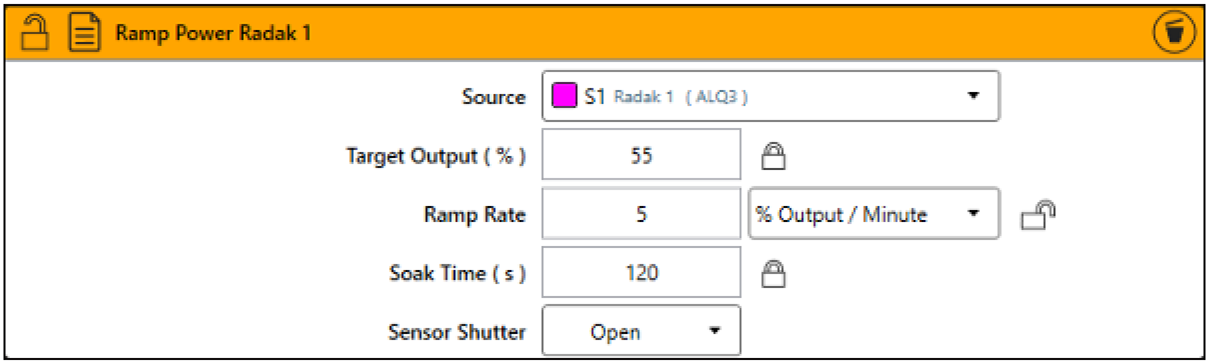
 Action is unlocked – all values are unlocked.

 Action is locked – all values are locked.

 Action is partially locked – at least one value is locked and at least one value is unlocked.

3. When a recipe action has been locked for the first time, the locking icon will appear next to each parameter that can be locked. In the example below, "Target Output" and "Soak Time"

are locked while "Ramp Rate" is unlocked.

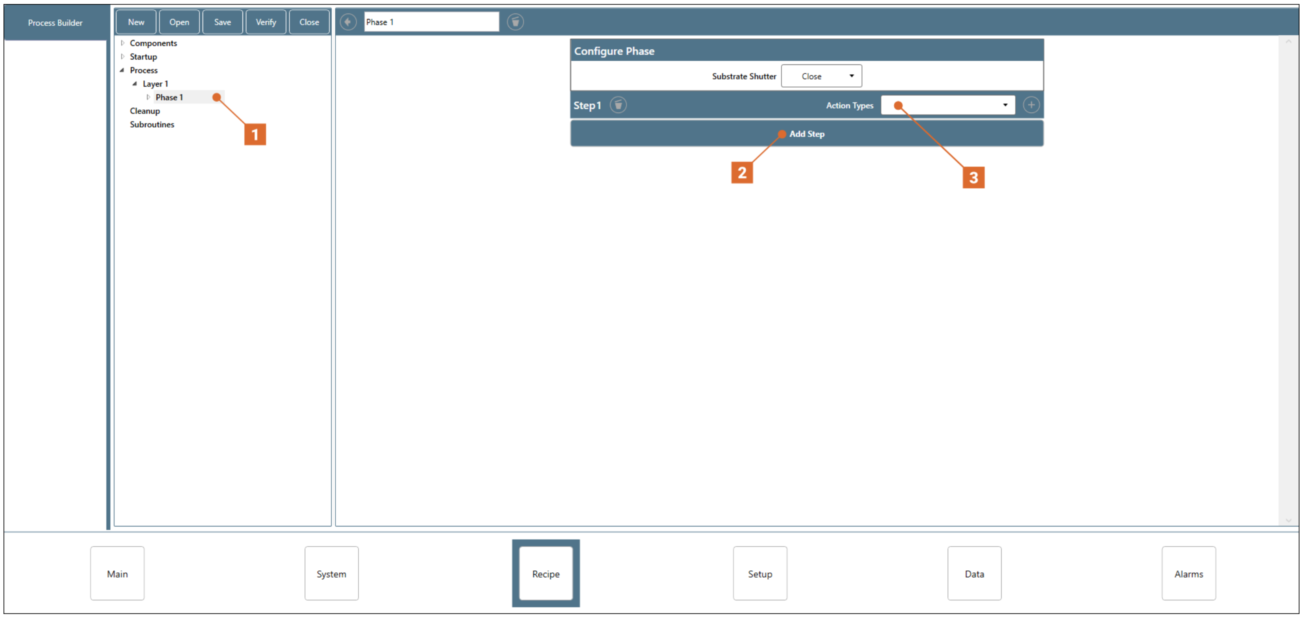


Steps

Steps are used to group recipe actions together within a phase. Each step can contain one or more recipe actions.

If a step contains multiple recipe actions, these will be executed simultaneously, and all these recipe actions must complete before Aeres® will move to the next step, phase, or layer in the recipe.

How to Add a Step Within a Phase:

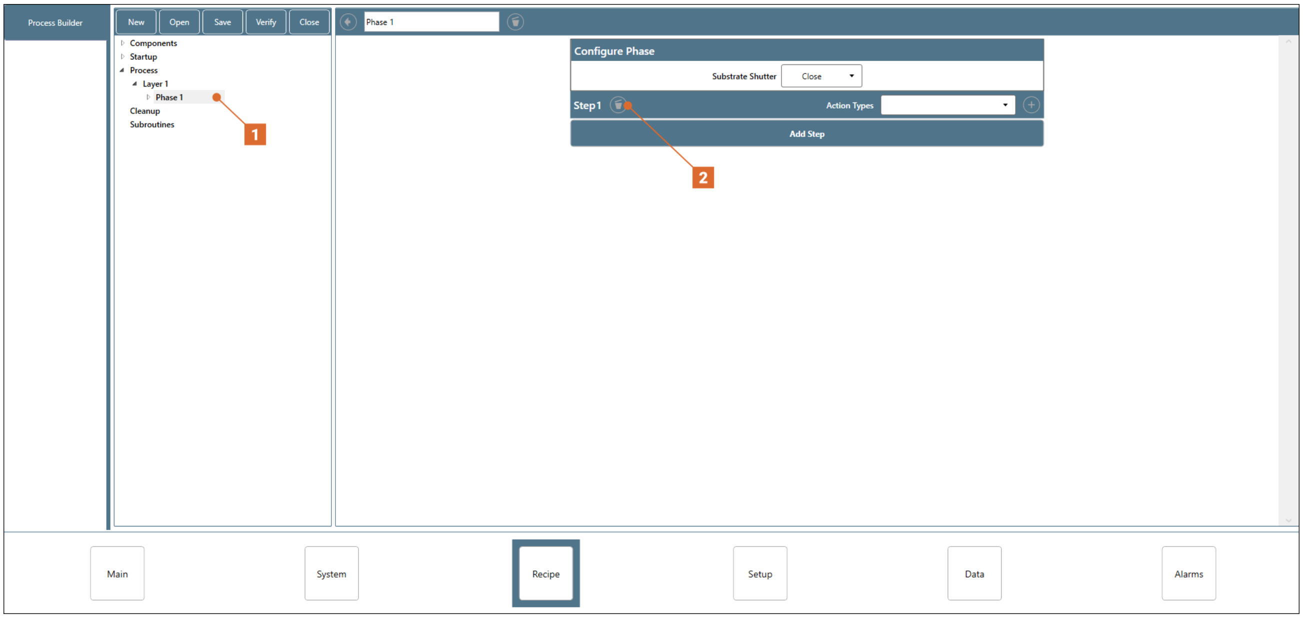


1. Ensure the phase to which the step is to be added is selected in the recipe tree.

2. From the edit window, click the "Add Step" button.

3. Steps can then be populated with recipe actions by selecting from the "Action Types" drop-down menu.

How to Delete a Step Within a Phase:



1. In the recipe tree, select the phase from which step is to be deleted.

2. Click the trash-can icon of the step's summary in the edit window. This step, and all of its recipe actions will be immediately removed from the recipe.

Cleanup

The cleanup section of an Aeres® recipe is used to execute recipe actions that must occur before processed substrates can be removed from the chamber. These actions typically correspond to the ramping-down of power or temperature in the system, or the venting of the vacuum chamber itself.

All steps in the cleanup section of a recipe will be executed sequentially by Aeres®, while recipe actions within a given step will be executed simultaneously, as described in steps.

Subroutines

Subroutines allow for the execution of a series of actions from within a layer without needing to build them directly into the layer. When subroutines are enabled, they can be called using recipe actions "Execute Subroutine" and "Loop Subroutines". Subroutines adhere to the same structure as layers in the process section, utilizing phases, steps, and recipe actions. Once all actions within a subroutine are completed, the process continues from the point of the original layer's subroutine call.

This "layer within a layer" approach allows for the execution of specific actions that might be tedious or impractical to build within the typical process layer/phase recipe structure. For example, instead of repeatedly creating multiple layers for a complex alternating layer stack, users can create a subroutine for each type of layer within the stack. The "Loop Subroutines" action can then be used to select and cycle through the desired subroutines any number of times.

Note: Since subroutines are treated as starting a new layer in Aeres®, actions that control source outputs will not be carried through into the subroutine. These source outputs will be reset to zero when starting a subroutine.

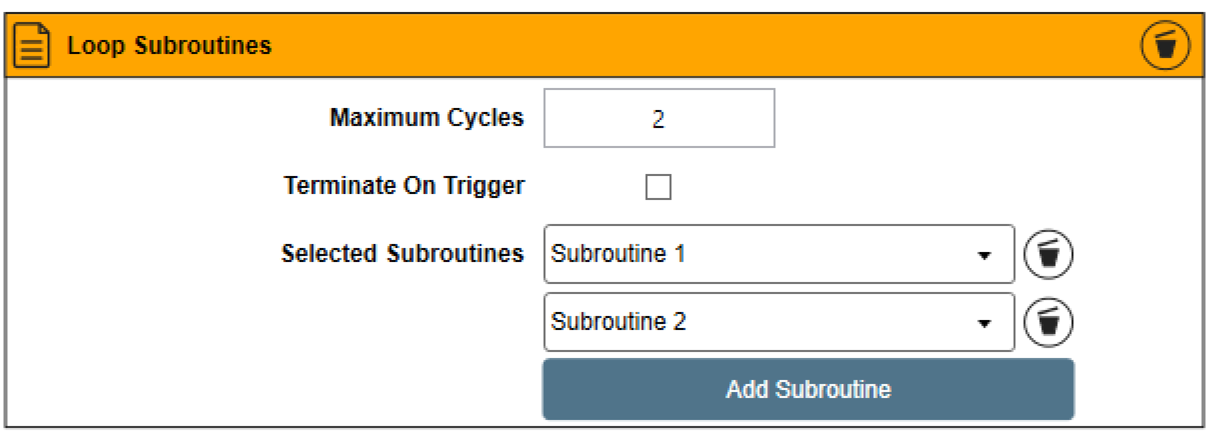
Note: The recipe actions "Execute Subroutine" and "Loop Subroutines" must be within their own step, with no other recipe actions in parallel. The Aeres® recipe will produce an error if any other recipe action is included in the same step as these actions.

How to Use Subroutines

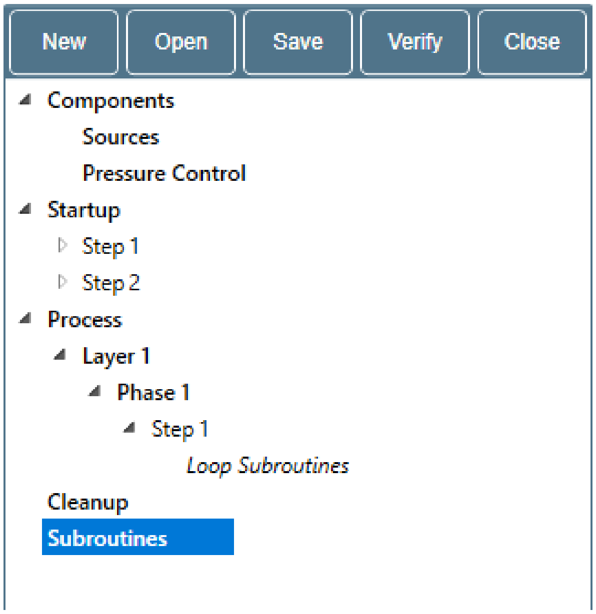
1. Create a new recipe or load an existing one into the recipe editor.

2. Create a layer and insert the phases, steps, and recipe actions to be executed before the subroutine is called.

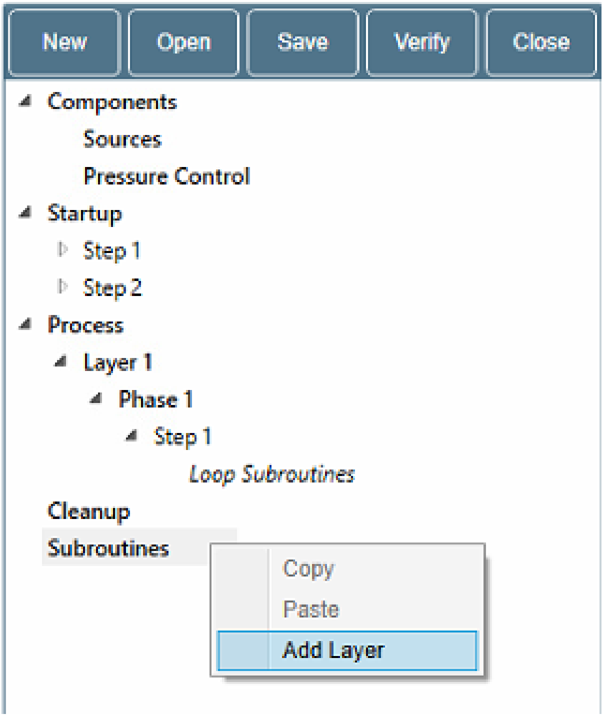
3. Insert either an “Execute Subroutine” action or a “Loop Subroutines” action in the next step.



4. Select the “Subroutines” section on the recipe tree.



5. Insert a layer using the top right drop-down menu, or right clicking on “Subroutines” and clicking on “Add Layer”.



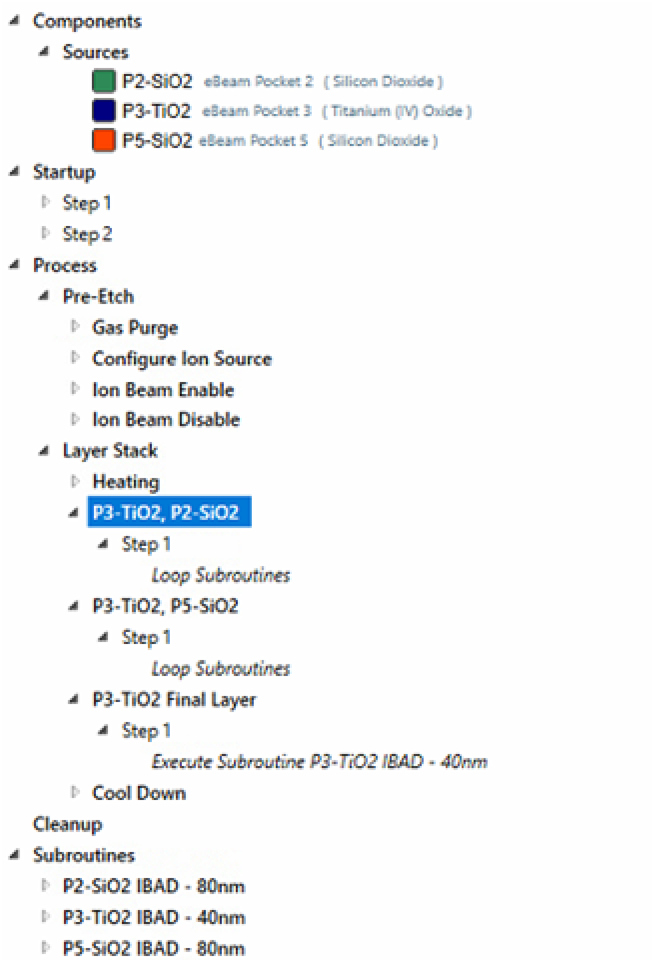
6. Create the subroutine(s), using phases, steps, and actions similar to a typical layer.

7. Select the relevant subroutines in the action(s) inserted in step 3 using unique subroutine names.

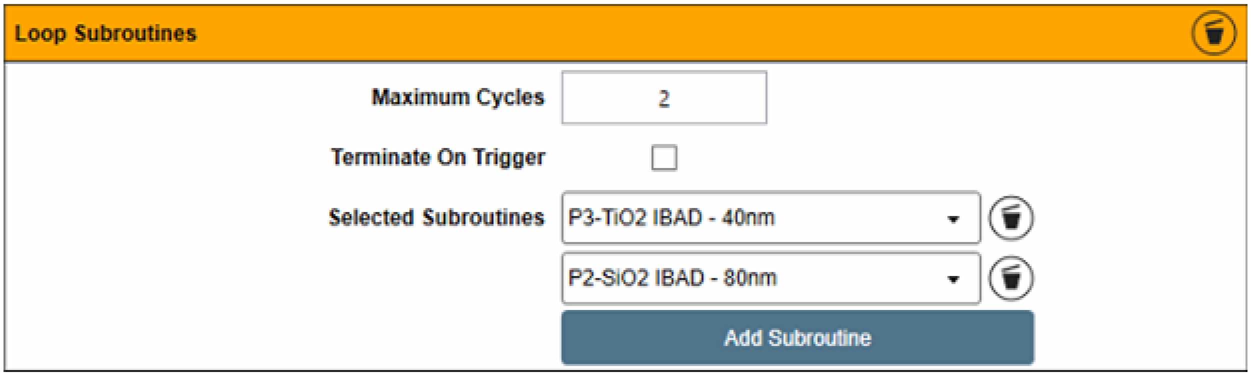
8. In the main process section, insert any phases, steps, and recipe actions to be executed after the subroutine is called.

Example Subroutine Recipe Structure

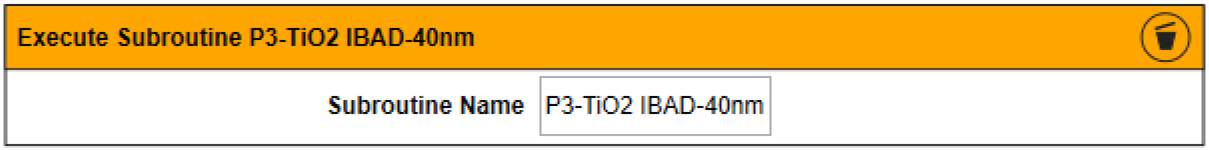
Below is an example recipe structure of an eBeam layer stack using SiO_2 and TiO_2. A pre-etch layer is run first before moving onto the SiO_2/TiO_2 layer stack which is done through an ion beam assisted (IBAD) e-beam deposition for each layer.



The process begins with a pre-etch layer to etch the substrate. Following this, the first phase of the alternating layer stack starts with substrate heating before moving onto the next phase. The “P3-TiO2, P2-SiO2” phase contains a single step with the “Loop Subroutine” action, looping between the “P3-TiO2 IBAD - 40nm” and “P2-SiO2 IBAD - 80nm” subroutine layers for two cycles.



The next phase, “P3-TiO2, P5-SiO2”, follows a similar structure to the previous phase, but utilizes a different set of subroutines. The “P3-TiO2 Final Layer” phase contains an “Execute Subroutine” action to deposit the final layer of the stack, selecting the “P3-TiO2 IBAD – 40nm” subroutine.



Running Processes

How to Run a Deposition Process:

1. Navigate to the right side of the Main > Process page (or Process > Process page on a Nebula tool). Click the drop-down menu under "Load" and select "Browse".
2. Select the desired recipe from the dialog box.
3. Click the "Load Recipe" button below the drop-down menu.
4. Click the green Start button in the top right corner of the Main > Process page (or Process > Process page on a Nebula tool). Note that the deposition cell will need to be offline from the cluster in order to run a process outside of a sequence.

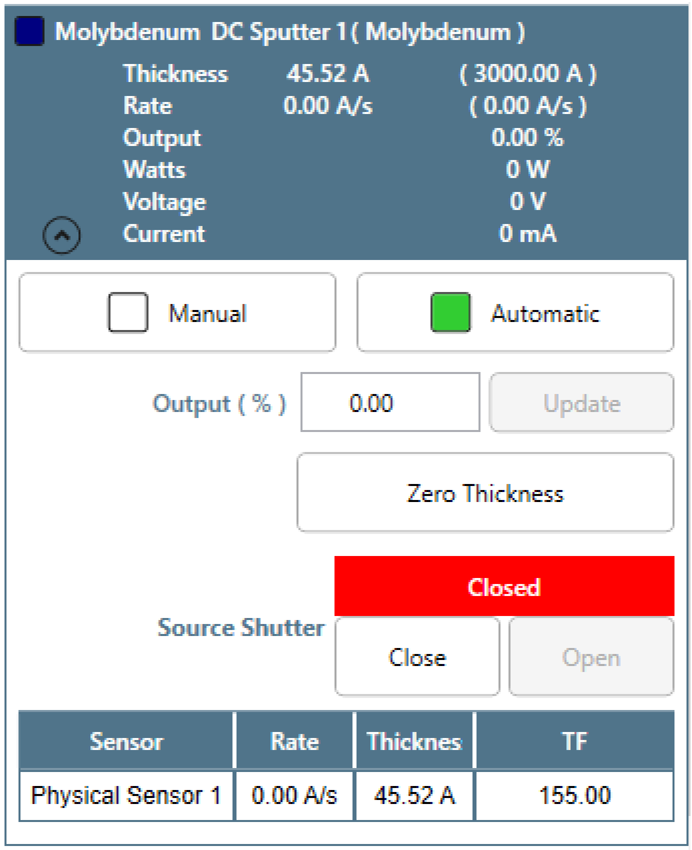
Live Edits

When an action is selected from the process tree on the process page, certain parameters are available for editing in real time. The recipe value (value when the recipe was loaded) and current value are displayed. An edit text box allows the user to enter new values for the process that is currently running.

1. Click update to replace the recipe value with the edit value in the process. The process will execute using the value in the current field even if the step/process is in progress.
2. At the end of the process, the user may select whether or not to save the edited process as a recipe (i.e. overwrite the old recipe or create a new one).

Live Overrides

The sources in operation (for the active layer) as well as its corresponding shutter are displayed on the Process page and can be overridden during an active process.



Click the arrow as shown in the figure for more options:

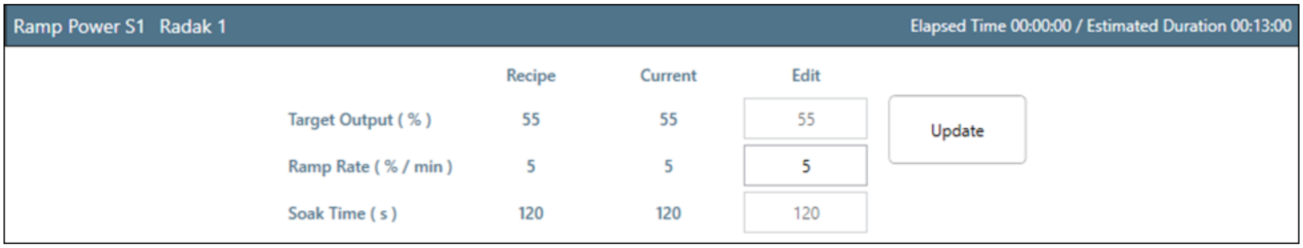
- The source can be switched between manual and automatic power control. When a source is in manual mode, the Output (%) can be adjusted to a value that is different than the current action.
- The accumulated thickness on the sensor can be zeroed by clicking the Zero Thickness button.
- If the active source shutter is open, it can be forced closed by pressing the Close button.
- The Tooling Factor (TF) for the source can be observed.

Recipe Action Access Control

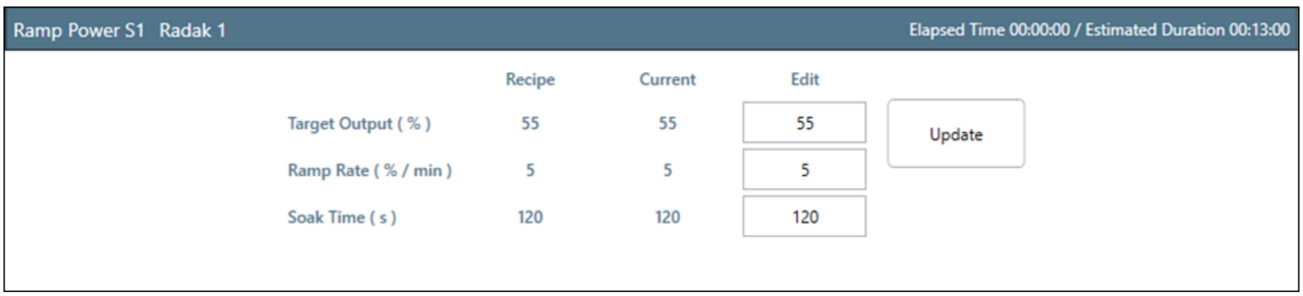
Locking enables recipe creators to restrict specific user groups from modifying loaded recipe parameters on the "Process" page. Certain recipe action parameters can be set to non-editable, ensuring that users executing the recipe can only modify unlocked values during a process.

Locked Parameters During a Process

A user that is not allowed to changed locked parameters will see greyed-out values in the live edit column during the process (e.g. Operator).

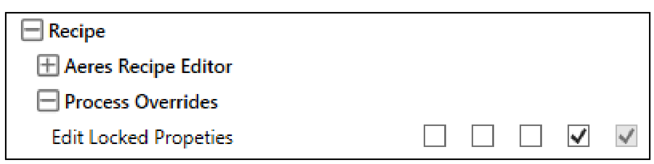


A user that is allowed to change locked parameters will be able to live edit during the process (e.g. Admin).



How to Change User Access for Modifying Locked Parameters

1. In Aeres®, Navigate to Setup > User Management > Features.
2. Under Recipe > Process Overrides, the Edit Locked Properties feature can be enabled or disabled for each user group.



Deposition Processes

This section details specific process setup and conditions for running a variety of recipes. Systems will generally come with some standard pre-built recipes that can be used as a starting point for building more customized processes. This section will provide detail for running more advanced recipes, like reactive sputtering.

Reactive Sputtering

Background:

RF sputtering of insulating targets can lead to low deposition rates. In some cases, this can be avoided by sputtering a metallic target with a DC bias while flowing a reactive gas, such as oxygen or nitrogen. Precise film stoichiometry can be obtained by controlling the flow, and thus the partial pressure, of reactive gas in the chamber at a fixed cathode current. As the partial pressure of the reactive gas increases, the metal sputter target begins to form bonds with the reactive gas, a process called "poisoning". This process typically creates a highly insulating layer with a lower sputtering yield due to the stronger bonds that form between the reactive gas species and the solid (e.g. Al and O) versus between metal atoms (e.g. Al to Al). It is this reduction in sputter yield that RF sputtering of insulating targets also suffers from. With reactive DC sputtering we wish to avoid this behavior (partially) by sputtering in the transition region between metallic and poisoned states.

When sputtering with a fixed current, an increase in cathode voltage with poisoning is known as "direct" reactive sputtering, whereas a decrease in cathode voltage with poisoning is known as "inverse" reactive sputtering.

As reactive gas partial pressure is increased, the metallic target will form a thicker poisoned layer. This layer is constantly being sputtered away, so the onset of the poisoned state is gradual. Once the metallic target reaches a fully poisoned state, a thick poisoned layer must be removed in order to return to a metallic state, this results in a gradual return to the metallic state.

Another important impact to sputtering physics to be aware of when sputtering with reactive gas is that as the target becomes poisoned, the likelihood of arcing will increase. The poisoned layer is generally less conductive than the metal it is covering and it also lacks homogeneity. This results in charge accumulation on the target surface which can lead to the formation of arcs that may lead to undesirable film properties for your process. Arcs could also damage power supply equipment, although most supplies come with arc protection circuitry built-in. By using a pulsed-DC supply, charge accumulation can be avoided by periodically switching between negative and slightly positive bias. Pulse rates supported by pulsed-DC power supplies are typically between 1 and 100 kHz (or more). Typical reverse times, where the voltage is held slightly positive, are between 0 and 5 us. In general, greater frequency of pulsing and longer reverse times will suppress arcing, although reverse times may not be necessary if the pulse frequency is high enough. Adjusting and optimizing the power, pulse frequency, and reverse time will be process dependent and will impact deposition rate, film stoichiometry, as well as other film properties.

Process Setup:

In order to develop a new reactive pulsed-DC sputtering process we must determine where the transition region between metallic and poisoned states is for a particular set of sputtering conditions. Any changes to sputtering conditions may change at what reactive gas flow rates where the transition region appears and require you to perform another Reactive Gas Ladder to determine those conditions. Therefore, before you begin, carefully choose the sputtering conditions, such as power, pulse frequency, reverse time, and process pressure.

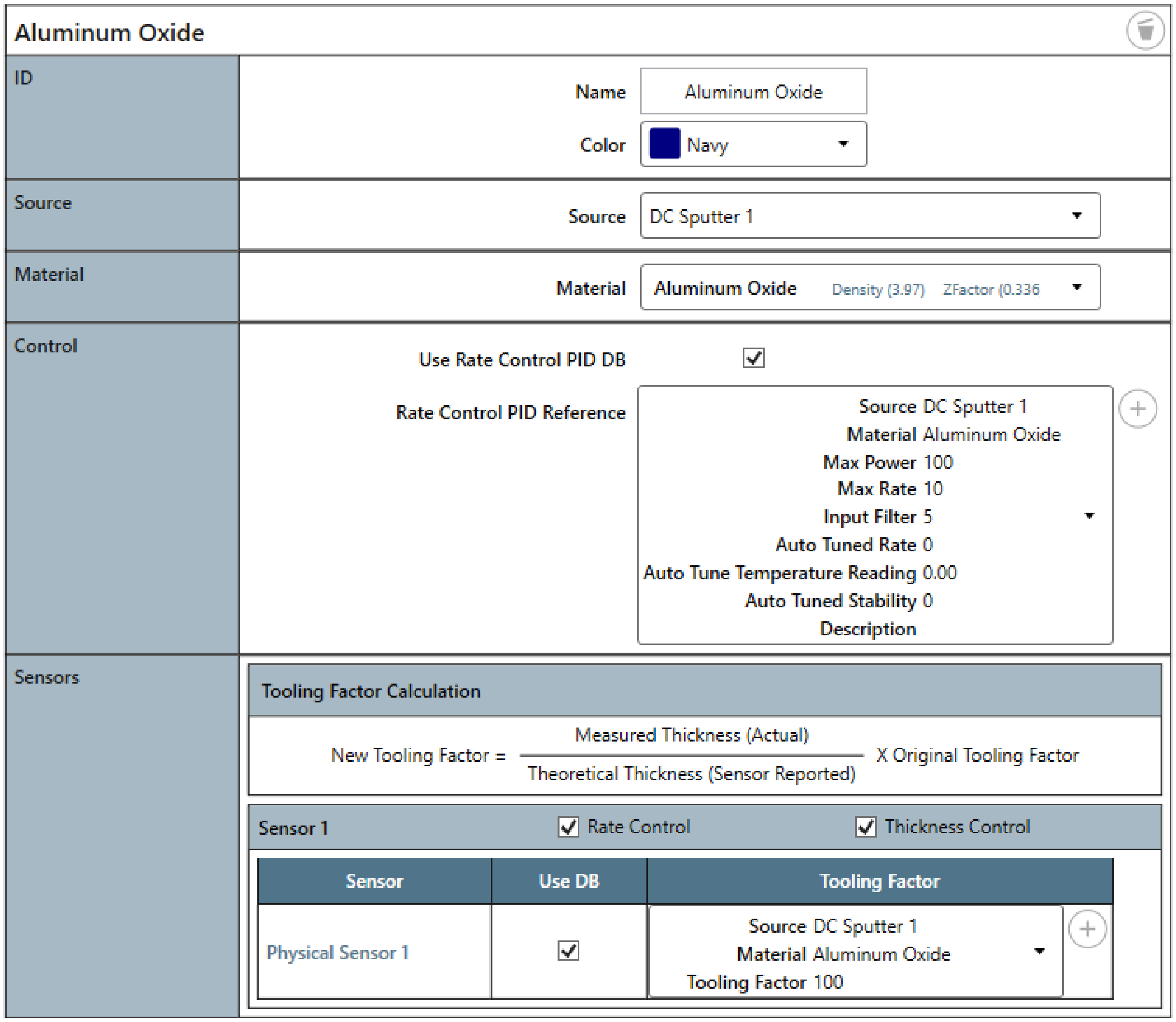
1. Configure Sources

   - In Sources, add a source, select the desired sputter head, DC sputter, and the material to be deposited (e.g. Aluminum Oxide).

     This material can be linked to the loaded target material (e.g. Aluminum) in the Materials Database. This allows for running recipes that call for a different material than that which is loaded.

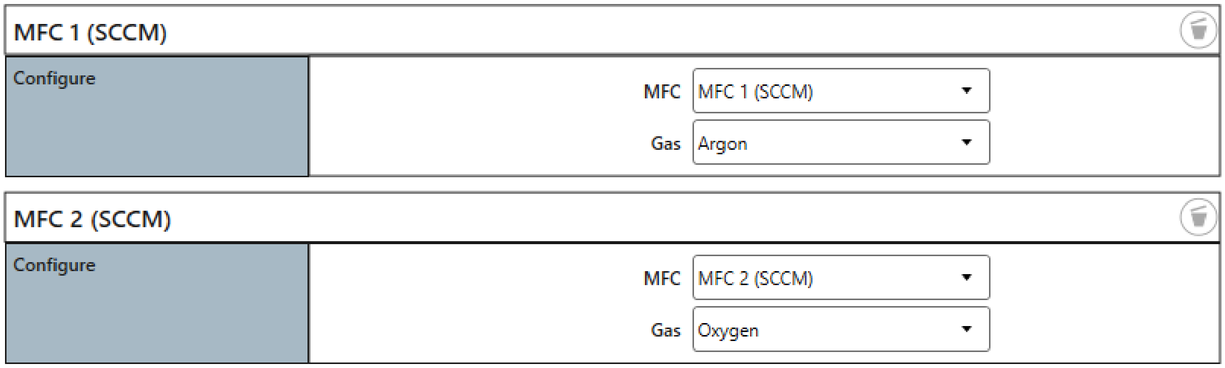
   - Set the Max Output that your target can safely handle (e.g. for Al 150 W/in^2 the max output is 1000 W for a 3" Al target).

   - You may need to add a new Tooling Factor for your material if using a QCM sensor.



2. Configure MFCs

- Under Pressure Control, add two mass flow controllers (MFCs).
- To reactive sputter, you will need an ignition gas and a reactive gas.



3. Set up Process

   - Use the Gas Flow recipe action to do the following:

     - Purge both MFC lines (e.g. 20 sccm) for a few minutes with the "Delay" recipe action.

     - Turn off flow to reactive gas MFC.

     - Maintain flow on ignition gas MFC (e.g. Ar - 15 sccm).

4. Ignite Plasma and Ramp Power

   - Configure Pulsed DC Supply

     Select current control mode for reactive sputtering as voltage will vary with the poison state of the sputter target.

     As the risk for arcing is strongly increased with reactive sputtering, choose the "Pulsed DC – Arc Detect" operation mode.

     A higher pulse frequency will help prevent charge build-up that can lead to arcing (at least 20-30 kHz is recommended).

     A longer reverse time can also help eliminate charge build-up (0 – 5 us).

   - Set the Process Pressure in the deposition chamber

     A typical sputtering pressure is 3 mTorr, which allows for sufficiently long mean free path for sputter material to reach the target with minimal scattering.

A low pressure setpoint may make it difficult to ignite a plasma, so the "Pressure Bump" option quickly raises the pressure to 20 mTorr in order to ignite the plasma before settling down to the pressure setpoint.

- Ramp Power to the target output

  Target Output is dependent on the sputter target material and diameter.

  Running a target at the maximum power density is convenient in order to have faster deposition rates; however, higher powers will require a greater flow of reactive gas to poison the target. This leads to a larger maximum gas flow required to begin poisoning the target. A very wide window between minimum and maximum reactive gas flows may make it difficult to achieve stable reactive autotune control. If this occurs, try reducing the Target Output power and doing the Reactive Gas Ladder again to determine the new voltage and gas flow set points.

  Use "Ramp Rate" to slowly (~ 10 %/min) increase power to the target to prevent cracking your target, more so for brittle and insulating materials than metallic targets.

5. Clean Target

   - It is recommended to clean the sputter target to a purely metallic state before beginning reactive sputtering.
   - Sputter the target until the bias voltage drops and stabilizes.
   - This can be accomplished by utilizing the "Time and Power" recipe action.

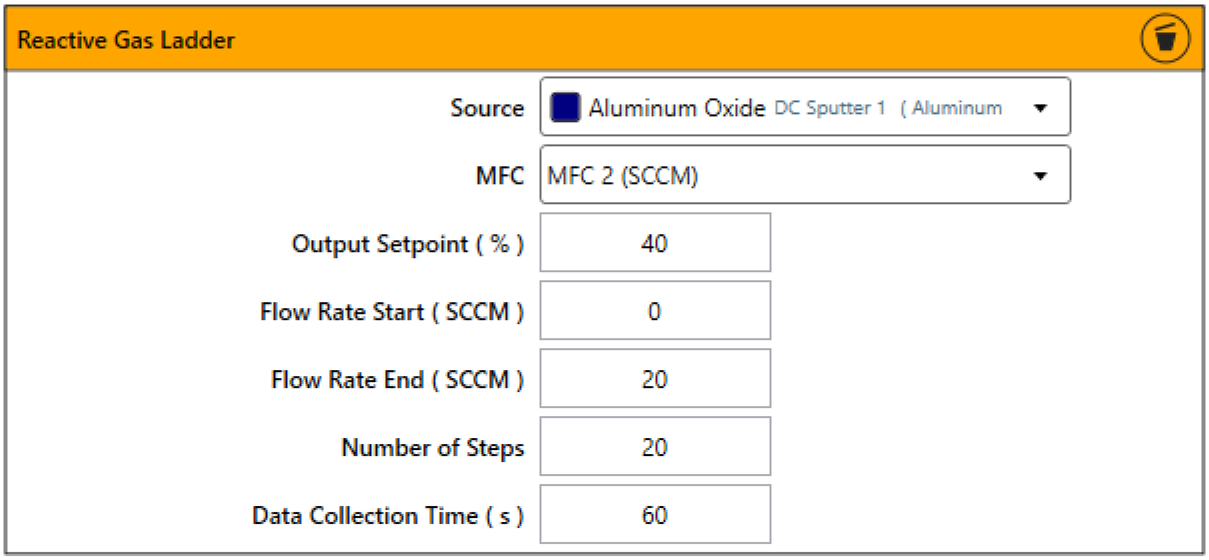
6. For a new reactive process, a Reactive Gas Ladder must be performed to identify the transition region between metallic and poisoned sputtering states and the associated target voltage as well as maximum and minimum reactive gas flow rates.

   - As a sputter target surface becomes chemically bonded with the reactive gas (e.g. the Al target forms a thin layer of aluminum oxide), the secondary electron yield from the surface will change.
   - The direction and magnitude of this change is dependent on the composition of the film.
   - The "Reactive Gas Ladder" steps the reactive gas flow rate between the specified minimum and maximum flow rates.

- The sputter current is held constant and therefore the change in the secondary electron yield from the target results in a change in bias voltage as the target becomes more poisoned. This may result in the voltage increasing or decreasing as the sputter target enters the poisoned state.

- We are interested in identifying the voltage at which the target is in the transition region between these two states. Note that a target material may have more than one poisoned state. As the reactive gas flow increases, additional voltage plateaus may be observed.

- As this transition occurs, you will likely see a change in the visible emissions from the plasma.



7. In the following step, run the Reactive Gas Ladder in the reverse direction (from high flow to low flow). This data will help us determine the minimum reactive gas flow required to return the target to the metallic state.

8. Ramp down the power.

    - To avoid cracking the target, it is good practice to slowly ramp the power down on the target.

- Prior to beginning the ramp down phase, one can include a depoisoning step to bring the target back to the metallic voltage (recommended). This can be accomplished by using a "Ramp Power" recipe action set to the same power and soak setpoints that were used to clean the target prior to the gas ladder. Also, users must set the reactive gas MFC (in this case, MFC 2) to 0 sccm, using the Gas Flow action.

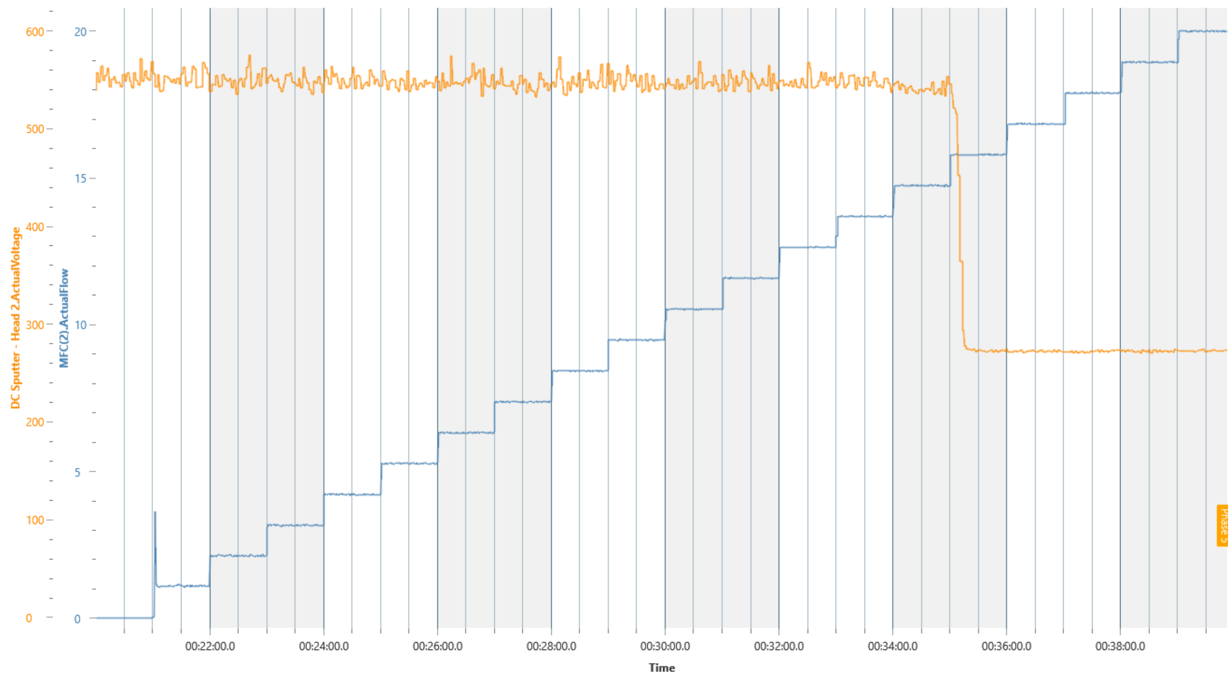
9. Analyze the Reactive Gas Ladder data by plotting reactive gas flow and DC bias voltage to determine several critical process parameters.

   - Target Voltage:

     Recommend selecting a target voltage that corresponds to 60 - 80% of the range between poisoned and metallic states. For example, if the process is "indirect" (e.g. decreasing voltage with poisoning), and our minimum voltage is 270 V and our maximum is 550 V, then a voltage of 345 V would correspond to 73% of the range. You may need to adjust this target voltage to suit your process needs, such as achieving a desired stoichiometry in your films.

   - Reactive Gas Flow Rate:

     It is recommended that you select a minimum and maximum reactive gas flow rate that corresponds to your Target Voltage on both sides of the hysteresis curve. Continuing the example using the plot below, the target voltage is reached at a flow of ~15 sccm when transitioning from metallic to poisoned state. Starting minimum and maximum flow rates of 17 sccm and 12 sccm should be sufficient; however, these may need to be adjusted to improve process stability as some reactive processes prefer leaner or richer reactive gas flows. Too high of a minimum flow may result in the voltage rising over time as the target is unable to depoison sufficiently.



Running a Reactive Sputtering Process:

With the Reactive Gas Ladder complete and a target voltage as well as minimum and maximum flow rates for your reactive gas determined, a reactive sputtering deposition process can be run.

Repeat above steps 1 to 5 to start the reactive sputtering process, ensuring that the same sputter conditions (power, pulse frequency, reverse time, process pressure) are used and that the power supply Control Mode is configured to "current".

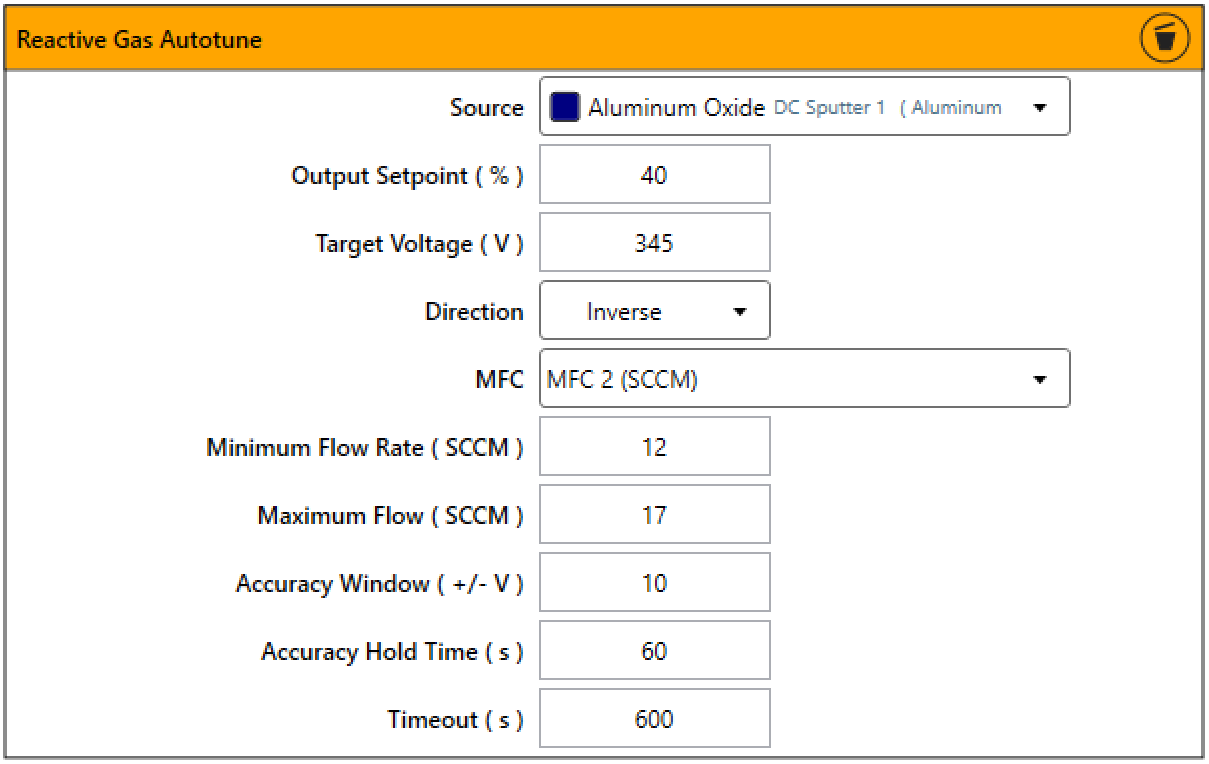
1. Using the Reactive Gas Autotune recipe action, the algorithm will maintain a Target Voltage by controlling the flow of reactive gas at a fixed sputter current.

   - Use the same "Output Setpoint" as you did when you conducted your Reactive Gas Ladder as the same current must be used. A different Output Setpoint requires that you conduct another gas ladder experiment to determine the Target Voltage and reactive gas flow rates.
   - Input the "Target Voltage" at which the sputter target was in the transition region between metallic and poisoned mode. You may need to experiment with different Target Voltages to obtain your desired film stoichiometry. See above for how to choose an initial Target Voltage from the Reactive Gas Ladder data.
   - The autotune algorithm requires knowledge of the "Direction" of the voltage change during transition from metallic to poisoned sputter states:

Choose "Direct" if the voltage increases when the target becomes poisoned (e.g. as with Ti with O_2 reactive gas).

Choose "Inverse" if the voltage decreases when the target becomes poisoned (e.g. as with Al with O_2 reactive gas).

- Choose the MFC of your reactive gas.
- Specify the Minimum and Maximum Flow Rates for your reactive gas that bound the transition region of your gas ladder. See above for how to choose an initial Minimum and Maximum Flow Rate values from the Reactive Gas Ladder data. These initial values may need to be adjusted to improve stability.
- Specify the Accuracy Window that you require the autotune algorithm to maintain the target voltage within. Too wide of a range will result in inconsistent film stoichimetry and deposition rates. Too narrow of a range may result in autotune failure.
- Specify a Data Collection Time for the autotune algorithm to maintain the Target Voltage within the accuracy window. A sufficiently long time is suggested in order to ensure stability during subsequent steps.



2. For systems with a Swing-in Sensor, use the Calibrate Rate recipe action to determine your deposition rate at the Reactive Gas Autotune setpoint. Include a delay (e.g. 10 sec) before and after measuring the rate in order to capture consistent data. Use a long Data Collection time to ensure a good average (e.g. 60 s).

3. Use the Deposit Calibrated Rate recipe action to deposit a film of a specified thickness using the previously determined rate.

4. For systems without a Swing-in Sensor, use the Time and Power recipe action. Set the power to the amount used previously and set the time corresponding to the desired length of the deposition.

   - A calibration run will need to be performed to obtain the deposition rate. First, perform a deposition for a sufficient amount of time (30 min) to measure a thickness. Divide the measured thickness (in Angstroms) by the deposition time (in this case, 1800 sec) to obtain the rate in Å/s. Now, the deposition time can be adjusted to reach the desired thickness. Note that changing other parameters (power, target voltage, process pressure, etc.) will impact the rate and require another calibration run and gas ladder.

5. Use the Ramp Power recipe action to slowly ramp down the power (~5 %/min) of the sputter source to 0% to avoid cracking the target.

High Power Impulse Magnetron Sputtering (HiPIMS)

Background:

What separates pulsed DC sputtering and HiPIMS is the goal of producing ions of film-forming target material. With the plume of sputter material ionized, the substrate-film interface, film micro-structure, and transport of fluxes to the substrate can be better influenced by substrate biasing and magnetic fields. This can lead to denser films, better adhesion, reduced stage heating, and better control of stoichiometry.

During HiPIMS, pulses of high power are delivered such that the current may rise up to two orders of magnitude greater than what would be encountered for DC sputtering. The current is able to reach such high levels because ions of the target material as well as sputter ions trapped deep within the sputter target also contribute to the sputter current. When tuning HiPIMS conditions, we will look for this significant increase in peak current, or the magnitude of the "pulse charge", to indicate what sputtering regime we are operating in.

Oscilloscope Setup:

In order to view the HiPIMS pulse output to determine key parameters, you will need an oscilloscope attached to the probe outputs of your HiPIMS unit. The oscilloscope images below are taken with a PicoScope 2000 Series USB oscilloscope. Open the PicoScope 6 program installed on the computer.

- Probe A: 1000x DC voltage in Volts
- Probe B: 100x DC current in Amps
- Set a 1kV scale and a 50 or 100 A scale
- Increase sampling to 1 MS
- Adjust time scale to a value between 100 to 1000 µs (depending on your pulse settings)
- Trigger Repeat
- Trigger Falling Edge

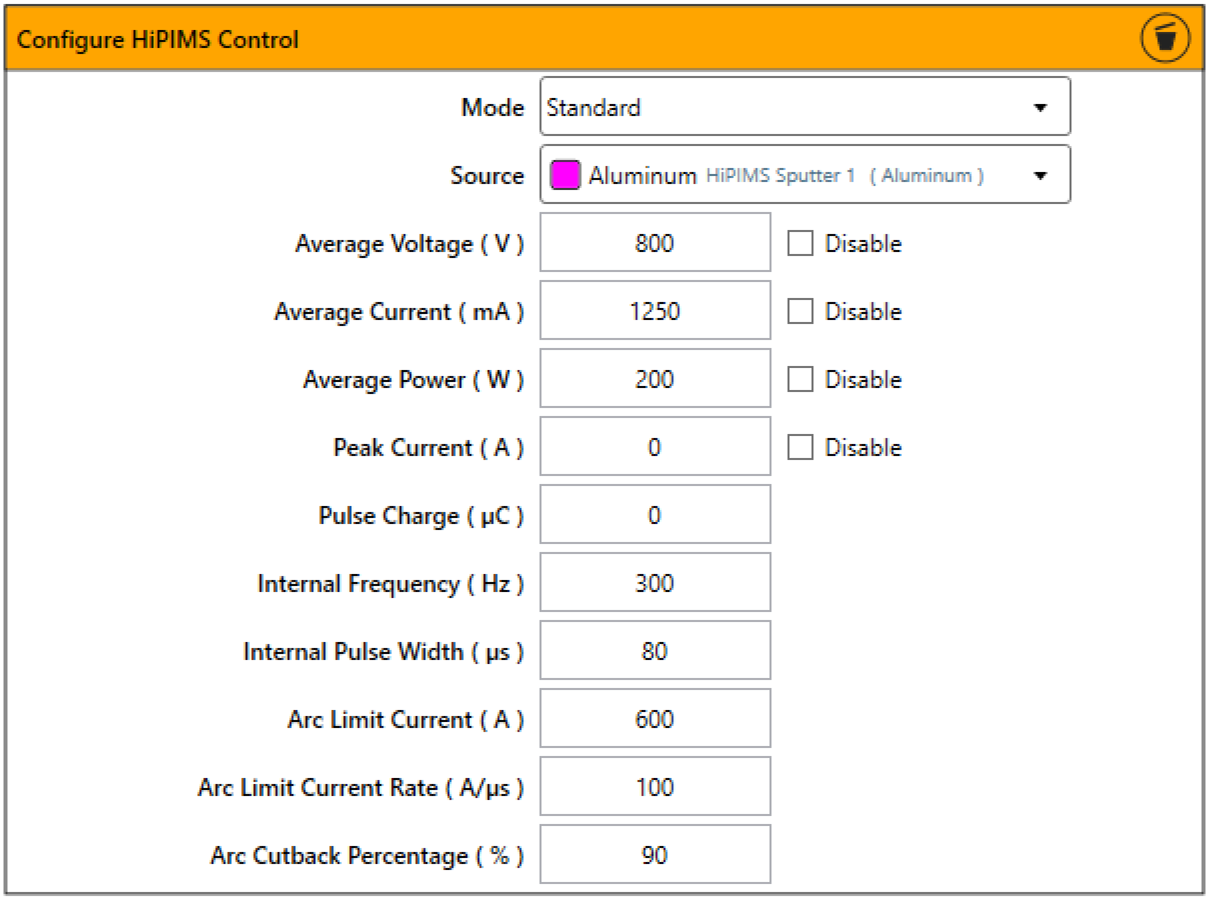
You can save these settings as default by selecting File -> Startup Settings -> Save as User Default Settings.

Process Setup:

It is difficult to know the optimal HiPIMS configuration settings for a target ahead of time, so some trial and error is necessary. In order to avoid repeatedly ramping power and stopping a recipe to change parameters, most of these parameters utilize Live Edits, meaning if the step is in progress they can be changed. When used in conjunction with a Delay recipe action, this can give you sufficient time to tune the parameters until you are satisfied.

1. Configure HiPIMS Supply
   - **Average Voltage (V)** is the upper limit to constrain the HiPIMS power supply. It is recommended to set this to the maximum allowable value, 800 V.
   - **Average Current (A)** is the upper limit to constrain the HiPIMS power supply. It is recommended to set this to the maximum allowable value, 1250 mA.
   - **Average Power (W)** is the upper limit to constrain the HiPIMS power supply. This must be a value that corresponds to your target material maximum power. The Ionatics HiPIMS controller will automatically ramp up/down to the target power.
   - **Peak Current (A)** is the maximum current that is detected during a pulse. It is measured as an average over multiple pulses as the value will vary. To avoid being limited by this value, set this parameter to 0.

- **Pulse Charge (μC)** is the amount of charge that is detected during a pulse. Similar to peak current, this value is measured as an average over multiple pulses. To avoid being limited by this value, set this parameter to 0.
- **Internal Frequency (Hz)** is the frequency of HiPIMS pulsing. Higher frequency pulsing will lead to lower Peak Current and Pulse Charge, and vice versa. This also has an impact on Average Power. At very high frequencies (and long pulse duration) sputtering will be in pulsed DC mode. As frequencies are reduced, there exists a threshold where self-sputtering and gas recycling become significant. In this region, Peak Currents and Pulse Charge increase dramatically, indicating sputtering in HiPIMS mode.
- **Pulse Duration (μs)** is the width of the HiPIMS pulse. Greater pulse durations leads to lower Peak current and Pulse Charge, and vice versa. A pulse duration that is too short will cut-out the voltage pulse before the HiPIMS current peak begins. Monitoring the oscilloscope will aid in correctly setting the pulse width.
- **Arc Limit Current (A)** is the maximum current before arc protection is triggered.
- **Arc Limit Current Rate (A/μs)** is the maximum rate of rise of the current permitted before arc protection is triggered.
- **Arc Cutback Percentage (%)** is how much the HiPIMS controller will reduce power when an arc is detected, from 0-100%

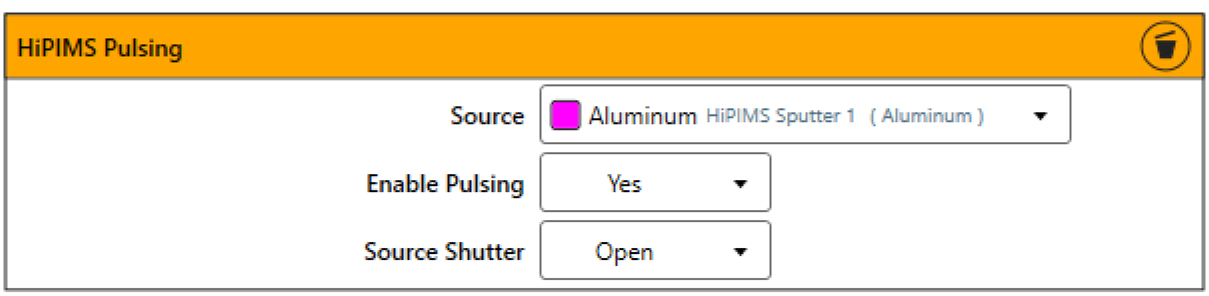


2. Process Pressure

   - Use the Process Pressure recipe action. Higher process pressure will lead to a higher Peak Current, Pulse Charge, Average Current, and Average Power. If the process pressure is too high, deposited material may have a higher chance of scattering. 5 mTorr is a recommended starting point, adjust as needed.

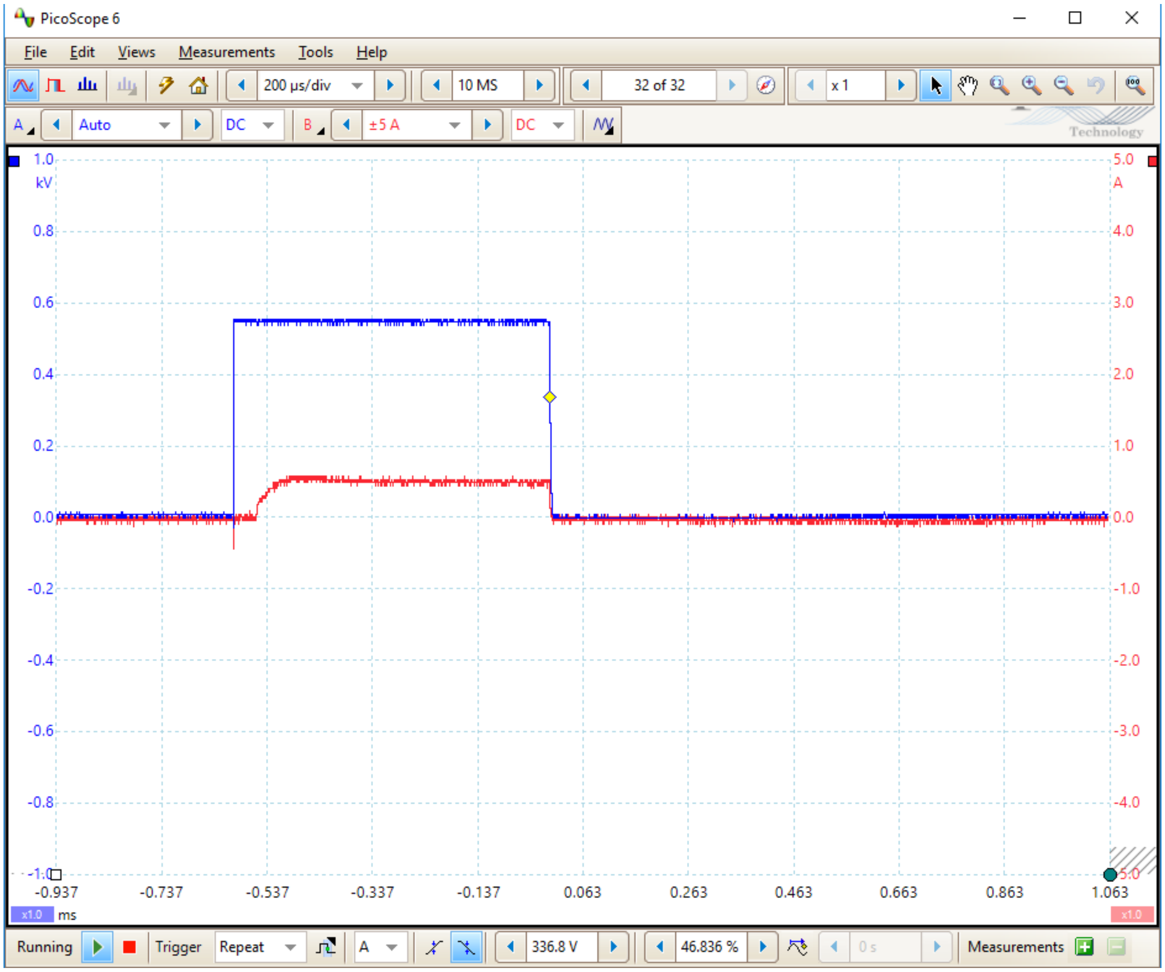
3. HiPIMS Pulsing

   - HiPIMS pulsing must be enabled.



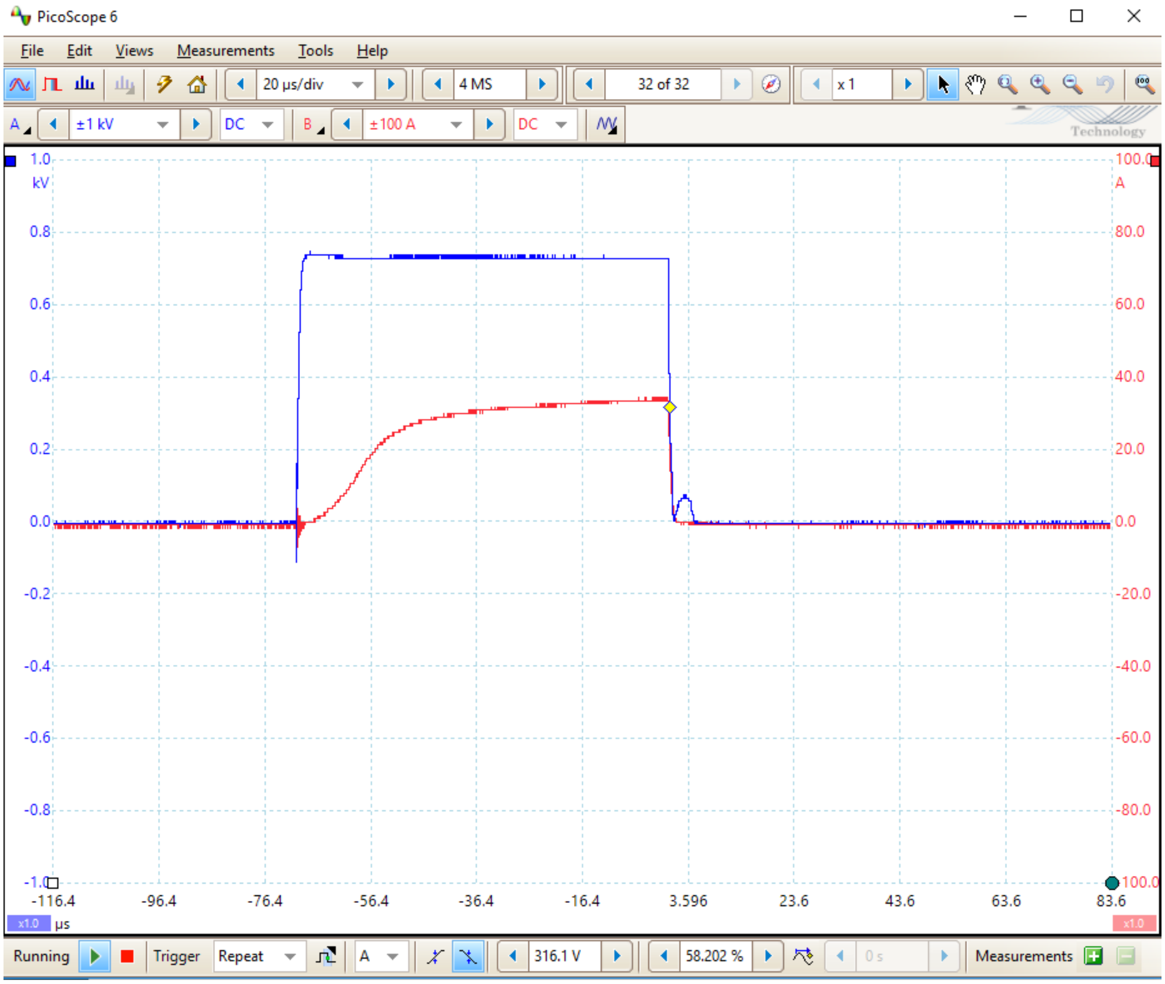
4. Oscilloscope Monitoring

- It is important to recognize when the oscilloscope output is showing pulsed DC type behavior of HiPIMS. Large gains in peak current (by orders of magnitude) is indicative of HiPIMS sputtering, due to self-sputtering and gas recycling effects.
- Below is an example of pulsed-DC mode sputtering signal on an oscilloscope. The Average Voltage has been limited to 550 V, which is preventing HiPIMS-mode sputtering, even though the Internal Frequency is relatively low (100 Hz).



A Pulsed-DC Mode Sputtering Signal on an Oscilloscope

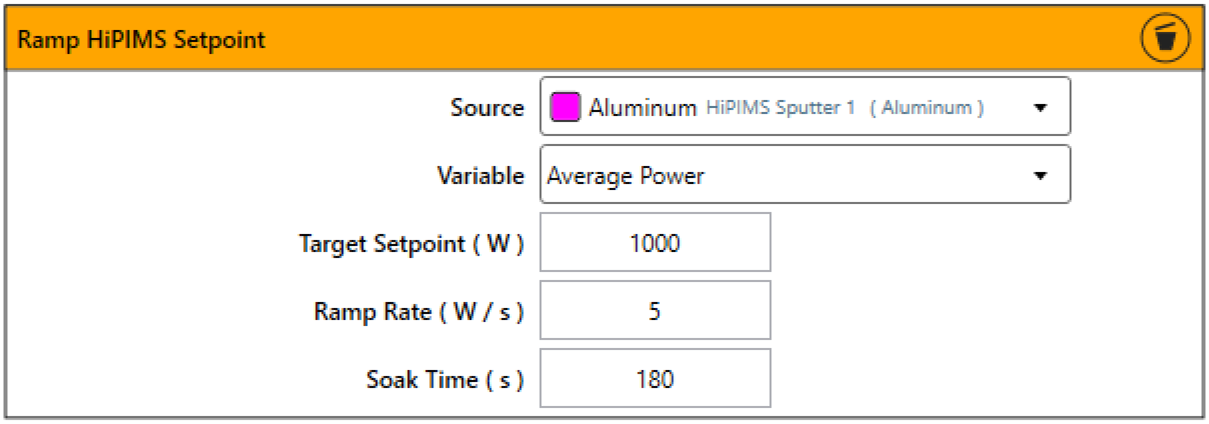
- Contrarily to the previous image, the image below displays a HiPIMS mode sputtering signal on an oscilloscope. What distinguishes this pulse from the pulse in the previous example is the magnitude of the peak current (35 A versus 0.5 A). A smooth and fast increase in current is observed after the onset of the voltage pulse, followed by a sustained high peak current for the remaining duration of the pulse.



A HiPIMS Mode Sputtering Signal on an Oscilloscope

5. Ramp HiPIMS Setpoint

- Select Average Power as the variable and input the target power to ramp to, as well as the ramp rate.



6. Calibrate Rate

   - For systems equipped with a swing in sensor, use the Calibrate Rate action to sample the deposition rate in order to determine the deposition time.

7. Deposit

   - Use the Deposit Calibrated Rate action to target a specific thickness. Deposition time will be automatically calculated based on the calibrated rate from the previous step.
   - If the system is not equipped with a swing-in sensor, use a Delay recipe action to leave the substrate shutters open for a specified period of time.

8. Ramp HiPIMS Setpoint

   - Select Average Power as the variable and set target power to 50 W to ramp down the power.

9. Vent

   - Vent the chamber (or load lock if equipped for transfer) and measure the thickness of the sample to determine the Tooling Factor and actual deposition rate.

Bipolar HiPIMS

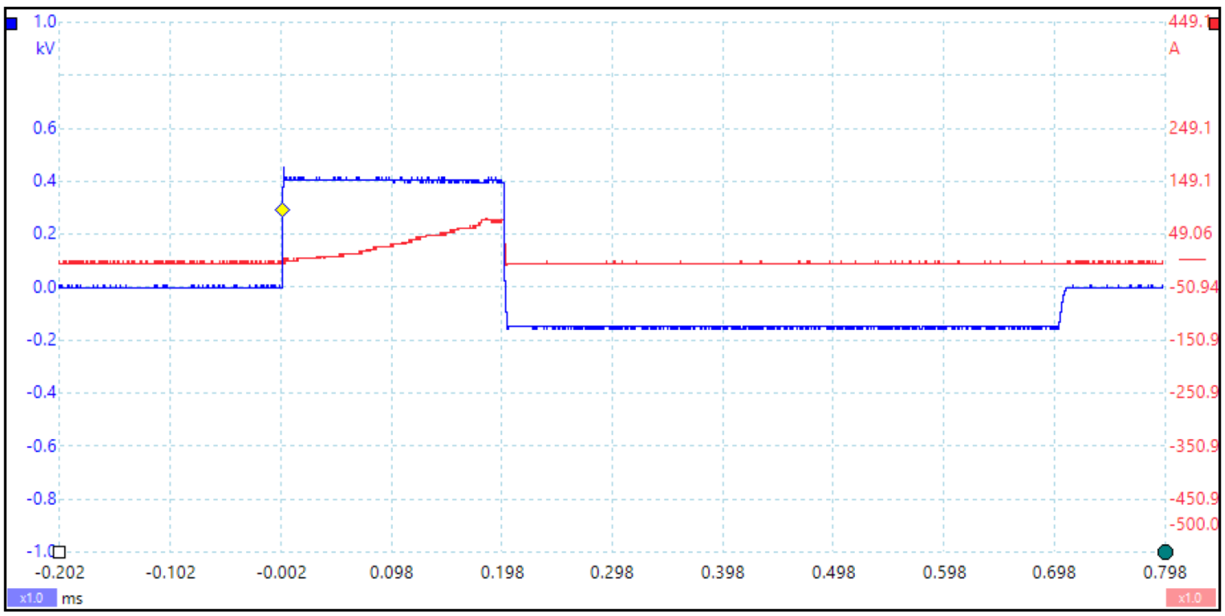
1. Configure HiPIMS Supply with Bipolar parameters (if equipped). The image below shows the oscilloscope image of a HiPIMS pulse followed by the Bipolar pulse.

   - **Bipolar Pulse Width (µs)** is the duration of the positive pulse after the initial HiPIMS pulse. This can be similar to the Internal Pulse Width parameter. (Note that the voltage axis on the oscilloscope is inverted)

   - **Bipolar Pulse Delay (µs)** is the duration of the delay between the HiPIMS negative pulse and the bipolar positive pulse. It is recommended to start with the minimum value of 1.5 µs to accelerate as many ions as possible towards the substrate before ionized material dissipates. Increasing this delay will reduce the amount of ionized material reaching the substrate which can be used to tune film stress and crystallinity.

   - **Bipolar Voltage (V)** is the magnitude of the bipolar pulse voltage. Since material that is sputtered via HiPIMS is highly ionized, applying a positive pulse after the initial HiPIMS pulse will accelerate the ionized material towards the substrate. Higher bipolar voltages can lead to denser films with more stress. This parameter can be used to fine tune film resistivity and hardness.

   - **Bipolar Current (A)** is the current limit of the bipolar power supply. This value should be set to the maximum (i.e. 6 A) to not limit the power supply when operating in fixed voltage mode.



200 µs HiPIMS pulse followed by a 500 µs Bipolar pulse

2. The remaining recipe structure is the same as the Standard mode HiPIMS process from the previous section. The bipolar options give the user more control over ionized material acceleration, allowing for more control over film characteristics.

Reactive (Bipolar) HiPIMS

1. Introduce the reactive gas using the Gas Flow action and select the MFC corresponding to your reactive gas (e.g. N2, O2)

   - The precise flow rate that is selected for the reactive gas is not critical since the partial pressure of the reactive gas in the chamber can be controlled independently by the amount of metal sputtered. The amount of reactive gas consumed by the growing film relative to argon increases with sputter rate. When using the reactive control loop of the HiPIMS unit, the amount of sputtered material (and therefore the reactive gas partial pressure and film stoichiometry) is adjusted by targeting a specific peak current instead of targeting a specific gas flow. The unit tries to output the desired peak current by varying the pulse frequency, without changing any other deposition parameters. A higher pulse frequency will sputter more metal and lead to lower peak currents (less poisoned), and a lower pulse frequency will sputter less metal and lead to higher peak currents (more poisoned).

2. Configure HiPIMS control and select Reactive (or Bipolar Reactive) from the "Mode" drop-down list. 3 new parameters are added.

   - **Reactive Peak Current (A)** is the peak current that the reactive control loop targets by adjusting the Internal Frequency parameter. This should be set to 60-80% of the difference between the metallic and poisoned states (similar to selecting the Target Voltage in a Reactive pulsed DC process). Film stoichiometry can be changed by selecting a value further or closer to the poisoned state.

   - **P Gain** and **I Gain** are the setpoints for the PI controller in the reactive control loop. The P gain controls the immediate response, while the gradual convergence is governed by the I gain. The PI values can be positive or negative. If the peak current increases as the reactive gas flow increases, use positive PI values. If the peak current decreases as the reactive gas flow increases, use negative PI values. Try starting with P = 150 and vary I from 10 to 50 to try and optimize stability of the Reactive Peak Current. I gain has been found to be the most important parameter based on recent studies.

3. Once these parameters are set, run the process with the substrate shutters closed for a few minutes to ensure process stability.

4. The rest of the recipe can be carried out as normal with subsequent Calibrate Rate and Deposit Calibrate Rate actions, or a simple Delay with substrate shutters opened.

5. Finally, ramp the power down and Disable HiPIMS pulsing to turn off the source.

Since the stoichiometry of the target when operating in reactive mode is largely correlated with the Peak Current, the reactive control loop of the HiPIMS unit will vary the Internal Frequency to achieve a desired Reactive Peak Current. The Internal Frequency setpoint is therefore just an initial starting setpoint when operating in reactive control mode, and will float during the process. The oscilloscope will also display seemingly unstable plots due to the constantly changing frequency, but this is intentional.

Note that peak current density (A/cm^2, relating to area of the target) has been shown in literature to affect film stress, with lower peak current densities leading to lower film stress. Higher peak current densities tend to produce denser films, and may have other benefits such as improved resistivity for TiN. To reduce the reactive peak current and still be able to achieve the same stoichiometry, the reactive gas flow and the Average Power limit will likely have to be reduced.

When operating in reactive HiPIMS mode, the Ionautics manual suggests it may be beneficial to let the Average Voltage limit the process by setting the maximum possible Average Current (i.e. 1000 mA for HiPSTER 1, 6000 mA for HiPSTER 6) and Average Power (i.e. 1000 W for HiPSTER 1, 6000 W for HiPSTER 6), and limit the Average Voltage to a value less than 1000 V. This can apparently improve stability of the Reactive Peak Current control loop (and presumably stoichiometry), but also has the effect of letting power (and thus deposition rate) fluctuate which can be problematic for film thickness repeatability. Plasma stability will also become an issue if voltage is limited too much. For simplicity, start developing a process using Average Power as the limiting factor and only explore limiting the process with Average Voltage if PI values cannot be found for stable Reactive Peak Current control in power mode.

Ion Beam Assisted Deposition (IBAD)

Background:

IBAD can be used to deposit denser films than traditional evaporation. Deposited material is continually etched away as more is deposited simultaneously, which aids in filling voids in the film. It is important that the etch rate and deposition rate are balanced to obtain desired film properties. Too high of an etch rate may result in little to no material deposited on the substrate, whereas too low of an etch rate may result in a less dense film. IBAD can be used in conjunction with thermal, eBeam, or sputtering processes.

Process Calculation:

In order to obtain ion assist parameters that will give a resultant deposition rate, a calculation can be done.

1. Discharge Current is calculated by:

$$Discharge\ Current\ (A) = \ Deposition\ Rate\ (\text{Å} \cdot s^{-1}) \times Dose\ \left(\frac{\mu A \cdot cm^{-2}}{\text{Å} \cdot s^{-1}}\right) \times Stage\ Area\ (cm^2) \times \frac{1\ A}{1{,}000{,}000\ \mu A}$$

   Where:

   - Deposition Rate is the desired resultant rate of material deposited on the substrate.
   - Dose is material dependent, obtained from literature.
   - Stage Area is the entire surface area of the substrate holder.

2. Emission Current can be set to the same value as the Discharge Current.
3. Discharge voltage should be selected such that the power (Discharge Voltage x Discharge Current) does not exceed the max power of the ion source (e.g. 400 W for eH400 sources).

Process Setup (Thermal and eBeam sources):

A new set of PID values for the Rate Control database will need to be obtained. These also depend on the ion beam parameters, as changing these parameters will impact your deposition rate.

1. Purge Gas Lines
   - Use the Gas Flow action to open the ion source MFC(s) for 1-5 min in order to purge the gas lines.
   - Turn off Ion MFC flow and pump down the chamber.
   - Some Ion Source models will require an Ion Beam Discharge step before operation to warm up the grids (e.g. KDC 75).
2. Turn on the source
   - Turn on the source using the Ramp Power action to a value slightly below the onset of deposition.
3. Configure the Ion Source
   - Configure Ion Source with desired parameters, depending on your process and model.
   - Leave Manual Mode unchecked to leave the source in Auto Mode.
4. Turn Ion Beam On

- Trigger Ion Source and check Enable.
- Add a Delay (e.g. 60s) to allow the source to stabilize.

5. Autotune Rate
    - Run the automated Autotune Rate recipe action at desired deposition rate to obtain and save new PID values.
6. Stabilize Rate
    - Use the Stabilize Rate action to bring the source to a stable deposition rate.
7. Deposit Rate
    - Use the Deposit Rate action to deposit desired thickness at the same rate as stabilize and auto tune phases.
8. Turn off Ion Beam and Ramp Down power
    - Use the Trigger Ion Source action and do not check Enable.
    - Ramp Power of the source to 0%.

Maintenance

Routine preventive maintenance requirements can vary primarily with the amount of use the machine sees, and in some cases by the types of materials and thicknesses deposited. There are however a few items on the system that require maintenance at designated intervals. It may be convenient to establish other routine maintenance intervals after the system has been in service for a while and these intervals can be predicted.

Maintenance Schedule

Operators are encouraged to contact Customer Service at Angstrom Engineering® with any concerns or doubts they may have at any time.

Interval	Maintenance	Requirements	Action
As Required	Shield removal and cleaning		Remove and clean the shields as detailed in Internal Debris Shield Cleaning
	View port replacement and cleaning		Remove sacrificial glass and clean/replace as needed
Weekly	Check alarm status on indicators on pump controller	Motor current, N2, gas flow, cooling water flow, and pump casing temp	Contact us if any alarms are active
	Check for any abnormal vibration/noise from pump		Contact us if any alarms are active
	Check water and gas supply lines for any leakage		Contact us if any alarms are active

Interval	Maintenance	Requirements	Action
Monthly	Back up Aeres ® recipes and log folders	USB memory stick or internet connection	
	Scan computer with antivirus software	Anti-virus software	Customer discretion
	Check for PC updates	Internet connection	
	Inspect chamber door o-rings	IPA and cleanroom wipe	Wipe o-ring.
	Check rough pump oil level	Rough pump oil (for oil rough pumps only)	Top up oil level as required.
	Check rough pump lubricating oil level	Lubricating oil (for Ebara dry pumps)	Top up lubricating oil level as required.
	Check color of lubricating oil	Ebara dry pump	If oil is dark in color, drain and refill.
	Check Z-stage has adequate lubrication on ball screw and drives	Lithium-based lubricant for out-of-vacuum parts	Add lubricant as required.
	Check in-vacuum parking elevators have adequate lubrication on ball screw and bearing blocks	High vacuum grease for in-vacuum parts	Add lubricant as required.
	Check cryo-pump helium pressure	Charging equipment	Contact Angstrom Engineering® for assistance
	Check house pneumatic pressure	Regulator, dry compressed air supply	
	Check water flow and level	Flow meter	
	Check purge gas flow	Regulator, N2 supply	
	Check process gas flow	Regulator, process gas supply	

Interval	Maintenance	Requirements	Action
6 Months	Pump down and Rate of Rise test		Use data logging feature to run a pump down and rate of rise recipe.
	Inspect gas and water lines		Open cabinet and visually inspect fittings. Replace if damaged.
	Inspect power cables and cords	Proper electrical safety procedures	Replace if worn or frayed.
	Ensure all resistive transformer secondary cables are tight	Proper electrical safety procedures	Check for discoloration. Tighten connection or replace cable.
	Regenerate cryo pump	Purge gas	Run the Aeres® automated Regen sequence overnight.

Interval	Maintenance	Requirements	Action
Annually	Change rough pump oil	Rough pump oil (Rotary vane pumps)	The oil level should be checked periodically and replaced at regular intervals.
	Replace Cryo adsorber	Cryo adsorber spare parts list	Replacement of the absorber in the 8200 compressor on a yearly basis greatly extends the life of the cryo pump, and will reduce overall maintenance costs.
	Clean chamber rough valve	IPA and cleanroom wipes	Vent chamber, unplug rough pump, remove rough valve. In overrides page turn on rough pump, open rough valve. Clean valve seat and surrounding area.
	Clean foreline valve	IPA and cleanroom wipes	Vent cryo, unplug rough pump, remove foreline valve. In overrides page turn on rough pump, open foreline valve. Clean valve seat and surrounding area.
	Clean cryo pump purge and overpressure valve	IPA and cleanroom wipes	Done during regeneration when pump is at room temperature. Poppet valve unscrews from pump. Wipe clean o-rings, seal faces, surfaces, and fitting connected to exhaust.
	Back flush water through system	Rags and bucket	For house water: remove supply line and connect to return fitting on tool. Collect water in bucket and dump appropriately. Do not reverse flush back into house system (ie. do not connect return line). Same applies for closed loop systems. Drain closed loop systems and replenish with new water.
	Add anti- fungal solution to cooling water	Anti- fungal/algae solution	Used to prohibit growth of algae or fungus in water lines for closed loop systems.
	Replace water supply filter	Filter element	Open and closed loop water supplies should have a filter in a cartridge that can be replaced at regular intervals. Recirculating chillers usually have filters or screens as well that need to be cleaned out. Replace more regularly if needed.
	Computer maintenance		Perform a clean and defragmentation on the drive. Clean air inlet filter on computer if present.
	Calibrate capacitance manometers and flow meters / controllers		Contact Angstrom Engineering® for assistance
	Clean flow switches	Wipes	Drain and blow out water form system. Open face of flow switch carefully by turning counter-clockwise. Remove paddle and wipe housing and cover clean.
Every 2 years	Replace door o-rings	O-rings	Extreme care must be taken when removing o-ring to avoid scratching seal face. Use plastic tools. Contact Angstrom Engineering® for assistance

Interval	Maintenance	Requirements	Action
Every 3 years	Overhaul rough pumps	Overhaul kit	Apples to glove box rough pumps as well.
	9700 Cryo compressor	Items same as 8200 compressor, with exception of adsorber replacement	Contact Angstrom Engineering® for assistance
Every 5 years	Refurbish cryo pump array	Cryo pump array	Consider having pump overhauled or replaced depending on performance. Contact Angstrom Engineering® for assistance.
	Clean gate valve and transfer valve	Hand tools, IPA, cleanroom wipes	Remove bonnet and slide gate from valve. Clean seal faces. Removal may depend on system configuration.

Internal Debris Shield Cleaning

As material continues to be deposited in the chamber, it will tend to flake and peel off of the inside walls and off internal shielding. This can lead to the contamination of source materials, slower pumping and deteriorating a Base Pressure. Shields are held in place using vented fasteners (if lost, these should not be replaced with standard fasteners).

To remove and clean the shields:

1. Loosen or remove bolts fastening shields to the chamber walls/components
2. Remove shields from chamber
3. Wipe any loose material off
4. Scrub off all deposited material from shields using a sand-blaster with the pressure turned down, or by hand using fine sandpaper and polishing pads
5. Wash the shields using a degreasing detergent
6. Wipe shields with methanol, ethanol or isopropyl alcohol
7. Place shields back into chamber in their original positions

Frequently Asked Questions

This section details common troubleshooting for various problems encountered in Aeres®.

Troubleshooting

Operators are encouraged to contact Customer Service at Angstrom Engineering® with any concerns or doubts they may have at any time.

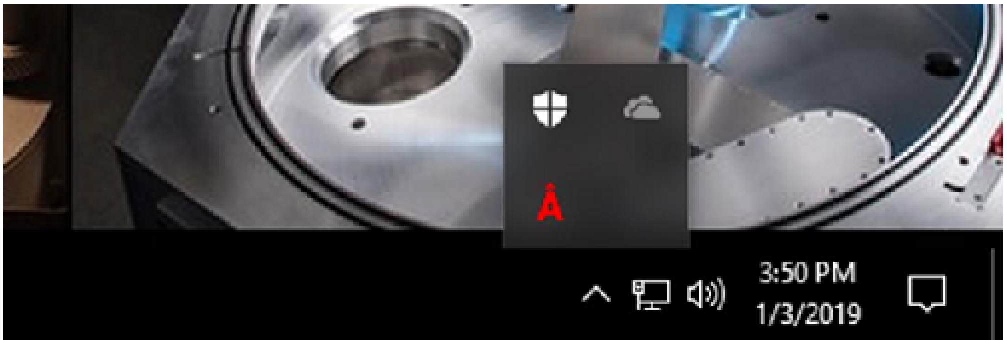
Observed Problem	Possible Cause	Resolution
System has lost base pressure	Check door o-ring for particulates	Wipe o-ring with IPA and cleanroom wipe. Replace if damaged
	Contamination	Clean chamber debris shields. Clean chamber debris shields and interior components. Or an item has been cleaned inappropriately with a substance that has affected the part, like acid etching aluminum for example or wet spun films
	Scratch on seal face, perpendicular across o- ring contact area	Carefully polish or sand surface with Scotchbrite or very fine sandpaper only in the direction of the o-ring. Keep in mind that the o-ring contacts only in the middle of the seal face, so scratches on the interior of exterior edges may not have an effect.
	Chamber gauge requires cleaning	Vent system, unplug and remove chamber pressure gauge. Follow the video tutorial on Cleaning Vacuum Gauges.
	Particulate in vent valve or rough valve	Clean seal face of roughing valve. Blank vent valve and pump to confirm valve is the leak. Replace valve if so.
	Particulate in cryo pump overpressure valve	Commonly occurs after a cryo regeneration. Most pumps now have screens to prevent charcoal from the pump from making it to the valve. Valve is easily disassembled and cleaned with the cryo pump at atmosphere and room temperature.
	Cryo compressor helium level is low	Top up as required. Special tools and procedure must be strictly followed. See cryo pump manual.
	Resistive source feed- through o-ring has been damaged	This is a rare occurrence where a source has run too hot for too long and the Viton seal for the feed through has deteriorated. Remove feed through and replace o-ring.

Observed Problem	Possible Cause	Resolution
Deposition from Aeres® is not working	Blown fuse, flipped circuit breaker	Fuses blow on occasion when the output power is very high and the source is shut off. This happens on occasion when the source runs out of material and runs to maximum power. Using a post condition ramp down in the deposition recipe may alleviate this. Consult the electrical drawing for the fuse location and replace with the correct type and rating as per the drawing. Repeated fuse blowing may indicate other concerns.
	Communication issue between Aeres ® and PC with PLC	This is a rare occurrence that may occur if another item or software has been added to the PC that uses Ethernet communication. Typically, a hard restart of the system will cure the problem. Check to see that the shutters open and substrate rotation is enabled when an Aeres® process is started with the Aeres® software in manual mode.
	Communication cable is unplugged	Check connections at the back of the PC and the PLC to ensure they are secure. These may become dislodged during maintenance
	Source is empty or broken	Vent chamber and inspect source and material for continuity and proper contact to the source clamps.
Deposition rate not registering in Aeres®	Shutters forced closed	If source is known to be working fine, shutters may have been selected to be closed in recipe editor, have been closed in the overrides, or are mechanically blocked from opening
Control Software not responding	Aeres ® engine has lost connection to PLC	Restarting the Engine and the UI should resolve any issues. If the engine icon is red, verify the PLC is powered and Sysmac Gateway is connected / running. Contact Angstrom Engineering® for assistance. Note that multi-chamber solutions require all systems to be running to start the Aeres® Software.
Cryo stopped and temperature is rising	Insufficient cooling of cryo compressor	The compressor has internal thermal protection. If it overheats the switch on the front of the compressor turns off. For water cooled compressors loss of water flow will cause this. For air cooled compressors typically a blockage of the cooling air through the compressor will cause the compressor to overheat. Resolve the cooling issue, flip the switch on the compressor to on and perform a full pump down.
Rough pump not working	Overload alarm triggered	Some rough pumps require an overload for protection in addition to fuses. If your system has an overload it will typically show an alarm when the overload is tripped. Find the overload on the electrical panel in the cabinet and push the reset. Consult Angstrom Engineering® customer service for additional guidance. Not typical but happens on occasion if pump runs for long periods of time or is low on fluid (rotary vane) or a pump runs for an extended period of time at atmosphere (door of chamber left open).
	Blown fuse	Check fuse and replace. Inspect power cord to pump for damage and repair or replace as needed. May indicate short in motor requiring repair. If the fuse blows repeatedly contact Angstrom Engineering® for assistance.
Chamber not reaching crossover pressure	Rough pump is low on oil	Top up oil level and try again. Be careful as pump will be hot! Failure or wear in a scroll pump dictates an overhaul is required.
	Leak in roughing line	Leak in the roughing line. Check all fittings and hoses for loose connections, failures or kinks.

Aeres® Startup Issues

Check the status of the Aeres® Engine:

1. Check the bottom right-hand corner of your screen for the Aeres® logo in red. You may have to expand the task bar tray.



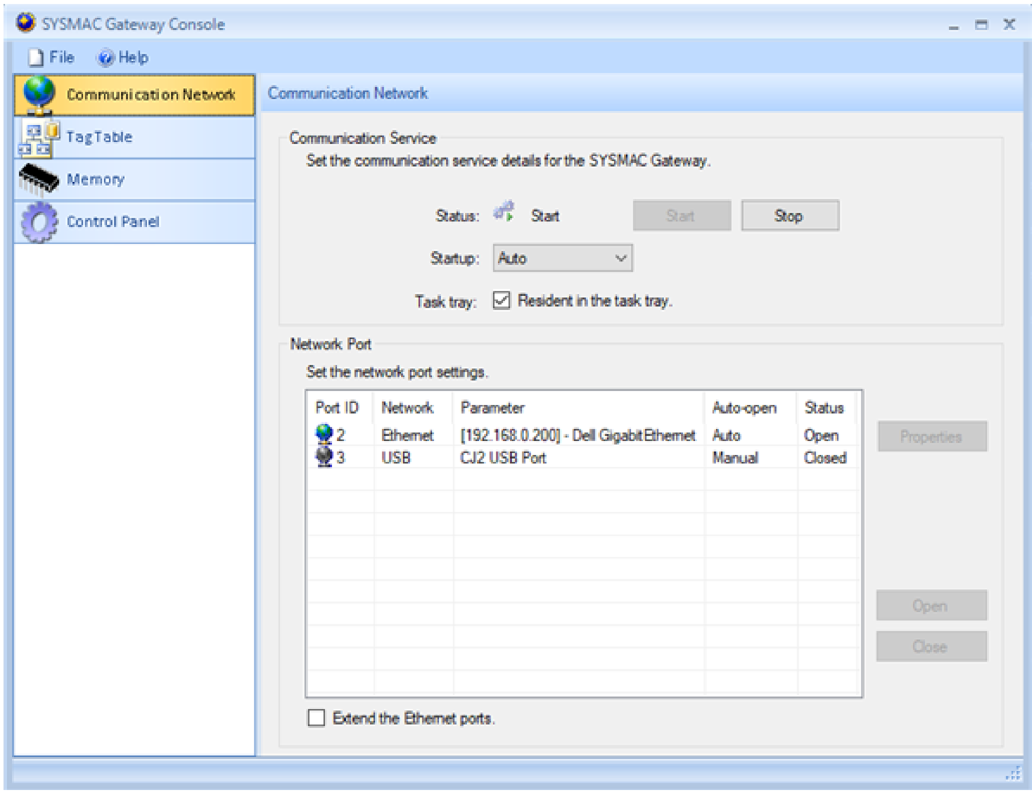
2. If you see a green Aeres® logo instead but cannot start the UI, please contact the Angstrom Engineering® service department.
3. Alternatively, you may not see the Aeres® symbol at all. In this case check the task manager for the Aeres® Engine under "Processes". Then continue to the next step.

If the problem is with the Engine, check the Sysmac Gateway:

1. Check the bottom right-hand corner of your screen for the Sysmac Gateway logo.
   - A red logo means there is a connection problem between the computer and the PLC
   - A blue logo means the connection is working as expected
2. Open by right clicking the icon and selecting Sysmac Gateway Console
3. If not present in the task tray, search for Sysmac Gateway Console in the Windows search bar and open the application

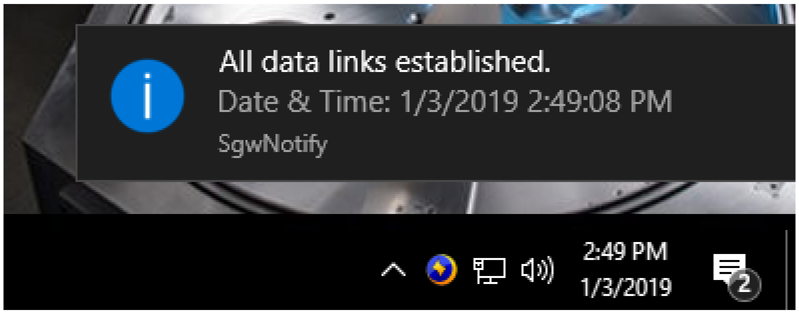
Ensure Sysmac Gateway Settings are Correct

1. Make sure your Ethernet pot at IP 192.168.0.XXX is set to "Open" and "Resident in the task tray" is checked



2. If the status is "Closed", use the "Start" and "Stop" buttons to reopen the port.

3. Once this step is complete, you should see a notification banner on the bottom right corner indicating that all datalinks have been established.



4. Stop Aeres® Engine (right click Aeres® icon in task tray) and close the Aeres® UI if open

5. Click on the Aeres® Startup Icon on the desktop

Glossary

A

Active Cooling

It is recommended to never expose the Radak® source filament to air when above 100°C, the system must allow the sources to cool below that point before completely venting to room pressure. This can take a very long time if left to occur under vacuum. The goal of active cooling is to accelerate the cooling of the source, so the chamber can be opened sooner. When enabled, the system will wait until all sources are below 400°C, then vent up to a target high pressure using nitrogen. The system will hold at this pressure for a set time to allow convection to aid in the cooling of the source, then pump down to a low pressure target using the rough pump. The cycle is then repeated using fresh gas until all sources are below 100°C, and the system is then allowed to completely vent to room pressure.

Automatic Mode

Places a Cell online and allows it to interact with other Cells in the cluster.

Autotune

For a process to be controlled based on the rate reading from the quartz crystal sensor, the software needs to have PID values to minimize the deviation between the current rate and the target rate. PID values are used to drive the power to achieve control at a certain rate. The Aeres® software includes an autotuning feature that allows the system to generate the PID values automatically. During an autotuning step, the system drives the power to the Max Power that was set in the recipe for that particular source until the rate overshoots the target rate by a certain amount. At this point, the power is set to 0% until the rate decreases below the target rate by a certain amount. During this time, the way the rate changes in response to the power applied is observed by the system and PID values are derived from it. The power on-power off is cycled two or three times and then the recipe will have PID values for that source. These PID values can be saved if the user saves the process immediately following its completion.

B

Base Pressure

Base pressure is the pressure at which the deposition process can begin.

C

Crossover Pressure
Crossover pressure refers to the specific pressure level at which the operation of a vacuum system is switched from a rough pump to a high vacuum pump.

D

Deposition Pressure
The deposition pressure is the pressure that must be achieved before a deposition can start.

H

Hard Arc
A current exceeding a user-defined arc current threshold occurs (0 - 110% of the maximum DC power supply current); Or a voltage drop below a user-defined threshold (0 - 300 V) occurs in conjunction with a current exceeding the user-defined spark current threshold (0 - 100% of the maximum DC power supply current).

I

Idle Power
Idle power is a user-defined power level that you can set a source to remain at when not actively being used in a process.

Idle Temperature
Idle temperature is a user-defined temperature that you can set a source to remain at when not actively being used in a process.

Input Filter
Determines how many data points are used in a rolling average that is then fed into the PID loop. Filtering helps reduce the impact of signal noise on the control loop.

P

PID

Proportional–Integral–Derivative: values used for controlling source power to maintain a user setpoint.

Q

QCM

Quartz Crystal Microbalance: measures a mass variation per unit area by measuring the change in frequency of a quartz crystal resonator.

R

Recipe

A recipe is a sequence of steps where the user can select the active sources and the deposition parameters of a process, in addition to any chamber sequences that need to be run before or after the deposition occurs.

S

Spark

An instantaneous voltage drop greater than 75% of the measured voltage occurs when hard arcs are detected, the DC power supply automatically switches off output power for a user-defined interval (3 - 60 ms). For sparks, the DC power supply automatically quenches output power for the user-configured reverse time (i.e. pause duration, 1 - 10 µs) while in Pulsed DC operation mode.

T

Tooling Factor

Relates the sensor thickness reading to the actual measured thickness on the substrate.

Z

Z-Factor

Acoustic Impedance Factor: used to match the acoustic properties of the material that is being deposited to the acoustic properties of the quartz crystal.