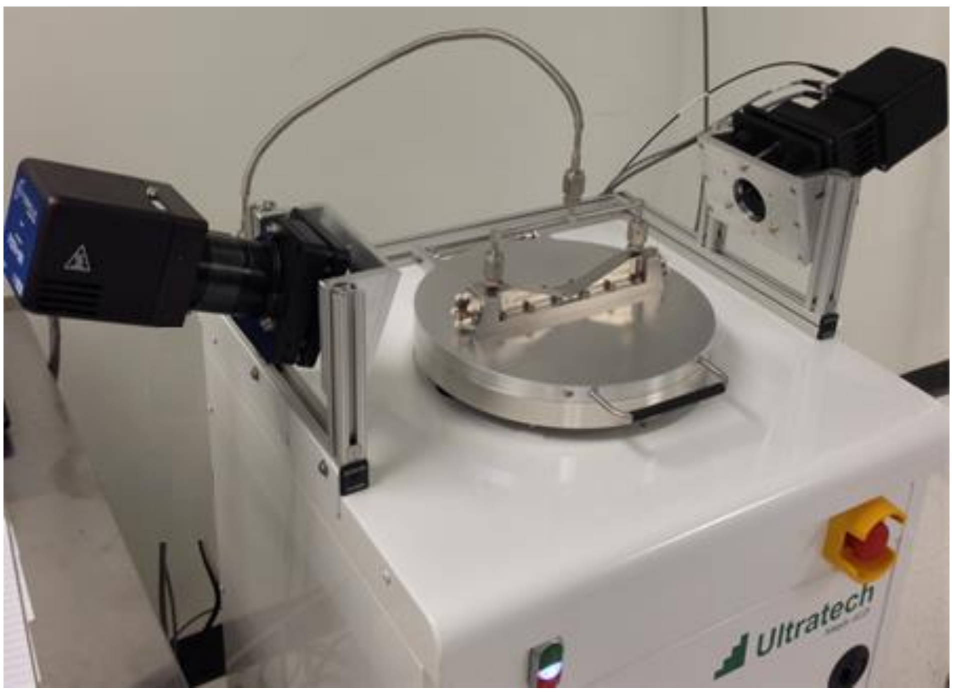
Savannah

S100, S200 and S300

Atomic Layer Deposition Systems

Installation and User Manual



Veeco welcomes requests for information, comments and inquiries about its products.

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Section 1.System Overview

System Description

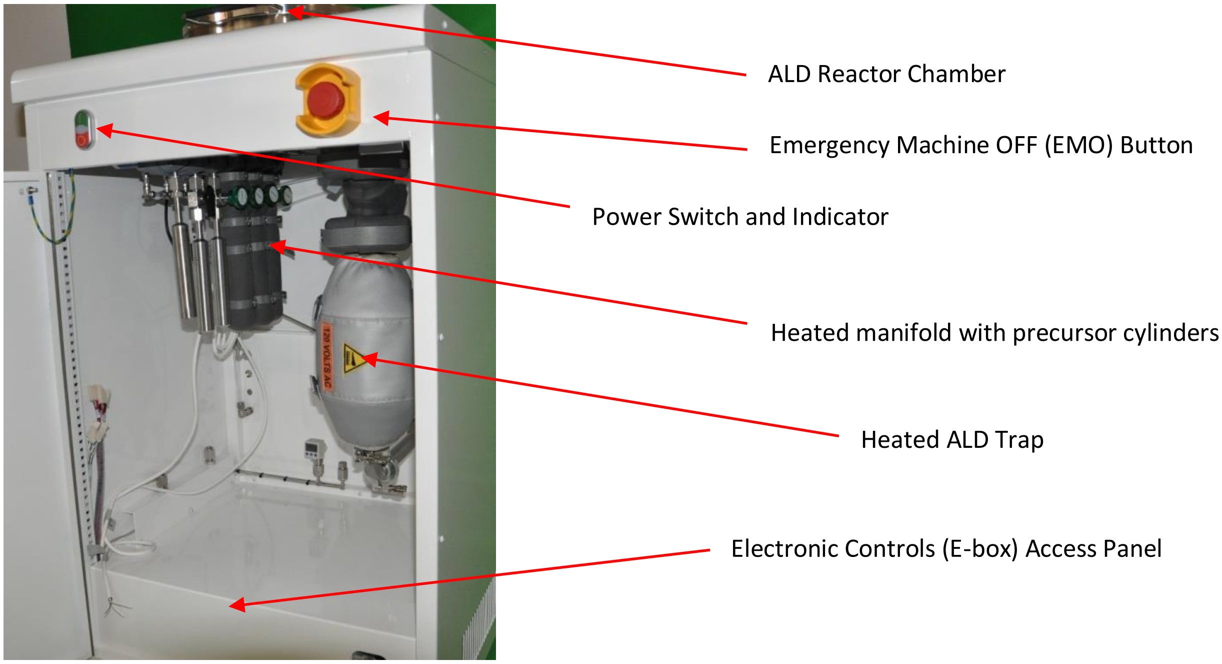
The Veeco Savannah series of advanced ALD systems deliver outstanding deposition results and provide maximum experimental flexibility for ALD research, development, and production applications. The base Savannah system can be enhanced with a large selection of upgrades to provide a wide range of film deposition improvements.

Precise films come from precise control

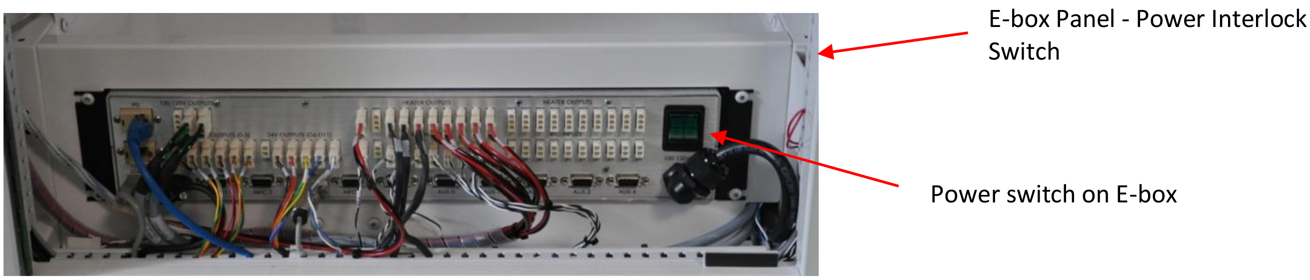
Each Savannah system enables digital control of your thin films by growing one layer of film at a time from the nano scale to the micro scale. Our unique Exposure Mode™, combined with our proprietary precursor delivery system and precise temperature control, enables conformal film growth on ultra-high aspect ratio features (greater than 2000:1), found in materials such as porous foams, fibers and nanogels. Our Continuous Mode™ enables the rapid growth of perfectly dense, uniform and conformal films.

Complete control of all key system parameters is easily achievable through our intuitive Graphical User Interface (GUI). The Savannah system allows you to control all key system parameters from the operating software and the process recipe. The LabVIEW™-based GUI software is powerful, yet simple to use.

Savannah S200 G2



Electronic Control Box (Ebox) with access panel removed



Custom Configurations

Each Savannah system is configurable with multiple options including up to six precursor lines, a compact ozone generator, the ALD Booster™, low vapor pressure delivery (LVPD) kit, particle kit, batch process, N2 pump purge, and a SAMs option.

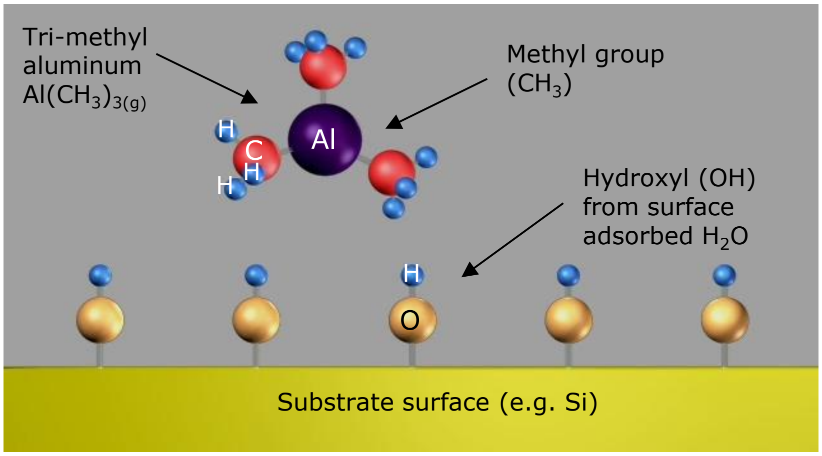
Theory

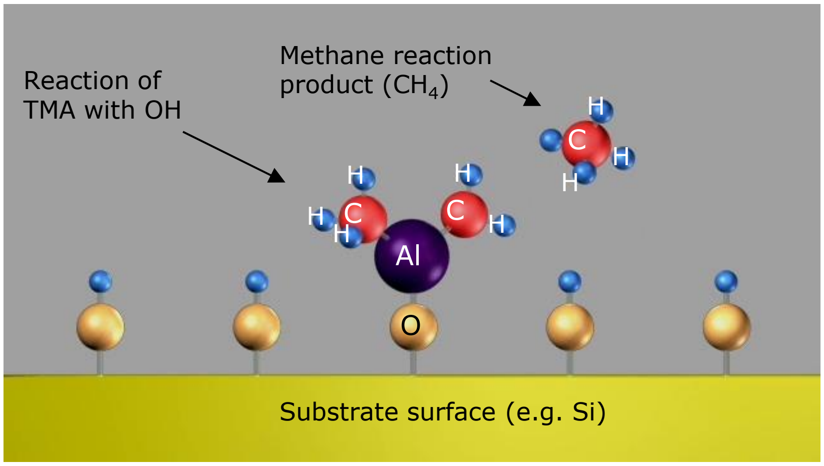
Atomic Layer Deposition: Principle of Al_2O_3 formation

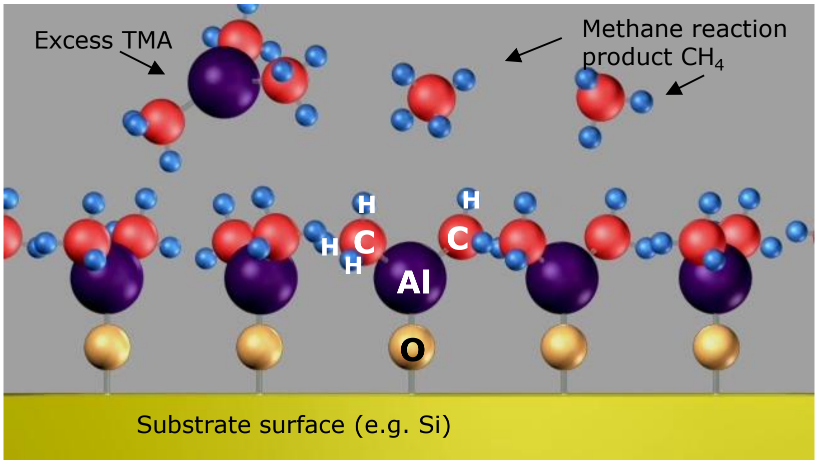
Atomic Layer Deposition (ALD) is a technique that allows the growth of thin films, atomic layer by layer. The typical ALD reaction is illustrated below for the Al_2O_3process from trimethylaluminum [TMA or $Al(CH_3)_3$] and water [H_2O]. Standard recipes for other ALD materials deposited using the Savannah system can be obtained from the technical support group at Veeco (**aldsupport@veeco.com)**.

Step 1: Introduction and adsorption of precursor A (TMA) to the surface.

The precursor, trimethylaluminum reacts with hydroxyl groups on the surface of the substrate, liberating methane. The reaction is self-limiting as the precursor does not react with adsorbed aluminum species.

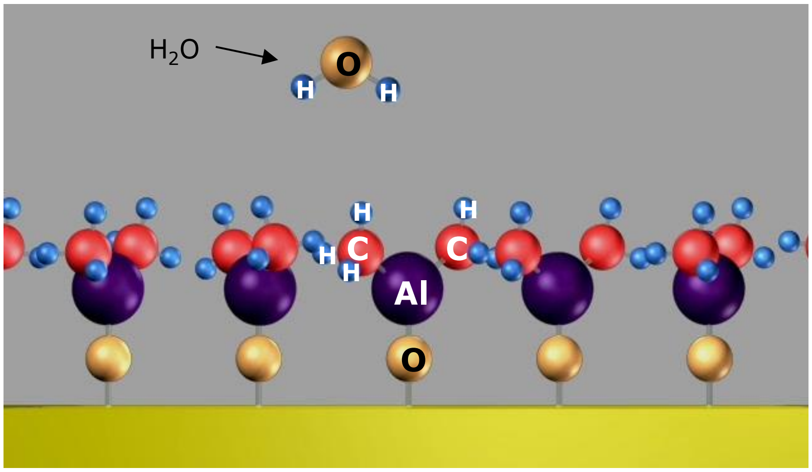


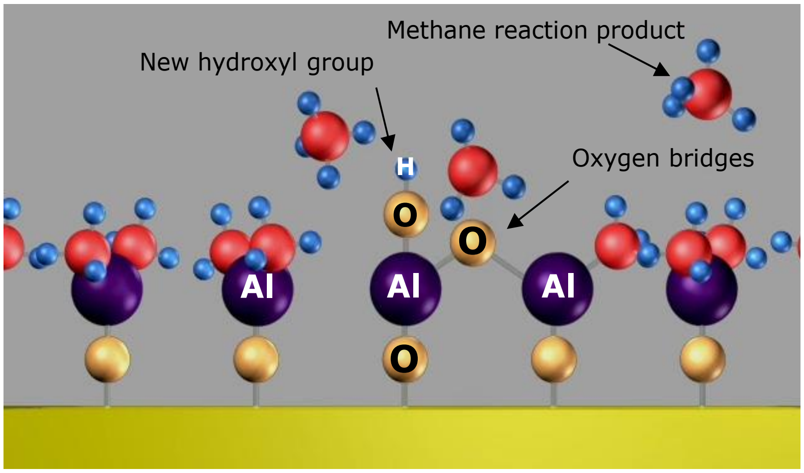


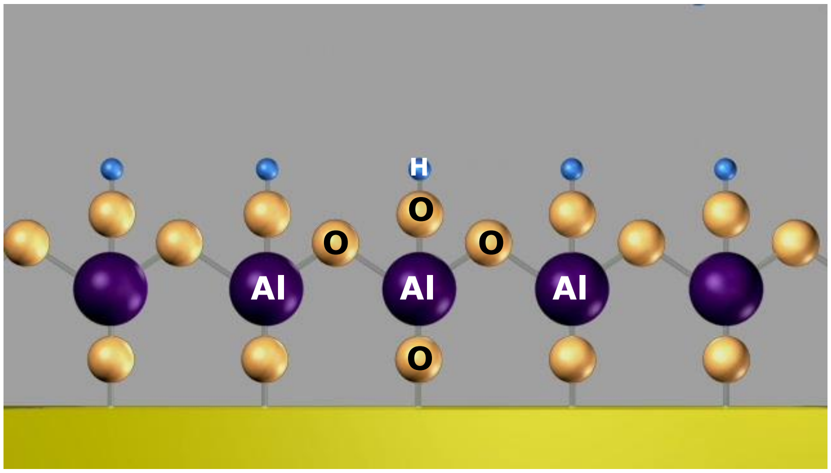


Step 2: Removal of the un-reacted precursor and reaction products.
Unreacted precursor and the methane (CH_4) liberated from the reaction are removed by simple evacuation of the sample chamber or by flowing inert gas over the surface.

Step 3: Introduction and adsorption of precursor B to the surface.
Water reacts with the methyl groups on the deposited aluminum atoms forming both Al-O-Al bridges, as well as new hydroxyl groups. The formation of hydroxyl groups readies the surface for the acceptance of the next layer of aluminum atoms. Methane is liberated as a by-product.







Step 4: Removal of the un-reacted precursor and reaction products via evacuation and/or inert gas flow.

Step 5: Repeat to create layers
The process begins again with the introduction of precursor A followed by B. Atomic layers are built up one after the other.

Modes of Operation

There are two primary modes of operation for ALD deposition.The Savannah system can operate in either mode. Refer to the Operations section for additional detail on each technique.

Continuous Mode

The carrier gas is continuously flowing while pulsing (adding) precursor and pumping is always ON (Stop Valve OPEN).

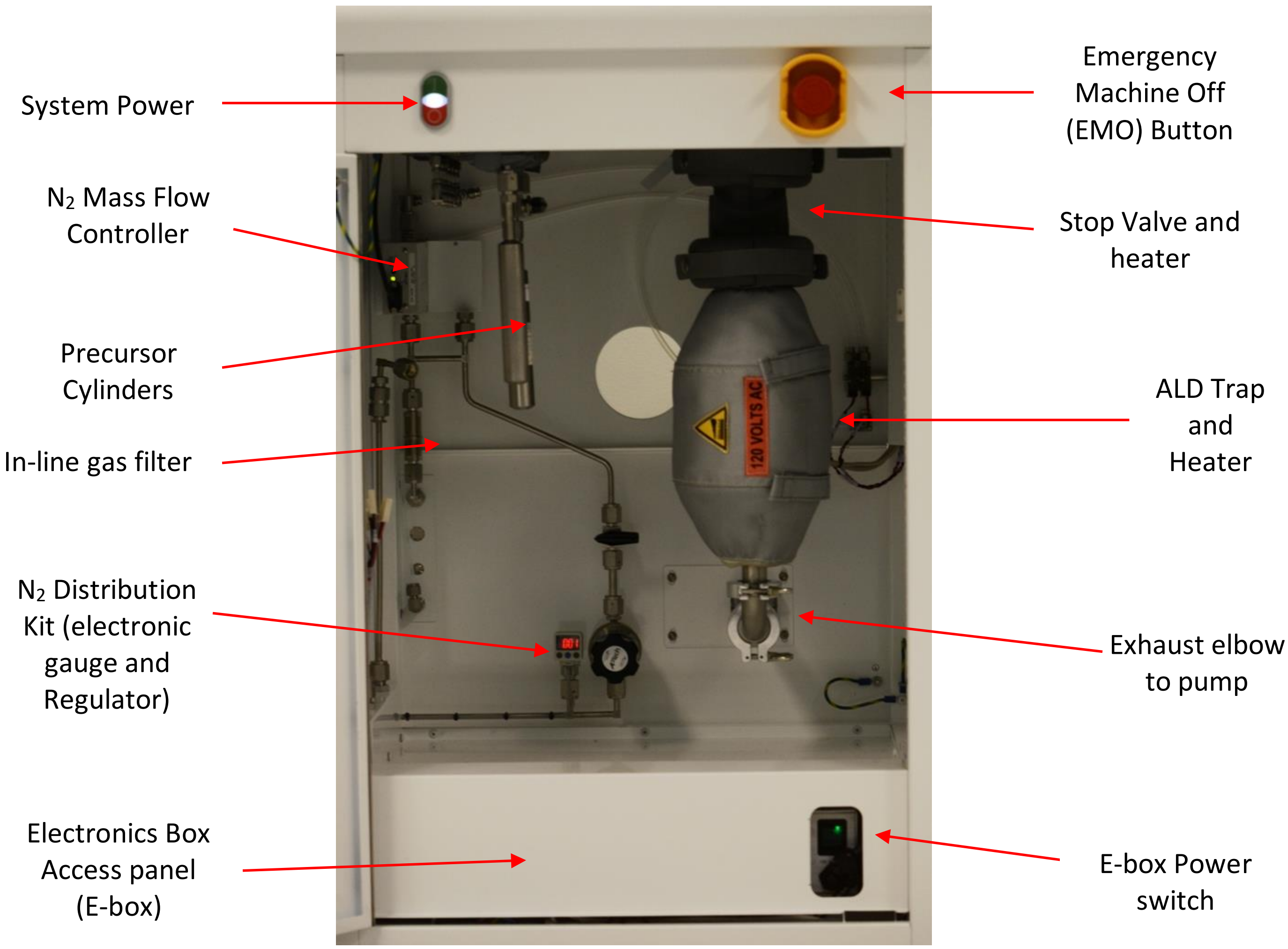
Exposure Mode

Precursors are pulsed with the stop valve closed and the stop valve is open for pumping in-between pulses.

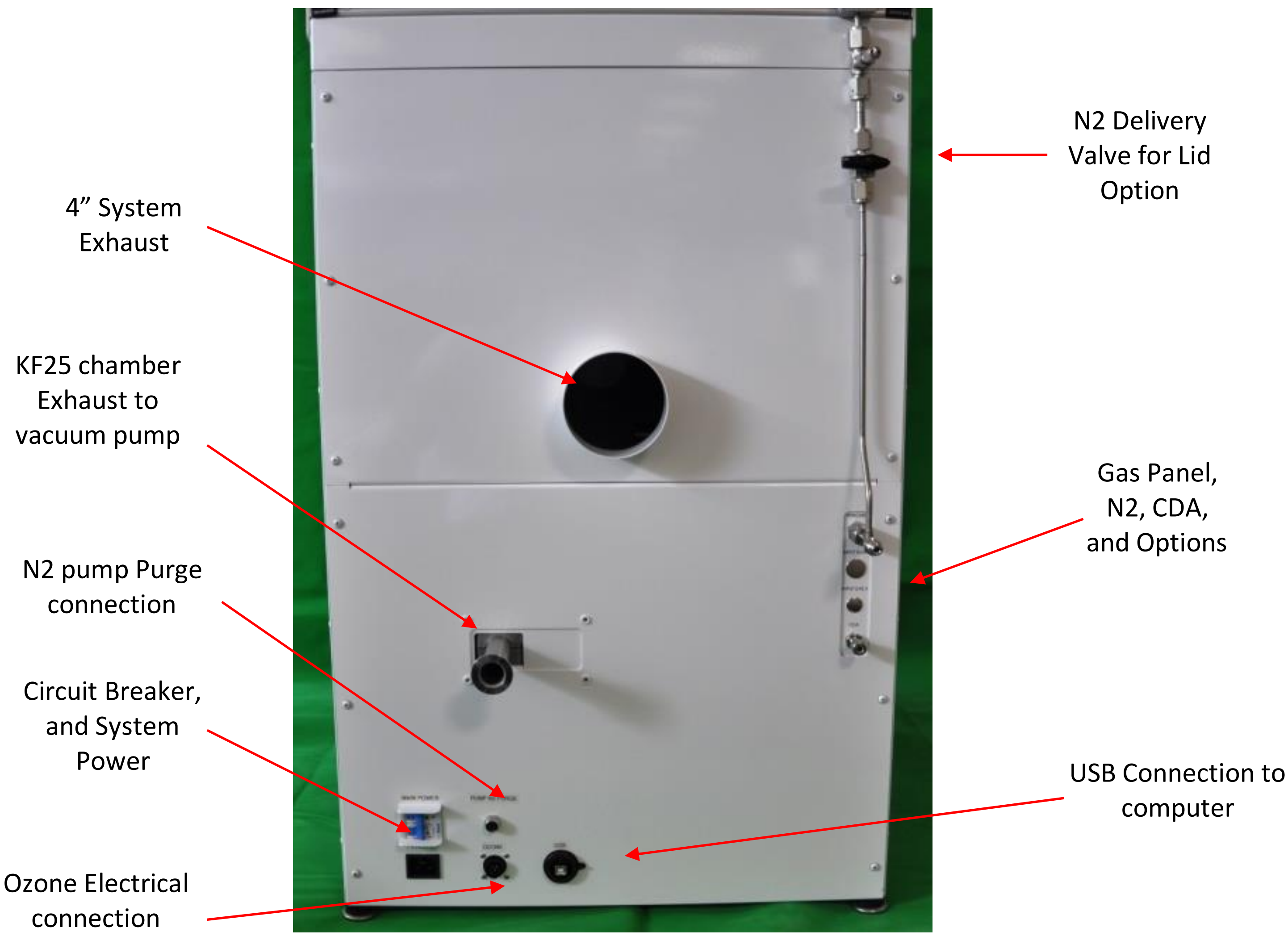
Section 2 Basic System Overview

The Savannah is designed to be both easy to operate and easy to maintain. The system is controlled via a PC thru a USB connection. Recipes are used to cycle the system through a series of steps from heating the components to flowing gases to pulsing ALD valves. The figure below outlines the basic components of the tool, with details for each device covered throughout this manual. The product manual included with the tool is supplied on a CD or USB "thumb" drive.

Savannah Front View

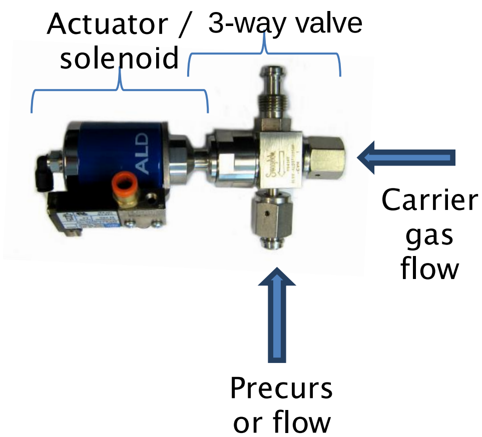


Savannah BackView



ALD Valves

The ALD valves pulse each precursor into the carrier gas through the manifold into the reactor where it meets the sample to be coated.

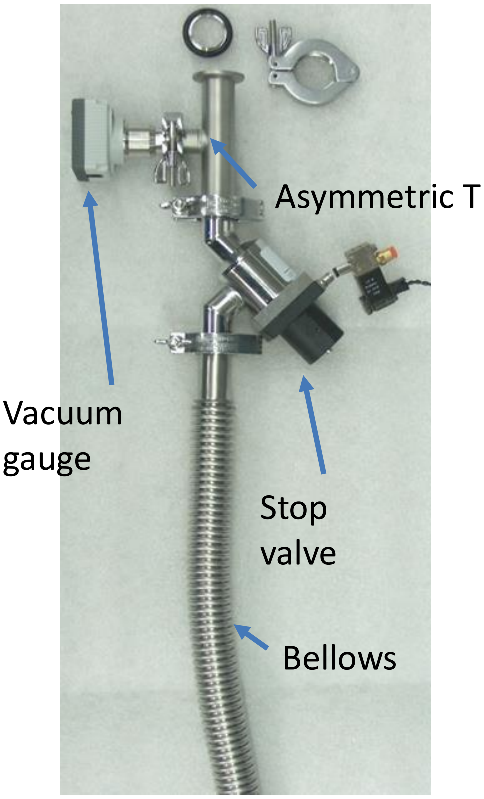


Reactor Chamber

The reactor is heated with an inner and outer heating element. The main chamber has a recessed grove for substrate placement in the main deposition zone. The precursor inlet carries the material into the chamber and the outlet is where it is exhausted.

Bottom View of Chamber

Top View of Chamber



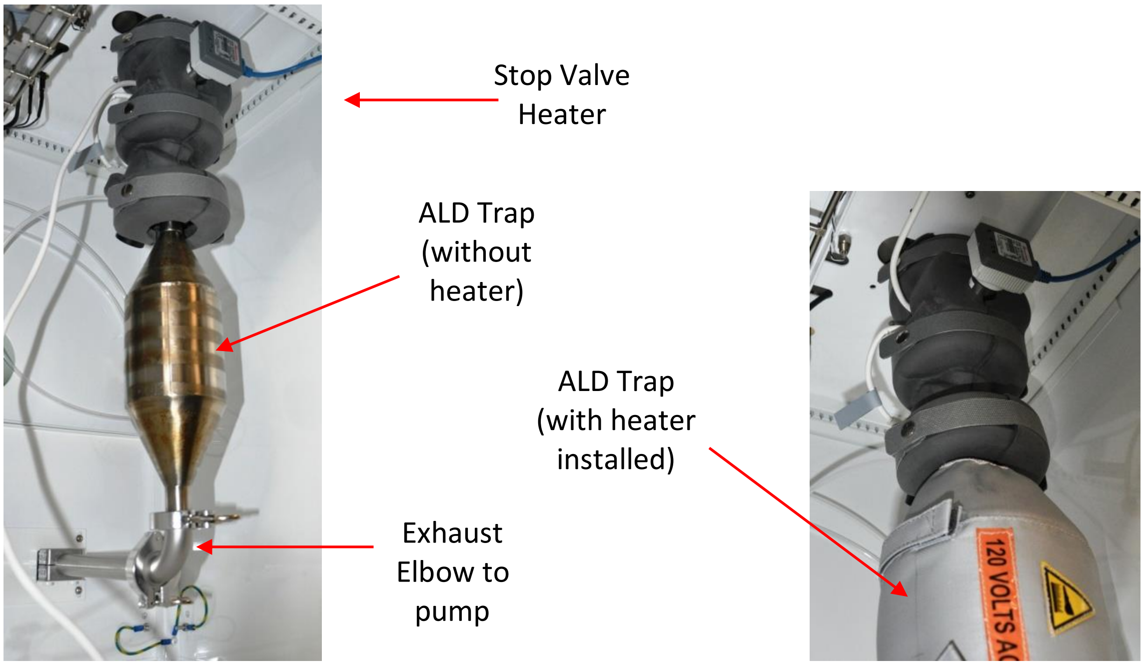
Exhaust line Assembly with-out ALD Vapor Shield installed

Stop valve

The stop valve assembly controls the pumping exhaust. It is a heated assembly with a vacuum gauge teed off to one side. The bellows in the figure below is typically replaced with a heated trap to capture unused precursor. The location of the stop valve is dependent on the type of deposition mode you will most commonly be using. Refer to the section on the trap for more details.

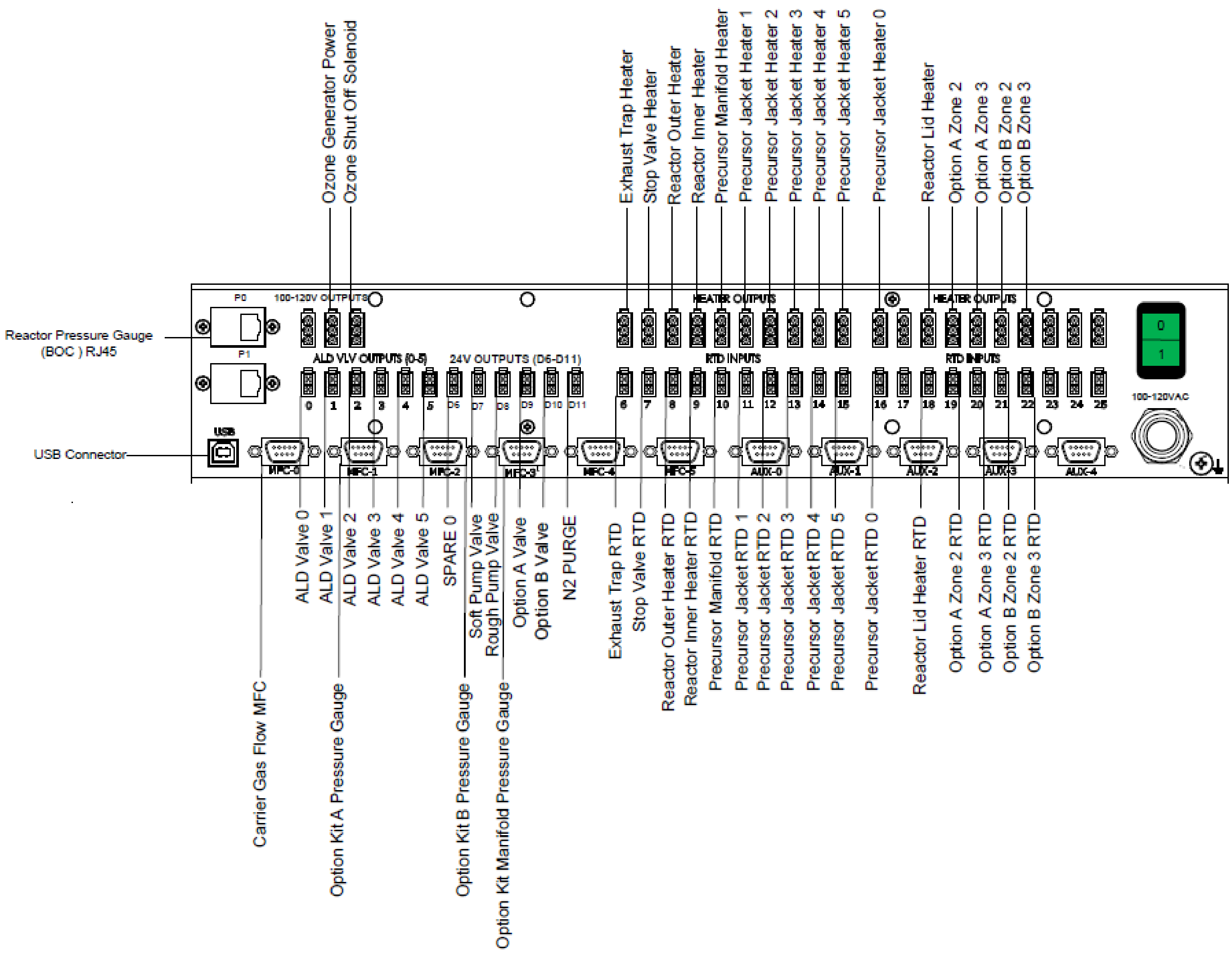
ALD Vapor Shield – ALD Trap

The heated trap is designed to fully react excess precursor and protect the pump from exposure to the organometallic precursor pulse, thus extending the usable life of the Fomblin oil and pump.



Electronic Control Box (E-box)

The Electronic control box (E-box) controls the I/O on the Savannah ALD system. The E-box is controlled by the system software that runs on a PC. The computer and control software communicate with the E-box via a USB connection located at the back of the Savannah system. The E-box controls the valves, heaters, pressure gauges, ALD valves and other electrical options. The figure below identifies which connection are used for each functional component in the system. These connections are preconfigured on the system and some connections may be defined for usable options in the GUI software or the config.ini file located in C:\Cambridge Nanotech\Configuration. This file determines which options can be controlled and are available in the GUI software.



Schematic of Electronics box (E-box) and electrical connections

Section3: Facilities

Pre-Installation Facility Checklist

The following items are required for operation of your Savannah system and are not provided by Veeco. After reading this document, if you have questions regarding the installation of your Savannah system, please contact: ALDsupport@veeco.com.

Electrical Requirements

- S100 - 120Vac power 20 Amp service
- S200 - 120Vac power 20 Amp service
- S300 - 120Vac single phase 40 Amp service – hardwired to the terminal block internal to the system.

Note: For European customers or locations with 220Vac power, a step down transformer is required.

Back Panel of the Savannah S100 and S200

Gas Connections

Process Gas:

- Recommended gas: Research grade(99.9995%) Nitrogen (N_2) or Argon (Ar).
- 40psi (276 kPa) of regulated pressure in stainless steel line delivery line with ¼" male VCR fitting.

Note: It is very important that a stainless steel line is used to prevent moisture and contamination in the process gas.

Actuation Gas for pneumatic valves:

80 psi (550 kPa) of regulated clean dryair or $N_2$for pneumatic actuation.

- Terminated with ¼" Teflon (PTFE) tubing or stainless steel tubing, connected to a male ¼" Swagelok fitting.
- Actuation gas is used to drive solenoid valves and ALD valves, low gas usage.

Gas connection panel

Vacuum Pump (Standard 14.6 CFM (24.8 m^3/hr)at 60 Hz)

- **Adixen 2021C – 14.6 CFM (24.8 m^3/hr)– Standard pump for Savannah system**. This pump is a corrosive series pump which can be upgraded with the N_2 pump purge kit.
    - Maximum oil capacity - 0.98 liters.

Other Pumps

- Edwards E2M28 – 22 CFM (37 m^3/hr)– Edwards equivalent, not compatible with the N_2 pump purge upgrade kit for corrosive gasses.
    - Maximum oil capacity – 1.32 liters.
- Edwards XDS 10 – 7 CFM (12 m^3/hr) – Dry Pump (Non-oil pump) with limited lifetime due to film coating of the internal mechanisms.

Note: the pump is not powered by the Savannah system, nor does it communicate with the Savannah software or electronics. A separate AC power source is required.

Vacuum Pump Oil

The recommended pump oil is a low back streaming vacuum pump oil.

- The vacuum pump is shipped from the vendor without oil installed and pump oil will need to be order separately. Follow the procedures in the pump manual for proper installation.
- The standard rotary vane pump oil is either the Adixen/Alcatel - 113 pump oil or the Solvay Solexis - Fomblin 25/6 oil.

Below is a list of equivalent products from the available literature.

Brand	Equivalent Fluid
Alcatel 113	Fomblin 25/6
Krytox 1525	Fomblin 25/6
Inland geminYe SV	Fomblin 25/6

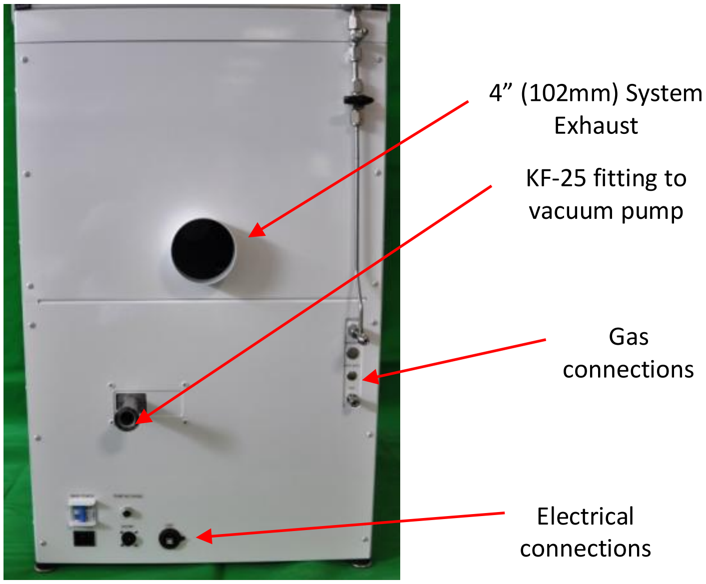
The performance of the vacuum oils should originate with a comparison of Kinematic Viscosity, Viscosity Index, and Vapor Pressure. The products available (Fomblin SV, Inland SV, Fomblin 25/6, Krytox 1525, and Alcatel 113) show similar performance in these areas. There are a number of companies that may distribute mechanical pump oils that are similar products, some may be rebranded with a different name. The pump oil must be a low back streaming oil with a low vapor pressure (~$6x10^{-8}$Torr at 25°C (77°F))

Note: Vacuum pumps do not ship with oil. It is the customer's responsibility to purchase the appropriate pump oil.

Exhaust Connections

- Pump Exhaust (pump output)
  - KF-25 fitting with 1 cfm (1.7 m^3/hr) at 0.5" (13mm) water column.
- System Exhaust
  - 4" (102mm) duct with 1 - 5 cfm (1.7-8.5 m^3/hr) at 0.5" (13mm) water column.

The Savannah system is configured with a two piece back panel. The upper section houses the 4" (102mm) exhaust duct to the fully enclosed vented gas box. The pump is installed external to the Savannah system's enclosure connected via a KF-25 flange mount extending through the back panel (see figure).



Savannah S100 and S200 System - Standard configuration

All process gases are run through the system pump to the exhaust. Each user's environmental requirements are different due to the chemical processes being employed. Consult the MSDS sheets of the precursors and contact your local safety office for appropriate venting precautions.

Environmental Specifications

Operating Temperature ....15-40°C (60-100°F)
Humidity .... Max 80% at 30°C (50% at 40°C)
Storage Humidity..................0-95% relative humidity, non-condensing
Indoor use only.
Pollution degree 2
Installation category.. II
Operation Altitude ....Max 2000m

Computer System

The Savannah system is shipped with a pre-configured laptop computer with the required Savannah software installed. Communication to the hardware is established using the USB cable supplied with the system and connected to the rear panel of the Savannah.

Ozone Generator (Optional Equipment)

The ozone generator kit (optional equipment) has integrated connections for connecting the Veeco Ozone Generator to the Savannah system. The power and control cable are connected to the Savannah system's rear panel and the O3/O2 is delivered into the Savannah system through the "Input gas 1" connection on the gas panel.

Oxygen Requirement:

Facility requirements for the ozone generator are oxygen (O_2) source, UPC grade O_2 (99.996%) 5-10 psig(1.4-1.7 bar) with and a flow rate of 0-1 lpm.

Chemical Precursors

Chemical precursors – It is recommended to obtain preloaded 50ml SS cylinders for the metal organic precursor material. Common chemical precursors can be purchased directly from a Chemical company. Some common suppliers include Sigma-Aldrich, Dow, Air Liquide, and Strem. The internet links for Sigma-Aldrich and Strem are provided below.

http://www.sigmaaldrich.com/materials-science/material-science-products.html?TablePage=21092525

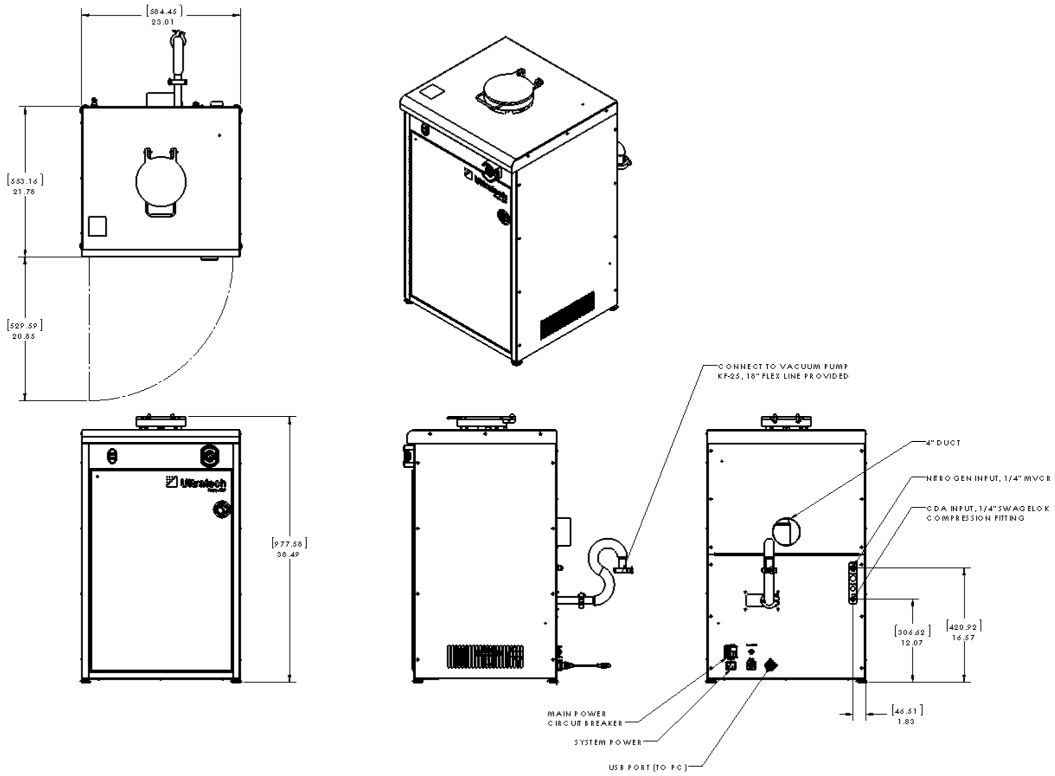
http://www.strem.com/catalog/d/mocvd/

The Savannah system ships with one empty water cylinder (no valve or heater jacket) and with kitted valve empty precursor cylinders (with heater jackets). These kits are provided, cleaned and packaged for use internally or to ship to a chemical supplier for filling.

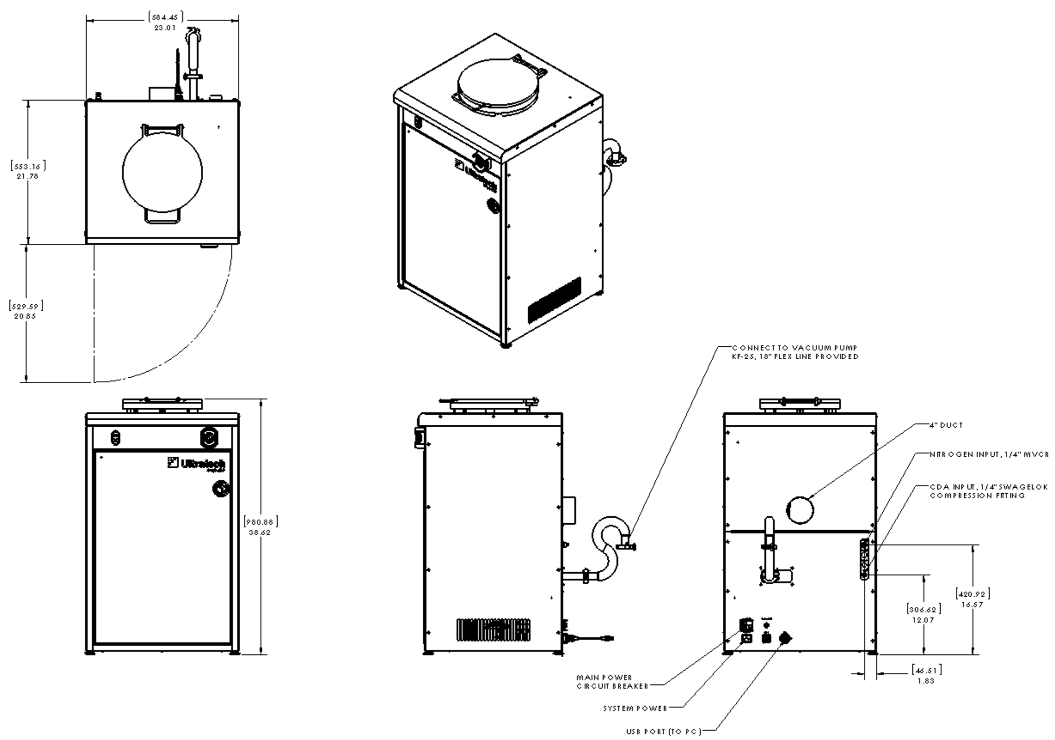
Trimethylaluminum (TMA) is used for Al_2O_3 deposition. It can be purchased from Sigma-Aldrich pre-packaged in the appropriate cylinder, P/N # 663301 or STREM P/N# 98-4003. TMA is a pyrophoric, and as such can only be shipped by ground transport. Be sure to order early to avoid delays in getting the proper precursors. Veeco recommends using distilled water as a precursor.

System Dimensions (Facility Drawings)

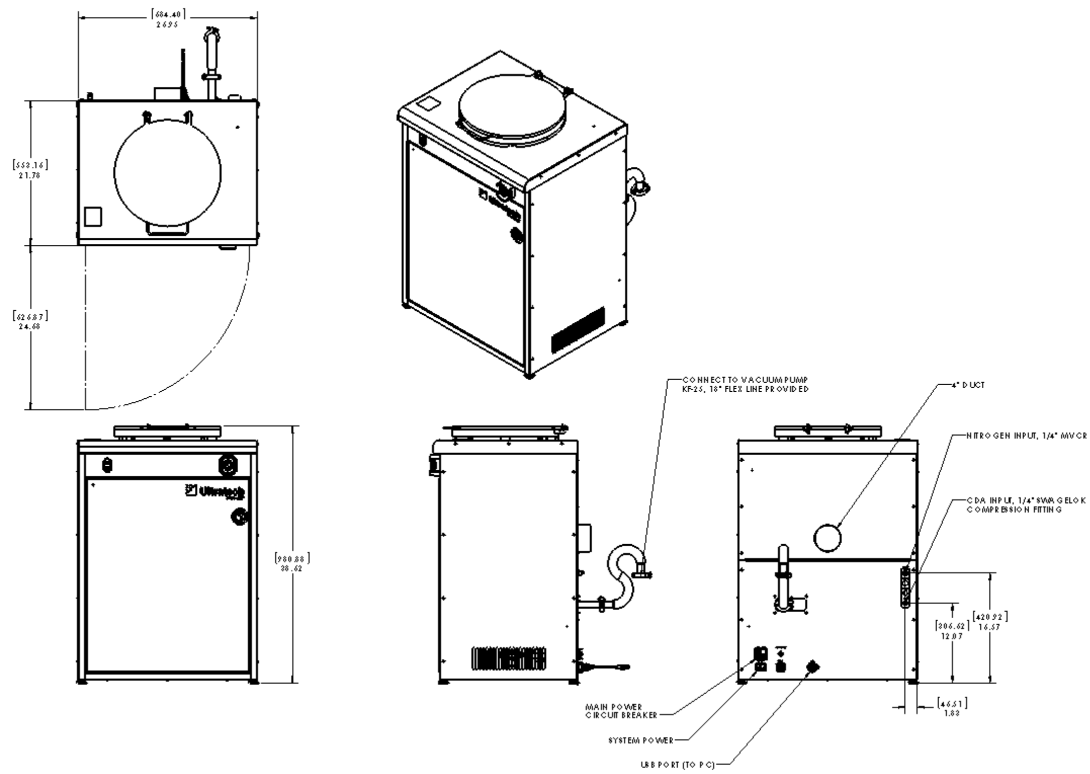
S100 Savannah



S200 Savannah



S300 Savannah



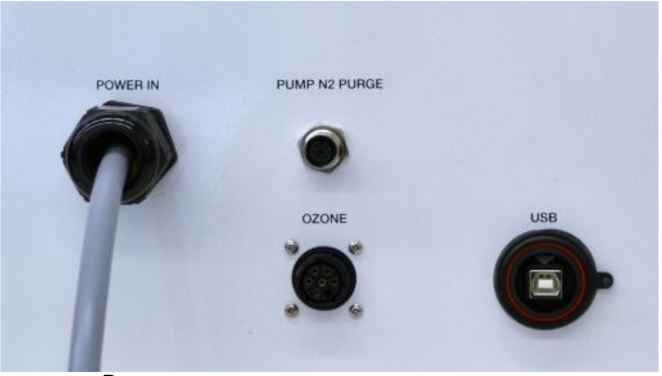
Savannah S300 Electrical Requirements

The Savannah S300 system has a number of electrical and hardware differences associated with the size and power requirements of the larger chamber size. The Savannah S300 system must be hard wired to the facilities power following National and Local wiring codes. It is strongly recommended that a lockable power disconnect switch is installed on the feed power to the Savannah S300.

S300 Power

50\60 Hz, 100-120 Vac single phase
40 Amp service

* note: 8AWG Cabling with a maximum outside diameter of 0.827 inches (21mm) is required.

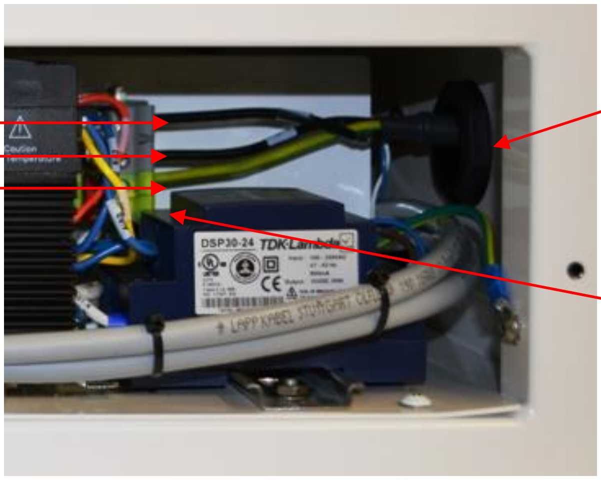


B
ack Panel of the Savannah S300

Note:

- ***System electrical wiring should be installed solely by trained electricians.***
- ***8 AWG wire is required for the power cable.***
- ***Power cable maximum outside diameter is 0.827 inches (21mm).***
- ***Installations at locations with 220Vac power require a step down transformer.***

The electrical terminal block is accessed by removing the panel on the right hand side of the system. After passing the wiring through the electrical gland nut (pass through fitting), the following connections are necessary: The power cable is connected as shown below, L1 at the top, Neutral (N) in the middle, and Potential Earth (PE) at the bottom. The gland nut provides stress relief for the electrical power cable and connections.



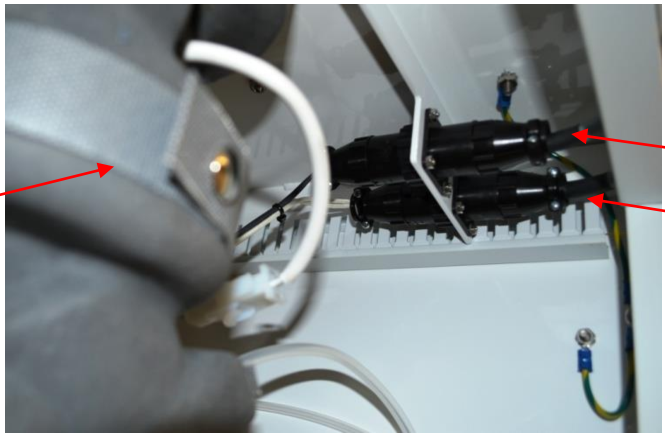
S300 terminal block location

Main Power Circuit Breaker

The main power circuit break for the S300 is located inside the cabinet to the right of the electronics box, as shown in the figure below.

Main power circuit breaker for the S300 (e-box cover removed)

To simplify maintenance and service of the S300 system, additional power connections have been added to the inner and outer chamber heaters. These two connections are located inside the cabinet on the top right hand side and are electrically keyed so that no power will be provided if connected improperly or incorrectly.



Inner and outer heaterelectrical connections

Section 4: Installation

Introduction

The Savannah ALD systems are shipped fully assembled. Carefully inspect all supplied parts for damage before proceeding with installation. Installation must be performed by qualified personnel observing all safety regulations and procedures. Helium leak checking of the entire assembled system is advised.

Unpacking Savannah System

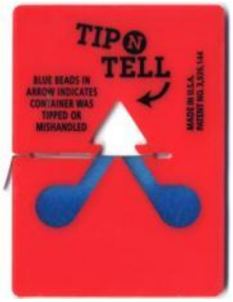
The Savannah ALD systems come packaged in a padded wooden crate and the vacuum pump is shipped in a separate box.

Note: Notify the shipping carrier immediately if any damage is found or the SHOCKWATCH or TIP N TELL monitors are in the "Fail" state. Retain the shipping cartons and packing material for the carrier's inspection and for repackaging in case reshipment is necessary.

1) Verify all SHOCKWATCH and TIP N TELL indicators show no sign of rough handling during transit. Make note on Bill of Lading and check for damage.

SHOCKWATCH – Proper Shipment

SHOCKWATCH – Bad Shipment with Failed (RED) Indicator



TIP N TELL – Proper Shipment

TIP N TELL – Bad Shipment with Failed (Blue) Indicator

If either indicator is in the failed state, Red for SHOCKWATCH or Blue for TIP N Tell, photograph the entire shipping crate and the Savannah system upon unpacking. There is a risk of damage associated with the shipping and handling of the wooden crate.

2) Remove the wood screws from the side of the crate to open one side. Remove any accessible components stored on top of the system.
3) Remove the box containing the heat shield and parts kit from the Accessory Box.
4) Remove the wooden cross-member by loosening the screws on either side of the crate
5) Remove the Savannah system from the crate.
6) Remove any loose components (shipped in protective wrap) from the rear of the system. DO NOT remove the shipping foam at this time.
7) Carefully unpack each box and package to check for damage, report all damage to the carrier and to Veeco.
8) Compare the contents of the materials shipped with the count and descriptions listed on the packaging list. Report all discrepancies to Veeco.
9) Make certain that each box and package is emptied of all smaller parts before discarding.

CAUTION: Avoid Particulate Contamination.

If the unit is to be used in a cleanroom environment, DO NOT unwrap any item until immediately before installation.

Parts List

The following items are included with the system in the Accessory Box within the create:

- Laptop Computer (Lenovo T430) with control software installed
- USB drive containing Savannah ALD control software and user manuals
- Power cable for Savannah system
- USB 2.0 Male A to Male B cable
- Swagelok ½" VCR gaskets (SS-8-VCR-2-GR) for main reactor / precursor manifold
- Swagelok ¼" VCR gaskets (SS-4-VCR-2-GR) for ALD valve / precursor cylinders
- O-ring removal tool
- Thermal (touch safe) reactor guard (not shown below)
- Edwards Vacuum Active Linear Convection Gauge NW 16 ST/ST
- Edwards Vacuum Active Linear Convection Gauge Manual
- Manufacturing build check sheet
- MKS Mass Flow Controller Certificate of Calibration
- Extra connectors / fittings

Contents of Accessory box for Savannah

Required Equipment and Supplies

Tools:

- Mechanic's Level
- Tubing cutter
- Metal tubing tools/fixtures: tubing cutter, tubing bender and related tools
- Helium leak checking equipment
- Cleanroom wipes
- Standard electrical and mechanical tool kits

Materials:

- ¼ inch diameter Teflon (PTFE) flex tubing for pneumatic actuation gas connection to system
- Stainless Steel tubing for process N_2 or Ar connection to system
- ¼ inch female VCR fitting and Swagelok fittings

Installation Procedure

Step 1: Move the System into Position

1) Be sure to follow all facility cleanroom procedures, if applicable, to properly clean any outer packaging wrap materials.

2) Check door and hallway clearances. Make sure that the final location of the system has adequate service clearances.

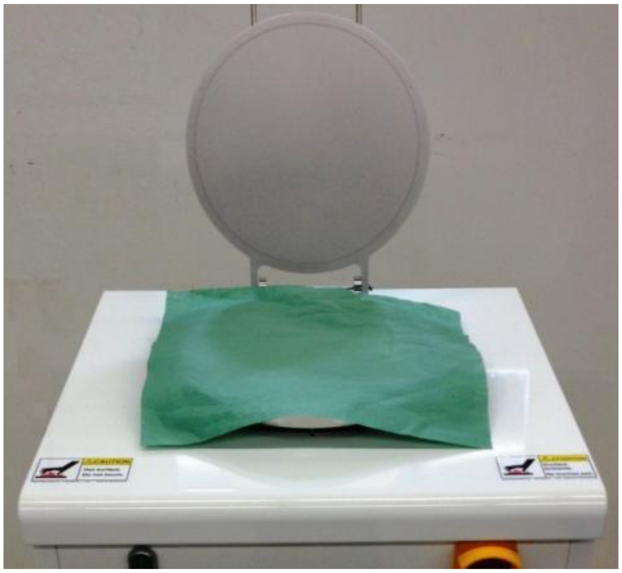
3) Carefully move the system into position with great care to prevent damage. Please consult professional movers.

CAUTION: PINCH HAZARD!
Protect yourself from any pinch or crush hazards.

4) Examine parts for any damage that may have occurred during shipment.

5) Remove any final protective plastic wrap from the system.

6) Open the Reactor Lid and remove any shipping and strapping materials, then open the front door.



Step 2: Level the System

1. The system is equipped with leveling feet. With the Reactor Lid open, place a sheet of cleanroom paper or wipe on top of the Reactor to avoid damage to the Reactor. Then place a Mechanic's Level on the center of the Reactor, front to back, side to side, and across to across, subsequently adjusting each leveling foot carefully to level the system.

Step 3: Connect Pneumatic Actuation Gas

1) Connect the Pneumatic Actuation Gas (Clean Dry Air or N_2 {preferred}) to the Gas Connection Panel's ¼" Swagelok fitting using ¼" PFA or metal tubing.

   NOTE: Ensure that the Actuation Gas pressure entering into the Savannah system is regulated to 80 psi (550 kPa)

Step 4: Connect Process Gas (N2 or Ar)

1) Connect the Process Gas (Research Grade N_2 or Ar 99.9995%) to the Gas Connection Panel's ¼" male VCR fitting using stainless steel tubing.

   NOTE: It is very important that a stainless steel line is used to prevent moisture from getting into the line. Ensure that the Process Gas pressure entering into the Savannah system is regulated to 40 psi (225 kPa) or the MFC will have difficulty delivering the correct flow to the system.

Step 5: Connect the Computer and electrical Power

1) Connect the power cord between the Savannah system and the 120VAC 20A wall outlet or power transformer for countries with >200V outlets.

2) Verify Savannah system's chassis has been properly grounded.

3) Connect the USB cable between the Savannah system and the laptop computer.

   NOTE: Make sure the USB cable is positioned as far as possible away from any vacuum pump to prevent electrical frequency interference.

4) Power on your computer and verify that your computer is disconnected from the Internet: Disconnect any Ethernet cable and disable the wireless adapter. For several reasons, isolating the PC from network communication results in a more reliable tool.

5) Confirm that the Savannah system's main circuit breaker is set to the ON position (located at the back of the cabinet). Confirm that the Savannah system's EMO button is not engaged. Press the green power ON button (located at front left of system) to energize the Savannah system, confirmed by a white power ON light. Also, verify that the E-box green light is ON through the E-box access panel (located inside the system).

6) Start up the Savannah software and confirm that it communicates with the Savannah system properly.

7) Verify that actuating gas, process gases, and exhaust connections are made and are available.

Step 6: Install the Vacuum Pump

1) Refer to the vacuum pump's manual for details and any pre-installation requirements.

2) Position the vacuum pump behind the Savannah system.

3) Connect the vacuum pump to the Savannah system with new/clean NW-25 o-ring fittings.

Alcatel 2021c2 - Fomblin Prepped:

Refer to vacuum pump's manual for connections and use.
Fill the vacuum pump with Fomblin 25/6 low back streaming vacuum pump oil.
A high voltage selector is available for plugging into 180 – 254VAC;consult vacuum pump's manual for details.

Note: **Remove the black plug from the vacuum pump's OUT port before turning ON your vacuum pump. Neglecting to do so may cause the vacuum pump to smoke, thereby causing permanent damage to the vacuum pump!**

Note: **DO NOT TURN ON THE VACUUM PUMP until the pump has been properly exhausted. (See following section on connecting the exhaust line before proceeding).**

Step 7: Connect the Vacuum/Exhaust Line

The exhaust of the ALD process from the Savannah system is directed exclusively through the pump. The exhaust of the ALD process may contain corrosive, reactive or toxic components, depending on the chemistries used inside the Savannah system. Choose appropriate exhaust line materials to suit the applications you are using. Ensure your compliance with local air quality and emissions regulations when planning on venting the process gas from your system.

The Adixen/Alcatel 2021C, Edwards E2M28 and the Edwards XDS10 pumps come with NW-25 fittings on the inlet and outlet side. Choose a pump line with a compatible fitting.

NOTE: LEAK HAZARD. HANDLE CAREFULLY. Always treat the vacuum connection flange faces with care and cover them with plastic caps if not in use, since scratching can cause leaks. Clean/replace each O-ring after use.

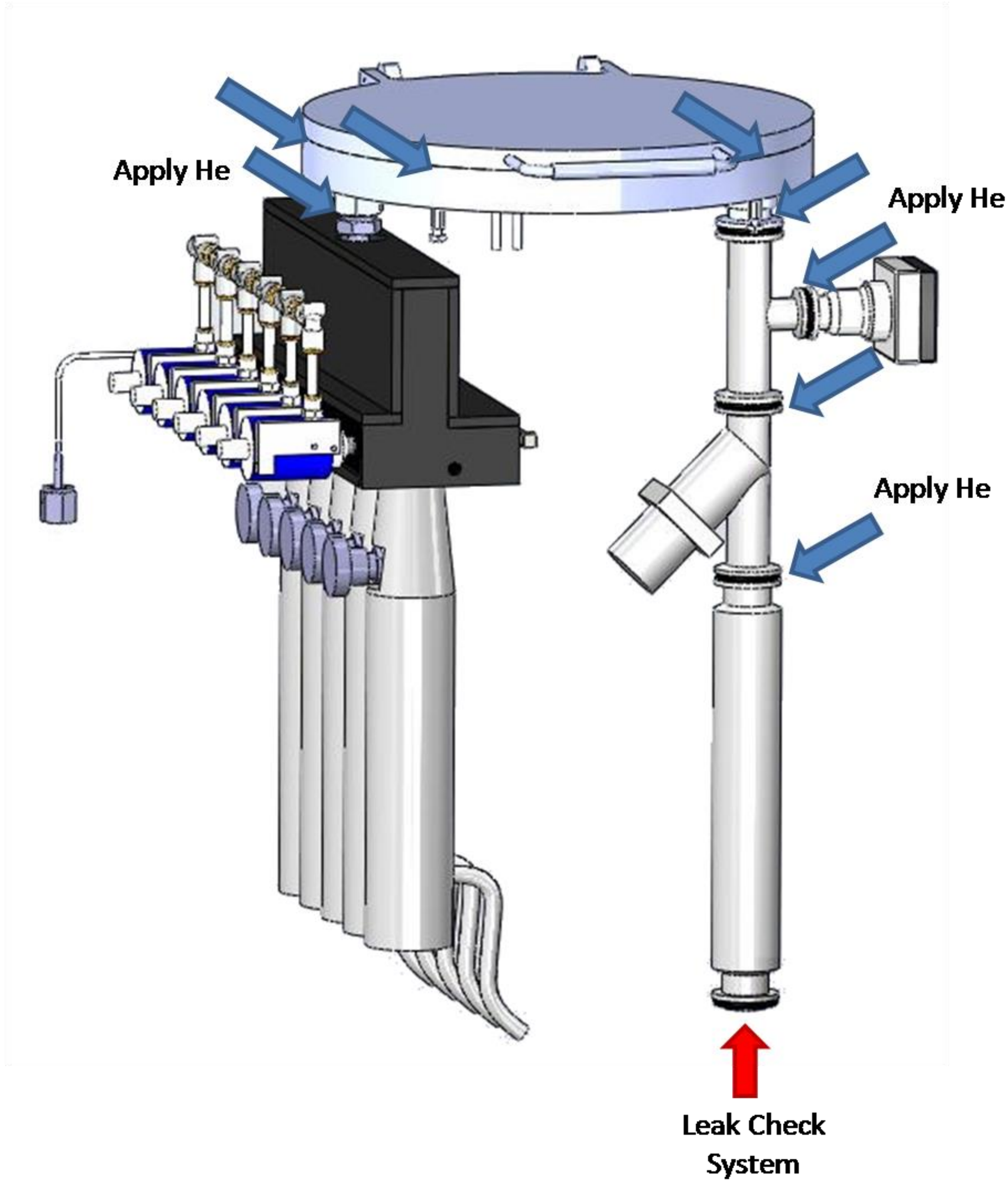
WARNING: Hazard Gas Exhaust Potential.
Thermal exhaust of the heat generated by the Savannah system as well as release of process chemicals/gases could be present in the exhaust line.

Connect the Savannah system only to an exhaust system that has been approved for your process effluents and your process chemicals/gases.

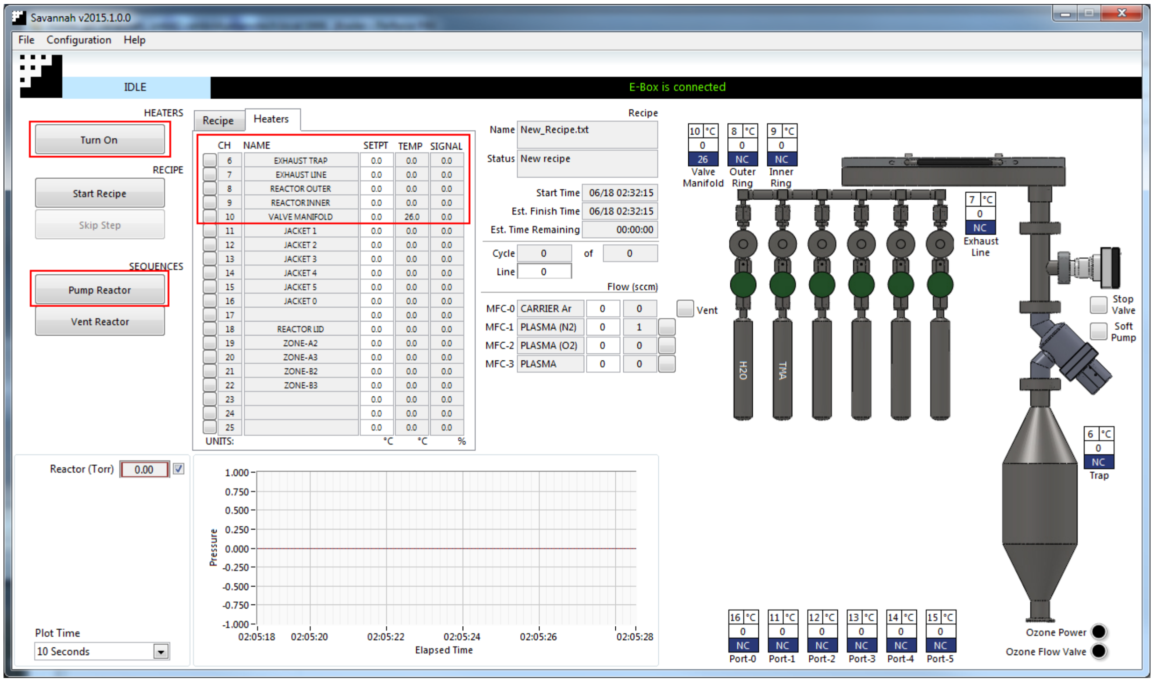
Step 8: Leak Check the System (optional)

If available, leak checking the system prior to usage is advised, but not required. The system is leak checked prior to shipping from the manufacturing facility. The leak rate obtained in the factory is reported in the manufacturing check sheet.

1) Connect the leak checking system to the bellows on the outlet side of the vacuum line or at the bottom of the ALD trap if installed.



2) Heat the Savannah system to 150°C, which allows the Kalrez O-ring and chamber components to heat up. Enter a "SETPT" value of 150°C for heaters #6-10, as shown. Note: the lid should not be forced open if the temperature is below 80°C, since Kalrez tends to stick at lower temperatures.



3) Wait for the heaters to reach their respective setpoint temperatures.

4) Press the "Pump Reactor" button to open the stop valve and pump down the system. The leak checking pump will now pump down the system. Wait until the base pressure for the leak checking system is achieved and stable.

5) Apply He to the connections indicated on the diagram (previous page). Be sure to read notes below before continuing.

   The helium leak rate should be between 1 X 10^{-9} and 8 X 10^{-9} mbar when checking the connections around the reactor and pumping line.

   NOTE: The o-ring sealing the reactor chamber and lid is permeable to He gas. Check this connection last by performing a quick sweep of He around the reactor lid. A large leak should be evident by this method. If He is applied to the o-ring for more than a few seconds, He transport will affect subsequent measurements of the system. A larger leak rate is expected and normal for the o-ring.

   NOTE: The precursor assembly is leak checked prior to installation into the system and shipping. Separate leak checking is not required.

Install Precursor Cylinders

The precursor cylinders are filled under inert atmosphere (inside a glovebox) by the chemical supplier. Never disconnect manual valves from the precursor cylinders. Always disconnect cylinder-valve assembly with manual valve closed.

The manual valve on the provided precursor cylinders SS-4H-VCR contains a bellows which requires evacuation. In order to minimize the exposed internal area that can accumulate precursor (and can contribute to clogged valves), the arrow on the side of the valve should be pointed toward the chemical side of the cylinder assembly.

Precursor Cylinder Replacement Procedure

Required Parts

Part Number	Description	QTY
SS-4-VCR2 or SS-4 VCR-2-GR (with retaining clip)	¼" metal VCR gaskets	1 per bottle

Required Equipment/Tools

- ¾" open end wrench
- $^{13}/_{16}$" open end wrench

Safety Precautions

WARNING: CHEMICAL HAZARD! Wear chemical-resistant garments and eye protection while performing system maintenance. Avoid skin contact and inhalation of any component exposed to process chemicals/gases. NEVER open a gas cylinder unless it is properly attached to a degassed plumbing system.

WARNING: BURN HAZARD! Allow system components to properly cool prior to performing maintenance to avoid personal injury.

DANGER: FIRE HAZARD! Follow instructions carefully. Never open any valves until specifically directed to do so. Certain Precursors will ignite upon exposure to air.

Some Precursors, such as Trimethylaluminum (TMA),are pyrophoric and will burn upon exposure to air. TMA reacts with water vapor in the air. For this reason, the TMA bottle may only be opened in a glove box with inert atmosphere by experienced professionals such as at the chemical supply companies (Strem, Sigma-Aldrich, etc).

Note: Not all Precursors need to be heated and TMA should NOT be heated.

Manual Valve Selection

The green headed bellows valve (SS-4H-VCR) is a bellows valve and can be heated to 220°C. The valve should be assembled with the arrow facing down into the cylinder. This configuration leaves a smaller dead space for Precursor to accumulate into which helps to prevent clogged valves.

While Veeco systems ship with SS-4H-VCR bellows valves, an optional ball valve SS-42GVCR4 can also be used. These valves are not for use with precursors requiring heating over 120°C.

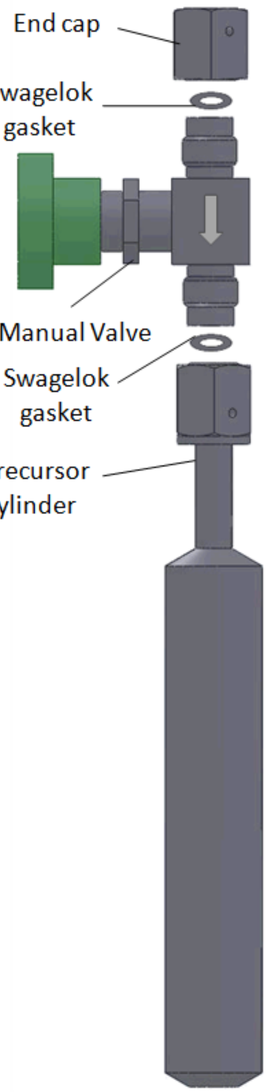
Precursor Cylinder

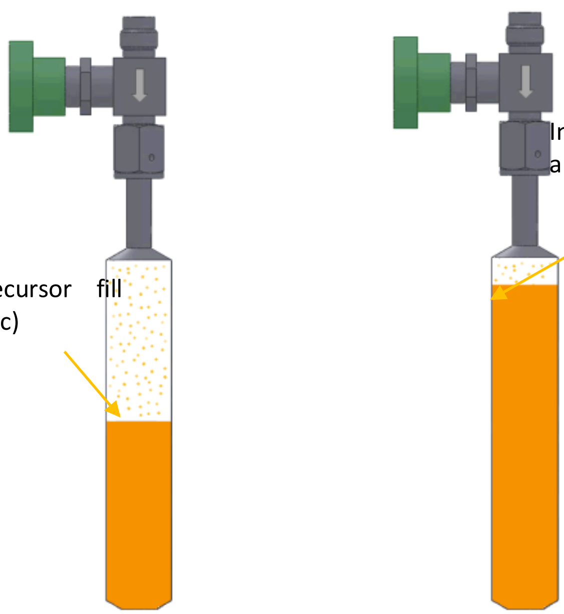
Many ALD Precursors are air sensitive and/or pyrophoric. Therefore, Precursors should be filled in an inert atmosphere (such as inside a glovebox) by the chemical supplier. Never disconnect manual valves from the precursor cylinders. Please contact ALDsupport@Veeco.com for recommended chemistries and suppliers.

Precursors should be dispensed into the cylinder so that they are no more than half full (or 25cc of material). This allows sufficient room for the Precursor to volatilize. As the Precursor dose is based on the vapor phase in the cylinder, if the cylinder is filled more than half full the Precursor dose may be smaller than expected. This may result in no film growing.

CAUTION: OVERFILLING THE CYLINDER MAY RESULT IN LIQUID BEING PULLED INTO THE SYSTEM.

The green headed valve (SS-4H-VCR) is a bellows valve and can be heated to 220°C. The valve should be assembled with the arrow facing down into the cylinder. This configuration leaves a smaller dead space between for precursor to accumulate into helps to prevent clogged valves. While Veeco systems ship with SS-4H-VCR bellows valves, an optional ball valve SS-42GVCR4 may also be used. These valves are not for use with precursors requiring heat exceeding 120°C.





Correct precursor fill amount (25cc)

Incorrect precursor fill amount – overfilled!

Correctly filled

Incorrectly Filled

Add an additional gasket and an end cap to the open, top end of the manual valve and remove the cylinder from the glovebox. Transport and store the cylinders according to local safety regulations.

Evacuating Precursor Headspace

A critical step for installing/removing precursor cylinders from the Savannah system is evacuating the precursor headspace. The goal is to remove air (cylinder install) or precursor material (cylinder removal) from the headspace between the precursor cylinder manual valve and the inlet of the ALD valve.

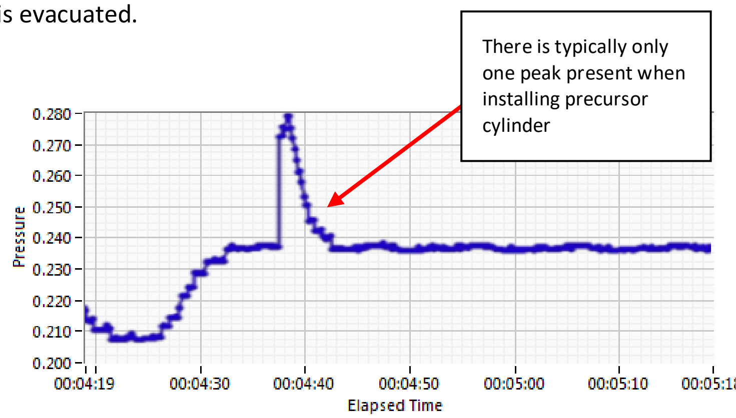
An evacuation of the precursor headspace MUST be performed every time a precursor cylinder is changed, or when the precursor will not be used for certain period of time.

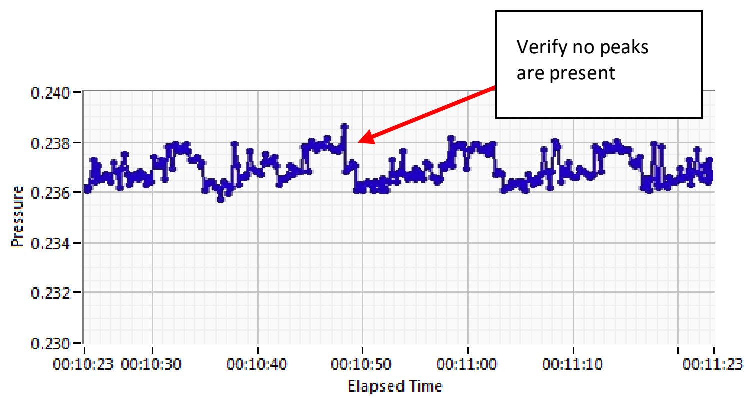
<table>
<tr><th>Step</th><th>Action</th><th>Details</th></tr>
<tr><td></td><td><u>Evacuating Precursor headspace</u></td><td></td></tr>
<tr><td>1.</td><td>Confirm that the Savannah system is pumped down and all heaters stabilized at setpoint temperatures.</td><td></td></tr>
<tr><td>2.</td><td>Close the manual valve on the precursor cylinder you will replace. DO NOT REMOVE THE BOTTLE AT THIS TIME!</td><td>CAUTION: HOT SURFACE!

If the precursor cylinder is hot, use thermal resistant gloves to close the manual valve. Close the valve by turning the valve head in the direction indicated.</td></tr>
<tr><td>3.</td><td>With the precursor cylinder valve closed, purge the headspace between the manual valve and the ALD valve.

Setup and run a “Headspace Purge” recipe as follows (where X is the precursor cylinder to be purged):
<table>
<tr><th></th><th>Instruction</th><th>#</th><th>Value</th></tr>
<tr><td>0</td><td>Flow</td><td></td><td>5</td></tr>
<tr><td>1</td><td>Wait</td><td></td><td>30</td></tr>
<tr><td>2</td><td>Pulse</td><td>X</td><td>1</td></tr>
</table></td><td>See the Operation section and Software Reference section for details on creating/loading/running recipes.</td></tr>
</table>

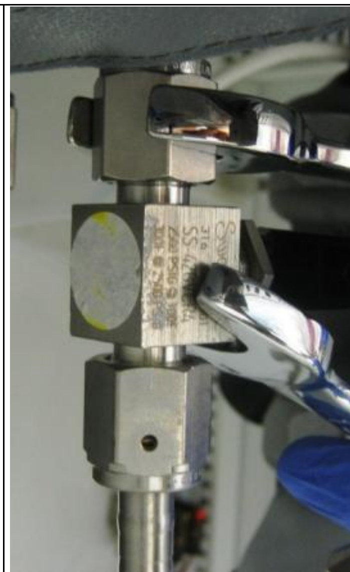
<table>
<tr><td></td><td><table><tr><td>3</td><td>Wait</td><td></td><td>5</td></tr><tr><td>4</td><td>Goto</td><td>2</td><td>20</td></tr></table>
Set the recipe to “open” the valve for 1 second pulse time. Set the wait time to 5 seconds. Repeat 20 times with the goto command.</td><td></td></tr>
<tr><td>4.</td><td>Purge the headspace until the base pressure during this run is the same as the base pressure of the system.</td><td>Less than 5 cycles will be required to purge the cylinder’s headspace. Repeat 20 cycles to ensure any remaining precursor is removed.

Ensure that the pressure plot does not have any peaks for the last few pulses. If not, repeat the program to ensure the space is evacuated.

</td></tr>
<tr><td>5.</td><td>Repeat headspace evacuation after > 10 minutes to confirm there’s no leaks.

Any pulses at this point identify that a leak is present.</td><td>
</td></tr>
<tr><td></td><td><u>Removing a Precursor Cylinder</u></td><td></td></tr>
<tr><td>6.</td><td>If applicable, turn off the power to the Precursor heating jacket by setting the</td><td></td></tr>
</table>

	temperature value to 0. This can be done by using the heater command in a recipe or by putting the cursor in the appropriate heater box (i.e. #13-18) and entering 0.	
7.	When cool, remove the precursor heating jacket from the cylinder.	
8.	Again verify that the precursor manual valve is closed.	
9.	Use two wrenches to remove the bottle: one on each end of the VCR fitting. **DANGER!**  Do NOT turn the VCR fitting below the manual valve!	 Remove the cylinder by gripping the square of the manual valve with a 13/16" wrench and the ALD valve connection with a 3/4" wrench. Rotate the top 3/4" wrench counterclockwise. **CAUTION!** *Do not twist the bottom connection to the precursor cylinder* This will disconnect the manual valve from the cylinder body exposing the precursor material.
	<u>Installing a new Precursor Cylinder</u>	
1.	In the empty precursor port, add a new precursor cylinder with a new, VCR gasket (SS-4-VCR-2) or (SS-4-VCR-2-GR) on top of the connection.	Use a new VCR metal gasket each time you open the VCR fitting.

2. Finger-tighten the precursor cylinder's VCR fittings then gripping the square of the manual valve with a 13/16" wrench and the ALD valve connection with a 3/4" wrench to further tighten the VCR fittings by 45° (1/8 turn).



Installing the cylinder by gripping the square of the manual valve with a 13/16" wrench and the ALD valve connection with a 3/4" wrench. Rotate the top 3/4" wrench clockwise by 45° (1/8 turn).

CAUTION!LEAK HAZARD! DO NOT OVER-TIGHTEN or the fitting will leak!

3. With the precursor cylinder valve closed, purge the headspace between the manual valve and the ALD valve.

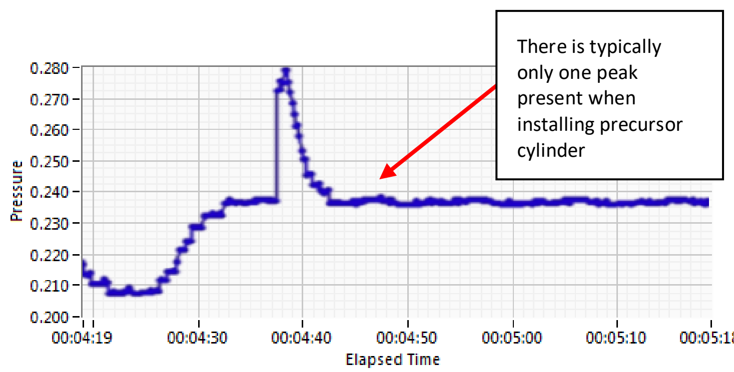
Setup and run a "Headspace Purge" recipe as follows (where X is the installed precursor cylinder):

	Instruction	#	Value
0	Flow		5
1	Wait		30
2	Pulse	X	1
3	Wait		5
4	Goto	2	20

Set the recipe to "open" the valve for 1 second **pulse** time. Set the **wait** time to 5 seconds. Repeat 20 times with the **goto** command.

Less than 5 cycles will be required to purge the cylinder's headspace. Repeat 20 cycles to ensure any remaining precursor is removed.

Ensure that the pressure plot does not have any peaks for the last few pulses. If not, repeat the program to ensure the space is evacuated.



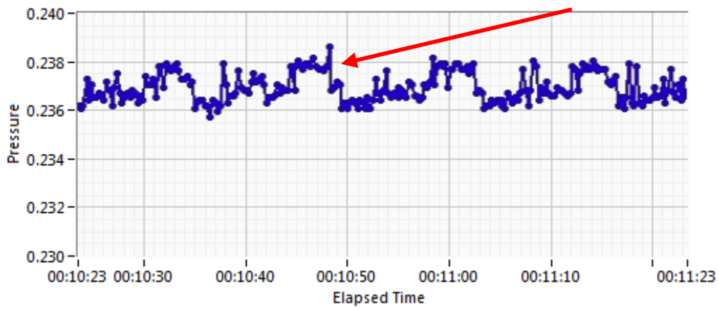
4. Reinstall the precursor heating jacket (if applicable).

5. Turn on precursor heating jacket (if applicable).

6. Repeat headspace

Verify no peaks are present

<table>
<tr>
<td></td>
<td>evacuation after > 10 minutes to confirm there's no leaks.

Any pulses at this point identify that a leak is present.</td>
<td>
</td>
</tr>
<tr>
<td>7.</td>
<td>AFTER evacuating precursor cylinder head space, open the cylinder's manual valve.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>With the precursor cylinder valve opened, pulse the trapped gas inside the cylinder.

Setup and run a "Pulse" recipe as follows (where X is the precursor cylinder to be pulsed):

<table>
<tr><td></td><td>Instruction</td><td>#</td><td>Value</td></tr>
<tr><td>0</td><td>Flow</td><td></td><td>20</td></tr>
<tr><td>1</td><td>Wait</td><td></td><td>30</td></tr>
<tr><td>2</td><td>Pulse</td><td>X</td><td>0.015</td></tr>
<tr><td>3</td><td>Wait</td><td></td><td>10</td></tr>
<tr><td>4</td><td>Goto</td><td>2</td><td>20</td></tr>
</table>

Set the recipe to "open" the valve for 0.015 second pulse time. Set the wait time to 5 seconds. Repeat 20 times with the goto command.</td>
<td>After precursors are installed, it is critical to 'pulse' out the trapped inert gas inside the cylinder before processing. Allow the pulse pressure peaks to stabilize to a magnitude exhibited under a steady state process condition.

You may need to run the "Pulse" recipe several times before reaching steady state process condition.</td>
</tr>
</table>

Step 10: Fill and Install the H_2O Cylinder

Refill the DI Water Cylinder

Required Parts

Part Number	Description	QTY
SS-4-VCR2 or SS-4 VCR-2-GR (with retaining clip)	¼" metal VCR gaskets	1 per bottle

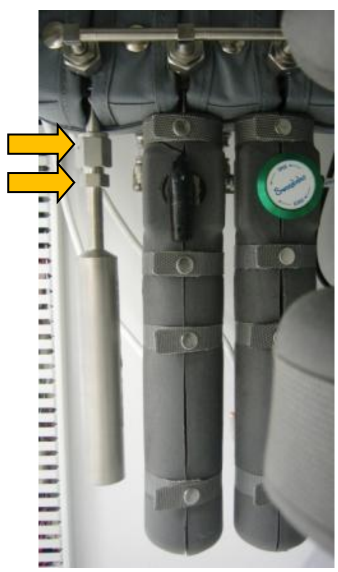
Required Equipment/Tools

- ¾" open end wrench
- $^5/_8$" open end wrench

Safety Precautions

WARNING: CHEMICAL HAZARD! Wear chemical-resistant garments and eye protection while performing system maintenance. Avoid skin contact and inhalation of any component exposed to process chemicals/gases. NEVER open a gas cylinder unless it is properly attached to a degassed plumbing system.

WARNING: BURN HAZARD! Allow system components to properly cool prior to performing maintenance to avoid personal injury.

Step	Action	Details
1.	Open the front door and remove the H_2O cylinder: place a wrench on each of the two VCR connections and carefully loosen and remove the cylinder. Use two wrenches to remove the bottle: one on each end of the VCR fitting.	CAUTION: Leak hazard! Extra care should be taken in order to protect VCR connection surfaces from scratches. Once disconnected, use plastic covers and plugs to protect polished VCR connection surfaces. 

<table>
<tr><td>2.</td><td>Fill the cylinder with up to 25 ml of water.</td><td></td></tr>
<tr><td>3.</td><td>Reinstall the filled H_2O cylinder with a new, genuine Swagelok gasket (SS-4-VCR-2) or (SS-4-VCR-2-GR) on top of the connection.</td><td>Use a new metal gasket each time you open the VCR fitting.

CAUTION! You MUST use a new gasket every time a connection is made.</td></tr>
<tr><td>4.</td><td>Finger-tight the H_2O cylinder's VCR fittings then tighten with wrenches by 45° (1/8 turn).</td><td>CAUTION!Do not over tighten VCR fittings. First finger-tighten the VCR fittings and then tighten with wrenches by 45°(1/8 turn).</td></tr>
<tr><td>5.</td><td>Setup and run a "Pulse" recipe as follows (where X is the water cylinder to be pulsed):

<table><tr><th></th><th>Instruction</th><th>#</th><th>Value</th></tr><tr><td>0</td><td>Flow</td><td></td><td>20</td></tr><tr><td>1</td><td>Wait</td><td></td><td>30</td></tr><tr><td>2</td><td>Pulse</td><td>X</td><td>0.015</td></tr><tr><td>3</td><td>Wait</td><td></td><td>10</td></tr><tr><td>4</td><td>Goto</td><td>2</td><td>20</td></tr></table>
Set the recipe to "open" the valve for 0.015 second pulse time. Set the wait time to 5 seconds. Repeat 20 times with the goto command.</td><td>After water cylinder is installed, it is critical to 'pulse' out the trapped air inside the cylinder before processing. Allow the pulse pressure peaks to stabilize to a magnitude exhibited under a steady state process condition.

You may need to run the "Pulse" recipe several times before reaching steady state process condition.</td></tr>
</table>

Section 5:Certificate of Compliance

ZERTIFIKAT • CERTIFICATE • 認證證書 • СЕРТИФИКАТ • CERTIFICADO • CERTIFICAT

TÜV SÜD America

CERTIFICATE

No. U8 13 10 85037 002

Holder of Certificate:	**Ultratech, Inc.** 3050 Zanker Road San Jose CA 95134 USA
Production Facility(ies):	80831
Certification Mark:	TÜV SÜD NRTL C US
Product:	**Electrical equ. for measurement, control and laboratory use (Atomic Layer Deposition System)**
Model(s):	**Savannah S100;** **Savannah S200**
Parameters:	Rated Input Voltage: 100-120 VAC Rated Frequency: 50-60 Hz Rated Input Power: 1300 VA-1700 VA; 1500 VA-2000 VA Protection Class: I Ingress Protection: IPX0
Tested according to:	CAN/CSA C22.2 No. 61010-1:2004 UL 61010-1:2008 EN 61010-1:2001

The product was voluntarily tested according to the relevant safety requirements noted above. It can be marked with the certification mark above. The mark must not be altered in anyway. This product certification system operated by TÜV SÜD America Inc. most closely resembles system 3 as defined in ISO/IEC Guide 67. Certification is based on the TÜV SÜD "Testing and Certification Regulations". TÜV SÜD America Inc. is an OSHA recognized NRTL and a Standards Council of Canada accredited certification body.

Test report no.: XI1309887-000

Date, 2013-10-30

Page 1 of 1

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UCB_F_12.02 2012-02

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Section 6:Operation

System Startup

Step 1: Verify Installation

1. Verify that all facility requirements and installation procedures have been completed and that all tubing has been properly installed.
2. Verify that all system panels are in place and closed.
3. Turn on all facility gas supplies.
4. Turn on the system's vacuum pump and verify draw.

Step 2: Powerup the System and Start the Control Software

1. Connect the computer to the Savannah with the USB cable.
2. Power the computer and wait for it to boot.
3. Turn on the main power at the upper left corner of the Savannah. For older tools open the front door and turn on the power switch on the E-box.
4. Start the control software on your computer by double-clicking the **"Savannah"** program icon.

Savannah

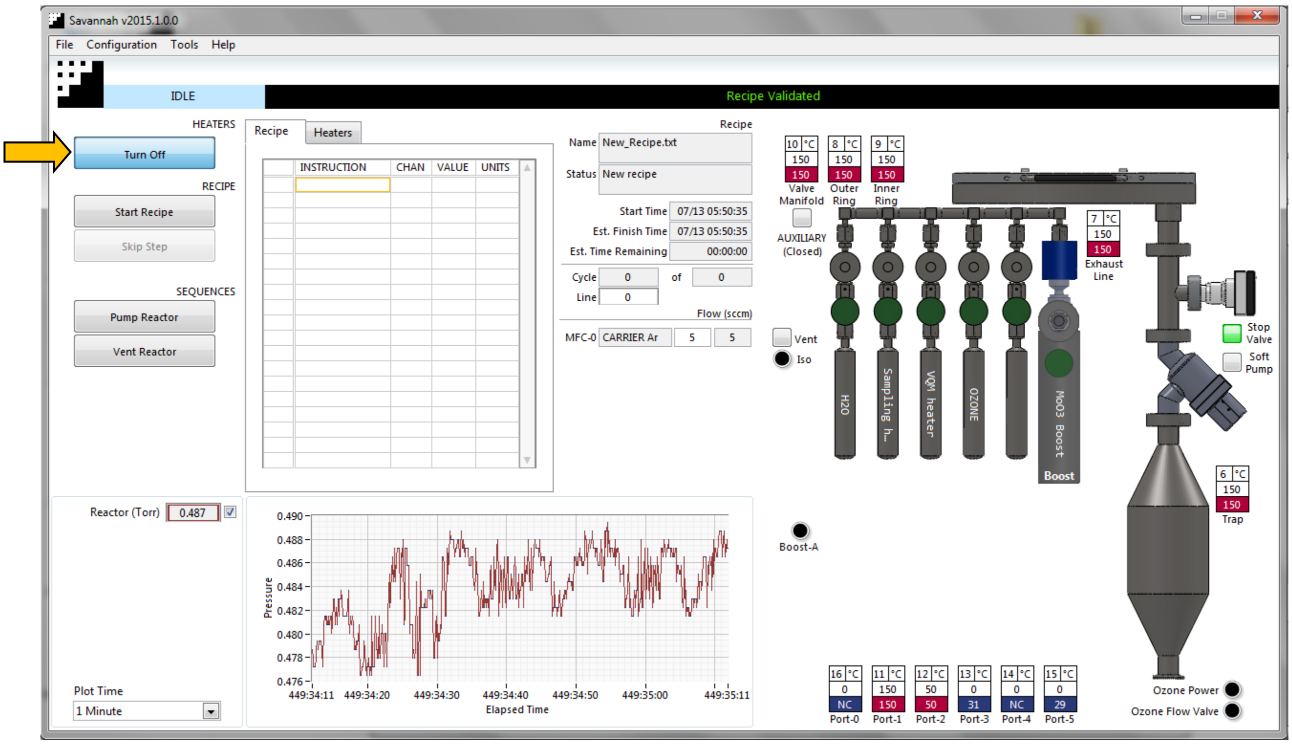
Step 3: Turn on the Heaters

IMPORTANT: The heaters should remain on during all system use to prevent condensate of precursor material in delivery lines and in the process chamber, chuck, and trap assemblies.

1. Use the graphical display to enter the following values for each heater in the white boxes. (See picture on next page for reference.)
   - Process Chamber Inner Heater: 200°C
   - Process Chamber Outer Heater: 200°C
   - Stop Valve: 150°C
   - Trap/Pump Line: 150°C
   - Process Manifold (ALD Valves): 150°C
   - Precursors: process dependent, see Standard Recipe Sheets provided by Veeco

     WARNING: Temperature of the precursors should not exceed safety or decomposition temperature of the chemical used. Consult Veeco for recommendations for your specific precursors.

2. Press the Heater ON button to turn on the heaters.



3. Wait until the temperature reaches the setpoint for each heater, as displayed in the colored box below each input.

Step 4: Degas the Precursor Cylinders

Refer to the "Software Reference" section for details on creating, loading, and running recipes.

Degassing the system removes air from the lines and the headspace between precursor valves and the system's ALD valves. You MUST degas the system every time you startup or change a precursor bottle. Refer to the "Software Reference" section of this manual for instructions or writing and running recipes/software instruction.

1. Press the Pump button to open the vacuum valve and begin the pump-down of the process chamber.
2. Note the base pressure of the system.
3. Enter a value of 20 sccm for the Carrier Gas Flow, typically MFC0.
4. Degas the water cylinder. This is done by writing and executing the following instruction set (recipe): "Valve 0" **Pulse** time of 0.015 second, and the **Wait** time set to approximately 10 seconds.

	Instruction	#	Value
0	Pulse	0	0.015
1	Wait		10
2	Goto	0	10

5. After the water source degassing run is done and the temperatures have stabilized, note the base pressure of the system. The pressure may take longer to return to normal if the temperature of the chamber heaters are lower than 200°C.
6. Degas the headspace between the ALD and manual valve of the precursors by writing and executing the instruction set (recipe) below. "Valve 1" corresponds to precursor cylinder # 1.

Pulse time of 1 second, and the **Wait** time set to approximately 10 seconds. Keep the manual valve on the precursor closed, while purging.

	Instruction	#	value
0	Pulse	1	1
1	Wait		1
2	Goto	0	10

Precursor cylinder 1 degas recipe

7. When the base pressure during this run is the same as the base pressure of the system then this area has been degassed. Approximately 100 cycles will degas a precursor headspace.

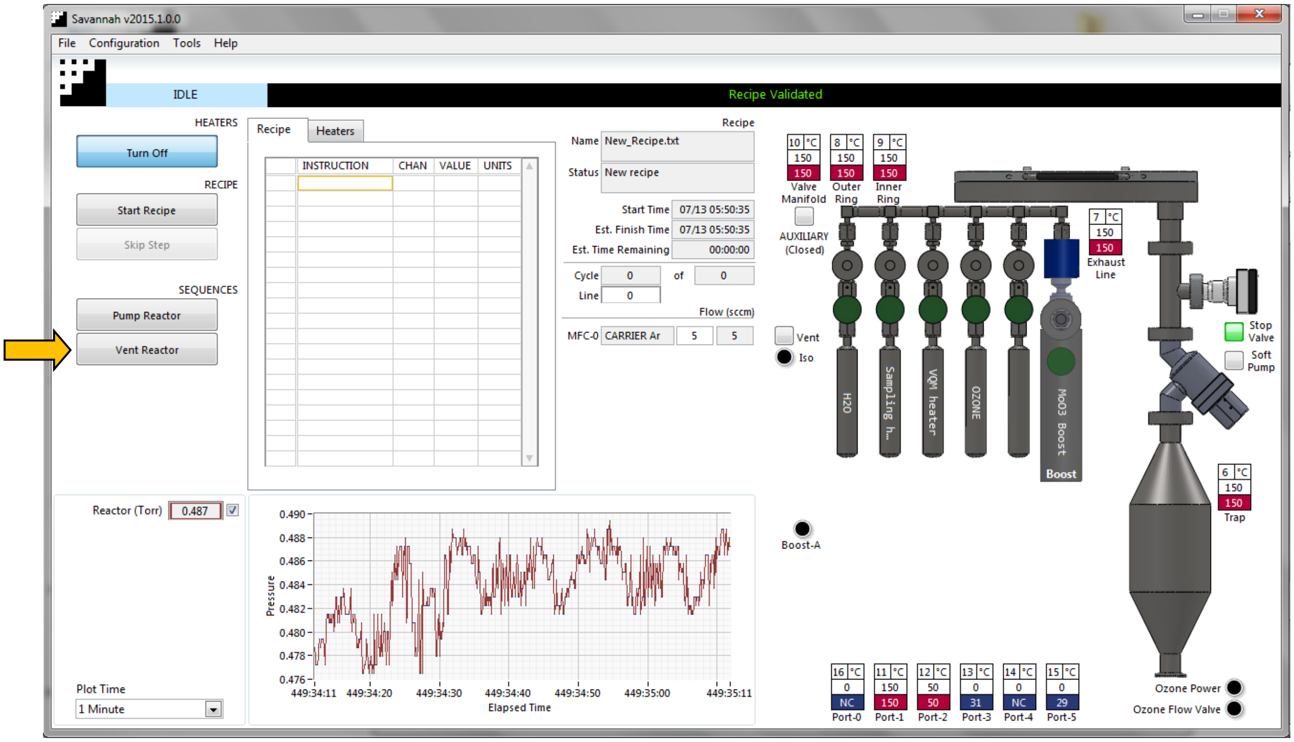
Note: Degas the headspace of atmospheric gases before opening the manual valve every time the space between manual and ALD valves has been exposed to air. Also degas this area after closing the manual valve if the ALD valve is to be removed.

8. Repeat the above degassing steps for each precursor cylinder.

System Normal Operation

Step 1: Load a Substrate

1) Verify that all setup steps have been completed and the system is at temperature and all precursor bottles and lines have been degassed. See prior pages.



2) If the system is under vacuum, press the "Vent Reactor" button and wait for the system to reach atmospheric pressure.

3) Lift the lid and load a substrate onto the heated plate.

CAUTION! BURN HAZARD.
The lid and plate areas are hot.
Use only the cool touch handle on the Savannah system lid.
Use appropriate tools and/or wear protective clothing.

CAUTION! Take care when opening the lid at less than 80°C
as the o-ring will be tacky and release slowly.

4) Close the lid.

Safety: position the heat shield (touch shield) over the chamber to prevent accidental burns. The plate is HOT!

Step 2: Bring the System to Vacuum

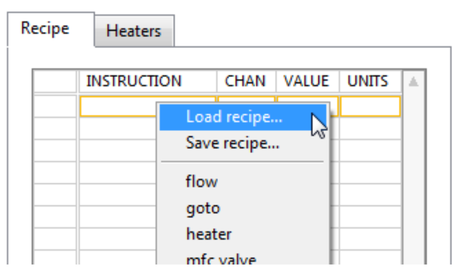
1. Press the “Pump Reactor” button to bring the process chamber under vacuum.

Step 3: Set a Process Gas Flow Rate

1. Set the carrier gas (N2) flow at 20 sccm. You can increase this flow for certain process recipes and film deposition, but a minimum process flow of 20 sccm is recommended. During system “Idle” time between ALD process runs the carrier gas flow can be reduced to 5 sccm. It is recommend to maintain a constant flow of N2 through the reactor.

Step 4: Run a Recipe

1. Load or create your process recipe as necessary for your run.



Right-click over the recipe entry area of the screen to display the recipe context menu (shown below). Refer to the “System Software” section of this manual for details.

2. Press the **Start Recipe** button and wait for the recipe to complete.

   Specific recipes and settings vary. Please consult your process engineer and/or Veeco.

Step 5: Remove the Substrate

1. Toggle the Pump/Vent button to the VENT position to bring the system to atmospheric pressure.
2. Lift the lid and remove the substrate.

CAUTION! BURN HAZARD.
The lid and chamber are hot. Wear protective clothing and use appropriate substrate handling tools.

System Parameters for Idle "Standby" Mode

Keep the system at temperature when not in use.

When the ALD deposition is complete, it is advised to keep the system at an idle temperature (reactor heaters >100°C, stopvalve, pumping line and precursor manifold at 150°C). Excessive temperature cycling can cause premature delamination of deposited film on the lid and reactor chamber. This will shorten the time between required cleaning of the lid and reactor.

Keep the system under vacuum when not in use.

This will prevent oxygen, moisture or other contaminates from entering the system when not depositing films.

Keep N_2flow at 5 sccm when not in use.

Reducing the flow rate of process gas to 5 sccm will maintain a continuous flow of N2 through the reactor to the vacuum pump and eliminate the possibility of back streaming into the chamber.

Unplug unused heater jackets when not in use.

Remove unused heater jackets from the system by unplugging their connections from the electronics box. Unused heater jackets should not be placed around TMA and/or water cylinders. Keeping heaters connected when not in use can lead to inadvertent heating of precursors.

Parameters for Standard Operation

Recommended Operation Temperatures:

Trap/ Pump Line heater:	150°C	
Stopvalve heater:	150°C	
Precursor Manifold heater :	150°C	
Reactor Chamber Heaters		
(inner heater)	50 - 350°C	varies according to process
(outer heater)	50 - 270°C	varies according to process
Precursor Heaters	0 - 200°C	varies according to material (see note below)

Precursor Cylinder Temperature Limitations

Precursor cylinders with green manual bellows valves (SS-4H-VCR)	Max Temp < 220°C.
Precursor cylinders with black manual ball valves (SS-42GVCR4)	Max Temp < 120°C

High Temperature (>300°C) Operation

NOTE: The O-ring sealing the reactor and the lid of the system are made of Kalrez and will melt if heated above 310°C. Be sure not to heat the o-ring over 310°C to avoid catastrophic failure of the chamber o-ring.

In order to prevent the o-ring from melting, it is necessary to use two different setpoints for the inner and outer heater when performing depositions above 300°C. The max setpoint for the outer heat should be reduced to 270°C when depositing films at >300°C

For the S100 System:

If the inner heater temperature is above 350°C, turn off the outer heater (outer heater setpoint = 0°C).

For the S200, S300 System:

If the inner heater temperature is above 350°C, set the outer heater to less than 100°C. The outer heater RTD will be heated from the Inner heater and the temperature can be quite high with a zero setpoint.

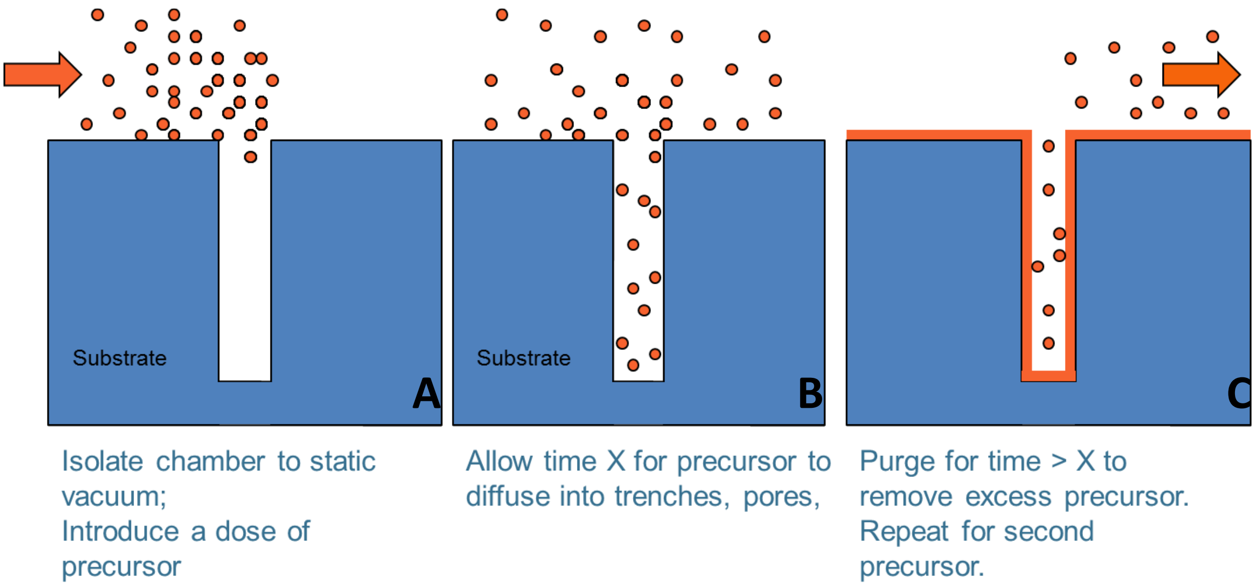
Exposure (Expo) Mode Operation

Exposure mode can be used for the coating of ultra-high aspect ratio (HAR) structures. This operation mode is achieved by dosing each precursor when the stop valve is closed. This allows the precursor to be exposed to the sample for an extended period of time and allows precursor to diffuse into high aspect ratio structures.

Expo mode is usually used when aspect ratios for geometries are >40:1 (e.g. holes 1 nm diameter and 40 nm deep). Other conditions that may require expo mode include the coating of particles, porous materials, MEMS structures, and vias. The wait time after the pulse, when the stop valve is closed, determines the time that the precursor can diffuse through the sample. Exposure times required will vary depending on the substrate, temperature of deposition and the precursors being used. For very high aspect ratio structures the exposure time can exceed 60 seconds,> 60 seconds.

For HAR structures it is important to calculate and understand the effective increase in surface area associated with the samples. The increase in surface area attributed to the vias and pores can require a corresponding increase in the delivered precursor dose.

Principle of Exposure Mode™



A- Isolate chamber to static vacuum (Stop Valve Closed); introduce a dose of precursor
B - Allow time X for precursor to diffuse into trenches, pores
C - Purge for time > X under dynamic vacuum (Stop Valve Open) to remove excess precursor and byproducts.
Repeat steps A, B and C for the second precursor.

Developing an Expo Mode Recipe

Higher doses of precursor are typically required to increase the reactant partial pressure at the top of the feature and provide sufficient dose to fully saturate the effectively large surface area of the sample/chamber, associated with the HAR structures.
During the exposure mode recipe, a minimum N_2 carrier gas flow of 5 sccm can be used, so that the ALD valves will maintain a constant N_2purge.

Tips for Exposure Depositions

Purge Time ≥ Expo Time
The purge time (under dynamic vacuum) should be equal or longer to the exposure time (time the precursor is in the reactor chamber under static vacuum). In the previous example recipe, the purge in line 5, (wait 20 seconds) is longer than the expo time in line 3 (wait 15 seconds).
If this condition is not met, then the precursor may not escape the feature it has diffused into.

Note: Pulsing the precursor before closing the stopvalve is not recommended. The stopvalve must be closed to isolate the chamber from the pump. Otherwise, the precursor may be streamed into the pump.

Do not lower the flow below 5 sccm, or the constant purge of the ALD valves is compromised. If the pressure in the chamber still rises too high, one can use a smaller expo time, but pulse the same precursor multiple times. This is especially useful for very large surface area porous or particle samples.

Example of Exposure Times as a function of Aspect Ratio

For the Al_2O_3 deposition times using TMA/H_2O at 200°C the follow table provides suggested exposure times.

Aspect Ratio	Suggested Expo Time
<20:1	None required
20:1 - 100:1	10 seconds
100:1 – 250:1	20 seconds
250:1 – 1000:1	30 seconds
1000:1 or over	More than 45 seconds

Example of Expo Al_2O_3 Recipe for 200°C

9=200°C, 8=200°C, 6=7=10=150°C,
Carrier flow rate =20sccm and 10sccm

First half cycle

Line 5: isolates chamber from dynamic vacuum
Line 6: reduces flow to 10sccm (optional for x < 60 sec)
Line 7: introduces water precursor, opens valve 0 for 0.015sec
Line 8: exposure time
Line 9: opens chamber to dynamic vacuum
Line 10: increases flow to 20sccm (required if flow is decreased)
Line 11: purge time +5 seconds

Second half cycle

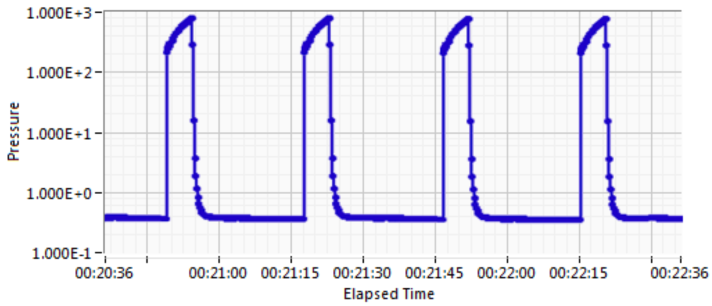
Line 12: isolates chamber from dynamic vacuum
Line 13: reduces flow to 10sccm (optional for x < 60 sec)
Line 14: introduces TMA precursor, opens valve 0 for 0.015sec
Line 15: exposure time
Line 16: opens chamber to dynamic vacuum
Line 17: increases flow to 20sccm (required if flow is decreased)
Line 18: purge time +5 seconds

Line 19: goto loop for 100 cycles

	Instruction	#	Value
0	flow		20
1	heater	9	150
2	heater	8	150
3	stabilize		360
4	wait		600
5	stopvalve		0
6	flow		10
7	pulse	0	0.015
8	wait		x
9	stopvalve		1
10	flow		20
11	wait		X+5%
12	stopvalve		0
13	flow		10
14	pulse	1	0.015
15	wait		x
16	stopvalve		1
17	flow		20
18	wait		X+5%
19	goto	6	100

Start with a Known Recipe

For growth of new materials with new precursors, it is best to first experiment with depositions onto a flat substrate without the use of exposure mode. This is because exposure mode runs mask the precursors pulses in large peaks. For example, this is the pressure plot of an exposure mode run:



From the screenshot, it is impossible to tell if a precursor has been introduced as the pressure peak is masked by the stopvalve being closed. Not the high measured Pressure value characteristic of the Expo mode process.

Section7: Software and Controls Operation

Getting Started

Launching the application

The Savannah control software application may be launched from the Windows desktop on the laptop computer. The computer must be connected to the Savannah by the USB cable and the Savannah system must be powered on for communication. The control software is launched by double clicking the Veeco icon.

Savannah

The control software may also be found on the Windows Start Menu under the [All Programs\Veeco] directory or launched from the location of the executable file, "C:\Program Files (x86)\Veeco\ALD".

Software Version

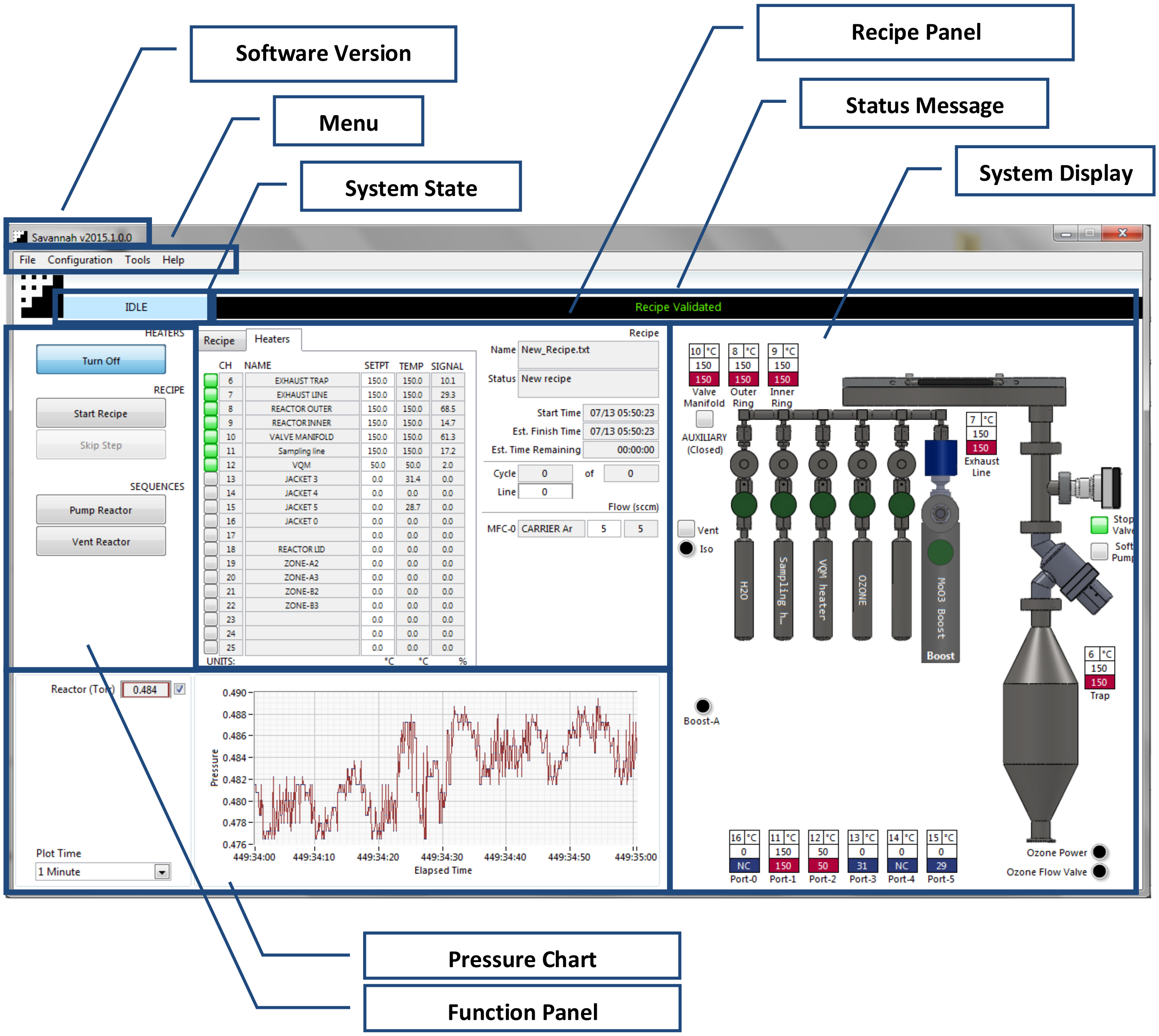
The software version is visible in several locations:

1. As the software launches, the version is visible on the splash screen
2. On the "about" dialog, visible by selecting "Help->About" on the software's menu bar
3. The software version is also prominently visible in the main window's title bar
4. Lastly, the software version is recorded in the recipe summary file, which is found in "C:\Cambridge Nanotech\log\data\[recipe name]\". The summary file has a suffix of "SUM" before the "txt" file extension.

Software Overview

User Interface

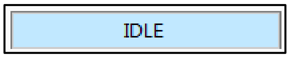
The Savannah software is arranged in a standard industry layout that is straightforward and intuitive. The design and layout present information in an efficient and logical manner for the operator and user.



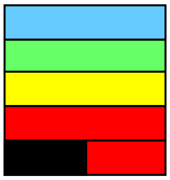
Status Message Panel

The message panel is constantly updated to report the most recent action of the tool. These system status messages are also stored in the event logs. The system event log is located in *C:\Cambridge Nanotech\log\event*, while recipe event logs are located in directories respective to their recipes in *C:\Cambridge Nanotech\log\data*. Event logs are explained in further detail later in this document.

System State

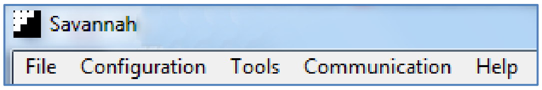


This panel describes the current state of the Savannah system. The color of the status box provides additional information to the user.



Blue	System Idle (Normal state, when not running process)
Green	Running Process (Recipe operation in progress)
Yellow	Warning State (System requires user interaction)
Red	Alarm State (abnormal operation, recipe aborted)
Flashing Red	Communication Error (The software is not communicating with the system)

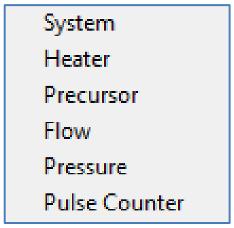
Menu Bar



The menu bar of the main interface provides additional functionality that is not included on the main interface itself, including tool configuration and settings.

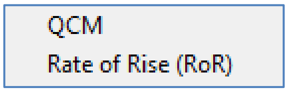
File Menu:
Allows the user to exit the software and closes the application (Ctrl+Q).

Configuration Menu
Allows the user to edit the system settings and system configurations



System: Provides an interface for configuring general options of the system.
Heater: Provides an interface for changing the label, default settings, alarm, and stability values of the heaters.
Precursor: Provides an interface for changing the names of the precursor ports installed on the system.
Flow: Provides an interface used for changing the settings related to gas flow.
Pressure: Allows the user to edit the pressure parameters.
Pulse Counter: Provides access to the pulse counter, a tool for estimating precursor usage.

Tools Menu



The Tools menu appears if the QCM lid option is selected or the Rate of Rise option kit is enabled in the system parameters interface window.
QCM: Opens the quartz crystal microbalance (QCM) interface window, or brings its interface window to the foreground
Rate of Rise (RoR): Opens the Rate of Rise (RoR) test interface, which is used for measuring the leak rate of the reactor.

Communication Menu
This menu appears if the plasma lid option is selected in the system configuration interface. A **Plasma** menu item provides an interface to view information related to communication with the plasma RF generator.

Help
Provides information about the software and the software version.

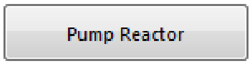
Function Panel / Status Banner

The function panel contains the primary set of buttons used to control the operation of the tool.

Heaters - This button turns the set of controlled heaters on or off.

- When the "HEATERS" button is pressed, any heater with a default setpoint greater than zero is enabled with the target temperature set to the default values.
- When the "HEATERS" button is pressed again, all heaters are disabled and the temperature setpoints are zeroed.
- The default temperature setpoints may be adjusted through the heater configuration interface, located in the main window's menu: Configuration→Heater

Pump Reactor - This button activates a sequence that places the reactor under vacuum.

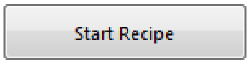


- When the "Pump Reactor" button is pressed the reactor is placed under vacuum.
- When the "Stop Pumping" button is pressed the pump sequence is immediately stopped.
- The pumping pressure thresholds are defined and adjusted through the system configuration interface, located in the main window's menu: Configuration→System

Vent Reactor - This button activates a sequence that brings the reactor to atmospheric pressure.

- When the "Vent Reactor" button is pressed the reactor is vented with the carrier gas.
- When the "Stop Venting" button is pressed the vent sequence is immediately stopped.
- The venting pressure thresholds are defined and adjusted through the system parameter interface, located in the main window's menu: Configuration→System

Recipe Start - This button starts and stops a recipe.

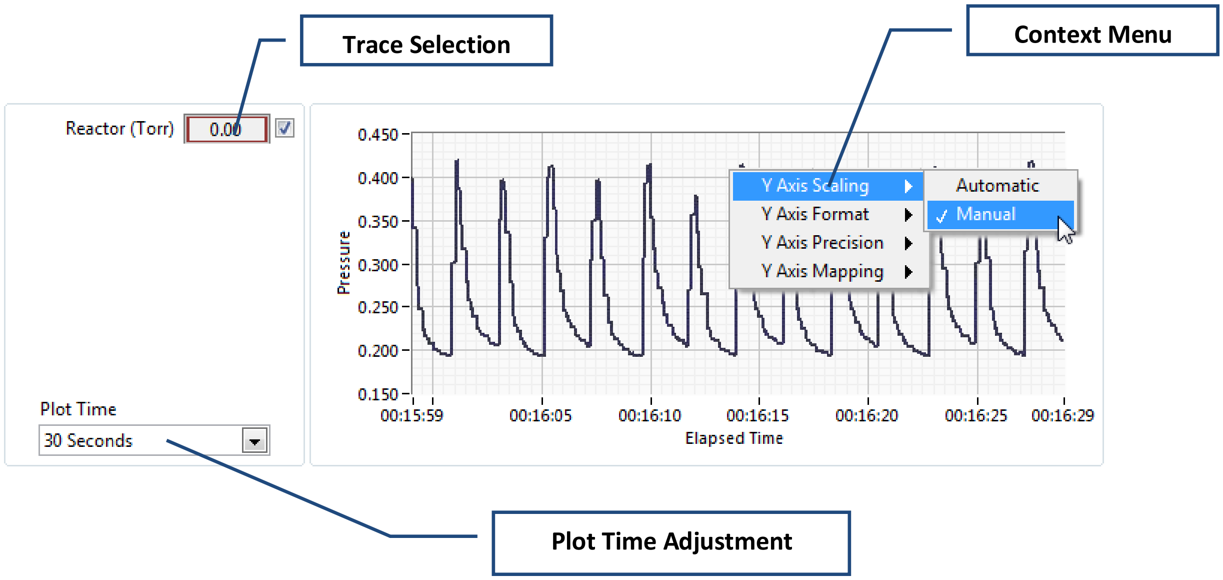


- When the "Recipe Start" button is pressed the recipe executes, contingent upon the tool being actively under vacuum and a valid recipe having been entered. Some additional prerequisites to starting a recipe may also apply, depending on the system configuration and lid option.
- When the "Stop Recipe" button is pressed recipe is manually aborted.

Skip Step - This button allows the current recipe step to be manually skipped.

- The function will skip one line item in the recipe per actuation.
- Only certain recipe instructions support the skip function. If the presently executing recipe instruction supports skipping, the button is enabled; otherwise it is grayed out and disabled.
- The behavior of skipping a step varies by the instruction type.

Pressure Chart

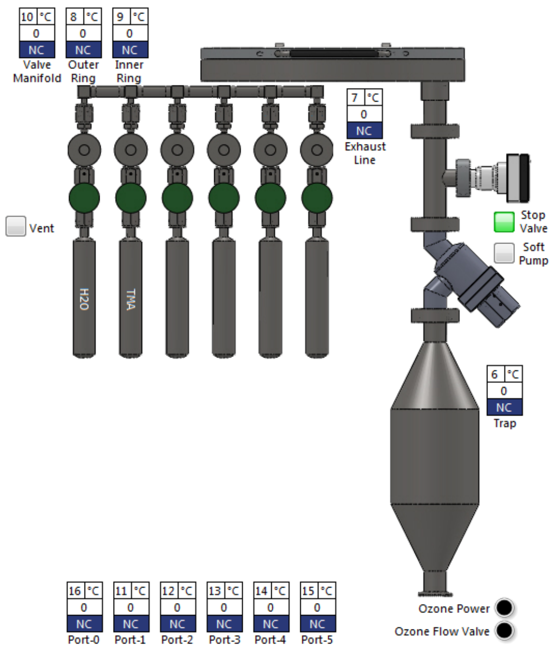


Real-time pressure plots are presented on the chart. The plot time maybe adjusted to display the pressure history in increments ranging from ten seconds to one hour in length. The reactor pressure is always selectable for plotting, while additional pressure channels may be available depending on the option kit configuration, which is adjustable in the system parameter window. The second channel relates to bubbler or low vapor pressure delivery (LVPD) kit nitrogen supply pressure, while the subsequent channels relate to SAM kits A and B, respectively, if the Savannah is so equipped.

A context menu is provided to conveniently allow the user to configure the Y axis and certain attributes of its appearance.

System Display

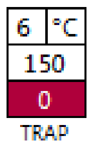
The system display panel depicts a simplified schematic of the tool and the installed hardware.



Heaters

A heater cluster is displayed for almost every heated component on the system. This information may also be found under the "Heater" tab in the recipe panel. Each heater cluster contains the following information:

Upper Left – Heater Number
Upper Right – Units (°C)
Center – Temperature setpoint
Bottom – Actual process temperature
Name – The name of the heater zone



Heater Number

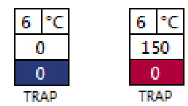
The heater number is the number that uniquely identifies the heater. This number is also used when referencing a heater in a recipe. (The numbering scheme traditionally corresponds to that of the heater channel numbering on the E-Box)

Changing the temperature setpoint

The temperature setpoint of a heater may be changed by entering a new setpoint in the center box, or in the "SETPT" column of the heater tab on the recipe panel. The temperature range is automatically limited by the alarm threshold defined in the tool configuration, and the software warns the user if an excessive setpoint is entered.

Heater Manual Enable

ON: When a heater in ON the temperature feedback field is red.
OFF: When the heater is OFF the temperature feedback field is blue.



Valves (Manual Operation)

A small, square button that is gray or green signifies a Boolean value that the user may set. The valve or component associated with the button may actuated by pressing the button with the mouse. A gray button indicates that the component is *not* actuated (i.e. Closed/Off) while a green button indicates that the component is active (i.e. Open/On) regardless of whether a valve is normally opened or normally closed, the green hue indicates an open valve.

Valves / Power Indicators

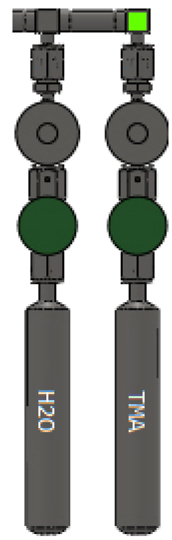
A round indicator circle can be either green or black. These are indicators of state only. A black indicator indicates that the component is *not* actuated (i.e. CLOSED/OFF) while a green button identifies that the component is active (i.e. OPEN/ON)

Stop Valve

The stop valve isolates the reactor chamber from the trap and vacuum pump. Actuating this valve opens the chamber to the vacuum. Interlocks prevent actuation of this valve while either the *Vent Valve* or *Soft Pump* valves are actuated. Most valves are also disabled during process recipe operation. The stop valve is sometimes referred to as the rough pump valve or exhaust valve, depending on traditional nomenclature.

Soft Pump
If the soft pump option is configured, it behaves similarly to the *Stop Valve*. The soft pump valve restricts the rate at which the reactor evacuates, effectively providing a slower pumping rate. This valve is prevented via an interlock from being opened when either the *Vent Valve* or *Stop Valve* is actuated or during process recipe operation.

Vent
The vent valve flows gas into the chamber at a high flow rate through the carrier gas mass flow controller (MFC). By opening a flow valve within the carrier gas MFC, the pressure of the chamber rises faster than can be achieved by the maximum flow rate of the MFC.

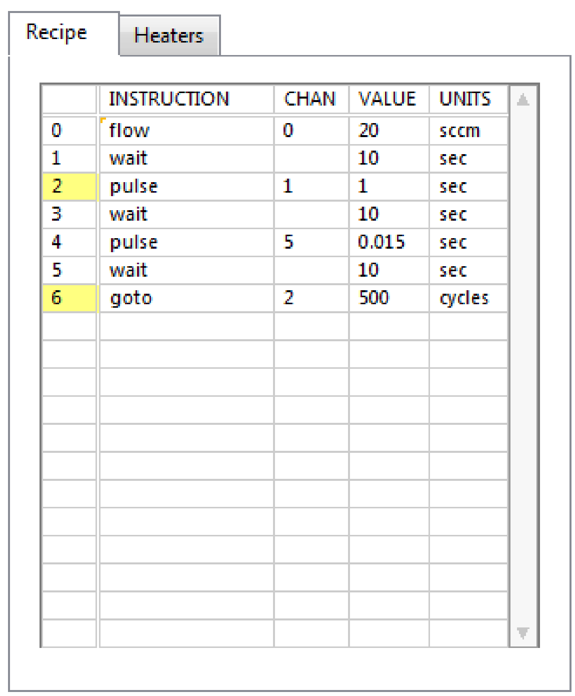


Precursor Status
Precursor names are displayed as labels on the precursor bottle graphics. The precursor names are configurable via the precursor configuration interface, which is accessible from the main window's menu bar under Configuration→Precursor. When a port's ALD valve is pulsed, a green indicator appears above the respective precursor bottle graphic.

Note: The duration of a precursor pulse is precisely regulated by the control hardware. For visualization purposes only, each software pulse indicator remains on for a minimum of 200 ms. The actual duration of pulse lengths less than 200 ms is unaffected.

Option Kit Graphics
A visual depiction of the boost, bubble, or SAMs option kits are respectively displayed in place of precursor bottle graphics on respective ports. Option kits and their respective ports may be configured via the system configuration interface, which is located on the main window's menu bar under Configuration→System.

Control Panel



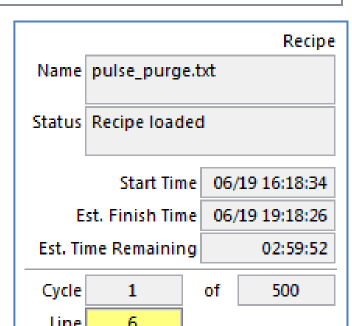
Recipe Table
The recipe table is used for developing and viewing recipes. Refer to the *Recipe Development* section for more detail.

Recipe
This section (to the right of the recipe table) provides information about the recipe contained in the table.

Name
A new recipe defaults to the name,"New_Recipe.txt". When the recipe is saved and renamed, or when an existing recipe is loaded, that recipe name is displayed.

Status
The recipe status indicator summarizes the condition of the recipe. The typical status conditions are as follows:

- Unprocessed
- New recipe
- Recipe modified
- Recipe running



If a recipe run is interrupted, the recipe status updates to reflect the cause of the interruption:

- Recipe stopped - Digital Output Error
- Recipe stopped - EBox communication lost
- Recipe stopped - Exhaust Valve No Vacuum Alarm
- Recipe stopped - Gas flow deviation alarm
- Recipe Stopped - Heater RTD Disconnection
- Recipe stopped - Heater Temperature Stability Loss
- Recipe stopped - High option kit supply pressure
- Recipe stopped - High pressure alarm
- Recipe stopped - High temperature alarm
- Recipe stopped - Low option kit supply pressure
- Recipe stopped - Manual stop
- Recipe stopped - MFC flow out-of-range
- Recipe stopped - Ozone, low gas flow
- Recipe stopped - Plasma Disconnected
- Recipe stopped - Plasma, high reactor pressure
- Recipe stopped - Plasma, low gas flow
- Recipe Stopped - Rate of Rise Could Not Start
- Recipe Stopped - Rate of Rise Test Failure
- Recipe stopped - Tumble at high pressure
- Recipe stopped - Tumbler Disconnected
- Recipe stopped - Tumbler Overtemp

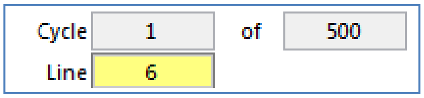
Start Time
A timestamp indicates the start time of the recipe. If a recipe is not running this field is updates with the system time of the computer.

Est. Finish Time
A timestamp indicates the estimated finish time of the recipe based on a step-by-step analysis of the recipe. An estimated time is provided rather than a precise time to account for recipe commands that are variable in time.

Est. Time Remaining
An indicator reflecting the estimated time remaining until completion of the recipe. If the recipe contains an instruction that is variable in time, such as the 'stabilize' instruction, the actual execution time may take longer than the estimate. This indicator may display a negative time value in such case.

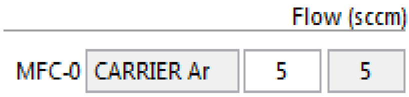
Cycle
When a 'goto' statement is used in the recipe, a cycle is created. During the execution of a recipe the values in this section update to reflect the status of the current cycle.

Line Indicates the recipe line number of the active cycle.
Cycle Indicates the iteration of the current cycle.
Of Indicates the total number of cycles of the Line #.



Flow

The names and flow rates of process gases are displayed in this section. The carrier gas is always accessible on the interface and may be defined as either N_2 or Ar gas in the system configuration. Additional mass flow controllers (MFCs) are accessible here depending on the selection of optional MFCs in the system configuration window. The plasma lid option typically uses MFCs MFC-1 through MFC-3, while MFC-4 is offered for future expansion.



Name

A description of the carrier gas is provided in the name field. This may be modified via the flow configuration window, accessible from the main window's menu bar under Configuration→Flow.

Changing the flow setpoint

The flow rate of each respective gas may be changed by entering a value in the center field. The upper flow range is automatically limited by the maximum allowed flow rate as defined in the flow configuration.

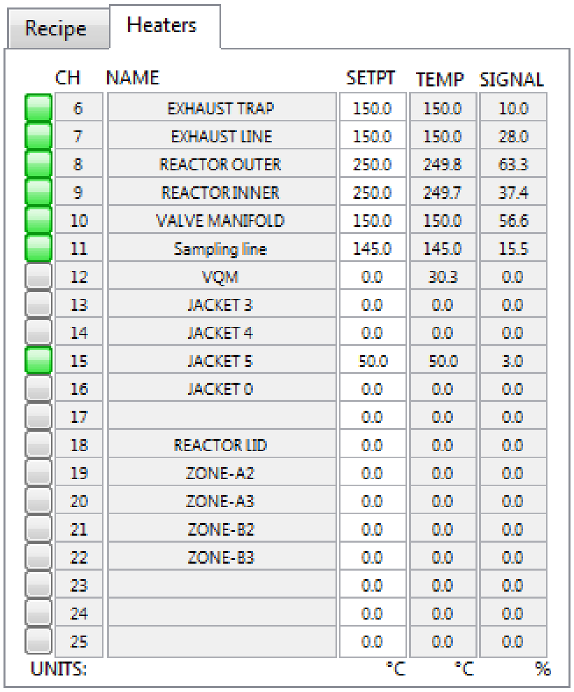
Changing the flow setpoint

The measured flow rate of each gas is provided in the right most field and is displayed in standard cubic centimeters per minute (sccm).

Heaters Tab

The heaters tab provides a complete tabular summary of every available heater channel available in the control hardware. In most cases, only a subset of these heater channels is used by the tool. This tab provides an alternate view of the heater zones with more information than is contained in the heater clusters on the system display.

Button	Enable or disable individual heater zones
CH	The heater zone number
NAME	A description of the heater zone
SETPT	The target control temperature
TEMP	The measured process temperature
SIGNAL	The dutycycle of the output channel



Changing the temperature setpoint

The temperature setpoint of a heater may be changed by entering a new setpoint in the SETPT box. The temperature range is automatically limited by the alarm threshold defined in the heater configuration.

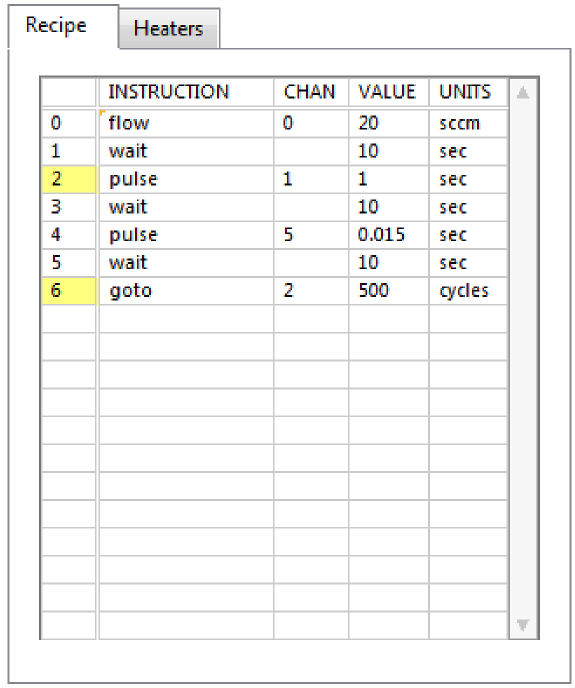
Developing a Recipe

Recipe Table

The recipe table provides an interface with which the user may load or create a process recipe for the Savannah system. The recipe operates stepwise from top to bottom. For ALD process cycles the "goto" command is used to repeat one or more commands. The goto syntax may be nested, but care should be taken so as not to inadvertently create infinite loops.

The table consists of five columns that describe each recipe instruction:

Line #	Displays the recipe line number
INSTRUCTION	The recipe instruction
CHAN	"Channel" argument of the instruction
VALUE	The value argument of the instruction
UNITS	Unit of the value argument, if applicable



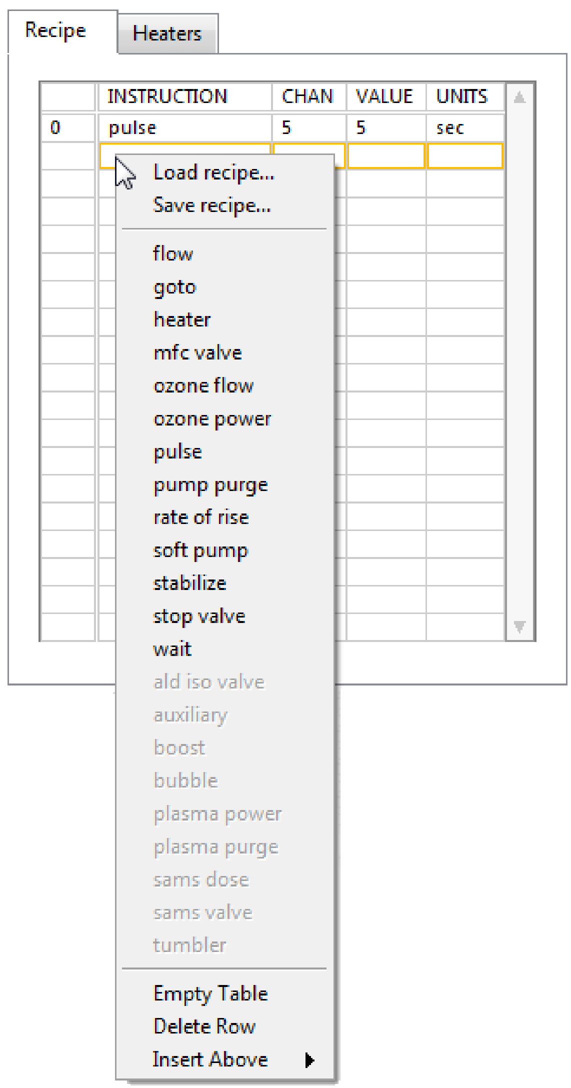
Recipe TableMenu

The recipe table's context menu is accessible by right-clicking anywhere within the recipe table. From this menu the user may select any instruction that is not disabled and grayed-out. The lower portion of the menu provides a list of options for modifying and saving the recipe. Instructions are enabled based on the system configuration.

Load recipe: Prompts the user with a dialog box to select a recipe to load.
Save Recipe: Prompts the user with a dialog box to save the current recipe in the table.

The default file location for both options is:
C:\Cambridge Nanotech\Recipes

Empty Table: Selecting this option clears the entire table.
Delete Row: This action deletes the right-clicked row
Insert Above: This operation presents the user with a sub-menu containing all available recipe instructions. The selected instruction is placed in a new row inserted above the row that was right-clicked.

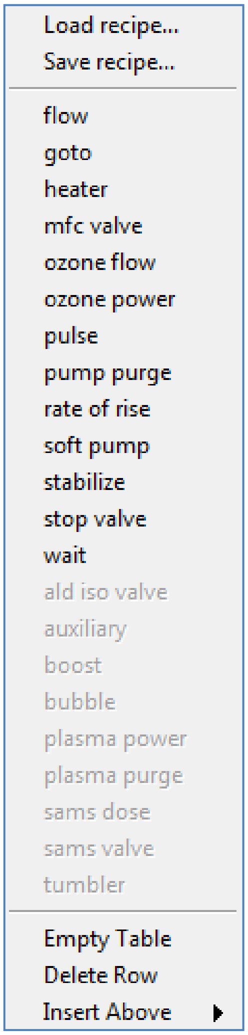


Creating Process Recipes

The menu defines the complete set of valid recipe instructions. Clicking on an instruction enters this command into the recipe.

WARNING: Recipes provided by Veeco use the period or dot character (.) as the separator between the integer and the fractional parts of numbers. Some operating systems may be configured to employ a comma character for this purpose, but this syntax is not supported by the Savannah control software. As such, recipes with comma decimal points must be edited for syntactical compatibility. For example, using a comma as the decimal point when specifying a pulse duration results in a failure mode such that a zero value is parsed and the ALD valve does not pulse.

Recipe Instructions



The recipe table is checked for correct syntax whenever a new instruction is entered or modified. In some limited cases the software automatically corrects syntax errors. In instances when the auto-correct feature cannot be used, the invalid cell is highlighted and the syntax error is briefly described in the status message banner.

ALD Iso Valve: Toggles a valve that is designated for isolating harmful or toxic precursor gases. Prior to the designation of this channel, the auxiliary channel was used for this purpose.

Auxiliary: Toggles a 24V channel used for control of various accessories and options.

Boost: This command is used with the boost hardware option to deliver N_2 to the precursor cylinder. For further details, please consult the Savannah Boost manual.

Bubble: The bubble command is used with the low vapor pressure delivery (LVPD) hardware option. For further details, please consult the Savannah LVPD manual.

Flow: The flow command is used to set an MFC flow to a given setpoint in sccm.

Goto: The goto instruction creates a loop and is often used for ALD cycling. The CHAN argument is the recipe line to which the loop will jump when the recipe runs. The value argument defines the number of prescribed loop cycles. This syntax is analogous to that a “for” loop.

Heater: The heater command sets a heater setpoint, and depending on the setpoint value may toggle control of that heater. Arguments required for this instruction area heater channel and the temperature setpoint for that heater in °C. The heater number may be identified within the “Heaters” tab or in the respective heater cluster within the system display panel.

MFC Valve: Toggles an MFC valve for MFCs 1 through 4, which are optionally configured. Note that the carrier gas MFC, or MFC-0 does not have an MFC valve.

Ozone Flow: Toggles the O_2flow to the ozone generator: 0=OFF, 1=ON.

Ozone Power: Toggles power to the ozone generator. 0=OFF, 1=ON.

Plasma Power: Adjusts the power of the plasma RF generator. This instruction is only valid with the Savannah plasma option kit. For further details, please consult the Savannah Plasma manual.

Plasma Purge: Toggles the plasma purge valve. This instruction is only valid with the Savannah plasma option kit. For further details, please consult the Savannah Plasma manual.

Pulse: The pulse command opens an ALD valve for a prescribed duration. Required arguments for this instruction are a value for the ALD valve (0-5) in the CHAN column, as well as a pulse duration. The value corresponds to pulse duration, the time the valve remains open. The minimum pulse duration is 15 milliseconds (0.015 sec).

Pump Purge: Toggles (0=OFF, 1=ON)the N2 pump purge gas flow. This option is needed for corrosive precursors and serves to protect the pump, thereby reducing the maintenance interval of the pump.

Rate of Rise: Performs a rate of rise (reactor leakage rate) test. All parameters related to this test except for the maximum allowable leak rate are set to their last respective values entered on the rate of rise window. (i.e. to adjust these parameters, perform a rate of rise test from the rate of rise window) If the maximum allowable leak rate is exceeded, the recipe is aborted, otherwise the recipe continues with subsequent instructions.

SAMS Dose: Provides a pressure defined dose of a SAM precursor. The SAMs valve opens until the desired pressure is achieved, at which point the SAMs valve is closed.

SAMSValve: Toggles the designated SAMs valve(0=CLOSED, 1=OPEN). The self-assembled monolayer (SAM) deposition technique is described in detail in the SAMs operation manual.

Soft Pump: The soft pump command is used to open or close the soft pump valve when running a recipe (0=CLOSED, 1=OPEN) in the value column. The channel argument is not used. The soft pump valve evacuates the reactor more slowly than the stop valve, thereby preventing surges of flow that may displace lighter substrates.

Stabilize: Requires all enabled heater zones to stabilize before proceeding to the next recipe command. The stabilization criteria for each heater zone is defined in the heater configuration. The channel argument is not used and the value field defines the minimum wait period, regardless of whether or not the heaters are immediately stable. The wait period is not, however, in addition to the time required for the heaters to stabilize.

Stop valve: The stop valve command is used to open or close the stop valve (rough pump valve) when running a recipe (0=CLOSED, 1=OPEN)in the value column. The channel argument is not used.

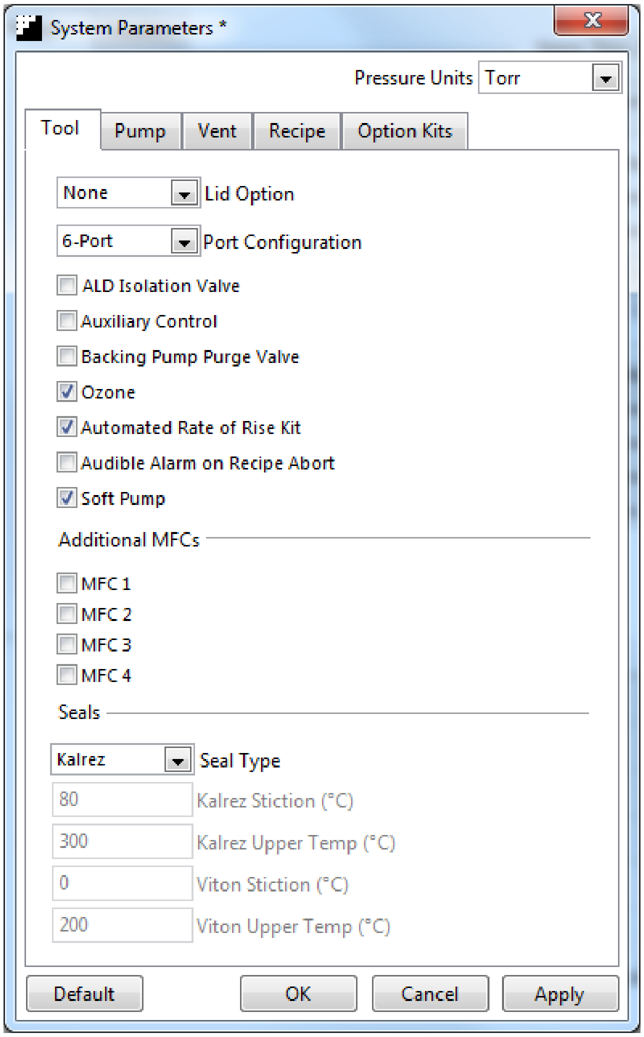
Tumbler: Adjusts the rotation rate in rpm of the particle kit tumbler. This instruction is only valid with the optional Savannah particle kit. For further details, please consult the Savannah Particle Kit manual.

Wait: The wait command causes the recipe to wait or pause for the prescribed number of seconds. The value argument defines the wait time, while the channel argument is not used.

System Configuration

Most of the available options pertaining to operating the Savannah tool are located on the system configuration interface, located on the *Configuration* menu. Values of parameters are and saved and applied after pressing either “OK” or “Apply”. Unsaved changes are denoted by an asterisk * in the title bar of the window.

Note: *The OK and Apply buttons serve the exact same function (except that OK closes the window), therefore pressing both of them in succession is not necessary. Furthermore, when no parameters have changed, these buttons are disabled.*



Pressure Units

The pressure units for all pressure values on the system configuration interface may be adjusted using the menu in the upper right-hand corner, allowing for instant unit conversion. This function is provided for convenience and does not affect the configuration of pressure transducers or any other portion of the software; it only affects the pressure units on the system configuration window.

Default Configuration Button

In the lower left-hand part of the window, a button labeled “Default” reverts all settings to those contained in C:\Cambridge Nanotech\Configuration\Default\config.ini. Some settings are not altered, namely Lid Option, Port Configuration, Auxiliary Control, Ozone, Soft Pump, Seals, and option kit assignments.

Tool Configuration

The tool configuration tab provides settings that affect how the tool operates. Additionally, many of these settings alter the appearance of user accordingly.

Lid Option: Configures the tool’s lid type, which often defines a major option kit such as the ellipsometer, QCM, plasma or tumbler option.

Port Configuration: Defines the number of precursor ports available on the tool (between two and six ports). The system display and precursor port indicators update to reflect the change.

ALD Isolation Valve: Enables the toggling of a valve specifically designated for isolating toxic or otherwise harmful precursors. Prior to the designation of this channel, the auxiliary channel (below) was used for this purpose. While the auxiliary channel serves this purpose adequately, Veeco recommend the use of the ALD isolation valve, since the aux channel may be used for any of several purposes, leading to a potentially dangerous situation. Moreover, the ALD isolation valve must be toggled via a recipe and cannot be toggled from the UI, thereby avoiding inadvertent toggling.

Auxiliary Control: Enables the toggling of a general purpose 24V channel that may be used for accessories or options.

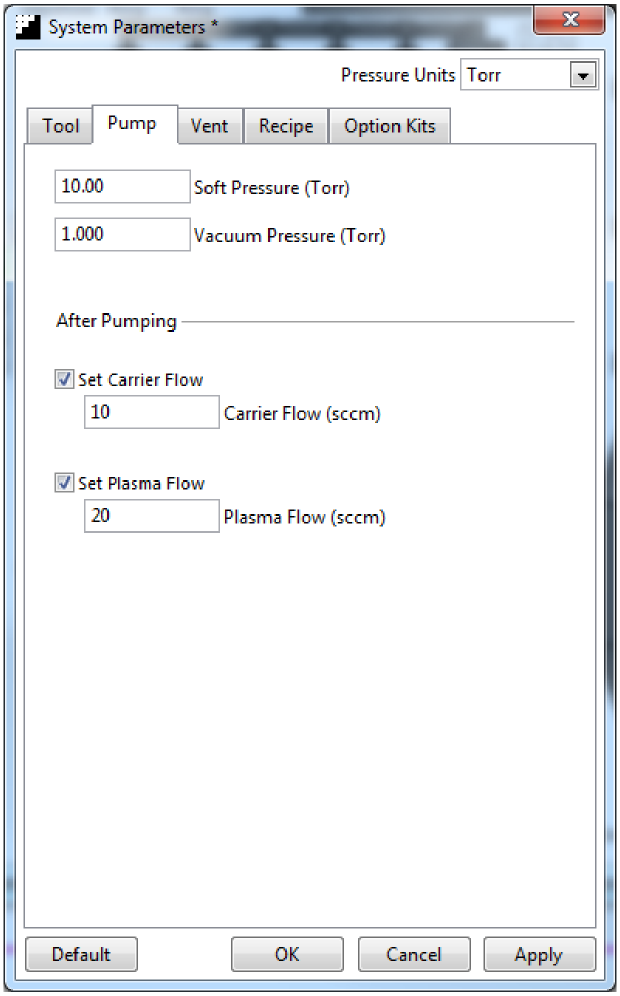
Backing Pump Purge Valve: Enables the toggling of an optional valve that is used to purge the backing pump. This option is needed for corrosive precursors and serves to protect the pump, thereby reducing the maintenance interval of the pump.

Ozone: Enables the use of two outputs for ozone option kit, namely ozone flow and ozone power.

Automated Rate of Rise Kit: Enables the rate of rise (RoR) option kit, which is used to measure the leakage rate of the reactor.

Audible Alarm on Recipe Abort: If the recipe is aborted for any reason other than successful completion, a sound file is played. The volume in Windows must be unmuted and adjusted to be sufficiently loud, and the sound file must be of the WAV format. The audible alarm sound file is located at "C:\Cambridge Nanotech\configuration\alarm.wav". If this sound file is missing, an alert window appears.

Soft Pump: Configures the presence of the soft pump option. The soft pump valve evacuates the reactor more slowly than the stop valve, thereby preventing surges of flow that may displace lighter substrates. Enabling this option causes a soft pump button to be displayed on the main interface adjacent to the rough pump / stop valve button. The soft pump threshold defines the cross over pressure for this option, below which the stop valve is opened during the pumping sequence. This threshold is configurable on the "Pump" tab of the system configuration window.



Additional MFCs: In addition to MFC-0, which is always accessible, up to four additional MFCs are configurable. Each MFC other than MFC-0 also includes a valve channel. The plasma lid option automatically selects MFCs 1 through 3, and MFC-4 is provided for convenience or future expansion of options. Specific parameters relating to MFCs are configurable under the flow configuration window, which is accessible from the main interface's menu bar under Configuration→Flow. MFCs configured in the system configuration window are addressable using the "flow" and "mfc valve" recipe instructions.

Seals: The process reactor maybe fitted with either Viton or Kalrez o-rings. Each o-ring material has an ideal temperature range under which it best performs. The default o-ring is Kalrez (80-300°C operating range). Viton is capable for temperatures from 0 - 200°C. Incorrectly configuring these temperatures may result in damage to O-rings due to stiction.

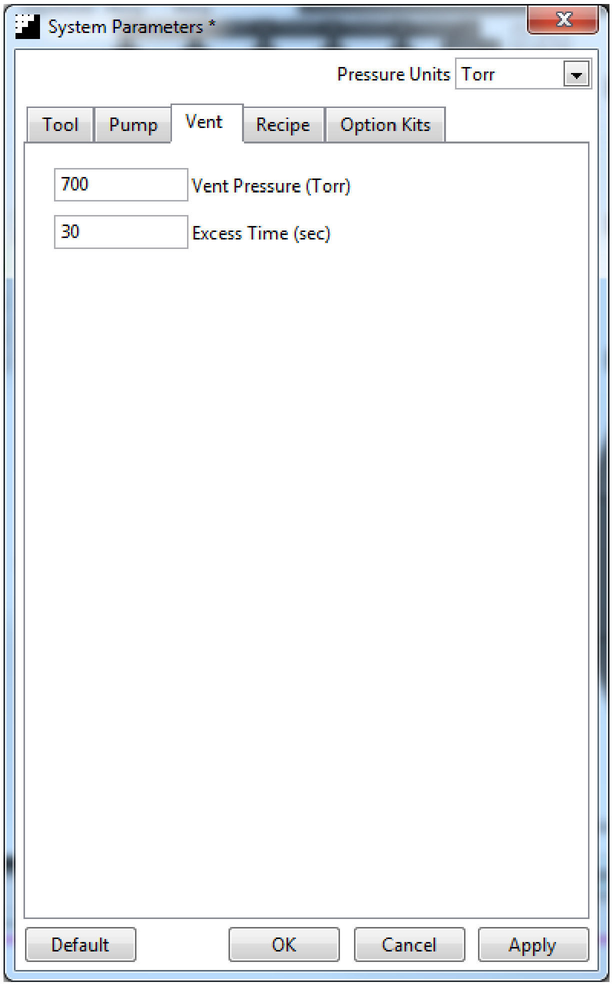
Pumping Configuration (Pump Tab)

These settings are used by the *Pump Reactor* sequence. Additionally, this includes the pumping sequence run after a rate of rise (RoR) test is completed, whether successful or unsuccessful.

Soft Pressure: If the *Soft Pump* option is configured on the tool settings tab, the pump sequence starts pumping the chamber through the soft pump valve. When the reactor pressure falls below this pressure threshold the *Soft Pump* valve closes and the *Stop Valve* opens.

Vacuum Pressure: When the reactor pressure is less than this value, the pump down sequence is complete and the system is considered to be under vacuum.

After Pumping, Set Carrier Flow: When the pump sequence completes, the carrier gas flow, MFC-0, is automatically set to this value. This option may be turned off by unchecking the corresponding box.



After Pumping, Set Plasma Flow: This parameter is only used when the lid option is set to "Plasma" under the tool configuration tab.
If this option is enabled, the following occurs when the pump sequence completes:

- The MFC valve corresponding to MFC-1 is opened.
- The plasma gas flow, MFC-1 (typically nitrogen), is automatically set to the prescribed flow value. This option may be turned off (set to FALSE).

Venting Configuration (Vent Tab)

These settings are used by the *Vent Reactor* sequence.

Vent Pressure: The reactor continues venting until it reaches this pressure threshold. The threshold may be adjusted to reflect current barometric conditions or variations in readings of the pressure gauge.

Excess vent time: If a non-zero value is configured for this parameter, the reactor continues to be vented after the Vent pressure is reached. The excess vent time allows the reactor to fully reach atmospheric pressure. When using the dome lid this value may need to be increased to accommodate the larger reactor volume.

RecipeSettings (Recipe Tab)

Overpressure: This parameter defines the maximum allowable reactor pressure during recipe execution. If the reactor pressure (BOC Edwards gauge) exceeds this value, the software disallows a recipe to start or aborts a recipe in progress. Additionally, if the tumbler (particle kit) lid option is selected, the tumbler motor is disabled if the reactor pressure exceeds the overpressure threshold.

After Recipe, Set Carrier Flow: When a recipe completes or is aborted, the carrier gas flow, MFC-0, is automatically set to this value. This option may be turned off (set to FALSE).

After Recipe, Set Plasma Flow: This parameter is only used when the lid option is set to "Plasma" under the tool configuration tab.
If this option is enabled, the following occurs when a recipe completes or is aborted:

- The MFC valve corresponding to MFC-1 is opened.
- The plasma gas flow, MFC-1 (typically nitrogen), is automatically set to the prescribed flow value. This option may be turned off (set to FALSE).

Option Kit Settings (Option Kits Tab)

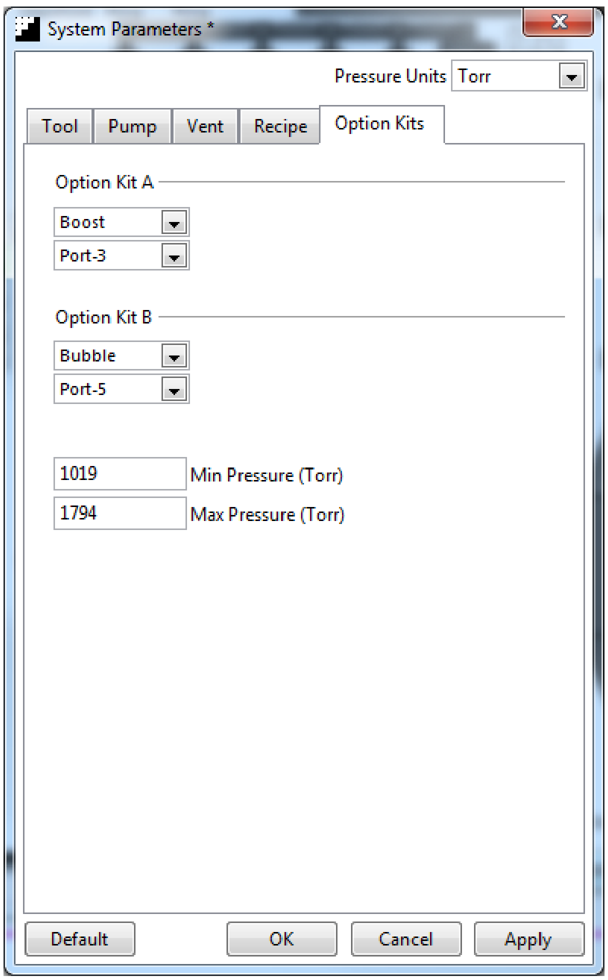
Kit Assignment: Two options kits may be installed on the Savannah system, Option-A and Option-B. Each respective kit may configured to be one of the following: None, Boost, Bubble, or SAM.

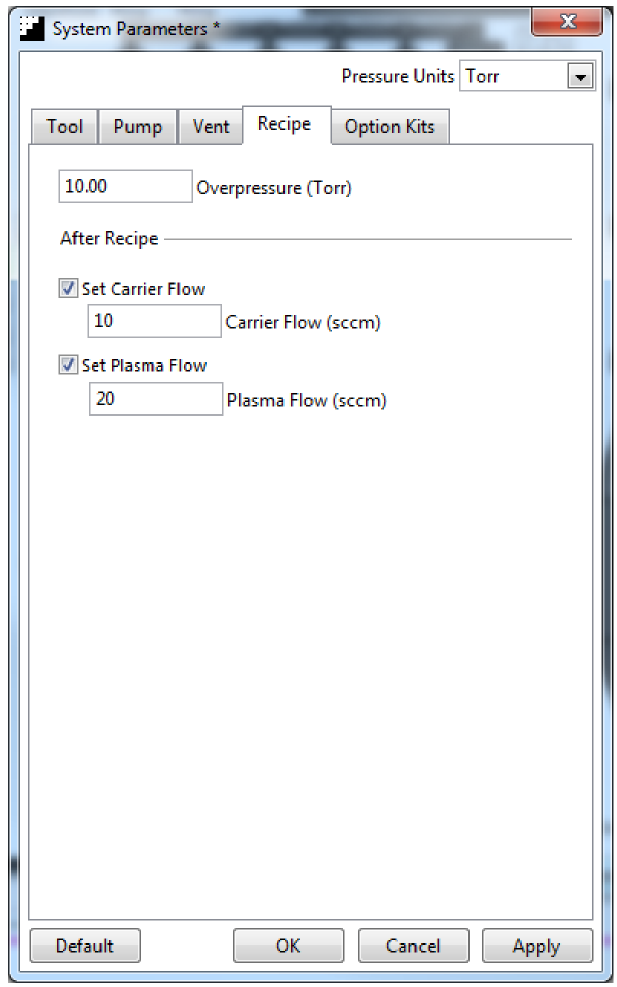
None – No Kit
Boost – booster precursor delivery hardware option
Bubble – Low Vapor Pressure Delivery (LVPD) hardware option
SAM – SAM precursor delivery hardware option

These options are described in detail in the options manual for each kit. Each kit is assigned a port/ALD location (Port-0 to Port-5) for a 6 port ALD manifold system.

Option Kit Pressure Thresholds

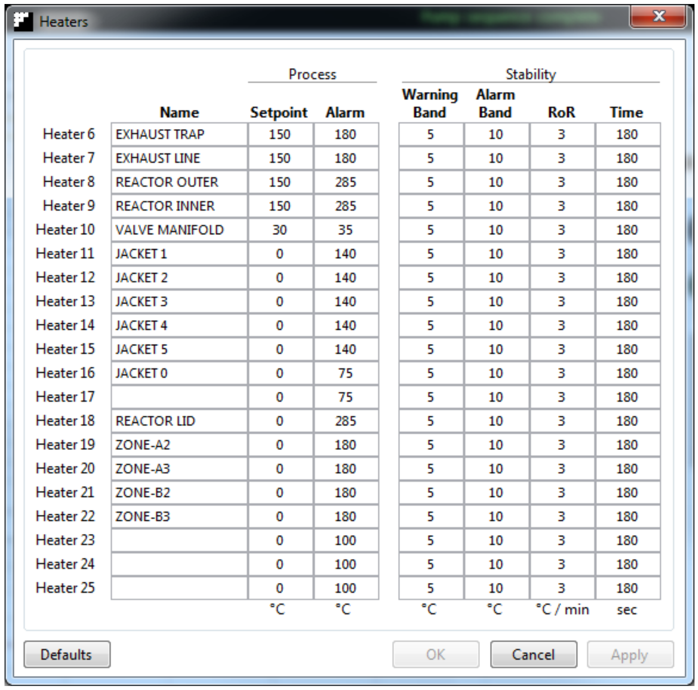
On the Option Kits tab, there are two pressure threshold values pertaining only to the "Bubble" (LVPD) option kit. If, during execution of the "bubble" recipe instruction the nitrogen supply pressure (channel 1) drops below the "Min Pressure" threshold or exceeds the "Max Pressure" threshold, the recipe is aborted.





Heater Configuration

Navigating from the Configuration menu to the "Heater" menu selection, the heater configuration interface provides a means for the user to modify settings related to each heater channel.


Heaters

	Name	Setpoint	Alarm	Warning Band	Alarm Band	RoR	Time
		Process		Stability			
Heater 6	EXHAUST TRAP	150	180	5	10	3	180
Heater 7	EXHAUST LINE	150	180	5	10	3	180
Heater 8	REACTOR OUTER	150	285	5	10	3	180
Heater 9	REACTOR INNER	150	285	5	10	3	180
Heater 10	VALVE MANIFOLD	30	35	5	10	3	180
Heater 11	JACKET 1	0	140	5	10	3	180
Heater 12	JACKET 2	0	140	5	10	3	180
Heater 13	JACKET 3	0	140	5	10	3	180
Heater 14	JACKET 4	0	140	5	10	3	180
Heater 15	JACKET 5	0	140	5	10	3	180
Heater 16	JACKET 0	0	75	5	10	3	180
Heater 17		0	75	5	10	3	180
Heater 18	REACTOR LID	0	285	5	10	3	180
Heater 19	ZONE-A2	0	180	5	10	3	180
Heater 20	ZONE-A3	0	180	5	10	3	180
Heater 21	ZONE-B2	0	180	5	10	3	180
Heater 22	ZONE-B3	0	180	5	10	3	180
Heater 23		0	100	5	10	3	180
Heater 24		0	100	5	10	3	180
Heater 25		0	100	5	10	3	180
		°C	°C	°C	°C	°C / min	sec

Defaults OK Cancel Apply

Process

Name: A brief description of the heater channel and hardware allocation

Setpoint: A temperature setpoint> = 0°C, Entering a zero value disables control the heater

Alarm: The maximum temperature of the channel > = 0°C. The heater is turned off if $T > T_{ALARM}$

Stability

A heater is considered "stable" when the following criteria are satisfied: (This relates most notably to the recipe "stabilize" instruction)

Warning Band: Temperature range (°C) that defines circumstances under which the channel is considered to be slightly unstable. The user is warned via an alert when this band is violated, but only after a recipe "stabilize" instruction has successfully executed. No other action besides the alert is taken. (example: a value of 2 = +/- 1°Cof the 'Setpoint')

Alarm Band: Temperature range (°C) that defines circumstances under which the channel is considered to be unstable enough to abort a recipe. This band is also used to determine when the channel is stable during the "stabilize" recipe instruction. If the "stabilize" instruction has been successfully executed and this band is violated, the user is warned via an alert and the recipe in progress is aborted.(example: a value of 2 = +/- 1°Cof the 'Setpoint')

ROR: Change in Temp (°C/min). Rate-of-Rise and Rate-of-Fall is < = the 'ROR' value

Band: Range of Temp (°C). Band = Range (example: a value of 2 = +/- 1°Cof the 'Setpoint')

Time: A value > = 0 seconds. For the channel to be considered stable, the ROR and Band conditions must be met for time >= to the period.

A heater is considered unstable when the 'Alarm Band' or 'ROR' conditions are not met.

Control

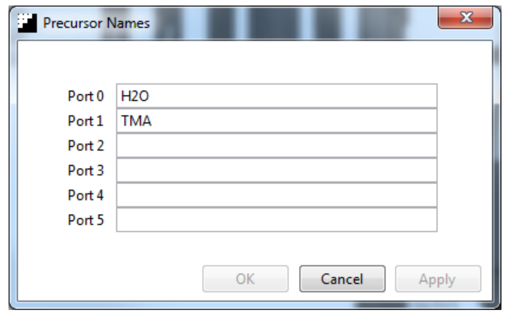
The heater temperatures are regulated using a PID controller with the heater channel temperature (°C) as the setpoint. The output power variable is reported as the heater duty cycle (0 - 100%). These values are factory set and are not displayed on the heater configuration interface.

P: Proportional Gain
I: Integral Time (min)
D: Derivative Time (min)
Min: Duty Cycle (Range = 0%-100%). *0% is required*.
Max: Duty Cycle (Range = 0%-100%). 100% is recommended.

Precursor Names

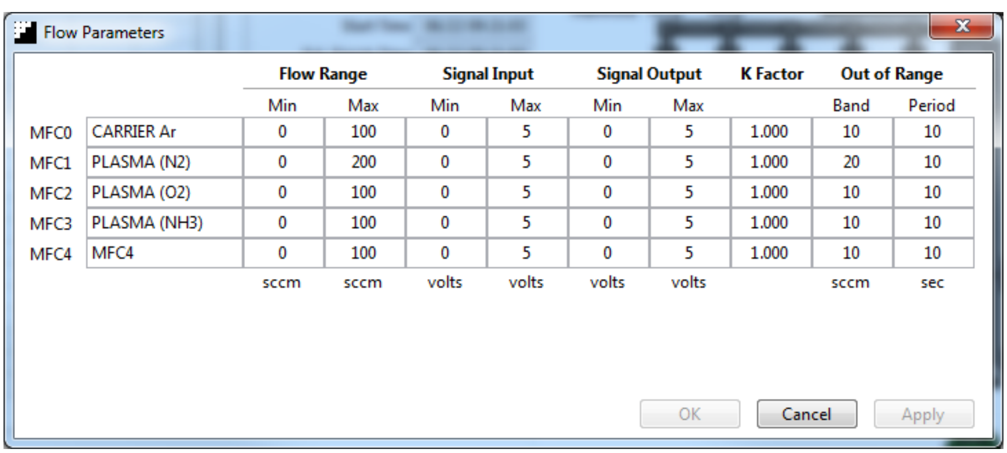
The precursor name configuration interface allows the precursor ports (Port-0 to Port-5 for a 6 port manifold) to be labeled with the precursor name installed. It is useful to label the location of precursors to avoid confusion and safely mange the precursors installed on the system.

Name: A very brief description of the precursor installed on the ALD port. Descriptions that are too long to fit on the main interface (eleven characters or less) are truncated by the software.



Flow Configuration

The flow configuration interface is factory pre-set with the default values for the carrier gas flow controller(MFC-0), as well as optional MFCs (MFC-1 through MFC-4). These values should not be changed; the standard carrier MFC on the Savannah system is 100sccm max flow. MFCs 1 through 3 are used primarily for the Savannah plasma lid option, but in the absence of that option kit may be used for general purposes. MFC4 is provided for future expansion. If Argon is used as the carrier gas, the name can be changed and the associated designation can be changed in the Pressure Configuration Interface.



Flow window displayed under the Configuration menu.

Flow Range

Min: Describes the minimum flow rate measured by the mass flow controller. Value must be set to 0.
Max: Describes the maximum flow rate measured by the mass flow controller.

Signal Input

Min: Describes the minimum flow rate control signal to the mass flow controller. Value must be set to 0.
Max: Describes the maximum flow rate control signal input to the mass flow controller.

Signal Output

Min: Describes the minimum flow rate signal from the mass flow controller. Value must be set to 0.
Max: Describes the maximum flow rate signal from the mass flow controller.

Calibration

K-Factor: the carrier gases calibration factor. The k factor for N_2 = 1.0000, the k-factor for Ar = 1.4573.

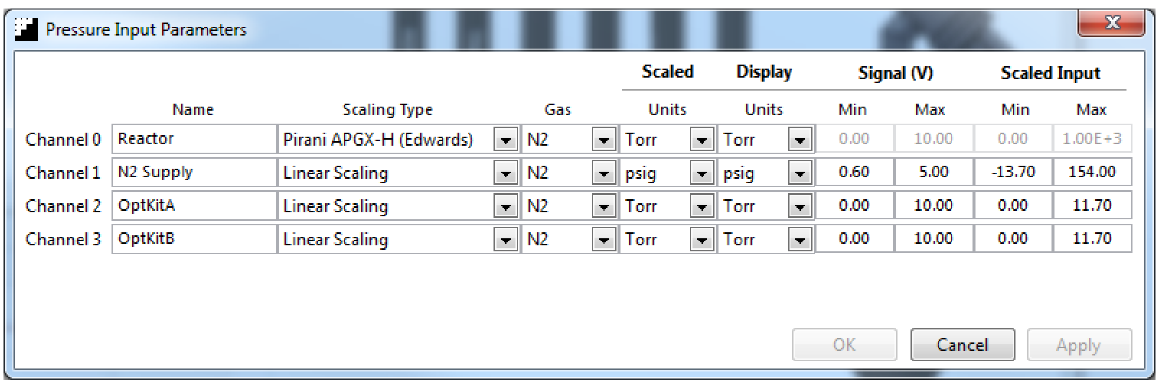
Out of Range

The flow is *"out-of-range"* when the flow rate is outside the flow 'Band' of the 'Setpoint' for a period > = a time 'Period'.

Band: A range of flow (sccm). Band = Range (example: a value of 2 = +/- 1sccm of the 'Setpoint')
Period: A value > = 0 seconds

Pressure Configuration

The pressure configuration interface allows the configurations to be managed for the various pressure gauges on the system. The base Savannah system has only one pressure gauge (PRESS-0). With the addition of optional equipment other pressure gauges may be installed. Channel 1 becomes available if one or more bubbler (LVPD) option kit is configured under the "Option Kits" tab of the system configuration interface. Likewise, channel 2 becomes available when the SAM option is configured for option A, and channel 3 becomes available when the SAM option is configured for option B.



Pressure window displayed under the Configuration tab.

Name: Brief description of the pressure gauge that should be named as appropriate for the configured option kit, if applicable.

Scaling Type: For convenience, several scaling types are offered that are specific to common transducer models shipped with Veeco ALD tools. Linear scaling is also available for many types of transducers. In general, the factory settings should be adequate for most scenarios.

GAS: The type of carrier gas can be adjusted so that pressure gauge properly manage and report pressure.

UNITS: The working units for the pressure gauge can be designated; atm, bar, mBar, mmHg, psia, psig, Torr, Pa, kPa, MPa. The standard default units are presented in the figure above. The "Scaled" units are used when scaling the voltage from the transducer, whereas the "Display" units are used on the software's user interface and when logging.

Pulse Counter Configuration

Pulse Counter

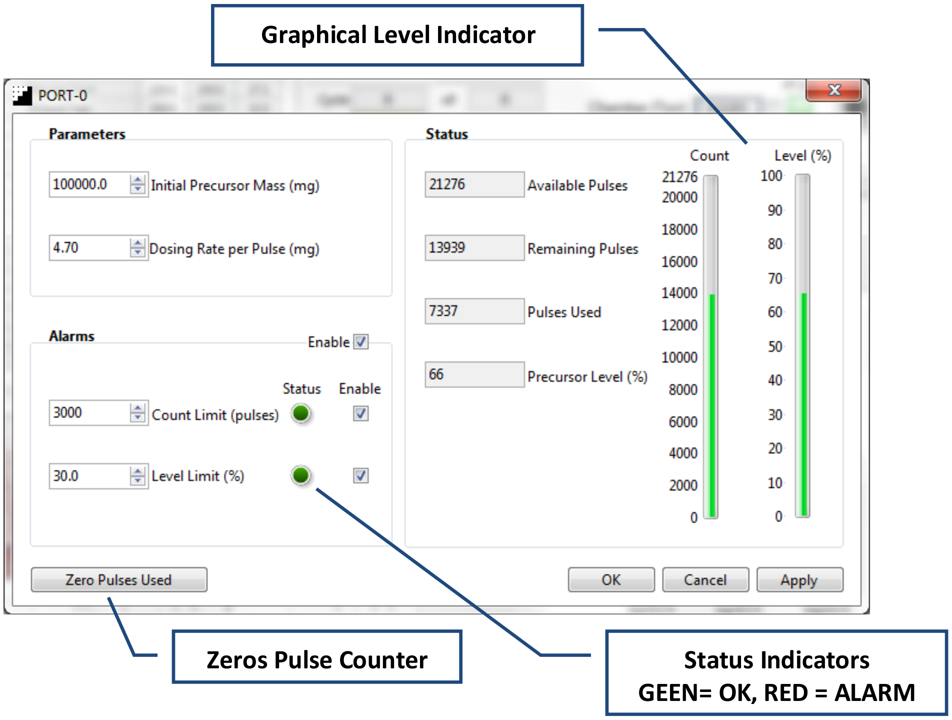
Enable	Level Alarm	Initial Mass (mg)	Rate Per Pulse (mg)	Level Limit (%)	Estimated Level (%)	Count Alarm	Available Pulses	Used Pulses	Count Limit	Remaining Pulses
☑ PORT-0	OK	100000.0	4.70	30.0	65.5	OK	21276	7337	3000	13939
☐ PORT-1	OFF	0.0	0.00	20.0	0.0	OFF	0	0	500	0
☐ PORT-2	OFF	130000.0	2.80	20.0	0.0	OFF	0	1073	10000	0
☐ PORT-3	OFF	0.0	0.00	20.0	0.0	OFF	0	0	500	0

The pulse counter can be enabled for each precursor cylinder installed on the system. The precursor fill amount (mg) and precursor usage rate (mg/pulse) must be measured for proper use. The pulse counter window summarizes the status of each precursor, (Port 0-3).

Enable: Check box to enable pulse counter function
Level Alarm: Indicates state of Level Alarm (OFF, OK, ALARM)
Initial Mass: The precursor weight must be know when installing the precursor cylinder and recorded here.
Rate Per Pulse: The precursor usage rate. This is a user defined value (mg/pulse) and can be calculated after each cylinder replacement. [(cylinder pre-weight – cylinder post-weight)/ # pulses].
Level Limit %: Weight% limit of initial mass for pulse counter alarm state. If "Estimated level (%)" < "Level Limit (%)" then level alarm will be indicated.
Estimate Level %: Calculated % value of precursor remaining in the cylinder
Count Alarm: Indicates state of Count Alarm (OFF, OK, ALARM)
Available Pulses: Displays the total number of pulses available for the Full cylinder
Used Pulses: Displays the total number of pulses performed on the cylinder (PORT #)
Count Limit: limit for pulse count alarm. If "Remaining pulses" < Count Limit then count alarm will be indicated.
Remaining Pulses: Displays the total number of remaining pulses available

Editing the Pulse Counter Parameters
The pulse counter settings can be accessed by double clicking on the desired precursor PORT (Port 0 - 5). The following interactive window will be displayed.

Port Configuration(ALD Port 0 - 5)



Parameters

Initial Precursor Mass (mg): The weight of the precursor material loaded into the cylinder (Precursor Weight = Total Weight – Weight of empty precursor cylinder). The empty weight or fill weight of the precursor cylinder is needed. Note: 1gram = 1,000mg.

Dosing Rate per Pulse (mg): The precursor usage rate per pulse (mg/pulse) is defined by the precursor used, the pulse time, and the precursor temperature. This measured value is used to determine the amount of precursor remaining in the cylinder by counting the number of pulses.

Dosing Rate per Pulse (mg) = (Precursor Cylinder Weight Change)/(Pulses Used)

Alarms (Precursor Level)

Enable: The precursor level alarm can be enabled by checking the appropriate box. Either the Count Alarm or the Level limit alarm.

Count Limit (pulse): Minimum number of remaining pulses without Level ALARM

Level Limit (%): Minimum value for Estimated Level % (Weight %), [(# of pulse *rate per pulse)/(initial weight)]

Status

Available Pulses: Displays the total number of pulses available for the Full cylinder

Remaining Pulses: Displays the total number of remaining pulses available

Pulses Used: Displays the total number of pulses performed on the cylinder (PORT #)

Precursor Level %: Calculated % value of precursor remaining in the cylinder

Modifying Settings

To save changes made to the system parameters press “OK” or “Apply”

To Cancel changes select “Cancel”

Tools Configuration Tab

Rate of Rise

An automated rate of rise (RoR) function is available with the installation of an optional hardware kit. This function is accessed by selecting Tools→"Rate of Rise (RoR)" from the menu bar of the main interface. Additional information is available in the Options section of the manual.

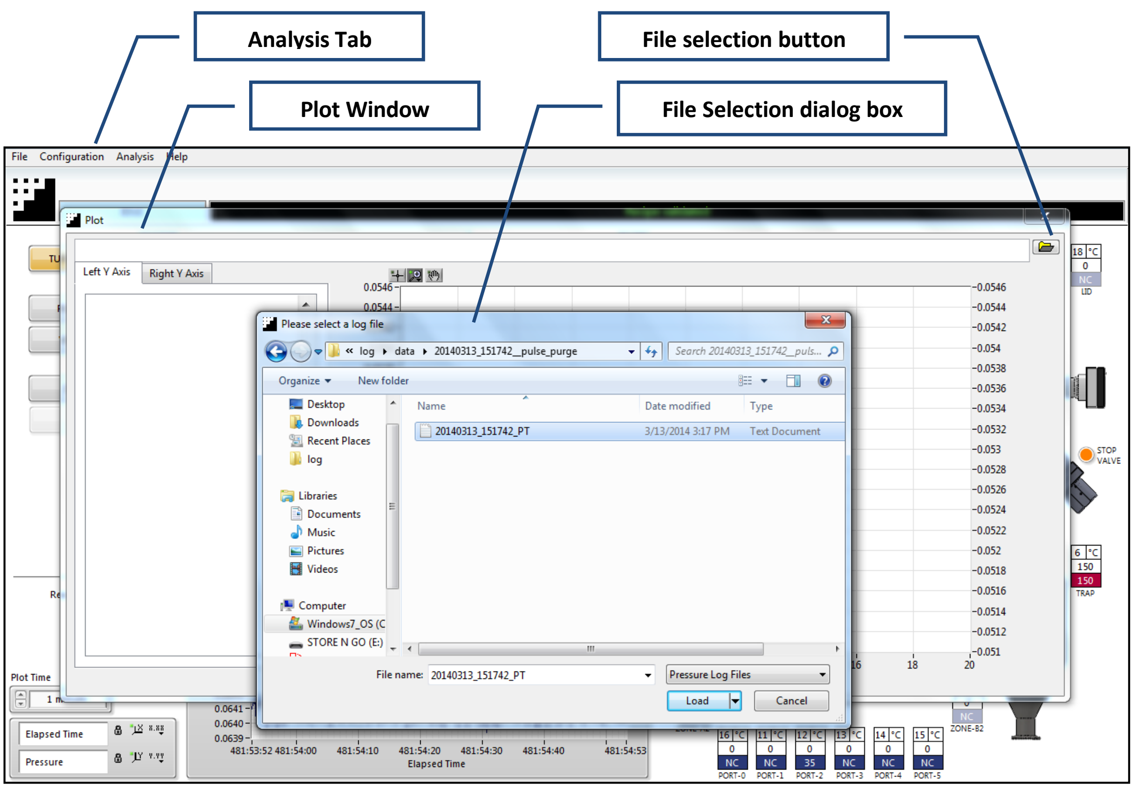
Log Plotter Utility

In older software versions, a plotting utility was available from the "Analysis" menu of the main interface. This is no longer the case, since for several reasons the plotting utility has been made into a standalone software application separate from the Savannah ALD control software.

To launch the Log Plotter utility, locate its shortcut either on the Windows desktop or in the "Veeco" folder within the Windows Start menu. This utility ships on all factory configured laptops, but for some reason it is missing, please feel free to contact Veeco for a download link.

Log Plotter

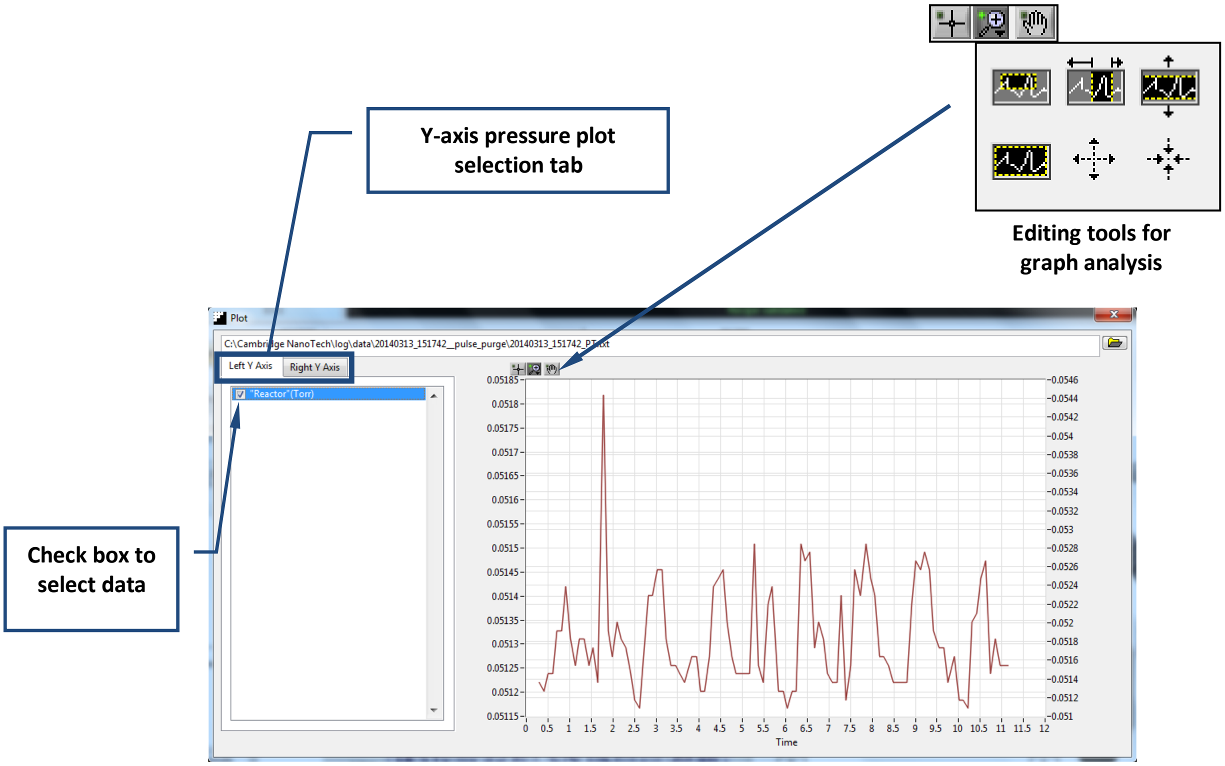
This utility provides the ability to plot pressure logs recorded by the Savannah ALD software for analysis. Pressure channels are plotted as a function of time (sec). To open a log file, use the file selection button and the resulting dialog to locate the appropriate pressure file (YearMonthDay_Time_Recipename_PT). All of the log files are located in "C:\Cambridge Nanotech\log\data". Within this directory the user must locate the directory corresponding to the recipe of interest to the, within which the pressure log file is located.



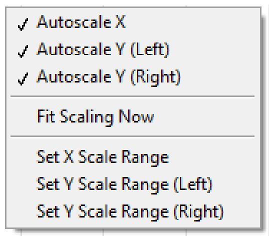
Pressure Plot

The pressure data can be plotted on either the Left or Right axis as a function of time (sec). The base Savannah system has one pressure gauge installed. With the addition of optional equipment, multiple pressure gauges may be installed on your system. For these systems, two axis pressure plots are a valuable technique for troubleshooting and optimizing the process recipe.

By right-clicking on the plot area, a context menu offers several scaling options.



Pressure plot window for data analysis.



Data Logging

The Savannah software has data logging capabilities. There are four different types of data being logged and saved in the following folder ***C:\Cambridge nanotech\Log*** . The following is a list of these four types:

Event Files
Heater Data
Pressure Data
Reports

Location of logged data files

System Event Files		
File Type	**File Name**	**File Directory**
Event File	yearmonthday_hourminsec_EVT.txt	**C:\Cambridge Nanotech\log\event**
Process Run Files		
File Type	**File Name**	**File Directory**
Event report	yearmonthday_hourminsec_EVT.txt	**C:\Cambridge Nanotech\log\data\yearmonthday_hourminsec_RecipeName**
Heater data	yearmonthday_hourminsec_DAT.txt	
Pressure data	yearmonthday_hourminsec_PT.txt	
Run summary	yearmonthday_hourminsec_SUM.txt	
Run report	yearmonthday_hourminsec.jpg	

Folder Structure

The following set of directories are created by the installer:

C:\Cambridge Nanotech\configuration
C:\Cambridge Nanotech\recipes
C:\Cambridge Nanotech\log\event
C:\Cambridge Nanotech\log\data

System Event file

This is a text file that records all major events. Every record contains the date and time when it occurred for the entire system state including system idle and system recipe processing. The file is created when the software starts and events are added to it as they occur. The events files are located in C:\Cambridge Nanotech\log\event folder. The following is an example of an event file:

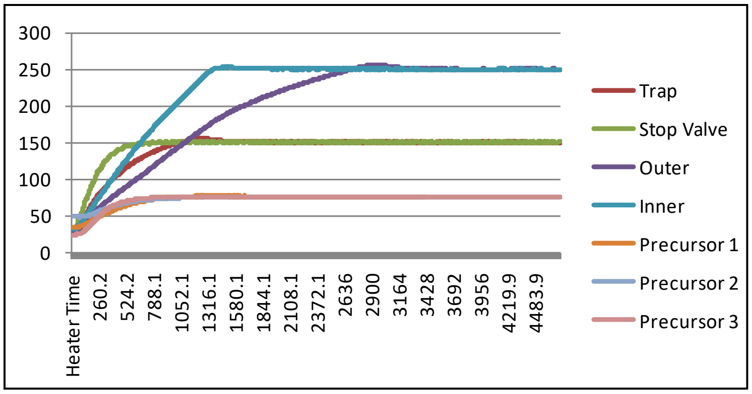
12/07/10 19:41:14: Program Started
12/07/10 19:41:14: System initialized correctly
12/07/10 19:41:30: Heaters On

Process Event File

This event file captures the events associated with a recipe controlled process run. These events are a subset of those recorded by the system event log.

Heater Data File

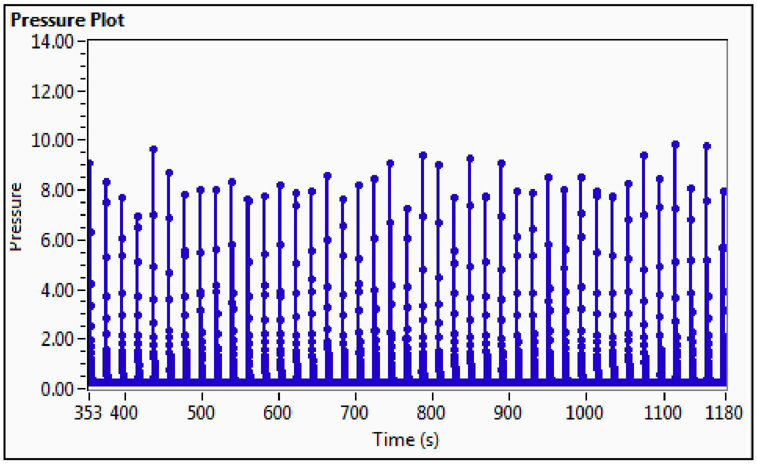
The software data logs the heaters, the MFCs, the remaining cycles, and the recipe name. The software data logs all of these with a time stamp around every 2 seconds. This data file is only generated during a run. The data files are named by the date and are placed in a run specific folder. The data folder for each run is located in C:\Cambridge Nanotech\log\data\yearmonthday_hourminsec_RecipeName.



Example of Savannah heater data file plotted in Excel

Pressure Data File

The software data logs the pressure with a time stamp every 0.15 seconds. This data file is only generated during a process run. The files can be plotted in excel. This is the actual data that you see in the software real time display during a run. When you plot this data you can see your pressure peaks, etc.



Example of plotting pressure data

Run Summary

The run summary contains a top level summary of the recipe, recipe run statistics, parameters, system configuration, and the status of run completion. This file is designed to be an overall run summary for evaluating the success or failure of a process run.

Run Reports

The software takes a screen capture at the end of every run (file.jpg). The software stores this screen shot in C:\Cambridge Nanotech\log\data\yearmonthday_hourminsec_RecipeName. These screen shots can be quite useful because you have a snapshot the last peaks, the MFC flow, and system state. This is basically a quick check that the user can do before they would review the other data files and the run summary file.

Modifying the config.ini file

The config.ini file is located in C:\Cambridge Nanotech\configuration folder. This file is meant for the experienced user and Support Engineer. Do not attempt to change this file unless you have consulted the Technical support team at Veeco.

Be sure to make a back-up copy of the original config.ini file incase the file is un-intentionally modified or corrupted.

Software Installation (If required)

To install the control application, launch the **setup.exe** executable in the installation kit and follow the prompts. The installation kit installs both the control application and the component driver required for connecting the computer to the tool via the USB port.

File System Directories

The following set of directories are created by the installer or control application:

C:\Cambridge Nanotech\configuration
C:\Cambridge Nanotech\recipes
C:\Cambridge Nanotech\log\event
C:\Cambridge Nanotech\log\data
C:\Cambridge Nanotech\installer\USBDeview

Configuration

The ...*configuration* directory contains a **config.ini** file. This file contains specific details regarding the configuration and operation of the specific tool. The will not run without this file.

Recipes

The ...*recipes* directory provides a central repository for any recipes used by the tool.

Log

The ...*log\event* directory contains a set of event text files providing specific details of the tool operation.
The ...*log\data* directory contains a set of files specific to a particular recipe run.

USBDeview

The ...*installer\USBDeview* directory contains a utility that may be used to identify specific details of the USB driver that connects the computer to the tool's control electronics box.

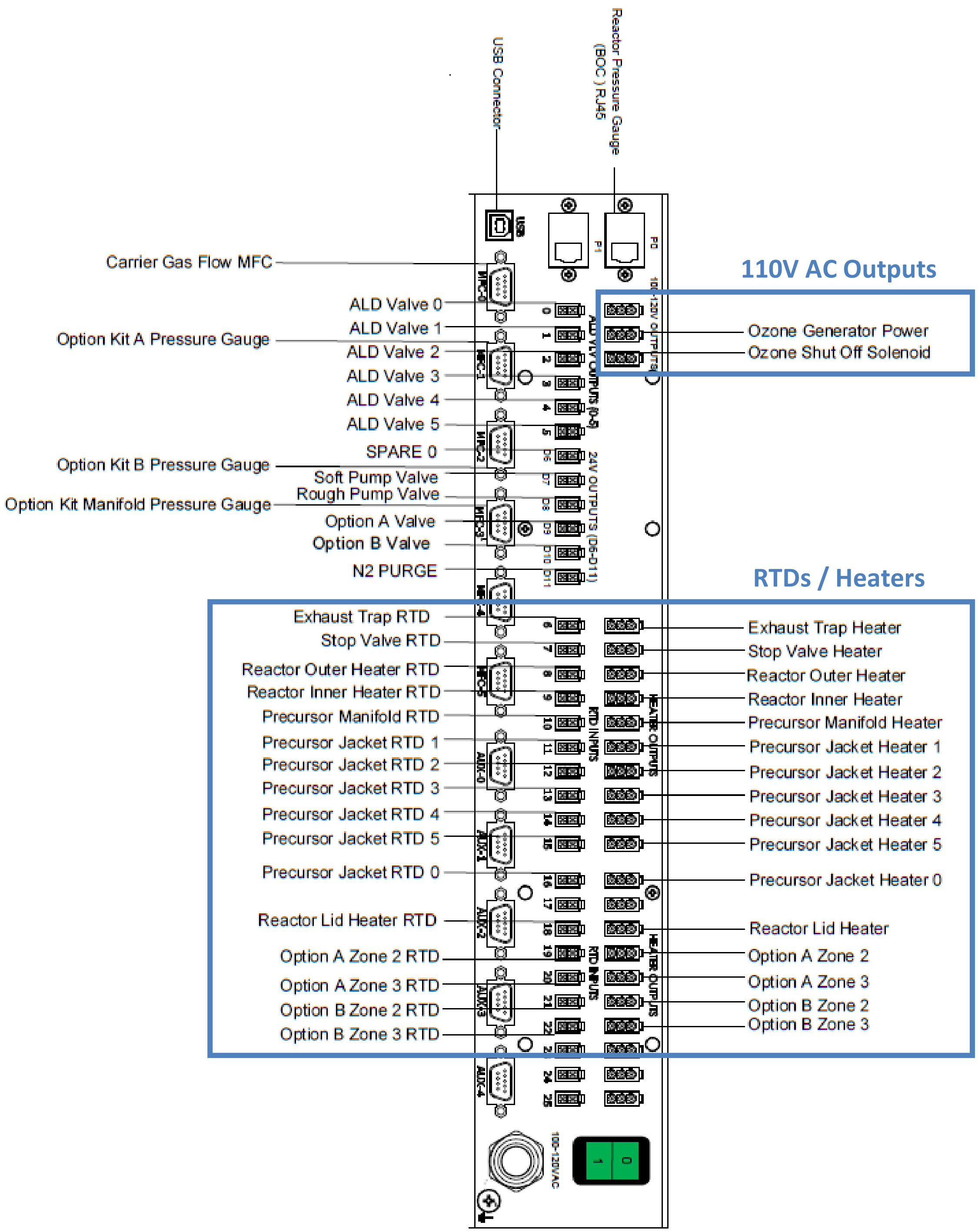
Drivers

The computer communicates to the tool over a USB connection. The installation kit installs the *WinUSB.sys* driver on the computer along with the necessary information file (*C:\Windows\inf\MCHPWinUSBDevice.inf*). The information file tells Windows to use the *WinUSB.sys* driver when connecting to the tool.

The tool will automatically connect to the computer when powered. No action is required by the user beyond the initial software installation.

Hardware Controller (E-Box)

All of the electrical and pneumatic controls are performed through the E-box, shown below. The figure identifies where each of the connections are made. Tools built prior to June 30, 2012 will have the stop valve (120VAC) MAC valve plugged into line ac out AC0 line out.



Recipe Development

A large number of ALD process recipes can be obtained directly from the Veeco Technical team by emailing ALDSupport@veeco.com. These Standard recipes will be a very good starting point for your ALD film deposition and subsequent process development. Included in the Standard recipe are recommend precursor materials, pulse times, purge times, and process temperatures.

Al_2O_3 Process Recipe – Standard Format and Considerations

Line #0 - carrier gas flow rate. The typical value is 20sccm, but can be higher up a maximum of 100sccm) or lower to a minimum flow of 5sccm.
Line #1 – Pre-heat and Outgassing. The *wait* allows heat-up of the substrate and chamber, allowing desorption of physisorbed moisture and out-gassing from porous substrates. The wait time depends on substrate, temperature and application. A minimum wait time of 300sec is advised for substrates like single silicon wafers, for 10 wafers in a dome lid the time should be extended to 7200sec. For porous substrates, time to pump down to base pressure should be used as a guideline to determine the wait time.
Line #2 - Oxidant Pulsed Dose. The precursor *pulse* time on line #2 is set to provide a saturation dose of precursor connected to ALD Valve #X. Typically, this precursor is H_2O, O_2, O_3 or H_2O_2, for growing oxides. For nitrides, NH_3 can be used. The pulse time depends on precursor pressure and reactivity. For a liquid or solid precursor, the precursor pressure is determined by temperature of the corresponding precursor heater. For a gaseous precursor, a two stage pressure regulator (for O_2 or NH_3) or a flow regulator (for O_3) is typically used to deliver a controlled dose. Please review the associated sections in this manual for ozone delivery and gaseous precursor delivery.
Line #3 – Purge. The *wait* time on line #3 is selected to allow the un-reacted precursors and reaction by products to be carried out of the chamber. This purge time depends on temperature, pump speed, precursor, carrier gas flow rate, and desired film properties.
Line #4 – Organometallic Pulsed Dose. The *pulse* time on line #4 is set to provide a saturation dose of precursor connected to ALD Valve #Y. This is typically the metal-organic precursor. The effective vapor pressure of the precursor will defined how best to delivery this material. High vapor pressure materials will not require heating, low vapor pressure materials will require heating and also an assisted delivery method, either N2 boost or the LVPD kit with heating.
Line #5 – Purge. The *wait* time line #4 is selected to allow the un-reacted precursors and reaction by products to be carried out of the chamber.
Line #6 – Goto Loop for ALD Cycle. Lines 2-5 constitute a full ALD cycle and define the cycle time for growing ALD films. Based upon the growth per cycle (GPC) which is reported in Angstroms/cycle the number of cycles required for a film thickness is determined. For example Al_2O_3 at 150°C has a GPC = 1.0Å/cycle, 500 cycles will produce 500 Å of Al_2O_3 film.
Line #7 – Idle N_2 Carrier flow Line #7 sets the carrier gas flow rate to a stand-by value of 5sccm.

	Instruction	#	Value	Units
0	flow		20	sccm
1	wait		3600	sec
2	pulse	X	0.015	sec
3	wait		2	sec
4	pulse	Y	0.015	sec
5	wait		2	sec
6	goto	2	500	
7	flow		5	sccm

Table 1. Typical Al_2O_3 process recipe at 250°C

SECTION 8: Savannah Options

The Savannah is a versatile ALD system which can be customized with a variety of configurations and Option kits which can dramatically improve the functional capability of the base system. The base Savannah system includes the following features which can be upgrade to increase the functionality of the ALD system.

Savannah Base System - S100, S200, and S300

- 110V and 220V configuration
- Fully enclosed and exhausted cabinet
- 2 ALD Port System
- ALD Vapor Shield™ (Trap) installed in exhaust line
- Standardized Computer with pre-loaded Software
- EMO (Emergency Machine Off) button and Power ON/Off button
- Recommend Standard Pump: Adixen 2021c2 pump

This section will review the available options. Not all options can be installed simultaneously on the system as there are hardware and software limitations that exist which impact the compatibility of different options. Please consult Veeco when considering the upgrade of your Savannah system. For the Savannah G2 product the following options are available:

Additional ALD precursor lines

The base Savannah (S100, s200 and S300) can be expand to 4 or 6 ALD precursor ports adding greater flexibility and capability for multi-user facilities. Additional ALD ports enables the integration of advance delivery options, including Booster, LVPD, and SAM options.

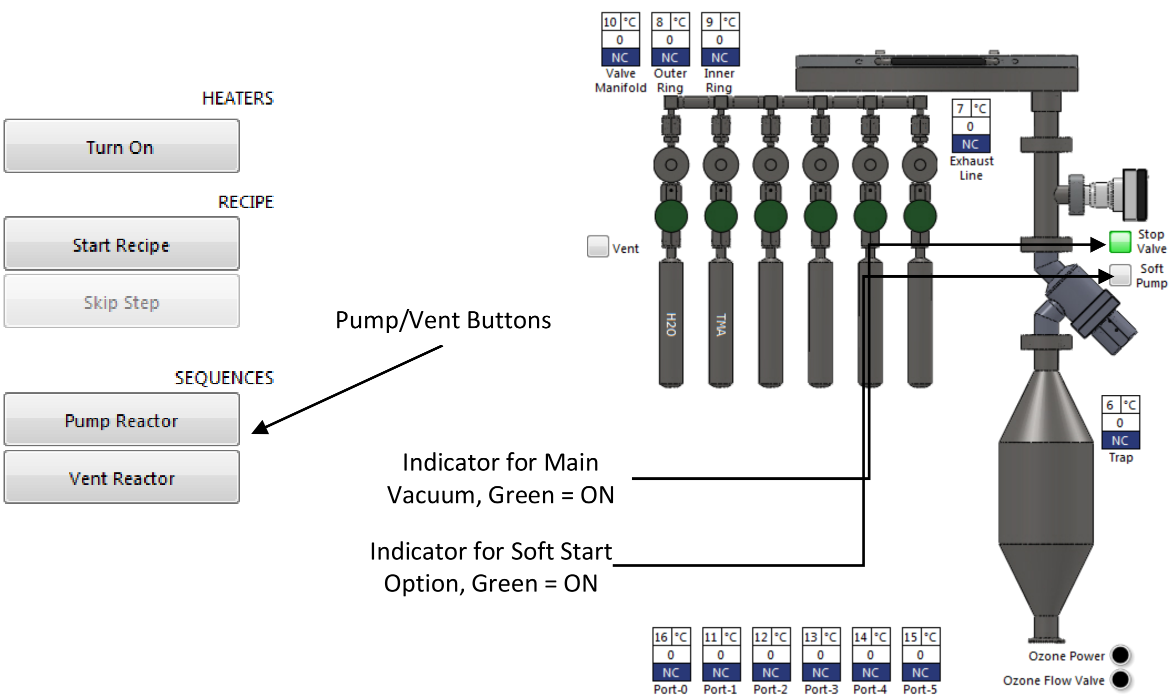
Six Port ALD Manifold

Two stage Pump Down Valve (Soft Pump) Option

The Savannah system can be upgraded with a two stage stop valve (soft-start pump-down) kit. This hardware allows the user to pump down the process chamber with two different pumping rates. The soft pump feature reduces turbulence in the chamber and unwanted movement of test samples during the chamber pump down sequence. The soft pump option includes a two stage stop valve that allows the system to be pumped to vacuum more slowly by using a slow pump valve with a configurable cross over pressure to main vacuum.
The pump down sequence operates automatically by pressing the Pump/Vent button. The chamber vent function is unaltered by this hardware upgrade and operates normally after pressing the Pump/Vent button.

	**BURN HAZARD** Caution: the Savannah chamber and lid are extremely hot. Do not touch hot surfaces! Allow the system components to properly cool before performing maintenance tasks or touching parts that may be hot.

The savannah lid is extremely HOT. Only use the insulated handle to close the chamber lid.



Soft pump option in the Savannah software

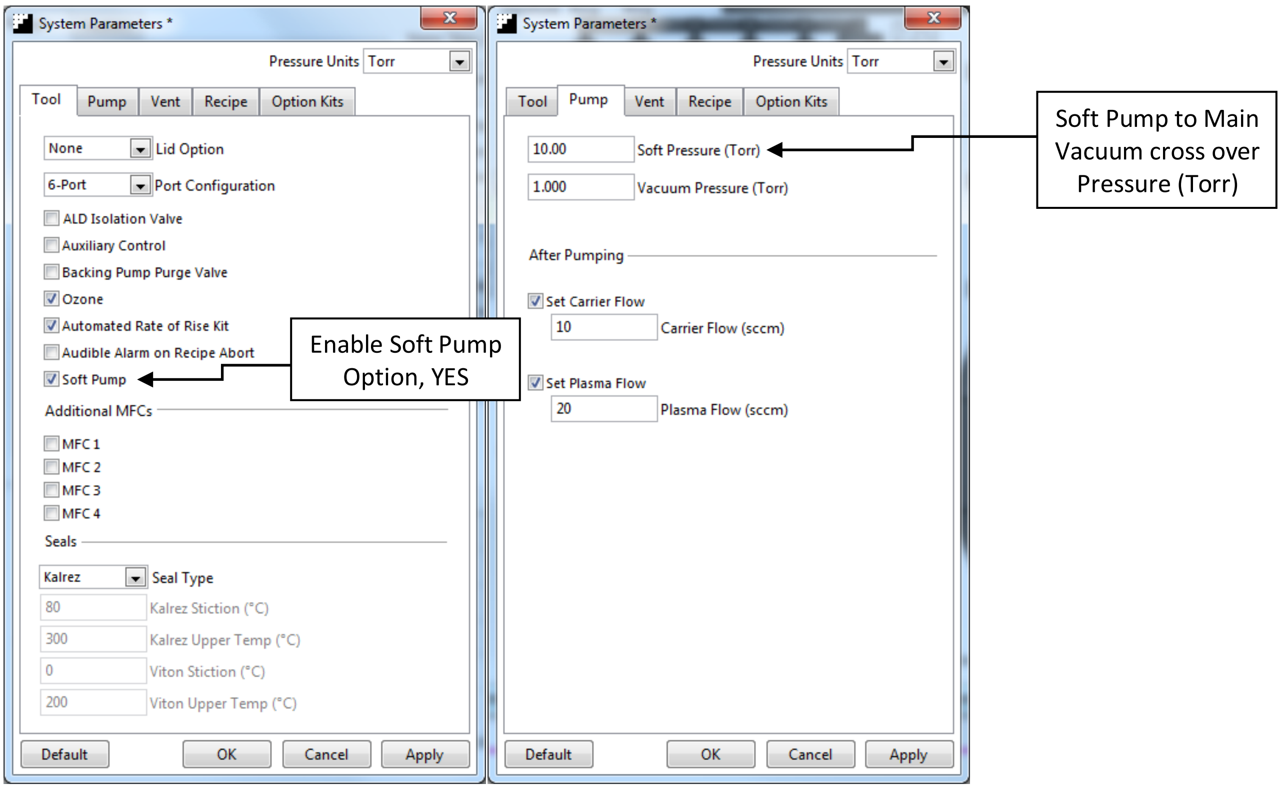
Operation

The Softstart function after proper configuration will operate automatically during Pump Down and Vent Functions. After pressing the “Pump chamber” button, the soft pump valve will open (Indicator = Green). To initiate evacuation of the chamber the operator may need to push down on the chamber lid handle until the chamber pressure starts to decrease. Once the pressure is <10Torr, the soft pump valve will close and the stop valve will open (Indicator = Green).

System configuration for Soft Pump

After installing the hardware the following software parameters will need to be adjusted. On the Parameter screen, under Tool Configuration, the Soft Pump setting needs to be changed to “Yes”. The Soft Pump cross over pressure should be set to 5-10 Torr in the Pressure Threshold settings.

Save the changes made to the System Parameters by pressing OK or Apply



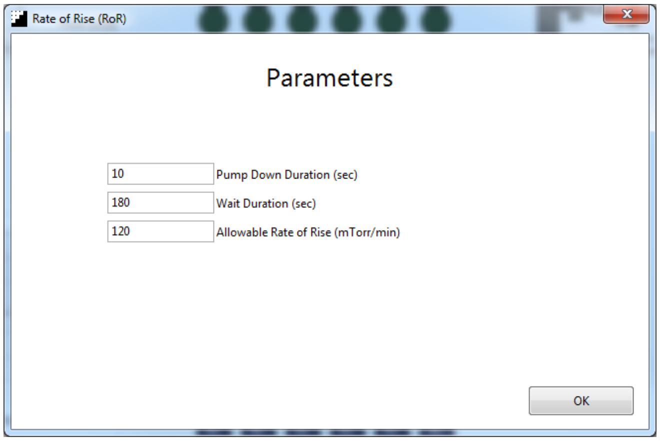
System Configuration Interfacein the Savannah software

Note: If soft start and main vacuum solenoids are both set to “ON” The system will not be ready for process and the chamber pressure will rise, >8 Torr.

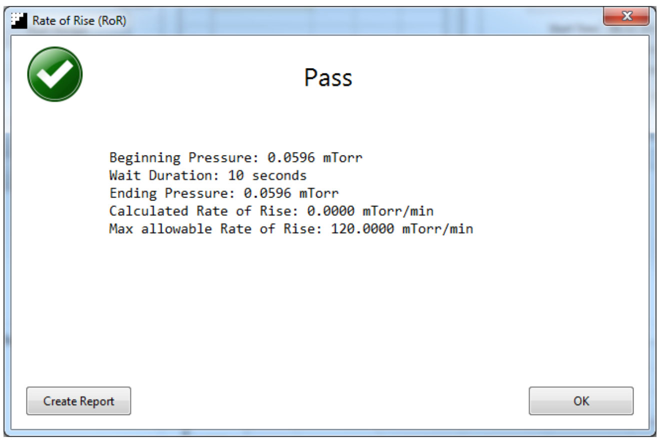
Automated Rate of Rise Option

An automated rate of rise (RoR) function is available with optional hardware. The Rate of Rise hardware includes a pneumatic valve that isolates the carrier gas flow at the chamber inlet and provides an automatic vacuum leak check of the system. The RoR function may be conducted by selecting Tools→"Rate of Rise (RoR)" from the menu bar of the main interface. The rate of rise test is intended to facility testing of the reactor's leak rate. This is useful for ensuring consistency and quality in ALD processes.

Upon launching the RoR interface, the following window appears:



The "Pump Down Duration" defines the amount of time in seconds that the procedure waits after the pump down sequence is complete. This is to provide a thorough evacuation of the reactor before the test begins. Once this portion of the procedure is complete, the reactor is isolated, an initial pressure is recorded, and the prescribed wait period begins. In the illustration above, the "Wait Duration" parameter defines the length of this wait period in seconds. After the wait period elapses, the software records a second pressure value and calculates the rate of rise. The test results are then displayed as follows:



Regardless of whether test passes or fails, the pump sequence is run after rate of rise (RoR) testing. For convenience, an optional text-based test report is provided. When the "rate of rise" recipe instruction is run, the report is automatically recorded and placed in the recipe's directory under "C:\Cambridge Nanotech\Log\Data\". Moreover, when run as a recipe instruction, the rate of rise interface does not appear, and in the event of a test failure, the recipe aborts.

Gaseous precursor delivery

Use of gaseous precursors such as oxygen, nitrogen dioxide, hydrogen sulfide or hydrogen may be required for certain ALD processes. Such gasses can be plumbed directly into the ALD valve of the Savannah system.

CAUTION: **Before beginning installation of gases, consult the MSDS sheet and follow the appropriate safety precautions. When dealing with compressed gasses, be aware that gases can be toxic, flammable, explosive, and may cause asphyxiation.**

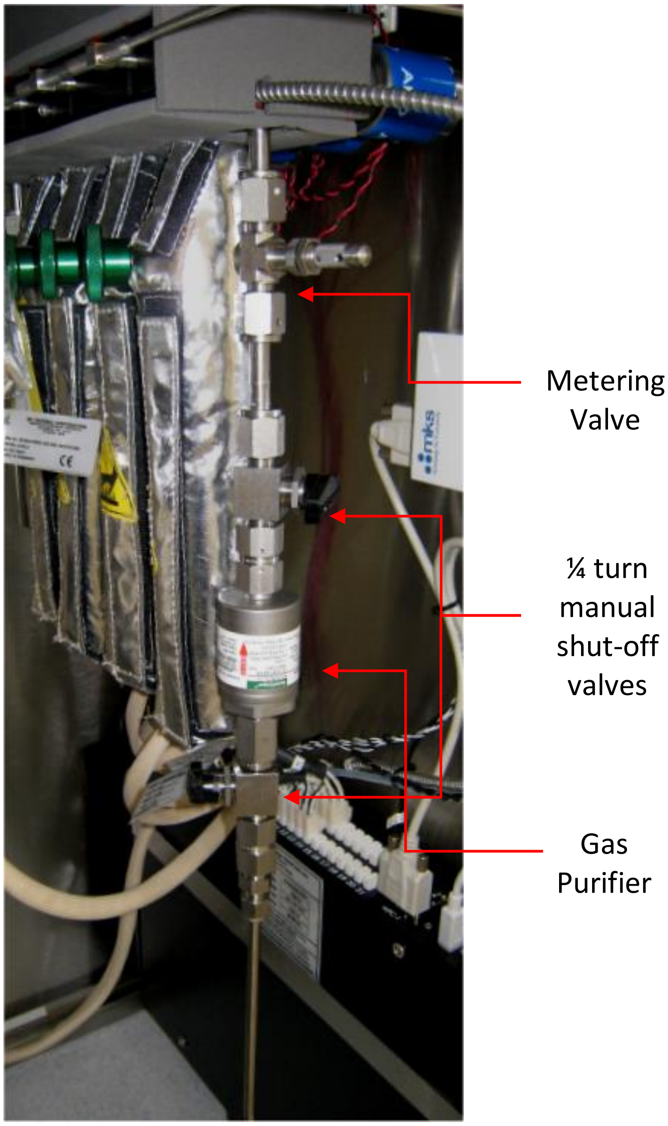
Incompatible Gasses

CAUTION: Do not plumb incompatible gasses to the system at the same time.
Do not plumb hydrogen (H_2) and a gaseous oxidant (oxygen, ozone, etc.) into the Savannah system at the same time.

Plumbing a gas on the Savannah System

Veeco suggests using the following configuration for plumbing a gas into the system:

1. Gas source (gas cylinder or delivery system)
2. Regulator (two stage)
3. Manual shutoff valve
    a. Gas purifier (Optional)
    b. Manual shutoff valve (optional)
4. Needle valve
5. ALD valve
6. Savannah Manifold



Process Gas

High-purity gas (such as electronic grade 99.999+%) is recommended in order to prevent residual contaminates in the gas from being incorporated into the film. For some gas sources (for example H_2) a generator can be used to reduce the risks associated with the use of hydrogen in your facility.

Regulator and Pressure Control

Choose the appropriate high purity regulator with all metal internal parts for the gas cylinder. A two-stage regulator capable of delivering low pressure 0 – 20psi absolute pressure should be used. The low pressure regulator setting will minimize the gas line pressure to the system and reduce the associated risks associated with a high pressure gas delivery line. Locate the gas source in a ventilated area. If using a gas that is toxic, reactive or one that may cause asphyxiation. Be sure to keep all Savannah panels and doors installed and verify system exhaust flow to the exhausted rear panel for the Savannah.

Tubing and delivery line plumbing

Use stainless steel tubing with VCR fittings for all of the gas delivery lines between the regulator and the ALD system. This will prevent contamination of the gas delivery system and reduce the risk of leaks in the delivery system.

Metering Valve (Needle valve)

The recommended metering valve for gas flow control, is a stainless steel construction with ¼ inch Male VCR fittings. Swagelok Inc. offers a stainless steel, low-flow, metering valve with VCR metal gasket face seals which works well for this application

Manufacturer: Swagelok
Part #: SS-SVR4.
Description: SS Low-Flow Metering Valve, 1/4 in. Male Swagelok VCR Metal Gasket Face Seal Fitting

Gas Purifiers (Optional)

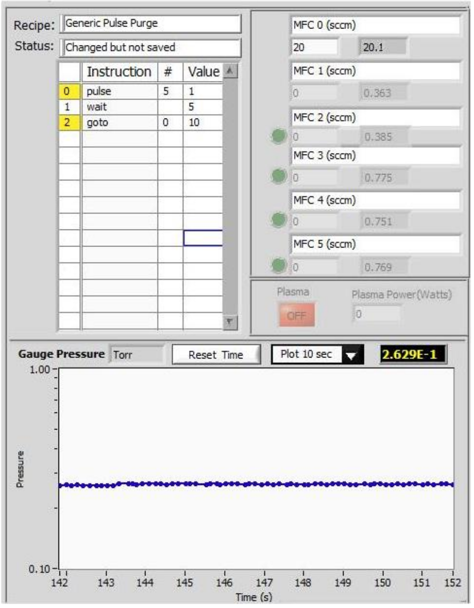
The use of a gas purifier is recommended in order to remove residual impurities which remain in the source gas or are introduced from the regulator of the bottle as well as to buffer the gas flow. The need for a gas purifier is determined by the sensitivity of the ALD process and the purity of the gas source. When growing nitrides with the Savannah, gaseous ammonia (NH_3) can be installed using the following gas purifier:

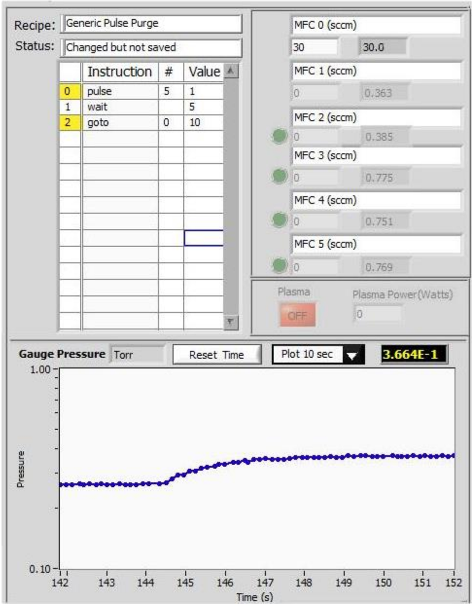
Manufacturer: Entegris
Part #: CE35KFSK4R
Description: Manganese Resinate Hydride Gas Purifier with ¼" VCR connections

Manual shutoff valves are recommended to prevent atmosphere from prematurely degrading the filter material during handling and when the gas filter is not in use.

Calibrating Gas Flow as a function of pressure

Record the pressure of the system when the flow of the process gas (N_2) is 20 sccm (i.e. 0.26 Torr). Adjust the pressure of the system by setting the flow to 30 sccm. (i.e. 0.36 Torr). A linear relationship exists between process N2 flow and the system pressure. Record the system pressure for carrier N_2 flow rates from 20 sccm and 40 sccm.


Recipe: Generic Pulse Purge
Status: Changed but not saved
Instruction # Value
0 pulse 5 1
1 wait 5
2 goto 0 10
MFC 0 (sccm)
20 20.1
MFC 1 (sccm)
MFC 2 (sccm)
MFC 3 (sccm)
MFC 4 (sccm)
MFC 5 (sccm)
Plasma
OFF
Plasma Power(Watts)
Gauge Pressure Torr
Reset Time
Plot 10 sec
2.629E-1
Pressure
Time (s)


Recipe: Generic Pulse Purge
Status: Changed but not saved
Instruction # Value
0 pulse 5 1
1 wait 5
2 goto 0 10
MFC 0 (sccm)
30 30.0
MFC 1 (sccm)
MFC 2 (sccm)
MFC 3 (sccm)
MFC 4 (sccm)
MFC 5 (sccm)
Plasma
OFF
Plasma Power(Watts)
Gauge Pressure Torr
Reset Time
Plot 10 sec
3.664E-1
Pressure
Time (s)

Evacuation of the Gas Delivery line

Before opening the gas cylinder valve, the entire gas delivery line needs to be evacuated using the “Pulse/Purge” recipe to remove moisture and air (N_2/O_2). This procedure will also determine if there are any leaks in the gas delivery line and the integrity of the gas delivery system.

Hardware setting for Evacuation

Gas Cylinder Valve	Closed
Gas Regulator	Fully Open – high pressure setting (100% clockwise)
Metering Valve	Fully Open (100% counter clockwise)

	Instruction	#	Value	Units	Description
0	flow		20	sccm	Carrier N2 flow
1	wait		15	sec	
2	Pulse	X	5	sec	pulse gas precursor
3	wait		1	sec	
4	goto	2	100		repeat 50 times

Pulse/purge recipe for gas delivery line evacuation

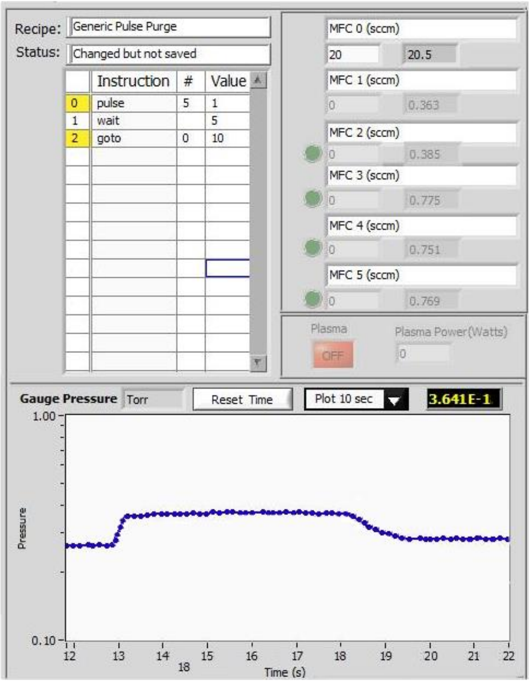
The gas delivery line should be pulse/purged until there are no observable peaks in the pressure plot. The procedure should be repeated after a 30minute wait to determine gas delivery line is leak tight. If pressure peaks are observed after waiting 30minutes, there a leaks in your gas delivery system which need to be corrected before running the gas precursor.

Hardware setting after Evacuation for Process Adjustment

Gas Regulator	Fully closed - low pressure setting (100% counter clockwise)
Metering Valve	Fully closed - low flow (100% clockwise)
Gas Cylinder Valve	Open after adjusting the regulator and metering valve.

Gas Precursor Pulse Adjustment

After purging the gas deliver line to the cylinder, the gas regulator on the cylinder should be set to a lower operating pressure,~5psi. Sub-atmospheric (<1 atmosphere) pressure delivery is an option, as the pressure of the Savannah ALD manifold is <3 Torr pressure. Sub-atmospheric gas delivery may be of greater interest when working with toxic and flammable process gasses.



Flow adjustment

Fine tune the metering (needle) valve so the flow rate for a 1 second pulse is equal to ~10 sccm (a pressure equal to 30sccm of N_2 carrier gas). Some recipes will require a larger pressure or a longer pulse or a longer pulse depending upon the desired dose. Adjust the flow as required.

Dome Lids and Associated Options

The Savannah product line offers an increased reactor volume option called the Dome lid. The dome lid can be installed on the Savannah chamber without any modifications. The dome lid can be used with the optional heaters and wafer cassettes. The wafer cassettes are standard sizes of 100mm, 150mm, 200mm, and 300mm wafers.

Dome Lids

S100 Dome lid
S200 Dome lid
S300 Dome lid

Dome Lid Heaters

S200 Dome lid heater – Max temp 300°C
S300 Dome lid heater – Max temp 300°C

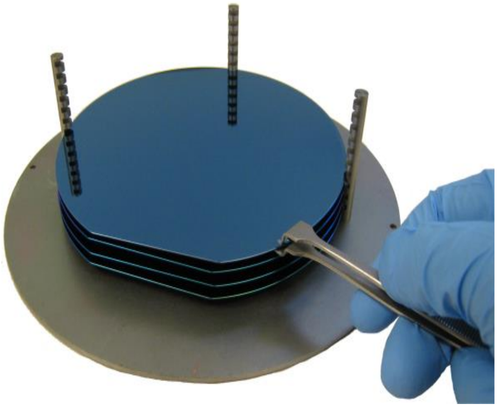
Wafer Cassettes

S100 cassette – for up to 10 wafers (non-Semi standard pitch)
S200 cassette – for up to 10 wafers (non-Semi standard pitch)
S300 cassette – for up to 10 wafers (non-Semi standard pitch)

S100 Dome Lid

S200 Dome Lid

Dome Lid Heater



10x 150mm wafer cassette

Applications notes for using Dome lids and heaters

Dome Lid Heaters

When using a dome lid the temperature uniformity from the bottom to the top of the chamber can have an impact on the uniformity when using temperature sensitive precursors. If uniform sample heating is critical to the process, the dome lid heater or the dome lid insulator is required. The maximum operating temperature for the system when using the dome lid and dome lid heater is 300°C. Do not heat the system above 300°C in particular the outer reactor heater as the sealing o-ring is Kalrez, which will melt at ~310°C.

Recipe concerns

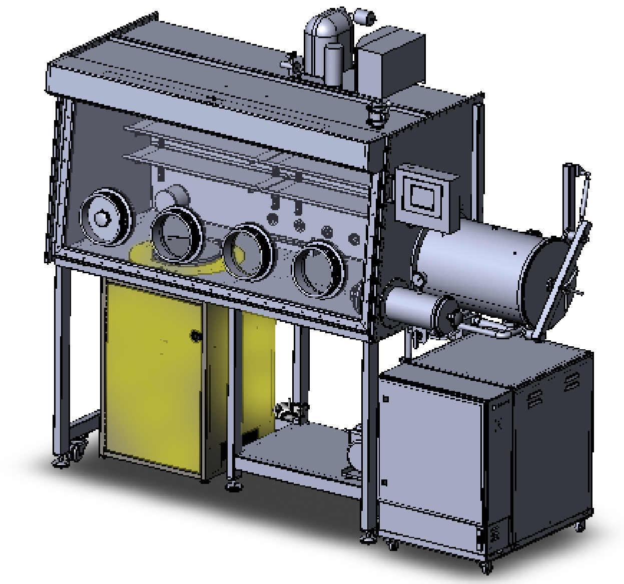
When using the dome lid recipes that have been defined for the flat lid systems may need additional precursor or wait purge time. Consult ALDSupport@Veeco.com if the recipe you are running requires any modifications.

Ozone Generator

The Savannah Ozone Generator is specifically designed to meet the purity and flow requirements for ALD processing in small chamber applications. The ozone generator provides a constant flow of ozone (O_3) generated from oxygen gas (O_2). The oxygen flow rate can be adjusted to determine the concentration of ozone in the delivery system, using flows from 0.1 to 1 LPM. The ozone kit is a fully integrated system and includes; recipe controlled operation, ozone destruct, O_2 flow solenoid valve, pulse delivered process ozone, and adjustable O_3 concentration. The ozone concentration can be adjusted to a maximum output of ~120mg/l (~7.5 wt % ozone)and process ozone is delivered to the system using the standard rapid response ALD valve.

Glove Box Integration

The Savannah system can be fully integrated inside a glovebox. The glove box integration kit allows an S200 to be installed inside an MBraun Labmaster Series glove box. The kit includes all of the hardware required for the installation, excluding the MBraun glove box which must be purchased directly from MBraun.



Auxiliary 24V outputs

The Savannah system is able to control additional custom components as required for research and development requirements. These 24 outputs are ON/OFF outputs that are actuated using the process recipe.

Toxic Isolation valve Kit

A recipe controllable toxic isolation valve can be installed on the system to provide additional protection for toxic gases used for ALD pulse delivery. The toxic isolation valve kit is controlled within the process recipe and utilizes an all stainless steel delivery line with metal seals.

Additional MFC Kit

Additional MFCs can be enabled and installed in the software.

Particle Coating Kit

The particle sample holder is designed to hold powders/particles in the Savannah reactor during ALD processing. The particle holder option enables a standard Savannah system to coat small batches of particles using the flat lid without reconfiguring of the hardware. The holder maximizes precursor access to the sample surface while containing the particles during film growth. Particles (>1.5 microns) can be coated using Exposure (Expo) mode deposition techniques with the permeable silver mesh

Enhanced Precursor Delivery kits

The Savannah system is capable of delivering pulsed precursor materials to the chamber for vapor draw ALD processes. The precursor molecule for a large number of materials has a sufficiently high vapor pressure, either heated or unheated, to deliver a saturating dose to the surface of the chamber. For more exotic materials the chemical properties may have low vapor pressure (<0.1 Torr) or extremely low vapor pressure (>0.01 Torr). For these cases a precursor delivery assist is required. Inorganic molecules can also be deposited.

Booster Kit (N_2 assisted precursor delivery)

A suitable ALD precursor should have a high enough vapor pressure at its volatilization temperature, typically less than 200°C. Some precursors have low vapor pressures, even after heating to high temperatures, which leads to an insufficient precursor dose. From a process standpoint, having a low volatility precursor can cause both underdosing and/or poor thickness uniformity. The ALD precursor boost kit provides the capability to inject a controlled amount of pressurized inert gas into a precursor cylinder to aid in the efficient transport of low-volatility precursors (with vapor pressures >0.1 torr at temperature) into the ALD chamber.

Low Vapor Pressure Delivery (LVPD) kit

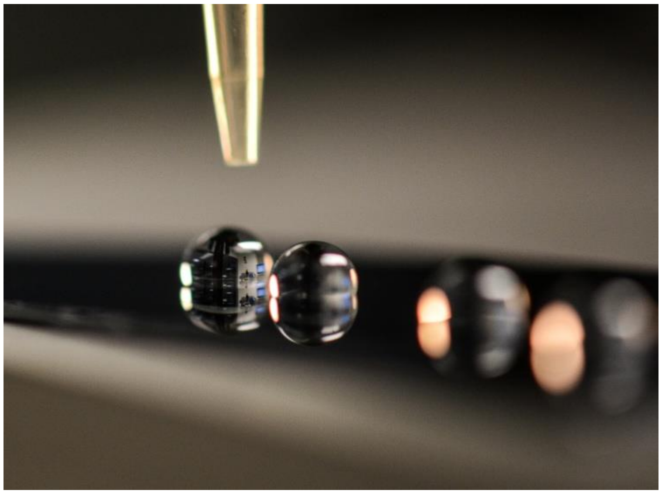
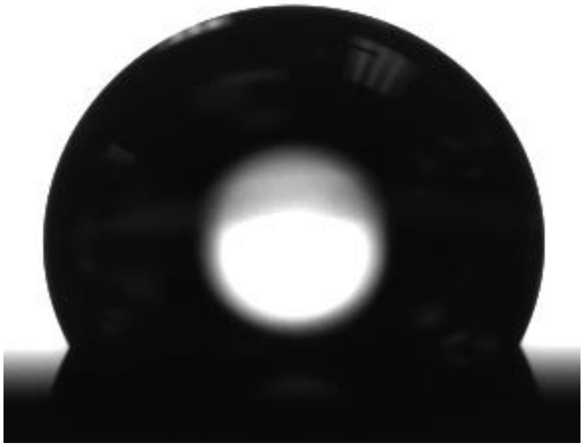
The Savannah low vapor pressure delivery (LVPD) option is designed to provide improved precursor delivery for low vapor pressure (P_{vapor}> 0.01 Torr) precursors for both solid and liquid materials. This option can also provide larger doses for high surface area samples and batch processing. The Savannah system can have either one or two LVPD kits installed. The kit is a fully integrated and includes; recipe controls, valves, heaters, insulation, and temperature control.

Self Assembled Monolayer (SAM) Deposition

Vapor-phase deposition of self-assembled monolayers can be tailored at the atomic scale to achieve controlled wettability (hydrophobicity, hydrophilicity), adhesion and stiction, electrical, chemical and biochemical properties to name a few. SAMs also provide an ideal vehicle to anchor nanoparticles, bio-molecules or be used as a seed layer.

With vapor phase deposition, stable monolayers can be deposited in 5-10 min. including over the most complex 3D micro and nanostructures encountered in MEMS and NEMS. This dry vacuum-based process ensures sample cleanliness and integration with our ALD process, allowing researchers to tailor the surface properties at the atomic level.

The SAMS kit provides highly reproducible reactant dosing via end-point pressure control in a well-controlled isothermal environment. This is critical to achieve optimal and reproducible performances despite the low evaporation rate of many organic SAMS precursors. Additionally, the in-situ diagnostic methods offered on the Gen2 Savannah (ellipsometry and QCM) offer a unique capability to researchers in order to characterize and optimize in real-time the SAMS film growth and self-assembly.

	
Surface functionalization with SAMS can be used for a wide array of application including wetting control (hydrophobic, hydrophilic), anti-stiction, FETs, biosensing and biomolecular screening.	FDTS SAMS coating on planar ALD film with 119˚ water contact angle

H_2S Compatible Hardware upgrade

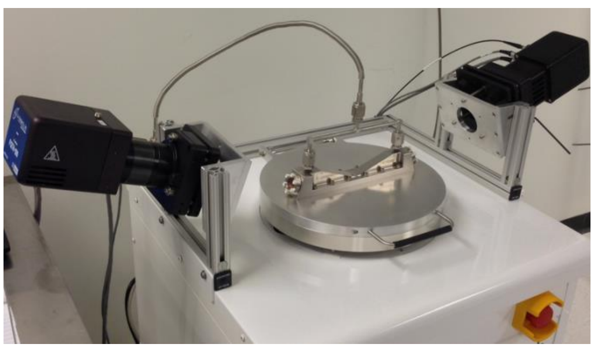
This hardware kit modifies the Savannah system so that it is compatible for use with hydrogen sulfide (H_2S) as a precursor material. H_2S as a precursor allows sulfides to be deposited using ALD techniques. The hardware upgrades include compatible materials for use with H2S and the nitrogen pump purge kit to protect the Savannah pump from the corrosive and toxic gas. The use of H_2S on the Savannah ALD system requires a number of modifications to the system and lab facilities in order to safely use this process gas. H_2S must be handled appropriately due to its corrosive properties, toxicity, and flammability. Hydrogen sulfide (H_2S) is toxic and will cause biochemical suffocation (shock, convulsions, coma, death) in exposure levels greater than 50ppm (refer to the Material Safety Data Sheet, MSDS).

Nitrogen Pump Purge – Corrosion Protection

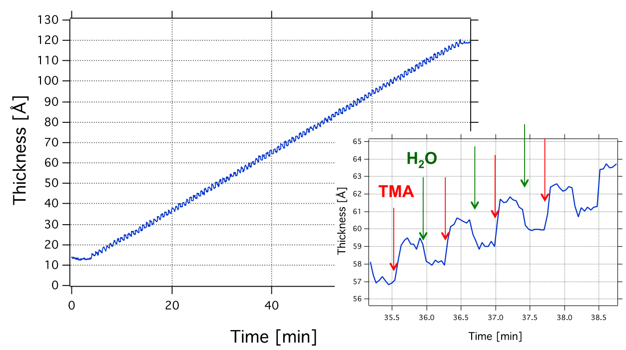
A Nitrogen purge kit is available for the Adixen 2021c2 pump. This N2 kit allows enables the User to purge the pump oil with N2 during process deposition of corrosive materials, protecting the pump oil and components from corrosive and toxic exhaust gasses. The N2 purge kit can be turned ON/OFF in the recipe allowing for an efficient use of house nitrogen.

In-situ Ellipsometry

Veeco offers a state-of-the art solution for in-situ film thickness measurements by spectroscopic ellipsometry. The ellipsometry kit provides a turn-key solution for scientists in needs of real-time wafer-state diagnostic in Savannah systems (S100, S200, S300) either for rapid process optimization, real-time process control or fault detection. The kit includes a custom-designed frame allowing rapid installation and accurate optical alignment. The modified Savannah lid integrates a compact dual window assembly allowing for continuous data acquisition while minimizing window deposition via localized window purge. This kit has been design to accommodate the Woollam M2000 in-situ spectroscopic ellipsometer though other models can be readily accommodated.



Woollam M2000 In-situ spectroscopic ellipsometer mounted on Gen2 Savannah S200. Ellipsometry windows in Savannah lid are nitrogen purged for continuous spectral acquisition.



Real-time wafer-state measurements during Al_2O_3 ALD deposition. Continuous data acquisition from 0.5s to 2.5s /scan (full scan 290-1000nm). Inset shows 4 consecutive TMA/H2O half-cycles

For additional information and a quote of the options presented in this section please contact the ALD experts at Veeco:***ALDsupport@Veeco.com*** or ***ALDsales@Veeco.com***.

Installation and Operation Manuals are provided separately for each purchased option.

Section 9: SEMI S2/S8 kit

Overview

The SEMI S2/S8 kit adds addition features to the Savannah system to allow it to meet the SEMI S2/S8 specification. This is only applicable to S200 systems and not all options have been certified for SEMI S2/S8 compliance. Compliance reports for the specific tool iteration tested are available upon request. Please refer to Veeco for addition details. Each user facing feature is described below. These features may extend or modify the tool functions described earlier in this manual.

Over Temperature Interlock

In order to protect against thermal runaways each thermal zone on the S200 has an independent mechanical thermal interlock. The interlock is "snap" switch that opens at a fixed temperature. Each snap is daisy chained in a loop that is in series with the nominal EMO circuitry. Therefore if any zone goes over temperature the system will go into EMO state as if the EMO button had been pushed. The snap switches will automatically reset once they cool down. They have some hysteresis (~20°C); if the snap switch cut out at 190°C to reset it would have to cool to 170°C.

Snap switches: 160°C, 95°C, 65°C (top to bottom, labeled)

Protected channels come in two typed: fixed temperature and selectable temperature.

Fixed temperature (5x): These snaps switches are permanently attached to the Savannah tool. They are each the 160°C version. Their position and thermal insulation has been calibrated to trigger at appropriate heater zone setting in the ALD software.

channel	Software trigger temperature
valve manifold	~180°C
trap	~240°C
exhaust valve	~240°C
inner reactor	~280°C
outer reactor	~280°C

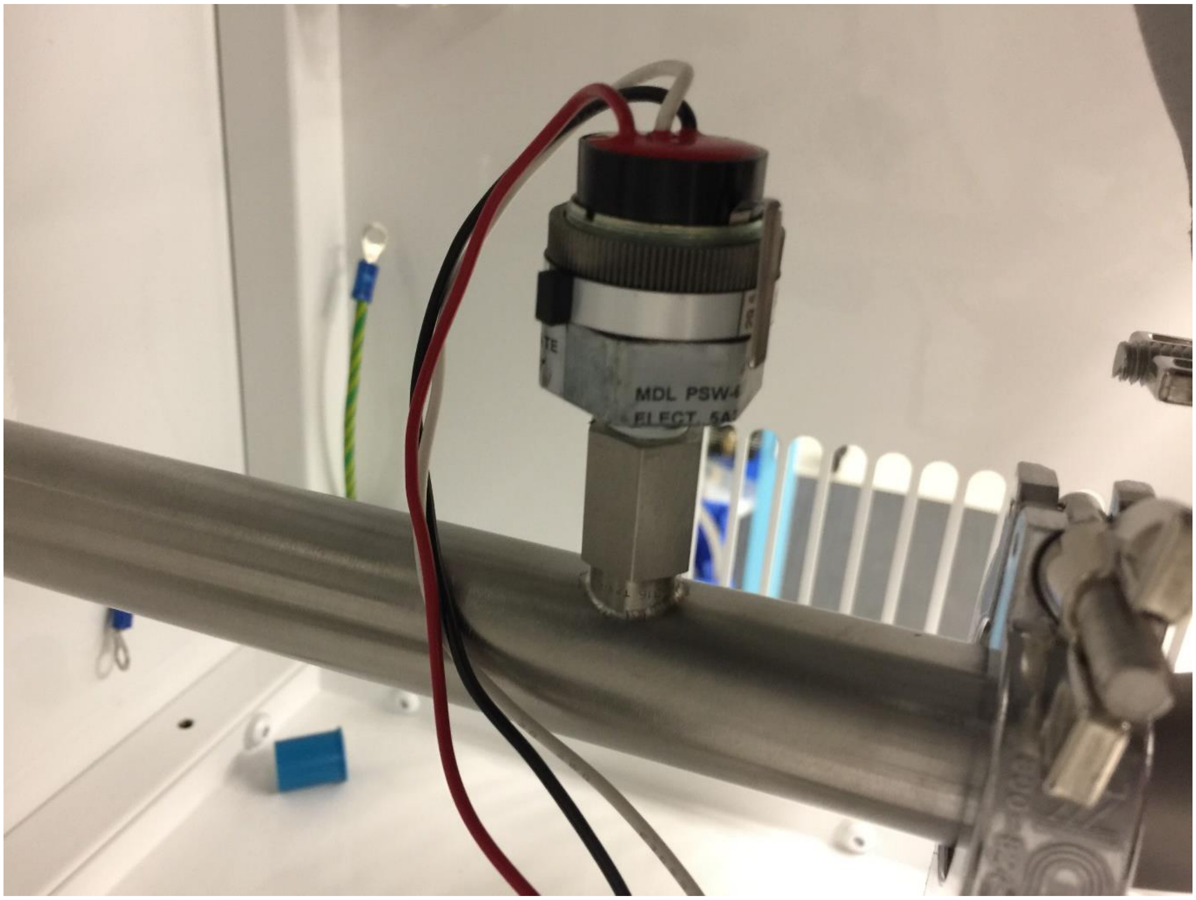
Selectable temperature: Some channels require the ability to select a range of temperature limits. All the precursor bottles use this feature. The user can select which temperature snap switch to use: low (65°C), med (95°C), or high (160°C). The snap switch must be plug into the snap switch loop. The sensor end is inserted into the body of the heater jacket alongside the precursor bottle. The snap switch selected is precursor dependent, for example TMA (trimethylaluminum) would never need to be heated over 50C°C therefore the 65°C snap switch should be selected.

Note: A snap switch must be plugged into each open position on the snap switch daisy chain loop (red wire). If any plug is left unconnected this will create an open circuit and the system will act as if an EMO button is pressed. A number of extra snap switches of each temperate are provide to allow the user to select the temperature needed for each chemistry.

Hazardous chemical protection

An independent system is used to protect the user from exposer to hazardous chemicals. In this case the chemicals under consideration are the precursors chemistries and the Ozone that is generated by the external ozone generator option.

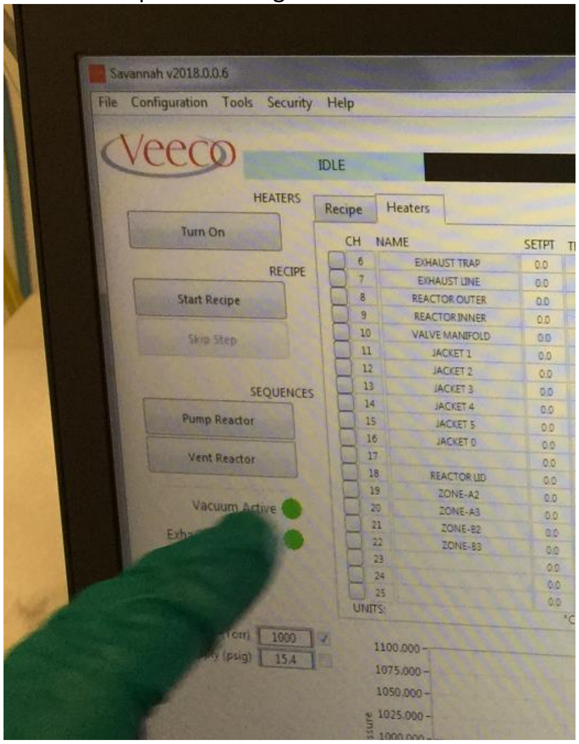
Any excess or accidentally leaked hazardous chemicals are drawn away from the system by two systems, the cabinet exhaust and the vacuum pump. Specifications capacity and flow rate are provided in the facilities drawings. To ensure that these systems are functioning each is monitored by a sensor.



On the rigid exhaust line between the trap and the external bulkhead is a vacuum switch. This sensor is closed when the vacuum is present and is open near atmosphere.

External to the tool, on the cabinet exhaust line a flow sensor is mounted. This should happen during tool install, the sensor must be 36” or more from the back of the tool. It must be oriented in the correct direction (As shown by the flow arrow) and the correct depth (sensor holes must be in the center of the tube). This sensor provides a closed signal when the exhaust is flowing at the appropriate speed and an open signal when the flow is too low or off.

Each sensor provides a signal to the software and an indication on the software GUI of its status.



Indicators in software.

A recipe cannot start if these signals are not satisfied.

In addition, the ALD valves are interlocked with each of these signals via mechanical relays. If either sensor gives an open signal (or is disconnected, or the cable cut) then the relays will disable control of the ALD valve. For example, the electronics may be command an ALD valve to pulse, but if the sensor condition is not correct that ALD pulse signal will not be allowed to pass through the mechanical relay and on to the ALD valve itself.

Thermal Enclosure

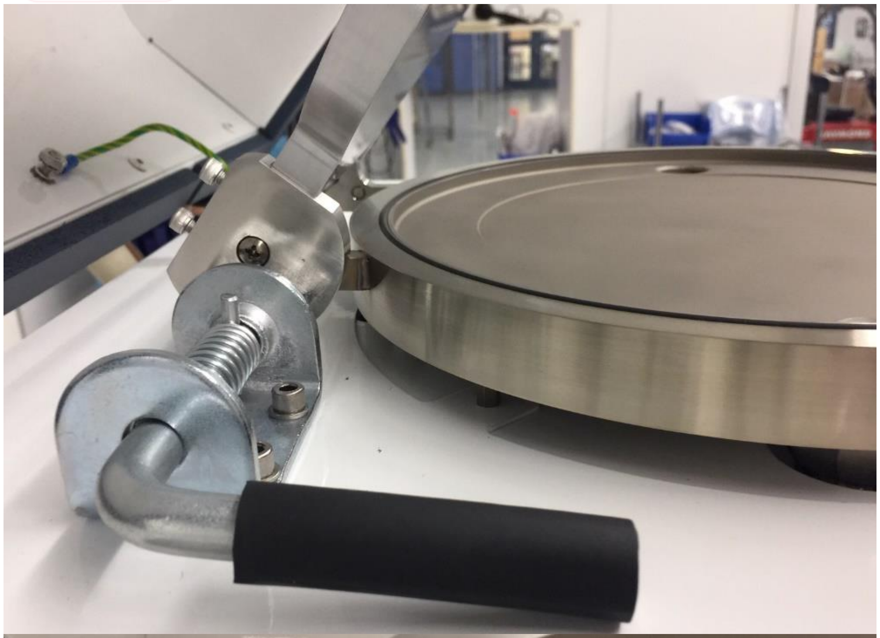
The system is provided with a thermal enclosure. This protects the user from the hot surface of the ALD chamber. It also provides a secondary benefit of creating a more uniform temperature in the process temperature. Note: the dome lid heater cannot be used with the thermal enclosure as the outer surfaces of the dome lid. It is supported by spring hinges and gas springs. The gas spring on the left side of the tool has a locking pin that holds the enclosure open and prevents it from falling on the user. The pin must manual disengaged to close the lid. This is a two hand operation, right hand on thermal enclosure handle, left hand releases the locking pin.

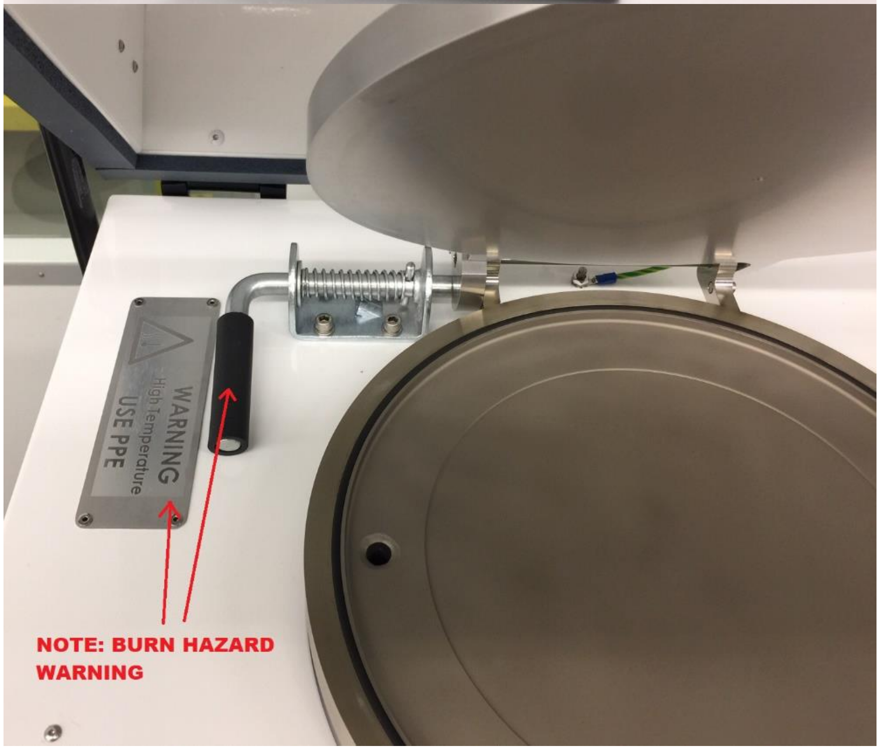
Gas spring closed and open.

Reactor lid lock

The vacuum chamber lid also has a locking mechanism. This mechanism holds the lid open when the sample is being placed or retrieved. The lock must be manual disengaged to lower the lid. This is a two-hand operation, one hand (right) on the lid handle, the other (left) disengages the spring lock mechanism.

WARNING BURN HAZARD: the spring lock handle could be very hot, PPE glove (provided) must be worn on the left hand.





LOTO

To safely access maintenance areas of the tool proper LOTO (Lock Out Tag Out) procedure must be followed. Please refer to site safety personal and standard to determine proper procedure. A plug lock cover is proved for to lock out the main power plug when the tool is in a maintenance shut down.

Seismic protection

The tool is provided with seismic tiedown brackets. See facility drawings for bolting locations. If these brackets are properly bolted to a suitable floor, then the tool place the seismic protection test. This performance has been determined via calculation and via actual sideload testing.

Section 10 Troubleshooting, Process Questions

Frequently Asked Questions

OEM manuals for the pressure gauge, mass flow controller, and optional equipment are listed in PDF format on the install CD.

Please find some of the most frequently asked questions for the Savannah ALD systems below. For an updated list please check our website (www.cambridgenanotechald.com) or contact the technical support team directly at aldsupport@Veeco.com.

I just received the system, what oil should I put in the pump?

If you received a pump from Veeco, then the pump is “B-prepped” also known as Fomblin prepped. The pump must be filled with a Fomblin based vacuum oil which needs to be purchased by the customer from Alcatel or another vendor. The recommended rotary vane pump oil is either the Adixen/Alcatel - 113 pump oil or the Solvay Solexis - Fomblin 25/6 oil. These are low vapor pressure and inert nature. Ordinary oils are flammable and should not be used. Please refer to the Facilities section of the User’s manual and the OEM pump manual for additional information

Used vacuum pump oil can be reclaimed or cleaned by a third party vendor during the pump PM, for example Inland vacuum.

Should Veeco install the Savannah system?

In our experience, our customers can install the Savannah ALD system themselves, after reading the manual and consulting with Veeco. We recommend purchasing the precursor material at least 4 weeks before expected delivery of the system, since the lead time of the precursor material can vary. The required customer supplied items can be found on the quote, or in a detailed specifications document (inquire). It is very important to read the manual. It is also useful to contact Veeco. for support (ALDsupport@Veeco.com) if things are not clear.

I can’t open the lid, it seems to be stuck!

It is often difficult to open the lid when the reactor is cold. It is best to keep the system warm at all times. We find that the lid opens very well at temperatures >80 °C. We also provide optional Kalrez O-rings with a proprietary coating which has anti-stick features. Please inquire if needed. It is always good to have a spare O-ring, in case something happens with the old O-ring although we find that the Kalrez O-ring performs extremely well for more than a year under normal conditions.

The pressure of my system is high and increasing, do I have a leak?

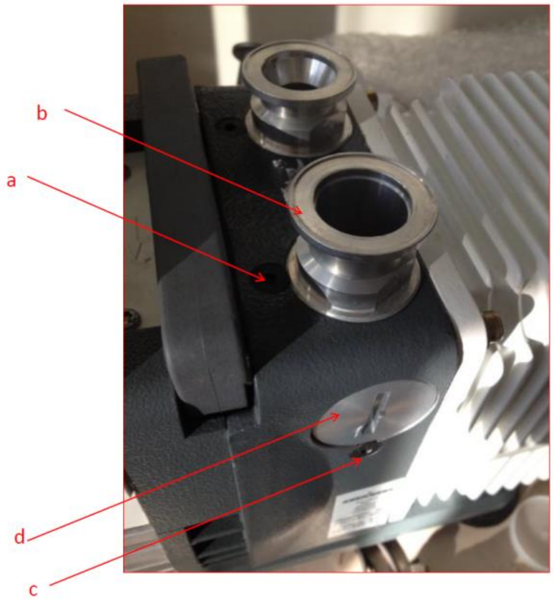
During ALD deposition the precursor material is pulsed into the system and can affect the pressure gauge over time. The pressure gauge is a Pirani (thermal conductivity) gauge and is quite durable but over time the coating on the filament will cause the reported pressure value to drift upwards. The gauge can be reset by depressing “Cal” button for more than 5sec, first at atmospheric pressure, and second at a pressure lower than 1e-5 Torr. The gauge is considered a consumable part and will need to be replaced as its performance will degrade.If the pressure gauge reports a pressure >0.75 Torr with 20sccm of carrier gas, it is time to replace the gauge. Also see “How can I check if my Savannah system has a leak?” section of the FAQ,.

How do I clean the pump inlet screen?

If the pumping power is diminished for high carrier gas flow or purge times become long to remove a CVD component. The pump inlet screen may have become dirty or clogged and need to be cleaned. This filter is located on the pump inlet and can be inspected visually.

For removing and cleaning the screen:

1. Remove the (a) with an Allen key
2. Remove (b) with a wrench
3. You might be able to remove the screen by grabbing it with pliers; else,
    1. Remove (c) with an Allen key
    2. Remove (d) with an appropriately sized flat instrument
4. You should be able to push the screen out



My system is quite dirty, how should I clean it?

Over time ALDfilm will be deposited layer by layer on the reactor and pumping line. This film as it gets thicker (up to 5 microns) can detach from the chamber parts, especially if the reactor and other components are heat cycled. Heat cycling can accelerate flaking because the difference of thermal expansion of stainless steel and ceramics like Al_2O_3. It is best to minimize thermal cycling. Chamber cleaning can be material dependent and is typically sent to a third part cleaning company.

Lid – Al_2O_3 glass bead, then apply a 32 finish , ultrasonic clean in DI, N_2 dry and bake-out at 105°C

Chamber – Al_2O_3 glass bead 80 grit, 40 psi, Keep old o-ring in groove to protect from media, cap VCR fitting, protect KF vacuum flange, backside, and edges. Ultrasonic clean in DI, N_2 dry and bake-out at 105°C

Exhaust Lines and Trap – Consult your local cleaning vendor for best the chemical cleaning solution per film deposition. 25% KOH etch at 80°C is recommended for Al2O3. For other materials, the appropriate etchant should be used. DI rinse, ultrasonic clean, N_2 dry and bake-out at 105°C

Consult the maintenance manual for detailed description.

The KF-25 o-rings in the pumping line are dirty, should I replace them?

The KF-25 o-ring material in the pumping line is typically Viton. Extended use at temperature coupled with thermal cycling can degrade and permanently deform the o-ring minimizing the effectiveness of the o-ring seal. The o-ring elastomer is designed to deform and apply a sealing force on each sealing surface. After deformation (flattening) the o-ring seal force can be dramatically reduced. Replace the o-rings and clean the o-ring sealing surface if a leak is observed in the vacuum line or during a Preventive Maintenance (PM). These o-rings are relative inexpensive and can be kept as spare parts.

Before reinstalling the o-ring, thoroughly clean and inspect the sealing surfaces for film growth and scratches. These sealing surfaces can be reconditioned with >800grit Al_2O_3 paper, IPA and DI wipe down prior to installing new o-rings.

How can I check if my Savannah system has a leak (Rate of Rise Test)?

The MFC on the Savannah is not a positive shut-off device. Therefore the N_2 line upstream of the Savannah must be pumped out or the N2 leak through the MFC will appear to be a system leak.

1. Set the reactor temperatures to 120C.
2. Isolate the N2 carrier gas supply to the system. Depending on your particular installation this could mean one of several things including at a regulator on the N2 cylinder or a shut-off valve on an N2 distribution system.
3. Set the MFC flow to 100 sccm until the N2 line has been evacuated back to the shut-off point.
4. Set the MFC flow to 0.
5. Wait for the reactor temperatures to equilibrate at 120°C.
6. Note the base pressure on the Savannah software screen.
7. Close the stop valve by toggling the green light switch on the screen next to the picture of the stop valve.
8. After 1 minute, note the system pressure.
9. Calculate a rate-of-rise (units of mTorr/min)by taking the difference between the two pressure measurements.
10. At 120C, the rate-of-rise should be < 50mTorr/min.

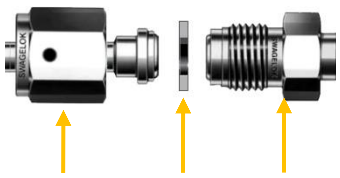
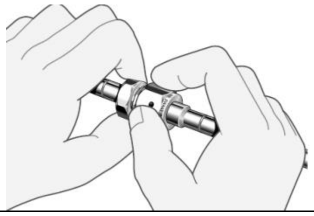
How can I check if my Savannah stop valve is operating properly (stop valve Test)?

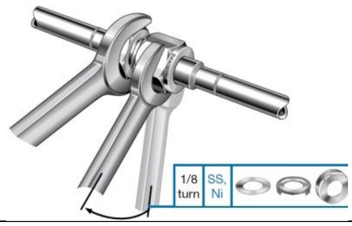
The functionality of the stop valve can be measuring by timing the chamber backfill time. The chamber is a known volume and with a closed stop valve, the vent time will be defined by this volume.

1. Pump system to Pbase (MFC flow = 0sccm)
2. Close the stop valve
3. Set MFC flow to 50sccm
4. System should vent in approximately 9min 30sec for an S200 flat lid system.

How do I install and tighten a VCR fittings?

A Swagelok ®VCR® fitting provides a high purity metal-to-metal leak-tight seal. The seal on a VCR assembly is made when a metal gasket is compressed by two beads during the engagement of a male nut and a female nut. Two wrenches are required to tighten the nuts just $1/8^{th}$ turn past finger-tight. See illustrations below. NEVER over-tighten a VCR fitting or it will leak! Prior to installing a VCR gasket inspect the VCR sealing surfaces for scratches or damage. Damage on the sealing surface will compromise the performance of the vacuum fitting.

Step	Action	Details
1.	Use two wrenches to disconnect any VCR connection. This prevents damage and twisting of gas lines.	**NOTE**: ALWAYS USE TWO WRENCHES on VCR fittings to prevent twisting of the tubing and stress on fine tubing.
2.	Install a new stainless steel VCR gasket in the fitting. Use ONLY a genuine Swagelok® gasket. ¼": SS-4-VCR-2 or SS-4-VCR-2-GR-VS ½": SS-8-VCR-2 or SS-8-VCR-2-GR-VS	 **CAUTION! LEAK HAZARD!** Never re-use a VCR gasket. You must use a new metal gasket each time you open a VCR fitting. The tightening process creates an indent in the metal gasket. Re-use of a gasket will result in a gas leak.
3.	Tighten the fitting finger-tight.	 **CAUTION! LEAK HAZARD!** Do not over-tighten VCR fittings.

4.	Tighten fitting 1/8 turn (45 degrees) past finger-tight. Use TWO wrenches. Use one wrench on each fitting, to prevent twisting/turning of the tubing.	 1/8 TURN ONLY! **CAUTION! LEAK HAZARD!** Do not over-tighten VCR fittings.

Should I install precursor material on all 6 Port of the Manifold or should I replace the precursor cylinders for different films?

The blue pneumatic ALD valves can be used for more than one precursor material, but it is more convenient to install multiple cylinders on the ALD manifold. A two port Savannah can be used to deposit a wide variety of films by exchanging the precursor cylinders (pulse/purge/exchange) between ALD runs, but a two port Savannah cannot be used to deposit nanolaminate films. For multi-user facilities with a large selection of ALD film capabilities, all 6 ports are typically occupied with a precursor cylinder. This added flexibility allows the user to rapidly transition between ALD materials. Idle precursor cylinders should be properly secured/closed.

How should I maintain an "Idle" or unused precursor cylinder on the system?

When not being used to deposit films, the 50ml precursor cylinder should be secured by closing the manual valve and purging the headspace.

1. Close the Manual Valve
2. Pulse/Purge Headspace
   (Pulse 0.015sec, 10sec Wait) repeat 20 times
3. Reduce the temperature of the idle unused cylinder
4. Change associated heater setpoint to 0

The effective temperature in the precursor volume ranges from ~150°C at the ALD valve to room temperature. If the manual valve is left open for extended periods of time, the precursor vapor will be exposed to high temperatures near the ALD valve and valve seat. For temperature sensitive materials this MAY lead to thermal decomposition at the valve seat causing the valve to "stick" closed.

Additionally, isolating the precursor cylinder with the manual valve will eliminate any risk of possible cross contamination or precursor decomposition behind the ALD valve.

CAUTION – never remove precursor cylinder with the manual valve open, and NEVER open the manual valve in air when there is precursor material in the cylinder.

How do I verify the operation of the ALD valve electric and pneumatic systems?

Verify the following items for proper ALD valve pulsing.

1. Confirm that the electric signal is getting to the MAC valve from the ebox. Observe a red indicator LED on the pneumatic MAC valve during pulse command in the recipe.
2. Verify that the compressed dry air (CDA) is set to 70-90 psi(5.9-7.2 bar) for the pneumatic gas.
3. Confirm that there is an audible sound of air being released from the MAC pneumatic valve (pressurized air release associated with the valve pneumatics).

There are no ALD pulses for an ALD valve

First confirm that the precursor cylinder valve is opened. The ALD valve requires a few items to "pulse" the valve properly. Confirm the following items are working as designed.

Confirm that the electric signal is getting to the MAC solenoid valve from the e-box. Observe a red indicator LED on the pneumatic MAC valve during open command.

1. If there is no signal (Red light) on the MAC valve check the following items.
    a. With a volt meter confirm the output voltage (24V) during the pulse command.
    b. Verify that the cable from e-box to MAC valve has electrical continuity.
    c. If there is an electrical signal, the MAC valve may be damaged/failed.
2. Verify that the compressed dry air (CDA) is set to 70-90 psi (5.9-7.2 bar) for the pneumatic gas.
3. Confirm that there is an audible sound of air being released from the MAC pneumatic valve (pressurized air release associated with the valve pneumatics).

If a 50ml precursor cylinder is installed on the manifold, close the Manual valve and attempt to un-stick the valve with the following recipe.

How can I open a Stuck (Sticky) ALD Valve?

If your ALD valve seems to be becoming sticky (see Idle precursor cylinder). It can probably be fixed by repeatedly running large pulses of air as follows: (1) Remove precursor cylinder attached to the sticky ALD valve (X). (2) Heat the ALD manifold to 150C and leave ALD valve X open to atmosphere. (3) Run the recipe below for a certain number of cycles until the valve opens normally:

1. flow 20
2. wait 5
3. pulse,X, 2
4. wait 5
5. goto, 2, 100 (try more cycles if it does not work, or abort it if problem is solved)
6. flow 5

What is the maximum temperature of the precursor cylinder?

The maximum temperature is limited by two factors maximum operating pressure (1000psi (69 bar)- cylinder limited) and maximum operating temperature (manual valve limited).

The50ml precursor cylinder comes equipped with one of the following manual valves:

1. SS-4H-VCR bellows sealed valve (green handle)– rated to 315°C, Max Temp <300°C
2. SS-42GVCR4 ball valve (black handle) – rated to 148°C, Max Temp < 130°C

Do not overheat materials with high vapor pressures as the cylinder is pressure limited (P_{max}< 1000psi(69 bar)).

What purity and how much water (H_2O) should I use in the precursor cylinder?

The recommend H_2O purity is HPLC grade or better.

The H_2O cylinder max fill is 25ml in the 50ml cylinder. The recommended practice for refilling includes the following

1. Weight the empty cylinder and label the cylinder with this value
2. Record the Max Fill weight on the cylinder to eliminate overfilling.
3. Verify H_2O is in the bottom of the cylinder and there is not a H2O “bubble” in the cylinder stem.

Install cylinder with a new VCR Gasket

Pulse Purge the H_2O cylinder prior to first product Run. This procedure will reduce the pressure in the cylinder to the vapor pressure of H2O. After the cylinder is install the pressure = 1atm

Flow 20 sccm
Pulse, H_2O, 0.5sec
Wait 5 sec
Repeat 20x

The H2O pulses should decrease until the standard pulse height is achieved. The cylinder is now process ready.

Should I put a heating jacket around a cylinder with TMA or water?

For standard operation, do not install the heater jacket on either the TMA or H_2O cylinders. The vapor pressure of TMA and water are high enough at room temperature, so that heating is not required. For some unique applications where temperature accuracy and larger doses are required, the heating jacket can be used with low temperature setpoints <40°C.

What is the best plot time to graph the process pressure?

It is recommended to plot only several pulses, for example 30 seconds or 1 minute total plot time. Setting this value to 1 hour during a run can reduce delay precision, because with a 1 hour plot time many data points need to be refreshed, which consumes a lot of processing resources. It is possible to set the plot time to 1 hour to get an overview of pulse heights, but plot times > 5 minutes are not recommended during a run.

What is the recommended Precursor Manifold temperature?

The Swagelok ALD valves can be heated up to 200°C. We recommend heating the precursor manifold to 150°C for the majority of the process recipes.

What is the dose that I should use for the precursors?

We recommend using the Standard process recipe provided to you from Veeco by the technical support team (aldsupport@veeco.com).The required precursor dose is dependent upon the following factors: temperature of the precursor, vapor pressure of the material the surface area of the product/chamber, etc. Adjustments may be required from the Standard process recipes, but typically less than 50% of the standard recipe values.

Why is there nitrogen (carrier gas) flow and what is the recommended setting?

The carrier gas typically Nitrogen (N_2)is used to continuously purge the process chamber and ALD manifold. In some cases the carrier gas is Argon (Ar). The standard Idle flow rate (when the system is not running process) for the carrier gas is 5 standard cubic centimeters per minute (sccm). During the ALD process the flow rate can vary from 5 to 80 sccm depending upon the process recipe requirements.

The nitrogen flow is used to purge the chamber between each ALD pulse. It is important that between precursor pulses all excess precursor is removed from the chamber. The presence of two precursors in the chamber at the same time will cause a vapor phase, CVD type deposition, which can lead to film non-uniformity, and powder formation in the chamber. Continuous Nitrogen flow is delivered to each ALD valve and constantly purges the ALD manifold and ALD valves providing long cycle life to the ALD valves.

What is Exposure (Expo) mode for and why should I use it?

The Exposure mode is used to coat high aspect ratio (HAR) structures (>1:50). The Exposure mode process uses the stop valve to isolate the pump from the process chamber to provide the precursor a longer residence time in the chamber and thus the opportunity to diffuse into the high aspect ratio spaces. For each precursor step, the stop valve is closed, the precursor is pulsed, precursor exposure time, the stop valve is opened, and then a precursor purge time. The exposure mode process is considerably slower than continuous mode process, due to the added time associated with the exposure time and purge time. For additional discussion see the Exposure mode section in the manual.

When the Savannah system is not in use (Idle), should I turn off all the heaters?

If permitted by your facilities and safe in your lab as judged by the owner or responsible individual, you may leave the heaters on when not in use. The advantages are: 1. no heat-up time between runs, 2. Better film holding on the reactor walls due to minimized thermal expansion, eliminate H_2O adsorption, and maintain vacuum integrity. We recommend that heaters for the trap (#6), the stop valve (#7) and the ALD valve oven (#10) are set to 150°C, and reactor heaters (#8 and #9) be set between 100°C to 200°C.

Actual temperature lower than setpoint, is my heater broken?

Check the duty cycle for the heater (information in the “Advanced” tab). If it is at 100%, then either (a) the heater is not working, or (b) the heater channel on the e-box is not working. The heater can be checked by measuring its resistance with a multi-meter. Heaters should measure greater than 25ohm (chamber heater) and less than 170ohm (precursor cylinder heater). Problems with the heater channel can be checked by connecting the heater and RTD to a different channel and checking if it heats up. Do not plug in a shorted heater to a different heater channel as it will likely burn out that channel too.

I used purge time X, it does not seem adequate now. What has changed?

Purge time recommendations are based on good uniformity, minimal CVD component. They assume that the pump is working well. Base pressure is one measure of pump condition. A more relevant metric is the pumping curve. It is recommended that the pumping curve be measured periodically with a new pressure gauge – upward drift in pressure at high flows likely means the pump needs attention. This can be clogged inlet mesh, change of pump oil or refurbishment of pump. If there is any oil visible around the pump, it is likely because of a compromised shaft seal – the pump will need to be refurbished.

Section 11 General Information

General Notes

The manufacturer reserves the right to make changes to the product covered in this manual to improve performance, reliability or manufacturability. Although every effort has been made to ensure accuracy of the information contained in this manual, the manufacturer assumes no responsibility for inadvertent errors. Contents of the manual are subject to change without notice.

Using this Manual

Purpose

This manual provides the following information for the Savannah series systems:
- System safety
- System description
- Operation procedures
- Reference materials

Scope

This manual covers the Savannah 100, 200 and 300 series systems only.

Revision History

Revision	Date	Changes
1.0		New.
1.1	4/09	Operation procedure additions/changes.
1.2	5/09	Safety and operation additions.
1.3	5/09	Operation additions.
2.0	11/12	re-write – New format, all options
2013 Rev 1	10/2013	Savannah G2
3.0	3/3/2016	Updated QCM section, removed incorrect partner reference
D	1/7/2019	Added Semi kit info, updated references to Veeco, added missing dual dimensions, fixed typos

Related Documents

Please refer to the **Savannah Maintenance Manual** for details on system maintenance and troubleshooting.

Recommended Training for Operation Personnel

All operators should be familiar with the system operation and documentation, and possess a thorough understanding of the safety considerations and system startup/shutdown procedures. Topics of focus should include:
- System safety
- System/components
- System startup
- Software operation
- System shutdown

All items in this manual are covered in detail to ensure that experienced operators and personnel can safely and efficiently perform each task.