www.costeffectiveequipment.com

+1-573-466-4300

Operations Manual

Apogee® X-Pro-II Workstation

Cost Effective Equipment

1) Introduction

1.1 Confidentiality Statement

Information supplied is for the use in the operation and/or maintenance of Cee® equipment. Neither this document nor the information it contains shall be disclosed to others for manufacturing or any other purpose without written authorization from, Cost Effective Equipment, LLC.

1.2 Warranty

Cost Effective Equipment, LLC warrants to the original purchaser (Buyer) that equipment is free from defects in material and workmanship under normal use and service in accordance with Cee® instructions and specifications. Buyer shall promptly notify Cee® of any claim against this warranty, and any item to be returned to Cee® shall be sent with transportation charges prepaid by Buyer, clearly marked with a Return Authorization (RMA) number obtained from Cee® Customer Support. Cee's obligation under this warranty is limited to the repair or replacement, at Cee® option, of any equipment, component or part which is determined by Cee® to be defective in material or workmanship. This obligation shall expire one (1) year after the initial shipment of the equipment from Cee®. This warranty shall be void if:

- Any failure is due to the misuse, neglect, improper installation of, or accident to the equipment.
- Any major repairs or alterations are made to equipment by anyone other than a duly authorized representative of Cee®. Representatives of Buyer will be authorized to make repairs to the equipment without voiding warranty, on completion of the Cee® training program.
- Replacement parts are used other than those made or recommended by Cee®.

CEE® MAKES NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, WITH RESPECT TO EQUIPMENT. NO WARRANTY IS MADE AS TO THE MERCHANTABILITY OF THE EQUIPMENT NOR ITS FITNESS FOR ANY PARTICULAR PURPOSE. In no event shall Cee® be liable for consequential loss or damages, however caused. No person or representative of Cee® is authorized to assume for Cee® any liability in connection with equipment nor to make any change to this warranty unless such change or modification is put in writing and approved by an authorized representative of Cee® in writing.

This warranty shall be governed by the laws of the state of Missouri, U.S.A.

1.3 Returned Materials

Any materials, parts, or equipment returned to Cost Effective Equipment, LLC must be clearly labeled with a Return Material Authorization (RMA) number.

To obtain an RMA number, contact:

Cee® Customer Support
Telephone .... +1-573-466-4300
Email .... *support@costeffectiveequipment.com*
Web Address.................................... *www.costeffectiveequipment.com*

1.4 Model and Revisions

The model and serial number information for the Cee® Apogee® X-Pro II Workstation are located on the rear panel. Software version information can be found on the *About* screen. See *DataStream™ Manual* for screen shots and a detailed explanation of the system software.

1.5 Environmental Considerations

Cee® fosters sustainability through innovation in the durability and reliability of our precision tools and equipment. Individual component modules are engineered for serviceability ensuring long lasting performance. Processes are designed to minimize use & consumption of chemical compounds ensuring accurate, replicable, industry-leading results every time.

Cee® diligently screens suppliers to ensure conflict-free sourcing of minerals and product components are constructed of recycled materials wherever possible.

Cee® tools and equipment operate without the use of ozone depleting substances (ODSs) including chlorofluorocarbons (CFCs), methyl chloroform, hydrochlorofluorocarbons (HCFCs), carbon tetrachloride, perfluoro compounds (PFCs), or other volatile compounds/organic solvents.

1.6 General Safety Hazards / Precautions

Read this manual in its entirety before servicing the machine.

The unit is very heavy and proper precautions should be taken to when handling the machine to minimize the risk of injury. Labels are placed on the machine to identify areas where caution is needed during operation.

1.7 Electrical

High voltage is present in the machine. Disconnect power before servicing.

Stored electrical energy is present in the machine. Before servicing allow sufficient time for discharge. The servo amp contains a charge light. Do not service the machine until this light has been extinguished.

1.8 Thermal

Bake plate process modules, if equipped, can reach temperatures sufficient to cause severe burns and may remain hot for a very long-time following operation. Do not service the machine until all surfaces have cooled to a safe thermal condition.

1.9 Mechanical

This machine may contain compressed gases which can provide motive force for components and can expand violently upon decompression. Disconnect N_2 or CDA before removing any panels.

Machines equipped with spin coaters and/or developers are capable of very high-speed rotation. Ensure all lids and panels are in place before rotating these devices.

Ensure that all panels are on and in their correct locations before powering up or operating.

When opening lids be aware of the pinch point at the hinge cover. Open lids only by using the handles on the lids.

1.10 Chemical

Cee® does not supply or dictate chemicals to be used in conjunction with the Cee® Apogee® X-Pro II Workstation or its respective process modules. Enclosure material data will be reviewed during equipment design and configuration to ensure compatibility with the customer's proprietary process.

Prior to introducing new chemicals, refer to your chemical supplier's factory specifications and MSDS. Material Safety Data Sheets (MSDS) contain crucial information regarding chemical safety, including details about hazardous components, physical properties, spill and leak procedures, waste disposal guidelines, and personal protective equipment requirements for handling.

⚠ Ensure chemical compatibility of all chemicals and materials being used inside the machine. This includes all wetted parts of the storage, supply, dispense, and waste systems.

⚠ All dispensed materials are held in one common waste storage tank. Ensure chemical compatibility and verify potential for negative interactions between chemicals before use.

⚠ Potential for flammable chemicals. No open flames/sparks.

⚠ Relieve pressure before opening canisters, tanks, cartridges, or syringes to refill.

⚠ Relieve pressure and shut off chemical valves before servicing supply lines, dispense valves or other components such as EBR/BSR tubes, dispense nozzles, spray tips, or developer lid.

⚠ Flush tubing and valves with an appropriate solvent and drain system before servicing.

⚠ When draining waste tank, use appropriate containers and connection methods.

⚠ Ensure proper ventilation/exhaust is always used.

⚠ Always wear appropriate Personal Protective Equipment. This includes safety glasses, gloves, and other equipment, as needed, to protect from mechanical and chemical hazards.

Exhaust and fume management is important to prevent the release of hazardous materials and ensure a safe working environment. Users should assume that all fumes are hazardous and take appropriate precautions to ensure system exhaust is functional per the guidelines outlined in section 6) of this operations manual.

1.11 Decommissioning & Disposal

The Cee® Apogee® X-Pro II Workstation II requires no special consideration with regard to retiring equipment. Adhere to organizational policy for guidance on decommissioning & disposal to ensure compliance with local, regional, and national hazardous waste regulations.

1.12 Lockout/Tagout Procedures and Information

Before servicing, turn off the machine and remove the power inlet cord by disconnecting the plug where it enters the machine.

Note: There are no LOTO (Lock Out/Tag Out) facilities supplied with the Cee® Apogee® X-Pro II Workstation. It is the responsibility of the customer/installer/end-user to ensure that the suitable LOTO devices are provided on utilities being supplied to the Cee® Apogee® X-Pro II Workstation in accordance with applicable laws, regulations, and/or company policies.

For more information, please contact Cee® Customer Support.

1.13 Intended Use of Machine

The Cee® Apogee® X-Pro II Workstation is intended for use as a semiconductor/optical application machine.

The Cee® Apogee® X-Pro II Workstation is not intended for use in food or medical applications or for use in hazardous locations.

The Cee® Apogee® X-Pro II Workstation is intended for use only by trained personnel wearing the proper personal protective equipment. Anyone not trained in the proper use of the Cee® Apogee® X-Pro II Workstation and having not fully read this manual, should not operate the equipment.

The Cee® Apogee® X-Pro II Workstation is intended for use in a cleanroom or laboratory environment to provide the proper processing conditions for the substrates. If it is used outside of these environments, substrate cleanliness may be compromised.

The Cee® Apogee® X-Pro II Workstation is not intended for use in a hazardous or explosive environment.

Normal Operating Conditions

Ambient Temperature..10°C - 30°C

Relative Humidity..≤80%

Altitude..up to 3000 m

Pollution Degree 2

Overvoltage Category...II

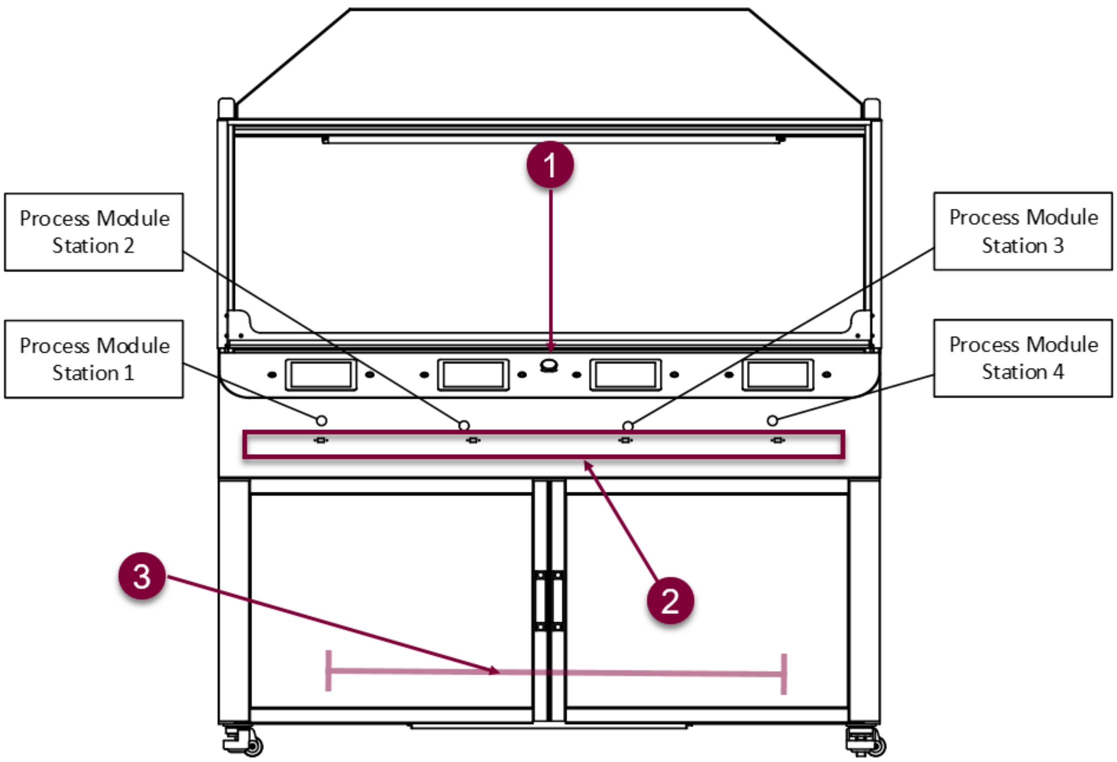
⚠ **If the Cee® Apogee® X-Pro II Workstation is used in a manner not specified by Cee® the protection provided by the equipment may be impaired.**

2) Equipment Description

The Cee® Apogee® X-Pro II Workstation is a modular workbench designed to house the industry leading Cee® Apogee® spin and bake process modules in a cleanroom environment suitable for fume control or reduction of airborne particulate contaminates. The Cee® Apogee® X-Pro II Workstation delivers track-quality performance with revolutionary interface capabilities and the utmost in chemical compatibility, in an efficient, space-saving design.

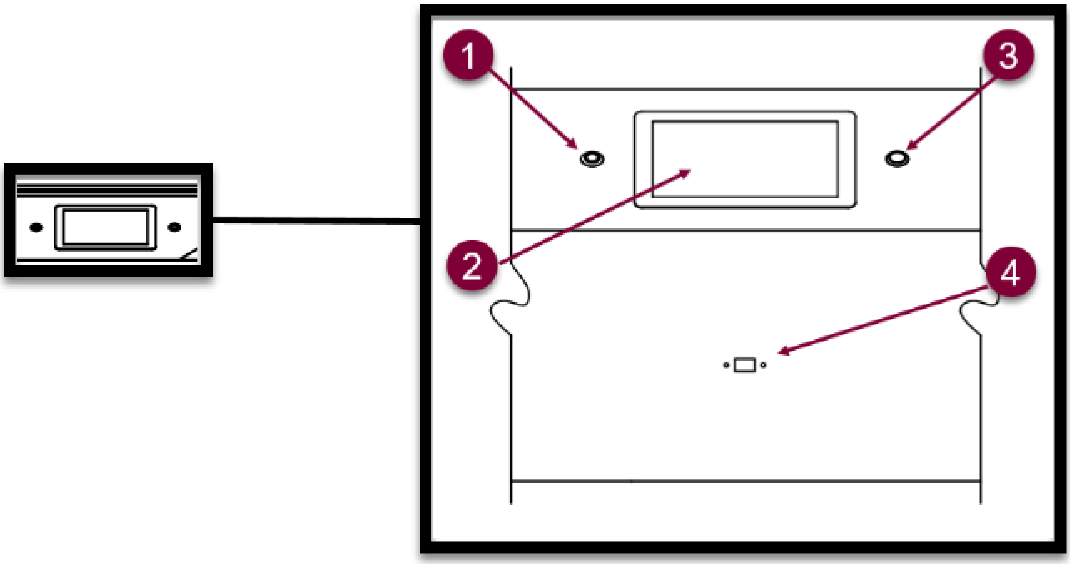
Fully programmable and user-friendly, the Cee® Apogee® X-Pro II Workstation features the accuracy and repeatability need to eliminate processing variability for critical experiments. With its convenient compact footprint, wide array of chemical compatibility, and durability, this easy-to-use benchtop system will provide years of high-performance operation, making your Cee® Apogee® X-Pro II Workstation purchase a smart and cost-effective decision.

2.1 User Controls



1. **emergency machine off (EMO)**........... immediate shutdown of process functions across all process modules
2. **process module station 1-4**[1].............. individual Apogee® process modules and user interface controls
3. **chemical storage cabinet**................... for storage of (optional) Cee® supplied chemical supply vessels

[1] All process modules are pre-installed and configured by Cee® during manufacture.



1. **module local presence**[2]....................... used for remote access
2. **module touch screen interface** .... touchscreen for interaction with process module functions
3. **module power on/off** .... used to turn individual process modules off/on
4. **module USB interface** .... facilitates data transfer per individual process module

2.2 Dimensions

66” (1676.4mm) W x 34.1” (866.1mm) D x 75” (1905mm) H

Machine Weight .... 400-800lbs *(varies with process module configuration)*

2.3 Features & Programmability

- compact & durable wet bench design for minimized footprint
- full-color touchscreen graphical user interface (GUI)
- supports unlimited user-defined program steps for each recipe
- operator convenience outlets for main voltage and USB charging
- updraft, downdraft, HEPA, and ULPA ventilation options available
- 0.1 second step time resolution (9,999.9 seconds maximum step time)
- spin speeds up to 12,000rpm
- spin speed acceleration up to 30,000 rpm/s unloaded
- up/download DataStream™ process parameters via native USB and Ethernet ports
- multiple simultaneous automated dispense capability
- in-process dynamic speed & acceleration control
- three automated bake methods: contact, vacuum, proximity (N_2 or lift pins)
- standard bake plate auto-sizing for 3” and 100mm, 125mm, 150mm, and 200mm substrates
- large format bake plate auto-sizing for 100mm, 125mm, 150mm, 200mm, and 300mm substrates
- up/download DataStream™ process parameters via native USB and Ethernet ports
- height programmed in 0.1 increments with an overall range of 0-19mm
- exhausted hood for removal of process chemical fumes
- optional nitrogen purge for inert bake environment

[2] See DataStream™ Manual for more information.

2.4 Precision

temperature resolution .... 0.1°C

temperature range .... ambient to 300°C *(400°C optional)*

temperature uniformity .... ±3% across working surface

spin speed repeatability .... <0.2rpm *(per standard spin module)*

spin speed resolution .... <0.2rpm *(per standard spin module)*

acceleration resolution .... <0.2rpm/s *(per standard spin module)*

- 0 to 30,000 rpm/s unloaded
- 0 to 23,000 rpm/s with a typical 300 mm silicon wafer
- 0 to 3,000 rpm/s with a 350 mm x 6 mm round recessed spin chuck
- 0 to 400 rpm/s with a 14 in x 14 in x 0.05 in photomask in a recessed chuck *(large format)*

2.5 Reliability

- industry-leading Cee® reliability and uptime
- low maintenance design
- indirect drive system protects spin motor from contact with process chemicals & solvents
- one-year full warranty on parts and labor
- complimentary remote technical support
- application process assistance for the life of the product

2.6 Bowl Design

- high-density polyethylene (HDPE) spin bowl for material compatibility
- optional polyethylene disposable liners available
- versatile lid design allows process flexibility and repeatability
- optional nitrogen purge for an inert spin environment
- integrated drain and exhaust ports

2.7 Utilities

voltage ranges[3] .... 208/230 VAC, 50/60Hz
power requirements .... varies with process module configuration
circuit breaker 30A
X-Pro II drawer exhaust port .... 8” OD
X-Pro II hood exhaust port .... 8” OD
spinner drain port[4] .... ¾” OD external (standard)
spinner module exhaust port .... 1” OD
vacuum .... 20-24 inHg
exhaust .... 20-50cfm at 0.2” water (spinner)
bake module exhaust port .... 2” OD
nitrogen or CDA 70psi

[3] See data plate on rear of machine for power requirements specific to your X-Pro II configuration.
[4] Optional internal drain bottle with full sensor.

3) Installation

3.1 Clearance Requirements

The Cee® Apogee® X-Pro II Workstation is a freestanding unit that requires a sturdy and level floor for location.

Clearance Requirements:

device rear .... 18” (457mm)

device sides.. 3” (76.2mm)

3.2 Facilities Requirements

The Cee® Apogee® X-Pro II Workstation requires the following utilities for operation.

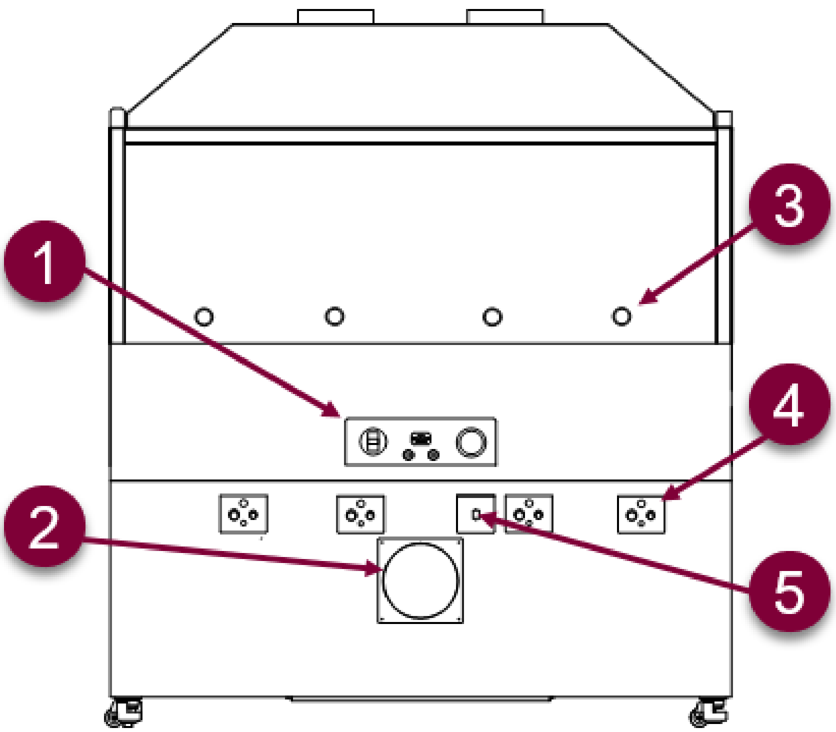


Figure 1: Facilities Connections for the Cee® Apogee® X-Pro II Workstation

1. **power connections** .... detail below
2. **chemical cabinet exhaust** .... external port for chemical cabinet ventilation
3. **bake module exhaust**[5] .... external port for bake plate fumes
4. **spin bowl exhaust/drain**[6] .... external port for spin bowl vapors and liquid drain
5. **Ethernet**... facilitates remote recipe writing and remote device control

[5] Figure depicts workstation equipped with four bake modules.
[6] Figure depicts workstation equipped with four spin modules.

Power Connections

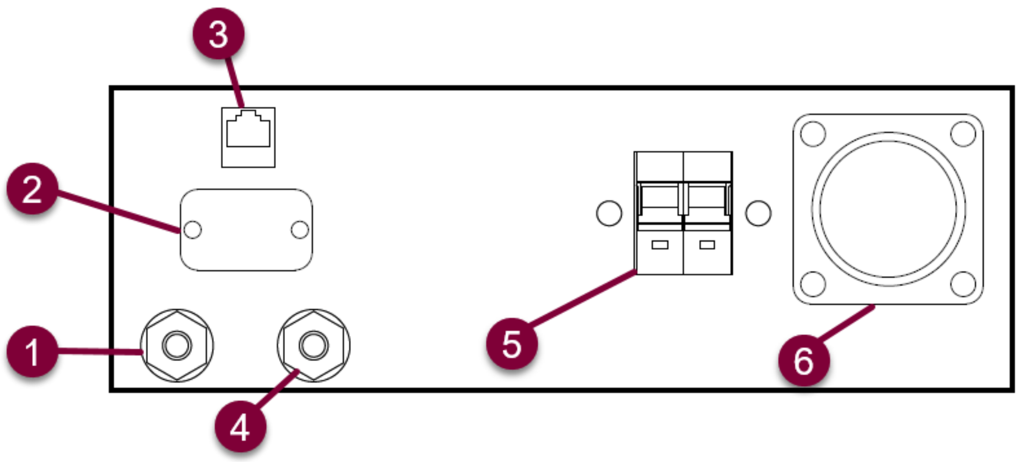


Figure 2: Power Connections for Cee Apogee X-Pro II Workstation

1. system vacuum .... ¼" NPT (National Pipe Taper) threaded connection
2. powered fan filtered unit.................. power supply for optional HEPA/ULPA FFU
3. ethernet .... facilitates remote recipe writing & remote device control
4. system nitrogen............................... ¼" NPT (National Pipe Taper) threaded connection
5. system circuit breaker .... electrical protection for the Cee® Apogee® X-Pro II Workstation
6. power in... single phase AC power in

3.3 Environment

The Cee® Apogee® X-Pro II Workstation should be operated in a clean, low-humidity environment.

3.4 Unpackaging/Inspection

1. Open the packing crate by removing Phillips-head screws and removing side panels.
2. Remove packing foam and plastic wrap.
3. Thoroughly check machine for shipping damage. If physical damage is seen, ***DO NOT APPLY POWER!*** Contact Cee® Customer Support immediately.

The following items are included with shipment:

- (1) Cee® Apogee® X-Pro II Workstation
- (1) power connector
- (1) operations manual (USB thumb drive)

Optionally included items: *(packed within Cee® Apogee® X-Pro II Workstation)*

- dispense systems and related components
- spin chucks with screws
- programmable exhaust
- substrate centering equipment
- waste systems
- vacuum pumps
- bake plate stop pins

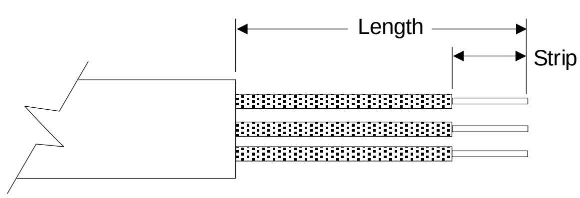
3.5 System Installation & Setup

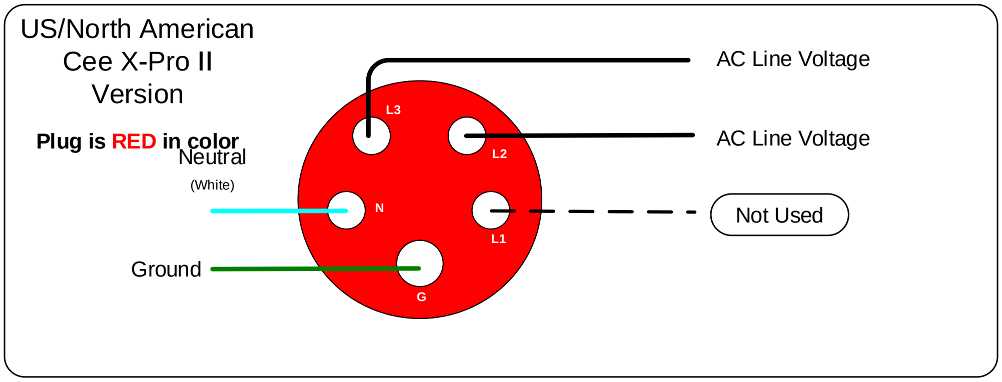
The Cee® Apogee® X-Pro II Workstation is an extremely heavy piece of equipment and will likely require machinery such as a forklift to safely unpackage and move. Do not lift by covers, handles, or protrusions. Do not roll, tip, or turn the unit on its sides or ends.

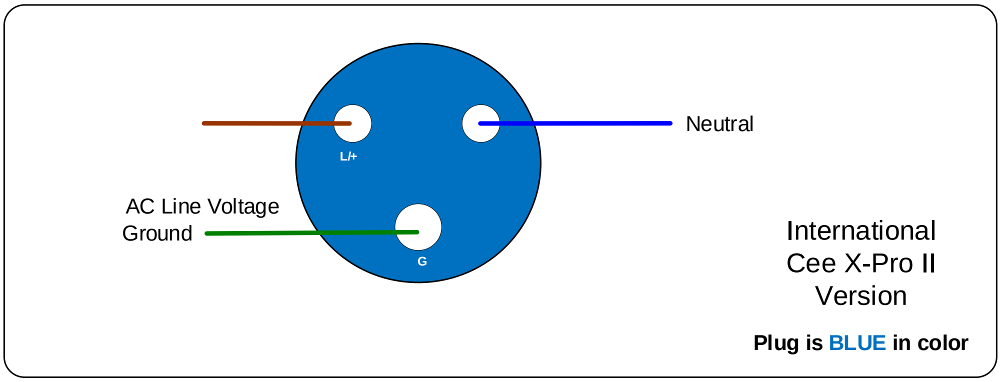
1. Open the bottom doors of the unit. An accessory angle iron is attached for assistance with forking/lifting the unit.
2. Carefully lift the unit off the packing crate base using assistance as required and forking from the front of the equipment.
3. When the Cee® Apogee® X-Pro II Workstation has been removed from the crate base and all lift equipment is clear, raise the leveling feet by turning the orange nuts. Once all four leveling feet are raised, the unit will be free to roll on the casters.
4. Remove and dispose of any remaining packing materials and plastic wrap.
5. *All process modules are pre-installed and configured by Cee® for plug & play usage.
6. Thoroughly clean all process areas of the Cee® Apogee® X-Pro II Workstation modules as well as the exterior of the unit. Refer to section 6.3 for cleaning guidance and follow organizational procedures to prepare the unit for cleanroom or laboratory installation.
7. The rolling cart/drawer is secured with metal angles. For ease of setup, it is recommended that these braces remain intact until the unit reaches its final placement to avoid damage to dispense plumbing/tubing.
8. Place the Cee® Apogee® X-Pro II Workstation on a floor of sufficient strength so that the process module controls, spin chuck(s), and/or bake surfaces are at the proper ergonomic height.
9. Connect utilities according to the reference diagram in section 3.2
    - Connect system vacuum to the vacuum fitting unless supplied with optional vacuum pump.
    - Connect system nitrogen to nitrogen fitting.
    - Connect any supplied spin module drains to the house-supplied drain facility unless optional waste carboys are installed.
    - Connect any supplied spin module exhaust ports to the house-supplied exhaust facility.
    - Connect any supplied bake module exhaust ports to the house-supplied exhaust facility.
    - Connect any supplied spin dispense or other accessory item as indicated in Section 3.2.
10. Identify the supplied electrical plug. A red plug is provided for North American customers the blue plug is for international customers. Wire connectors to the plug as shown in the illustrations below. Cee® only provides the plug to the machine and does not supply wire and connections to the customer's electrical facilities.
    - Allowable cordage diameter for connector strain relief is 0.472" – 0.866" (12mm – 20mm).
    - Maximum conductor size accepted by connector terminals is 10 AWG (4mm)
    - Always observe all local wiring codes, colors, and other applicable industry standards.

Cordage Preparation

All conductors:	2.17" (55mm) "Length"
Ground:	0.59" (15mm) "Strip"
All other conductors:	0.51" (13mm) "Strip"







11. Once plug is wired, connect to the back of the X-Pro, turn the breaker on (up position), twist the EMO to release, and press the Reset button to turn the X-Pro II on. The inside yellow light will turn on. Each module will have turned on individually by pressing the respective power buttons.

3.6 Level Process Modules

Leveling the Cee® Apogee® Spin Coater and/or Developer

Measure the level of the Cee® Apogee® Spin Coater and/or Cee® Apogee® Developer by placing a spin chuck onto the spinner shaft of the module and measuring with a level.

Please note that spin coat and developer modules must be leveled in conjunction with the Cee® Apogee® X-Pro II Workstation. Ensure level by adjusting the feet of the unit before adjusting bake or chill process module mounts (if equipped).

Leveling the Cee® Apogee® Bake Plate and/or Chill Plate

Assess the level of the Cee® Apogee® Bake Plate and/or the Cee® Apogee® Chill Plate by measuring the bake/chill plate surface with a level. Note that bake and chill plate surfaces should tilt backwards *slightly*.

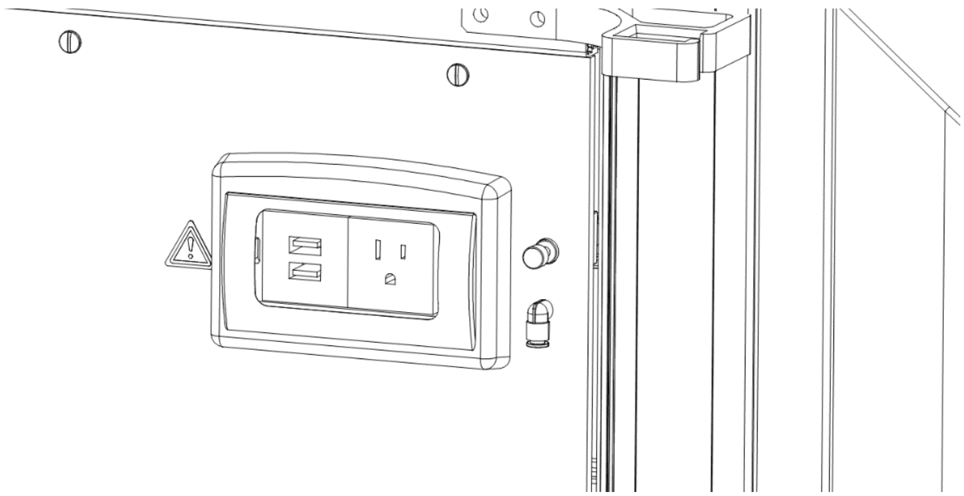
Review section 6.4 for service access instructions.

1. With the service access panel extended, identify four mounting bolts located beneath the module.
2. Each bolt includes a nut above and below the mounting surface for adjustment. Loosen the bottom nut on the mount and use the top nut to adjust the level.
3. Check the level after each adjustment and repeat these steps as needed for each mounting bolt. You may have to repeat these steps several times to achieve the desired result.
4. Once the proper level is achieved, secure the top nut while tightening the bottom nut to ensure position.
5. Reinstall the front panel.

3.7 Accessory Outlets

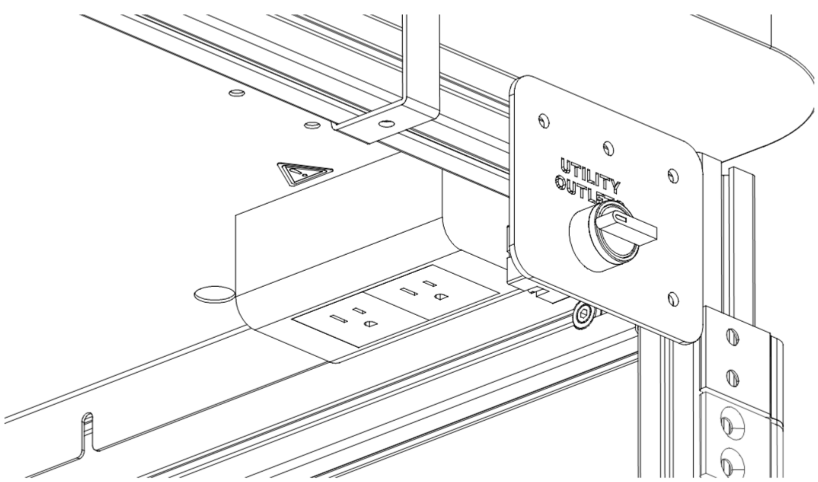
The X-Pro II Workstation is equipped with accessory outlets on the left side and inside the lower cabinet. The accessory outlet installed on the left side of the unit includes a receptacle and USB power (Not a data port).

Utility Outlet
Voltage (AC): 120VAC
Outlet Current (MAX): 15A
USB Outlet
Voltage (DC): 5VDC
Outlet Current (MAX): 1.5A



The accessory outlets installed underneath can be switched off and on with the Utility Outlet switch located at the front. When the switch is lighted, the outlets are powered.

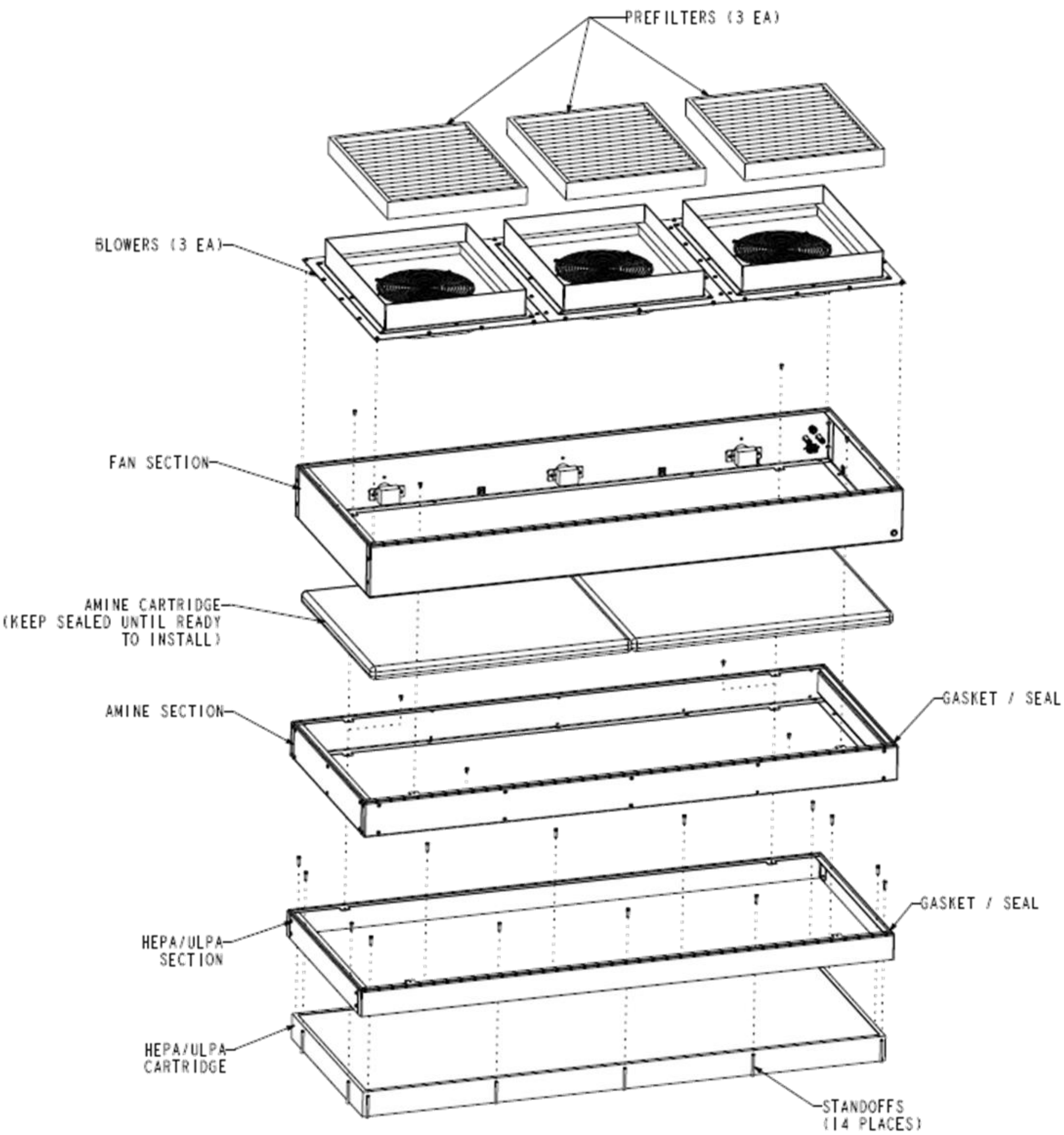
Voltage (AC): 120VAC
Combined Outlet Current (Max): 15A



3.8 Fan Filter Unit (FFU) Installation *(optional)*

***DO NOT* unwrap cartridges until ready to install. Keep amine cartridges lying flat until ready to install.**

1. Attach standoffs to workstation roof with hardware supplied. Place HEPA/ULPA cartridge on workstation roof between standoffs.
2. Install HEPA/ULPA section to top of workstation. Standoffs attach to top surface of workstation. Drop housing over standoffs and attach with supplied screws.
3. Install self-adhesive gasket material along top edge of HEPA/ULPA section.
4. Place amine section on top of HEPA/ULPA section and attach with supplied screws as shown.
5. Unwrap amine cartridge(s) and install in amine section.
6. Install self-adhesive gasket material along top edge of amine section.
7. Place fan section on top of amine section and attach with supplied screws as shown.
8. Connect fan electrical wiring (black 4-pin connector) and attach fans to fan section with supplied screws as shown. Install middle blower first, and then proceed to the two outermost blowers.
9. Install prefilters in the compartment above each blower.



3.9 <u>Start Up</u>

Plug in the machine and flip the circuit breaker (back of machine) to the *on* position. Twist the EMO to ensure that it is not engaged and press the reset button to switch the main power on. Power up the individual process modules by pressing the lighted power switch as indicated in section 2.1. Each display will cycle through a series of boot screens and before arriving at the main login screen.

Enter default administrative login credentials:

Username: .... admin
Password: admin2

3.10 Preliminary Checks

Perform all relevant system checks for each Cee® Apogee® X-Pro II Workstation integrated process module.

3.10.1 Apogee® Spin Coater and or Developer Process Modules

On the ***Process*** screen, navigate to ***Tools>Manual Control*** and perform the following system checks for initial validation of the Cee® Apogee® Spin Coater or Cee® Apogee® Developer.

Vacuum:
Turn the vacuum on and verify that vacuum is pulling through the hole of the spin shaft. Turn the vacuum off and verify that vacuum ceased at the hole of the spin shaft.

Spin Speed:
Close the lid and set spin speed to 1000rpm. Verify that the shaft spins and that the tool reads 1000rpm.

Lid Lock: (*Large Format Spin Coaters/Developers Only)
Attempt to open the spin bowl lid to test the lid lock functionality. If properly functioning, you will NOT be able to open the lid while the shaft is spinning.

Lid Interlock:
If properly functioning, opening the spin bowl lid while spinning > 120rpm will abort the process. Dispenses will not actuate if the lid is not closed.

Temperature & Humidity Sensor:
On the left side of the Process screen, confirm that temperature and humidity readings are present.

Automated Dispense: (optional)
If equipped with automated dispenses, navigate to Tools>Manual Control>Dispenses, tap Dispense 1 to select, then tap Apply to validate that Dispense Triggers are operational. Repeat as needed for additional dispense triggers.

Programmable Exhaust: (optional)
If equipped with programmable exhaust, navigate to Tools>Manual Control>Programmable Exhaust, enter 100 into the field and tap Apply. Verify that the valve is fully open. Next enter 0 and tap Apply to verify that the valve closes completely.

Spin Chuck(s):
Aligning the spin chuck slot with the pin or key on the spin shaft, firmly press the chuck onto the shaft ensuring the pin or key is fully engaged. If equipped, insert chuck screw, and tighten.
Place substrate on the spin chuck.
Navigate to Tools>Manual Control>Vacuum and set vacuum threshold to 64kPa.
If the vacuum is less than 64kPa, the chuck passes inspection.
Turn off the vacuum and remove the substrate. Spin chuck removal is reverse of installation.

3.10.2 Apogee® Bake Process Module

On the ***Process*** screen, navigate to ***Tools>Manual Control*** and perform the following system checks for initial validation of the Cee® Apogee® Bake Plate.

Set Lift Pins:
Select a Control of ***Lift Pins*** and an **Action** of ***Set***. Enter a value into the Height field and tap Apply. Verify Lift Pin Height readings respond to changes on the System Values list.
Inset supplied stop pins into the desired holes on the bake plate surface. These stop pins keep the substrate centered on the bake plate surface. Holes closest to center are for 2" substrates. From center, stop pin locations are for 2", 3", 100mm, 125mm, 150mm, and 200mm substrates respectively.

Bake Methods:
Vacuum - Set Bake Method to ***Vacuum***. Place a substrate on the center of the bake plate and check that the vacuum holds the substrate.
Proximity - Set Bake Method to ***Proximity***. This will turn off the vacuum and purge N2 to float the substrate above the bake plate surface.
Contact - Set Bake Method to ***Contact***. This will turn off vacuum and N2. Remove the substrate.

Temperature & Humidity Sensor:
Ensure the temperature & humidity sensor is functioning by verifying that Ambient Temperature and Humidity readings are present on the System Values List.

Enable & Test Plate Temperature:
Use the Control drop-down to select ***Plate Temperature*** then select an Action of ***Set***, enter the desired plate temperature for your application, and tap *Apply*. *Note that the System Values list displays a Set Point of null (--).

Change the Control selection to ***Plate Temperature*** then select ***Enable*** from the Action and Value dropdowns and tap *Apply*. Note that the temperature entered in the previous step is now displayed as the Set Point in the System Values list. The Actual temperature in the System Values list will increase/decrease as the bake surface heats/cools.

3.10.3 Apogee® Chill Process Module

On the ***Process*** screen, navigate to ***Tools>Manual Control*** and perform the following system checks for initial validation of the Cee® Apogee® Chill Plate.

Set Lift Pins:
Select a Control of ***Lift Pins*** and an **Action** of ***Set***. Enter a value into the Height field and tap Apply. Verify Lift Pin Height readings respond to changes on the System Values list.

Inset supplied stop pins into the desired holes on the chill plate surface. These stop pins keep the substrate centered on the chill plate surface. Holes closest to center are for 2" substrates. From center, stop pin locations are for 2", 3", 100mm, 125mm, 150mm, and 200mm substrates respectively.

Bake Methods:
Vacuum - Set Chill Method to ***Vacuum***. Place a substrate on the center of the chill plate and check that the vacuum holds the substrate.
Proximity - Set Chill Method to ***Proximity***. This will turn off the vacuum and purge N2 to float the substrate above the chill plate surface.
Contact - Set Chill Method to ***Contact***. This will turn off vacuum and N2. Remove the substrate.

Temperature & Humidity Sensor:

Ensure the temperature & humidity sensor is functioning by verifying that Ambient Temperature and Humidity readings are present on the System Values List.

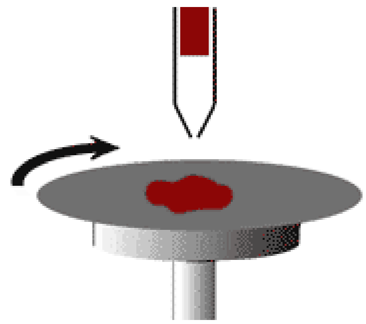
Enable & Test Plate Temperature:

Use the Control drop-down to select ***Plate Temperature*** then select an Action of ***Set***, enter the desired plate temperature for your application, and tap *Apply*. *Note that the System Values list displays a Set Point of null (--).

Change the Control selection to ***Plate Temperature*** then select ***Enable*** from the Action and Value dropdowns and tap *Apply*. Note that the temperature entered in the previous step is now displayed as the Set Point in the System Values list. The Actual temperature in the System Values list will increase/decrease as the chill surface cools.

Once operations have been validated, the Cee® Apogee® X-Pro II Workstation is ready for use. Begin by creating a recipe. See the DataStream™ Manual for more information.

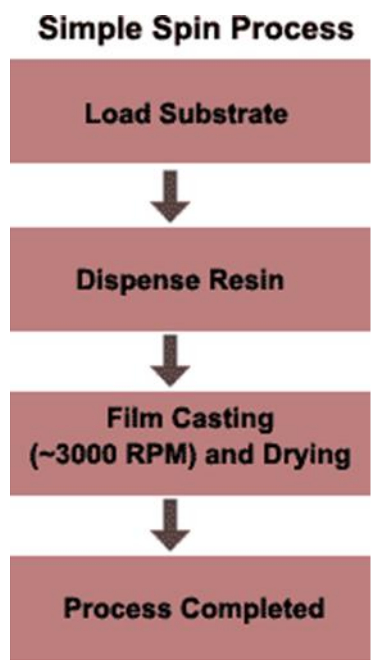
4) Spin Coater Theory



Spin coating has been used for several decades as a method for applying thin films. A typical process involves depositing a small puddle of a fluid material onto the center of a substrate and then spinning the substrate at high speed (typically around 3000 rpm). Centripetal acceleration will cause most of the resin to spread to, and eventually off, the edge of the substrate leaving a thin film of material on the surface. Final film thickness and other properties will depend on the nature of the fluid material (viscosity, drying rate, percent solids, surface tension, etc.) and the parameters chosen for the spin process. Factors such as final rotation speed, acceleration, and fume exhaust affect the properties of the coated films. One of the most important factors in spin coating is repeatability, as subtle variations in the parameters that define a spin-coating process can result in drastic variations in the coated film.

4.1 Spin Coater Process Description

A typical spin process consists of a dispense step in which the resin fluid is deposited onto the substrate surface, a high-speed spin step to thin the fluid, and a drying step to eliminate excess solvents from the resulting film. Two common methods of dispense are Static dispense, and Dynamic dispense.



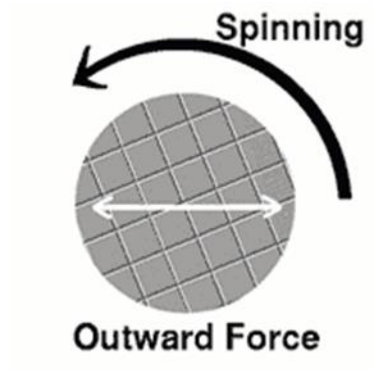
Static dispense is simply depositing a small puddle of fluid on or near the center of the substrate. This can range from 1 to 10 cc depending on the viscosity of the fluid and the size of the substrate to be coated. Higher viscosity and or larger substrates typically require a larger puddle to ensure full coverage of the substrate during the high-speed spin step. Dynamic dispense is the process of dispensing while the substrate is turning at low speed. A speed of about 500 rpm is commonly used during this step of the process. This serves to spread the fluid over the substrate and can result in less waste of resin material since it is usually not necessary to deposit as much to wet the entire surface of the substrate. This is a particularly advantageous method when the fluid or substrate itself has poor wetting abilities and can eliminate voids that may otherwise form.

After the dispense step, it is common to accelerate to a relatively high speed to thin the fluid to near its final desired thickness. Typical spin speeds for this step range from 1500-6000 rpm, again depending on the properties of the fluid as well as the substrate. This step can take from 10 seconds to several minutes. The combination of spin speed and time selected for this step will generally define the final film thickness.

In general, higher spin speeds and longer spin times create thinner films. The spin coating process involves many variables that tend to cancel and average out during the spin process, and it is best to allow sufficient time for this to occur.

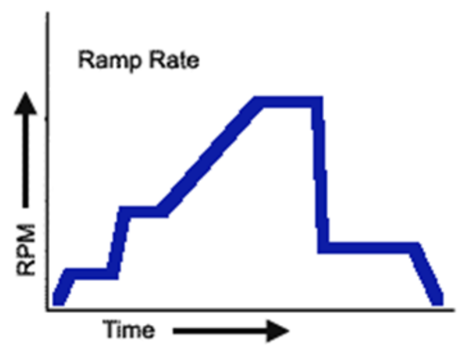
A separate drying step is sometimes added after the high-speed spin step to further dry the film without substantially thinning it. This can be advantageous for thick films since long drying times may be necessary to increase the physical stability of the film before handling. Without the drying step problems can occur during handling, such as pouring off the side of the substrate when removing it from the spin bowl. In this case a moderate spin speed of about 25% of the high-speed spin will generally suffice to aid in drying the film without significantly changing the film thickness. Each program on a Cee® spin coater may contain up to ten separate process steps. While most spin processes require only two or three, this allows the maximum amount of flexibility for complex spin coating requirements.

4.2 Spin Speed



Spin speed is one of the most important factors in spin coating. The speed of the substrate (rpm) affects the degree of radial (centrifugal) force applied to the liquid resin as well as the velocity and characteristic turbulence of the air immediately above it. The high-speed spin step generally defines the final film thickness. Relatively minor variations of Â±50 rpm at this stage can cause a resulting thickness change of 10%. Film thickness is largely a balance between the force applied to shear the fluid resin towards the edge of the substrate and the drying rate which affects the viscosity of the resin. As the resin dries, the viscosity increases until the radial force of the spin process can no longer appreciably move the resin over the surface. At this point, the film thickness will not decrease significantly with increased spin time. All Cee® spin coating systems are specified to be repeatable to within Â±5 rpm at all speeds. Typical performance is Â±1 rpm. Also, all programming and display of spin speed is given with a resolution of 1 rpm.

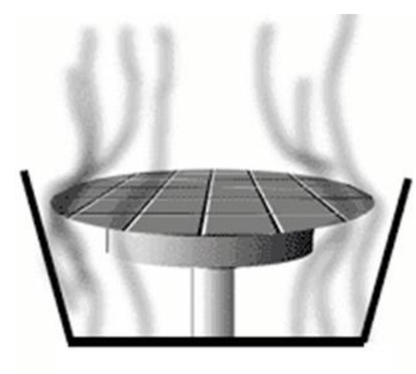
4.3 Acceleration



The acceleration of the substrate towards the final spin speed can also affect the coated film properties. Since the resin begins to dry during the first part of the spin cycle, it is important to accurately control acceleration. In some processes, 50% of the solvents in the resin will be lost to evaporation in the first few seconds of the process.

Acceleration also plays a large role in the coat properties of patterned substrates. In many cases the substrate will retain topographical features from previous processes; it is therefore important to uniformly coat the resin over and through these features. While the spin process in general provides a radial (outward) force to the resin, it is the acceleration that provides a twisting force to the resin. This twisting aids in the dispersal of the resin around topography that might otherwise shadow portions of the substrate from the fluid. Acceleration of Cee® spinners is programmable with a resolution of 1 rpm/second. In operation, the spin motor accelerates (or decelerates) in a linear ramp to the final spin speed.

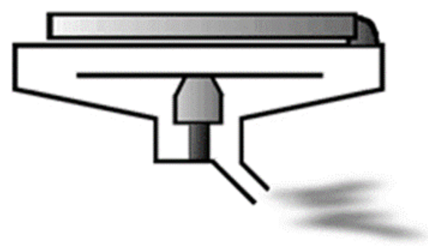
4.4 Fume Exhaust



The drying rate of the resin fluid during the spin process is defined by the nature of the fluid itself (volatility of the solvent systems used) as well as by the air surrounding the substrate during the spin process. Just as a damp cloth will dry faster on a breezy dry day than during damp weather, the resin will dry depending on the ambient conditions around it. It is well known that such factors as air temperature and humidity play a large role in determining coated film properties. It is also very important that the airflow and associated turbulence above the substrate itself be minimized, or at least held constant, during the spin process.

All Cee® spin coaters employ a "closed bowl" design. While not actually an airtight environment, the exhaust lid allows only minimal exhaust during the spin process. Combined with the bottom exhaust port located beneath the spin chuck, the exhaust lid becomes part of a system to minimize unwanted random turbulence. There are two distinct advantages to this system: slowed drying of the fluid resin and minimized susceptibility to ambient humidity variations.

The slower rate of drying offers the advantage of increased film thickness uniformity across the substrates. The fluid dries out as it moves toward the edge of the substrate during the spin process. This can lead to radial thickness non-uniformities since the fluid viscosity changes with distance from the center of the substrate. By slowing the rate of drying, it is possible for the viscosity to remain more constant across the substrate.

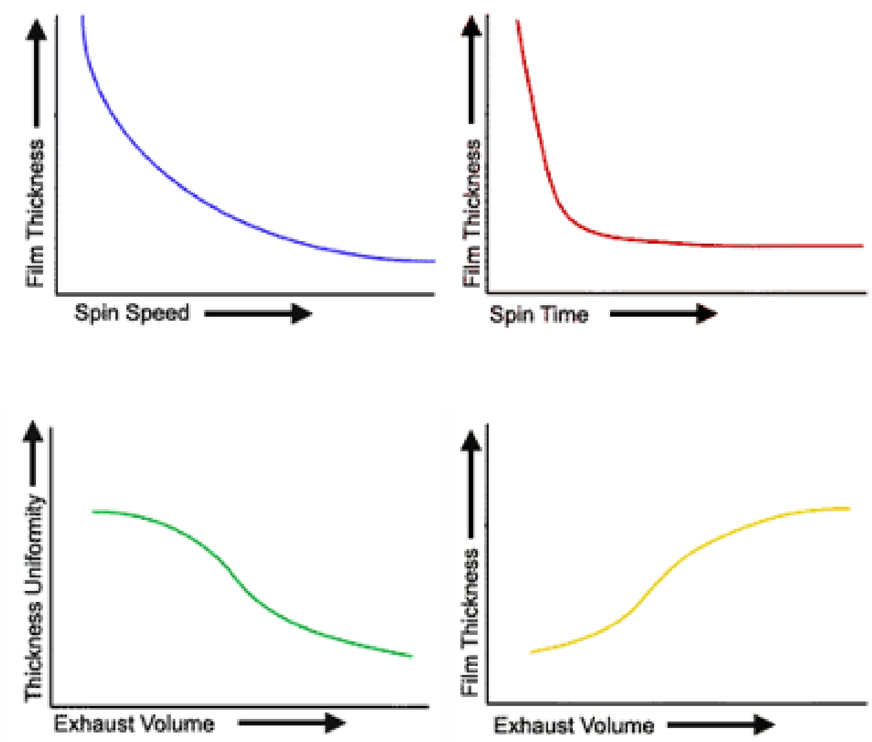


Drying rate and hence final film thickness is also affected by ambient humidity. Variations of only a few percent relative humidity can result in large changes in film thickness. By spinning in a closed bowl, the vapors of the solvents in the resin itself are retained in the bowl environment and tend to overshadow the effects of minor humidity variations. At the end of the spin process, when the lid is lifted to remove the substrate, full exhaust is maintained to contain and remove solvent vapors.

Another advantage to this "closed bowl" design is the reduced susceptibility to variations in air flow around the spinning substrate. In a typical clean room, for instance, there is a constant downward flow of air at about 100 feet per minute (30m/min). Various factors affect the local properties of this air flow. Turbulence and eddy currents are common results of this high degree of air flow. Minor changes in the environment can create drastic alteration in the downward flow of air. By closing the bowl with a smooth lid surface, variations and turbulence caused by the presence of operators and other equipment are eliminated from the spin process.

4.5 <u>Process Trend Charts</u>

These charts represent general trends for the various process parameters. For most resin materials, the final film thickness will be inversely proportional to the spin speed and spin time. Final thickness will also be somewhat proportional to the exhaust volume although uniformity will suffer if the exhaust flow is too high since turbulence will cause non-uniform drying of the film during the spin process.



4.6 Spin-Coating Process Troubleshooting

Film too Thin

spin speed too high.. select lower speed
spin time too long.. decrease time during high-speed step
inappropriate choice of resin material..................... contact resin manufacturer

Film too Thick

spin speed too low .... select higher speed
spin time too short... increase time during high-speed step
exhaust volume too low.. adjust exhaust lid or house exhaust damper
inappropriate choice of resin material..................... contact resin manufacturer

Poor Reproducibility

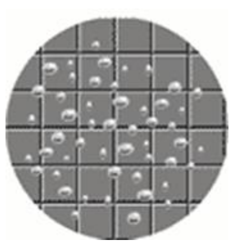
variable exhaust or ambient conditions .... adjust exhaust lid to fully closed
substrate not centered properly.............................. center substrate before operation
insufficient dispense volume .... increase dispense volume
inappropriate application of resin material.............. contact resin manufacturer
unstable balance in speed/time parameters .... increase speed/decrease time or vice versa

Poor Film Quality

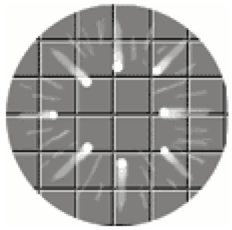
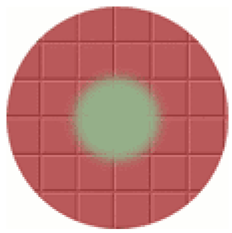
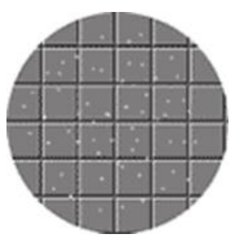
exhaust volume too high .... adjust exhaust lid or house exhaust damper
acceleration too high.. select lower acceleration
unstable balance in speed/time parameters .... increase speed/decrease time or vice-versa
insufficient dispense volume .... increase dispense volume
inappropriate application of resin material.............. contact resin manufacturer

Other Findings

Air Bubbles on Wafer Surface



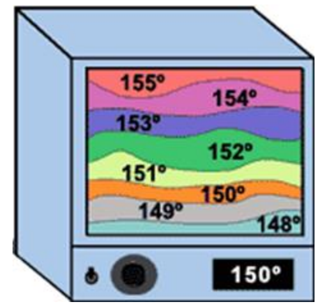
Air bubbles in dispensed fluid (resin).
Dispense tip is cut unevenly.

Comets, streaks, or flares		Fluid velocity (dispense rate) is too high. Spin bowl exhaust rate is too high. Resist sits on wafer too long prior to spin. Spin speed and acceleration setting is too high. Particles exist on substrate surface prior to dispense. Fluid is not being dispensed at the center of the substrate surface.
Swirl pattern		Spin bowl exhaust rate is too high. Fluid is striking substrate surface off center. Spin speed and acceleration setting is too high. Spin time too short.
Center circle *(chuck mark)*		If the circle is the same size as the spin chuck, switch to a Delrin spin chuck.
Uncoated areas		Insufficient dispense volume.
Pinholes		Air bubbles in dispensed fluid (resin). Particles in dispensed fluid (resin). Particles exist on substrate surface prior to dispense.

5) Bake Plate Theory

Hotplate bake processing has increased in popularity since the early 1980s. Previously the most common technique for film drying and curing was the convection oven. Bake plates, also known as hotplates, offer several advantages in the form of increased throughput, increased uniformity and reproducibility, and decreased particle contamination. In a typical bake process, the substrate quickly rises to temperature. Drying and curing steps generally take about one minute. This contrasts with traditional oven processes which generally take thirty minutes or more.

5.1 <u>Bake Plates vs Conventional Ovens</u>

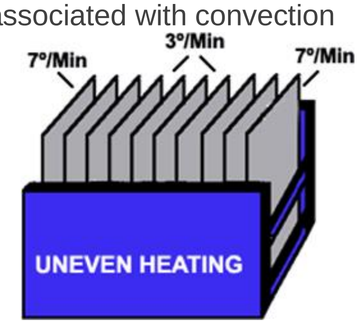


Bake plates have several advantages over conventional ovens.

- decreased bake time
- increased reproducibility
- better film quality

This section will describe these differences and set a few guidelines for using bake plates.

Stratification, the formation of different temperature zones, is a problem associated with convection ovens and can severely affect film quality and reproducibility.



The heating rate of a substrate in an oven depends not only on the heated air flow past a substrate but also on its proximity to other cold substrates. Thus, the heating rate for each substrate in a cassette of substrates that are being baked will be less than if each substrate is baked alone.

In addition, substrates near the ends of a cassette heat faster than the substrates in the middle, producing a non-uniform heating.

Particle generation also occurs within a standard oven. In a forced-air convection oven, substrates are commonly exposed to a flow of particle laden air for at least thirty minutes.

During resin film cures, the substrates will be exposed to considerable particulate contamination. The substrates are vulnerable since the film may still contain solvents and during this *soft* state the film is very susceptible to having particle adhere to it.

5.2 <u>The Skin Effect</u>

Another disadvantage of normal oven baking results from baking substrates from the *outside in*. Since heat is applied to the outer surface of the film first, a skin forms on the surface of the film, trapping solvents. Upon vaporizing, these solvents form blisters or bubbles which results in adhesion loss or even bulk film failure. This problem prevails in processes involving thick film resins, e.g., polyimides.

No skin effect occurs on a hotplate since hotplate baking heats the substrate from the bottom up. This *inside out* approach offers advantages for thick films since solvents in the film nearest the substrate are baked off before the film surface seals over.

5.3 <u>Hotplate Bake Variables and Methods</u>

A typical bake process consists of preheating the surface to a known temperature, loading the substrate onto the surface for a specific length of time and removing it promptly at the end of the cycle.

The selection of the temperature and time values used as well as the bake method employed all affect the overall performance of the process.

5.4 Bake Temperature

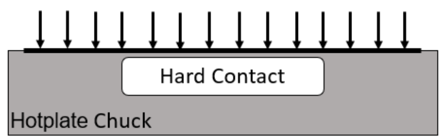
The bake temperature used is dependent on several factors. The material and substrate being baked as well as the results desired are key factors to be considered in developing a bake process

In general, hotplate baking will be performed at temperatures slightly higher than those used in oven bake processes. The film being baked will reach a temperature somewhere between the temperature of the hotplate and the ambient air above the film. As an example, with a hotplate surface temperature of 115°C, a layer of photoresist on a silicon wafer will reach a final temperature of about 105°C after a few seconds. Thicker substrates and/or substrates with lower coefficients of thermal conductivity will require even higher temperatures to compensate for this phenomenon.

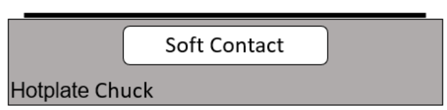
5.5 Bake Methods

Another important factor is the method of bake. Cee® hotplates allow for three distinct bake methods:

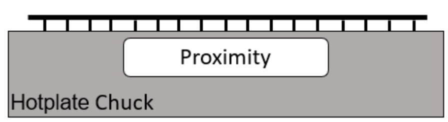
Hard Contact



Soft Contact



Proximity



In a hard contact bake, the substrate is held onto the hotplate surface by the application of vacuum to the underside of the substrate. Small holes are machined into the hotplate surface in a pattern which optimizes vacuum distribution without the formation of cold spots or warping of the substrate. This method is usually preferred for silicon and other flat substrates where back side contact is not a problem.

Soft contact baking uses gravity alone to hold the substate to the hotplate. This method generally offers less uniformity since the substrate-hotplate thermal interface is not as efficient.

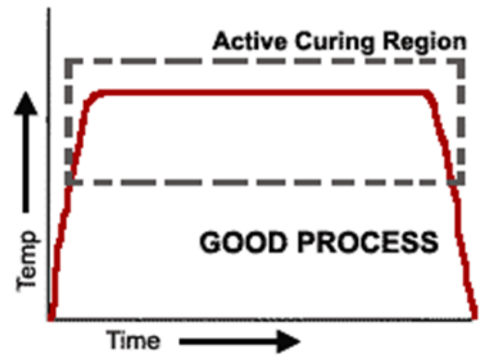
Proximity baking is accomplished by forcing nitrogen through ports in the hotplate surface. This forces the substrate to float at a distance of one to four millimeters (25-100µm) above the hotplate surface. Proximity baking allows for a slower warm-up than contact bake methods and can be advantageous when baking thick films where blistering would otherwise be a problem.

Another advantage of proximity baking is that often, cambered, or warped substrates can be baked with a high degree of uniformity. This is usually not possible with the contact methods since it is not possible to achieve a vacuum under a substrate that is not flat to start with. Processing cambered substrates with the soft contact method creates hot spots where the substrate touches the hotplate and cold spots where it does not. It should be noted as well that this type of proximity process is *self-leveling* in that substrate will tend form a uniform gap to the hotplate surface.

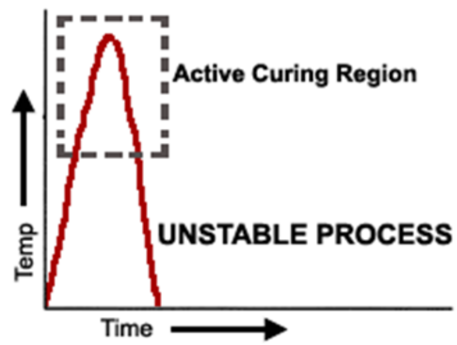
Proximity baking also offers the unique advantage of allowing hotplate processing without touching the bottom side of the substrate. An example of this application is photomask processing. In processing these relatively thick glass plates it is important that the backside of the glass not directly touch the hotplate since rapid heating will cause micro-fractures in the glass. By performing the entire bake process in proximity mode, the integrity of the substrate is not endangered, and the uniformity is excellent.

5.6 Bake Time

The selection of the bake time parameter plays an important role in the reproducibility of the bake process. Substrate thermal properties and the choice of bake method greatly affect the amount of time necessary for the substrate, and therefore film temperature, to stabilize during the bake. Thicker substrates and the use of proximity bake methods will increase the time necessary for the film to reach its final temperature. It is important that most of the baking action in the film take place after this temperature is reached. A silicon wafer will reach a stable temperature within a few seconds and so it is traditional to adjust photoresist bake processes to be completed in 60-90 seconds with an appropriate bake temperature.



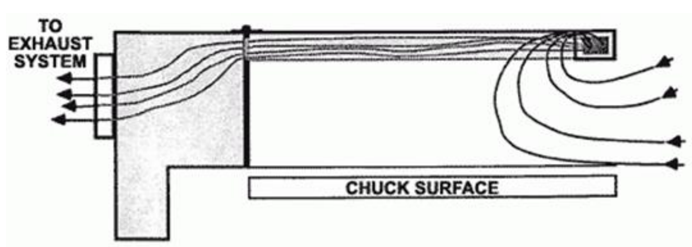
For thicker substrates such as photomask and ceramic modules, the increased time necessary to heat the larger mass of the substrate results in bake times approaching five minutes. It should be noted that these substrates can be processed with higher temperature and shorter bake times, but reproducibility may suffer. If the bake time is too short, a significant amount of the actual bake process will take place during the loading and unloading steps as well as while the substrate is cooling after removal from the bake plate. This is an unstable condition since it is very difficult to exactly reproduce conditions during these steps.



In general, the temperature-time relationship in a bake process can be taken as a dose of the (temperature) x (time) product. Increasing the bake temperature results in a need for decreasing bake time. The limits for both parameters can be reached when the process is no longer reproducible or when the physical temperature limitations of the resin or substrate have been reached.

5.7 Exhaust Cover

The design of the Cee® exhaust cover promotes dissipation of vapors removed from a substrate placed on the chuck, without drawing air across the chuck surface.



5.8 Oven vs Bake Plate Examples

The chart below presents process examples for commonly used resins. These figures should *not* be used as a rigid guideline since the best method with a particular baking application can only be achieved through experimentation.

Application

Positive Photo Resist

Oven Bake

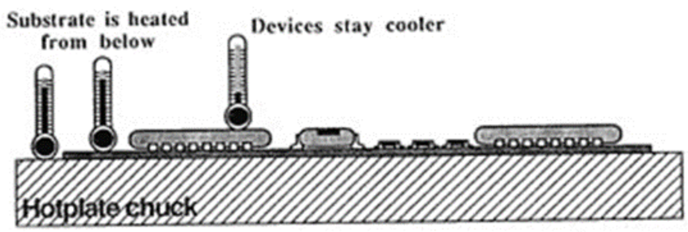
90°C, 30 minutes, Polyimide beta (partial imidization)
135°C, 30 minutes, Polyimide alpha (solvent removal)

Hotplate Bake

115°C, 30 seconds, hard contact bake, Polyimide beta (partial imidization)
150°C, 15 seconds, proximity bake, 150°C-90 seconds, hard contact bake, Polyimide alpha (solvent removal)

5.9 Reflow Soldering

Bake plate processing heats the substrate and the solder without applying heat directly to the devices on the board. Using a combination of proximity and hard-contact bakes, the bake profile can be adjusted to suit any process.



5.10 Bake Plate Process Troubleshooting

As with spin coating process, there are no absolute rules for bake plate processing, only general guidelines. The following is a list of issues to consider for specific bake plate process problems.

Film overbaked

bake temperature too high .... reduce temperature

bake time too long.. decrease bake time

Film underbaked

bake temperature too low.. increase temperature

bake time too short .... increase bake time

Film blistering or cracking

unstable balance in temp/time parameters.............. decrease temp/increase time

warm-up time too fast.. use proximity bake to preheat substrate

Non-uniform bake

unstable balance in temp/time parameters.............. decrease temp/increase time

operating with exhaust lid raised............................. lower the exhaust lid

unstable ambient conditions.................................... protect against major fluctuations

bake time too short .... increase bake time

bake plate surface contaminated .... clean surface of bake plate

6) Preventative Maintenance

6.1 Safety Checks

Inspect the Cee® Apogee® X-Pro II Workstation and included Apogee® Process Modules for the following defects each day prior to use:

Cee® Apogee® X-Pro II Workstation

- missing or loose exterior panels or guards
- improper operation of sash or other movable guards
- proper connection of utility connection facilities such as system nitrogen, system vacuum, and module exhaust facilities.

Cee® Apogee® Spin Coater and/or Developer

- loose assemblies
- improper closure
- improper bowl ring placement

Cee® Apogee® Bake Plate and/or Chill Plate

- loose assemblies
- improper closure
- improper exhaust condition

6.2 Mechanical/Utilities Checklist

Evaluate	Frequency	Detail
Pressure Range	Daily	Check all pressures for ranges specified in tool manual.
Drains	Daily	Verify that there is a proper drain facility.
Exhaust	Daily	Verify that exhaust is functioning.
Spin Chuck Cleanliness	Daily	A dirty spin chuck could cause vacuum errors. Wipe the spin chuck clean with isopropyl alcohol or acetone. For major buildup of material, a glass slide can be used to gently scrape the material away and then wipe clean. See the Cleaning section for more detailed instructions.
Bake Plate Surface	Weekly	A dirty bake plate may result in vacuum errors. Wipe light build up from the bake plate surface with isopropyl alcohol or acetone. For major buildup of material, a glass microscope slide can be used to gently scrape the material away. Hold the slide at a 45° angle so you do not scratch the

		surface and then wipe clean with isopropyl alcohol or acetone.
Water Chiller Reservoir	Monthly	Confirm the water chiller fluid level is within the acceptable range shown on the rear cover of the chiller unit.
Spin Chuck Flatness	Quarterly	A non-uniform spin chuck can cause vacuum errors. Inspect visually against a straight edge. Small uniformity issues such as a burr can be gently removed with a glass slide. Larger deformations can be removed with fine sandpaper. Contact Cee Customer Support if the above methods are not successful.
Bearing Wear	Quarterly	Bad bearings can cause erratic spin speed and acceleration. When rotating the spindle shaft by hand, the shaft should spin easily with little noise. If the shaft does not spin easily or if a grinding noise is heard during a process, the bearing should be replaced.
Vacuum at Spindle	Quarterly	If low vacuum is present, check system supply. If supply is in spec and problems persist, contact Cee Customer Support for more information.
Vacuum Liquid Trap	Quarterly	Material in the vacuum trap will cause vacuum issues. There should be no material in the vacuum trap.
Lift Pin Planarity	Quarterly	Evaluate the plane of the wafter relative to the bake plate surface. If an angle is present, adjust lift pins to compensate/level.
Lift Pin Height	Quarterly	Measure wafer height against programmed lift pin settings and calibrate as needed.
Axial Spindle Shaft Play	Bi-Annually	Axial play will cause excess bearing wear and possible vacuum error. There should be no axial play in the shaft.
Connections	Bi-Annually	Inspect all connections for proper installation.
Power	Bi-Annually	Verify that AC power is connected and of the proper voltage.

6.3 Cleaning

The Cee® Apogee® X-Pro II Workstation should be cleaned following daily use. When cleaning the spin chuck, remove it from the equipment to keep solvent from getting into the spin coater vacuum system. It is good practice to use the mildest solvent possible such as acetone or isopropyl alcohol. ***Do not use caustic acids or bases.***

When cleaning the spin bowl, a small substrate should be on the spin chuck to keep solvent from getting into the vacuum system. Spin the wafer at approximately 100 RPM and use solvent in a wash bottle to flush out the spin bowl. Keep solvent from going down the spin shaft or the spin shaft tube. Shields and seals will protect the bearings from a small amount of solvent, but they will not tolerate large doses. Do not direct the solvent stream down the shaft or tube.

Bake and/or chill plate surfaces may be wiped clean with acetone or isopropyl alcohol. For major buildup of material, gently scrape the plate with a glass microscope slide. Position the slide at a 45° angle to avoid damage to the plate surface. Wipe clean with acetone or isopropyl alcohol.

Use only water-based cleaner on the labels on the rear of the machine. Use only isopropyl or water-based cleaner on the *Power*, *Cee®* logo, *Caution ... Eye Protection*, and the *Cee® model/serial number* labels. The display may be cleaned with glass cleaner, water, or isopropyl alcohol.

6.4 Service Access

Please ensure that all electrical power, compressed gasses, and other energy sources are shut off and/or disconnected before removing panels or performing service on the Cee® Apogee® X-Pro II Workstation and/or integrated process modules. Ensure that all panels are fitted and locked into place before restoring utility service. ***Failure to observe these guidelines may result in damage to the Cee® Apogee® X-Pro II Workstation, personal injury, or death.***

The user panel is designed to slide forward for convenient service access to the integrated process modules. To release the panel, open the access doors to the chemical storage cabinet of the Cee® Apogee® X-Pro II Workstation. Identify the two metal clips holding the user interface panel in place and unthread the fixing screws securing them. Once the clips are free, the user interface panel can be extended outward on roller slides providing access to the process modules.

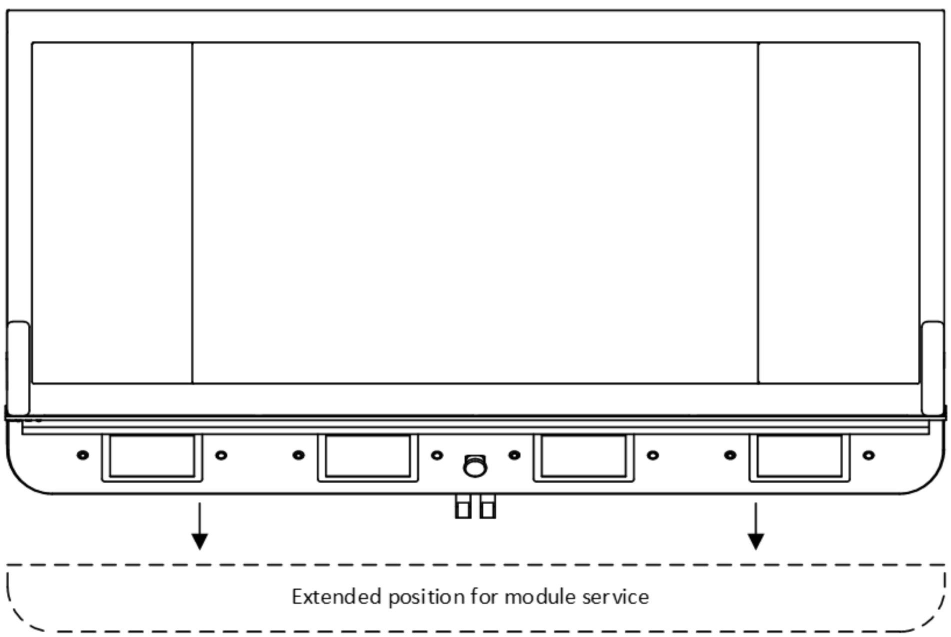


Figure 3: Service Access to Integrated Process Modules

Once the necessary maintenance/repairs are complete, push to close the user interface panel and reattach the holding clips and fixing screws. In doing so, ensure that no cables are pinched anywhere along the length of the user interface panel before tightening the fixing screws to hold that clips and panel in place.

Additional service access can be obtained by removing the plastic side panels of the Cee® Apogee® X-Pro II Workstation. The panels can be easily removed with a slotted screwdriver by turning the slotted panel hardware ¼ turn until it releases and pops free from the surface of the panel. Once all fasteners have been released the panel(s) can be pulled from the Cee® Apogee® X-Pro II Workstation frame.

7) Table of Revisions

Doc Rev #	Author	Description of Change(s)	Reviewed/Approved By	Date
1.2	J. Adams	Update *Apogee* from ™ to ® post patent changes.	B. Waterworth	10/05/2023