



FC 1800 #3 User Instructions

General Precautions

Contacts

For problems, clarification of procedures, or general information pertaining to this machine please contact lab staff at staff-ndnf-list@nd.edu.

**In Case of Emergency, Please Contact Notre Dame Security at
911**

Sweeping of the Electron beam is Mandatory. Failure to sweep the beam can cause damage to the machine and cause you to lose your privileges to use this machine.

If any step does not respond as it should, stop and put the machine into standby if you can and contact help. If unsure on how to get to standby mode safely, leave the machine as it is and contact fab staff as soon as possible.

Standby Conditions

(These conditions allow for the safest and best conditions for the machine, your safety, and the best results for your research)

1. Main Chamber lid should be closed and under High Vacuum.
2. Verify that a plastic shield is behind the top view port. If not, contact staff before proceeding.
3. Valves that should be illuminated, open, or on in Standby conditions on the automatic pump down controller.
 - a. "Cryo Isolation"
 - b. "Cryo pump"
 - c. Gate should be in the "away" position.
4. Valves that should closed or not be illuminated in Standby Mode.
 - a. "Roughing" Valve
 - b. "Fore Line" Valve
 - c. "Mechanical Pump"
 - d. "Vent" Valve
 - e. "Hi Vac" Position
 - f. "Home" Position
5. Shutter in "Auto" position (indicator not illuminated).
6. Bottom view port shutter is in closed position.
7. High Voltage & Emission (e-beam gun) Controllers should be off.
8. CV14 Main Breaker OFF.

Depositing a metal

From Standby Conditions:

1. Enable FC 1800 #3 in iLab. Machine will not operate unless enabled.
2. Follow the procedure to “To change a sample” on Page #6. If you need assistance, ask for help!
3. Follow the procedure “Programming the SQM-160” to setup the film thickness monitor on Page #7.
4. Switch the pocket to the position of your desired source by rotating the thumbwheel on the Pocket Selector to the desired number. When the numeric display reads your position then the pocket has moved to your settings. The pocket metal list is located just below the SQM 160 Film Thickness Monitor.
5. Wait for the system vacuum to be below 2×10^{-6} to continue.
6. Pull up on the High Voltage Power Supply Breaker to turn it on. Located on the front of the High Voltage Power Supply.
7. Verify interlock light stacks on CV-14 HVPS Controllers:
 1. On the Gun Controller:
 - i. “Vac Tank” is illuminated.
 - ii. “Vac Gauge” is illuminated.
 - iii. “Gun Water” is illuminated.
 - iv. “Aux” is illuminated.
 - v. “Focus” is illuminated.
 - vi. “Gun 1 Tank 1” is illuminated.
 2. On the HVPS Controller:
 - i. “Power ON” is illuminated.
 - ii. “Triode Water” is illuminated.
 - iii. “Doors” is illuminated.
 - iv. “Air” is illuminated.
 - v. “PC Cards and key lock” is illuminated.
8. Verify “Emission Current” knob is fully counter clockwise.
9. Turn High Voltage on by depressing the “HV ON” button on the High Voltage Controller.
10. Switch on the Filament on by depressing the “GUN 1 Fil ON” button on the gun controller.
11. Open the shutter by pushing the shutter switch up on the shutter controller.
12. Verify filament is on by looking thru the view ports and making sure a white light is coming from the filament area. NOTE: May need to look thru bottom viewport due to Cryo Restriction Plate.
13. **Slowly** advance “Emission Current” on the gun controller until you are just able to see the blue beam spot on the crucible when looking into the top view port.
14. Position the beam on the metal **inside** the crucible by adjusting the lat and long beam position on the XY controller for the settings you are wanting. **Warning:** The beam spot should never come into contact with the crucible walls or turret at any time or location
15. Verify the beam is sweeping across the source within the crucible. **Warning:** Failure to sweep the beam can cause damage to the source crucible, turret, FC 1800 system, your wafers, and/or your privileges to use this machine.
16. Close the shutter by pushing down on “shutter” switch on the shutter controller.
17. **Slowly** ramp current over a couple of minutes until a deposition rate of 0.5 to 1 Å/s on the film thickness monitor is achieved.
18. **Slowly** increase emission current by turning the “emission current” control pot on the gun

controller until you have reached your desired deposition rate.

1. After deposition rate of 0.5 to 1 Å/s is achieved, you must **slowly** advance the emission current. A tiny nudge causes noticeable rate change.
 2. 1 to 3 Å/s is typical and recommended for most materials and applications. Higher rate should be discussed with staff first before doing that. Bad things can happen faster at higher rates.
19. To start deposit onto your substrate: zero Film thickness meter by pressing “zero” and open shutter by pressing up on the “shutter” toggle switch on the shutter controller.
1. Keep monitoring the rate.
 2. Keep monitoring the tool status.
 3. Wait until desired thickness is almost achieved
 4. For longer-than-1-hour deposition of one material, you must turn off the current and high voltage after every one-hour deposition and wait 10 mins to let the HVPS cool down before continuing.
20. When the target thickness is achieved, close shutter by pressing down on the “shutter” toggle switch on the shutter controller.
21. Set emission current to ZERO by rotating the “emission current” control pot fully CCW on the gun controller **slowly** but continuously.
22. Switch off Filament by pressing the “GUN 1 FIL OFF” button on the gun controller.
23. Switch off HV by pressing “HV OFF”, located on the High Voltage controller.
24. **Wait 10 minutes** for turret and source to cool down from last deposition before continuing to the next step.
25. Repeat step #3 thru step #24 for as many layers as you need.
26. Push down on the High Voltage Circuit Breaker on the CV-14 High Voltage Power Supply.
27. To remove your samples, follow the procedure “Change a sample” on page #6.
28. Remove the plastic shield behind the top view port. Put it in the METAL RECLAIM bag by Oerlikon evaporator.
29. Place a new plastic shield behind the top view port. Make sure it is not falling off the clamps easily!!! Use a tape to fix it in place if needed. Warning: If a plastic shield fell into the chamber, it can cause source contamination or damage to the filament assembly
30. Verify the machine is in Standby.
1. Main Chamber lid should be closed and under High Vacuum.
 2. Valves that should be illuminated, open, or on in Standby conditions on the automatic pump down controller.
 - i. “Cryo Isolation”
 - ii. “Cryo pump”
 - iii. Gate should be in the “away” position.
 3. Valves that should not be illuminated or open in Standby Mode.
 - i. “Roughing” Valve
 - ii. “Fore Line” Valve
 - iii. “Mechanical Pump”
 - iv. “Vent” Valve
 - v. “Hi Vac” Position
 - vi. “Home” Position
 4. Shutter should be on “Auto” and the indicator should not be illuminated.
 5. HV & Gun Controllers should be off.
 6. Ion Vacuum Gauge should be heading into the 10^{-6} range or better.
31. Disable the machine in iLab, take trash with you when you leave the machine.

To change a sample:

1. Move the Gate Valve to the "Home" position.
2. Verify the indicator light switches from "Away" to "Home".
3. Close the "High Vac" valve by pressing down on the switch labeled "High Vac".
4. Verify the "High Vac" light comes on and the "Home" light goes out.
5. Open the N₂ "Vent" valve by pressing up on the switch labeled "Vent".
6. Verify the "Vent" light illuminates.
7. Allow a minute or so for the load lock chamber to come up to atmosphere pressure.
8. After the lid has been released from vacuum, it will pop up slightly. Pull up and open the lid carefully without touching anything else behind the machine. Pay attention to the LN₂ stacks.
9. Make sure a new and clean plastic shield is in place for your deposition. As a rule, always verify there is a new shield installed when you put your sample in and always change the shield after your deposition.
10. Clean cryo restriction plate with a wipe and alcohol as needed.
11. Install or remove samples on the sample holder. Note that the sample holder cannot be removed!
12. Verify the Lid O-ring has not popped out of the groove.
13. Verify the Cryo Restriction Plate is properly installed.
14. Pull down the lid and set it gently down on the O-ring.
15. Start mechanical pump by depressing the "ON" button on the M.P. Control.
16. Wait for 10-15 seconds for the mechanical pump to start.
17. Close N₂ "Vent" Valve by pressing down on the switch labeled "Vent" on the Automatic Pump Down Controller.
18. Verify the "Vent" indicator goes out.
19. Open the "roughing" valve by pressing up on the switch labeled "roughing" on the Automatic Pump Down Controller.
20. Verify the "roughing" indicator illuminates.
21. Allow system to pump down to 5.0×10^{-2} Torr or lower on Gauge A.
22. Close "roughing" Valve when the gauge A reads less than 5.0×10^{-2} Torr by pushing down on the switch labeled "Roughing" on the Automatic Pump Down Controller.
23. Verify the "Roughing" indicator goes out.
24. Open "High Vac" by pressing up on the switch labeled "High Vac".
25. Verify "High Vac" indicator goes out and the "Home" indicator illuminates.
26. Move the gate valve to the "Away" position by pressing up on the switch labeled "Gate".
27. Verify the "Home" indicator goes out and the "Away" indicator illuminates.
28. Shut off the mechanical pump by depressing the "stop" button on the M.P. Controller

Programming the SQM 160:

This monitor is capable of retaining the characteristics of 9 different films. However due to the many different films we use here at ND, the number of users this machine has, and the amount of use it sees I suggest that you verify your information every time you use this machine.

1. If you start using this monitor and it is displaying CRYSTAL 1, press “Xtal life” button to bring it back to its normal view. This reading shows the amount of life the Crystal has left.
2. Press “Zero” button to zero the monitor readings.
3. On the film thickness monitor. Press the “program” button.
4. Pick your film by rotating the knob to the loaded film number.
5. Press “Next” button. “Density” should be displayed. Density and Z-Factor charts will be available in Appendix B and posted on side of the control rack as well.
6. Rotate the knob until the density you want is displayed.
7. Press “Next” button. “Tooling” should be displayed.
8. Rotate the knob until the tooling for your sample holder is displayed. Appendix A contains a list of tooling factors for the different sample holders and will be posted on side of control cabinet as well. **NOTE:** Do not use the numbers from FC 1800 #1, these numbers will be wrong for the setup in the FC1800 #3.
9. Press “Next” button. “Z-Factor” should be displayed.
10. Rotate knob until the Z-Factor you desire is displayed. Density and Z-Factor charts will be available in Appendix B and posted on side of control rack as well.
11. Press “Next” button. “Finl Thk” should be displayed. This step saves the last setting of “Z-factor” into the program.
12. Press “Program” button to exit program mode. It is now ready for the deposition.
13. Go to step 4 on page #4.

NOTE1: The Film thickness monitor does not stop sampling of the deposition when you close the shutter. You will need to watch the monitor and log the thickness when you close the shutter.

NOTE2: The Film Thickness Monitor should be on at all times.

LN₂ operations (Start Procedure):

See Figure #5 on page #12 for the LN Controls

From Standby Conditions:

1. Enable FC 1800 #3 in iLab. Machine will not operate unless enabled.
2. Follow the procedure to "To change a sample" on Page #6.
3. Wait for the system vacuum to be below 20×10^{-6} to continue.
4. Turn Cold Plate Valve to "LN Flow".
5. Turn on the LN, located on the wall behind the evaporator.
6. On the Meissner Trap Controller, flip the switch from "Off" to "Auto".
7. Wait 2 hours for the Meissner trap to remove the moisture and contamination of the system.
8. Wait until the Vacuum on the Ion Gauge Controller is in the middle of the 10^{-7} range.
9. Turn Substrate Plate LN₂ Cooling controller key switch to "ON".
10. Turn the Substrate Plate Temperature Indicator to "ON".
11. On the Substrate Plate LN₂ Level controller, turn the power switch from "Off" to "Auto".
12. Wait until the Substrate Plate Temperature Indicator reads about 80 Kelvin.
13. Pull up on the High Voltage Power Supply Breaker to turn it on. Located on the front of the High Voltage Power Supply.
14. Open the front left main chamber door and open the top (E-Gun) and bottom (Sensor) chilled water valves.
15. Follow the procedure "Programming the SQM-160" to setup the film thickness monitor on Page #7.
16. Switch the pocket to the position of your desired source by rotating the thumbwheel on the Pocket Selector to the desired number. When the numeric display reads your position then the pocket has moved to your settings. The pocket metal list is located just below the SQM-160.
17. Verify interlock light stacks on CV-14 HVPS Controllers:
 - a. On the Gun Controller:
 - i. "Vac Tank" is illuminated.
 - ii. "Vac Gauge" is illuminated.
 - iii. "Gun Water" is illuminated.
 - iv. "Aux" is illuminated.
 - v. "Focus" is illuminated.
 - vi. "Gun 1 Tank 1" is illuminated.
 - b. On the HVPS Controller:
 - i. "Power ON" is illuminated.
 - ii. "Triode Water" is illuminated.
 - iii. "Doors" is illuminated.
 - iv. "Air" is illuminated.
 - v. "PC Cards and key lock" is illuminated.
18. Turn High Voltage on by depressing the "HV ON" button on the High Voltage Controller.
19. Switch on the Filament on by depressing the "GUN 1 Fil ON" button on the gun controller.
20. Open the shutter by pushing the shutter switch up on the shutter controller.
21. Verify filament is on by looking thru the view ports and making sure a white light is coming from the filament area. NOTE: May need to look thru bottom viewport due to Cryo Restriction Plate.

22. Advance Emission Current on the gun controller until you are just able to see the blue beam spot on the crucible when looking into the top view port.
23. Position the beam on the metal inside the crucible by adjusting the lat and long beam position on the XY controller for the settings you are wanting.
24. Verify sweeping of beam by increasing the Long and Lat Freq. switches on the XY controller if necessary. **Warning:** Failure to sweep the beam can cause damage to the source crucible, turret, FC 1800 system, your wafers, and/or your privileges to use this machine. The beam spot should never come into contact with the crucible walls or turret at any time or location.
25. Close the shutter by pushing down on “shutter” switch on the shutter controller.
26. Slowly ramp current over a couple of minutes to 2-3Angstroms per second on the film thickness Monitor. Allow the crucible to heat for approximately 2 minutes.
27. Slowly increase emission current by turning the “emission current” control pot on the gun controller until you have reached your desired deposition rate.
28. Zero Film thickness meter by pressing “zero” and open shutter by pressing up on the “shutter” toggle switch on the shutter controller. Wait until desired thickness is almost achieved.
29. Close shutter by pressing down on the “shutter” toggle switch on the shutter controller.
30. Set emission current to ZERO by rotating the “emission current” control pot fully CCW on the gun controller slowly but continuously.
31. Switch off Filament by pressing the “GJN 1 FIL OFF” button on the gun controller.
32. Switch off HV by pressing HV OFF, located on the High Voltage controller.
33. Wait 10 minutes for turret and source to cool down from last deposition before continuing to the next step.
34. Depress “GUN 1 off” button on the Gun Controller to turn off the Filament.
35. Depress “HV Off” on the High Voltage Controller to turn off the High Voltage.
36. Repeat step #15 thru step #36 for as many layers as you need.
37. Push down on the High Voltage Circuit Breaker on the CV-14 High Voltage Power Supply.
38. Close all chilled water valves.
39. Turn off LN₂ valve on the wall behind the evaporator.
40. Allow 15 minutes for machine to use the remaining LN₂.
41. Behind the machine, Turn Cold plate valve from LN₂ to N₂ Purge.
42. Open the Trap Purge valve slowly.
43. Wait 1 hour for machine to warm up.
44. To remove your samples, follow the procedure “To change a sample” on page #7.
45. Verify the machine is in Standby Conditions on Page # 3.



Figure 1: HVPS Controls
High Voltage and Beam Control sitting on top of the CV14 power supply.



Figure 2: Lid Interior
Lid Sample holder in the center and cooling coils on the outer edge of the lid.



Figure 3: Gate restriction plate;
To protect the lid interior never start beam without this in place.



Figure 4: Shutter Control (Top Left), Mechanical pump Control (Top Right), and Pocket Selector (Bottom).



Figure 5: Regeneration Control (Top Left) And LN controls (Bottom and top Right).

Appendix A:

Tooling Information

Cold Plate: 112

Appendix B:

Density and Z-Ratio Chart

Material	Formula	Ratios	Density	Z-Ratio
Aluminum	Al		2.700	1.080
Chromium	Cr		7.200	0.305
Cobalt	Co		8.710	0.343
Copper	Cu		8.930	0.437
Gold	Au		19.300	0.381
Gold Palladium	AuPd	60/40	16.380	0.371
Iron	Fe		7.860	0.349
Manganese	Mn		7.200	0.377
Molybedum	Mo		10.200	0.257
Nickel	Ni		8.910	0.331
Palladium	Pd		12.038	0.357
Permalloy	NiFe	81/19	8.711	0.334
Platinum	Pt		21.400	0.245
Scandium	Sc		2.99	0.910
Silicon	Si		2.320	0.712
Silicon Dioxide	SiO ₂		2.65	1.070
Silver	Ag		10.500	0.529
Superalloy	NiFeMoMn	79/16.7/4/.3	8.781	0.341
Tin	Sn		7.300	0.724
Tin Aluminum	SnAl	95/5	7.070	0.742
Titanium	Ti		4.500	0.628
Tungsten	W		19.300	0.163
Bismuth Telluride	Bi ₂ Te ₃		7.6	0.514