thermionics laboratory, inc.

VE-160-PVD System Manual

Document Control Number

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Version 2.0

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VE-160-PVD System Manual
DC-OM-1013
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1.0 PRODUCT DESCRIPTION

1.1 GENERAL DESCRIPTION

The VE-160-PVD system is a high vacuum deposition system which has been designed for deposition using an e-Gun™ and/or resistive means, co-deposition of both e-Gun™ and resistive means is possible.

VE-160-PVD: Sales Order Number 10373

Figure 1: Front View

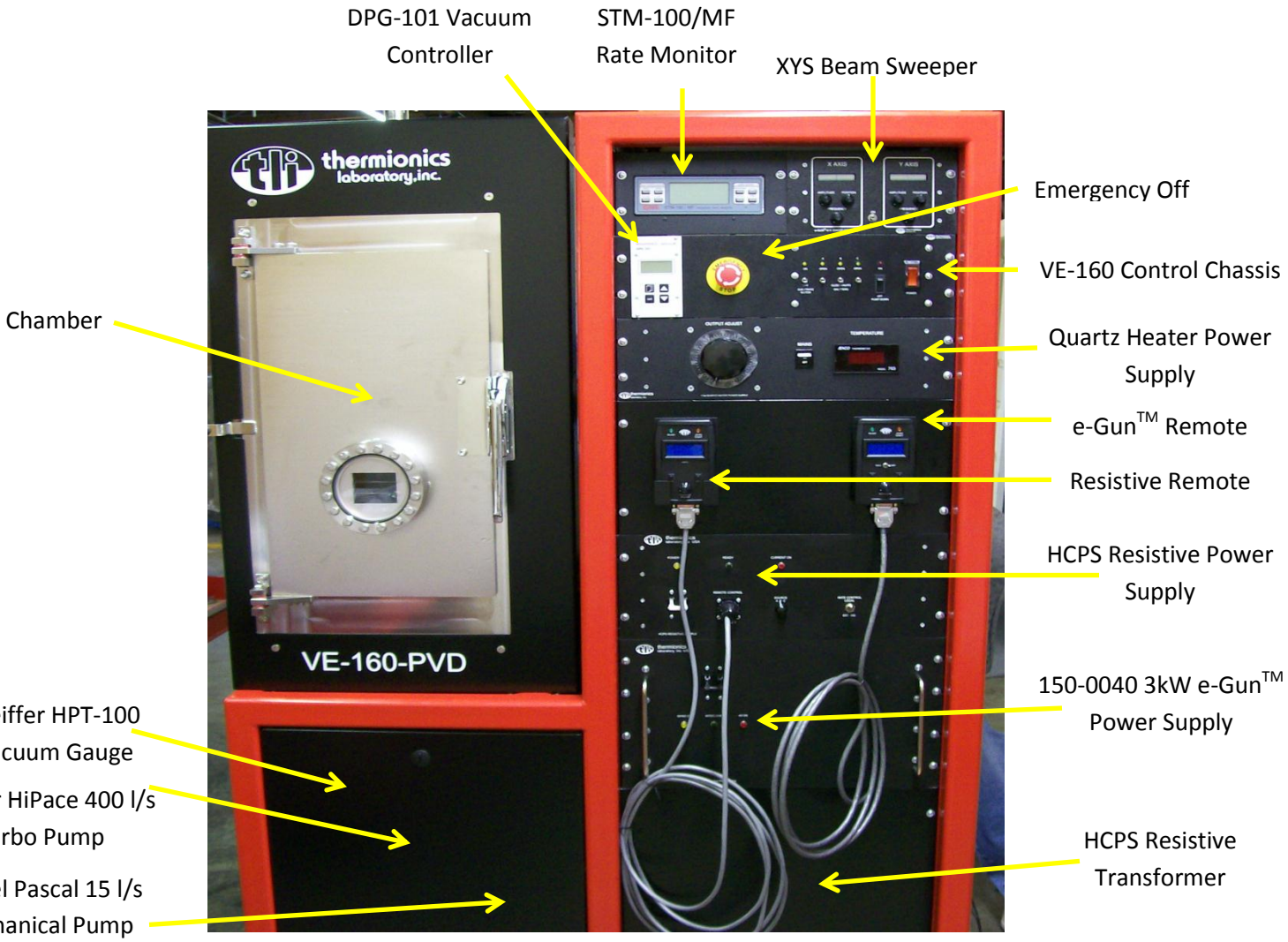
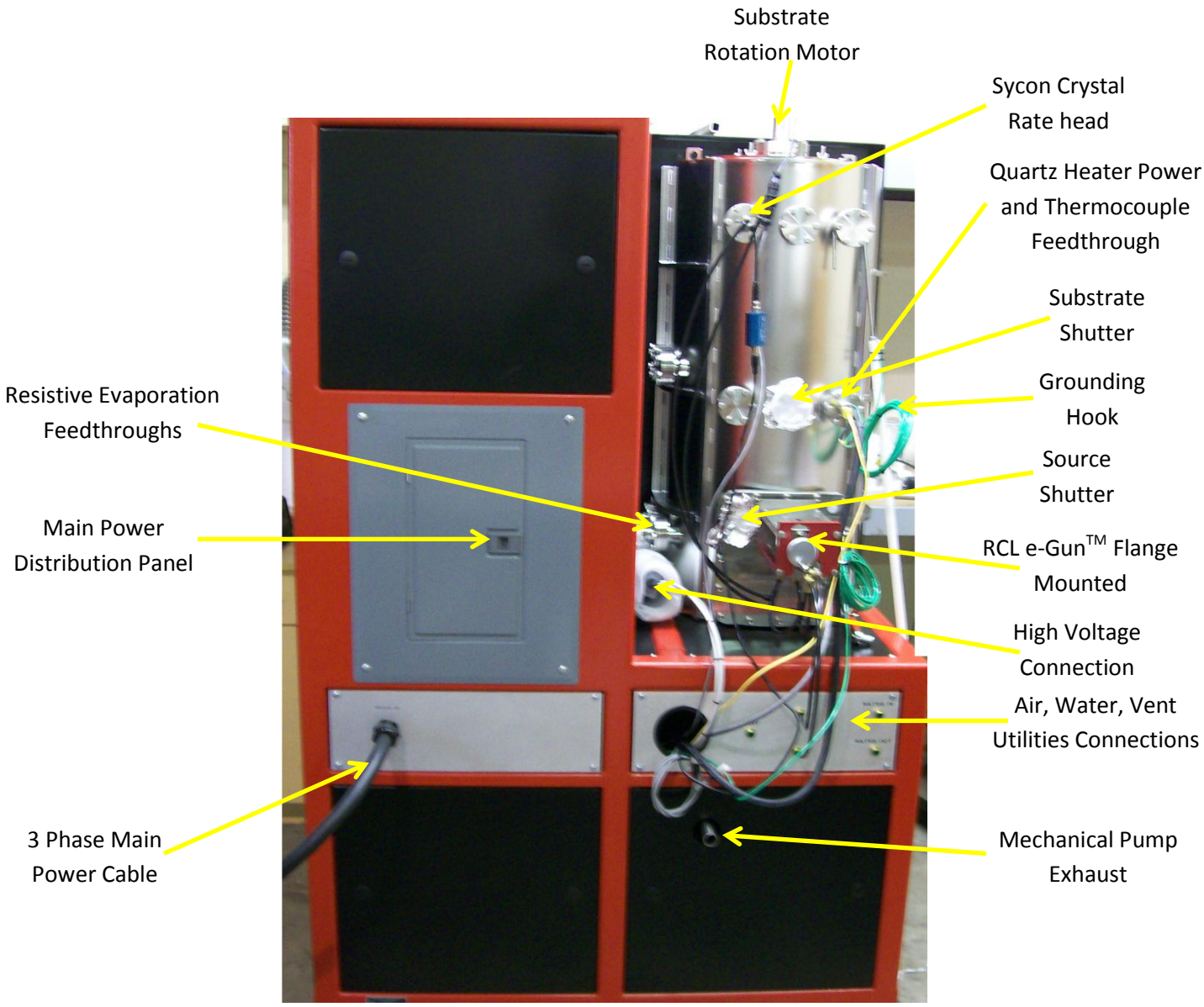


Figure 2: Back View



1.2 DETAILED DESCRIPTION

1.2.1 **Growth Chamber**

The chamber is a 'D' type chamber that has a work area of 16" x 16" x 35" constructed of 304 stainless steel with a combination of Viton 'O' ring and metal seals. The surface has been electro-polished for a smooth UHV surface.

1.2.2 **Pumping System**

A 400l/s turbo-molecular pump is supplied for high vacuum chamber pumping. Base pressure is better than $2*10^{-6}$ Torr. An Alcatel Pascal Series 15l/s two stage direct drive oil sealed mechanical pump is supplied for roughing.

1.2.3 **e-Gun™**

A Thermionics' three pocket 3kW RC series linear e-Gun™ with 2.2cc crucibles is mounted on a flange with all feedthroughs require for operation and manual indexing. A pneumatic controlled source shutter is provided on the flange.

1.2.4 **e-Gun™ Control Electronics**

A Thermionics' 3 kW e-Gun™ power supply with high voltage cable and hand held remote control is provided. A Thermionics XYS sweep controller is supplied for the sweep. A Sycon STM-100/MF rate monitor is provided for monitoring of film thickness is provided.

1.2.5 **Resistive Evaporation**

Provided are 3 high current feedthroughs with 2 filaments for resistive evaporation. There are 2 sets of 3 2.75" ports to move the feedthroughs for versatility in source to substrate distances.

1.2.6 **Resistive Control Electronics**

A Thermionics dual HCPS (High Current Power Supply) is provided with hand held remote control is provided. You may choose between 1 channel at a time to resistively evaporate.

1.2.7 **VE Control Chassis**

A system control box that provides shutter actuation, emergency off mushroom switch, DPG-101 vacuum controller, and 1 button system pump down.

1.3 SPECIFICATIONS

See individual product manuals as listed in Appendix F.

1.4 RECEIVING, INSPECTION AND UNPACKING

Some crates and boxes have special labels which change color if a box is not transported with up arrow observed and/or if the box has been dropped. Check for these specific labels. If present, and if the seal has changed, notify the shipper and Thermionics immediately.

Upon receipt of the shipment, inspect the outside of the box(s) and crates for damage such as crushed corners and tears which would indicate the parcel was mishandled in shipping. If damage is noted, immediately notify the shipping company of the damage and that there may be hidden damage.

Unpack the equipment and check the contents to be sure everything shown on the packing list is identified and located. If something later on is found missing it is difficult to establish responsibility.

Give particular attention to small parts such as cables and/or spare gaskets as they can be overlooked in the unpacking process and are then difficult to locate during the installation process.

Do not overlook the big components either. Inspect the chamber, frame, and quick access panels for dents and bend(s) that could signal transport mishandling.

It is always good to save the packing material until the equipment is fully installed. Should anything be missing the original packing can be checked.

2.0 INSTALLATION

The standard VE-160 has all major assemblies in place. Let us first make sure all major assemblies shipped are still intact and in functioning order by completing the below checklist.

- Inspect the interior of chamber for dislodged components, broken brackets or loose electrical leads.
- Attach all items shipped with system, i.e. linear and rotary feedthroughs for shutters and substrate holders.
- Remove all quick access panels and inspect vacuum lines, water lines, pressure air lines, and electrical cables. Keep panels off until instillation is complete.
- Hook-up pressurized air and make sure there are no leaks, See appendix B.
- Hook-up water, open valve, and make sure there are no leaks, See appendix B.
- If, using a gas to vent with hook-up and make sure there are no leaks.
- Open power panel door and turn all breakers off. Check emergency off switch is released.
- Hook up main power cable for this system, See appendix B.
- Make sure all electronics components are off. Turn on main breaker wait 5 seconds and then repeat for all breakers.

- Test emergency off switch, red mushroom switch, by depressing and then confirming main breaker was tripped and that all power is off. Reset mushroom switch and then reset breaker(s).
- Turn on all electronics. Check all individual components are powered on and functioning.
- On VE-160 control chassis box check all shutters for operation.
- On VE-160 control chassis box check substrate rotation for operation.
- System has passed all initial instillation checks and is ready for operation.

See appendices at the end of this manual for operation of evaporation sources.

3.0 SYSTEM OPERATION

EMERGENCY SHUT OFF

An emergency shut off system is supplied. Operation of the mushroom switch located on the VE control chassis will kill all power to the system.

To restore the power rotate the button until it pops out and then reset main power shunt trip breaker at breaker box on back of system.

VE Systems can be set-up to utilize a variety of different evaporation methods, See appendix C, D, and F. For operation of each of these different methods see the aforementioned appendices and evaporation equipment manuals for more information.

3.1 INTERLOCKS

3.1.1 This VE-160 has a water flow switch interlocked to the e-Gun™ power supply. Unless there is flowing water at a high enough rate to satisfy the factory set water flow interlock the high voltage will not turn on.

3.1.2 This VE-160 utilizes the DPG-101 vacuum controller's set-points as interlocks. Unless the set-point is achieved the high voltage from the e-Gun™ power supply will not turn on and the resistive power supply will not apply current.

3.1.3 All Thermionics power supplies utilize a zero start interlocks so that every application of power starts at zero. Always make sure to turn potentiometer to zero upon completion of depositions. This is not the case for the SEB series of power supplies for the high voltage potentiometer. This series is made to set the high voltage and then you can turn the high voltage on and off without having to reset the high voltage every time.

3.1.4 All Thermionics dual box high voltage cable assemblies utilize a high voltage interlock to make sure the high voltage connection is secure. This is in the form of a red switch that makes contact with the flange is the connection is secure.

3.2 PUMP DOWN AND VENT

3.2.1 This VE-160 is equipped with a one touch pump down system as well as one touch up to atmosphere venting.

3.2.2 Once you have set-up and filled your e-Gun™ and/or resistive evaporator close the door and make sure the VE control chassis is on and then depress the "Pump Down" switch to on and the system will pump itself down. In approximately 15 minutes the system should be at 10^{-5} Torr or below.

3.2.3 When the system is under vacuum and it needs to come up to atmosphere depress the "Pump Down" switch on the VE control chassis from on to off. In about 15 minutes the system will have automatically vented.

3.3 VE-160 MAITENANCE

3.3.1 VE systems are designed for a minimum of required maintenance. For detailed procedures for changing the oil and periodic maintenance of the pumps, please refer to the operation manuals for the respective pumps.

3.3.2 All other components typically do not require any maintenance other than routine periodic cleaning of evaporant off the chamber, shutters, e-Gun™ and anything else in the chamber getting coated. This is especially important as the flakes and debris that build up, often find their way into the pump inlet during the violent air currents that occur during initial pump down.

3.3.3 Within the turbo pump inlet, there is a screen which captures such debris, periodic inspection of the inlet by removing the protective cover plate and taking out the accumulation is advised. A vacuum cleaner works very well for removing flakes as long as the coating material is not hazardous.

3.3.4 In addition, it has been our experience that the following tips will increase the lifetime of the system:

3.3.4.1 Routinely check the oil level in the mechanical pump, since small amounts of the oil is lost as vapor in the exhaust.

3.3.4.2 Proper lubrication of the bearings in the turbo pump is greatly enhanced by operation of the system at least once a month. This prevents the bearings from "drying' out and the resulting friction from shortening the life of the pump.

3.3.4.3 Continuous operation of the system while not necessary, will greatly improve the rapidity of cycling and the ultimate system pressure.

3.3.5 Refer to specific manuals for deposition equipment and/or optional features maintenance.

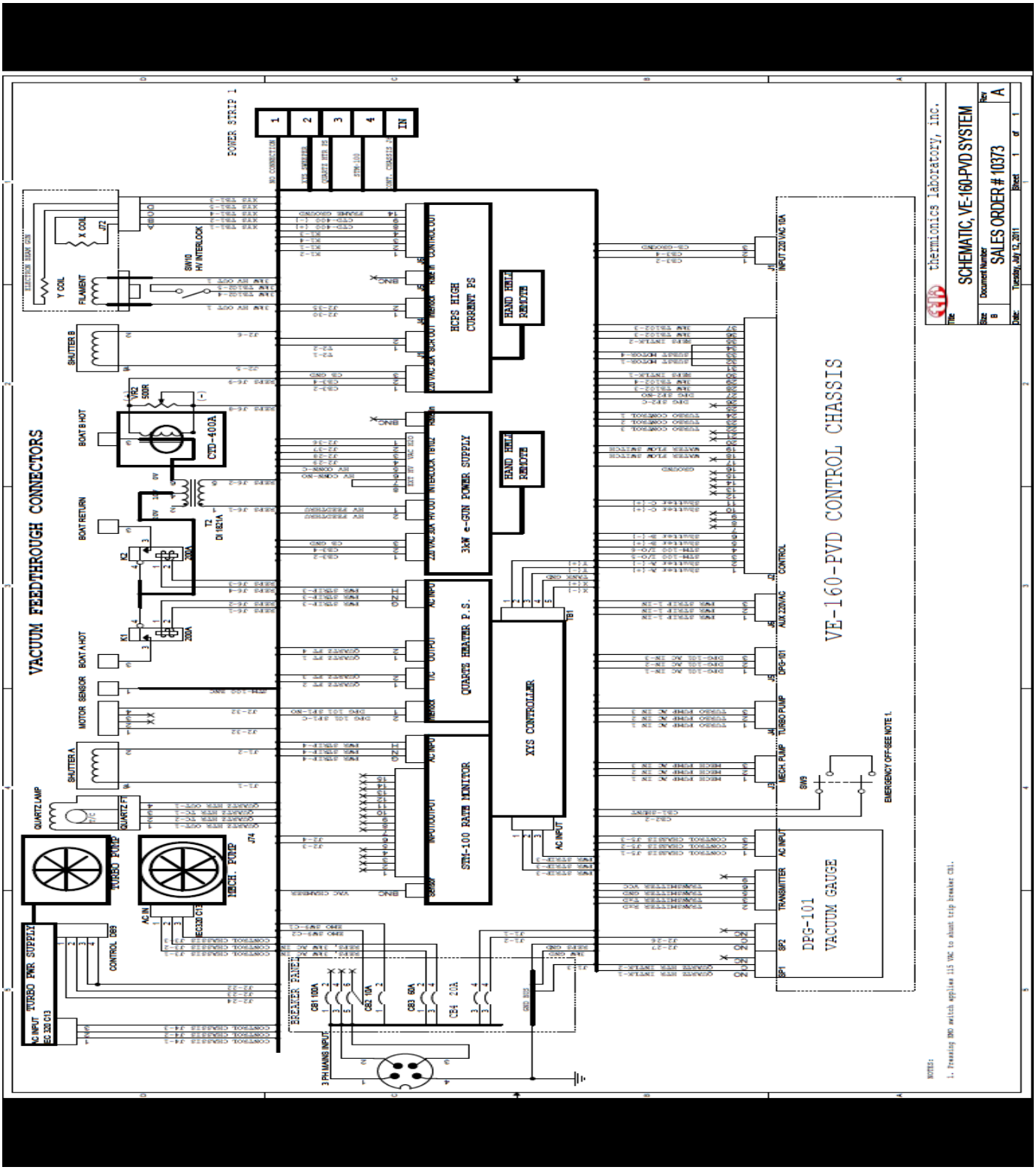
4.0 TROUBLSHOOTING

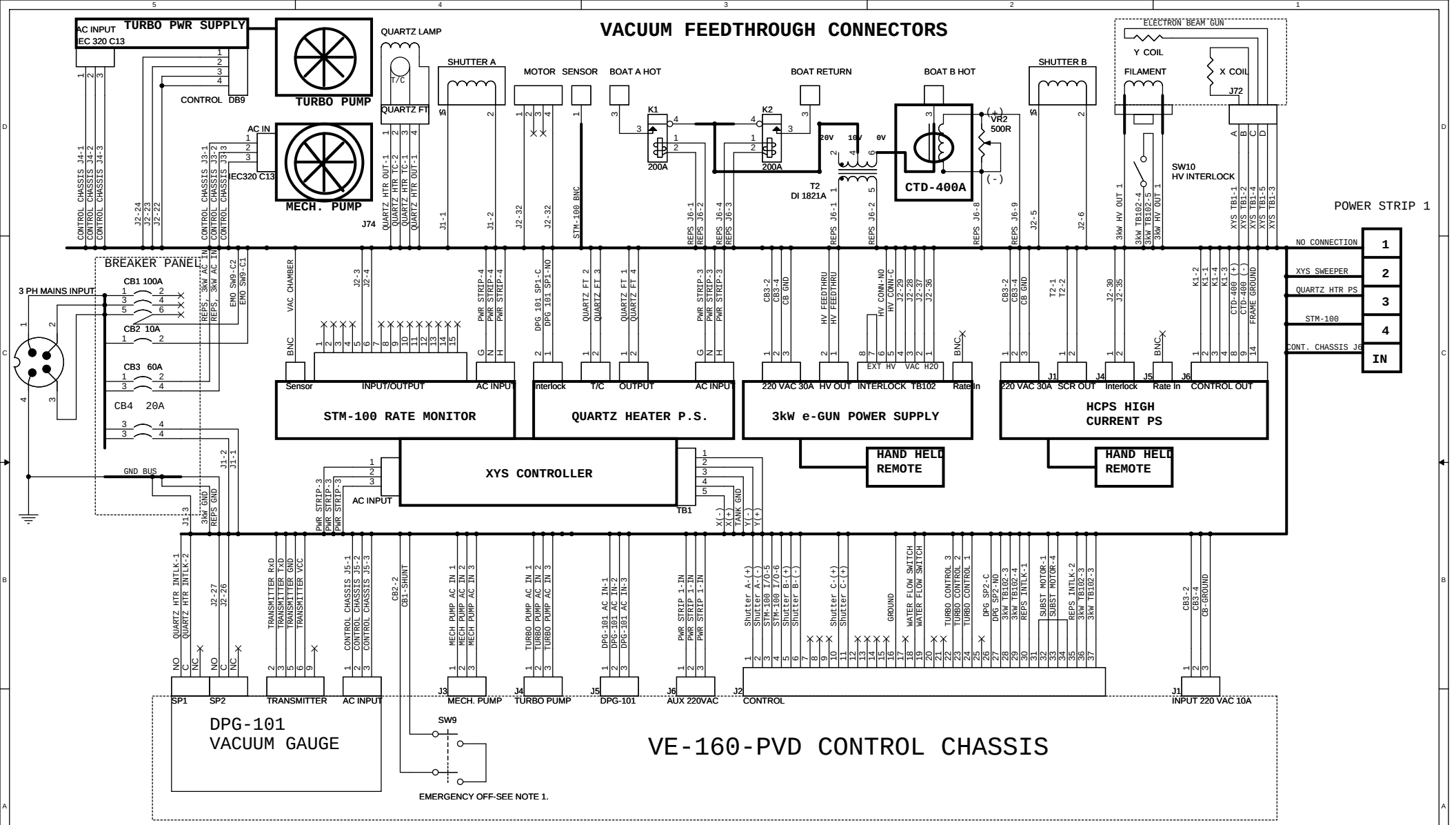
HIGH VOLTAGE ARE PRESENT WITHIN THE SYSTEM ENCLOSURE AND PROVISION HAS NOT BEEN MADE FOR PERSONNEL TO BE SAFELY WITHIN THE ENCLOSURE DURING THE APPLICATION OF POWER. THE SYSTEM SHOULD BE COMPLETELY DISCONNECTED FROM POWER DURING ANY ENTRY INTO THE ENCLOSURE FOR SERVICING.

#	Symptom	Possible Cause	Action
1	System will not reach high vacuum state.	Leak in system.	Leak check system
		Pumps not operational.	See number 2 and 3 in this section
		Defective gauge control circuitry.	Turn power off and check connections. Consult factory pump manuals.
2	Mechanical pump will not operate.	Circuit breaker tripped.	Reset circuit breaker.
		Pump fuse blown.	Replace pump fuse.
		Defective mechanical pump.	Consult factory manual.
3	Tubromolecular pump will not operate.	Leak in system resulting in excessive gas load (pump will turn off after trying to pump down for approx. 12 minutes).	Fix leak then toggle pump down off to on. Consult factory manual for more information.
		Defective pump and/or Control.	Consult factory manual for more information.
4	Vacuum gauge reading incorrect.	If high vacuum reading, this happens with use.	Consult factory manual for degas function.
		Readings have drifted.	Consult factory manual for retro-adjust
5	Vacuum gauge will not operate.	Gauge connector loose.	Switch off controller and check connections

		Defective power supply, gauge, and/or controller.	Consult factory manuals.
6	Valves opening and closing randomly.	Valves are interlocked to guard against improper use. Interlocks based off pressure set points.	If improper pressure readings then set points affected. Check item 4 to fix.

APPENDIX A: VE-160-PVD System Schematic





NOTES:

1. Pressing EMO switch applies 115 VAC to shunt trip breaker CB1.

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APPENDIX B: Utilities Connections

Provision for power connections is located at rear service panel directly below the breaker box. Our standard is 10 ft. of the appropriate cable stripped and tinned so that you may hardwire or attach plug. Provisions for water and air connections are located below chamber and next to the power connection.

Grounding of this system is crucial to a safe environment. This system requires two grounds. One ground is the normal reference that is given by the single 220Vac 3-phase service that all the electronics uses. The other ground, see e-Gun™ power supply manual, is used for carrying away RF noise created by the e-beam. Make sure both of these grounds are correctly utilized and independent as death and equipment destruction may result.

Power Connection and Requirements

1. The VE-series vacuum system is designed to operate from a single 220VAC 3-phase service. This power service will operate the entire system.
2. Service amperage depends upon specific system requirements. Typical service input of 80 amperes will cover all standard options. The table below covers some of the more common optional equipment.

Model #	Description	Power requirement
HCPS-1000	1kVA resistive power supply	220 VAC 15Amp single phase
HCPS-2000	2kVA resistive power supply	220 VAC 30Amp single phase
150-0040	3kW e-Gun™ power supply	220 VAC 30Amp single phase
SEB-06	6kW e-Gun™ power supply	220 VAC 30Amp 3 phase
SEB-10	10kW e-Gun™ power supply	220 VAC 40Amp 3 phase
SEB-15	15kW e-Gun™ power supply	220 VAC 60Amp 3 phase
XY(C)S	e-Gun™ X-Y sweep controller	220 VAC 10Amp single phase

Water Connection and Requirements

1. The VE-series vacuum system is design to have one water inlet and one water outlet at the bulkhead. This service has an outlet and inlet with both requiring 3/8" poly tube water lines, included. Water pressure of 50 PSI with a flow rate of 2.5 minimum GPM is required. If utilizing a recirculating water chiller the unit should be rated for 4,500 watts minimum. If the system is equipped with a water-cooled chamber additional water lines will be required.
2. Service flow rates depend upon specific system requirements. Typical service water flow rates of 2.5 GMP cover all standard options. The table below covers some of the more common optional equipment.

Model #	Description	Water requirement
100-0010, 100-0030, 100-0040,	3 kW e-Gun™ source	0.5 - 1 GPM, 25 PSI pressure

100-0050, RC series		differential
HC-series, Hm2 -series	6kW – 10 kW e-Gun™ sources	2 - 3 GPM, 50 PSI pressure differential
XTM, XTC	Crystal rate monitor/controller	.25 GPM
Special	Water cooled bell jar	5.0 GPM

Air Connection and Requirements

The standard VE system does not require pressurized air; however some optional devices may require this provision. In versions featuring pneumatic valves for gate valve or shutter actuation air may be required. Standard valve require 60 PSI and filtered air is recommended.

APPENDIX C: Process Equipment Operation

Prior to operating process equipment you should read the specific operating manuals. VE-series coaters can be configured with a wide variety of processing equipment including but not limited to; resistive evaporators, e-Gun™ evaporators, sputtering sources, effusion cells and/or combinations of these products. In addition to the various sources a wide variety of other options can influence process procedures. The use of various sources in conjunction with other accessories such as sample manipulators, heaters, shutters and/or rate controllers can become complex and require advanced process techniques. Individual manuals should be studied completely. There are several good books published about coating technology including "Handbook of Deposition Technologies for Films and Coatings" by Rointain F. Bunshah (available through Noyes Publications). The American Vacuum Society (AVS) and the Society of Vacuum Coaters (SVC) are also valuable resources for locating publications and information on coating processes.

The following chart lists various options available for the VE-series coater along with their basic function. Appendix C gives examples of typical operating procedures for some of the more common process devices. Vacuum coating is a continually evolving industry and as such items and options will undoubtedly be omitted.

Optional device	Common use
Resistive evaporator	Resistive evaporators are the most economical evaporation sources. Resistive evaporators use a high current power supply to heat a wire or "boat" to indirectly heat material to the point of evaporation. These sources have a limited heat range as well as material capacity.
e-Gun™ evaporator	e-Gun™ evaporators are more versatile than resistive sources. In this system electrons are directly bombarded onto the material were their kinetic energy is converted into heat. Temperatures in excess of 4000 degrees C are possible allowing the evaporation of virtually every material known. Material capacity from 2cc's up to several hundred cc's is possible depending upon e-Gun™ model.
Sputtering source	Sputtering sources can be used to deposit almost any material. They are stable sources and repeatable results are obtained by monitoring time and power. Rates are typically lower than evaporation sources. Normal operation is with DC power although RF power is required for Dielectric and Insulating materials.
Effusion cell	Effusion cells use resistive heating elements to heat a crucible (normally Boron Nitride). These sources have refractory shielding to reflect all of the filaments heat into the crucible. At the bottom of the crucible they incorporate a thermal couple to allow for temperature regulation. These sources are very stable and can accommodate large volumes of material. Effusion cells are only effective for certain materials. High temperature materials and

	materials prone to sub-surface boiling cannot be evaporated effectively in this manner.
Source shutter	A source shutter is a mechanical device that prevents material from the deposition source from coating the substrate. When starting a deposition source some materials will "outgas" contaminates and may "spit" cold material. The use of a source shutter allows pre-conditioning of the material preventing unnecessary contamination. Source shutters can also be used to stop the deposition process allowing a precise thickness to be achieved.
Substrate shutter	Substrate shutters offer many of the same benefits of a source shutter. The substrate shutter cannot isolate individual sources, which in some cases could limit its effectiveness.
Static substrate holder	Device for holding a substrate (sample) to be coated. Substrate holders come in a variety of sizes and shapes depending upon coating requirements. Typically they are located above the source. Distance from the source to the substrate varies with process parameters.
Rotating substrate holder	By rotating the substrate uniformity can usually be increased in a coating. The geometry of the holder and axis it is rotating on must be configured based on the source and coating requirement. In some cases best uniformity is with multiple axis rotation (planetary system) or off axis rotation.
Substrate heater	In some processes the use of sample heaters is employed. Heating a sample can help to clean the surface (degas) and may aid in mechanical adhesion. When using a substrate heater vacuum pressure may be affected. Care must be taken to determine a proper heat cycle to avoid excessive out gassing and/or overheating any elastomer seals in the system.
Ion source	Ion sources are often employed in coating processes. They can be used to pre-clean and/or condition the substrate. They can be used during a deposition cycle to assist in the process… providing more energy at the sample for increased adhesion –or- a specific ion might be provided to form special film composition (nitrides, oxides etc.).
Gas controller	Gas controllers can be used to provide a constant flow rate of a specific gas or to maintain a constant pressure (or partial pressure) of a specific gas. These systems are normally used in conjunction with sputtering sources or in reactive deposition.
Auto indexer	Automated indexers can be used with e-Gun™

	sources to provide multi-layer films. These units in some cases can be integrated with a crystal rate controller to provide completely automated coating sequences.

Typical Deposition source to substrate distances.

Source type	Typical source to substrate distance in inches
Resistive evaporator	8” to 12”
3 kW e-Gun™	10” to 14”
6kW to 10kW e-Gun™	12” to 24”
Sputtering source	2” to 4”

APPENDIX D: Operation of a Resistive Evaporation Source

Thermionics resistive evaporation sources and power supplies (HCPS) can be used to deposit a wide variety of materials in a research or pilot production mode. The power supply can be operated in a manual or remote mode. The manual mode allows regulated control of current to the evaporation source by the hand held control's potentiometer. In the remote mode an external signal can be provided to the power supply through its rear panel BNC style connector to control current output. This signal (0 to –10VDC) can come from almost any source; however it is typically from a rate controller. If the system is used in an automated form with a rate controller or other type of external source please refer to the manual for this equipment for operating procedures.

Operation in Manual mode

1. Pump down the VE system following the appropriate procedure (outlined in 3.3). System pressure should be less than 9x10^-4 Torr.
2. Locate the HCPS front panel and the hand held control. The remote / local switch should be in the local position. The potentiometer on the hand held control should be all the way counter clockwise (minimum position).
3. Turn on the HCPS main circuit breaker.
4. There are two lights on the hand held control… interlock and zero start. Both of these lights must be illuminated prior to turning on the source. The interlock is connected through the vacuum gauge controller to prevent operation above a factory set vacuum level. This interlock can be field adjusted or by-passed if desired. Refer to the factory gauge controller manual for details.
5. Once the interlocks are met and the vacuum is at the desired level the source can be turned on by depressing the on button located on the hand held control. Slowly increase the power by rotating the potentiometer clockwise. Watch the current meter also located on the hand held control. Increase the power until the material melts or "wets" the filament/boat. Allow the system to set here briefly to degas the material (20-30 seconds is normally adequate). Increase power quickly to "flash" off the desired material. Typically resistive evaporation is done relatively quickly (less than 2 or 3 minutes). Prolonged operation at high currents can cause excessive heat in the system.
6. Once the desired film has been deposited decrease the potentiometer to zero, turn CCW until the potentiometer stops, and turn off the power supply by depressing the off button on the hand held control.
7. Turn off the HCPS front panel circuit breaker.
8. Allow the substrate adequate time to cool prior to venting the VE system.
9. Vent the system following the appropriate procedure (outlined in appendix 3.3).

If a source or sample shutter is used follow the same procedure above with the following exception. Keep the shutter in a closed position until the evaporant material is melted (wets) the filament/boat (outlined in step 5). Allow the source to soak at this level for a short time (20-30 seconds) to allow the material to degas. Open the shutter and increase power quickly to "flash" off the desired material as outlined in step 5.

APPENDIX E: Operation of a e-Gun™ evaporation source

e-Gun™ sources operate at high voltages that can be instantly fatal. Read the specific e-Gun™ and accompanying power supply manual thoroughly prior to attempting to operate this type of equipment. System grounding must be done in compliance to the e-Gun™ power supply manual. This requires both power utility ground as well as a RF earth ground. Proper grounding of this equipment cannot be over emphasized. Improper grounding can present severe safety hazards as well as performance problems. Without a proper RF earth ground it is COMMON to see component failures in both the e-Gun™ power supply controls as well as other controls incorporated in the system or located near the system including but not limited to ion gauges, convectron gauges, computer (microprocessor) controls, sweep generators and rate monitor/controllers. Read the power supply section on grounding and make sure your system is properly grounded.

Thermionics e-Gun™ evaporation sources and power supplies can be used to deposit a wide variety of materials in a research and production modes. The power supply can be operated in a manual or remote mode. The manual mode allows regulated control of emission current to the evaporation source. In the remote mode an external signal can be provided to the power supply through its rear panel BNC style connector to control emission current output. This signal (0 to –10VDC) can come from almost any source; however it is typically from a rate controller. If the system is used in an automated form with a rate controller or other type of external source please refer to the manual for this equipment for operating procedures.

Operation in Manual mode

1. Load the e-Gun™ crucible with the desired evaporant material. A liner can be used if desired. Liners are not required to operate the source; however they do offer advantages in some applications. e-Gun™ sources MUST have at least 20% of the crucible volume filled with evaporant material to prevent damage to the source. Normally the crucible should be filled and a level maintained between 20% and 100% of the crucible volume. When using a liner the level should be between 20% and 80% of the volume to avoid overspill which will cause liner failure (liners used for aluminum evaporation should never be filled above 70%)
2. Turn on the water and make sure the source is cooled. It is a good idea to check for water leaks prior to pump down. Most sources are installed with removable water lines that have elastomer or metal seals. These seals can be damaged in initial shipping or during periodic maintenance and should be routinely checked.
3. Pump down the VE system following the appropriate procedure (outlined in appendix 3.3). System pressure should be less than 5x10^-4 Torr.
4. e-Gun™ sources require direct water-cooling and should be interlocked through an appropriate water flow interlock switch. The e-Gun™ source should also be interlocked through the vacuum controller. Factory installed e-Gun™ sources for VE-series systems incorporate both water flow and vacuum pressure interlocks that must be satisfied prior to operation.
5. When the system is pumped down and all interlocks are satisfied the power supply may be turned on. There are many different power supply types and you should refer to your specific power supply manual for detailed operation instructions.
6. Most power supplies provide the same basic functions including; main power on/off (normally a circuit breaker), high voltage on/off, emission current on/off, high voltage adjust (except on 3kW models) and emission current adjust.
7. Turn on the main power circuit breaker
8. Leave sweep controller OFF during initial beam setup.

9. Turn the emission current control potentiometer all the way counter clockwise (minimum setting).
10. Turn the high voltage control potentiometer all the way counter clockwise (if applicable).
11. Make sure you have adequate viewing of the e-Gun™ crucible as you must be able to see the crucible to properly adjust the beam position.
12. Turn on the high voltage. If you have a 3 kW system skip to step 16
13. Slowly increase the high voltage stopping briefly if arcing is noticed (most power supplies have an arc LED to indicate arcing). When pausing for arcing (common condition) allow the power supply to stabilize and arcing to stop before further increasing power.
14. Continue to increase Voltage until reaching the suggested operating voltage for your particular e-Gun™. The following chart list common voltages for Thermionics e-Gun™ sources. Recommended voltage and actual operating voltage may vary and may also require adjustments over time.

3kW e-Gun™ models: 100-0010, 100-0011, 100-0030, 100-0040, 100-0050	Typically factory matched for fixed power supply voltage (-4,000 VDC)
HC-series e-Gun™ including: HCR, HCF and HCL models	-6,000 to –10,000 VDC, suggested starting voltage of –8,000
Hm2 series e-Gun™, rotary and single crucible models	-6,000 to –10,000 VDC, suggested starting voltage of –8,000
Hm2 Dual mount, Triad and Hydra	-8,000 VDC

15. After reaching the appropriate Voltage let soak for 10-20 seconds to assure that the source is not arcing.
16. Slowly increase the emission current while observing the e-Gun™ source. DO NOT EXCEED 50mA until you are sure the beam is in the crucible. You should be able to see a whitish –or- blueish haze on the evaporant material. Normally you can see this florescence on the material at a power level of 20 to 50 mA of emission current.
17. After locating the beam, adjust the high voltage (if applicable) to center the beam in the crucible. NOTE on HC-series sources use the high voltage to place the beam passed center until it is approximately 0.25 inches from the rear of the crucible (away from the filament).
18. Note high voltage for future reference _____VDC to center beam.
19. Reduce emission current to ZERO
20. You can now turn ON the sweep controller (if applicable). Center the LED display, or set sweep current to zero.
21. Increase the emission current level to 50 mA. The beam should remain centered and can now be positioned or swept with the beam sweep controller if desired. Refer to sweeper manual operating with sweep.
22. At this point the source is operational and emission current can be increased to the desired level

APPENDIX F

System Components Manuals Included

Section	Document Control Number	Manual Description
1 – System		VE-160-PVD System Manual
2 – e-Gun™ Components		
		RCL Linear e-Gun™ 0303
		150-0040 3kW e-Gun™ Power Supply
		XYS Beam Sweep Controller
	Vendor Supplied	STM-100/MF Thickness/Rate Monitor
3 – Additional Thermionics Manuals		
Sample Rotation		
	DC-OM-1022	MCLR Magnetically Coupled Rotary Linear Feedthroughs
Chamber	DC-OM-1003	FLM-133-25-1 /PNM
		Quartz heater
4 – Additional Vendor Supplied Manuals		
		Adixen Pascal Series Rotary Vane Pump (*Book*)
		Adixen Standard Oil Mist Eliminator OME 25S (*Booklet*)
		Pfeiffer HPT-100 Pirani/Bayard-Alpert Transmitter
		Pfeiffer DPG-101 Controller
		Pfeiffer Hi-Pace 400 Turbomolecular Pump

APPENDIX G

DOCUMENT CONTROL and APPROVAL

VE-160-PVD System Manual

Document Control Number

DC-OM-1013

Version 2.0

April 10, 2011