INSTRUCTION MANUAL

Hanks HM^2 e-GUN™
Evaporation Source Manual

e-Gun™ is a trademark of thermionics laboratory, inc.

Version 2

SERIAL # ______________________

2024
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Safety Instructions

A. Before servicing or operating this equipment, read this manual paying special attention to all safety precautions.

DANGER: HIGH VOLTAGE

B. The high voltage used by these evaporation sources can be INSTANTLY FATAL. Fur- thermore, because of internal capcitance in the power supply, THIS LETHAL VOLTAGE CAN PERSIST EVEN AFTER THE POWER SUPPLY IS TURNED OFF! Before entering the chamber, first make sure that the power supply is off, and then use a grounding hook on the high voltage lead from the e-GUN™. Do not touch the high voltage leads unless the power is off and a grounding hook is attached to the part to be serviced.

C. In order to keep the system adequately clean, wear lint free gloves at all times when work- ing with parts that are used inside the vacuum chamber. Contamination by so much as one small finger print can cause very serious coating and vacuum problems. Use proper clean-room procedures at all times.

Theory of Operation:

An electron beam evaporation source uses a beam of electrons to vaporize material in a vacuum chamber. The vaporized material then condenses on an object (called a substrate) in the same chamber to form a thin film of the material. The material which is evaporated to create the film can be anything which is solid in a vacuum, such as gold, silicon dioxide, or some mixture of substances, depending on the specific application.

To evaporate a material with'an e-Gun™ electron beam evaporation source, a load (or "charge") of material is placed in a water cooled copper crucible inside the vacuum chamber. Then a substrate is placed above the crucible to receive the vapor. The chamber is evacuated. A tungsten filament, inside the vacuum chamber near the crucible, is given a high negative potential relative to the grounded crucible. The filament is heated by an electric current. The hot filament produces a cloud of electrons, similar to those produced in old radio vacuum tubes, but far more intense. The high voltage negative potential applied to the filament causes a beam of electrons to leave the filament and, bent by a magnetic field, travel to the crucible. At the crucible, the beam encounters the material to be evaporated. The resulting discharge of energy produces local temperatures in excess of 3500° C. This intense heat directly vaporizes almost any material.

Since the hot electron beam is quite capable of drilling through the material to be evaporated, it is common to add a pair of magnetic "sweep" coils to the evaporation source. These pro- vide a modification to the gun's magnetic field so that the beam can be swept back and forth across the sample to make, maximum use of the material loaded into the crucible.
The use of a High Frequency Sweep (up to 500Hz) on the electron beam makes possible a new technique of evaporation control called a hyper uni-melt.

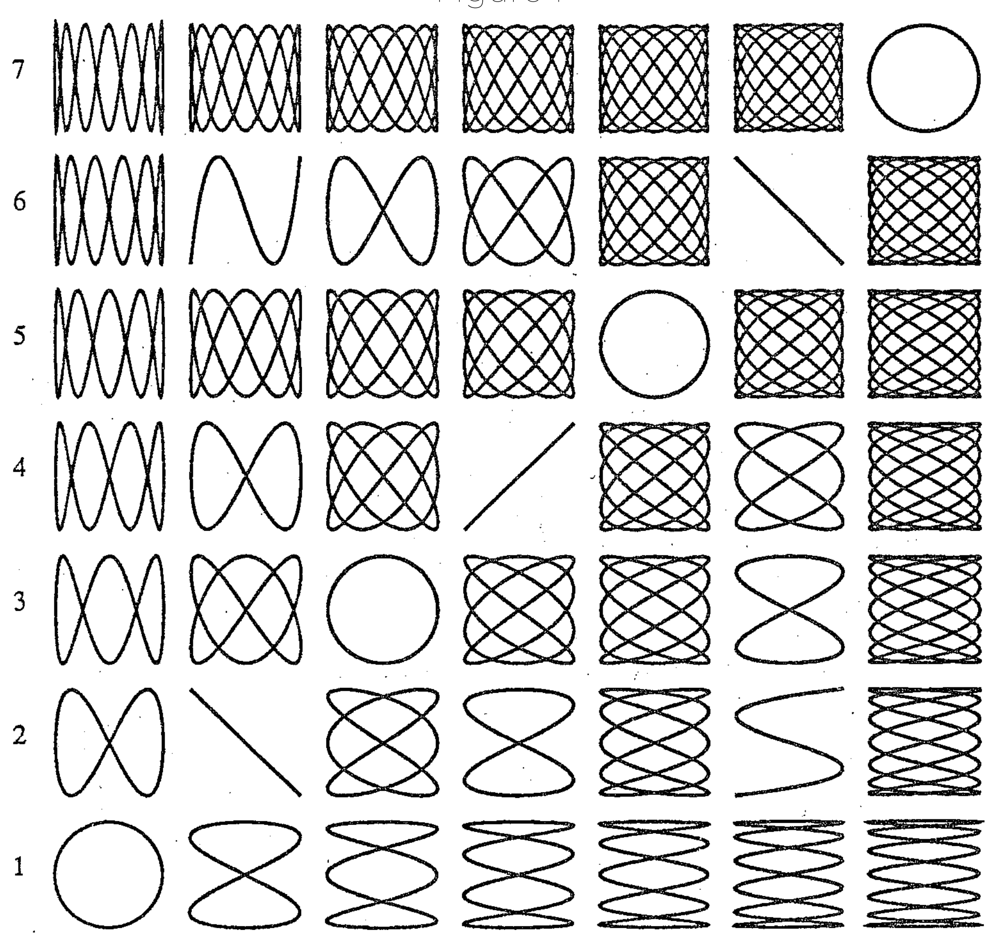
Hyper uni-melt starts with a very small spot size, which produces a very uniform temperature within the spot. This spot is swept very rapidly around the crucible, using two independent .. electromagnets which produce mutually perpendicular harmonic motions, at high frequency. The result is a zone of evaporation in the form of a Lissajous figure. [See Note.] The zone of evaporation is extremely uniform in temperature, without containing any hot spots, thus creating what is a known as hyper uni-melt. The effect this produces on the material depends on the material. For any given evaporant, whether a metal, ceramic, or dielectric, there will be an.optimum hyper uni-melt for maximum evaporation.

But the very fact that there is a hyper uni-melt for maximum evaporation, means that evapo- ration can be less, and hence hyper uni melt can be used to control evaporation rates. (Conventional electron beam evaporation sources hav had only two choices for beam size: small, and diffused. Furthermore, the system had to be brought to atmosphere to change pole extentions to switch from one to the other. Beam size was thus not a candidate for deposition rate control. Beam sweeps were low frequency and could not provide hyper uni-melts.)

The technique of hyper uni-melt control allows the operator to adjust the deposition rate as low as 1 or 2 A/sec. Previous rate control techniques relied on increasing or decreasing emission current by increasing or decreasing the temperature of the filament by increasing or decreasing the power of the filament heater current. Because of unavoidable lags in response, especially the thermal inertia of the filament, the result was an oscillating deposition rate.

That oscillating deposition rate was a limiting factor in thin film thickness control. The hyper uni-melt concept creates an entirely new level of thickness control.

Figure 1



Available Options

The TLI HM2 e-GUN™ System is designed to be part of any high or ultra-high vacuum system for uniform thin film, optical coating and vacuum metallurgical processes. It has been used to evaporate dielectric materials as well as common conductive and semiconductor materials. The e-GUN™ source is reliable in production environments as well as laboratory settings. Its simplicity and non-contaminating operation makes it equally suited for demanding industrial production and for exacting scientific research.

TLI H1v12 e-GUN™ Systems are manufactured in three crucible/ emitter configurations:

1. One crucible, one emitter ("single position")
2. Two crucible, two emitter ("twin position")·.
3. Five position, three emitter (the HYDRA™ Configuration)

These systems have several crucible capacity and power options:

	10cc 10kw	15cc 10kw	40cc 15kW
1. Single Position:	STD	STD	c.f.
2. Twin Position:	STD	STD	c.f.
3.HYDRA™:	STD	STD	STD

(STD: Standard, c.f; consult factory)

Crucible liner accessories are available in molybdenum, intermetallic, graphite, pyrolytic boron nitride, boron nitride, tungsten, tantalum, aluminum oxide and vitreous carbon materials. They allow the source material to be isolated from the water-cooled crucible so evaporation at higher deposition rates using lower power is achieved. Crucible liners also help keep _ the crucible clean. After an evaporation has been done with one type of material, the liner containing that material may be removed. Then a liner containing a second type of material may be inserted. Thus several types of source material may be evaporated without cross-contamination.

Custom designed e-GUN™ systems may be specially ordered from 1LI. They can offer (among other possibilities): Various types of e-GUN™ feedthroughs. Special vertical configuration of water lines. Side-to-side multiple-cluster e-GUN™ systems, all single position, for multiple, sequential or combination evaporation.

Installation

The following components are required for customer installed e-GUN™ systems:

1. Water feedthrough and tubing (3/8" [o.d.] type 304 stainless steel).
2. Low voltage feedthrough and wire for connecting the deflection coil (#16-AWG).
3. High voltage hook up: either 1/16" thick by 1/2" wide copper strap, or 1/4" diameter rod.
4. 5/16" o.d. tubing using Cajon ss-4-vcr type fittings for 10 and 15cc single crucible e- GUN source. ·

3/8" o.d. tubing using Cajon ss 8 vcr fittings for 40cc crucible e-GUN source. 1/2" o.d. tubing using Cajon ss 8 vcr fittings for 156cc crucible e-GUN source.

5. High voltage shielding (type 304 stainless steel).
6. Interlock switches.
7. Filtered water at 3gpm at 60 psi minimum.
8. High voltage power supply.

Installation for a Flange-Mounted e-GUN™ system requires :

Two water lines (one supply and one return), either as rigid metal lines with fittings, or as flexible tubing with hose clamps, to connect with stainless steel tubes. The size of the e- GUN™ system tubing is shown in the following table.

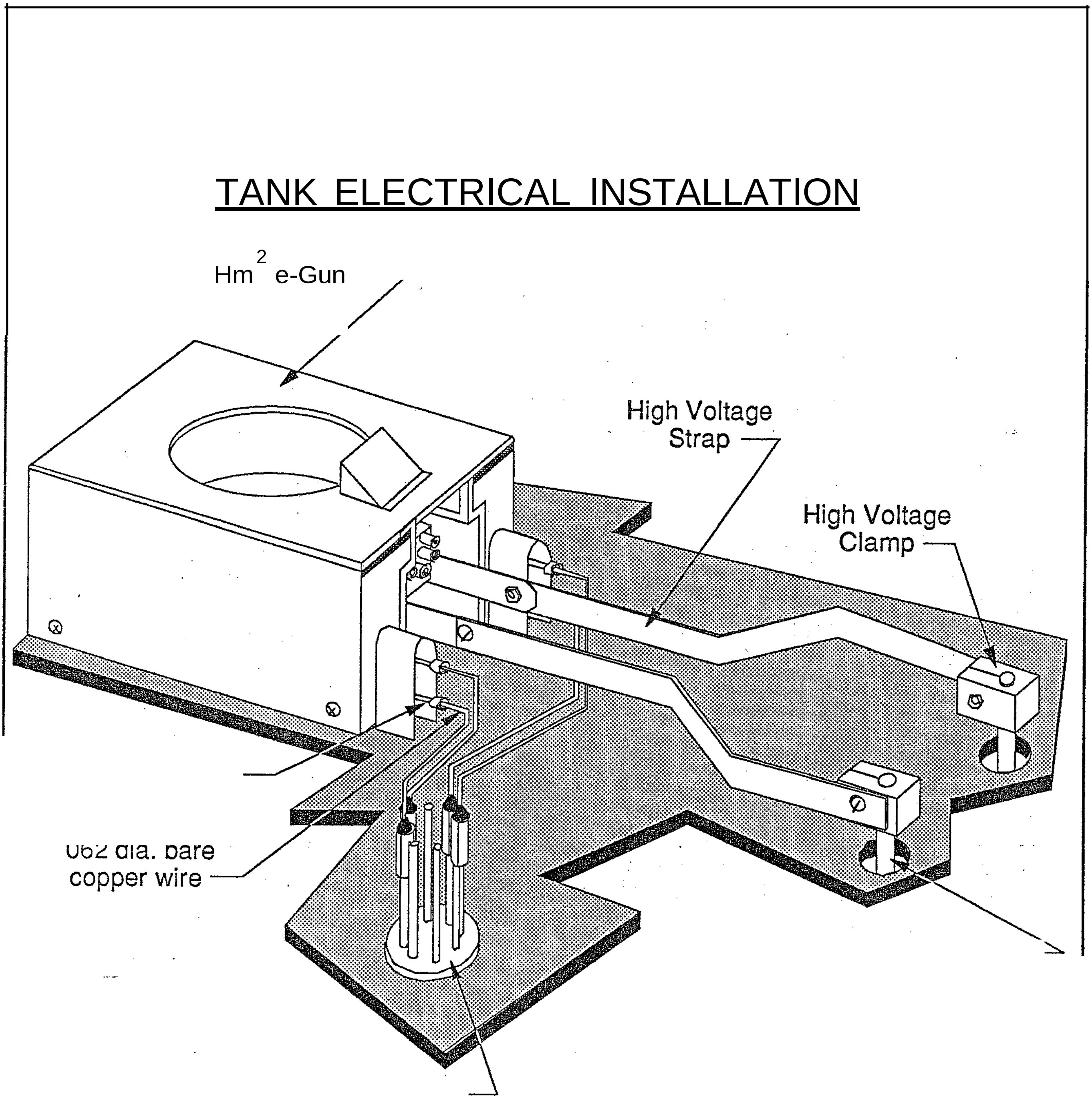
SIZE OF CRUCIBLE	SIZE OF WATER LINE TUBES
10cc	5/16" o.d.
15cc	5/16" o.d.
40cc	3/8" o.d.
156cc	1/2" o.d.

To Install the Flange-Mounted e-GUN™:

1. Connect 4-#16 AWG wires from power supply to the beam deflection feedthroughs.
2. Connect 2 high voltage leads to the emitter feedthroughs.
3. Connect all protective interlock switches.

TO INSTALL THE E-GUN™ SYSTEM

1. Mount the e-GUN™ system in the chamber.
2. Form the water lines from the chamb r to thee-GUN. Use 3/8" o.d., type 304 stainless steel tubing. Make the bends at least 1/2" from the connection.
3. Join the lines by heliarc welding.
4. Tighten mounting bolts. Make a positive ground through the mounting bolts.
5. Attach leads to the deflection coil assemblies from the low voltage feedthrough. Use #16- AWO wire. As an option, ceramic beads may be used to insulate these leads. Note: The coils are not connected to each other. Each has its own pair of leads. One coil is intended for longitudinal sweep; the other for lateral sweep.
6. Connect the high voltage leads by using either a1/16" thick by 1/2" wide copper strap or a 1/4" diameter rod.
7. Install high voltage shielding to prevent arcing and metal corrosion over the high voltage leads. Make certain that the shields have ample clearance.
8. Install a shutter 2 inches above the crucible.
9. Connect all protective interlocks. ·.
10. Externally connect the low voltage leads from the X-Y beam sweep controller to the low voltage feedthrough. Provide an external positive ground to the baseplate and an auxiliary ground between the baseplate and the power supply. . ·
11. Externally connect the high voltage leads using a copper strap or 1/4" rod. Make sure the strap is 1/16" thick by 1/2" wide. Space leads 1-1/2" from ground potential. Make sure the ends of the high voltage leads are securely clamped. Note: Cover external high voltage leads at the high voltage feedthrough.
12. Make sure water pressure is at a minimum of 60 psi.


TANK ELECTRICAL INSTALLATION
Hm^{2} e-Gun
High Voltage Strap
High Voltage Clamp
062 dia. bare copper wire

Operation

CRUCIBLE PREPARATION

Cleanliness is critical for high quality films and trouble-free operation. CLEAN the crucible thoroughly before each new material is used to remove the build up of coatings from previous evaporations. A heavy build up of condensed coatings on the crucible surface causes the melt to flow out rather than "balling up" from surface tension. Heavy deposits cause eruptions during a run if a piece of the cooled deposit breaks loose and enters the melt.

Fine emery paper is recommended for cleaning; stainless steel wool can also be used. Heavy deposits can easily be scraped or chipped loose with a small scraper. When using stainless steel wool, remove all small pieces left on the crucible. If they remain on the crucible, static charges will cause them to jump around during operation and cause shorting. A vacuum cleaner with an extension base and crevice tool is recommended for final clean-up. The use of a condensate shield on the crucible eliminates the need to clean the side wall of the crucible.

The evaporant is desirable in solid form. Loose powders can be used for dielectric or optical coatings.

Very few materials are pure enough to be melted the first time without some spatter or gaseous outburst. A shutter should be used to protect the substrate during the initial melt. It is desirable to pre-melt the evaporant in an separate pump down cycle especially when new and unfamiliar materials are used. Once the materials are purified, the coating run can be made without fear of erratic operation.

When evaporating materials with high thermal conductivity (e.g. gold), it is advantageous to place a thermal isolation barrier between the crucible and the evaporant material.

Crucible liners are a good thermal insulator between the crucible and the melt. They provide:

1. Lower electron beam power to obtain the same deposition rate.
2. Deposition rates higher than those obtainable in a bare crucible.
3. Elimination or reduction of charge splattering.
4. Decreased X-ray damage.

NOTE: To obtain maximum benefits, the liners should be handled using conventional clean room techniques. The crucible liners have been purified to less than 200ppm total ash.

To obtain the same deposition rates, the electron beam power is reduced to 1/3 - 1/4 the power used when bare crucible evaporations are performed. If the same power settings are used, the deposition rates will be two to four times greater (depending on the material being evaporated).

The surfaces of the crucible cavity should be cleaned, and any marred or rough surface refinished to a smooth surface.

Normally, the best crucible liner load is maintained between 80% and 30% of the crucible volume. Over 80% volume may cause spillover thus causing a thermal short and crucible liner breakage. Under 30% load may cause crucible overheating and breakage of the liner.

NOTE: Make sure the electron beam does not strike the crucible liner or breakage will occur.

SOURCE OPERATION

1. Make sure the vacuum chamber is operating at a pressure lower than 1 x 10·5 torr, otherwise a· glow discharge may develop. This will not harm the e-GUN™ system but will prevent it from operating. ·
2. Make certain all of the interlocks are operating properly. All of the safety grounds must be secure.
3. Turn on the crucible cooling water.
4. Be sure the emission control switch is in the "off' position..
5. When ready to begin coating, turn on the main circuit breaker and check to see that the inter- lock lights are on.
6. Press the H.V. "on" button. The H.V. (red light) should light. If the light doesn't go on, check the power. Check the emission control to make sure the normally closed switch is closed. Make sure the main power cord is plugged into a "hot" receptacle. If not corrected, go to the troubleshooting chart.
7. Slowly turn the emission control clockwise while watching the front panel meter. Wait for a blue glow to make sure the beam is in the center of the crucible before the current is increased. As the current increases, the evaporant will begin to get hot (red). At this point hold the current steady for a moment to allow the source material to equalize in temperature. Different materials require various power levels, but in general the power can be increased until evaporation begins. One the evaporant has stabilized the power may be increased to the desired power level for efficient evaporation.

   The TLI focus current operates the beam in a diagonal X configuration instead of a lateral/longitudinal configuration. Varying the amplitude frequency allows the beam to move in a circular or elliptical pattern for more control over the beam's position. By wiring the coil in a series, the standard beam can sweep either laterally or longitudinally.

Source Shut Down

1. Slowly turn the emission control counterclockwise, until it points to "start". Only in an emergency press the "off' button while the power supply is emitting current to the e-GUN™ system.

2. Allow the e-GUN™ system to cool down before releasing chamber to air. Failure to do so will cause unnecessary oxidation.

MAINTENANCE AND ADJUSTMENTS

GENERAL MAINTENANCE

One of the most important maintenance procedures is maintaining cleanliness. All of the components within the vacuum system must be as clean as possible. Clean all items according to "clean room" procedures. One small fingerprint can cause very serious coating and vacuum problems.

Make certain the e-GunTM crucible, filament, and all related parts, are completely free of small particles and overspray. Bead blast the surface until it is clean, then clean all parts in an ultrasonic cleaner.

FILAMENT ADJUSTMENT

For the most efficient operation, follow the sketch dimensions below when adjusting or changing the filament. If too much of the filament is exposed, the anode will be bombarded - decreasing the power to the crucible. If, however, too much of the filament is hidden, the space charge will increase and the filament will have to be excessively heated for sufficient emission.

The filament alignment tool allows for proper filament alignment without the need to adjust it by hand.

TO CHANGE THE FILAMENT:

1. Remove the emitter assembly.
2. Remove beam deflector in front of filament.
3. Loosen right and left filament clamp screws.
4. Pull filament out.
5. Remove clamp blocks and clean filament clamp grooves using emery paper.

TO INSTALL THE FILAMENT:

1. Install clamp blocks and back off clamp screws 1/2 turn.
2. Insert filament legs into the grooves of the clamp blocks.
3. Insert the alignment pin through the center of the filament.
4. Tighten the left clamp block screw.
5. Place .010 thick aluminum shim between the filament and the beamformer and .050 thick shim between the beamformer and the anode.
6. Tighten the right clamp block screw.
7. Remove alignment pin and both shims.
8. Reinstall beam deflector.
9. Check spacing between beamformer and anode. Spacing should be .050 (± .010).

MAGNETIC FIELD CONFIGURATION

The HM2 e-Gun™ is configured with three or four vertically mounted magnets on each side of the crucible.

TROUBLESHOOTING

PROBLEM	PROBABLE CAUSE	CORRECTIVE ACTION
Melted material in crucible wets or erodes crucible.	(1) Beam not centered (2) Water flow less than 3 gallons per minute. (3) Emitter out of adjustment	(1) Readjust focus current (2) Improve water flow. (3) Adjust emitter.
Beam spot off center in lateral direction -or- Beam spot has tail(s) on one side.	(1) Parts loose or out of alignment. (2) Warped or sagging filament.	(1) Realign & tighten parts. (2) Replace filament.
Excessive longitudinal coil current	(1) Weak magnetic field in main field permanent magnet. (2) Partial short in focus coil.	(1) Re-magnitize or replace permanent magnet. (2) Replace focus coil.
Beam spot not centered in longitudinal direction.	Coil current improperly adjusted.	Adjust focus current..
Emission voltage erratic -or- visible arcing-or- high voltage insulators becoming hot.	(1) HY insulators dirty with conductive material . (2) HV insulators damaged.	(1) Clean by bead-blasting (2) Replace HV insulators.
Beam voltage low,* beam current low,* filament current correct.*	(1) High resistance short to ground at emitter. (2) High resistance short to ground at filament leads. (3) High resistance short to ground at feedthrough.	(1) Correct positioning of emitter and adjacent parts. Clean all parts. (2) Correct positioning of filament leads and adjacent parts. Clean all parts. (3) Repair or replace feedthrough. Clean all parts.
Beam voltage correct,* beam current correct,* filament current high.* ---	Shorted filament.	Replace filament.
Beam voltage correct,* beam current zero, filament current zero.	(1) Filament broken (2) Filament loose (3) Oxide corrosion on filament clamps.	(1) Replace filament. • (2) Tighten filament clamps. (3) Clean or replace filament clamps.
	(4) Broken H.V. hookup. (5) Loose feedthrough connection. (6) Broken feedthrough. (7) Broken cable. (8) Open filament circuit in power supply.	(4) Replace strap or rod. (5) Tighten feedthrough connection. (6) Replace feedthrough. (7) Repair cable. (8) Repair power supply.

* Power supply nominal operating values are listed in the appropriate power supply instruction manual

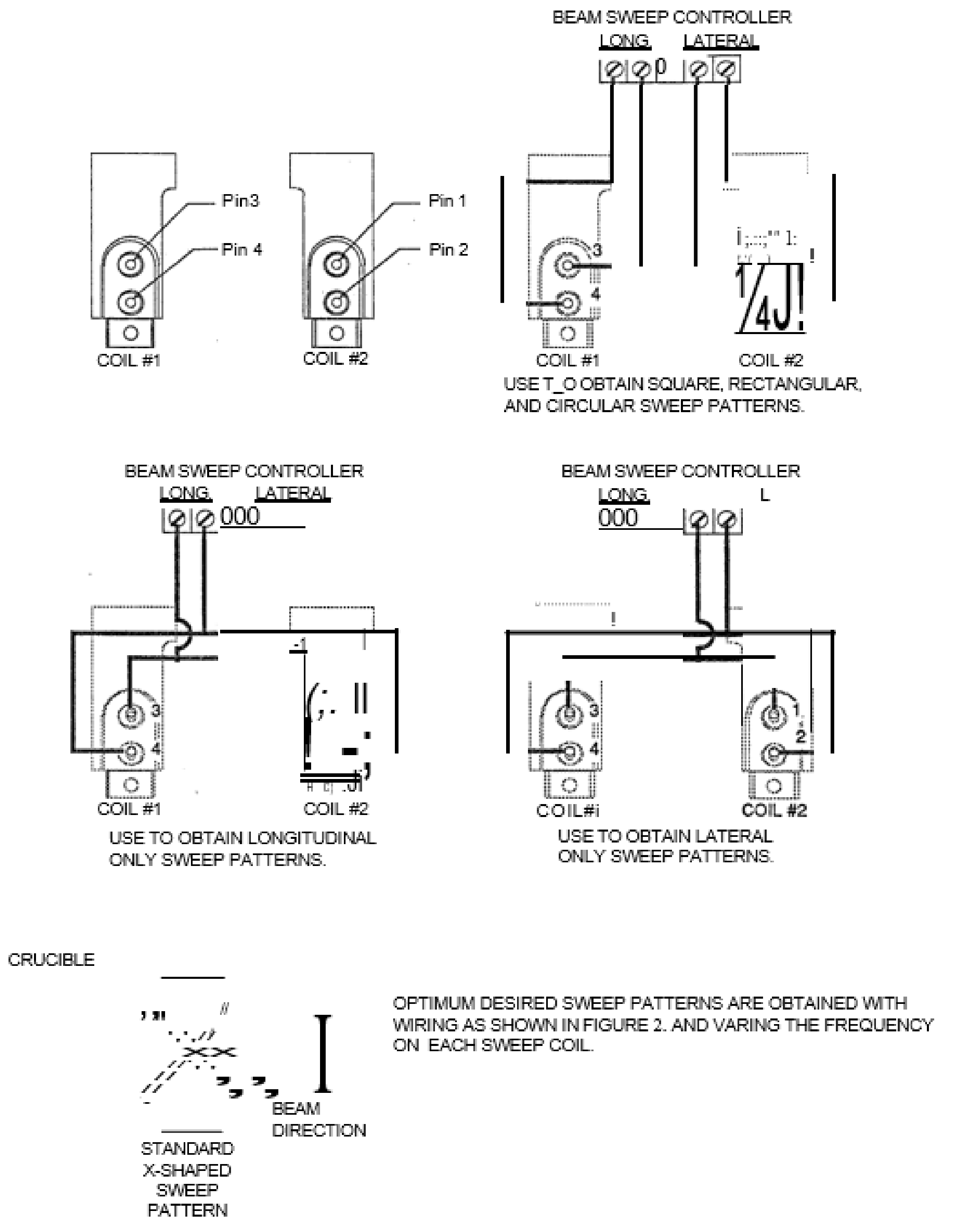

BEAM SWEEP CONTROLLER
LONG.
LATERAL
Pin3
Pin 4
Pin 1
Pin 2
COIL #1
COIL #2
COIL #1
COIL #2
USE T_O OBTAIN SQUARE, RECTANGULAR, AND CIRCULAR SWEEP PATTERNS.
BEAM SWEEP CONTROLLER
LONG.
LATERAL
COIL #1
COIL #2
USE TO OBTAIN LONGITUDINAL ONLY SWEEP PATTERNS.
BEAM SWEEP CONTROLLER
LONG.
L
COIL#i
COIL #2
USE TO OBTAIN LATERAL ONLY SWEEP PATTERNS.
CRUCIBLE
BEAM DIRECTION
STANDARD X-SHAPED SWEEP PATTERN
OPTIMUM DESIRED SWEEP PATTERNS ARE OBTAINED WITH WIRING AS SHOWN IN FIGURE 2. AND VARING THE FREQUENCY ON EACH SWEEP COIL.

Figure 3

PRESSURE BARRIER INSTALLATION

(pressure barrier units only)

TO INSTALL THE PRESSURE BARRIER:

1. Locate the tantalum pressure barrier which is attached to the Beam Cover. Remove it by sliding it upward. (Use lint free gloves, and place the barrier in a clean location.)

2. Place a load of material in the crucible. Then pump down the system and, following proper procedures, operate the e-Gun to verify that the beam is centered in the crucible.

3. Once the beam is known to be centered, shut off the e-Gun and bring the system back to atmosphere. Replace the tantalum pressure barrier by sliding it down into place. (Use lint free gloves again.) Make sure that there is still a charge of material to be evaporated in the crucible.

4. Pump down the system. Now, OPERATE THE SYSTEM SO AS TO BURN A HOLE THROUGH THE TANTALUM PRESSURE BARRIER WITH T".dE ELECTRON BEAM. If a Beam Sweep is to be used in normal operation, use it during this step so as to enlarge the hole for beam clearance.

5. The hole which has just been created is termed the Pressure Barrier Orifice. Installation of the pressure barrier is now complete.