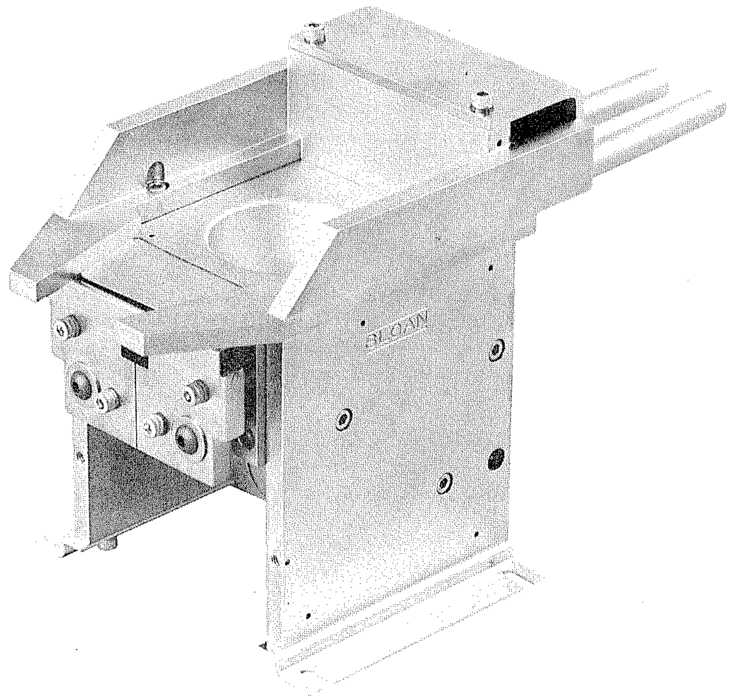

INSTALLATION
AND
OPERATING
INSTRUCTIONS

SINGLE HEARTH ELECTRON BEAM SOURCE 270° BENT BEAM

M-609-773
July, 1973

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SECTION I

GENERAL INFORMATION

DESCRIPTION

The Sloan Single Hearth 270° Electron Beam Gun, identified as Part Number 000195, is a heavy-duty source for production deposition of thin films. It offers large hearth capacity, high deposition rates, long filament life, and industrial-level reliability in a package small enough to be compatible with virtually any vacuum system. A unique asymmetrical emitter configuration eliminates harmful ion bombardment effects on the filament and thus assures long filament life.

The Sloan 270° Single Hearth Gun is designed for operation at input power levels up to 12 kilowatts. The electron beam is bent through a full 270° of arc before impacting in the hearth, permitting the filament to be completely shielded from the evaporant and falling debris. The substrates are also shielded from materials evaporated from the filament.

The gun is equipped with a water-cooled trap, located behind the hearth, which effectively prevents the escape of secondary electrons. The trap contains a permanent magnet, the field of which is carefully controlled during manufacture. Secondary electrons released in the impact area are captured by the field and directed into the trap.

The electron beam can be swept in both the X (longitudinal, perpendicular to the filament axis) or Y (transverse) directions to optimize evaporation characteristics for various materials. (Y-axis deflection requires use of optional accessory equipment available from Sloan.)

Figure 1-1 illustrates the 270° Single Hearth Electron Beam Gun and shows its major components. Figure 1-2 provides all critical gun dimensions, as an aid to installation.

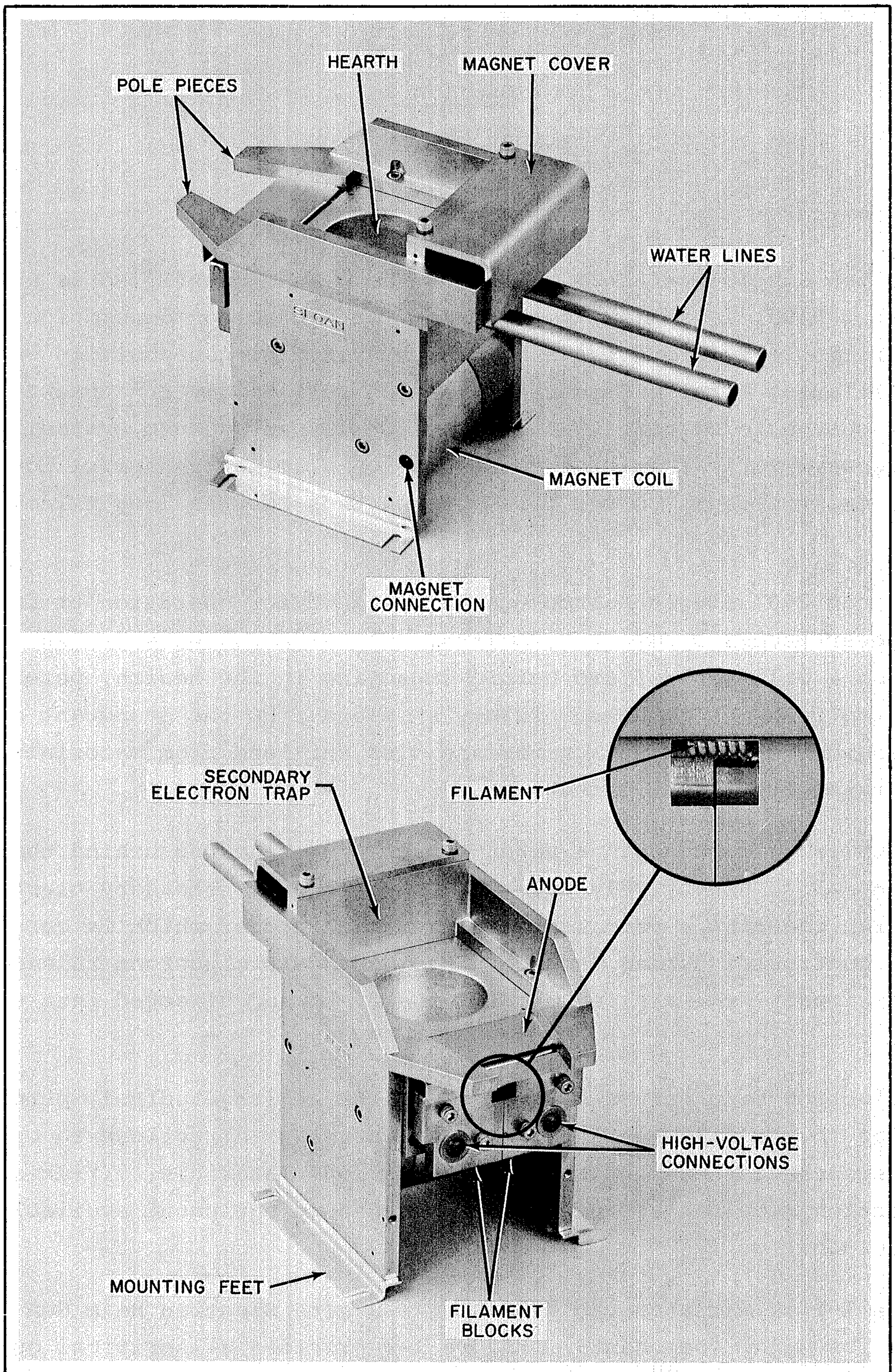

Figure 1-1. Sloan Single-Hearth Electron Beam Gun, 270° Bent Beam

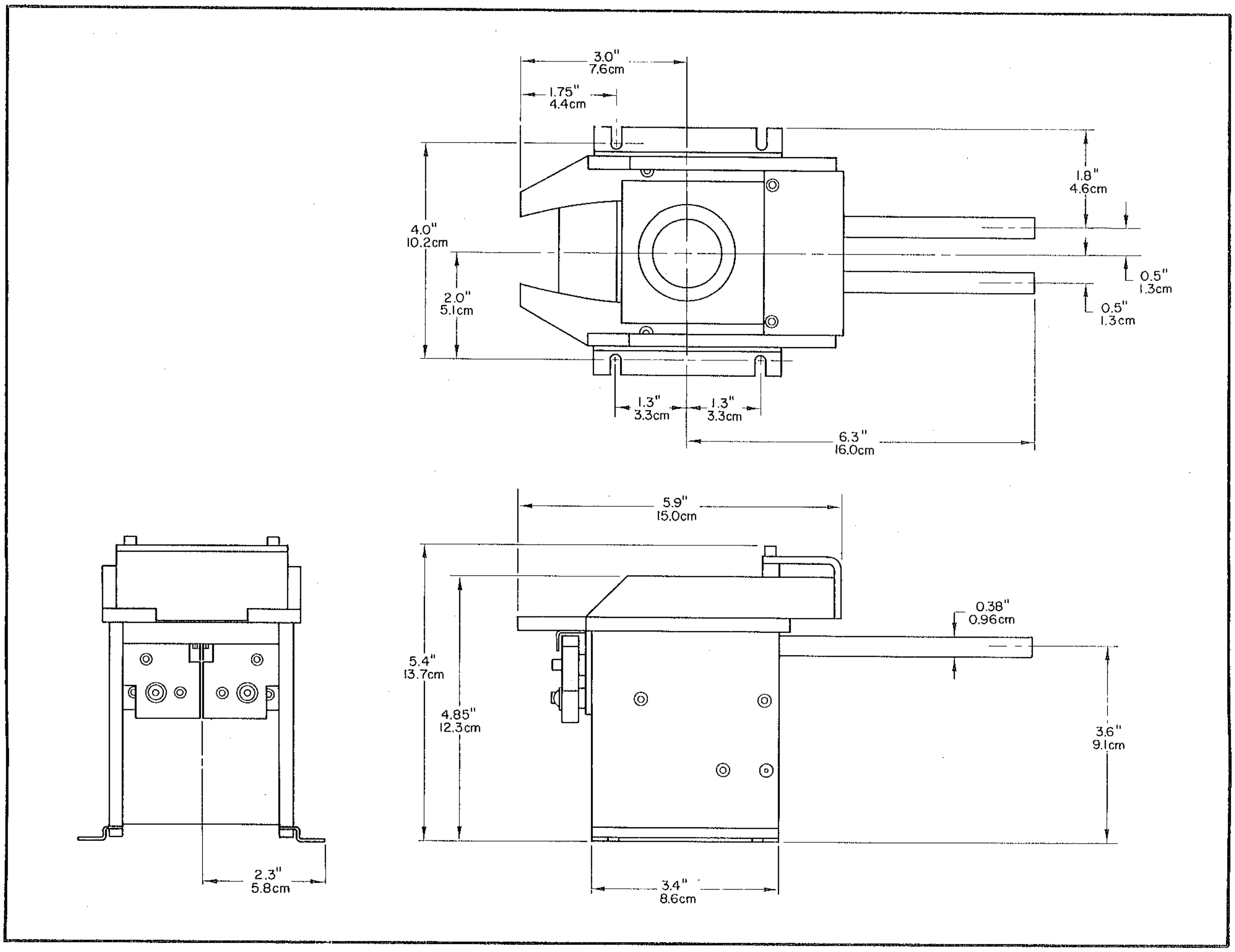

Figure 1-2. Dimensional Drawing of Single Hearth Electron Beam Gun, 270° Bent Beam.

SPECIFICATIONS

Type	270° Bent Beam
Beam Voltage	-10,000 volts d-c
Beam Current	Up to 1.2 amps d-c
Maximum Power	12kW
Operating Pressure	Below 5 x 10^{-4} torr
Operating Efficiency	In excess of 99% of beam power into hearth
Electromagnet Supply	0.3 to 3 amps d-c, -10 volts maximum
Filament Supply	0 to 6 volts a-c, 40 amps
Cooling Water	2 gpm (7.6 liters/min) minimum, 30 psi (2 kg/cm^2) drop directly across gun
Spot Size	0.48" x 0.44" (1.22 x 1.12 cm) at 12kW
Bakeout Temperature	250°C maximum
Evaporant Exit Angle	90°
Hearth Capacity	30 cc
Hearth Dimensions	Truncated 30° cone: 1.75 in. top dia., 1.25 in.bottom dia., 0.92 in. deep. (4.5 cm top dia., 3.2 cm bottom dia., 2.3 cm deep.)
Hearth Liner	Volume 15 cc
Over-all Size Excluding Water Lines . .	5.4" H x 4.5" W x 5.9" L (13.7 cm H x 11.4 cm W x 14.9 cm L)
Weight	7 lbs. (3.2 kg)
Construction Materials	OFHC copper, magnet iron, stainless steel, molybdenum, silver solder, nickel plating, alumina ceramic, tungsten

RELATED EQUIPMENT

Proper operation of the electron beam gun requires:

1. An electrical power source capable of supplying the necessary fixed accelerating voltage (-10,000 volts dc), filament current, and magnet current. (See gun specifications for current requirements.) The Sloan FIVE/TEN (5kW) or TWELVE/TEN (12kW) Electron Beam Power Supplies are recommended.

2. One dual high-voltage feedthrough (or two single feedthroughs) capable of carrying up to 50 amperes of filament current at a standoff voltage of 15 kv. The Sloan Dual High Voltage Feedthrough, p/n 000321, is ideal for most installations. This Viton-sealed unit is compatible with any 1-inch diameter feedthrough port. For metal-sealed systems, two Sloan Single High Voltage Feedthroughs, p/n 000320, are recommended. These units mate with any standard 2-3/4 inch diameter non-rotatable flange.

3. An Electron Beam Service Feedthrough (or equivalent) capable of supplying cooling water and magnet current to the gun. Sloan Electron Beam Service Feedthroughs (p/n 000318, Viton sealed; p/n 000323, metal-sealed) are recommended. Both styles provide two 3/8-inch diameter water lines and two 3-ampere, 10-volt electrical connections for magnet current.

4. A water flow meter for checking adequate flow to the gun. The meter should cover the range up to at least 2.5 gallons (9.5 liters) per minute. Simple, reliable, and inexpensive float-type meters covering the range from 0.5 to 5 gallons (1.9 to 19 liters) per minute are available from Sloan.

5. Appropriate interlock circuits for equipment and operator safety. A safety interlock kit (p/n 000156), which includes sensors for chamber closure, vacuum, and water flow, complete with compatible cables, is available from Sloan.

SECTION II

PREPARATION FOR USE

UNPACKING

Carefully remove the Electron Beam Gun from its shipping container. Do not destroy the container in case the gun must be reshipped. Inspect the Electron Beam Gun for any visible signs of physical damage that might have been incurred during shipment. If obvious damage is indicated, see "Warranty and Claims" section for further instructions. Check the shipment to make certain all parts are complete.

The following items should be included in the shipping container, and are identified in Figure 2-1:

Qty.	Item	Part No.
1	Single Hearth EB Gun, 270° beam deflection	000195
3	Spare Filaments	126710
4	Alumina Insulating Spacers (1 set)	126116
1	Hearth Liner (Graftite[R])	126326
1	Allen Wrench, 7/64"	-
2	Filament Retaining Screws	126740
2	Lockwashers, Split, #6	-
1	Filament Removal Hook	126726
4	Screw, Stainless, Hex Socket Head, 6-32 x 1/4	-
1	Screw, Stainless, Hex Socket Head, 6-32 x 1/2	-
1	Screw, Stainless, Hex Socket Head, 6-32 x 1	-
1	Instruction Manual and Warranty Card	-

If any of the above listed parts are missing, contact your nearest Sloan Representative or the Service Department of Sloan Technology Corporation prior to installing the gun.

INSTALLATION OF ONE ELECTRON BEAM GUN

An electron beam gun and related power supply, no matter how well designed, are no better than the conditions in which they must work.

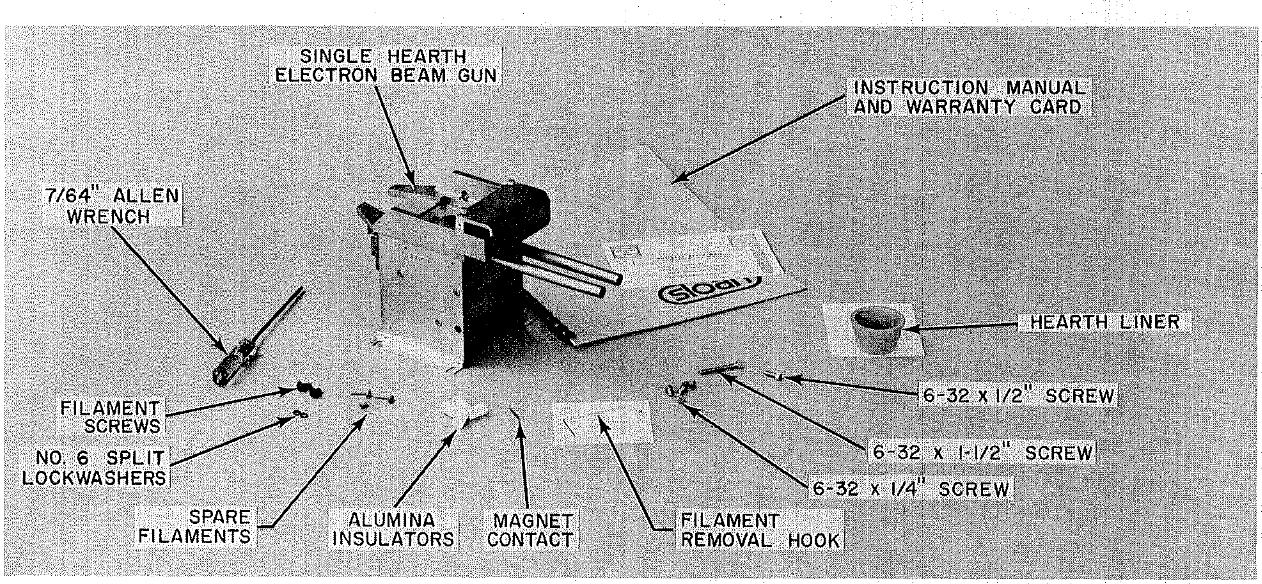

Figure 2-1. Sloan Single Hearth Electron Beam Gun, 270° Bent Beam, and Standard Supplied Accessories.

Such factors as chamber pressure (both total and local), high-voltage lead position, proper water flow, ion shielding, and gun alignment can all have significant effects on performance. They must be carefully controlled, or inconsistent operation and possible damage to the gun may occur.

Proper installation of an electron beam gun requires the following conditions:

1. The gun must be mounted in the chamber in such a way that it is properly positioned with respect to the substrates, and positively grounded electrically to the baseplate or equivalent electrical ground.

NOTE

The gun must NOT be mounted on a baseplate of magnetic material without the mounting feet provided. The feet are necessary to prevent shorting of the gun magnetic field by the baseplate.

2. Cooling-water lines must be adequate to maintain a flow of at least 2 gallons (7.6 liters) per minute.

3. High-voltage connections must be equipped with adequate ion shields.

4. Suitable magnet current connections must be supplied.

5. Adequate equipment and operator safety interlocks must be in use.

6. Any additional precautions that may be necessary to minimize high-voltage hazards to personnel or equipment must be taken.

Figure 2-2 is a schematic diagram of a typical 270° electron beam gun installation.

To install the gun, proceed as follows:

(1) Select installation positions for the electron beam gun and related feedthroughs. The gun should be level, and preferably mounted on a well-grounded plate. The feedthrough locations should be selected for convenience in making the required connections. Ideally, the high-voltage feedthrough will be placed so that electrical lead lengths of no more than 4 to 5 inches (10 to 13 cm) are required. (Long electrical runs increase the difficulty of providing adequate shielding; very short runs may transmit undesirable amounts of heat to the feedthrough.)

    The gun water lines should never be cut closer to the gun than 1-1/2 inches (4 cm), or it may be difficult to make a leak-tight brazed joint. A feedthrough location that will allow use of vacuum-tight quick-disconnect fittings in the water lines is often convenient; such fittings facilitate removal of the entire gun for cleaning or other maintenance.

    Shutters for deposition control must be <u>at least</u> 2-1/2 inches (6-1/2 cm) above the top of the hearth.

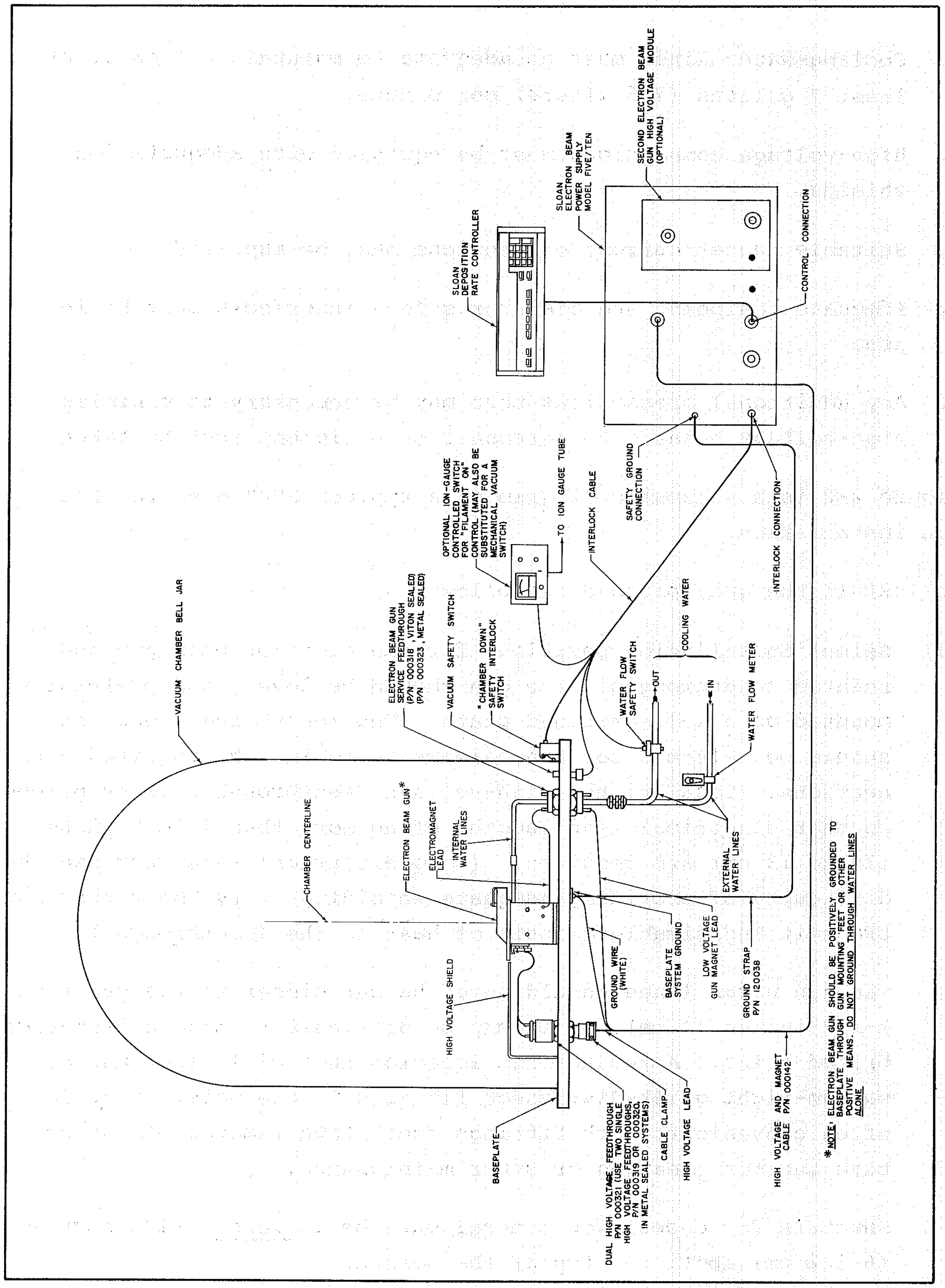

Figure 2-2. Typical Installation of the 270° Single Hearth Electron Beam Gun in a Vacuum System.

(2) Complete all necessary machining operations on the baseplate or feedthrough collar. Size 6-32 or 8-32 stainless steel machine screws and washers are adequate for mounting the gun. Figure 1-2 provides all necessary dimensions for locating the tapped mounting holes precisely with respect to the center of the hearth.

(3) Cut the copper inlet and outlet water lines to the length desired. If the lines are to be bent, the bends should start no closer than 1/2 inch (1.3 cm) from the gun and undue strain should not be placed on the tube-to-gun joint.

Quick-disconnect fittings may also be installed on the gun water lines at this time if they are to be used. A pair of suitable Cajon Viton-sealed vacuum connectors is included with each Sloan Electron Beam Service Feedthrough. Silver soldering with a nickel alloy vacuum-grade silver solder (HH Braze 715VTG* or Wesco** Nicusil 3) is recommended for all water line joints.

To make the joints, proceed as follows:

a. Remove the O-rings from the connectors, and store them temporarily in a clean container.

b. Make absolutely certain that the surfaces to be joined are scrupulously clean. Vigorous use of abrasive cloth is suggested.

c. Slip the attachment nut over the gun water line before joining the line to the fitting.

d. Apply a liberal amount of silver brazing flux.

e. Place a solder preform in the coupling and push it on the gun.

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* A product of Handy and Harman.
**A product of Western Gold & Platinum Corporation, Los Angeles.

f. Heat sink the tubing immediately adjacent to the gun or the feedthrough with a wet rag, and keep the rag wet during soldering.

g. Torch-braze the connections.

h. Wash in hot water to remove all flux.

j. Replace the O-rings after lubricating them lightly with Apiezon L or other high-vacuum lubricant. If a leak tester is available, assemble the lines and check for leaks. A leak-check port is provided on the coupling nut of the Cajon connector for this purpose.

(4) If the gun is to be used with a Y-axis Beam Control, install the Y-axis Deflection Kit as described in the instructions accompanying it.

(5) Mount the gun and feedthroughs in the chamber. THE GUN MUST BE POSITIVELY GROUNDED THROUGH ITS MOUNTING SCREWS.

(6) Connect the water lines and make certain that all connections are leak-tight. The gun requires a cooling-water flow of 2 gallons (7.6 liters) per minute and will be severely damaged if it is operated without adequate cooling water. For example, uncooled operation at 5 kilowatts with molten aluminum in the hearth will cause the aluminum to alloy with the copper, so that it cannot be removed without destroying part of the hearth. In addition, operation without adequate cooling can cause serious overheating of the insulators and the magnet coil.

For these reasons, the gun should be installed with a safety interlock flow switch on the outlet water line and a filter screen on the inlet line. The switch should be set to open if water flow becomes less than 2 gallons (7.6 liters) per minute. A suitable flow switch is provided with the standard Sloan Safety Interlock Kit (p/n 000156), which also includes a chamber-closure switch, a vacuum switch, and compatible cabling.

NOTE

To avoid damage to the gun, it is more important to maintain adequate water flow than a cold inlet water temperature. Slightly warm water will not harm the gun. Water flow should be measured with a flowmeter and potential pressure drops due to the water demanded by other equipment should be considered. Special care must be taken when the outlet of the gun is connected to a drain line shared by other equipment. The line may become pressurized and reduce the differential pressure across the gun.

(7) Connect the electromagnet lead from the service feedthrough to the connector on the side of the gun. (See Figure 1-1 for location.) Maximum electromagnet current requirement is 3.0 amperes. Route the lead in such a manner that it will not be shorted to ground by the tooling or shielding, or insulate it with Teflon sleeving or ceramic beads. Two 3-foot sections of Teflon-insulated wire with pin connectors at both ends are supplied with all Sloan Electron Beam Service Feedthroughs as a convenience to the user.

(8) Connect the high-voltage leads from the high-voltage feedthrough(s) to the filament block of the gun. Bare solid #8 (3.26 mm dia.) copper wire should be used to provide low resistance and adequate rigidity. The leads connect to the filament block as shown in Figure 2-3. The ends of the wires should be looped as shown for positive retention, and should pass under the washer as shown. The retaining screws should be tightened with the 7/64" Allen wrench provided*. The high-voltage lead screws and the filament screws are molybdenum-disulfide coated by a proprietary process to ensure long, trouble-free operation. All screws except those passing through the alumina insulating spacers should be recoated occasionally with molybdenum-disulfide spray. Use only uncoated screws in the spacers.

*This standard-size wrench will fit ALL screws on ALL Sloan Electron Beam Guns.

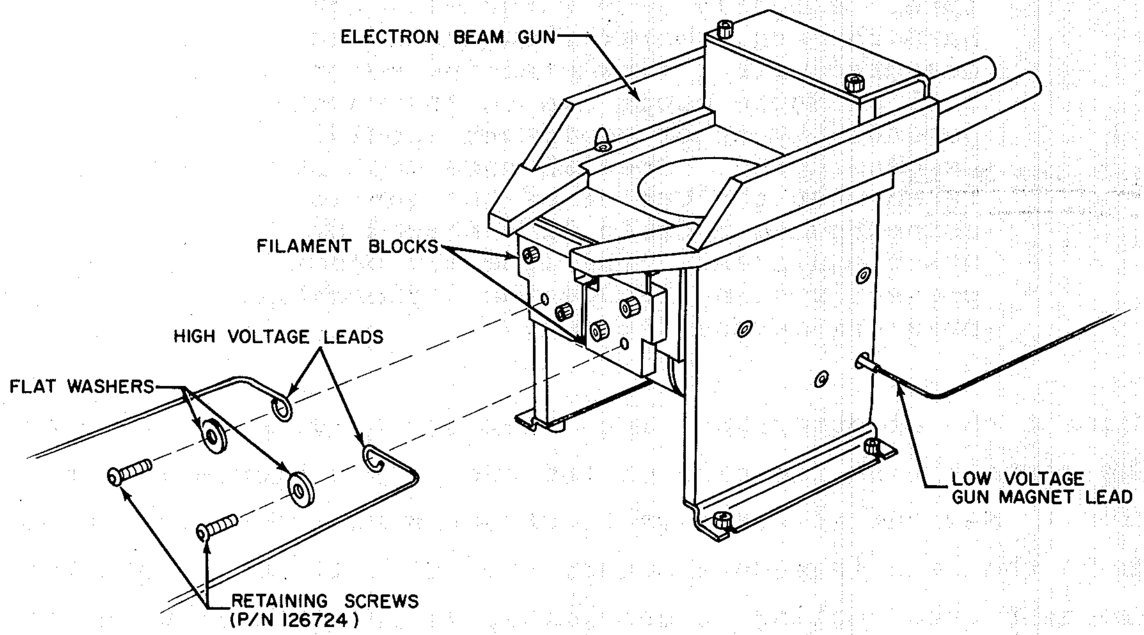
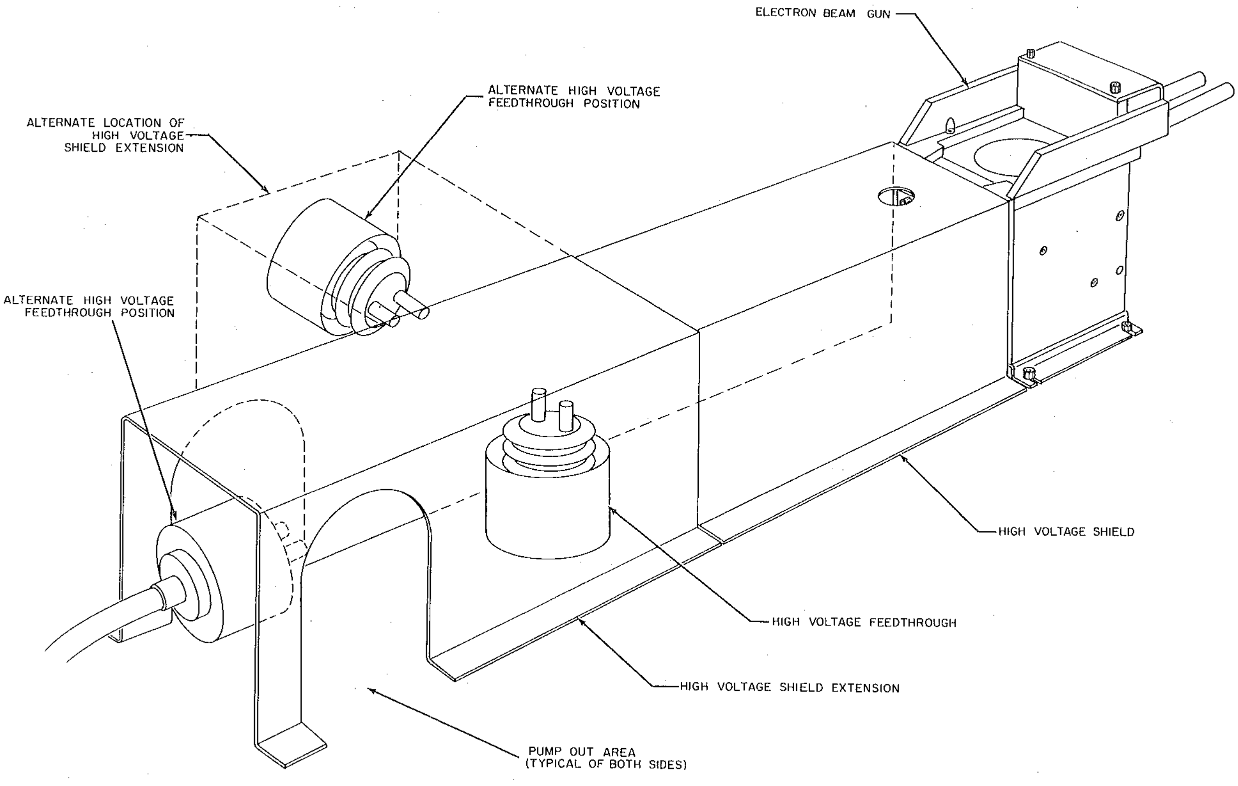


Figure 2-3. High Voltage Connections to Gun.

The path to the high-voltage feedthrough should be well clear of grounded elements, and preferably should be 4 to 5 inches (10 to 13 cm) long. Loop the leads for positive retention by the feedthrough terminals. Avoid sharp bends in the leads, but provide a gentle bend on the high-voltage feedthrough end to allow for thermal expansion.

(9) Install grounded shields over the entire length of both the high-voltage leads and around the high-voltage feedthrough to protect them from ions generated by the electron beam. Shielding should be installed in such a way that it can be removed without disturbing either the gun or other shielding, to facilitate maintenance. Figure 2-4 is a guide to proper shield installation. Shields may be formed from any non-magnetic metal compatible with the system. Stainless steel is recommended.



NOTE: AMPLE ALLOWANCE MUST BE MADE FOR PUMPING OUT THE AREA UNDER THE SHIELDING. THIS CAN BE DONE BY PASSING THE SHIELD OVER PUMPING PORT OR BY OPENING SIDES OF SHIELD (OUT OF SIGHT OF E.B. GUN) WITH A MINIMUM OF 25 SQUARE INCHES AS SHOWN ON DRAWING

Figure 2-4. Typical Installation of High Voltage Shielding.

Shields should be kept at a minimum of 1/4 inch (6 mm) from the leads and high-voltage feedthroughs. Make certain grounded items are kept clear of the area within the high voltage shield.

CAUTION

Ample allowance must be made for pumping out the area under the shielding. This can be done by constructing the shielding over the pumping port or by providing an opening on both sides of the shielding, out of sight of the electron beam gun, with a minimum area of 25 square inches (160 cm^2) as shown in Figure 2-4.

(11) Connect all interlocks to the electron beam power supply.

(12) Connect the external high-voltage and magnet cables, and provide a positive external electrical ground on the system baseplate adjacent to the gun mounting position. The auxiliary grounding connection supplied with the power supply must also be connected between the baseplate ground and the chassis of the electron-beam power supply.

The high-voltage cable should be routed in such a way as to remain slack rather than tight, and without sharp bends or contact with sharp edges. Avoid paths that carry the cable close to hot objects, particularly diffusion pumps.

DANGER

THE CABLE MUST BE CLAMPED SECURELY AT THE FEEDTHROUGH END. A DETACHED CABLE EXPOSES THE OPERATOR TO LETHAL VOLTAGES.

(13) If the vacuum chamber also includes resistance sources, ground one side of the heaters or filaments to the baseplate, and carry this ground through to the low side of the primary transformer if feasible. Ground other floating elements also wherever possible with #16 (1.3 mm dia) or larger wire if they are not already grounded by their feedthroughs or mountings.

DANGER

HIGH VOLTAGE DISCHARGE!

Ungrounded elements can assume hazardous potentials during operation of electron beam guns, and these voltages may be carried to the exterior of the chamber through associated feedthroughs. Arcing associated with ungrounded elements may also damage equipment.

Electron beam guns operate at very high potentials with respect to ground. They are capable of charging ungrounded elements to dangerous potentials. The amount of charge varies directly with the coupling between the electron beam gun and the elements, and with impedance to ground. A floating element, such as a resistance source and its associated feedthrough terminals or interconnecting wires, can become electrically charged and be a hazard to life if contacted. This can occur even if the resistance source is energized. Remember, these points are normally considered to be at a low potential when a resistance source is used alone or with other resistance sources. This may lull one into a false sense of security about the safety of touching high-current feedthroughs.

(14) Completely check the entire installation to make certain that all leads are connected, that the connections are tight, and that no leads are grounded.

INSTALLATION OF TWO ELECTRON BEAM GUNS

Two electron beam guns may be mounted in a single vacuum chamber if the following procedures are observed:

(1) The guns must be mounted with at least 3 inches (7.6 cm) of separation, and they must be side-by-side with the hearths centered and with water lines facing in opposite directions as shown in Figure 2-5.

(2) A separate high-voltage feedthrough must be provided for the second gun, and appropriate shielding must also be provided for the second set of high-voltage leads and associated feedthroughs. Follow the same precautions as described for installing only one gun.

(3) Plumb the water lines for both guns in series so that the normal water supply will be sufficient for both guns. A service feedthrough for each gun will generally result in the simplest installation. With more complex internal plumbing, the two guns can be installed with a single Sloan Electron Beam Service Feedthrough. If Y-axis deflection is to be provided, another low-voltage feedthrough will be required.

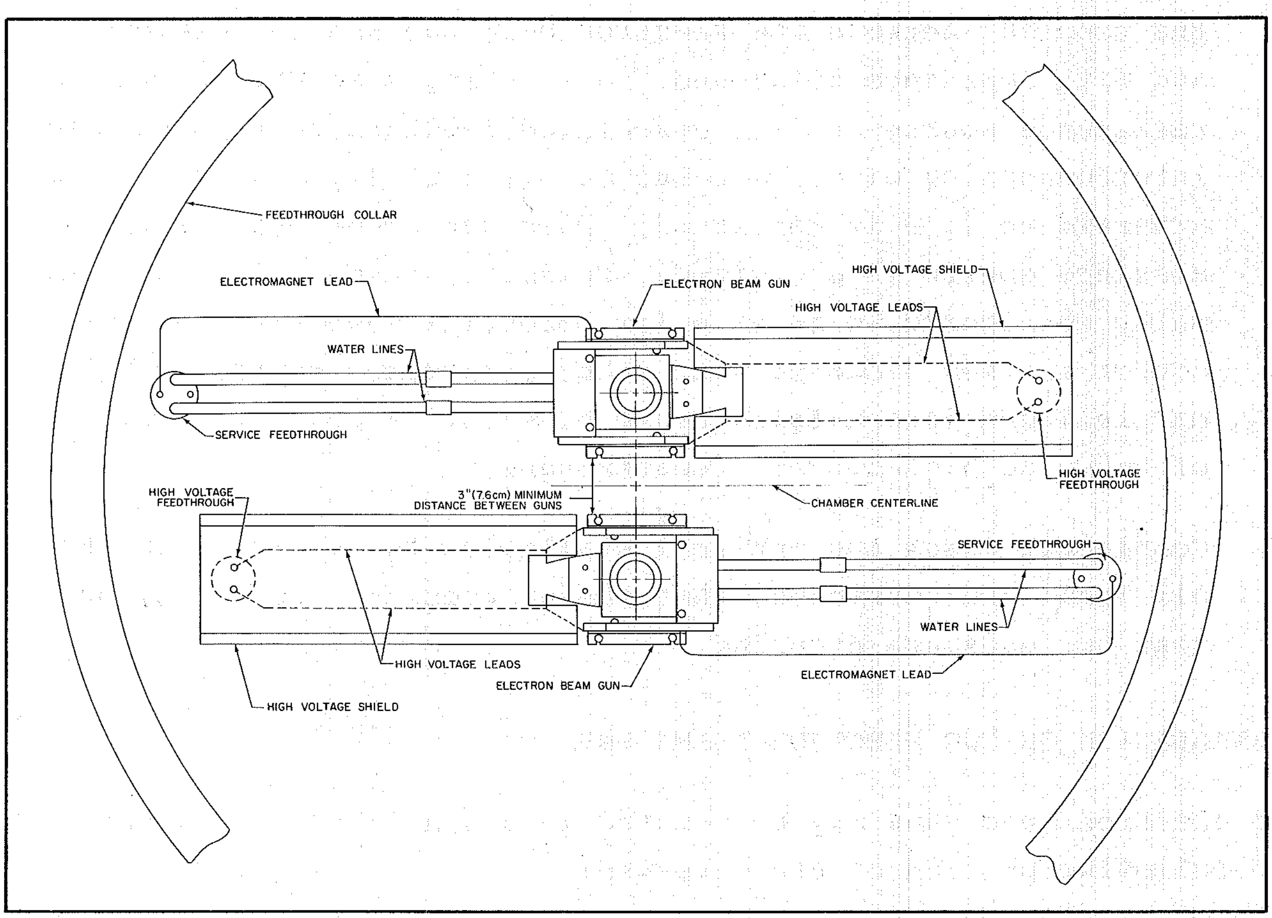


Figure 2-5. Typical Mounting of Two Electron Beam Guns in One Vacuum Chamber.

INSTALLATION OF THICKNESS MONITORS

If thickness monitors of the quartz crystal, resistance, or ionization type are used, they should be well shielded and grounded. It is a good practice to ground one end of resistance monitors to provide a drain for any collected charged particles. The monitor cables should be wrapped around a piece of grounded tooling or water line if practical. In some systems, extensive electrical shielding of the leads may be necessary. NOTE THE PRECAUTIONS OF PARAGRAPH 13 ABOVE WITH RESPECT TO HIGH-VOLTAGE DISCHARGE WHEN INSTALLING MONITORS, TEMPERATURE SENSORS, OR OTHER INSTRUMENTATION.

Detailed instructions for the installation of Sloan deposition monitor sensor heads are included in Section II of Sloan Instruction Manual M-605, Vacuum Chamber Fixtures and Accessories, and in the instruction manuals for Sloan deposition monitoring instrumentation.

SECTION III

OPERATION

The procedure below describes the operation of the 270° Electron Beam Gun with the Sloan FIVE/TEN or TWELVE/TEN Electron Beam Power Supply. Refer to the installation and operating instructions contained in the FIVE/TEN or TWELVE/TEN Operating Manual.

DANGER -- HIGH VOLTAGE

Electron beam guns operate at potentially lethal voltages. To avoid hazard to the operator:

1. BE CERTAIN ALL SAFETY INTERLOCKS ARE CONNECTED AND FUNCTIONING BEFORE ATTEMPTING TO OPERATE THE GUN.
2. NEVER BYPASS THE SAFETY INTERLOCKS.
3. WHEN WORKING IN THE CHAMBER, BE CERTAIN THAT THE HIGH-VOLTAGE KEY SWITCH ON THE POWER SUPPLY IS TURNED OFF, AND KEEP THE KEY IN YOUR PERSONAL POSSESSION.

(1) Install a hearth liner if one is to be used. A titanium diboride hearth liner should always be used if indium is to be evaporated, because this material will alloy even with a water-cooled hearth and damage the gun. With meltable materials, use of hearth liners will generally result in significantly higher deposition rates than can be obtained with a bare hearth at the same power input. They may also be advantageous if high-value materials (e.g., gold) are to be deposited.

Liners give no particular advantage when non-melting or subliming materials are to be evaporated. Liners also reduce the useful hearth volume, may introduce contamination of the film, and require additional operator care to prevent damage.*

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*"Deposition of Aluminum from an Electron Beam Gun"(JVST, Jan/Feb, 1972, Vol. 9, No. 1).

Evaporation Rates of Materials for 12 kW Gun without Hearth Liner

Material	Melting point °C	Evaporation rate, Å/min at 25 cm	Power, KW	Beam Mode	Evap. Charac.	Charge Form
Aluminum	660	10,000	6	Stationary	Melts	Cut Wire
		35,000	12	Stationary	Melts	Cut Wire
Chromium	1890	4,000	1.3	Max. Sweep	Melts in beam	Hot Pressed
Magnesium Fluoride	1266	1,800	1.5	Max. Sweep	Melts	Hot Pressed
Silicon Monoxide	1702	3,000	0.5	Max. Sweep	Sublimes	Hot Pressed
Titanium	1675	5,000	6	Stationary	Melts	Chunks

(2) Load the hearth with the material to be evaporated. (Refer to the table for evaporation rates and preferred forms of some of the more widely used source materials.) The hearth should never be filled more than 1/8 inch (3.2 mm) above the top of the hearth block, and should not be emptied in use below one-third full (approximately 0.6 inch or 1.5 cm below the top).

(3) Start water flow through the gun water lines. Make certain water flow is a minimum of 2 gallons (7.6 liters) per minute as indicated on a flowmeter.

(4) Pump the vacuum chamber down to a pressure of less than 5×10^{-4} Torr.

(5) Set the EMISSION and SWEEP controls of the Sloan Electron Beam Power Supply to zero.

(6) Set spot X POSITION control on the Sloan Electron Beam Power Supply to approximately 50% (Model FIVE/TEN) or "4" on the left-hand scale of the POSITION control (Model TWELVE/TEN). Set Y-POSITION Control (if provided) to zero.

(7) Apply high voltage, and turn on the filament.

(8) Slowly increase EMISSION current until the electron beam spot becomes visible in the hearth. (Do not exceed 50 mA.)

WARNING

DO NOT OPERATE THE ELECTRON BEAM IN AN EMPTY GUN HEARTH. SUFFICIENT POWER IS AVAILABLE TO SEVERELY DAMAGE THE HEARTH IF IT IS NOT LOADED WITH MATERIAL. If necessary for checkout, the gun may be operated for very brief periods of time at low power levels with an empty hearth.

(9) Adjust POSITION Control (electromagnet current) on the Sloan FIVE/TEN or TWELVE/TEN Power Supply until the electron beam spot is centered on the material in the hearth.

(10) Adjust the beam SWEEP Control on the FIVE/TEN or TWELVE/TEN Power Supply until the spot width is suitable for the material to be evaporated. Beam sweep along the X-Axis can be adjusted as described in the FIVE/TEN or TWELVE/TEN Power Supply Manual.

(11) Slowly increase the emission current while observing the gun. If the edge of the anode plate near the filament becomes red hot, immediately turn off the power. Vent the vacuum chamber and examine the gun adjustments. In particular, make certain that the lower edge of the anode is aligned with the upper edge of the recess in the filament blocks and that the gap between the two filament blocks does not exceed 0.015".

When the gun is properly adjusted, no visible signs of heating of the anode plate should appear.

(12) Increase the EMISSION current to consolidate and degas the evaporant. After degassing and consolidation, increase the EMISSION current to the desired evaporating level.

<u>WARNING</u>

DO NOT ALLOW THE BEAM TO WANDER FROM THE EVAPORANT AND IMPACT THE GUN STRUCTURE OR THE INTERFACE BETWEEN THE EVAPORANT AND THE HEARTH.

SECTION IV

THEORY OF OPERATION

GENERAL

An electron beam gun as used for vacuum deposition of thin films is, in its simplest form, a source of electrons, a means of focusing and accelerating the electrons, and a target.

The electron source is a tungsten-coil filament, held at -10 kV, which is heated to a white heat by passing a current through it. When the energy levels of the electrons on the hot surface exceed the binding force which holds them to it, they leave the surface at a low velocity, following the principles of thermionic emission.

The electrons in the immediate vicinity of the filament are accelerated along the electrostatic field lines toward the lower edge of the anode (See Figure 4-1). They are prevented from impacting on the anode by the presence of the lower edge of the filament block, located in front of and close to the filament. The edge induces a sharp bow in the field lines between filament and anode, so that centrifugal force on the electrons makes them take an outer path and they miss the anode completely. This asymmetric lens is responsible for the exceptionally long filament life of the gun.

After passing the anode, the electron beam is bent through a 270° arc and focused into an image of the filament on the surface of the target by a transverse-field magnetic lens. The second lens provides a small and very hot beam impact spot that in turn permits high evaporation rates at relatively low power inputs.

The 270° beam arc completely shields the emitter from evaporant and ejecta from the crucible. Together with the operating efficiency assured by the asymmetric electrostatic lens, this design provides long, trouble-free life of all gun components.

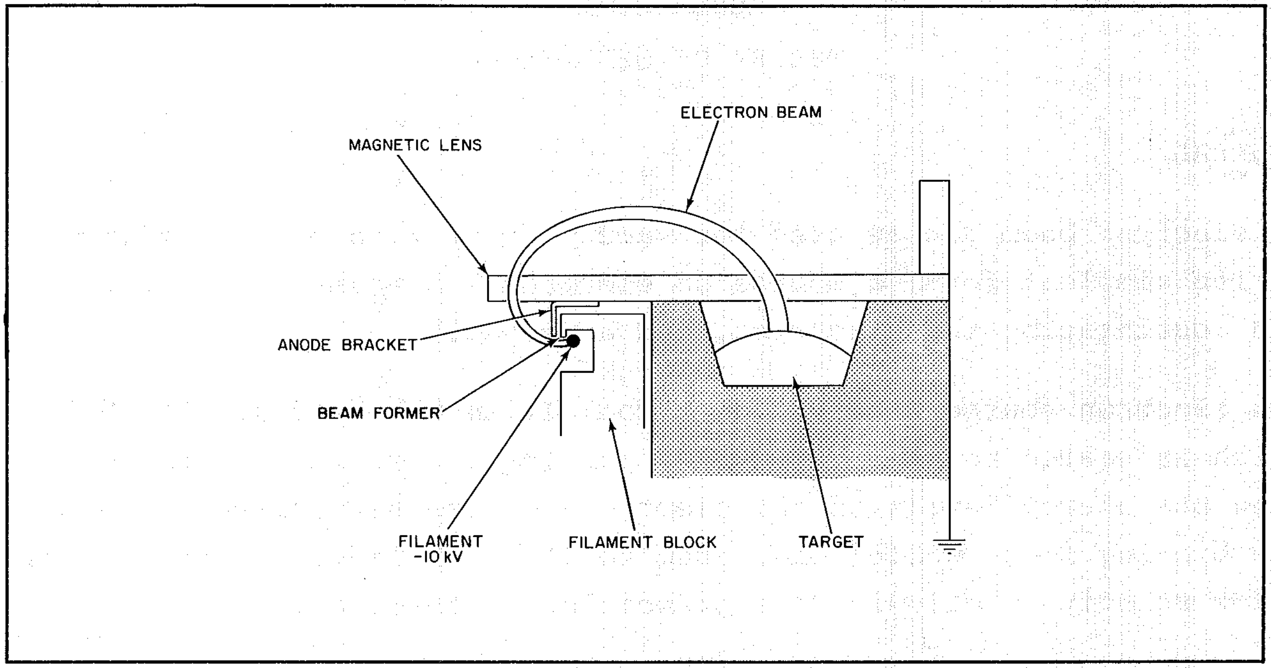

Figure 4-1. Beam Orientation of a Sloan 270° Bent-Beam Gun.

The hearth or target of the gun contains the material to be evaporated. A copper hearth is used for high thermal conductivity. Water passages in the hearth carry away excess heat (approximately 70% of the beam energy). A thin frozen layer, or skull, of the material that is being evaporated forms at the cooled copper surface, effectively providing an inner hearth. The inner hearth insures the purity of the evaporant and shields the cavity from the highly corrosive characteristics many materials acquire when they are heated to evaporation temperatures.

PHYSICS OF EVAPORATION

In 270° bent-beam guns, the electrons are thermionically emitted from a hot filament at -10 kV, accelerated by a grounded electrode, and focused into the hearth by a magnetic lens. During bending and focusing of the beam, less than 0.1 percent of the electrons escape and fail to impact in the hearth. Upon impact, most of the beam penetrates the evaporant material, heating it by electron-electron interactions, to yield an energy flux on the order of 10^4 W/cm^2.

However, evaporation is not advisable at power densities beyond a certain level because electrons do not give up their energy at the surface of the material but penetrate a comparatively long distance, giving up energy along their path. A 10 kV beam will penetrate about 60 microns in aluminum and will give up half its energy in the last fourth of its travel*. Materials must be able to dissipate this energy by evaporation, conduction, and radiation. If the energy cannot be dissipated, microscopic evaporant vapor bubbles explode and cause some of the spitting observed from electron beam guns. (Spitting is also caused by release of gas inclusions and the release of bound gas through thermal decomposition.)

Several methods can be used to increase the evaporation rate without increasing the power density. The most obvious ones are to defocus the beam slightly, reducing power density and increasing evaporation area, and to sweep the beam over the melt. Although sweeping the beam can enlarge greatly the area from which evaporation is occurring, it is very difficult to sweep a beam fast enough to materially reduce the energy density of the beam.

As a result of the impact of high-energy primary electrons on the surface atoms of the evaporant, some electrons are ejected out of their atom shells. Their flight paths are directed towards all points of the hemisphere above the hearth. Fortunately their energy in nearly all cases is very low, and the strong magnetic field at the rear of the hearth area forces them to the water-cooled copper secondary electron trap located in front of the permanent magnet (See Figure 1-1).

Infrequently, high-energy primary electrons undergo an elastic impact with surface atoms and are redirected to a new flight path. However, their number is kept to an absolute minimum by the angle at which the beam strikes the evaporant surface. In effect, the gun permits essentially no secondary electrons to escape from the magnetic field above the hearth.

*C. J. Calbick, Physics of Thin Films, Vol. 2, edited by G. Hass and R. H. Thun, Academic Press, New York, 1964, pg. 69.

ARCING IN A VACUUM CHAMBER

The causes of high-voltage arcing in a vacuum are not fully understood. There are some known causes, however, for arcing across small gaps in a vacuum, and some explanation for arcing across large distances when an evaporation is taking place.

An arc is the product of charge movement from one potential to another. Electrons may be forced to leave the surface of a charged conductor in two ways: a) thermionic emission (where the kinetic energy of the electrons due to thermal conditions is sufficient to overcome the forces holding them to the surface) and, b) field emission (where the effect of an electric field has enough force to release the electrons). In an electron beam system, both thermionic and field emission can exist.

During an evaporation, the impact point of the beam on the melt is superheated, possibly to the 10^5 K° range, and large numbers of ions are formed. These ions then move away from the melt, most remaining as ions until they strike the substrate while some recombine and give up energy and at the same time emit a photon.

This electron-ion recombination and photon emission takes place in a region just above the melt and creates a luminous cloud called a plasma, which exhibits a characteristic color for each evaporant.

At high evaporation rates, most of the ions do not recombine. However, very few of them migrate into the emitter area. While it is theoretically possible for a positively charged particle with the same momentum as a 10-kV electron to follow the same path backwards from hearth to emitter, the probability is small because two rigorous conditions must be met: a) A narrow "energy window" of ±10% of the correct value is required to make the particle follow the necessary path curvature, and b) the initial direction of travel must be within ±5° of the required flight path to the gun area.

The few ions that do bombard and sputter the anode-cathode area are formed from atoms of the vacuum chamber atmosphere in the area of the densest part of the electron beam, immediately above and in front of the filament. Because they originate in a region with a negative voltage gradient, they are immediately accelerated toward the filament blocks. The skewed electrostatic field set up by the anode deflects them away from the filament and into the lower part of the filament blocks, where the slight sputtering they may do has no significant effect on the operating characteristics of the gun.

If well-grounded shields confine the electrostatic field sufficiently, the ions drift away from the plasma and ultimately recombine without disturbance to the high-voltage components or contamination of the system.

Clean insulators and high-voltage components, together with proper shielding to prevent ion bombardment, should provide the user of electron beam guns relatively arc-free operation.

SELECTING MATERIALS FOR EVAPORATION

Evaporation from an electron beam gun is, in many ways, identical to evaporation from a resistance or induction heated source, and some of the same considerations govern materials selection. There are two basic differences between electron beam and other evaporation methods. First, the hearth or crucible of an electron beam gun is cold, and therefore, does not react with the evaporant, thus permitting deposition of ultra high purity films. Second, the local application of up to 10^4 W/cm^2 by the beam makes possible very high temperatures and evaporation rates.

Materials that melt before evaporation begins, as most metals do, evaporate well from an electron beam gun. When a metal melts, it forms a lump with a solid skin or skull in contact with the hearth. While the metal does not wet the hearth, it does make a good physical contact and is loose and easy to remove after cooling.

Some meltable materials, such as magnesium fluoride, absorb large amounts of gas or water from the air during processing. The explosive evolution of these gases during heating necessitates either a gradual increase in temperature until the gas is liberated, or the use of vacuum-melted raw material.

Many materials, such as silicon monoxide and chromium, sublime without melting or melt only at the impact point of the beam. These materials usually have poor thermal conductivity and make poor thermal contact with the hearth, resulting in a very low power dissipation. Materials that sublime can be deposited at high rates despite power limitations, but the power density must be kept low. For evaporation from electron beam guns, materials that sublime should be in a form having minimum surface area and maximum thermal conductivity. Large solid lumps or hot-pressed rods fill these requirements, and are available in a vast number of materials.

If a subliming material is evaporated with a focused, stationary spot, deposition rates will be low and there is some danger of subliming a small hole completely through the charge and into the hearth. This type of evaporation does not occur if the beam position is swept back and forth across the charge. Moreover, the sweep also greatly increases the rate, and permits simultaneous evaporation from the entire source if the sweep is faster than the thermal time constant of the loaded hearth. Many materials require slow heatup and thorough degassing to prevent spitting or fracturing and popping out of the hearth. For example, powder or fine granular materials are difficult to evaporate satisfactorily without pressure rises in the vacuum chamber or excessive spitting of the melt. The small particle size provides a large surface area and thus the potential for large volumes of adsorbed gas. Such material requires a long warm-up and out-gas time and a relatively low power input and evaporation rate to prevent the half-molten grains from flying out of the hearth.

Three- and four-component alloys with vapor pressures varying as much as 100 to 1 can be evaporated with electron beam sources, by a method that requires a precise match between the rate of evaporation and the rate at which new material is introduced into the melt.

The necessary control can be obtained by injecting material in wire form from above the pool level. When the feed rate has been selected, the electron gun power is adjusted to maintain a constant pool height. Under these conditions, the vapor composition coming off the liquid will be the same as the solid material entering the pool. It is essential that the power be adjusted so that the evaporation rate matches the feed rate and the pool height is kept constant. The pool should be allowed to stabilize for 10 minutes before deposition begins.

Evaporation from two or more guns concurrently is feasible if adequate measures are taken to monitor and control the rate of each gun and consequently the composition of the deposited alloy.

Reactive evaporation of two components or evaporation in a reactive gas is also used to deposit some difficult compounds such as tantalum nitride. Compounds that tend to decompose thermally can frequently be evaporated with a minimum of decomposition by using a very small beam spot. This minimizes decomposition by heating only a small part of the crucible charge at once. Many alloys, when evaporated at high rates, do not fractionate (within commercial tolerances) because diffusion of the constituents is slower than the evaporation rate.

Data is available on the suitability of materials for thermal evaporation from the Sloan Notebook and from published papers such as "Evaporation Characteristics of Materials from an Electron Beam Gun" (JVST, Jan/Feb 1971, Vol. 8 #1); and "Deposition of Aluminum From an Electron Beam Source" (JVST, Jan/Feb, 1972, Vol. 9 #1). However, it is difficult to predict whether a particular material will work well in a process without an actual test.

CHARACTERISTICS OF ELECTRON BEAM GUNS

Some highly reactive materials, such as aluminum, will attack the copper hearth if the beam impinges near the edge of the pool or hearth cooling is inadequate, or if the gun is run at power levels beyond its design limits. Hearth liners will protect the copper from attack, but they can contaminate the film due to their high operating temperatures, and they have a limited lifetime. Hearth liners are also used as thermal barriers between the melt and the hearth to substantially increase both the thermal efficiency of the hearth and the evaporation rate. Some materials are so reactive or form such low-melting alloys with copper (e.g., indium) that a hearth liner is necessary to protect the crucible from attack even with sufficient water cooling and good technique.

The precision of control obtainable with an electron beam gun is determined by the thermal mass of the charged hearth, the stability of evaporation, and the system response time. A hearth with an average charge has a total (0-6kW) response time of about a second. Most power supplies designed for automatic control using rate feedback are very fast. An electron beam gun with rate feedback is able to establish rate control less than five seconds after the start signal is given, once the charge has been pre-conditioned.

Vapor distributions from electron beam sources have been measured and found to be slightly dependent upon both beam power and charge volume. This distribution variation is much less severe than that of many resistance sources, and distributions remain stable over long production runs because only the evaporant instead of the source is replaced.

SECTION V

MAINTENANCE

The Sloan 270° Single Hearth Electron Beam Gun should give long, trouble-free service with a minimum of maintenance if it is operated properly and adequately cooled. It will be necessary, however, to keep the gun and feedthroughs clean, to maintain an adequate flow of cooling water, and to check insulating spacers periodically.

This section provides instructions for routine maintenance of the gun and filament replacement. If properly performed, all such operations can be carried out safely. However, since the electron beam gun operates at potentially lethal voltages, strict precautions must be taken to avoid exposure of personnel to these voltages.

DANGER

HIGH VOLTAGE!

Electron beam guns operate at potentially lethal voltages. To avoid hazard to the operator:

1. NEVER BYPASS THE SAFETY INTERLOCKS.
2. WHEN WORKING IN THE CHAMBER, BE CERTAIN THAT THE HIGH VOLTAGE KEY SWITCH ON THE POWER SUPPLY IS TURNED OFF, AND KEEP THE KEY IN YOUR PERSONAL POSSESSION.

Figure 5-1 is an exploded view of the 270° gun and identifies all replaceable parts of the gun as an aid to maintenance.

PERIODIC SERVICING

(1) Before each run, make certain there is sufficient material in the hearth for the complete evaporation process.

(2) Before each day's operation, verify that the water flow rate is a minimum of 2 gallons (7.6 liters) per minute, and check the water flow switch by turning the gun water off and on again and observing the interlock light on the electron beam power supply.

(3) Remove the evaporant buildup from the pole pieces when it loosens, to avoid contamination of the melt.

(4) After twenty hours of operation, inspect the insulating spacers (p/n 126116 , item 17, Figure 5-1) and the high-voltage feedthrough for build-up of conductive films. Change the spacers if they are coated over more than 50% of their total length. (Four spare spacers are provided with the gun initially.) This is particularly important when metals are being deposited.

(5) Clean the hearth thoroughly with a scraper and small wire brush after every ten to twenty operating hours. Clean evaporant residue from bell jar, tooling, and chamber, and clean all loose material from the base plate.

(6) Always clean the hearth thoroughly when changing evaporants.

(7) If the permanent magnet mounted beneath the top cover is removed for any reason, verify that it is replaced in the correct orientation. THE BEVELED EDGE OF THE MAGNET MUST FIT OVER THE PIN IN THE MAGNET HOUSING. See Figure 5-1, Item 4. If the magnet is not correctly installed, the top cover cannot be properly fitted. If the gun is operated with the magnet in the wrong orientation, the electron beam will bombard the chamber walls or the fixturing in front of the gun.

(8) In the event of accidental damage to the permanent magnet such as a chip or crack, replace it with a new magnet available from Sloan Technology Corporation. New magnets are furnished with the correct value of magnetic flux and are treated to assure field stability under normal conditions of handling and use in the vacuum system.

(9) Do not subject the permanent magnet to temperatures higher than 450°C.

(10) In accordance with generally accepted practice, never store the permanent magnet in close proximity to other magnets, to avoid degradation of the magnetic field.

SPARE PARTS

Three spare filaments (p/n 126710), a spare set of alumina insulating spacers (p/n 126116), and an assortment of spare small hardware is provided with the gun (Figure 2-1). Filaments and spacers are expendible items consumed in the operation of the gun; spares should therefore always be kept on hand to support normal operation. If Sloan feedthroughs are used, spare O-rings for the Cajon fittings (p/n 045111) and vacuum seal (p/n 045216) should also be stocked. Spare seal O-rings (p/n 045117, Viton only) should always be stocked.

If minimization of potential down time is imperative, stocking of spares of the following items is suggested, in order of importance:

PART	PART NO.	Figure 5-1 REFERENCE NO.
Filament	126710	22
Insulating Spacer	126116	17
Anode	126838	16
Magnet Coil	126105	11
Filament Block Rt. Hd.	126706	18
Filament Block Lt. Hd.	126705	21
Filament Clamp Rt. Hd.	126714	23
Filament Clamp Lt. Hd.	126713	24
Filament Screws (2 ea.)	126740	15
Gun Hearth	126708	7
O-ring	045117	-

FILAMENT REPLACEMENT

Two methods for filament replacement are outlined below. The first provides filament replacement only, while the second allows inspection and replacement of insulating spacers as well. Refer to Figure 5-1 for identification of all gun parts.

Note that all screws in the gun assembly can be removed with the 7/64" Allen wrench provided.

A. Simple Filament Replacement Only (See Figures 5-1 and 5-2)

To replace the filament, proceed as follows:

(1) Remove high-voltage shielding.

(2) Disconnect the high-voltage leads from the filament blocks by loosening screws #19.

(3) Loosen two anode base mounting screws (#14) and remove the anode-cathode assembly.

(4) Remove the two anode screws (#15) and the anode (#16).

(5) Remove the filament screws and the filament clamps.

(6) Remove the filament.

(7) Place a new filament with its legs alongside each guide pin.

NOTE

The filament must be properly aligned as shown in Figure 5-3. If necessary, bend the legs slightly with pliers to achieve correct alignment.

(8) Lubricate the filament screws with molybdenum disulfide.

(9) Install the filament clamps and screw them down onto the filament legs until a light contact is made.

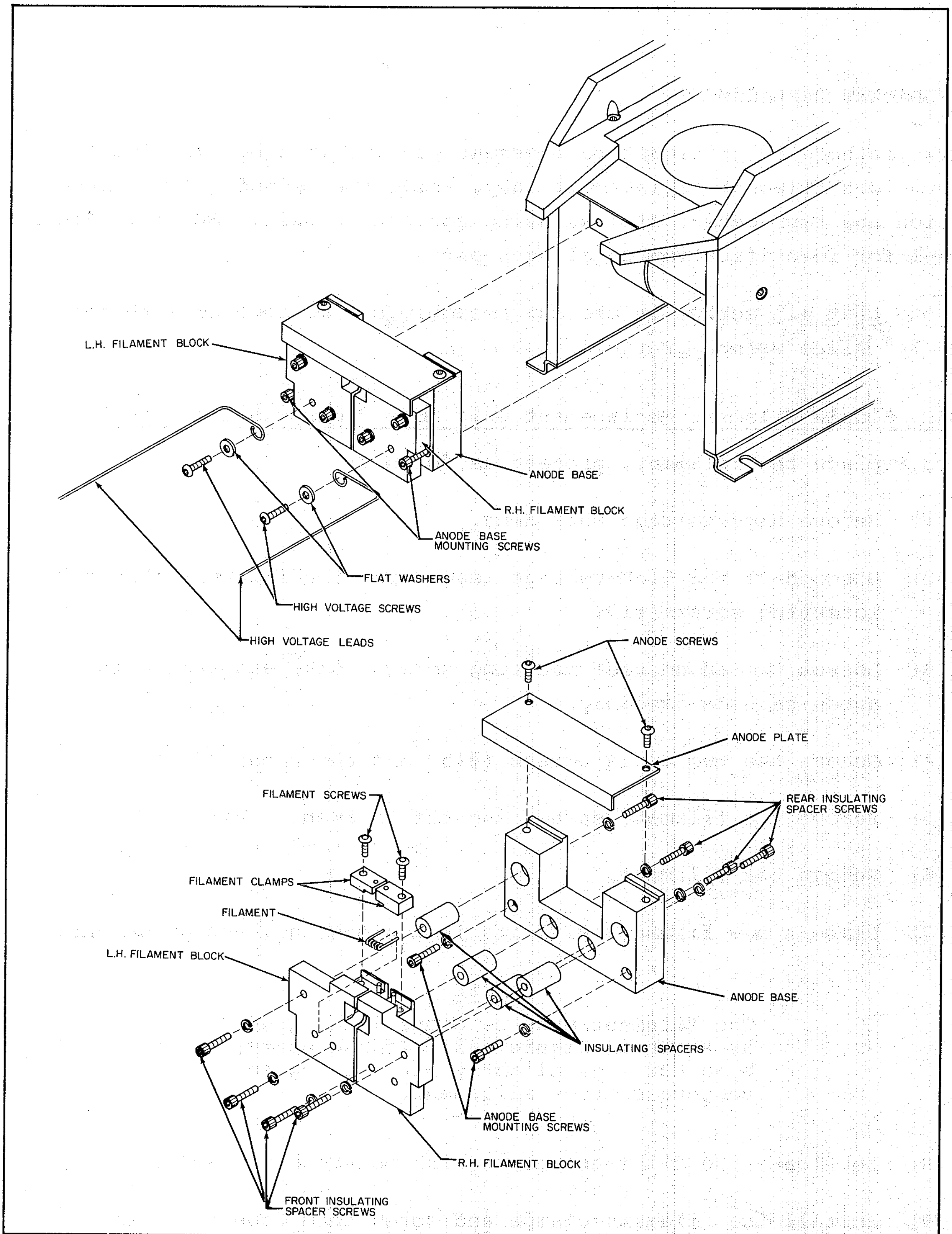

Figure 5-2. Filament Block Inspection and Maintenance.

(10) From the front of the anode-cathode assembly, verify that the filament is centered in the cavity. Move it slightly from side to side to make sure the legs are centered in the V-groove in the clamp blocks. See Figure 5-3.

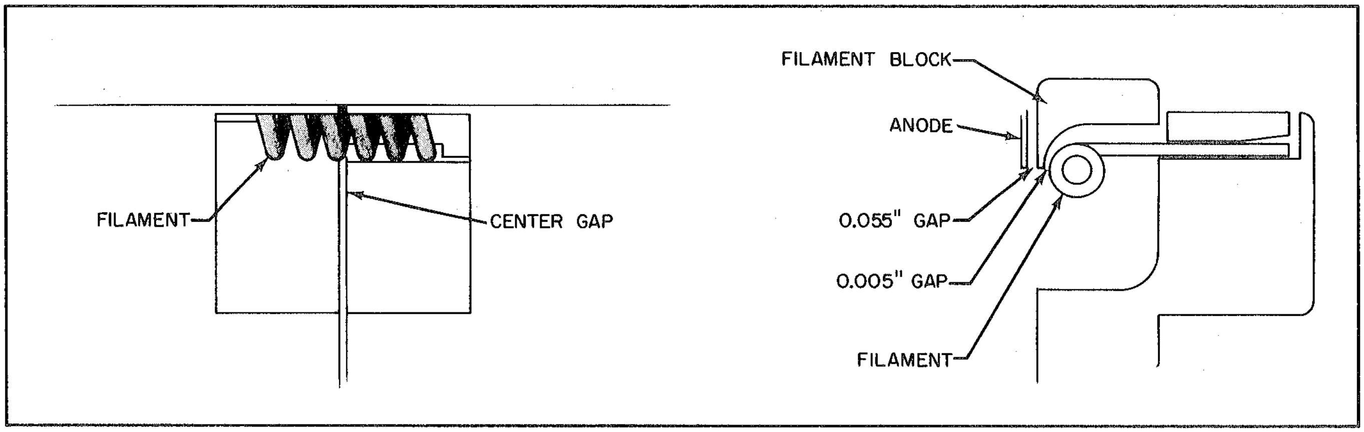

Figure 5-3. Cutaway Views Showing Properly Installed Filament.

(11) Tighten the filament screws to clamp the filament in position, making sure that there is a minimum of 0.005" clearance between the filament turns and the inner edge of the filament block directly in front of the filament. When properly located, the gap between the two middle turns of the filament should be immediately below the gap between the filament blocks.

(12) Install the anode on the anode base. Be sure to push it snugly against the shoulder of the recess in the base before tightening the anode screws. This will ensure the proper clearance of 0.055" ±0.005" between the anode and the filament blocks.

(13) Install the anode-cathode assembly on the gun and tighten screws #14.

(14) Replace the high-voltage leads and tighten the screws firmly.

(15) Replace high-voltage shielding.

B. Filament Replacement, Inspection, and Insulating Spacer Replacement (See Figures 5-1 and 5-2). If only filament replacement and insulator inspection is required, Steps 7 through 11 may be omitted.

(1) Remove high-voltage shielding.

(2) Disconnect the high-voltage leads from the filament blocks by loosening screws #19.

(3) Loosen two anode base mounting screws (#14) and remove the anode-cathode assembly.

(4) Remove the two anode screws (#15) and the anode (#16).

(5) Remove the filament screws and the filament clamps.

(6) Remove the filament.

(7) Remove the four screws on the back of the anode base and the four screws on the front of the two filament blocks and carefully separate the two filament blocks, four insulating spacers, and the anode base. Do not allow the two mounting screws (#14) to fall out of the anode base, as they cannot be replaced with the filament blocks installed.

(8) Clean or replace the insulating spacers. They can be cleaned by glass-bead blasting or scrubbing with a mild abrasive household cleaner, followed by a thorough washing and drying. When handling new or freshly cleaned spacers, always use clean gloves.

(9) Carefully place the clean spacers in the recesses in the filament blocks and loosely install the four screws from the front of the filament blocks.

(10) Make certain the two mounting screws (14) are in place in the anode base. Place the spacers in the recesses in the anode base and loosely install the four screws from the back of the anode base.

(11) Align the filament blocks so that the lips of each block at the filament recess are parallel and set the gap between them at a uniform width of 0.010 to 0.015 inch (0.03 to 0.04 mm). Tighten all eight spacer screws.

(12) Lubricate the filament screws with molybdenum disulfide.

(13) Place a new filament with its legs alongside each guide pin.

(14) Screw the filament clamps down onto the filament legs until a light contact is made.

(15) From the front of the anode-cathode assembly, verify that the filament is centered in the cavity. Move it slightly from side to side to make sure the legs are centered in the V-groove in the clamp blocks.

NOTE

The filament must be properly aligned as shown in Figure 5-3. If necessary, bend the legs slightly with pliers to achieve correct alignment.

(16) Tighten the filament screws to clamp the filament in position, making sure that there is a minimum of 0.005" clearance between the filament turns and the inner edge of the filament block directly in front of the filament. When properly located, the gap between the two middle turns of the filament should be immediately below the gap between the filament blocks. See Figure 5-3.

(17) Install the anode on the anode base. Be sure to push it snugly against the shoulder of the recess in the base before tightening the anode screws. This will ensure the proper clearance of 0.055" ±0.005" between the anode and the filament blocks.

(18) Install the anode-cathode assembly on the gun and tighten screws #14.

(19) Replace the high-voltage leads and tighten the screws firmly.

(20) Replace the high-voltage shielding.

SECTION VI

TROUBLE SHOOTING

GENERAL

The following Trouble Shooting Guide covers problems originating in the Electron Beam Gun, as well as those involving both the gun and the Electron Beam Power Supply. It is not always obvious whether the gun or the power supply is at fault, so portions of the trouble shooting procedures for the Sloan FIVE/TEN and TWELVE/TEN Electron Beam Power Supplies have also been included.

DANGER

HIGH VOLTAGE!

Electron beam guns operate at potentially lethal voltages. To avoid hazard to the operator:

1. NEVER BYPASS THE SAFETY INTERLOCKS.
2. WHEN WORKING IN THE CHAMBER, BE CERTAIN THAT THE HIGH VOLTAGE KEY SWITCH ON THE POWER SUPPLY IS TURNED OFF, AND KEEP THE KEY IN YOUR PERSONAL POSSESSION.

If the trouble cannot be located within the scope of these procedures, refer to the Trouble Shooting Chart contained in the Sloan FIVE/TEN or TWELVE/TEN Operating Manuals for additional checks.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
1. Filament does not light, magnet light ON, high voltage light ON.	A. Filament OPEN.	A. Replace Filament.
	B. Loose high voltage wires.	B. The resistance across the filament as measured at the feedthrough must be under 1/4 ohm. If it is higher, there is a loose connection. The screws in the filament blocks sometimes appear tight, but the wires are loose, so tighten mounting hardware and check position of filament. All connections should be secure, but <u>do not overtighten</u>.
	C. Filament shorted.	C. Check the high voltage wires and between the filament blocks for shorts across the filament.
	D. Filament fuse open.	D. Replace.
2. No emission, filament glows, or High Voltage light not flashing.	A. High voltage arcing to ground.	A. Check high voltage leads, under anode plate, and behind filament blocks for shorts to ground.
	B. High voltage cables shorting.	B. Check resistance to ground with a megohm meter.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
3. No beam spot, filament burns brightly, magnet light on, high voltage indication, beam heats or burns the tooling.	A. Magnet power grounded. (12/10 Power Supply is open and short protected.)	A. Check wire to the magnet for shorts to ground, magnet resistance is 1.7 ohms or higher.
	B. Shorted turns in magnet.	B. Coil resistance should be over 1.7 ohms, replace if lower.
	C. Magnet supply out.	C. Check power supply.
	D. Magnetic baseplate shorting magnetic field.	D. Use mounting feet.
4. Beam spot jumps or vanishes briefly, no clicking from power supply. (Normal during shorts or arcs with TWELVE/TEN.)	A. Magnet wire connector damaged.	A. Check for loose connections; push on connectors, and replace, if necessary. (When the supply clicks, the spot normally vanishes for an instant.)
5. Beam spot moves toward the filament as the power is increased.	A. High voltage is dropping under load.	A. Check power supply, check V1 in FIVE/TEN.
	B. Line voltage dropping under load.	B. Check line voltage.
6. Magnet light out, no emission.	A. Magnet circuit OPEN. (In 12/10, circuit shorted, or open.)	A. Check magnet wire connections and coil resistance.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
6. Cont'd	B. Magnet supply defective.	B. Check the supply: output is 13 Vdc open and 3 Amp minimum through 2 ohms with position pot. maximum clockwise.
7. Anode bracket glows red hot.	A. Filament assembly out of alignment.	A. Align filament per instructions, Section V.
8. Evaporant sticks to hearth.	A. Inadequate water cooling.	A. Check water flow rate; it must be at least 2 gallons (7.6 liters) per minute.
	B. Hearth too full or not full enough.	B. Hearth cavity should not be filled to overflowing or used to less than 25% full.
9. Hearth liner of hard material cracks.	A. Thermal expansion of evaporant on heating.	A. Cracks normally form in hard liners due to differences in the coefficient of thermal expansion between the liner and the evaporant.
	B. Beam striking the hearth liner.	B. The beam will crack and evaporate a liner in a second or two at high powers, if it hits liner or the liner runs empty.
	C. Liner installed incorrectly.	C. Be sure liner fits properly and hearth is clean.
	D. Charge attacking liner.	D. Use another more compatible liner material.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
10. Gun leaks water.	A. Gun overheated during installation or operation.	A. The gun is assembled with silver solder and the joints can be remelted during brazing to the water lines if the gun is not kept cool with a wet rag. Repair of braze leaks is difficult and should be attempted only by a skilled technician.
	B. Cajon connectors leak.	B. Replace O-ring in the connectors.
11. Maximum power limited by break-down.	A. Poor chamber vacuum	A. Chamber pressure must be below 5×10^{-4} Torr.
	B. No high voltage shielding.	B. Install high voltage shielding per instructions in manual.
	C. Evaporant degassing or decomposing excessively.	C. Use hot pressed material instead of powders. Be sure evaporant is not decomposing as some materials, e.g., BN will not evaporate.
	D. Evaporation rate increases uncontrollably with constant beam power.	D. Use beam sweep. Some materials evaporate explosively under the sharply focused beam and must be evaporated at a low power density.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
11. Cont'd.	E. Filament block insulators dirty.	E. Replace or clean the insulators and check to see that high voltage shielding is adequate.
	F. Gun is insufficiently grounded.	F. The gun requires a ground in addition to that provided by the water lines. Mounting the gun to the vacuum system baseplate is usually adequate.
	G. Power supply is oversensitive.	G. Check power supply and be sure it is well grounded to the baseplate.
	H. Line voltage taps incorrectly set in the power supply.	H. Check line voltage and taps.
	J. High voltage feedthrough dirty or improperly installed.	J. Dismantle and clean the feedthrough. When re-installing, be sure the feedthrough nut is tightened to compress the O-ring thoroughly. Check the high-voltage shielding.
	K. One phase of 220 power out.	K. Check all three input phases.
	L. Glass shields have been used on wires or insulators.	L. Remove the glass shields; use only metal shielding.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
12. Evaporant spits, explodes, and sparks.	A. Powder used for evaporant.	A. Use hot-pressed material.
	B. Beam power density too high.	B. Use beam sweep. Some materials cannot absorb high power.
	C. Evaporant is contaminated.	C. Degas the evaporant with a longer soak before evaporation, or use higher purity material.
	D. Hearth is dirty.	D. Clean thoroughly.
	E. Charge is decomposing.	E. Some materials, e.g., BN, will not evaporate.
13. The beam will not center in the hearth.	A. Filament blocks or filament crooked.	A. Align the filament blocks and filament as described in Section V.
	B. Filament off center.	B. Replace filament and center properly.
	C. Nearby magnet interfering with the gun.	C. Remove the interfering magnet. Reversing the position of a second nearby gun will keep it from interacting. (See installation of two guns in single chamber, Section II.)

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
14. The spot cannot be brought close enough to the filament end of the hearth.	A. High voltage too high.	A. Check line voltage taps on transformer. Check regulator in TWELVE/TEN.
	B. Magnet has shorted turns.	B. Check the magnet resistance; it should be over 1.7 ohms.
	C. Magnet supply output is low.	C. Check the power supply current; it should be over 3 amps. at maximum beam position (10 on the front panel).
	D. Gun design.	D. The spot should move no closer to the edge of the hearth than 1/8 the length of the hearth.
	E. Limit Settings improper (12/10).	E. Check spot limit settings on TWELVE/TEN.
15. Spot will not move far enough away from the filament.	A. Supply position limit is set too high.	A. Adjust position limit pot in the supply.
	B. High voltage too low.	B. Check line voltage taps on the transformer. Check HV adjustment (TWELVE/TEN).
16. Small arcs are observed from the magnet lead in the Service Feedthrough to ground.	A. Gun is poorly grounded.	A. This condition need not be repaired. An improved gun ground will sometimes remove it. If not, a 10-pf, 5000 V capacitor

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
16. Cont'd.		A. Cont'd. from the magnet lead mounted externally at the feedthrough to ground will stop the arcs.
17. Filament burns brightly, emission indicated with emission pot fully counterclockwise (OFF).	A. Supply not correctly adjusted.	A. Adjust the emission minimum per instructions in power supply manual.
	B. SCR Failure in 12/10 supply.	B. Check supply.
18. Emission (spot and filament glow brightly) but no meter indication.	A. Defective power supply.	A. Repair the supply. DO NOT CONTINUE TO RUN. (See power supply Trouble Shooting Guide.)
19. After running a short time, 1-3 min, supply goes into over-current (clicking) and will not recover.	A. Insufficient water cooling.	A. Measure cooling water flow with a flowmeter. 2 gallons (7.6 liters) per minute minimum is required.
	B. Filament block insulators dirty.	B. Replace the insulators.
	C. Filament blocks dirty.	C. Clean with a wire brush.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
20. Filament blocks glow red. (At 12 kW, the blocks will normally glow dull red after about 15 min. of operation.)	A. Insufficient water.	A. See 19 A above.
	B. Spacers poorly matched.	B. Check spacer condition and length; they must match within $\pm$.001 inch ($\pm$.02 mm).
	C. A spacer is on a burr in the mounting block.	C. Check spacer mounting holes for burrs.
	D. A spacer is chipped or broken.	D. Replace the spacer.
	E. Loose screws.	E. Tighten.
21. Small arcs are observed on the high voltage wires and feedthroughs.	A. Poor vacuum.	A. 5×10^{-4} Torr required.
	B. Poor shielding.	B. Install shielding per the instruction manual.
22. Gun will not reach 1.2 Amp. at maximum "Emission."	A. Emission maximum set low.	A. See power supply manual for adjustment instructions.
	B. Filament or high voltage leads are loose.	B. Tighten.
	C. Filament assembly incorrect.	C. See instructions under "Filament Replacement" in Section V.
	D. Anode gap excessive (i.e., more than 0.060").	D. See instructions under "Filament Replacement" in Section V.

SYMPTOM	PROBABLE CAUSE	SUGGESTED REMEDY
23. Filament lights in short bursts, Full "ON".	A. R.F. interference on the power line.	A. Replace a filter on the SCR or a filter in the Power Supply as explained in the Sloan Power Supply Manual.
24. A gun roars or whines at 10-12 kW.	A. Local boiling of cooling water.	A. See 19 A above.
	B. Beam striking hearth.	B. Center Beam. On 12/10 adjust position limits.
25. Spot size too large.	A. Anode plate burned by beam.	A. If beam has burned a groove where it passes anode more than .032" (.8 mm) deep, re-place the anode.

SECTION VII

WARRANTY AND CLAIMS

WARRANTY

Sloan Technology Corporation warrants that each new Electron Beam Gun manufactured or sold by it, is free from defects in material and workmanship under normal use and service. Liability under use warranty is limited to servicing or adjusting any equipment returned to the factory for that purpose and replacing any defective parts thereof. This warranty is effective for one year after delivery to the original purchaser when the equipment is returned (transportation charges prepaid by the original purchaser) and when upon our examination is disclosed to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before work will be started.

Sloan Technology Corporation shall not be liable for damages by reason of the failure of the equipment to perform properly or for any consequential damage. This warranty does not apply to any equipment that has been subject to neglect, accident, misuse, improper installation or operation, or that in any way has been tampered with, altered or repaired by any person other than an authorized Sloan service organization or employee thereof, or to any equipment whose serial number has been altered, defaced or removed.

This warranty shall, upon Sloan Technology Corporation option become void unless registration thereof is prompt, and as provided below. This warranty is in lieu of all other warranties expressed or implied, and no one is authorized to assume any liability on behalf of Sloan Technology Corporation, or impose any obligation upon it in connection with the sale of any instrument other than as stated above.

CLAIMS FOR DAMAGE IN SHIPMENT

The equipment should be tested as soon as it is received according to the checkout instructions enclosed. If it fails to operate properly or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be made to the claim agent, and this report forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for its repair or replacement. Include model number and serial number when corresponding about this equipment for any reason.

REGISTERING THE WARRANTY

To register this equipment, the enclosed warranty card must be properly filled out and mailed to the Sloan Service Department immediately upon receipt of the equipment. When making in-warranty claims complete information is necessary. When writing to the factory in this respect, address:

SLOAN TECHNOLOGY CORPORATION
Instrument Service Department
P. O. Box 4608
Santa Barbara, California 93103

The Instrument Service Department will then send to the customer the written procedure and instructions for shipping. All equipment should be packed and shipped in accordance with this procedure.

REPLACEMENT OF PARTS

If it is necessary to order a replacement component from the factory, always give the Type, Model Number and Serial Number of the equipment. If you are ordering parts for warranty replacement or out of warranty replacement, be sure to consult the parts list in the Instruction Manual. The parts list gives the values, tolerances, ratings and Sloan designation of all electrical components used in the instrument. This will help expedite service.

SLOAN TECHNOLOGY CORPORATION
Instruments Division
P. O. Box 4608
Santa Barbara, California 93103