AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301-587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

SAND93-2183
Unlimited Release
Printed May 1994

Category UC-410

In Situ Evaporation of Lithium for LEVIS Ion Source

Bob Gerber
Lasers and Atomic Physics Department
Org. 1275, MS 1188

Mike Lopez
Tube Prototyping and Analytical Support Department
Org. 2566, MS 0958

Kerry Lamppa
Wilbur Stearns
Intense Beams Research Department
Org. 1231, MS 1193

Kevin Bieg
Defense Programs Technology Transfer Program Management
Org. 4231, MS 1380

Abstract

This report describes the In Situ evaporation of pure lithium on the anode of PBFA II which then can be evaporated and ionized by Laser Evaporation and Ionization Source (LEVIS). Included in this report are the necessary calculations, light laboratory experiments and details of the hardware for PBFA II. This report gives all the details of In Situ evaporation for PBFA II so when a decision is made to provide an active lithium source for PBFA II, it can be fielded in a minimum of time.

MASTER *rp*

Table of Contents

Abstract	1
Table of Contents	2
Introduction	3
In Situ Calculations for PBFA II Diode	5
Light Laboratory Experiments and Results	9
Rapid Cooling of the Evaporator	9
Uniformity and Thickness of Lithium on the Anode	11
Survival and Optical Transmission of the Gas Cell	12
History of In Situ Evaporation for PBFA II	13
Present and Future In Situ Hardware	17
Conclusions and Recommendations	18
Acknowledgments	19
References	20
Figures	21-29
Appendix A	30-36
Appendix B	37-54
Distribution	55

INTRODUCTION:

Lithium ions were chosen as the baseline for light ion fusion studies on PBFA II over ten years ago.¹ The use of lithium enables a large anode-cathode spacing, resulting in less impedance change during the pulse due to electrode plasma expansion. Lithium ions experience less magnetic deflection than protons in the diode, making focusing less sensitive to beam energy spread and allowing ions to reach the target for a longer portion of the pulse. Also, since the ionization potential of Li^+ is low (5.4 eV), while that of Li^{2+} is very large (75.6 eV), high Li^+ source purity should be achievable without significant contamination from Li^{2+} . Ions heavier than Li^+ would require either operating voltages greater than 15 MV, or the ions would have to be accelerated in a multiply charged state, to effectively couple to the Inertial Confinement Fusion (ICF) target.

Although there are many advantages of using lithium, there are also disadvantages. A major problem is that lithium reacts exothermically with air that includes water, nitrogen, and oxygen to form LiOH , Li_3N and Li_2O . Data exists² which shows that when 0.2 grams of lithium metal are exposed to circulating air with relative humidity of 50% all of the Li will react in less than an hour to form LiOH and Li_3N . This points out two problems when lithium is used in PBFA II. One of the problems is that once lithium is coated on an anode external to PBFA II, the anode must be taken over to PBFA II, placed in the center section, and then pumped down. The Relative Humidity (RH) in the PBFA II building is between 40 and 60 percent in the summer; therefore, a means must be made to protect it before placing in the machine. Another problem is that the vacuum in the diode of PBFA II is about 5×10^{-5} Torr and consists of at least 90 percent H_2O . Consequently, much of the lithium could react and be lost in the diode itself before the shot.

Because of the contamination problems, many of the different proposed lithium ion sources had to develop some way to keep the lithium or lithium compound clean. The BOLVAPS-LIBORS active ion source³ used LiAg , which reacts in the ambient atmosphere much

slower than pure lithium. In addition, a slow capacitor bank was used to heat a thin Moly film and the LiAg film, which cleaned the surface about a millisecond before the source was produced. There was a considerable amount of work done on LiAg films for BOLVAPS at SNL. Calculations on the reaction of LiAg with the atmosphere showed that more than ten percent consumption of the Li in LiAg was not acceptable because the layer of LiOH was too thick and the melting point was increased to about 600°C. Thermogravimetric analyses⁴ (TGA) were performed which showed acceptable exposure times to be: At RH $\geq$ 45%, < 1 min, RH = 20%, 20 min, and at RH = 10%, 3→4 hours. Since the RH of the PBFA II building is between 40 and 60 percent, a decision was made to overcoat the LiAg with a thin layer of silver, which extended the time to several hours. The electrohydrodynamic (EHD) source^{5,6} which relies on liquid lithium had a large protected reservoir and provided a thick liquid lithium layer in less than four minutes.

Another lithium source presently being used on PBFA II uses a thin layer of LiF evaporated onto an anode. This source may not require any elaborate means to prevent contamination. LiF is not very hygroscopic and water vapor does not stick on the surface in significant amounts⁷. At the present time, there are plans to heat the surface to investigate the reduction of the emission threshold and its effect on divergence of the ion source and also to determine if heating does clean the source⁸. The only active source now being considered for PBFA II is LEVIS, which stands for Laser Evaporation Ion Source. A glass laser ($\lambda=1.06\mu\text{m}$) evaporates lithium from the surface and then the vapor is ionized³ by a resonant laser process called LIBORS. The baseline for LEVIS is to put a layer of LiAg on the anode, so the 1.06 μm laser will form lithium atoms. Here again LiAg is used because it is much less reactive than pure lithium; however, as previously mentioned for the BOLVAPS-LIBORS source, LiAg will still react very quickly.

The technique described in this report places lithium on the anode, but as was already mentioned, lithium is very reactive, so to use it, it must be evaporated very soon before the shot. The process called In-Situ evaporation uses a lithium evaporator in the diode. There are many

advantages of using lithium from an In-Situ scheme. First the evaporation of lithium will cover up impurities on the surface and the 1.06 μ m laser will provide a pure lithium vapor. Secondly, the laser requirements are less severe using lithium rather than lithium silver. Lithium melts at 180°C and produces a vapor of 10¹⁶cm⁻³ at 800°C. Lithium silver on the other hand melts at 400°C and must be laser heated to 1100°C to produce a lithium vapor of 10¹⁶ cm⁻³. These LiAg numbers assume a 50/50 lithium- silver alloy. Another advantage of evaporating lithium is that the thickness can be greater than the thermal layer thickness⁹ which is $\delta=(4\alpha t)^{1/2}$ where α is the thermal diffusivity and t is the laser (heating) pulse width. The numbers indicate that a lithium thickness of 1.2 μ m is required for a 10 nsec pulse width. Another advantage is that since the evaporator is in the diode, we can evaporate more than once if for instance there is trouble with PBFA II on the first try. Of course, in the future, In Situ evaporation could be used in a repetitively-pulsed machine.

The reason for this report is that Sandia's ICF Program Managers decided to put LEVIS (which includes In Situ) on hold for FY94 in order to meet short term milestones with available funding. Without this report and details given in it, the source could not be taken off hold in the future. This report will include calculations of the evaporation process, results of light laboratory experiments, history of the In Situ program, and the present and future optimized hardware. Appendix A will give the hardware inventory and will go into details on assembly hardware for PBFA II experiments. Appendix B will include drawings of the hardware.

IN SITU CALCULATIONS FOR PBFA II DIODE

The object of these calculations is to determine if there is a way to deposit lithium on the anode almost up to shot time to prevent massive contamination to the lithium. First we determine vapor pressure, density, and evaporation rate as a function of temperature at the evaporator (reservoir). We then use the PBFA II diode geometry to determine evaporation rate and film thickness on the anode as a function of time and evaporator temperature. Next, we determine the optimum temperature history to reduce contamination. These calculations assume evaporation

into a vacuum, no collisions, and a unity sticking coefficient on the surfaces. The vapor pressure and rate of evaporation for lithium as a function of temperature shown in Table I were obtained from Table 10.1 in Ref. 10.

TABLE I

Vapor pressure, density, and rate of evaporation as a function of temperature on an evaporator.

Vapor Pressure (Torr)	Temp (°C)	ⁿ Density (cm ⁻³)	$W\left(\frac{\text{g}}{\text{cm}^2 \text{ sec}}\right)$
10 ⁻⁶	298	1.66 x 10 ¹⁰	6.47 x 10 ⁻⁹
10 ⁻⁵	348	1.56 x 10 ¹¹	6.17 x 10 ⁻⁸
10 ⁻⁴	399	1.42 x 10 ¹²	5.93 x 10 ⁻⁷
10 ⁻³	460	1.31 x 10 ¹³	5.68 x 10 ⁻⁶
10 ⁻²	534	1.20 x 10 ¹⁴	5.41 x 10 ⁻⁵
10 ⁻¹	623	1.06 x 10 ¹⁵	5.13 x 10 ⁻⁴
1	737	0.96 x 10 ¹⁶	4.84 x 10 ⁻³

The density is calculated from the vapor pressure and is equal to $3.54 \times 10^{16} \left(\frac{273}{T} \right) p$,

where p is the pressure in Torr and T is the temperature in °K. W is the rate of evaporation from an orifice, which is proportional to $nv/4$, where v is the average velocity.

The first calculation that must be made is the rate of lithium evaporated from the evaporator as a function of temperature. Figure 1 shows a drawing of the presently used PBFA II In Situ diode and the pertinent dimensions. The amount of lithium leaving the evaporator is the rate at the orifice times the orifice area.

$WA = W2\pi r_o y_o$ grams/sec = 4.66W grams/sec, since

$$r_o = 5.0" \times 2.54 \text{ cm/in} = 12.70 \text{ cm}$$

$$\text{and } y_o = 0.023" \times 2.54 \text{ cm/in} = 0.058 \text{ cm.}$$

Again, if we assume no collisions, no loss of lithium on the hot evaporator, and a unity sticking coefficient, the lithium leaving the evaporator will all go to the anode. The height where most of the lithium is on the anode, y_1 , is estimated from In Situ laboratory tests to be about 5.5 cm.

The rate of lithium evaporation on the anode is then given by

$$W \frac{2\pi r_o y_o}{2\pi r_1 y_1} = W \frac{r_o y_o}{r_1 y_1} = W \frac{(12.7)(0.058)}{(14.89)(5.5)} = 9.06 \times 10^{-3} W \left(\frac{\text{gm}}{\text{cm}^2 \text{sec}} \right),$$

since $r_1 = 14.89$ cm and $y_1 = 5.5$ cm.

The numbers we are really interested in are the thickness at the anode and the density in the gap.

Lithium is deposited as a body-centered-cubic (bcc) with the monolayer surface density of 8.126×10^{14} atoms/cm² and a thickness of 1.754×10^{-8} cm¹¹. Therefore,

$$\begin{aligned} \text{Rate} &= 9.06 \times 10^{-3} W \frac{\text{grams}}{\text{cm}^2 \text{sec}} \frac{6.022 \times 10^{23} \text{ atoms}}{6.941 \text{ grams}} \frac{1 \text{ monolayer}}{8.13 \times 10^{14} \frac{\text{atoms}}{\text{cm}^2}} \frac{1.754 \times 10^{-8} \text{ cm}}{1 \text{ monolayer}} \\ &= (9.06 \times 10^{-3}) \left(\frac{6.022 \times 10^{23}}{6.941} \right) \left(\frac{1.754 \times 10^{-8}}{8.13 \times 10^{14}} \right) W = \left(1.70 \times 10^2 \frac{\mu\text{m}}{\text{sec}} \right) W \end{aligned}$$

Table II gives the average rate of evaporation on the anode and maximum density at the evaporator as a function of temperature.

TABLE II

Deposition rate and maximum density at evaporator as a function of temperature.

Temp (C°)	Rate on Anode (μm/min)	Density at Evaporator (n/4)cm ⁻³
298	6.60×10^{-5}	0.415×10^{10}
348	6.29×10^{-4}	0.390×10^{11}
399	6.05×10^{-3}	0.355×10^{12}
460	5.79×10^{-2}	0.328×10^{13}
534	5.52×10^{-1}	0.300×10^{14}
623	5.23	0.265×10^{15}
737	49.39	0.240×10^{16}

Figure 2 gives a plot of the evaporation thickness on the anode and the maximum lithium density at the evaporator as a function of evaporator temperature obtained from Table II. From these calculations it appears like the best way to put a relatively clean film on the anode is to

evaporate very close to shot time and cool the anode very rapidly. In our first calculations we were going to fire the machine when the density at the evaporator was about one tenth of the density in the diode so that we wouldn't get gas breakdown in the diode. We tried PBFA II experiments in January 1992 and found out that if we shot the machine with the reservoir temperature greater than the melt temperature (180°C), the applied magnetic field expelled the liquid in the reservoir into the Anode-Cathode (AK) gap and shorted the diode. We now cool the reservoir, as will be described later, so that we can shoot the machine in about two minutes after evaporation. In addition, we want to evaporate at a high temperature so that the amount of lithium deposited on the anode is much larger than the amount of water vapor deposited from the background pressure. A temperature of 600°C was selected as the ideal evaporator temperature for three reasons. One is that we can put down at least 10 times more lithium than water vapor. Secondly, temperatures of 600°C are compatible with the hardware and we have been evaporating at this temperature. Thirdly, we can deposit two or three microns of lithium in a few minutes.

The calculations given in Figure 2 and the electrical current and temperature measurements of the evaporator, obtained from the light laboratory experiments, were used to determine the ideal timing and performance for a PBFA II In Situ lithium LEVIS shot. Figure 3 shows the measured temperature history and the electrical current to the heater in the evaporator as obtained from both the light lab and PBFA II experiments. Also shown is the calculation of the rate of evaporation on the anode. The cooling rate of the evaporator with no current in the heater and the relationship between the current and temperature were obtained from light laboratory In Situ evaporation cooling experiments which will be described in the next section.

In order to deposit about two microns of lithium on the anode, the temperature must be at 600°C for 2 minutes. The current to the heaters should initially be brought up slowly to about 300°C to prevent heater burnout. The vapor pressure at 300°C is negligible (10^{-6} Torr).

LIGHT LABORATORY EXPERIMENTS AND RESULTS

In order to save valuable time on PBFA II, we did many light laboratory experiments to both solve potential problems and to characterize the operation for In Situ evaporation systems. The major topics were rapid cooling of the evaporator, thickness variation of lithium on the anode and survival, as well as a lithium deposited on the gas-cell mylar.

Rapid Cooling of the Evaporator

As was previously mentioned, our initial goal was to have the power pulse from PBFA II arrive when the evaporator had cooled enough so that the maximum lithium pressure was about one tenth that of the PBFA II vacuum. The time this would take is about three minutes after the evaporation process using the natural cooling of the evaporator. At this time, without additional cooling, the temperature of the evaporator would be about 375°C. Original calculations indicated from the heating and cooling time periods that the ratio of Li to H₂O striking the anode would be about 10 to 1, so impurities should not be a major problem. With great anticipation of the ideal lithium source, we tried three PBFA II shots (discussed in the history section of this report) and discovered that two out of the three shots shorted because the applied magnetic field forced all the liquid lithium out through the evaporation nozzle shorting the diode. This was a major setback to the In Situ program. If we shot with a good Li/H₂O ratio on the diode, the diode shorted. If we waited until the lithium was a solid, the anode coating was probably LiOH. There was obviously two ways to solve the problem. The first was to only put the amount of lithium in the reservoir that was required on the anode. The mass of lithium required on the anode is 0.2 grams and normally the reservoir held 2 grams to maintain purity. We decided not to limit the amount of lithium because there is always some reactions with the lithium and there was a good chance that all the lithium would be reacted by shot time. In addition, putting in only enough lithium for one shot would preclude us from doing two or more evaporations. The second way to solve the problem was to actively cool the reservoir at shot time. Our goal was to find out if we could cool the reservoir from 600°C to 100°C in a minute. This would allow us to deposit lithium with Li/H₂O ≈ 10 at a background pressure of 5×10^{-5} Torr. At 100°C the lithium would be a

solid and thus would not be forced into the AK gap by the applied magnetic field. Engineers from the Pulsed Power Engineering Department (1239) designed a two winding cooling coil which we had built and then was attached to the reservoir as shown in Fig. 1. Our plan was to flow nitrogen gas to cool the reservoir quickly after heating. We did about 20 light-laboratory tests using high pressure N₂ or He or water. In these tests the evaporator, attached to the upper PBFA II cathode, was heated in vacuum to 600°C for two minutes. The cooling was started and the temperature was monitored with thermocouples. Fig. 4 shows representative temperature graphs from these tests. The pressure shown in the figure is the source pressure which regulates the flow rate. The gas at the exit of the cooling coil flowed into the atmosphere. The initial experiment at 200 psi N₂ looked very promising since we cooled the reservoir to 100°C in ten minutes which was much faster than the hours required with no cooling. The time to cool to 100°C at 400 psi N₂ or 400 psi He was about five minutes. However, when we tried 800 psi N₂ the cooling curve overlayed the 400 psi one. Also 30 and 50 psi with water looked very similar to 400 psi N₂. It was clear that the cooling rate of the evaporator was determined by the thermal conduction in the evaporator parts themselves. In order to decrease the cool down time the temperature of the cooling medium had to be reduced as much as possible so a coil immersed in LN₂ was installed on the inlet piping to the evaporator. We did several experiments using He through LN₂. As shown in Fig. 4 the time to reach 100°C was slightly less than two minutes. The major problem using helium was that if there was a small leak of the coolant in the vacuum section, the Cryo pump shut down since it doesn't pump helium very effectively. Following the helium experiments, we switched to N₂ through LN₂. A typical result is also shown in Fig. 4. The time to cool to 100°C was less than a minute and one half. We have done several other experiments on the Integrated Test Facility (ITF) and on PBFA II. The cooling times were very similar. Cooling using 400 psi N₂ through LN₂ is now the standard for the In Situ program. This cooling scheme will allow ten times more lithium than water vapor on the anode surface during the heating and cooling cycle.

Uniformity and Thickness of Lithium on the Anode

The original plan was to place another evaporator on the lower cathode so the lithium deposited on the anode would be uniform in the z direction (height). The first few designs of the evaporator for the PBFA II diode, as will be discussed later, had a dummy evaporator on the lower cathode in order to make the applied magnetic field the same near the top and bottom cathodes. We now have a much simpler dummy evaporator as shown in Fig. 1. The reason for the simpler one is that it will allow us to deliver more laser light to the anode, making an ion source about 6 cm high, rather than the 4 cm originally used. The non-uniformity in the z direction on the anode will be about a factor of 3 from the top to the bottom. This non uniformity should not be a problem for short pulse laser evaporation if the minimum thickness is comparable to the thermal layer thickness⁹ which is $1.2\mu\text{m}$ for a 10 nsec laser pulse. In order to determine the lithium thickness on the height on the anode, several light laboratory tests were done in which glass slides were placed at various anode positions before the evaporation and cooling process. After the experiment the thickness of the lithium was measured with a DEKTAK II surface profilometer. Although the non-uniformity in the z direction is not very important because of the short laser pulse, the non-uniformity around the anode at a given height is important because if there is a location where there is no lithium, the source divergence will be high because there will be no plasma. Since the reservoir coaxial electrical heater is a ring with the heater leads coming out at the same radius as the heater, there will be a lower temperature at that anode location. We have designed and had constructed heaters with a very small gap to solve the problem. Also if the reservoir nozzle which is 0.58mm isn't uniform around the periphery of the reservoir, the lithium will not be uniform. We measured the axial uniformity of the lithium at three different heights on two separate light laboratory experiments. We found that the non-uniformity was $\pm 25\%$ at each height around the entire anode. The major problem here is probably the non-uniformity of the reservoir temperature. As shown in Fig. 2, a difference of $\pm 25\%$ in density at a temperature of 600°C only corresponds to a temperature difference of $\pm 10^\circ\text{C}$ which is very small at a temperature of 600°C .

The deposited lithium thickness at various height locations is shown in Fig. 5. The total anode height is about 20 cm, the center of the anode is at 10 cm and the cathode tips are located at 5 and 15 cm. The evaporator on the top cathode is located at about 13 cm and the 6 cm active height of the anode is between 7 and 13 cm. The measurements of the film thickness shown in Fig. 5 were obtained from the experiments following the standard heating and cooling times shown in Fig. 3. In order to determine whether the modeling of the lithium deposition were correct, a comparison between the data and calculations were made. The data shown in Fig. 5 were integrated to determine the total amount of lithium on the anode surface, assuming the film was uniform around the anode for each given height. The result is that the total is $23.3\mu\text{m-cm}$ or 0.12 grams of lithium. The total amount of calculated lithium was obtained by integrating the lower graph of Fig. 3, taking into account that the height was not 5.5 cm as originally assumed. Using Fig. 3, the integral is $28.8\mu\text{m-cm}$ or 0.15 grams of lithium which is about 25% higher than the experiment. Based on the uncertainties in the nozzle size, non-uniformities, and the original assumption of unity sticking factor, the agreement is very good and the calculations can be used to estimate the amounts of lithium on the anode.

Survival and Optical Transmission of the Gas Cell

It is important during a PBFA II experiment that the gas cell will hold between one and two Torr of argon to neutralize both the charge and current from the lithium ion beam. Early attempts of using In Situ deposition of lithium on PBFA II were without a gas cell since the $1.5\mu\text{m}$ -thick gas-cell mylar did not survive for several reasons. First, the heat from the 600°C evaporator would melt the gas cell mylar or the cement holding it on the upper gas cell skirt. Second, in some cases, the hot lithium vapor or drops of lithium would also cause the gas cell to leak and third, the applied cathode magnetic field would deflect the evaporator and cause it to strike the gas cell skirt and break the mylar. The evaporator shown in Fig. 1 which was used on the past few shots on PBFA II has solved most of our gas cell survival problems. Improvements to the In Situ hardware to solve gas-cell survival problems are described in the history section of this report. The hardware shown in Fig. 1 has survived many heating/cooling light laboratory and

Integrated Test Facility (ITF) experiments using applied magnetic fields. Although the hardware shown in Fig. 1 has now been redesigned to optimize In Situ performance, most of the gas cell problems have been solved.

The major problem with the gas cell at the present time is lithium evaporation on the gas cell mylar. Both the output of the anode evaporation laser at a wavelength of $1.06\mu\text{m}$ and the output of LIBORS ionization laser at 670nm pass through the optical window, off the optical cone through the gas cell mylar and onto the anode surface. If the gas cell mylar has too much lithium on it, the optical transmission will be very low and more laser energy will be needed to evaporate and ionize the lithium on the anode.

Brian Clark in Org. 01275 measured the optical transmission of the mylar before an evaporation test and a few times after the light laboratory tests. The transmission of the $1.5\mu\text{m}$ thick mylar, before a test, was 91% at 670 nm and 85% at $1.06\mu\text{m}$. Since the index of refraction should not change very much between the two wavelengths, about 6% of the $1.06\mu\text{m}$ light was probably lost by absorption in the mylar. Using the temperature history shown in Fig. 3 for light laboratory evaporation, the measured transmission of the $1.06\mu\text{m}$ light after evaporation was 75% and 83% for two different runs and the corresponding transmission at 670 nm was 52% and 63%. This means there was about a 12% additional loss at $1.06\mu\text{m}$ and about 27% additional loss at 670 nm . Part of the loss is probably due to reflection off the lithium metal surface, and there may be high resonant absorption at 670 nm . The bottom line is that the ionization laser energy needs to be increased by about 30% over the energy measured in the laboratory for In Situ deposition of pure lithium.

HISTORY OF IN SITU EVAPORATION FOR PBFA II

This section will go into detail about the problems and improvements that were made to the In Situ hardware over the years. This history section is presented so that when the In Situ technique is again used for a source for PBFA II or other ion beam machines, the experimenters will not have to "reinvent the wheel."

As was previously stated, the reason for using evaporation in the diode is that lithium reacts very fast with the background gas and will form lithium compounds, which makes it very difficult or impossible to produce a pure lithium beam. Kevin Bieg in 1988 generated the interest and did experiments to learn how to effectively deposit pure lithium rapidly in the diode. The major concern in the early days was for the EHD lithium source⁵ which requires pure liquid lithium on the anode surface. Techniques investigated for providing the pure lithium for an EHD source were (1) a flowing lithium "water fall" by ETEC Corp, which didn't work, (2) the wicking up of liquid into a porous material from a heated reservoir on the bottom of the anode, a technique established by Gerber, Cianciabella, and Woodworth, and (3) the In Situ evaporation technique, worked on by Kevin Bieg. The wicking technique was selected and tested on PBFA II by Woodworth and Adams. The wicking resulted in a thick layer of liquid lithium which is required for EHD, but research on In Situ continued. When the Laser EVaporation and Ionization Source (LEVIS) became popular, the In Situ scheme was a back-up to the LiAg coating on the anode. Kevin Bieg's first experiments investigated how to build an evaporator. At first it was thought that if one had a lithium-filled tube with a slot in the entire length and heated it, then we could get uniform evaporation in the diode. The major problem was that the lithium sprayed all over in the diode region. It was at that time we realized we needed a nozzle on the evaporator to put most of the lithium on the anode. Also it was found that to uniformly heat the reservoir, a coaxial heater like the one used on EHD anodes gave the best results.

The first In Situ hardware used on PBFA II is shown with the cathodes in Fig. 6. The evaporator is very similar to the one shown in Fig. 1. The hardware shown in Fig. 6 is attached to the same place as the gas cell skirts near the center of the diode. Shields are used to protect the gas-cell mylar from the heat and the liquid lithium in the reservoir. A dummy evaporator is located near the bottom cathode to balance the applied magnetic field near the top and bottom cathode. The gas-cell mylar was located at a much smaller radius than the cathode tips, which is not optimum for an Applied B-field diode, because the gas-cell mylar establishes the virtual cathode at the beginning of the pulse. The major problem with the design in Fig. 6 is that the

Applied B-field would move the evaporator toward the center and, in the process, would break the gas-cell mylar. In 1990 Kevin Bieg did two shots (3590 and 3596) on PBFA II with the hardware shown in Fig. 6, except with no gas-cell mylar. Although there were many problems such as non-uniform evaporation, heater burnout and arcing of the heater levels, shot 3596 produced 47 kJ of lithium ions, even though there was a delay of about an hour from evaporation to the shot. Although few things were optimized, the results were encouraging, and work on In Situ continued, even though Kevin Bieg went to Washington D. C. to work with DOE.

Figure 7 shows the next generation In Situ hardware which solved some of the problems with the one shown in Fig. 6. The evaporator was attached to the upper cathode with twelve bolts. The hardware was made slightly smaller using thin shields. The gas cell skirt was made longer so the gas-cell mylar was at about the same radius as the cathode tips. We did several light laboratory experiments to look at uniformity, thickness, etc., and did a couple of ITF tests to determine the maximum magnetic field we could use before we broke off the bolts that attached the evaporator to the cathodes. It was found that the magnetic field banks could be charged to give a critical voltage in the diode of $V_{crit} = 14\text{MV}$, which corresponded to a 14.6 kV cathode bank charge and 10.4 kV anode bank charge on PBFA II. At this time we did the initial calculations¹² which showed that in order to have the amount of lithium on the anode higher than the amount of water vapor from the 5×10^{-5} Torr vacuum, we had to shoot PBFA II within three minutes after evaporating the lithium. We fielded three PBFA II shots (4937, 4949, and 4956) in January 1992. In order to deposit lithium quickly, the evaporator must be heated to about 600°C. The first shot, the temperature was 400°C when we shot three minutes after the 600°C evaporation. This diode shorted because the Applied-B field forced the liquid lithium out of the 0.058cm wide nozzle. On the second shot, because of the problems with PBFA II, we didn't shoot for an hour and one half until the reservoir temperature decreased to 100°C. This shot looked good. It was similar to an LiF shot mainly because all the lithium probably reacted to form LiOH, which is similar to LiF. The last shot, which also shorted, was fired 40 minutes after evaporation and the temperature was about 200°C.

Because of the shorting out of the diode, we looked at a scheme to cool the reservoir very rapidly as was previously described. One of the problems with the hardware shown in Fig. 7 was that the active anode height is only 4 cm and it is desired to have a height of 6 or 7 cm. Also the spacing between the gas-cell skirt and the lower shield was too small (2 mm) and the heat from the evaporator warped the skirt. The next diode hardware, shown in Fig. 1, had cooling coils, higher anode height and more spacing between the shield and the skirt. We had originally planned to do two PBFA II shots in June 1992 but the special In Situ cathode tip was destroyed in another test, so we had two new cathode tips made by January of 1993. In PBFA II, both the heating and cooling cycles and the temperature diagnostics were set up so that we could control them from the experimenters' screen room in the PBFA II building. The set up is shown in Fig. 8. For the cooling cycle only a high-pressure line to control the cooling valve had to be run. We planned to do two or three In Situ LEVIS shots in the spring or summer of 1993, but because of the scheduling of other experiments on PBFA II, we started the LEVIS series in August.

The first PBFA II shot (6157 on 7/20/93) was scrubbed because the In Situ heater wires in the vacuum chamber were too close to some polyflow tubing, causing a vacuum leak. The heating cycle of the In Situ evaporator to 600°C and the fast cooling to <0°C worked well, but because of the vacuum leak, we did not shoot. The second shot (6152 on 7/22/93) was much better. The major problem before the shot was a leak in the gas cell before the heating cycle was started. We lost the pressure when we heated to 530°C. The vacuum was good (2.9×10^{-5} Torr) and the shot occurred without gas in the gas cell. The heating and cooling cycle worked well and the shot occurred four minutes after cooling started. The shot was not successful because the diode shorted. When the diode hardware was removed, we noticed that many of the bolts holding the evaporator to the upper cathode were sheared off and the entire metal dummy evaporator, normally attached to the lower cathode, was located between the gas cell skirts. It was obvious that the B-field was higher than expected. In the memo from Lopez and Gerber about the "In Situ LEVIS Series on PBFA II", we specified the maximum B-field bank charge. This was based on the three previous In Situ attempts (shots 4937, 4949, and 4956) in which there was very little

damage due to the magnetic field pressure. The total cathode current on shot 4949 was 53 kA. After we developed the cooling system, we did two ITF shots with cathode currents on 49.7 kA and 49.5 kA, respectively. Again there was very little damage, although we bent a couple of the small brackets. Because of these tests and since damage was minimal on PBFA II when the cathode bank was charged to 14.6 kV and cathode current of 53 kA, we specified this number. The reason the B-field was too high and the diode shorted was that the Principal Experimenter for LEVIS made the decision to charge the cathode bank to 16.7 kV just before the shot (the actual bank charge was 16.0 kV). This is an increase in the current ratio of 1.12 or an increase in magnetic force (energy) of 25% which is higher than the In Situ hardware would withstand.

It is unfortunate that the LEVIS ion source program is on hold at the present time since we feel most of the problems have been solved and it would be great to test a tractable active lithium ion source.

PRESENT AND FUTURE IN SITU HARDWARE

The evaporation hardware shown in Fig. 1 was not optimized. When cooling coils were needed, they were just brazed to the original hardware. This caused the hardware to warp because of the heat required for brazing. Also the evaporator shown in Fig. 1 had different nozzle distances, so each evaporator had to have the gap measured and shimmed up to the working gap of 0.058 cm. The lid on the evaporator had to have all the bolts torqued so the gap wouldn't change with angle. Jim Dritt (EG&G) from Dept. 1239 with help from Dept. 1237 redesigned and had manufactured the new evaporator shown in Fig. 9. The complete drawings for the entire evaporator system are given in Appendix B. The advantages of the new hardware is that the cooling and heating coils make better contact because of the machining grooves in the evaporator. Also the braze will make good contact over half the diameter of the coils. Also the nozzle is machined so that the gap is better defined than the first ones. The new evaporator is somewhat smaller, but uses the same four angle fixtures to hold the evaporator to the shields and also uses the same shields. We have enough new hardware for twelve evaporators. We have assembled

one entire evaporator and all the parts fit perfectly. Before tests are done on PBFA II, a couple of light laboratory experiments and an ITF experiment should be done to obtain thickness and uniformity and to test the hardware to determine maximum B-fields and obtain cooling rates. The hardware on hand and the procedures used to field the system are given in Appendix A.

Two new things are being considered for the next PBFA II shots. One involves the magnetic field since with existing hardware one cannot go higher than $V_{crit} = 14$ MV. Harry Ives, (EG&G) with Dept. 1239, has designed and had built new cathodes with 22 windings, so the B-field will come up slower so diffusion will reduce the B-field forces in the evaporator. In addition, he has doubled the number of bolts holding the In Situ hardware to the cathode tips. These modifications should allow us to go to much higher B-fields without massive damage. The other change being considered involves the upper gas cell skirt. The present ones are made of Lexan and are formed by heating to a temperature of about 80°C . They still warp slightly from radiation from the evaporator operating at a temperature of 600°C . Our plan was to machine the upper skirt from an insulator that can withstand higher temperatures. We looked at Vespel, but it would cost about \$3000 for the material for one gas cell skirt. Other possibilities are G-10 or Phenalic, both of which cost about \$30 a skirt. When In Situ is activated again, the experimenters should have the skirt material machined, probably from G-10. It would also be a good idea to find a new glue to attach the mylar to the skirt. We would test a cement called Master Bond EP65-HT which is good to a temperature of 200°F .

CONCLUSIONS AND RECOMMENDATIONS

This report has given all known details of In Situ evaporation of lithium on the anode for the LEVIS ion source. It was written so that when an active source is needed for ICF, then In Situ LEVIS can be fielded on PBFA II in a short period of time. This report gives the calculations and analysis as well as the results of numerous light laboratory experiments and of course the history of the program over the last few years. The goal of the program was to develop a lithium source for the PBFA II diode operating at a pressure of 10^{-5} Torr that will be a pure lithium ion source.

ACKNOWLEDGMENTS

The authors would like to thank the previous ion source leaders, Regan Stinnett and Gary Tisone, who had enthusiasm, interest, and provided funding for the In Situ program. We would also like to acknowledge the support of the previous 1200 Director, Pace VanDevender, who realized the importance of the active ion sources including the In Situ program. We also appreciate the work done by Rich Adams, Matt Dillon, Brian Clark, Colleen Wakefield-Reyes, Tim Renk, Jim Dritt, Gene Lujan, and Dean Rovang, all of whom helped on many aspects of the LEVIS In Situ program. Finally, we would like to thank Traci Strandberg for deciphering, typing, and editing this report.

REFERENCES

1. J. P. Van Devender in Proceedings of the 5th International Conference on High-Power Particle Beams (Beams '83), San Francisco, CA, September 12-14, 1983, R. J. Briggs and A. J. Toepfer (Eds.) p. 17.
2. M. M. Markowitz and D. A. Boryta, J. Chem. Eng. Data 7, p. 586-591 (1962).
3. P. L. Dreike and G. C. Tisone, J. Appl. Phys. 59, 371 (1986), also P. L. Dreike, Sandia Report, SAND91-0994 (1991).
4. Tom Christensen - Private Communications. Sandia memo to P. Dreike from T. Christensen, 12/4/87.
5. A. L. Pregenzer, J. Appl. Phys. 58, 4509 (1985).
6. Electrohydrodynamic Lithium Ion-Source Experiments on PBFA II, R. G. Adams, J. R. Woodworth, A. L. Pregenzer, T. R. Lockner, R. A. Gerber, D. J. Johnson, W. H. Jaramillo, M. M. Dillon, R. S. Coats, M. Halliburton, P. Primm, G. Torres, G. Ziska, T. Atwood, Proceedings of XIV International Symposium on Discharges and Electrical Insulation in Vacuum, Santa Fe, NM, September 17-20, 1990.
7. P. B. Barraclough and P. G. Hall, Surface Science 46, 393 (1974).
8. S. Slutz and R. Adams, Sandia Labs - private communication.
9. E. U. Condon, Chapter 5, Handbook of Physics, second edition McGraw-Hill, 5-64 (1967).
10. S. Dushman and J. M. Lafferty, Editor. Scientific Foundations of Vacuum Technique, second edition. John Wiley and Sons, Inc. 1962. Chapter 10, pp. 691-737.
11. Tom Green - private communication.
12. Sandia memo entitled "In Situ Evaporation of Lithium on PBFA II Anodes" from Bob Gerber and Mike Lopez to Gary Tisone, Tim Renk, and Regan Stinnett, October 7, 1991.

Figure 1. PBFA II diode used for LEVIS/In Situ ion source. The evaporator first puts a pure lithium film on the anode. Then two laser beams from a $1.06\mu\text{m}$ glass laser and a 670nm dye laser pass through the optical window and are distributed to the anode with the cone to evaporate and ionize the lithium on the anode. The pertinent dimensions, r_0 , r_1 , y_0 , y_1 , are for the In Situ calculations.

Figure 2. Calculated lithium evaporation rate on the anode as a function of the evaporator temperature.

Figure 3 The top graph gives the ideal evaporation temperature and heater current for the PBFA II electron evaporator as a function of time. The zero time would correspond to when the machine would be fired. The lower graph gives the evaporation rate on the anode over the same time interval.

Figure 4. Results of the evaporation cooling experiment which gives evaporator temperature as a function of time for various gases at various input pressures

Figure 5. Lithium thickness as a function of the anode height. The active source height of 6 cm is shown on the figure.

Figure 6. The first design of the In Situ hardware for PBFA II.

Figure 7. The second iteration of the In Situ hardware.

Figure 8. The cooling system and controls for the PBFA II experiment for the LEVIS/In Situ source.

Figure 9. The future optimized In Situ hardware for PBFA II.

APPENDIX A

This appendix goes into detail on how to get the hardware ready for a PBFA II shot. Included first is an inventory of the hardware that now exists for In Situ. This hardware and documentation are stored together to keep the program intact. If anyone is interested, Wilbur Stearn and Kerry Lamppa know the location. The appendix goes through the assembly steps of the cooling for the evaporation which must be done first. Procedures are then given to assemble and install the entire evaporation, including the heating cooling, and diagnostics. Finally the procedure for installation on PBFA II and testing will be given. Results of various In Situ tests are located with the hardware.

In Situ Inventory List

<u>PARTS/DESCRIPTION</u>	<u>QUANTITY</u>
1. Evaporators - with cooling tubes attached	2 ea
2. Evaporators - without cooling tubes attached	8 ea
3. Evaporator lid	10 ea
4. Heater shields - top	12 ea
5. Heater shields - bottom	12 ea
6. Dummy evaporator	8 ea
7. SEMCO Heater wire	6 ea

Note: There are also 3 each evaporators, 3 each evaporator lids, and various 5, 10, and 20 mil shims for the evaporator shown in Fig. 1. The hardware listed above is for the new evaporator shown in Fig. 9.

ASSEMBLY STEPS FOR THE TUBE FORMING & BRAZING OF THE RAPID COOL IN SITU EVAPORATOR

PARTS REQUIRED

1. Stainless evaporator boat, Part #3A2922 "Housing Ion Source".
2. Stainless tubing 0.125" O.D. x 0.016" Wall x 24' length. SUPERIOR TUBE COMPANY, Wapakoneta, Ohio 45895.

SERVICES REQUIRED

1. Custom Blacksmithing and tube forming services can be provided by FORGECO, 13 Imnaha Rd. Tijeras, NM 87059. Contact Robb Gunter (505) 281-8080. Gunter did work on previous evaporators when he was at Sandia.
2. Custom Brazing of tubing to evaporator services can be provided by SANDIA NATIONAL LABORATORIES, THIN FILM AND BRAZING DEPT. 2471 BUILDING 878, ROOM B1703, contact Chuck Walker (505) 844-7103.

PROCEDURE

The bottom of the evaporator has been machined with special grooves large enough to accommodate the stainless tubing and the braze material. The blacksmith must form the tubing inside the grooves so that there is approx. 36" of tubing remaining at each end. Please see drawing packet # jod 10/19/92 for specific dimensions and crossover locations.

After the tube forming has been completed, the assembly must be sent to the Thin Film and Brazing Lab for Hydrogen furnace brazing. The tubing must be free from defects and flow restrictions and the reservoirs on top of the evaporator must remain free from braze material. A strong bond between the evaporator and the tubing must be present.

ASSEMBLY PROCEDURE FOR THE RAPID COOL IN SITU EVAPORATOR

PARTS REQUIRED:

- a. Titanium top shield (Ti 6AL 4V). Drawing # 3A1610
- b. Titanium bottom shield (Ti 6AL 4V). Drawing # 3A0017
- c. Stainless Evaporator boat Part # 3A2922 with brazed cooling lines described in previous section
- d. Stainless Evaporator boat lid. Drawing # 3A2923
- e. 2 ea. K type glass insulated TC with washer attachment. Part # EI-1109102-WTK-6-S-36-HH-K-20. OMEGA ENG. CORP.
- f. 1 ea. SEMCO heater wire assembly. part # SK040192 REV. A.
- g. 4 ea. support brackets. Part # 3A1611
- h. 1 ea. stainless dummy evaporator. Drawing # 3A3079
- i. 2 ea. 6 ft. long OMEGA 16 gauge glass insulated heater wire.
- j. 12 ea. Titanium 8-32x1/4 skt. cap screw (Ti 6AL 4V) for top cathode attachment assembly, "boat, cooling tubes and shields".
- k. 12 ea. Titanium 8-32x3/8 skt. cap screw (Ti 6AL 4V) for bottom cathode attachment. Assembly "dummy evaporator".
- l. 12 ea. s. s. 8-32x3/16 skt. button head screw for shield assembly.
- m. 4 ea. s. s. 6-32x5/16 skt. cap screw for support bracket attachment. Holes in evaporator boat must be drilled in 4 places for support brackets.
- n. 20 ea. s. s. 4-40x3/8 skt. cap screw for evaporator boat lid attachment.
- o. 20 ea. s. s. 4-40 nut for evaporator boat lid attachment.

GENERAL

Start by assembling the hardware as a fit check. Assemble all of the evaporator boat and shields, make sure to double check critical dimensions like lithium gap on the evaporator and the cooling line crossover gap.

Make sure the evaporator boat is level and B-dot holes line up. It's also very important not to have the glass insulated heater wire resting on the top of the evaporator. Final assembly will bolt directly on to the PBFA II cathode tips that are specially designed "drilled and tapped" for the hardware. B-dot through holes are used for cooling lines, TC and heater wires. Pay close attention to alignment and orientation.

Cooling line connections inside PBFA II's cone should be made with Swagelok type fittings and leak checked prior to the machine going under vacuum.

HEATER WIRE INSTALLATION

1. Insert SEMCO heater wire into evaporator using the inside diameter groove, align heater wire terminations with machined slot in boat.

Use OMEGA CC High Temperature Cement to insulate around bare heater wire terminations.

Let paste set for 24 hours.

2. Insulate bare heater wire with high temperature glass insulation.
3. Using a small 22-16 gauge PANDUIT Terminal connector crimp 3 ft. of OMEGA 16 gauge glass insulated heater wire to bare heater wire, make sure to insulate crimp connector with high temperature glass insulation.
4. Transfer entire assembly into glove box, for lithium installation.

LITHIUM INSTALLATION AND WETTING

1. For molten lithium operations, make sure that the oxygen level and water vapor levels in the glass box are less than 10 ppm.
2. Place assembly on top of the two fire bricks located in glove box. Insure the evaporator is electrically isolated from the glove box and clear evaporator from any and all objects located in glove box. Connect the two heater wire leads to the variac transformer located in the glove box, again insure the wires are electrically isolated from glove box.
3. Locate thermocouple readout and thermocouple and attach it to the evaporator, making sure not to obstruct lithium reservoir.
4. Remove approximately ten inches or about two grams of 3.2mm diameter lithium wire 99.9% pure, stored in mineral oil located in glove box. Manufacture: ALDRICH CHEMICAL COMPANY.
5. Place the lithium wire on top of a clean MARATUFF wipe and let the mineral oil absorb into the wipe.
6. Cut the lithium wire in half and place sections in the evaporator's lithium reservoir, use only enough to fill the evaporator with one layer of lithium all the way around the boat.
7. Plug in the POWERSTAT variable transformer and turn on the thermocouple readout.
8. Start heating the evaporator by slowly increasing the output of the variac, monitor the temperature of the evaporator and lithium during the entire wetting process. Lithium melts at 180°C/356°F and should wet to the stainless at approximately 225°C/400-450°F.
9. Using a clean stainless spatula help the lithium wet into the evaporator by agitating and spreading the molten lithium during the heating cycle.

10. Try to spread the lithium as uniformly as possible around boat.
11. Turn off variac and let lithium cool to room temperature.
12. Apply a thin layer of mineral oil on top of lithium to help prevent corrosion. Boat is now ready to remove from glove box for assembly.

EVAPORATOR AND SHIELD ASSEMBLY

1. Place evaporator lid on top, align both with bolt hole pattern. Using items "n" and "o" on the parts required list, assemble and tighten finger tight, uniformly. Measure nozzle spacing at several locations to be sure pieces are not warped. Save four locations required for brackets, direct north, south, east and west. And two locations for TC's.
2. Attach brackets to the four locations.
3. Attach two TC's, 180 degrees apart.
4. Place assembly to top of the bottom heater shield, align so that the brackets line up with the correct bolt hole pattern.
5. Next place the top heater shield on top of the assembly and the two halves should squeeze together. Tighten the entire assembly together using items "l" and "m".
6. Pay close attention to the orientation of the cooling lines the heater leads and TC's with relation to the B-dot cut outs on the top heater shield.

FINAL ASSEMBLY ATTACHMENT TO TOP CATHODE TIP

1. Align B-dot holes on top cathode tip with cutouts on top heater shield, carefully feed cooling lines through B-dot holes. Make sure drilled and tapped attachment bolt hole patterns align with top heater shield pattern.
2. Start feeding heater wires and TC's through the appropriate B-dot holes.
3. After cooling lines and wires are fed through B-dots, attach assembly with item "j" on the parts required list.

FINAL ASSEMBLY ATTACHMENT TO BOTTOM CATHODE TIP

1. Align B-dot holes on bottom cathode tip with cutouts on bottom dummy evaporator, make sure drilled and tapped attachment bolt hole patterns align with bottom dummy evaporator pattern.
2. Attach assembly using item "k" on the parts required list. Tighten uniformly.

CONNECTIONS INSIDE PBFA II CONE

1. Once inside PBFA II cone, there will be six connections that will have to be made. Two TC's, two heater wires and two stainless cooling lines.
2. Run all wires and cooling lines separate from all other cables or existing lines in the center of PBFA II.
3. Coordinate with PBFA II's vacuum personnel to determine the correct port to be used and the proper type of vacuum feed through.
4. Once all hardware has been assembled, heat evaporator about 20°C to 30°C from the experimenters' screen room to be sure all wiring is correct.

APPENDIX B - DRAWINGS

This appendix contains all the pertinent drawings for the In Situ hardware. Included are the drawings for brazing the cooling lines to the evaporator, the evaporator parts, as well as the upper and lower shields, and the support brackets. Also shown is the mandrel for making the gas cell from Lexan. If the new ones are machined as mentioned in the text, the dimension can be obtained from the mandrel drawings.

Ø 50

WLE007

1

LINE	QUANTITY	REVISED BY	DESCRIPTION	DATE	QTY
1		ANDY SETH, 2653/
MIKE LOPEZ, 1264			
2		ANDY SETH, 2653/
MIKE LOPEZ, 1264	CHANGED PART # FROM 10.670
TO 10.000.
CHANGED PART ISSUES FROM
LETTERS TO NUMBERS.		
3		ER LUJUAN, 2653/
MIKE LOPEZ, 1264	CHANGED TAPPED HOLES TO
UNTAPPED HOLES. 12
ADDITIONAL THRU HOLES.		
4		ER LUJUAN, 2653/
MIKE LOPEZ, 1264	2653 WAS A BOMB AND 400
WAS A BOMB. 2653 WAS
NOT SELECTED 4
NOTICES IN I.O.		

		4	RECEIVED FROM - SECTION - DO NOT WRITE IN THIS SPACE	
	3			
	2			
	1			

NOTES:

1. GENERAL REQUIREMENTS PER 9900000.
2. MATERIAL: CRES TYPE 304
3. MARK PART NUMBER PER 9919100, CLASS H-1-A&B.

DESIGN AGENCY PART NUMBER		REVISIONS					
ISS	SHEET ZONE	PREPARED BY	DESCRIPTION	DATE	CHKD	APCD	
3A2932-000	1	R. BLACKBURN 1237 J. ORITT 1238					JD

		AGENCY APPROVALS			SHEET						TITLE		
		ORG	DATE	APPROVALS	1 2 3 4 5 6						BRACKET, SUPPORT (U)		
					1						(INSITU)		
					PART CLASSIFICATION						(PB2-90)		
					UNCLASSIFIED						(INSITU)		
					DRAWING CLASSIFICATION						SIZE	DRAWING NUMBER	
					UNCLASSIFIED						B	3A2932	
											CAGEC	SCALE	
											14213	2/1	
											SHEET	1 OF 1	
NEXT ASSY.	LIBED ON							STATUS					
APPLICATION								LOCAL-STOR-B-18-92					
								ORIGIN SA-ANS-V2.1					

GEOMETRIC PRECISION = XX.XXX XX

DESIGN AGENCY		REVISIONS	
PROJECT NUMBER	DESCRIPTION	DATE	BY
3A3079-000	EVAPORATOR, DUMMY	12/27	1
1	1	12/27	1

- NOTES:
1. GENERAL REQUIREMENTS PER 9800000.
 2. MATERIAL: CRES, TYPE 300 SERIES.
 3. MARK DESIGN AGENCY PART NUMBER PER 9818100 CLASS C-1-A. LOCATE APPROXIMATELY AS SHOWN.

SECTION F-F

AGENCY APPROVALS		1	2	3	4	5	6	TITLE
DATE	DATE	DATE	DATE	DATE	DATE	DATE	DATE	EVAPORATOR, DUMMY
12/27	12/27							
DESIGN CLASSIFICATION		UNCLASSIFIED						DESIGN NUMBER
DESIGN CLASSIFICATION		UNCLASSIFIED						3A3079
SCALE		1/2" = 1"						SCALE
APPLICATION		LOCAL - 10-14-52						DESIGN SA-ANS-V2

SECTION C-C

SCALE: 2/1

Semco

INSTRUMENTS, INC.

25700 Rye Canyon Road, Valencia, California 91355

Telephone 805 257 2000

FAX 805 295 0044

TELECOPIER INFORMATION SHEET

DATE: April 1, 1992

COMPANY NAME: Sandia Nat'l Labs

FAX #: (505) 845-7650

ATTENTION: Mr. Michael Lopez

TOTAL NUMBER OF PAGES: 2
(INCLUDING THIS PAGE)

DEPT OR TITLE:

SENDER'S NAME: S. Guy Moore

SUBJECT/COMMENTS/REFERENCE: Special Heater

Dear Michael,

Sketch #SK040192 follows for the heater we discussed.

Price: 12 each @ \$370.00 each

Delivery: 5 weeks ARO

FOB: Valencia, CA

TERMS: Net 30 Days

Should you have any further questions, feel free to contact me.

Sincerely,

S. Guy Moore

cc/ref.: SNI File

QTY. REQD	NOMENCLATURE OR DESCRIPTION	IDENTIFYING NO.	SPECIFICATION	MATERIAL OR NOTE	ITEM NO.																			
LIST OF MATERIALS																								
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>EXCEPT FOR USES EXPRESSLY GRANTED, INFORMATION DISCLOSED HEREIN IS CONFIDENTIAL AND ALL RIGHTS, REPRODUCTION, PATENTS AND OTHERWISE ARE RESERVED.</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">DRAWN</td> <td style="width: 30%;">L. CRAVENS</td> <td style="width: 15%;">92-04-01</td> </tr> <tr> <td>CHECKED</td> <td> </td> <td> </td> </tr> <tr> <td>APPROVED</td> <td> </td> <td> </td> </tr> <tr> <td>APPROVED</td> <td> </td> <td> </td> </tr> <tr> <td>APPROVAL</td> <td> </td> <td> </td> </tr> </table> </div> <div style="width: 50%;"> <div style="display: flex; align-items: center;"> <div> <p>SEMCO INSTRUMENTS, INC.</p> <p>25702 RYE CANYON ROAD VALENCIA, CALIFORNIA 91355</p> </div> </div> <p>TITLE: HEATER, SPECIAL</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;">SIZE A</td> <td style="width: 25%;">CODE IDENT NO. 24735</td> <td style="width: 30%;">PART NO. SK040192</td> <td style="width: 30%;">REV.</td> </tr> </table> </div> </div>		DRAWN	L. CRAVENS	92-04-01	CHECKED			APPROVED			APPROVED			APPROVAL			SIZE A	CODE IDENT NO. 24735	PART NO. SK040192	REV.	<p>MATERIAL: NOTED</p>		<p>SCALE: NONE NEXT ASSY.: SHEET 1 OF 1</p>	
		DRAWN	L. CRAVENS	92-04-01																				
		CHECKED																						
		APPROVED																						
		APPROVED																						
APPROVAL																								
SIZE A	CODE IDENT NO. 24735	PART NO. SK040192	REV.																					

Distribution:

MS 0360	1000	A.R.C. Westwood
MS 1190	1200	D. L. Cook
MS 1195	1202	J. P. Quintenz
MS 1192	1205	R. W. Stinnett
MS 1187	1207	T. A. Mehlhorn
MS 1178	1212	R. A. Hamil
MS 1193	1231	M. E. Cuneo
MS 1193	1231	D. L. Hanson
MS 1193	1231	D. J. Johnson
MS 1193	1231	S. K. Lamppa
MS 1193	1231	J. E. Maenchen
MS 1193	1231	P. R. Menge
MS 1193	1231	I. Molina
MS 1193	1231	T. J. Renk
MS 1193	1231	D. C. Rovang
MS 1193	1231	W. F. Stearns (2)
MS 1192	1236	D. D. Bloomquist
MS 1192	1236	T. D. Atwood
MS1184	1237	R. L. Williams
MS1184	1237	E. R. Lujan
MS 1184	1239	J. D. Boyes
MS 1184	1239	J. O. Dritt
MS 1186	1241	C. L. Olson
MS 1186	1241	M. P. Desjarlais
MS 1186	1241	S. A. Slutz
MS 1186	1241	M. A. Sweeney
MS 1187	1271	E. J. McGuire
MS 1187	1271	L. P. Mix
MS 1187	1271	M. K. Matzen
MS 1194	1273	C. W. Mendel
MS 1188	1275	R. A. Gerber (5)
MS 1188	1275	R. G. Adams
MS 1188	1275	B. F. Clark
MS 1188	1275	M. M. Dillon
MS 1188	1275	G. C. Tisone
MS 1188	1275	C. Wakefield-Reyes
MS 1105	1277	R. J. Leeper
MS 1105	1277	T. R. Lockner
MS 1105	1277	C. L. Ruiz
MS 1105	1277	W. A. Stygar
MS 0522	2566	L. E. Pope
MS 0958	2566	M. F. Lopez (2)
MS 1380	4231	D. W. Larson
MS 1380	4231	K. W. Bieg (5)

MS 1369 4700 J. P. VanDevender
MS 9018 8523-2 Central Technical Files
MS 0899 7141 Technical Library (5)
MS 0619 7151 Technical Publications
MS 0100 7613-2 Document Processsing (10)
for DOE/OSTI

DATE

FILMED

7/7/94

END