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Observations on the LIMITs Lithium Furnace and Rotary Pump

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Abstract: LIMITs is a lithium loop in the Plasma Materials Test Facility at Sandia National Laboratories. The full system comprises a lithium furnace, heated piping, heated transfer casks, and an argon glove box for transferring lithium in an inert atmosphere. Lithium was pumped using a mechanical impellor and housing at the bottom of the furnace rather than an external mechanical or an electro-magnetic pump. The impellor received from the vendor of the LIMITS furnace did not work, and Sandia rebuilt the impellor to make LIMITS operational. Sandia used LIMITs initially for flow experiments to support the studies of a flowing lithium wall module in NSTX and later for high heat flux experiments with lithium-cooled targets. During this operation, we had some concerns that the impellor on the pump (or its housing) had suffered some damage, but had to mothball the loop four years ago. We recently reopened the furnace to clean and inspect the components. This paper describes our experience in cleaning and dismantling this system and the observations on the pump and other hardware.

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Introduction

LIMITs is a lithium (Li) loop and a part of the Plasma Materials Test Facility[1] at Sandia National Laboratories. The full system comprises a lithium furnace and pump, heated piping, heated transfer casks, and an argon glove box.[2] We remove Li ingots from their containers and load them into a transfer cask under an inert atmosphere in the glove box and then seal the cask. The glove box has a small crane to assist the operator in lifting and placing the top flange cover on the cask. The sealed cask, still under argon cover gas, is then moved from the glove box after one wall of the glove box has been removed to gain access to the cask, and then relocated and connected to the furnace and LIMITS piping. Then the system is evacuated. The Li in the transfer cask is melted and transferred to the hot furnace by gas pressure.

Figure 1 shows the layout of LIMITS as arranged for its first use to study a Li jet, as desired in the next section. Figure 2 is a photo of the furnace in place for the Li jet and before the installation of piping. This location was adjacent to our small electron beam test stand (EBTS) which has now been fitted with a more powerful e-gun (EB60) and 60 kW power supply.

The Li furnace (Fig. 2) is an inverted hemispherical vessel. In LIMITS, a mechanical pump rather than an electromagnetic pump drives the Li flow from the furnace. The impellor and housing of the rotary pump at the bottom of the furnace are suspended from a large flange on the top with a vacuum penetration for the drive shaft to the 5 HP pump motor above the flange. Instrumentation includes thermocouples, pressure taps, a level meter in the furnace and an electromagnetic flow meter.[3]

In 2004 we made LIMITs inactive by isolating and sealing the furnace and tanks under a positive pressure of argon. We recently reopened the furnace to clean and inspect the components. We had some concerns that the impellor on the pump (or its housing) had suffered some damage. This first part of this paper describes our experience with LIMITS, particularly in cleaning and dismantling this system and our observations on the pump and other hardware. The paper also briefly describes our current adaptation of limits and considerations for replacing the mechanical pump with an EM pump. In the past two years, we have extended the helium cooling loop to our large dual beam 1.2 MW electron beam, E1200, and are readying the refurbishing LIMITs to test a Li-He heat exchanger.

Experience in Operating LIMITS

We originally designed LIMITS to force a 5-mm-diameter free jet of Li flowing at 10 m/s in while a video camera recorded the fluid motion.[4] The jet passed through a magnetic field that duplicated that in the poloidal direction across the divertor of NSTX. We developed the experiment to obtain these data due to (a) interest in creating a plasma facing component (PFC) in NSTX with an exposed surface of flowing Li and (b) the inadequacy of computational tools to treat the magneto-hydrodynamic effects that control the flow of a liquid metal in a strong magnetic field and complex geometry. The jet of Li traveled laterally from a nozzle on one side of the vacuum chamber, between the appropriately shaped pole pieces of a permanent magnet and into a receiving orifice on the far side of the chamber.

Our approach in building LIMITS was to assemble a system for the objective above as fast as possible and to limit the cost. We avoided the high cost of an electromagnetic pump by using a rotary pump suspended from the flange at the top of the furnace. We purchased the pump and furnace as a system from a vendor but the pump as built did not perform satisfactorily. The pump's impellor housing, vertical standoffs and pump flange are a welded unit and alignment depends solely on the mounting of the motor, shaft and impellor. In its initial operation the pump chattered and showed wear on the housing and impellor. In subsequent modifications, we replaced the 25.4 mm (1 inch) shaft with one 51 mm (2 inches) in diameter and then added bearing surfaces made of a cobalt alloy on the top and bottom of the outer diameter of impellor, as shown in Figure 3.

These tests were performed in EBTS, our smaller electron beam high heat flux test stand that preceded the current upgraded version, EB60. We subsequently used LIMITS in experiments in closed systems with Li-cooled targets for high heat flux tests. For experiments with LIMITS, we discontinued the previously used water-cooling system for the e-gun and the fittings on the vacuum chamber and cooled these with Shell Diala oil and cooled the oil reservoir with the chilled water system. The change reduced the chance of mixing water accidentally with hot Li.

LIMITS is a stainless steel system. We use Swagelok connections on 25.4-mm (1-inch) lines. The 101.6-mm (4-inch) return line has a Conflat® flange on the vacuum chamber side and pressure flanges at the 4" gate valve. The Helicoflex gaskets for the pressure flanges must be replaced and the mating surfaces polished each time the flanges are taken apart. Copper gaskets are not acceptable. Trace heating in such systems must be designed with careful attention to the extra mass of the flanges or other added mass to avoid cold spots that cause plugging. After the installation of trace heating, the piping is covered with insulation and no longer visible for inspection.

One of our lessons learned occurred after we had inadvertently left in place a copper gasket that had been used in leak testing the system. With the system hot, Li dissolved a portion of the copper gasket, leaked into the insulation and caused a small Li fire. With our lab staff, the planning and procedures included Lithex on hand for fire suppression and related training of our lab staff. We now require an independent safety inspection by a technical person no involved in performing the experiment. Their concern is only safety without regard to the experimental schedule. We also learned that the site-wide emergency response scenarios were geared for fires and radiation but had not included training for Li fires. Our event resulted in extended training with site response personnel at an outdoor burn pad used for fire suppression training Sandia, in which we performed and filmed a demonstration of the correct techniques for suppression as well as the effects of incorrect procedures such as use of water or CO2. We also worked with the site response team to increase their understanding of the response needed for a Li fire, which includes how the fire itself is suppressed, shut down of equipment, evacuation of personnel and examination of personnel for exposure to vapor, etc.

We put LIMITS on standby in 2004 to make room for other experiments. To do so, we disconnected piping, capped the inlet and outlet and placed the furnace vessel under a slight positive pressure of argon as a cover gas.

Cleaning of LIMITS

The LIMITS furnace remained full of Li for seven years under vacuum. Our first task was to determine how much contamination had occurred to the Li. Our primary concern was contamination and plugging in the drain line at the bottom of the furnace. If the contamination were localized at the end of the pipe, then this plugging could be easily removed and the furnace heated and emptied of Li.

To examine the Li in the capped drain pipe, we prepared a work space with an inert environment by elevating the furnace in a support stand and placing a skirt around the lower portion of the furnace vessel that was then flooded with argon. We were pleased to find that the Li near the end of the drain was slivery in appearance. After this verification, we replaced the cleaned section of drain pipe and connected the furnace to a transfer cask, and the Li in the heated furnace was transferred into the cask by an overpressure of argon on the top surface of the furnace. We were subsequently able to pull the pump (motor, shaft, impellor and housing) vertically up out of the furnace without resistance, i.e., the impellor was free of the housing although the impellor retained a coating of Li.

The impellor and the housing both had retained a coating of Li that was oxidized after exposure to atmosphere. Parts and equipment that we can move, we clean outdoors in a tank of water. Figure 4 shows the pump unit in the process of cleaning. After a cleaning operation, we must then dispose of the Li hydroxide solution as hazardous waste

Future Experiments with LIMITs

LIMITs has been readied for use in a test in our large electron beam, EB1200, of a lithium-helium heat exchanger. This is a collaboration between Sandia and Ultramet, Inc. of Pacoima, CA being carried out under a Cooperative Research and Development Agreement. As part of this work, a new helium loop with a larger blower has been extended to serve EB1200. Since we built LIMITS, we have acquired several electromagnetic pumps and a liquid metal loop previously intended for monitoring the chemistry in a TOPAZ reactor. We are investigating the potential for adding an external electromagnetic pump for LIMITs.

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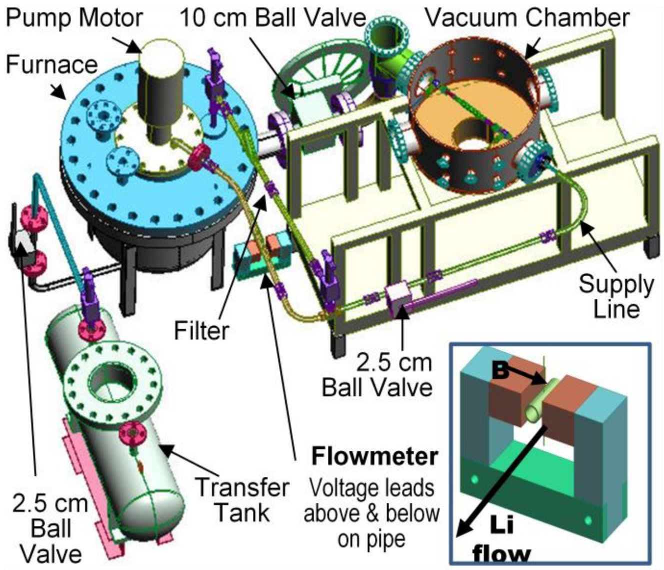

Fig. 1. Here LIMITS is configured to test a Li jet flowing across a vacuum chamber previously used with our small e-beam. Parts: lithium furnace with rotary pump, heated piping, heated transfer cask, and, for the NSTX test shown here, a nozzle and flow collector. The e-gun and its vacuum system are not shown to reveal base of vacuum chamber.

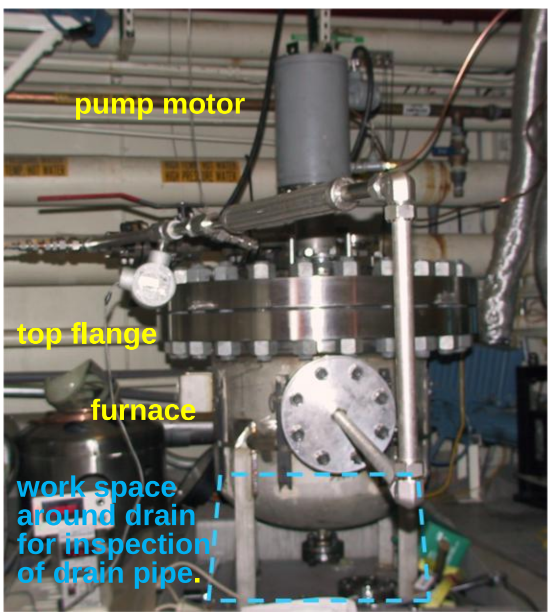

Fig. 2. LIMITS furnace and pump (above). Area indicated around drain was isolated by skirt so that a cover gas could be used when the drain pipe was opened for inspection.

Fig. 3. Impellor and bearing in LIMITS pump

Fig. 4. Cleaning of the LIMITS pump outdoors by immersion in a tank of water.