01-222N(C) -- LIQUID LITHIUM STRIPPER FILMS AND WINDOWLESS TARGET

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Purpose: Since the early 1990's in the field of low energy nuclear science there has been worldwide interest in an advanced facility capable of producing energetic, high-quality beams of radionuclides. The purpose of this LDRD project is to develop design concepts for the major components of the Rare Isotope Accelerator (RIA). This project aims to develop strippers and targets capable of handling the high power density energy deposition of the heavy ion beams from the RIA driver.

Approach: The high primary beam intensity of RIA will deposit high power density into the accelerator strippers and primary targets. The heavier beams in particular, with their very high stopping powers, would destroy most solid materials. We propose to use flowing liquid lithium for these tasks.

Technical Progress and Results: Design studies and engineering concepts for testing both the liquid lithium strippers and windowless targets for RIA were carried out during this past year. In both cases it is the high current uranium beams that set the required specifications. The base-line design of the RIA driver linac is for 400 kW of all ion beams delivered to the production targets. This corresponds to 4 particle microamps of uranium beam on target at 400 MeV per nucleon. The stripper foils are located at intermediate locations through the linac. The first stripper is at 9-MeV/u uranium and the second is at 85 MeV/u. The uranium beam currents at these locations are slightly higher than at the output, allowing for some charge-state losses. The stripper currents are assumed to be about 5 particle microamps. The vapor pressure of lithium sets the tolerable temperature rise in the strippers and the final target. We have set a design goal of a maximum temperature of 350 C (vapor pressure of 10^{-5} Torr) or less at the hot spots of all lithium films. The flowing lithium liquid is assumed to be 200 C, i.e. 20 C above the melting point. This leaves a temperature rise of 150 C at the hot spot. Thermal calculations show that this hot spot temperature is not exceeded by using a linear flow velocity of 100 m/s at the first foil, 50 m/s at the second foil, and 20 m/s at the final target. These calculations are for 1 mm wide beam spots at all these locations. Vapor pressures of 10^{-6} to 10^{-7} Torr are achieved at spot widths of 2 mm.

The various combinations of linear flow rate and thickness required set the liquid lithium pump requirements. In general the stripper foils require very high pressure, very low volume flow rate pumps, while the final target requires a medium to high volume flow rate at very low pressure. During the year we have considered various pump options,

including mechanical rotating centrifugal types, three-phase AC electromagnetic induction pumps, and DC permanent magnet pumps. For their simplicity of construction and large range of potential design parameters, we have chosen the DC magnetic pumps for proof-of-principle. The only caveat about the permanent magnet pumps is that the choice of material is limited to that which is stable at the ambient temperature of the liquid lithium. The proper material for this application is the less common Sm_2Co_{17} (useful up to 350 C), rather than the more common NdFeB (useful only below 180 C). It is also good that the SmCo material is about 1000 times more resistant to neutron radiation damage than NdFeB.

We are now in the final stages of design for a windowless target test stand. This design uses a permanent magnet pump that is a simplified version of one of the pumps at the APS. The design is modified because we need much lower pressure at an intermediate flow rate relative to the performance of the APS pump. We are currently mocking up a model of the modified pump that works at room temperature with Ga/In alloy. This will be a table-top windowless target model that operates in air. It will be useful in checking our pump design calculations and in testing the target nozzle shapes. For example, we will compare circular and oval cross sections to see if oval or rectangular shapes may be a viable option for the large systems. We have done tests with water nozzles that indicate oval shapes with a 2:1 aspect ratio are likely to work well. The advantage of such shapes is in reducing the volume flow rate requirement for a given target thickness and linear flow velocity. The goals of this windowless lithium test stand are to demonstrate a 1-cm thick target at a flow rate of 5-10 m/s. It will be a critical test of our pump concepts and be flexible enough to permit experimentation with nozzle designs. In the process we will be developing the safety procedures that will be much more significant at the full-scale RIA target system.

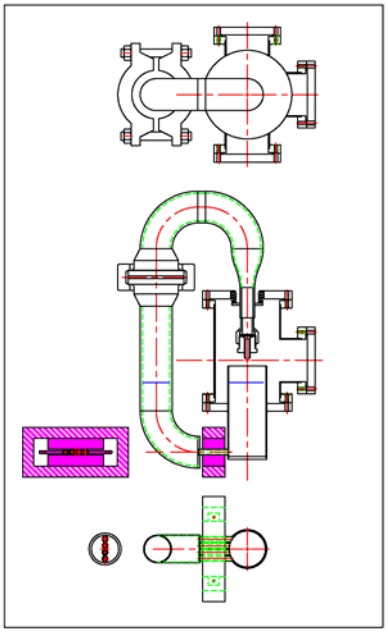
In parallel, we are working on the concepts for the high pressure/low flow rate systems required for the strippers. There is no obvious way to create the high velocity thin films of lithium that are needed for this application. Thin carbon foil strippers are traditionally used for this type of accelerator. However, the RIA driver linac has uranium beam currents ~1000 times higher than existing accelerators such as that at GSI in Germany. Carbon foils can be used as a fallback design option if the liquid lithium film development is not successful. However, the carbon foils would have to be mounted on a wheel with a 1-m circumference to keep the temperature rise tolerable. During a period of minutes or hours the properties of the foils would change, leading to beam tuning problems. Such a system would clearly be a weak link in the driver linac design. Also, lithium yields somewhat higher average charge states than carbon, another advantage.

Initial work with water-jets looks promising. At first we compared slit-shaped nozzles with round ones. This work is not complete, but the initial results favor the round nozzles. We have achieved flow velocities of up to 30 m/s at 50 psi water pressure with 0.3 mm diameter orifices. Calculations show that water and lithium are predicted to be very similar at such flow conditions. Lithium has a factor of 2 lower viscosity than water, but in this highly turbulent regime the pressures are nearly independent of the viscosity.

However, the extra factor of 3 in linear flow rate requires about a factor of 10 in pressure, or about 500 psi. We are currently building a higher pressure water system for experimenting with nozzles at the full 100 m/s flow velocity. The round water jets are converted to thin films by spraying at a glancing incidence near the edge of a stainless steel sheet. It appears that film thicknesses of 10-20 microns and possibly less are possible by this method. The resulting water films at the flows achieved to date appear very uniform and stable. A further design issue is the erosion rate of the nozzle and the associated choice of nozzle material.

Design concepts for achieving the high pressure/low flow conditions for the lithium films appear reasonable. The gallium pump at the APS achieves 200 psi at much higher flow rates than needed here. Following nozzle and pump development, the construction of a test loop for in-beam evaluation of the thin films at ATLAS will be pursued.

Figure 1. Test loop layout for the windowless liquid lithium target system.



Specific Accomplishments: No papers have been published yet on this work.