# CONTROL OF THE SARAF HIGH INTENSITY CW PROTON BEAM TARGET SYSTEMS

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*Abstract*

Several experiments are being prepared or conducted at the first phase of the SARAF linac. Two of these experiments are: the Liquid Lithium target and the Foil target. The present report describes the new hardware and software control systems which are currently being built for these experiments.

## INTRODUCTION

A temporary beam line has been built for the 4 MeV 1 mA CW proton beam at phase I of the Soreq Applied Research Accelerator Facility (SARAF) [1,2]. Two of the experiments planned for this new beam line are the Liquid Lithium Target (LiLiT) [3,4,5] and the Foils target [6]. New hardware and software control systems were built and being tested for these experiments. The LiLiT target will be used to create an intense keV neutron source, produced via a $^{7}Li(p,n)^{7}Be$ reaction. This target was successfully tested off-line and will be installed at the accelerator beam line in the near future. The foils target is planned for irradiation experiments, examining issues of radiation damage in thin metallic foils. The control systems of both experiments include various diagnostic elements, vacuum control, temperature reading etc. These systems were designed to be modular, so that in the future new targets can be efficiently replaced.

## THE LiLiT TARGET

The LiLiT target is a windowless forced liquid-lithium jet in vacuum [3,5]. Lithium is heated to ~ 200°C (above the melting temperature of 181°C). The liquid-lithium loop is designed to generate a high velocity lithium jet (10 m/s or larger). The lithium nozzle and the concave supporting wall are located inside the target vacuum chamber. An electromagnetic (EM) induction pump (figure. 1, E) drives the lithium flow from the containment tank (figure. 1, D) to the lithium nozzle. After passage through the target vacuum chamber, the lithium is collected back into the containment tank (figure 1, D). A heat exchanger, based on a separate loop of oil, circulating around the lithium tank, was designed to remove heat from impinging proton beam (up to 10 kW).

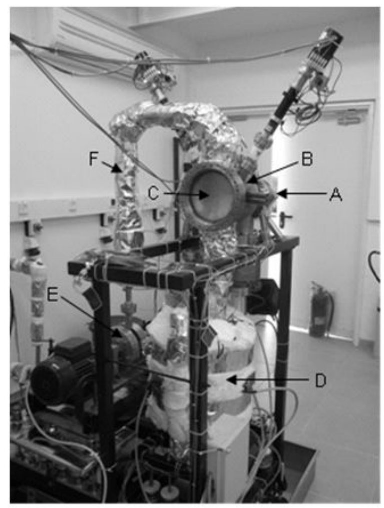


Figure 1: The LiLiT target: A-proton beam entry (will be connected to SARAF proton beam line), B-Target chamber (with lithium nozzle inside), C- neutron port, D-Lithium containment tank, E-Electromagnetic (EM) pump, F-lithium jet loop line.

A stand-alone fire resistant laboratory was built to test the liquid-lithium loop, its heat removal capabilities using an attached electron gun as a heater and to establish the safety regulations. The LiLiT control system provides full and safe control of the lithium and its cooling oil loops. The control system is based on a National Instruments compact field point (cFP) 2020 controller. The controller governs the following I/O interface modules:

1. NI-AI-111 analog current input for reading the temperatures values at various positions of the Li tank. The temperature readings are converted to current by a ConLab USD-2 universal transmitter.
2. Two NI-AI-110 modules, of analog voltage and current inputs for reading the vacuum, Li speed, temperature etc.

3. AI/O 610 analog input/output module for operation of the Li and oil flow control, linear control etc.
4. DO 401 digital outputs for Li heaters, fans, Li and oil motor etc.
5. DI 304 for monitoring of Li temperature status and alert signals.
6. TC 125 for direct temperature reading.

Additionally, the control system includes drivers for the Li and oil motors, vacuum controllers, linear motors for the diagnostic wire scan and for the beam blocker, temperature controllers, etc.

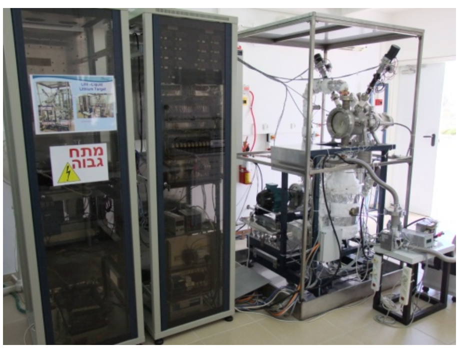


Figure 2: LiLiT target and control racks in the off-line lab

The code for the cFP controller is divided in two subsystems. The real time controller program with the critical code controls the most important parameters: the different set points (lithium speed, vacuum safety level, etc.) and the parameters of lithium heating process. The host computer program handles all the other control functions.

The Humane Machine Interface (HMI) was built to reflect as closely as possible the system structure, presenting its functionality and parameters in the most intuitively clear way (figure. 3).

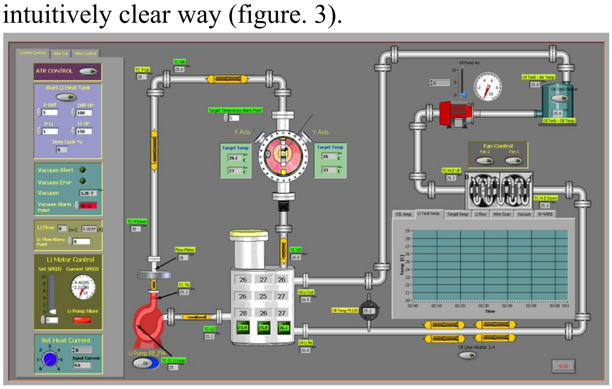

Figure 3: LiLiT control HMI

The left side of the screen enables operation of the various systems, such as the local temperature controllers, the Li tank and other heaters, the EM pump motor and wire control. Given the safety concerns associated with liquid lithium, the initial heating process of the solid Li must be performed carefully using a proportional temperature feedback algorithm. The Li loop is presented in the centre of the HMI. The diagnostics of the loop include the temperature mapping of the various locations in the loop (in the Li tank, target and pipes) and control of the EM pump. The oil loop is presented on the right side of the screen. This loop handles the operation of the oil motor, cooling fan and the oil heaters in the pipes. On the same side, the different parameters are also shown in the running plot.

Before installing the LiLiT experiment at the SARAF proton beam line, we intend to substitute the controller of the system with a new one, a cRIO which has field-programmable gate array (FPGA). This is necessary because the current controller has a relatively low performance and memory and it lacks an FPGA.

## FOIL TARGET

The foil target is used to examine the effects of proton irradiation of thin foil targets. A 25 microns thick Havar foil of 20 mm diameter is irradiated by an intense proton beam. Another side of the foil is cooled by liquid metal NaK alloy, which is in contact with a water cooled stainless steel plate.

The Foil target control hardware is located in a mountable rack in the RF Hall (approximately 30 meters from the target). It contains an NI compact reconfigurable Input/Output (cRIO) 9073 control system. The cRIO includes three components: a real-time controller, a reconfigurable FPGA, and industrial I/O modules. We used the following I/O modules:

7. NI AI-9205: Analog input for reading the different devices inputs.
8. NI AI-9264: Analog voltage output for operation of the water flow and the x-y scanner.
9. NI AI-9421: Digital input used to indicate the status of the flow switch.
10. NI AI-9421: Digital output for the operation of the accelerator Machine System Safety.

The Foil control systems HMI (figure 4) is divided to two parts, the first of which operates and controls the water cooling systems (figure 4). This part presents the differential pressure gauge, temperature of the water in different locations along the pipe line, ultrasonic water flow meter, pressure gauge, water valve control and water flow switch. The second part in the HMI presents the target parameters (figure 5) such as target currents, temperatures in several locations (measurement by 4 thermocouples) and target temperature as measured by a pyrometer sensor. The control systems enable the user to direct the pyrometer to a specific point on the target or to perform a two dimensional scan. The scan system consists of two drivers (MicroMaxTM Series 671) and of two accurate mirror positioning systems.

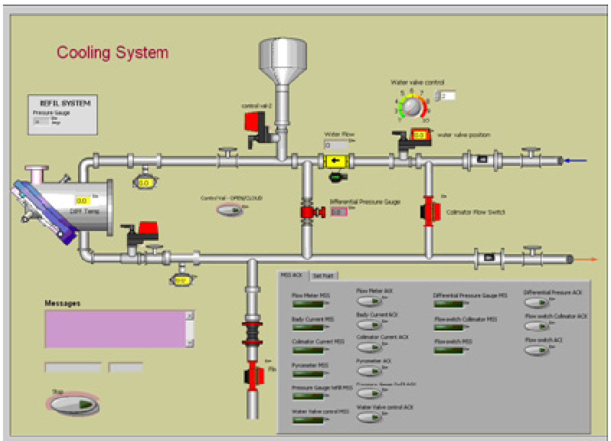


Figure 4: Foil target control system – water cooling systems.

The control system provides a "target ready" signal for the accelerator Machine Safety System (MSS). We therefore used the FPGA, which provides high reliability, high speed and determinism. The "target ready" signal is set by the chain of the following signals: water flow value, pyrometer temperature reading and flow switch status. The "target ready" signal ensures that the target cooling system is operating and that the target temperature is in the permitted level.

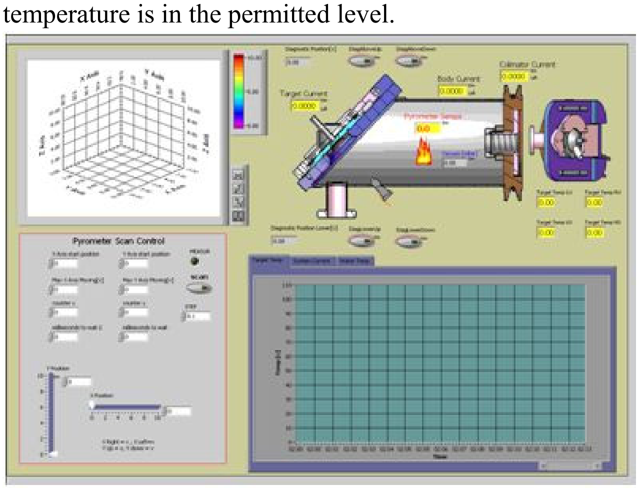


Figure 5: Foil target control system – target parameters.

## SUMMARY

The present report gives a brief description of the control systems of the two experiments at the SARAF accelerator temporary proton beam line. Both systems are fully operational, enabling an excellent control of the targets. At the moment, the Foil target experiment is routinely running at SARAF. The LiLIT experiment is routinely in operation, irradiated by an electron gun and will be moved to the proton beam line in early 2012.

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