# A NEW SLED TEST STAND IN THE APS INJECTOR LINAC *

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*Abstract*

Recently, a new SLED test stand located in the Advanced Photon Source (APS) linac klystron gallery was developed using a spare modulator-klystron system and a recently developed prototype water station. The new test stand will be used to condition, tune, and perform rf measurements on spare SLEDs without interfering with normal daily linac operations. This will allow technical groups to replace a low-performance SLED from one of the operational linac sectors with a fully conditioned SLED. The pre-conditioned SLED is expected to require less conditioning time after being put into operation compared to an unconditioned SLED. As an additional benefit, the prototype water station system developed to replace aging linac water systems can be tested under realistic conditions. In this paper, we describe the test stand design, prototype water station system, and first results using it to condition SLEDs and perform SLED rf measurements.

## INTRODUCTION

The Advanced Photon Source [1] injector linac provides excellent availability in supporting storage ring top-up goals. Our operational record is the result of strong preventative maintenance programs, implementation of redundant klystron and source rf gun operation modes, and the use of Procedure Execution Manager [2] tools.

Redundancy is achieved by having a spare klystron and rf gun available, each of which can be quickly switched to replace the standard operational systems in the event of a problem [3]. Additional redundancy is provided by having the ability to achieve 325MeV beam from the linac without one of the last two SLED'd systems that provide rf to the final linac accelerating structures. Recently, the SLED in the final linac system, (L5), developed problems that only allowed it to achieve 20 MW which is less than 15% of the power needed to support beam operations on its own. Even though this low power still allows us to achieve 325MeV, effectively one of our redundant operations modes was no longer available. As a result, the SLED was replaced with a fully conditioned SLED using our new test stand described in this paper.

## TEST STAND PREPARATION

A team of engineers and technicians from various support groups were assembled and given the task of assembling a new test stand in the linac using limited money, resources as well as limited material and time. They understood that the test stand must be capable of providing sufficient rf power to three different areas utilizing two S-band rf waveguide switches. The first rf flow path (mode 1) is a provision for one or more of several possible future uses. The second path (mode 2) is the waveguide component test stand where new S-Band waveguide switches and other waveguide pieces can be conditioned. And finally, the third path (mode 3) will be used for conditioning spare SLAC Energy Doublers or SLEDs [4].

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## TEST STAND RF SUPPORT

The L6 Test Stand modulator is a conventional PFN-type pulser with a step-up pulse transformer capable of producing DC pulses required for the operation of the Thales' TH2128A and TH2128D S-band klystrons [5]. The klystrons are able to produce pulsed rf power at the frequency of 2,856 MHz.

Parameters of the pulses are:

- Pulse widths (DC): - 5 µsec;
- Peak voltage: up to 300 kV;
- Peak current: up to 300 Amps;
- Pulse widths (rf): up to 4.5 µusec;
- Klystron output rf power: up to 30 MW (TH2128A);
- Klystron output rf power: up to 37 MW (TH2128D);
- Repetition rate: up to 30 Hz.

The modulator and low-level rf systems provide very high level of protection against all possible faults in the components under test including excessive vacuum activity and arcing.

## PROTOTYPE WATER STATION

The APS linac is divided into five sectors, four of which use individual closed-loop, deionized (DI), temperature-controlled water systems to regulate the temperature of high-power rf components [6].

The rf components in the linac as well as the test stand are made of oxygen-free high-conductivity copper and respond quickly to temperature changes. Changes in water temperature will influence copper components resulting in reflected rf power and, in some cases, beam energy changes.

Because temperature regulation is held to better than ± 0.1°F in the linac, we could not take the chance of disrupting the main injector water system to support the L6 test stand for SLED conditioning. In light of that, our mechanical operations and maintenance group designed a prototype water system similar to the ones used in the linac today. Some differences in the prototype (Figure 1) are the overall physical size, which houses a smaller, more efficient pump motor, and an improved temperature regulation, which are monitored and controlled by a PLC controller.

Prototype water station requirements:

- Flow rate: 80 gpm
- Temperature stability of: ± .05 degrees F
- System pressure: not to exceed that of the components of the system. < 90 psig
- Deionized water: at > 8 Mohms/cm

The main components of the system consist of a 7.5 hp Grunfos multistage pump, a 14kW heater, a water-to-water heat exchanger, and a three-way mixing valve.

Figure 1: Prototype water skid.

An Allen Bradley Control Logix 5000 PLC is used to achieve the precise temperature control required for rf stability. A standard PID loop is used, which compares the temperature at the RTD located near the mixing valve to the set point selected in the controller. A control signal is then sent via the PLC to the mixing valve to achieve the desired set point. There are two different water temperatures being mixed at the three-way valve: one with heated water and one that has been cooled through the heat exchanger. To improve water quality, a slip-stream of water is bypassed through a mixed-bed resin tank to polish the water through an ion exchange process to achieve the desired resistivity of > 8 Mohms/cm, which is monitored via the PLC as well.

The PLC also handles all of the binary and analog control equipment. Communications with the PLC are achieved through an Ethernet connection that allows an interface with the EPICS control system at the APS. The connection with EPICS allows us to monitor data remotely and offers the ability for selective control of system operations.

## TEST-STAND MECHANICALS

The test stand provides accommodation for mounting various types of SLEDs. A SLED mounting jig shown in Figure 2, was developed and centrally mounted between the rf source and rf load for the test stand (Mode 3) rf conditioning. This apparatus provides flexibility in leveling and aligning of the SLED for easy hook-up of the input and output waveguide. A big time saver!

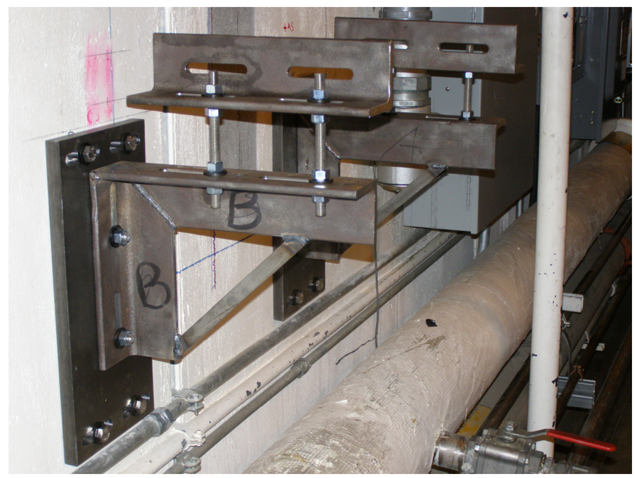

Figure 2: SLED support jig.

## S-BAND SWITCH SYSTEM

The SLED test stand shares use of the sixth klystron in the linac gallery (L6) with a component test stand and provides the opportunity for future use. The most probable of several possible future uses is for L6 to serve as a hot spare for the L4 and L5 klystrons in the same basic way that the L3 klystron serves as a hot spare for the L1 and L2 klystrons in the existing high power S-band switching system [7]. Two reworked commercially available WR340 waveguide switches [8] are used to implement multiple mode functionality for the L6 klystron in essentially the same way as for the L3 klystron. However, the present installation does not use a programmable logic controller (PLC) to implement the switching logic. Instead, a local (only) control panel activates the waveguide switches and steers interlocks via relay logic. A key-controlled switch must be changed from operate mode to switch mode, disabling the klystron drive, before power is made available to the position-selecting push buttons and indirectly to the switch coils. This feature is essentially as described in the Linac 2000 "Testing and Implementation Progress on APS Linear Accelerator High Power S-Band Switching System" [7], but has not been included in the actual implementation of the existing L1-L2-L3, high power S-band switching system, which relies on the PLC to prevent the possibility of inadvertent hot switching.

## TEST-STAND INTERLOCKS

The L6 test stand is designed to be operated concurrently with normal operations of the linac. Since some of the components can be used for multiple purposes, a system of interlocks was designed to provide controlled operation of the multiple components in a safe manner.

From a machine-protection interlocks perspective, we have three modes of operation defined by the position of two S-band waveguide switches shown in figure 3. In addition, each mode has its own subset of inputs (vacuum, SF6, water flow) to be monitored. The rf can be directed towards the L3 water load, which provides for future uses (mode 1); through the waveguide component test stand towards the L6 water load (mode 2); or towards the SLED test stand (mode 3). The interlock system provides a PERMIT signal to the rf system based on the waveguide switch position (the mode), vacuum, SF6, and water.

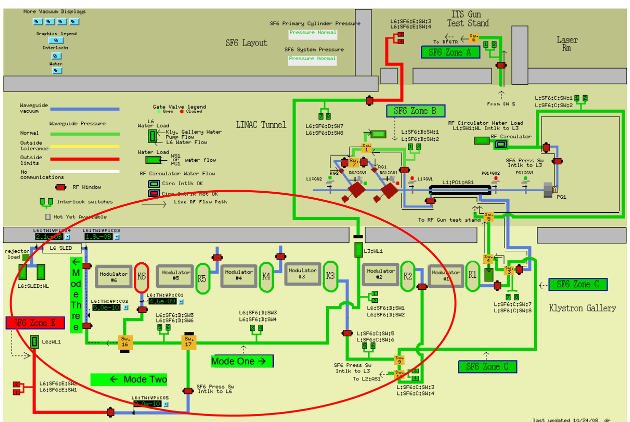


Figure 3: S-band switch 16 and 17 selects one of three possible mode paths.

## LINAC REPLACEMENT SLED

When the L6 test stand is used for pre-tuning and rf condition a spare SLED, the process must be conducted in controlled steps. Once the SLED is mounted and under vacuum it is very important that the SLED cavity temperatures become stabilized to the intended operating temperature and are maintained to within ± 0.1 degree Fahrenheit. Measurements on both cavities for resonant frequencies are verified and, if necessary, each cavity is adjusted for the correct tuned frequency. A quick check of the return loss is performed to ensure that reflected power at high levels will be acceptable. The process of rf conditioning to its highest level is slow and vacuum dependent. For example, the AS&E SLED serial number 004 required approximately 112 hours to reach 144 MW in the L6 test stand.

Once our replacement SLED was installed in the L5 operating system, fine SLED cavity adjustments still needed to be made since all parameters, such as temperature and SLED input and output match, were not exactly the same as in the test stand.

The desired operating goal for L5 SLED was 144 MW. Conditioning time was focused during daytime hours. The conditioned level reached during the day was held through the evening and night followed by continued conditioning the next morning until our goal was reached. To our surprise, the goal was reached in approximately 20 conditioning hours.

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## REFERENCES

[1] 7-GeV Advanced Photon Source Conceptual Design Report, ANL-87-15, April 1987.

[2] M. Borland, "The Procedure Execution Manager and its Application to Advanced Photon Source Operation," Proc. of PAC1997, Vancouver, B.C., Canada, May 12-16, 1997, p. 2410 (1998); http://www.JACoW.org.

[3] S. Pasky and R. Soliday, "Conducting Research and Operator Training While Maintaining Top-up Reliability Using the Advanced Photon Source Linear Accelerator," Proc. of PAC2003, Portland, Oregon, May 12-16, TPAG002, p. 1419 (2003); http://www.JACoW.org.

[4] Z.D. Farkas et al., "SLED: A method of doubling SLAC's energy," SLAC-PUB-1453, June 1974.

[5] A. Cours, T. Smith, "The Advanced Photon Source Linac Modulator. PSpice Simulation and Upgrade" Proc. Twenty-Fifth Int'l Power Modulator Symposium and 2002 High-Voltage Workshop, CD, 2002.

[6] R. Dortwegt, S. Pasky, M. White, "Improved Temperature Regulation of APS Linac Rf Components," Proc. of LINAC98, Chicago, IL, August 23-38, 1998, TH4103, p. 1001 (1998); http://www.JACoW.org.

[7] A.E. Grelick et al., "Testing and Implementation Progress on the Advanced Photon Source (APS) Linear Accelerator (LINAC) High Power S-Band Switching System," Proc. of LINAC2000, Monterey, CA, THE07, p. 983 (2000); http://www.JACoW.org.

[8] S. Berg, D. Bromberek, J. Gagliano et al., "Rebuilding WR-340 and WR-284 Waveguide Switches to Meet Higher Power at the Advanced Photon Source" Proc. of PAC2003, Portland, Oregon, May 12-16, 2003, TPAG001, p. 1416 (2003); http://www.JACoW.org.