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CRYOMODULE STORAGE FOR LCLS-II HE*

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Abstract

The Linac Coherent Light Source-II High Energy (LCLS-II HE) project will upgrade the superconducting LCLS-II with 23 additional cryomodules, increasing the beam energy from 4 GeV to 8 GeV. Due to the user schedule of the existing linac, Cryomodules arriving at SLAC cannot immediately be installed in the linac. They are scheduled to be stored for up to three years before the 12 month installation window. During this storage period, the risk of damage to Cryomodules prior to installation will be mitigated with procedures and best practices incorporating experience from LCLS-II.

STORAGE AREA ACTIVITIES

While the LCLS-II HE project plans to install similar equipment used on LCLS-II, the installation window will be much shorter to accommodate SLAC's user schedule. To prepare for this timeline, several changes to the receipt of Cryomodules have been made. Instead of inspecting, preparing, and then immediately installing Cryomodules as they arrive on site, Cryomodules will be delivered to various storage areas where inspection and preparation for final installation will be performed (Figure 1). Cryomodules will be stored in these locations for up to three years.

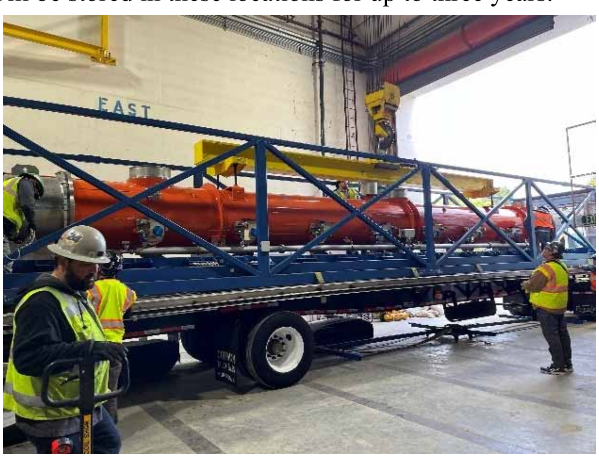

Figure 1: Cryomodule unload in storage area.

After being shipped from Fermi National Accelerator Laboratory (FNAL) or Thomas Jefferson National Laboratory (JLab), newly arrived Cryomodules have their systems inspected for damage from being shipped across the country. Results are compared to measurements the partner labs made before shipment. Once arrived, the Cryomodule is immediately connected to a vacuum monitor to confirm the beamline vacuum is still intact. Then, a complete physical inspection is performed to check couplers, cryo valve stems, and sealing surfaces of the outer vacuum flange are all in good condition. Data from shock loggers is analyzed for any shocks above 1.5 g during shipment. Transport fixtures are removed, then an alignment team confirms key fiducials. Cavity tuners, instrumentation, and magnets are all tested to verify correct wiring and functionality. The gauges on the coupler vacuum manifold are connected to a local controller to ensure it remains at an acceptable pressure. Lastly, the insulating vacuum system is tested by installing caps on either end of the Cryomodule, and helium leak checking all joints. The insulating vacuum test is performed last in case electrical connectors may have damaged electronics feedthroughs on instrumentation flanges.

After inspection is finished, the Cryomodule is prepared for installation by removing remaining transportation fixtures (Figure 2) and installing missing heat shield parts behind the tuner access ports. Helium process pipes are cut to their correct lengths for welding as shown in Fig. 3 and actuators are mounted on the cryo valves. The gauge tree and right-angle valve adapter on the beamline are kept on the Cryomodule for the entire length of storage.

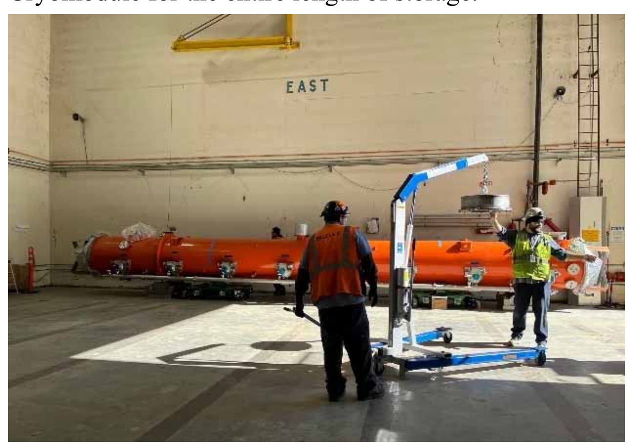

Figure 2: Removal of transport fixtures in storage.

Figure 3: Cutting helium process pipes to length.

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STORAGE FACILITIES

Storage facilities for Cryomodules must support all inspection and preparation activities and protect Cryomodules from damage during the long storage period. Storage layouts were planned with adequate aisleways around Cryomodules for movement of people and equipment. For 23 Cryomodules, around 10,000 square feet of storage space is needed. It was preferred that storage areas had an integrated bridge crane for controlled unloads from the shipping frame and be remote from other work areas to prevent untrained workers from entering the storage area. Each building also needed a foundation suitable enough to anchor Cryomodules for the storage period due to California seismic requirements.

For LCLS-II, certain Cryomodules were planned to be installed in specific slots in the accelerator housing. LCLS-II HE Cryomodules have no such restriction and can be positioned in any location along the new Cryomodule string. Given this installation flexibility, Cryomodules can be removed from one storage area at a time, ensuring an efficient, steady stream of equipment ready to be installed.

To fit the need, private storage areas and available buildings at SLAC were considered. Some suitable commercial warehouses were found in the Sacramento and North Bay area. These were ultimately rejected due to the distance from SLAC. It would take over an hour to reach any of the viable areas and add significant time to installing Cryomodules in the accelerator housing. Instead, five buildings around SLAC were chosen and retrofitted to accommodate storage (Figure 4). Access to the Cryomodule storage areas is controlled with key-card access to prevent untrained groups from entering. A list of authorized personnel is maintained by SLAC security, building managers, and the lead integration engineer.

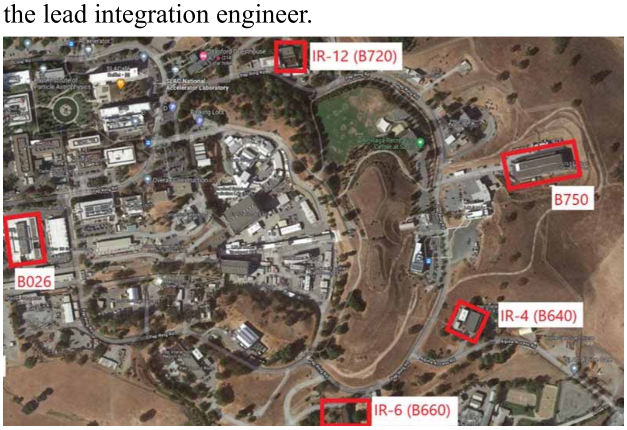

Figure 4: Chosen storage buildings at SLAC.

For further protection of Cryomodules while in storage, storage caps were developed to safeguard beamline components from accidental bumps from people or moving equipment (Figure 5). Storage caps are connected to the insulating vacuum vessel flanges with a rubber seal to prevent scratches to the sealing surface and protect the interior from dust and pests. A transparent window on the ends allow technicians to view the interior of the Cryomodule while the cap remains on.

Figure 5: Storage cap with transparent end.

SECURING IN PLACE

As SLAC plans to store Cryomodules for three years before installation in the accelerator housing, they need to be secured with an appropriate seismic design for California. During the LCLS-II project staging, Cryomodules were supported with a temporary stand without anchors. This was determined to be appropriate by SLAC's Building Inspection Office for the few weeks of testing before installation. Since the LCLS-II HE project increases time before installation to years instead of weeks, Cryomodules must be anchored to the ground with a design that limits movement while in storage. It must also cushion Cryomodules as they contact the ground to prevent damaging shocks.

Stands that secure Cryomodules in the accelerator housing were designed to meet the need of a permanent installation. They could not be used in storage due to their design and installation timing (Figure 6). The permanent stands were developed to secure Cryomodules as pressure vessels, and are meant to move with Cryomodules during cooldown cycles. The stands use 12 anchors per Cryomodule and are grouted in place. Securing stands with grout and large numbers of anchors would not be ideal for the storage locations as Cryomodules will need to move across the floor when retrieved for final install. Additionally, the majority of the accelerator housing stands are planned to be installed in short downtimes to meet the tight installation window for the LCLS-II HE project, making them unavailable for use in storage facilities. Ordering double the amount of tunnel supports for temporary storage would not be a reasonable solution.

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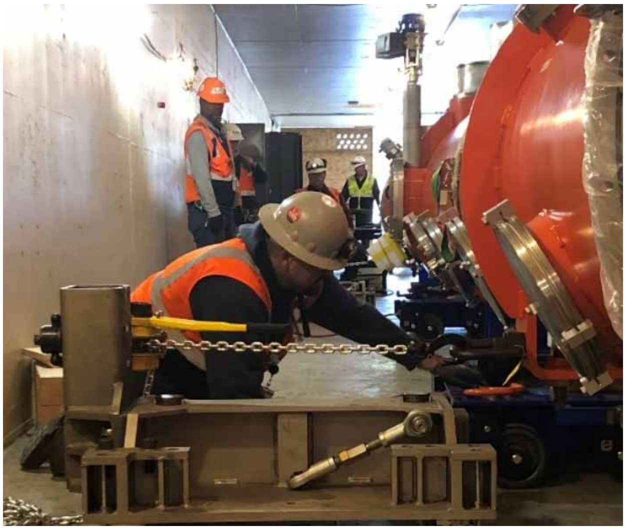

Figure 6: Permanent Cryomodule stand.

Instead, a simple, cost-effective design of two stacked, 8x8 box tubes secured with four anchors was developed to support Cryomodules in storage (Figure 7). The temporary stands are light enough that they can remain attached to Cryomodules during transport with a crane and existing lifting equipment. They attach to Cryomodules with two M36 screws that thread into the bottom of each foot. Stands are attached with Cryomodules raised on pneumatic jacks. To cushion Cryomodules as they land, pads of Ethafoam 400 are put underneath each end of the stand. The air jacks then lower the Cryomodule and attached stands to the floor. Once a Cryomodule has settled on top of the foam, the anchoring hardware is tightened, and the Cryomodule is securely in place for the storage period before installation.

Figure 7: Temporary storage stand.

BEAMLINE MONITORING

SLAC must maintain two vacuum systems for each Cryomodule during storage and installation: coupler and beamline vacuum. The coupler manifold is shipped under vacuum and tested at SLAC to make sure it remains undamaged after transit. The right-angle valves to the coupler spaces are closed as an extra precaution from damage during storage and installation periods. Couplers are one of the most sensitive areas of the Cryomodules- and stick out the furthest from the sides. Closing the right-angle valves contains damage to one coupler in the case of an uncontrolled vent.

The beamline vacuum space is the most carefully monitored system of stored Cryomodules. SLAC has no way of cleaning and reassembling the cavity strings on site, so any vent must be controlled to avoid contamination with particles. All work to the beamline is planned with SLAC's enhanced rigor policy and carefully conducted under particle-free conditions. During transit from partner lab, Cryomodules are shipped with a gauge tree with two cold cathode gauges to continuously monitor pressure (Figure 8). Once at SLAC, all Cryomodule beamline pressures are remotely monitored and archived. Figure 9 contains a representative plot of vacuum pressure during storage.

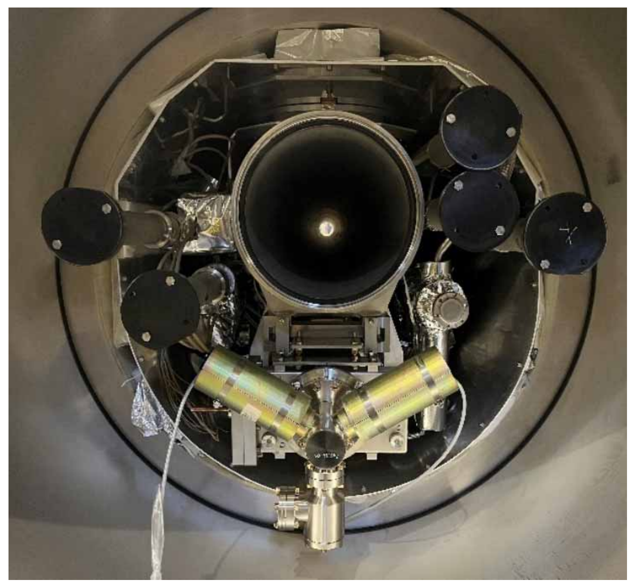

Figure 8: Gauge tree on beamline vacuum.

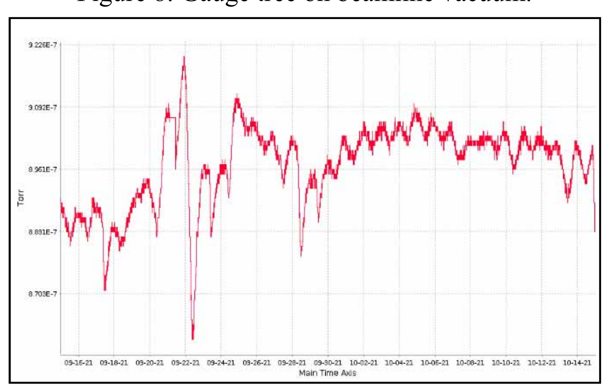

Figure 9: Sample Cryomodule beamline vacuum.

To reduce risk to the beamline, particle-free work to the cavity string is minimized. No additional pumping or monitoring devices are installed. During LCLS-II, it was determined that the small amount of pumping from the cold cathode gauges was enough to maintain the beamline string at an appropriate vacuum level for the storage period. The gauge tree is removed immediately before Cryomodules

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are transported to the accelerator housing for final installation. This must happen before the Cryomodules reach their final spot in the accelerator housing. The length of the Cryomodule with the right-angle valve and gauge tree in place is too long for a successful move onto permanent stands. There would be risk of running into the beamline components of the Cryomodule next to it and venting the string. The interconnect clean room is also too small to accommodate removal of the gauge tree and right-angle valve adapter in the field.

CONCLUSION

Cryomodule storage facilities for the LCLS-II HE project need to accommodate a variety of inspection and preparation activities while protecting Cryomodules in storage. Suitable locations at SLAC were identified and modified to meet storage needs. To further protect Cryomodules in storage, storage caps were designed to protect sensitive beamline components from physical damage and maintain cleanliness of interior. Once in storage, Cryomodules are secured to the ground to accommodate any potential seismic activity with temporary stands. Beamline vacuum of each Cryomodule is maintained and carefully monitored with two cold cathode gauges to ensure they remain ready for installation.