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Fermilab Engineering Document
AP0 Lens/Transformer Change-out Procedure
ED0007742, Rev. -

Rev.	Date	Description	Originated By	Checked By	Approved By
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1. INTRODUCTION

This document outlines the procedure and potential safety hazards associated with changing the Muon g-2 lithium (Li) collection Lens/transformer assembly located in the vault of the AP0 Target Hall Building. It is an updated version of document ADDP 000131, which was approved in 2008. Based on the experiences and observations during 2018 April Lens/transformer change-out process, this procedure is revised with updated information.

The Li lens is a device providing the focus of pions downstream of the target. The Li lens cylinder is contained within a toroidal transformer, shown in Fig. 1, both are cooled with closed loop RadioActive Water(RAW). The lens' magnetic field is generated by passing high current through the stripline to the transformer and then to the central conductor cylinder. Pions passing through this cylinder will see an inward focusing kick back toward the center of the cylinder proportional to the magnetic field strength.

1. Since the collection lens is located downstream of the target, the assembly is directly exposed to the secondary particle shower that results from the interaction of the primary proton beam and the target. Assemblies that have been subjected to beam typically exhibit high values of residual radioactivity, which is typically Class 5.
2. The closed loop water system utilized to cool the Li core / transformer becomes radioactive and contains tritium and other radioactive isotopes.

Special precautions are necessary to ensure the safety of personnel and minimize any potential for radiation contamination. Pre-job preparations are as important as the change-out process. Due to the high level of residual radioactivity, the used Lens/transformer assembly shall be stored in a steel shell/lead lined coffin. Table 1 is a list of the tasks to be discussed in this document.

Table 1: Tasks for Lens/transformer change-out:

Pre-job preparations	Preparations in Target Hall	Change-out process
• Functions of Accelerator Division Radiation Safety Officer (AD/RSO) • Pre-job planning meeting • LOTO power supply devices • New Lens/transformer testing and inspection • Crane safety and job specific tools	• LOTO lens RAW system and Target air blower • Alcove check-up • Shielding block removal • Draining RAW cooling water • Module inspection and cable/tube disconnections • Space check-up • Coffin preparations	• Remove module from Vault to Alcove • Dis-engage Lens/transformer assembly from module • Store Lens/transformer in coffin • Install new Lens/transformer to module in Alcove • Install new Lens/transformer with module in Vault • Test newly installed Lens/transformer

Surrounding the lens central cylinder is a jacket of titanium (Ti) alloy (6Al-4V ELI) called the Septum. The Septum's purpose is to contain the Li against various thermal and magnetic forces while allowing cooling (melting point of Li is 180.5 ºC) by an annular water passage. The ends of the Li cylinder are bound by end windows made of beryllium (Be) and a thin Ti foil, shown in Fig. 2.
There are several loads are developed on the lens during a current pulse:

- High magnetic loads act radially and longitudinally outward on the steel body halves and radially inward on the central conductor cylinder. This latter force on the Li cylinder is termed the magnetic pinch effect and could result in the separation of the Li from the septum inner wall. To prevent this from happening, the Li is actually pre-loaded when the Lens is filled.
- During the current pulse, ohmic losses heat various components and create thermal stresses.
- The pre-loaded tie rods add yet another load to the Lens.

When the lens failure is a result of fast and high conductivity in the return water, it is indicative of a septum breach in which water comes into contact with lithium metal which forms lithium hydroxide solution. In this case, a pH measurement of Lens RAW water sample and reading of local conductivity cell meters shall be performed. Once confirmed of the high conductivity, it is suggested that the entire RAW system water be changed.

2. SUPPORTING DOCUMENTS

The reference documents are listed in Table 2. The files linked here are for quick reference only. Please check with the responsible personnel or department for the most current information.

Table 2: Reference documents:

Description	Document #	Date issued	Figure
Documents			
Lithium lens water system draining (& DEMIN cartridge replacement) procedure	ED0007776	April 2018	
Accelerator division radioactive waste disposal procedure	ADSP-10-0201	Sep. 2013	
Fermilab ES&H lockout and tagout (LOTO) manual	FESHM 5120	Nov. 2012	
Drawings			
10mm H.G. lithium lens and transformer assm	MD-413677-C	Sep. 2009	Fig. 1
10mm H.G. lithium lens assm	MD-413621-G	Sep. 2009	Fig. 2
Internally cooled transformer assm	ME-413540-A	June 2008	
Transformer stand assm	ME-208547-F	June 2008	
Lens module strip-line assm	ME-254441-C	June 2008	
Strip line clamp eccentrics crank layout	ME-216582	May 1984	

3. PRE-JOB PREPARATIONS

3.1 Radiation Safety

Since the level of residual radioactivity on a used lens assembly is typically Class 5, Accelerator Division/Radiation Safety Officer* (AD/RSO) *must be present to properly monitor and supervise activities relevant to personnel radiation safety.

Table 3: Functions of AD/RSO:

Item	Description
a	Supervising vault access, specifying clothing requirements, unlocking and securing appropriate radiation security padlocks, performing radiation surveys and contamination checks and closely monitor the securing and disposal of the radioactive collection lens/transformer assembly.

b	**Radiation Work Permit** (RWP) must be completed by AD/RSO and signed by all workers involved in the change-out.
c	***ALARA (***as low as reasonably achievable) should be completed to examine the steps required for change-out and to estimate the integrated radiation exposure that workers are expected to receive during each phase of activity.

Table 4: Radiation safety requirements for all personnel participating in this activity:

Item	Description
a	Have current Radiological Worker and Radioactive Waste Disposal training. If required, the AD/RSO will specify additional training prior to performing the collection lens/transformer assembly change-out.
b	Read and sign RWP, and following the requirements stated in RWP.
c	In addition to specified protective clothing, nitrile gloves (or equivalent, approved by RWP or AD/ES&H) shall be worn for all lens water system operations.
d	All personnel and tools leaving the vault enclosure must be frisked for contamination upon every exit of the vault enclosure.
e	All radioactive waste or hardware removed from the vault enclosure must be checked for radioactivity, properly tagged and disposed if radioactive.

3.2 Pre-job Planning Meeting

Prior to performing a Lens/transformer change-out, all lead personnel involved in the activity and the AD/RSO must attend a pre-job ALARA planning meeting to examine the steps required for change-out. The purpose of such a meeting is to estimate and minimize potential hazards and radiation exposure that may be encountered.

Table 5: Topics which shall be addressed at the meeting include but are not limited:

Item	Description
a	This procedure and the steps outlined within to ensure that the level of radiation which each individual is expected to receive is as low as reasonably achievable and determine job stop points.
b	Additional radiation monitoring required during specific phases of the change-out activity (e.g. use of digital dosimeters, check of dose rates using teletector, check of surface contamination, etc.).
c	Clothing, time, distance, and shielding requirements during critical phases of the lens/transformer change-out.
d	Discussing previous jobs or requests.
e	Proposed activities that deviate from the normal collection lens/transformer assembly change-out as described in this procedure. Such activities shall be discussed and modified, if required, to comply with Fermilab Standards.

3.3. LOTO Power Supply Devices

Before accessing the vault enclosure, the following devices must be locked out and tagged out (LOTO) by qualified personnel and each individual entering the vault enclosure per Chapter 5120 of the Fermilab ES&H Manual.	
1	***Collection lens main power supply***
2	***Pulsed magnet power supply***

Add a short description of job specific LOTO procedure for Lens power supply and pulsed magnet power supply

3.4 New Lens/transformer Testing and Inspection

The new lens/transformer assembly shall be thoroughly tested prior to installation. Certification is accomplished via operational life testing using the module assembly located in the test cage at the AP0 target hall enclosure. The assembly is electrically tested utilizing an excitation waveform similar to that encountered during beamline operation. Signals monitored during testing include but are not limited to the secondary current waveform (i.e., lithium core current), the lens body temperature, primary transformer housing temperature, water system temperature and flowrate, and the titanium septum cooling water conductivity.

Table 6: New Lens/transformer inspection and preparation:

Item	Description	Figure
a	Test thermocouples, verify polarity.	
b	Test Rogowski coil resistance: 0.7 Ω	
c	Check torque on compression fittings: 20 ft-lb	
d	Hi-pot transformer strip-line: <1 µA @ 3 kV	Fig. 3
e	Measure primary circuit resistance: ~450 µΩ	
f	Apply radiation grease to alignment pin receivers	
g	Confirm that the center strip-line connector has a chamfer on its west side.	
h	Leak check two cooling circuits with argon gas at 15 psig for 20 min	

3.5 Crane Safety and Job Specific Tools

1. Any person(s) operating the 20 ton crane located in the AP0 target hall enclosure must be a qualified crane operator.
2. The crane and all rigging components shall be inspected.

Add a short description of Crane controls or inspection check list

The weight of the (steel) lens module (72"x32"x11.375") accounts for approximately 7500 lbs alone. Support hardware and a lens/transformer assembly could account for an additional 600 lb. load.

A remote lifting fixture.is used for lifting the radioactive Lens/transformer assembly from the Alcove table and placing it on a coffin base. This fixture serves for two purposes:

- Engaging the steel eye-bolt on top of the transformer can be difficult. The eye slip hook needs to be tipped and guided into and out of the steel eye bolt from a distance.

- The Lens/transformer assembly spins when lifted and swings when moved requiring that it be controlled and guided from a distance using a long pole.

Due to the high levels of residual radioactivity, the lens/transformer assembly shall be stored in a steel shell/lead lined coffin.

Camera on stick will be needed to inspect the condition of devices (Target and Collimator) on either side of the Lens/transformer in the vault.

Table 7: Lifting fixtures and storage coffin:

Description	Capacity	Drawing #	Document #	Date issued	Figure
AP0 Target Hall Module Lifting Fixture	25,000 lbs.	ME-216293-B	1323-ES-296153	March 2005	Fig. 4
AP0 Target Hall Lens/Transformer Remote Lifting Fixture	650 lbs.	MC-413280	1323-ES-296410	Dec. 2003	
Pallet assembly and weldment (Coffin)			MD-216859	May 1984	Fig. 5
Coffin cover assm			ME-216908	July 1985	

Other job specific tools are listed below:

- Water tube supports (2 pieces)
- Lens-Transformer aluminum base for coffin
- 2-1/4” wrench for water tube brass block
- 2-1/4” open end wrench
- 1-1/2” combo wrench
- 1-1/2” deep socket
- 1-3/4” backing wrench
- 1/2” Craftsman reversible ratcheting wrench
- 1/2” drive torque wrench
- High Pot Machine
- Water tube gauges and blank-offs
- 3/4” eye-bolt installation block & 1/2 rigid pipe
- 3/4” eye-bolt
- 1-1/8” combo wrench with modified cut-out

4. PREPARATIONS IN TARGET HALL

Subsequent to LOTO, the concrete vault shielding blocks must be unlocked by AD/RSO. A plastic sheet (or tarp) shall be placed on the floor where the shielding blocks are to be stored. Remove shielding blocks from the vault enclosure, and placed on the floor at the north end of the building near the hi-bay entrance.

AD/RSO will perform radiation survey of the vault enclosure and specify additional dosimetry (e.g., digital dosimeters and ring badges) or clothing requirements for all subsequent operations as deemed necessary on site.

Table 8: Preparations in the Vault enclosure:

Step	Description	Note
Vault Preparation		
a	Ensure that space is available in the storage rack for the lens module and vault filler block.	
b	Make sure Lens water skid and Target air blower are shut down and completed LOTO	
Alcove Preparation		
c	Check that the alcove moveable table and lights are operational.	
d	Place clean plastic, herculite or masselin cloth over the alcove floor area and moveable stage to contain any possible contamination.	
e	Center the moveable stage, and place 1/2” plate on the table. Place the aluminum lens-transformer locating base on the 1/2” plate, with the alignment pin of the locating plate oriented toward the northwest corner. Lower the table all the way down.	The locating base should be 10 3/4” from the west (concrete) wall, and 12 3/8” from the east wall. Fig. 6
Module Inspection/Readiness		
f	Discharge the transformer strip-lines in the vault with the grounding rod.	
g	Check over the new lens/transformer assembly for readiness: such as thermocouple pin-out, strip line continuity, water circuit, etc.	Fig. 7
Draining Cooling Water in Lens/transformer		
h	Close the 1/2" supply and return ball valves located on the east wall of the AP0 vault. Close the supply valve first, then close the return valve.	This isolates the appropriate water system located in the cage area from the module cooling lines in the vault.
i	Place the drain hose located on the appropriate return line drain valve tee in the vault into a 5-gallon carboy. Open the drain valve slowly, releasing any residual line pressure in the system. Drain the water from the purge tank into carboy.	
j	Attach the argon line from an argon gas cylinder fitted with a regulator to the quick disconnect fitting on the supply line drain valve tee. Slowly open the supply drain valve located on the tee, and gradually increase the regulator (up to a maximum of 20 psi) to introduce argon gas pressure in the isolated cooling water lines.	This operation will force the water remaining in the **lens** module cooling lines into the plastic carboy. Use care to avoid excessive splashing in the carboy. Purge system in this manner as necessary.
k	When the return line drain hose is clear of any remaining water, shut off the flow of argon gas and secure the cap on the carboy. Repeat steps c - d for the **transformer** cooling loop if utilized on the assembly. The tubing connections on the top of the module may now be disconnected.	

l	Cap and plug all water hoses/tubes.	
In the case of a Lens septum breach, drain the entire water of Lens RAW skid, per Lithium lens water system draining (& DEMIN cartridge replacement) procedure ED0007776.		
Disconnect Cables & Inspect Clearance		
m	Check the target PIVOT for clearance. Move D:TGTE if needed.	
n	Disconnect stripline. Disconnect all read back cables and reconnect to alcove cables. Disconnect the ground strap located on the top of the lens module, then re-install the bolt for the grounding strap, because it fastens the V-block to the module.	
o	Using an appropriate lifting sling and the 20 ton overhead crane, remove the filler plates from each side of the lens module and each side of Filler Module #1 (FM1). Place them at the north end of the vault.	The approximate weight of the heaviest plate is 100 lb. Note the locations of the filler plates for re-installation.

AD/RSO may now unlock the safety padlocks securing the lens module and the filler module.

5. LENS/TRANSFORMER CHANGE-OUT PROCEDURE

Any deviation from the following steps during the procedure will require personnel involved in the change-out and the AD/RSO meet to discuss the implications of the procedural change.

5.1 Remove Module from Vault to Alcove

Before lifting the lens module from the vault, all personnel with the exception of Radiation Safety and the crane operator must exit the vault enclosure area.

Table 9: The sequences for Lens/transformer module removal:

Step	Description	Note
a	Attach the module lifting fixture to the FM1	
b	Remove FM1 and place it in the hot storage rack.	
c	Install the Rail Clamps at the downstream (DS) of the lens where FM1 was prior to its removal.	Fig. 8
d	Attach the module lifting fixture to the Lens module.	Note the crane location for use during installation.
CRITICAL: The DS side of the lens may stick out past the module, depending on the lens configuration installed. There is ½ - 1" of space between the DS side of the lens water tubes and the collimator thermocouple. The US side *may* stick out slightly past the module. Use appropriate visual checks and assurances to center the module for removal.		
e	Remove the lens module from the vault and place on the alcove rails. A radiation survey of the lens/transformer assembly may be conducted by the AD/RSO as the lens module is removed from the vault. Close the alcove lead door.	The module assembly is now secured for lens/transformer removal. Fig. 9
f	Use camera on stick to inspect the condition of Target and Collimator	

5.2 Dis-engage Lens/transformer Assembly from Module

Most of the following operations will be conducted from the top of the module or behind the lead viewing glass and concrete alcove shielding.
If directed by the AD/RSO, secure lead shielding blankets at the top of the module over any line of sight cracks between the module and the alcove walls. A general area radiation survey may now be conducted by the AD/RSO.

CAUTION: On all subsequent stage movement operations, monitor the table force transducer output. The transducer voltage should never exceed 1.5 volts or damage to the transducer or hardware may result. A reading in excess of this value indicates a binding or interference condition. If such a condition occurs, stop and investigate the cause before proceeding further!

Table 10: The sequences for removing Lens/transformer assembly from module:

Step	Description	Note
a	Raise the moveable table while visually monitoring the position of the components through the lead glass. Position the stage to align the locating base pin and the lens/transformer assembly stand register ring. Raise the stage such that the Lens/transformer assembly stand just contacts the locating base.	
b	Remove the module lifting fixture from the module.	
c	Open the stripline clamp by turning the clamp screw counter-clock wise to the orientation mark "O".	Use the box end of a *Craftsman Reversible Ratcheting Wrench*; DO NOT use the open end of a 1/2" wrench.
d	Unscrew the four water tube disconnecting sleeves, two for lens cooling and two for transformer cooling. Raise and secure them approximately 12" up	Using the *water line holding fixtures*
e	Loosen the 2 set screws that lock the draw screw to the inner shaft. Using a backing wrench (opposing forces), unscrew the lens/transformer draw screw.	Verify that the draw screw is completely unfastened by lifting upward a few inches by hand.

The lens/transformer assembly is now disengaged from the module. Lower the moveable stage to the lowest point of travel while visually monitoring the position of the lens/transformer assembly through the alcove lead viewing glass.

5.3 Store Used Lens/transformer Assembly in Coffin

Move the collection lens coffin into the vault enclosure using the overhead crane hook and hardened pin placed through the lifting tabs on the cover. Place the coffin assembly on the herculite diaper. Remove the coffin cover pin and lift the coffin cover off the base. Place it in a location that will not interfere with other operations and could possibly provide shielding for steps e & g. Remove the overhead crane hook from the cover assembly.

Table 11: The sequences for storing lens/transformer assembly in coffin:

Step	Description	Note
a	Open the lead alcove door and remove the lens module using the overhead crane and attached lifting fixture. Place	***The only personnel allowed in the vault enclosure during this***

	the module in the vault storage rack and close the alcove lead door.	***step are Radiation Safety personnel and the crane operator.***
b	The next operation involves attaching a 3/4" eyebolt to the top of the transformer/lens assembly. Using the eyebolt assembly tube (i.e., a length of 1" dia. pipe with a 1/2" pipe thread attached to the eyebolt installation fixture) while receiving guidance instructions from a technician viewing through the alcove lead glass, thread the eyebolt completely into the transformer mounting block. Raise the table up as necessary.	Using specially designed long tools while working from the top of the alcove shielding blocks.
c	Connect the Lens/transformer remote lifting fixture to the crane, lower the crane and hook the eye-bolt on the transformer.	Working from the top of the alcove shielding blocks.
The following shall be performed using the crane from behind the alcove lead glass window.		
d	Lift the Lens/transformer assembly from the stage in the alcove. Remove the assembly from the alcove and place on the coffin base aligning the transformer stand register ring and the coffin base pin.	Use special long-handled tooling designed to help align the lens/transformer assembly on the coffin base.
e	Verify that the Lens/transformer assembly is sitting properly on the coffin stage.	View both the US and DS side of the assembly with remote viewing equipment.
f	Remove the Lens/transformer remote lifting fixture from the eyebolt.	
g	Plug water lines to the lens *if required* (such as in the case of a septum breach)	
h	Pick up the coffin cover using the crane hook and hardened pin and lower it onto the coffin base. Align the base and cover, and insert the coffin pins. Enclose coffin in appropriate diaper material.	

AD/RSO will then perform a contamination check of the alcove and enclosure area. When it is determined that the area is free of potential radioactive contamination, AD/RSO will padlock the coffin using a radiation safety controlled padlock.

5.4 Install the New Lens/transformer Assembly to Module

Hi-pot the module stripline to 3 kVwhile it is in the vault storage rack. Connect the positive red wire of the high pot source to the stripline and connect the black ground wire to the module. The current leakage is generally between 1.0 - 3.0 µA at 3.0 kV.

Table 12: The sequences for installing new Lens/transformer assembly to module:

Step	Description	Note
Preparations in Alcove		
a	Adjust the table and aluminum locating block	
b	Using a 3/4" eyebolt attached to the top of the new transformer/lens assembly, connect one end of a sling to the overhead crane and the remaining end to the eyebolt.	

c	Move the lens/transformer assembly onto the stage in the alcove. Align the register ring of the transformer stand and the stage locating pin.	
d	Remove the eyebolt and apply anti-seize to the female threads on the top block of Lens/transformer assembly.	
e	Lower the table all the way.	
During the following step f, only the Radiation Technician and the crane operator are allowed in the vault area.		
f	Remove the lens module from the vault storage rack and place on the alcove rails.	Use the crane markings as guides.
g	Remove the lifting fixture from the module. Install lead shielding blankets on top of Alcove.	Make sure that the water tubes are raised up and out of the way.
h	Roughly position the lens/transformer assembly such that the two bushings on the assembly will engage the pins on the module, but do NOT fully engage the strip-line in this step.	
Engaging the new Lens/transformer into module		
i	Before raising the Lens/transformer assembly, prepare an ohm-meter to monitor the strip-line connection during engagement.	This is monitored on top of the alcove.
j	With someone monitoring the ohm-meter on top of the alcove, raise the alcove stage slowly while visually monitoring the Lens/transformer assembly through the lead glass viewing window. The ohm-meter should start “open”, and when the strip-line first touches it will “close”.	Note the height of the assembly.
k	Continue raising the lens/transformer assembly so that the stripline fully engages. Once the stripline is fully engaged, it should have approximately 1/2" engagement.	**CAUTION**: Be sure that the stripline is properly and fully engaged. An experienced technician and/or engineer should verify this step before proceeding.
l	Slowly raise the table until the locating pins are engaged.	Raise to a point where an 1/8" gap exists between the locating pins and bushing shoulders
m	Slowly tighten the lens draw screw from the top of the module to engage the threads. *Using a backing wrench* (opposing forces), torque the draw screw to 100 ft-lbs to fully engage the locating pins. Tighten the set screws located on the backing nut.	
n	Check the Rogowski coil resistance and all thermocouple connections against known values.	It is best to also use a thermocouple meter to check the thermocouples.
o	Close the stripline clamp by turning clockwise to position "C". Check the continuity of the strip line before and after	Use the box end of a *Craftsman Reversible Ratcheting Wrench*;

	with a micro-ohm meter. The resistance should be less when the clamp is tightened. **Lower the table.** Given that 12 o'clock is in the *beam-right direction* (facing east in the alcove), the stripline clamp is closed when the yellow dot is at 12 o'clock, and is open when it is at 7 o'clock.	DO NOT use the open end of a 1/2" wrench.
p	Check that the lens/transformer assembly is electrically isolated from the module by high potting the assembly to 3 kV. Connect the positive red wire of the high pot source to the stripline and connect the black ground wire to the module. The current leakage is generally between 1.0 - 3.0 µA at 3.0 kV.	Consult with Muon Target Hall Group Leader if the leakage current is significantly higher than 1.0 µA at 3.0 kV.
q	Carefully lower each water tube, checking for interferences with thermocouples.	
r	Engage each of the water tubes individually, then tighten each one.	

The module water circuit shall now be pressure checked to ensure no leaks are present. Connect the water leak test equipment to the water tube connections located at the top of the module. Using argon gas, pressurize the **lens** water systems to 50-60 psi for 10-20 min. If the system doesn't hold pressure repeat installation procedure. Use snoop to check all joints and fittings. Purge gas through the system for 30-60 seconds to remove any foreign particles that may be present when done.

Repeat for the **transformer** water system.

5.5 Move the New Lens/transformer Module into Vault

Verify that the table in alcove has been completely lowered.

Prior to moving the module, have a brief meeting to coordinate this move with AD/RSO, the crane operator and one observer.

Table 13: Discussions prior to moving the module into the Vault:

	Description	Note
1	The *Critical Crane Position* is when the bottom of the module daggers are between a foot above and a foot below the top of the modules. During this time an *observer* may be requested by the crane operator to assist the crane operator during the installation of the module.	
2	The crane operator must have direct view of the E-W direction, and must stand with proper perspective to view the clearance between the module daggers and the rails.	
3	The observer must have direct view of the N-S direction, and must stand with proper perspective to view the clearance US and DS of the module, daggers and Lens/Transformer assembly.	
4	AD/RSO will provide radiation readings and exposure estimates of where the crane operator and observer will be standing.	
5	During this time, no N-S or E-W movements are allowed. If crane adjustments need to be made, the observer will leave the area and the crane operator will raise the load and make the	

	adjustments. Only after the load has stopped swaying will the crane operator lower the load back into the ***Critical Crane Position***. The observer can then be called back.

During this step only AD/RSO, the crane operator and one observer are allowed in the vault enclosure.

Table 14: The sequence for installing the new lens/transformer assembly in the Vault:

Step	Description	Note
	Install module in the Vault	
a	Open the alcove lead door. Remove Lens module assembly from the alcove and center over available clearance space in the vault.	Use the crane markings, **visually check** to make sure there is adequate clearance before lowering the lens module.
b	SLOWLY lower the lens module into the vault (using the module daggers for guidance against the rail clamps) until the module V-blocks rest on the rails.	Visually check for clearance.
c	Remove Rail Clamp(s).	
d	Re-install FM1	
e	Remove the module lifting fixture and check for contamination	
f	Re-install the filler plates.	
	Reconnections	
g	Reconnect the read back cables, instrumentation lines and ground strap located at the top of the lens module. Use the connection plan map to ensure that the correct connections are made. Check the ACNET readout of all instrumentation.	
h	Connect water pipes	
i	Install the strip line per Proton Mode.	**Caution**: Be sure that the stripline and water tube connections are made correctly. An experienced technician or engineer should verify before proceeding. Fig. 10

6. GENERAL CLEAN-UP, TESTING AND BLOCK INSTALLATION

Table 15: The sequences for clean-up, testing and block installation:

Step	Description	Note
a	Put away all tools and clear the vault & pit area of waste matter. Do a general clean-up of the vault and pit area.	Do NOT leave any hazardous materials (batteries, aerosols, chemicals, etc.) in the pit area. This will create mixed waste.

b	Remove all locks and tags, in preparation for water system testing.	It may be necessary to re-install locks if further work is required in the pit or vault area.
c	Turn on the lens water system and check for possible leaks around the fittings.	
AD/RSO may now secure the vault enclosure after performing a contamination check. RSO may also install the padlock to the lens module and make up the vault electrical safety system to allow the lens to be tested		
Lens testing procedure		
1	Set the lens pulse counter to 0 (D:LENSTR)	
2	Set D:LENS current to 0 amps	
3	Run M48 – aggregate ->Set DR Number of Pulses to 1	
4	Inform crew Chief to Load TLG with 20 - $93 events	
5	Prepare the Vault boom camera to look at the lens stripline connection to look for sparks or arcing	
6	Reset the lens External interlock module	
7	Plot or record the lens body temp M12 <2> D:LNTC2	
8	Reset the Lens power supply (D:LENS)	
9	Turn the lens power supply ON (D:LENS)	
10	Set D:LENS from 0 to 5,000amps	
11	Confirm there are no sparks. Wait 1 minute to come up to current	
12	Inform crew Chief to Load TLG with 20 - $93 events	
13	Set D:LENS from to 10,000amps	
14	Confirm there are no sparks. Wait 1 minute to come up to current	
15	Set D:LENS from to 19,500amps (or operating current)	
16	Confirm there are no sparks. Wait 1 minute to come up to current	
17	For g-2 operation: Confirm lens can run at nominal current and 11.4Hz rep rate	
18	Increase rep rate over 10min until the lens is at 11.4 Hz rep rate. Watch temps	
19	Run M48 – aggregate ->Set DR Number of Pulses to 8 Inform crew Chief to Load TLG with 43 - $93 & $ 94 events	
20	Turn lens off once test is complete	
Final clean-up		
a	Re-install the vault shielding blocks. Frisk all personnel, tools and fixtures.	AD/RSO may now secure the vault enclosure gate.
b	Fold the plastic sheet (or tarp) used for setting the blocks onto the floor outside the vault. If plastic, place in rad waste bags for storage within AP0. If no radioactivity is detected, then plastic may be recycled or disposed of as regular trash. If tarp, fold up and store appropriately for re-use.	Do not remove or dispose of plastic until a proper contamination survey has been performed.

APPENDIX: FIGURES

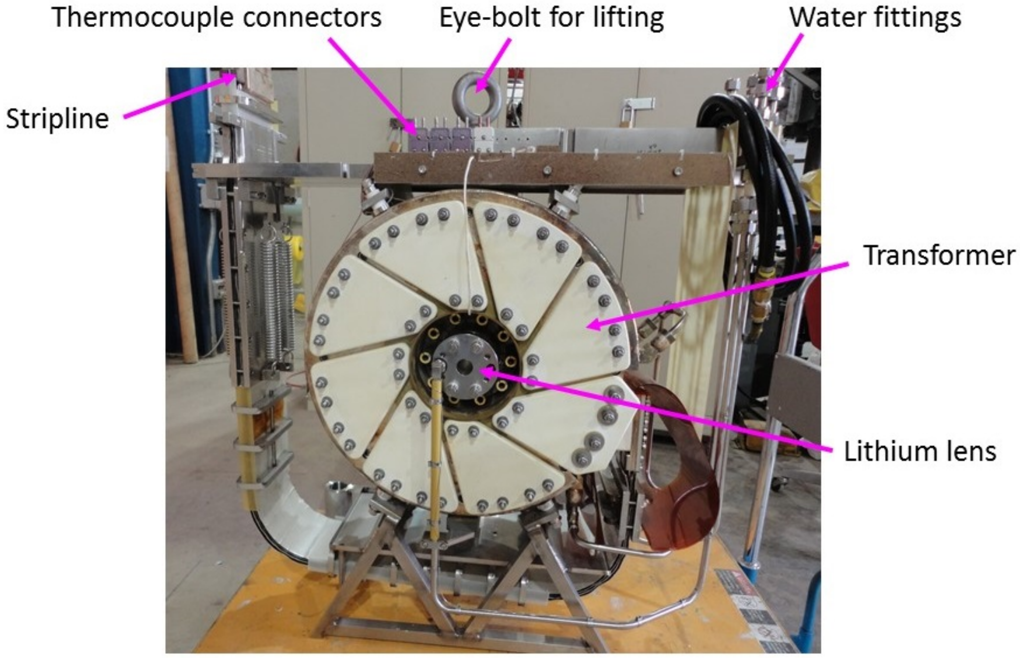

Figure 1: Lithium lens nested in a toroidal transformer

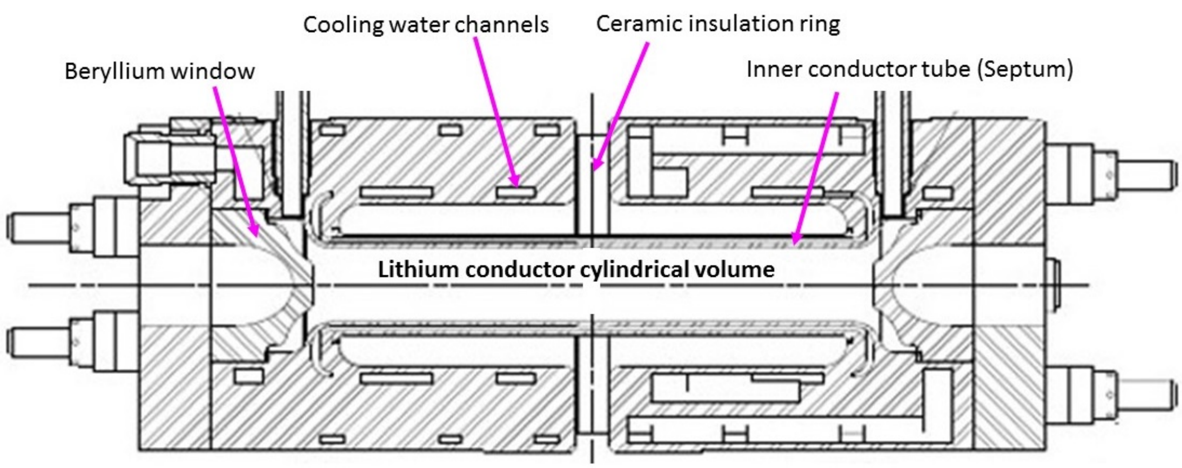

Figure 2: Lithium lens

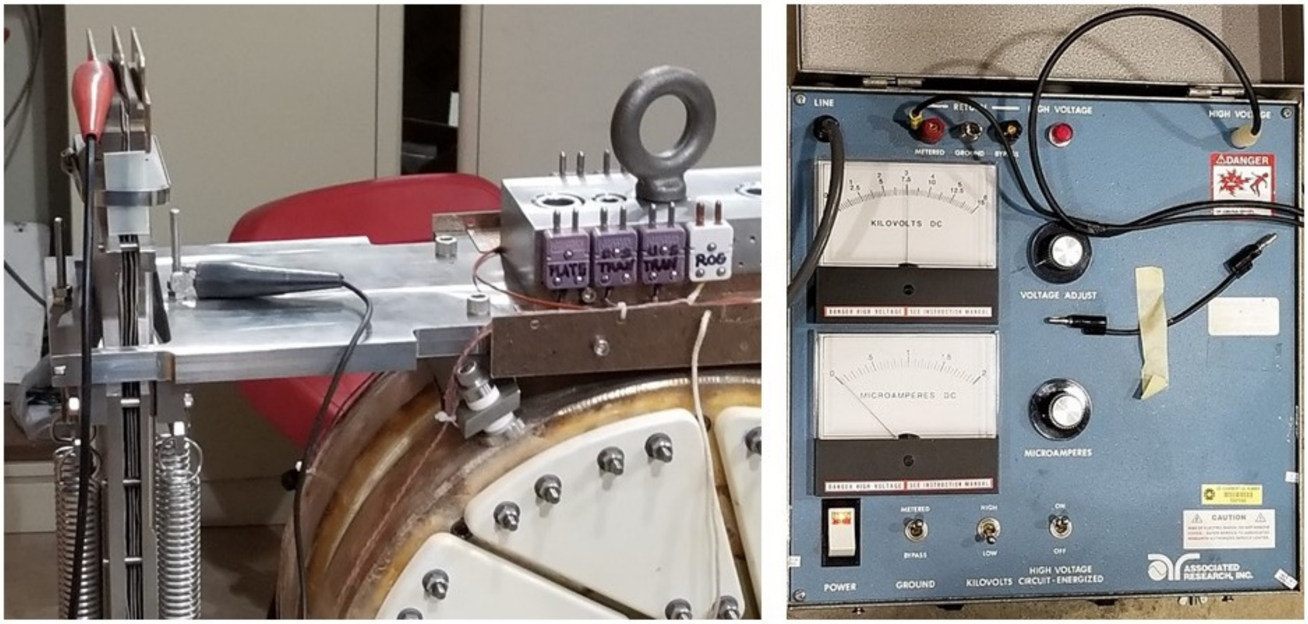

Figure 3: Hi-pot transformer stripline

Figure 4: Lens/transformer module lifting fixtures

Figure 5: Lens/transformer coffin

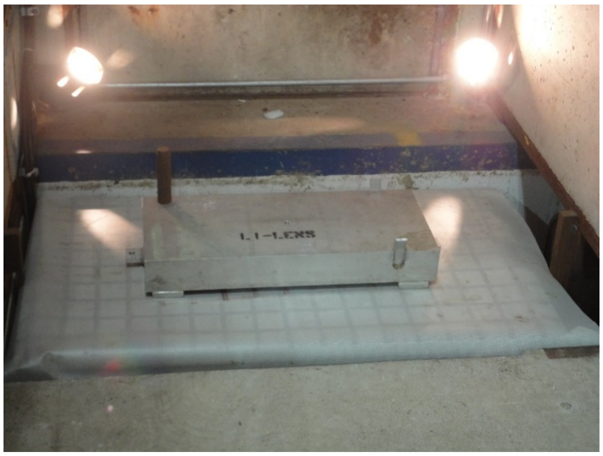

Figure 6: Alcove preparation

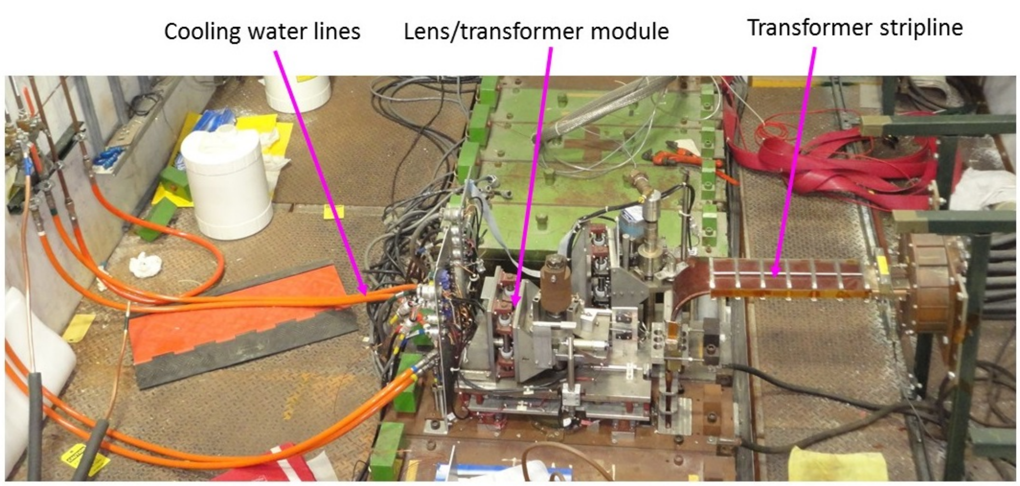

Figure 7: Top view of Lens/transformer module in the Vault

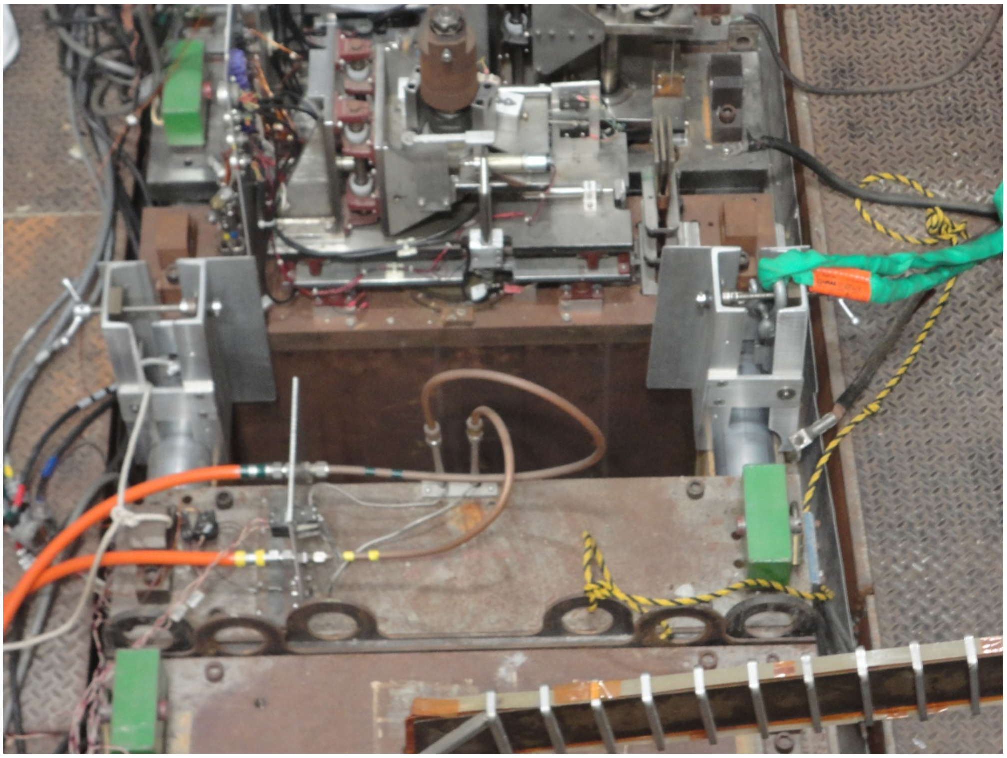

Figure 8: Rail clamps installed at downstream of Lens

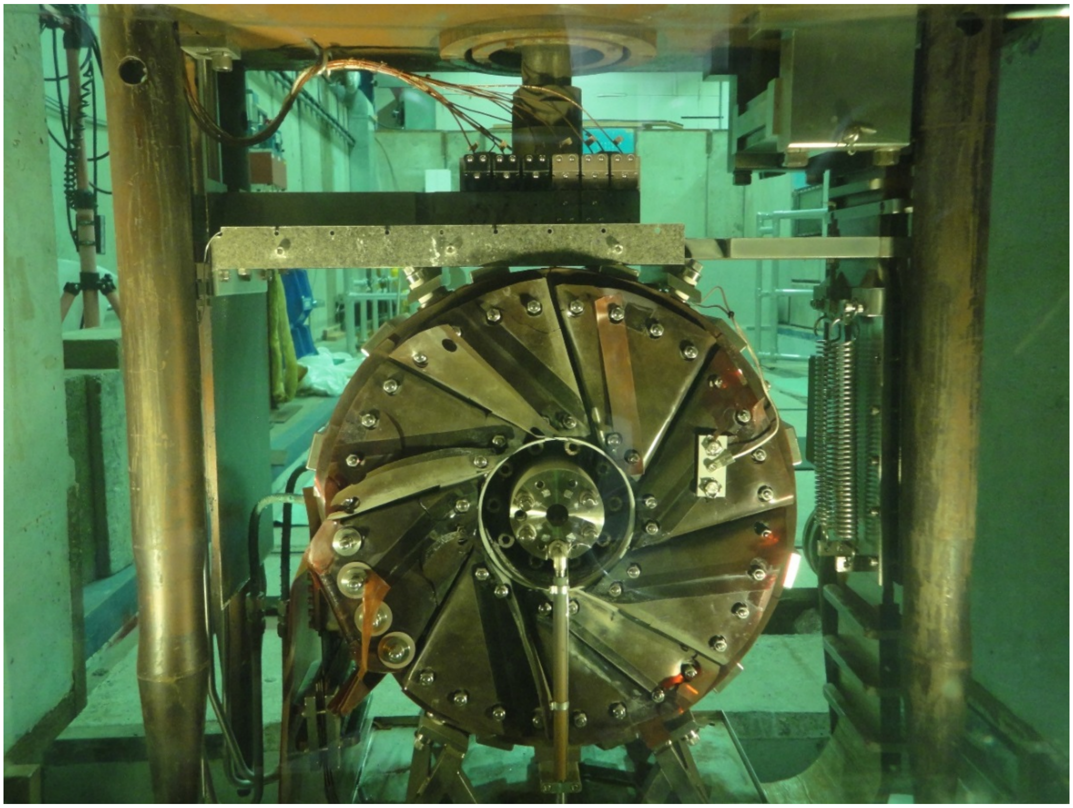

Figure 9: Used Lens/transformer in the Alcove, still engaged to module

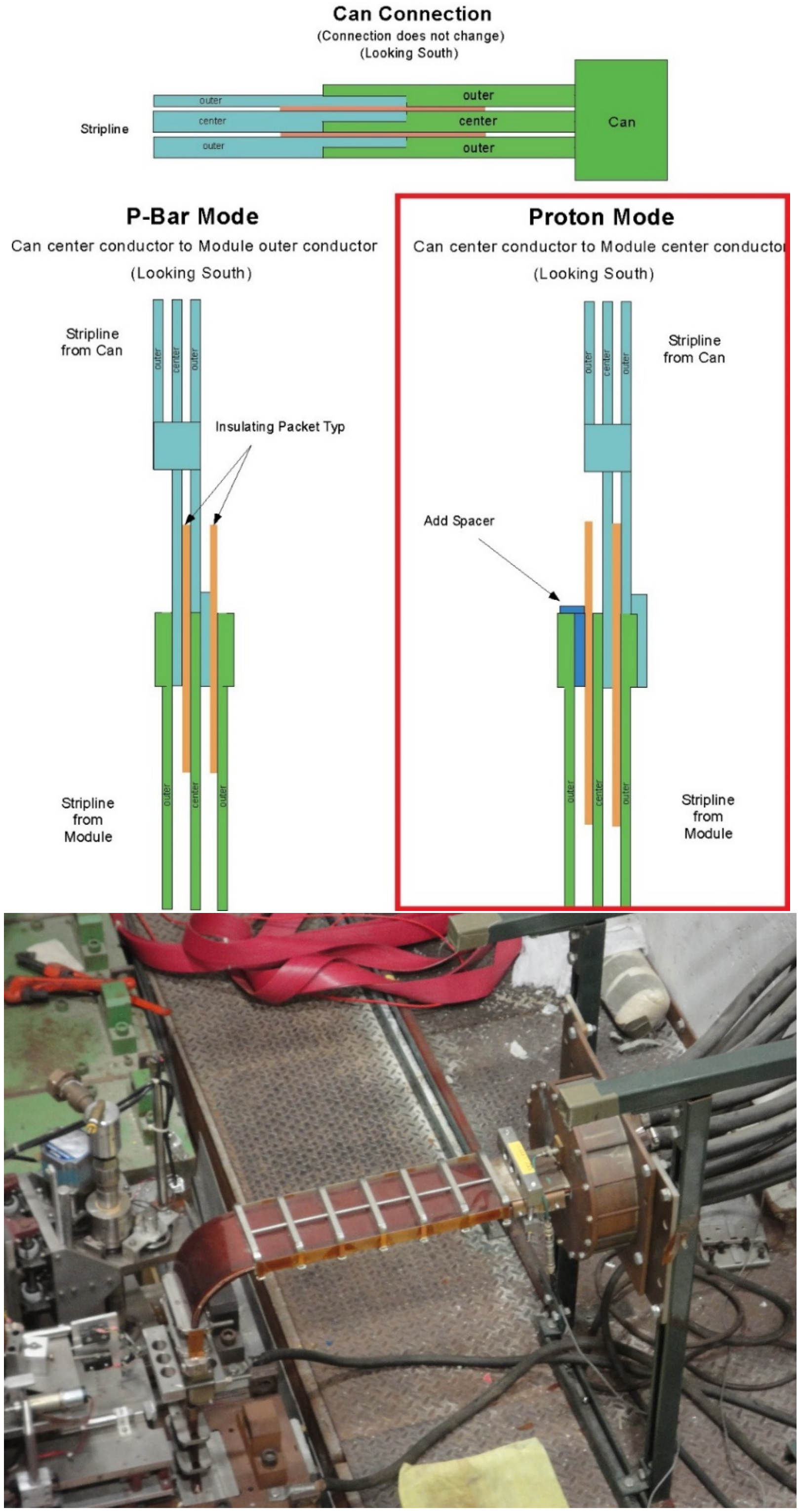

Figure 10: Lens stripline connections