Response to Committee (June 3, 2010) Report

The committee formed on June 3 2010, issued a report from which 45 action items were derived. A response for each item Is given in the following sections.

## Administrative Action Items

### Task 1:

Appoint a lead person at JLAB, a design authority, who will emphasize the engineering aspects of the target system and who will be responsible for the design, fabrication, procurement, installation and operation of the system.

This has been completed. The JLAB Design Authority Is David Meekins.

### Task 2:

Establish an engineering team.

This task has been completed the team members are

* Dave Meekins (Responsible Engineer)
* Hall A Engineering Group (R. Wines lead)
* R. Holt and T. O’Conner ANL
* JLAB Target Group (C. Keith lead)
* SRTE (J. Novajosky manager)
* SRNL (H. Lee Nigg lead)

### Task 3:

Develop clear responsibilities for INL, JLAB, and collaboration; and determine who will sign off on safety checkout plans.

This requirement is no longer directly applicable. There are two current agreements (ICO) with SRS/SRNL to perform the cell filling and material testing  [1] [2]. These agreements clearly define tasks and budgets. SRS personnel shall be responsible for completing the required Safety Basis. JLAB personnel shall provide all necessary calculations and proof testing data to SRS. Additionally JLAB shall provide leak test, weld and material documentation, and inspection assembly reports to SRS with the active cell in preparation for filling.

### Task 4:

Administrative requirement that beam blow-up optics are used in experiment.

A thermal analysis of the cell when the raster is off in full beam current assumes a square beam profile of 0.150 mm width. This model is shown in Section 6.1.3 and shows that the cell is sufficiently designed to survive this condition for a limited time period. Concerns over beam induced hydrogen corrosion indicate that the cell operating temperature must be kept below 180K. The raster off condition does not meet this requirement thus, it is only allowed for very short periods of time prior to the FSD trip on raster.

### Task 5:

Administrative limit on beam trip rate when cell is in the beam.

A full fatigue screening analysis was performed in accordance with ASME BPVC VIII D2 Part 5. This analysis indicates that beam trips occurring at a rate of 15 per hour. A cell duty factor of 30% was assumed (there are 5 other targets). This calculation is given in TGT-CALC-103-002 and indicates that this trip rate does not warrant a formal fatigue analysis due to the low stress of the cycle.

A safety algorithm was developed by R. Holt that also addresses this issue  [3].

### Task 6:

Make a provision that if the H or He target fails, a failure mode determination is made before the experiment continues with tritium gas.

A failure of any other cell will cause the vacuum monitor alarm to trip activating the getter system and many other controls. An RGA shall be installed to give some indication of the species of the gas after such a failure. Vacuum will have to recover prior to using this device. If it is determined that the one of the other cells failed for an undetermined reason the experiments shall be stopped and the tritium cell secured and shipped back to SRTE for recovery. If the failure mode is from an operational or procedural source then the situation can be assessed at the time of failure. A determination to continue the run shall be made by JLAB management.

### Task 7:

Extensive review of final cell design and test results should be performed by JLAB, Argonne, and outside experts.

This process is ongoing. In addition to the institutions listed above SMEs at SRTE/SRNL shall also review the design.

## Target Cell

### Task 1:

Develop a modular target design.

The current design is modular and uses techniques and components similar in design to existing JLAB cryogenic hydrogen and helium targets.

### Task 2:

Use a 1000 Ci source.

The current design specifies a fill of 1099 Ci of tritium. This is under the limit required for Type A shipments. Release and mechanical calculations indicate that this is a safe design. See TGT-CALC-103-002 and TGT-CALC-103-0011.

### Task 3:

Determine maximum target window thickness based on physics requirements.

The operation of the polarized 3He gas target cell at JLAB provides a baseline for this study since this target has many similarities to the present tritium gas target design in terms of length and gas pressure. It appears that we can use up to three times thicker windows than that of the polarized 3He target without seriously compromising the experiment. From a Monte Carlo simulation, it appears that there would be less than a 20% loss in target thickness that would be necessary to cut out the target windows from the data. Thus, the present tritium gas target design uses windows that are approximately a factor of three thicker than those of the polarized 3He target.

### Task 4:

Target cell should comply with ASME Boiler and Pressure Vessel Code, Section VIII Div 2 2007

This is not truly possible at the cell cannot be meet all the requirements of this Code nor can it be stamped. Furthermore, this Code is not the most applicable ASME Code. Using JLAB policy for selecting the proper ASME Pressure Code results in the code selection of ASME B31.3 (2014). This shall be the Code of record. This Code may be followed in full with the exception of impact testing. The JLAB policy for fracture toughness testing shall be followed  [4]. Section 304.7.2 of B31.3 allows for the use of ASME BPVC VIII D2 FEA analysis. This shall be performed using the allowable stress in tension from B31.3.

### Task 5:

Cell should be filled offsite and be designed to survive transport.

The cell has been developed to safely operate with the design pressure of 675 psi. This design pressure includes safety margins required by ASME B31.3. The actual maximum operating pressure for the tritium cell is 200 psi. Therefore an additional factor of safety exists above Code requirements. The cell shall also be fitted with custom (precision fitted to each cell) shipping/filling covers. These covers act as stays for the thin sections (which is allowed by Code). An analysis of the cell assembly with these covers (compliant with ASME B31.3 using FEA and elastic-plastic model TGT-CALC-103-007) shows that the design pressure of 1000 psi is acceptable. These covers also serve to protect the thin sections from impact loading. A proof test was performed on two assemblies using a hydrotest incompliance with ASME BPVC VIII D1 UG-101. The correctly assembled cell burst above 5500 psi. The incorrectly assembled cell did not fail but developed a leak on the damages sealing surface above 4000 psi. We conclude that this design is sufficient for protecting the cell while shipping/handling and while filling.

### Task 6:

Cell should survive cyclic loading (beam trips).

See Section 22.1.5. The cell design is adequate for beam trips.

### Task 7:

The tungsten collimator should be better supported.

The current design of the target system specifies two collimators: 1) a short collimator installed on the face of the cell (that moves with the cell) and 2) a long collimator upstream of the target located in the reentrant tube. This collimator is now fully supported by the tube.

### Task 8:

Valves should have all metal wetted parts.

Selected valves are Swagelok all metal bellows sealed valve. Specification is also in accordance with SRTE requirements.

### Task 9:

Cell must sustain a full vacuum load.

The cell is of sufficient design to with stand a full vacuum load.

### Task 10:

Target system should be designed to be cooled with 90K N2.

The target system has been designed to use the ESR supplied 15K coolant which shall be heated to 40K. This will provide more than sufficient coolant to prevent the cell walls from reaching 180K which is the temperature of concern. See Section 22.1.4.

### Task 11:

Verify that Al 2219 is a suitable material for tritium gas.

The current cell material is Al 7075. This aluminum alloy is shall be considered acceptable for tritium use. See Section .

### Task 12:

Determine strength of welded Al 2219.

This is obviated by the current design.

### Task 13:

Weld coupons should be tensile and bend tested

See above.

### Task 14:

Al –ss transition piece should be purchased and elbows should be used

This is obviated by the current design.

### Task 15:

An elastic plastic model of the cell (ASME D2 5.2.4) should be used.

Completed in the following calculations: TGT-CALC-103-002 -007 -012 and -014. These models indicate that the design is adequate for all conditions.

### Task 16:

Proof tests on more than 3 endcaps and at least one complete cell should be performed.

Testing has been performed on multiple assemblies including assemblies with shipping covers installed. These tests all indicate a conservative design.

### Task 17:

Heat cycling tests with a tritium loaded cell should be performed for a period of 6 months.

This action item creates challenges that are difficult to overcome and of results of questionable value. Note that to pressure test the exposed cell would require removing the tritium that it contains. Any embrittlement that would be present (many references indicate that there would be none See Section 6.3) would be reversed by the removal the gas. The exception to this reversible embrittlement is swelling (or blistering activated by He3 in the lattice). Studies at SRS indicate that we are many orders of magnitude below the concentration required for this process to initiate. Nonetheless, a study is underway at SRTE/SRNL to investigate the fatigue crack growth of Aluminum 7075 at pressures exceeding 3000 psi. This is 15 times higher than the room temperature design pressure. Data from this study shall be collected every 4 months for one year  [2]. See Section 6.3 for more detail.

### Task 18:

Consult Wayne Kanady at INL and Walter Shmayda at University of Rochester regarding tritium diffusion.

Several models for tritium diffusion were developed  [5,6]. The estimated diffusion for the cell at room temperature over 1 year is 0.5 Ci. This is conservative estimate because the cell will be cold and at much lower pressure much of this time. R. Ricker at NIST and Brian Somerday at Sandia were consulted and this resulted in a report on the diffusion and permeability in the target cell.

### Task 19:

If insufficient information exists on beam shock wave tests, perform such tests at JLAB.

Cyclic loading from beam trips was determined not to be an issue  [7–9].

### Task 20

Cell must survive off-normal beam conditions for at least 3 times the amount of time that it takes for an interlock to turn the beam off.

The cell can survive more than 10 seconds with no raster. See Section 6.1.3.

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### Task 1

Determine DOT and DOE regulations for shipping filled target cells to JLAB.

This process is ongoing at this time. JLAB is consulting SRTE shipping and packaging SMEs as well as DOE/DOT for shipping requirements for small quantities of compressed gas. Three layers of containment shall be provided in the final solution.

### Task 2

Secondary containment should be physically isolated from beamline.

The beam line is isolated by a beryllium window. See Section 8.3.

### Task 3

The scattering chamber pumps shall be vented through tritium stack.

All pumps including the scattering chamber, getter, and dump line pumps shall be exhausted through the tritium exhaust system to the stack. See Section 8.

### Task 4

The scattering chamber should be monitored for high and low levels of tritium.

True real time monitoring of the tritium levels in the chamber may be unrealistic given the high radiation field in the Hall when the beam is on. Multiple vacuum gauges shall be employed however. If the vacuum level rises the first response will be to assume that this rise is due to tritium release. An RGA system shall be connected to the chamber as well which should aid in the diagnosis of the vacuum rise. The stack monitor will also indicate tritium if the vacuum pumps are removing tritium from the chamber. The source of the vacuum failure shall be assessed before continuing with repair procedures.

### Task 5

A U getter bed should be attached to the scattering chamber.

To avoid hazard associated with uranium, a getter from SAES systems shall be used. This getter is described in Section 8.2.

### Task 6

An additional long collimator should be placed upstream.

A collimator shall be placed on each of the target cells (that moves with the target) and a second long collimator shall be placed just upstream of the Be isolation window.

### Task 7

Dedicated vent pumps/fans and lines should be installed over the scattering chamber and used for installation and removal procedures.

See Section 12.

### Task 8

Airborne radioactivity detectors interlocked with the vent/fan stack system should be used.

The system design incorporates this. See Section 12.

### Task 9

Manual scram buttons in the hall and counting house for the ventilation.

### Task 10

Additional beam raster detector and interlock system.

The fast raster now has a FSD on a current comparator in addition to the FSD on the power supply enable signal. This system is currently in use.

## EHS Tasks

### Task 1

Establish baseline for detectable tritium at the JLAB site.

See Ref  [10,11] for basis and details.

1. Tritium in water  
- We can readily detect tritium in water at about 500 pCi/L.  The EPA drinking water limit is 20,000 pCi/L.  Environmental permits for groundwater and stormwater effluent require a minimum detectable activity (MDA) of 1000 pCi/L.  
  
2. Tritium as surface contamination  
- The DOE surface contamination limit for tritium is 10,000 dpm/100 cm^2.  We can easily detect surface contamination at levels 100 times below this.  
  
3. The manufacturer reports that the air monitor JLAB has will see 10^-7 uCi/cc of tritium.  The DAC for elemental tritium is 2E-1 uCi/cc and for HTO is 2E-5 uCi/cc.  So, even if all the activity was HTO, the monitor can see it at less than 1% of the DAC.  
  
4. According to the spec sheets, the portable samplers that SRS uses (Sartrex 209L) will see 1E-5 uCi/cc tritium.  We expect to use these during transfer of the target.  
  
5. Grab air samples can also be taken for HTO using bubblers. This is not expected to be used as a primary sampling technique, due to the T2 source material but, we may employ this method as a confirmatory process.  MDA for this technique is usually in the 10^-8 uCi/cc range or lower.  
   
6. We are currently working on analysis techniques to measure tritium in oils and other material such as concrete.  These are not directly related to the operational aspects of the tritium target, but are part of our efforts to increase our ability to make measurements to confirm absence of radioactivity in materials released from control.  The capability to measure tritium in such materials should not be thought of as a necessary component of the program, as I doubt that even SRS can do it (they probably send these kinds of materials out for analysis, if needed).  
  
7. Based on feedback from SRS, and our own procedures and ALARA concerns, we will run some sort of H3 spot check bioassay.  We would probably get these analyzed offsite (mainly because of the biohazard issues handling urine).  Typical sensitivity for urine is like our sensitivity in water (less than 1000 pCi/L).  At 1000 pCi/L in the urine, the dose is about 2E-4 mrem per day.

### Task 2

Develop algorithm for safety involving amount of tritium, beam current, beam time.

Complete. See Tritium Technical Report Ref  [3].

### Task 3

Worst-case scenarios for worker exposure and all dose calculations should be analyzed or calculated by qualified personnel.

Several models for tritium release have been developed by qualified personnel. See Section 16.

### Task 4

A more detailed assessment of impact of target loss on Hall A should be performed by qualified personnel.

Several models for tritium release have been developed by qualified personnel. See Section 16.

### Task 5

A more detailed assessment of impact of target loss on Hall A should be performed by qualified personnel.

Several models for tritium release have been developed by qualified personnel. See Section 16.

### Task 6

Use the ICRP-68 dose coefficient of 1.8E-11 Sv/Bq reference for exposure evaluations.

The requirement that the released tritium is immediately converted to HTO is overly conservative. Many measurements  [12] indicate that the conversion is typically less than 1% per day. The rate assumed for conversion is 10% in current calculations. Note that several models for tritium release have been developed by qualified personnel. See Section 16.

### Task 7

Use 10 mrem as the maximum allowed site boundary dose.

Several models for tritium release have been developed by qualified personnel. See Section 16. The expected dose at the site boundary is less than 1 mrem for a stacked release. For the worst case scenario, the expected dose at the nearest site boundary is slightly above the limit (with the conservative 10% HTO assumption). The expected dose at 300 meters is however less than the 10 mrem limit.

### Task 8

The risk analysis should follow tables 4.2-4.5 of JLAB’s FSAD, rev. 6 and use realistic target failure probabilities.

See Ref  [13] and Section 20.

# References

[1] M. J. Morgan, H. L. Nigg, and J. D. Novajosky, *( U ) FY15 / 16 TJNAF-SRTE Tritium Target Structure Evaluation* (2016).

[2] T. S. Mcgee, H. L. Nigg, and J. D. Novajosky, *ICO FY15 / 16 TJNAF-SRTE Tritium Experiment Activity* (2016).

[3] R. J. Holt, JLAB Tritium Tech Note 1 (2012).

[4] D. Meekins and et. al., *Policy for Fracture Toughness Testing Requirements for Pressure Systems and Components at Low Cryogenic Temperatures* (2010).

[5] D. Meekins, *Estimated Tritium Pressure, Solubility, and Permeation in Cell* (2015).

[6] R. J. Holt, R. E. Ricker, and D. Meekins, *Tritium Permeability of the Al Target Cell* (2012).

[7] D. Meekins, *Tritium Target General Target Cell Calculations (Code)* (2015).

[8] D. Meekins, *Thermal Stress Analysis in Entrance Window* (2015).

[9] D. Meekins, *Thermal Stress Analysis of Main Body Author* (2015).

[10] K. Welch, *Thomas Jefferson National Accelerator Facility Jefferson Lab Process for Release of Material From Radiological Control* (2010).

[11] K. Welch, E. Abkemeier, and B. May, *Technical Basis Document for Radioactivity Limits in Liquids as a Result of Activation or Contamination* (2006).

[12] P. Y. Pan and L. D. Rigdon, LANL (1996).

[13] E. J. Beise, B. Brajuskovic, R. J. Holt, A. Ktrama, W. Korsch, T. O’Conner, G. G. Petratos, R. Ransome, P. Solvignon, and B. Wojtsekhowski, *Tritium Gas Target Hazard Analysis for Jefferson Lab* (2012).