Questions and Comments for Isotope Review

Bob May & Tim Michalski

9/25/19 Rev 3

Purpose: The purpose of this document is to provide some insight into the thoughts of the reviewers. While it is a little late in the process, the hope it is will help steer the review discussions to the areas of question and further consideration rather than areas which are clearly met. Some of the questions/comments may already be addressed by the presentations.

Things we are not reviewing:

- Costs
- Anything related to 5 kW performance of the target. **(It appears the team's plan is to run 1 kW then run 5 kW – is this a correct statement? Is another review required on certain elements to prepare for a 5 kW run?)**
- Anything related to 50 kW performance of the target.
- Detailed technical review of the components or sub-systems. However, review of appropriate documentation and validation of requirements will be done to understand readiness to be installed in the experiment will be done.

Requirements Encountered in the Documentation:

1) Design for ALARA.
    a. Plan to wait 24 hours for decays of short-lived isotopes, to avoid unnecessary High Rad Area work
    b. Engineering solution for quick release of the target holder
    c. Engineering solution for quick release of the activated copper cooling station
    d. Prepared shielded location to store the copper cooling station in the tunnel nearby for decay
    e. Standard RadCon procedures involve ALARA considerations: reviews, RWPs, mock-up training
2) Environmental Requirements (from Pavel's previous review presentation):
    a. No prompt radiation in the environment produced.
    b. No contaminated water release.
    c. No Airborne radiation outside the Accelerator operations envelope.
    d. Activated target sent to VCU via commercial courier in the proper DOT-approved package using proper procedures.
    e. All activated materials subject to the standard Radiation Controls, not released in the environment.
    f. VCU Rad safety officer to authorize transfer of possession under their license. Disposal not an issue due to ^{67}Cu decay.
3) Accident/Emergency Response (from Pavel's previous review presentation):

   a. General accidents in the tunnel during irradiation: actions by the Crew Chief according to the OPS Procedures; staff: OPS
   b. (Highly unlikely) target break/gallium spill during the run: gallium will be contained in the copper cooling tray; the cleanup will be subject to RadCon operating procedures (surveys, RWPs); staff: RadCon
   c. (Highly unlikely) target break/gallium spill during the target movement: the procedure will include the requirement that the target must always be above a gallium-intercepting and catching tray or bucket. The cleanup will be subject to RadCon operating procedures (surveys, RWPs, decontamination procedures); staff: RadCon
4) Documented to a level that others could duplicate the work and testing.
5) 1kW beam on target assembly. 40 MeV @25 uA. Isotope Production Beamline Commissioning states use of 25 MeV @ 40 uA. 18.5 MeV also mentioned. **Which is right?**
6) Use of Ga >99.9999% purity as base material → Cu67. Some additional requirement regarding documenting and handling Ga are listed (from JLab IH):
   a. Anywhere MSDS is written needs to be changed to SDS. If MSDSs are referenced they are out of date resources and new versions of SDS for the materials need to be referenced and shown on slides.
   b. PPE from current SDS is faceshield over safety glasses, a minimum of 11mil nitrile gloves (regular blue exam glove are too thin) and a lab coat. A vent hood is required, Lab 1 or Lab 5.
   c. Slide 33: discusses paint to "avoid lead poisoning".....painting lead only helps reduce oxidation. A skin contact/cross-contamination hazard still exist. So PPE like gloves are still required for handling a painted pig.
7) Gallium expands by about 3% when it freezes, so we need to take that into account. It seems impractical to try and ensure that the temperature never drops below 30°C, so we will ensure that there is sufficient space to allow for the expansion. **How was this achieved?**
8) The graphite plug will be machined to provide “flats” that allow the plug to be unscrewed in the hot cell.
9) The graphite plug will serve to ground the specimen.
10) Sealed raised edge on copper plate to prevent spillage in the event of hBN crucible failure. (from Kevin’s presentation at first experimental review)
11) Temperature monitoring to prevent overheating of the radiator and target. (from Kevin’s presentation at first experimental review)
12) Diagnostics and Instrumentation (from Kevin’s presentation at first experimental review):
   a. Two additional video cameras will be monitor irradiation of Gallium; One for position of beam on radiator – or BPM?, Second is to give overview in case something goes wrong.
   b. Radiation sensitive detector & camera to monitor beam position on radiator
   c. 3 Thermocouples to monitor critical temperatures
      i. All monitored in EPICS w/alarm
      ii. #1 Tungsten Radiator
      iii. #2 Boron Nitride target holder
      iv. #3 LCW outlet
   d. LCW return water flow switch
13) Lattice file development in the LERF:

a. provide lossless transport of different energy beams to the isotope target
b. provide sufficient operational tunability
c. provide ease of setup
d. provide ease of verifying setup
e. keep the recirculation transport relatively intact
f. avoid unnecessary complexity, so as to maximize the budget available for beam operations
g. Beam Viewers:
    i. Need to work at low energy. Therefore all view screens should be replaced with YAG crystals. Note that these are a long lead time item (10 weeks) [7].
    ii. Need to image well. This means there is sufficient signal to make quantitative measurements or appropriate neutral density filters installed in the event that there is too much signal.
    iii. Need to be calibrated. In order to get quantitative information, namely the beam size, the view screens need to be calibrated so the imaging software can convert sizes from units of pixels to units of length. One way to do this is to put well-defined markings on the view screen which can then be correlated to pixels in the imaging software.
    iv. Need to be aligned. To avoid unnecessary downtime and machine accesses, viewers should be aligned.

14) A camera should be set up to view the front face of the radiator, which should be replaced with a phosphor coating.
15) Target shielding design up to 5kW, per the analysis.
16) Target assembly must contain the Ga sample size in the event of the BN vessel breaks.
17) Seismic – apparently, there is some seismic requirement on stacking SEG blocks as there is an e-mail discussion on the specific requirement.
18) Operational temperatures for the 1kW application? Ga/Cu67, crucible, raft/plate, radiator, cooling water inlet/outlet? Diagnostics to measure? Redundancy in diagnostics?
    a. 5kw application?
19) No material handling until 24 hours after irradiation.
20) Standard RadCon survey and postings, checks of contamination levels.
21) DOT Transportation Regulations:
    a. U.N. (D.O.T.) Certified 4G Box.
    b. 4G/Y8.3 combination packaging.
    c. Meets all DOT requirements for a gallium (Class 8, Packing Group III) shipment.
    d. Proper Packaging
        i. We will pack the Boron Nitride capsule in a steel can which will have foam cushioning.
        ii. The can will be shielded to meet the radiation requirements
        iii. The box will be multiply lined with heavy duty plastic material.
        iv. The package weight will be well below 15 kg
        v. A Safety Data Sheet will be provided by Jennifer Williams
        vi. Qualified DOT shippers from EH&S, RadCon and Shipping & Receiving will oversee packaging, provide proper marking/labeling and shipping paperwork.

22) Interlocks between the target/radiator assembly and the LERF control system in EPICS. This is assumed, although nothing is stated.
23) Pressure Systems on cooling water circulation.
    a. Must be evaluated per JLab Pressure Systems Program.
    b. Operating conditions requirements:
        i. operating pressure,
        ii. circulated fluid,
        iii. material certification and/or certified components,
        iv. assembled in compliance with MSINST OSP,
        v. pressure test to insure integrity of the assembled system

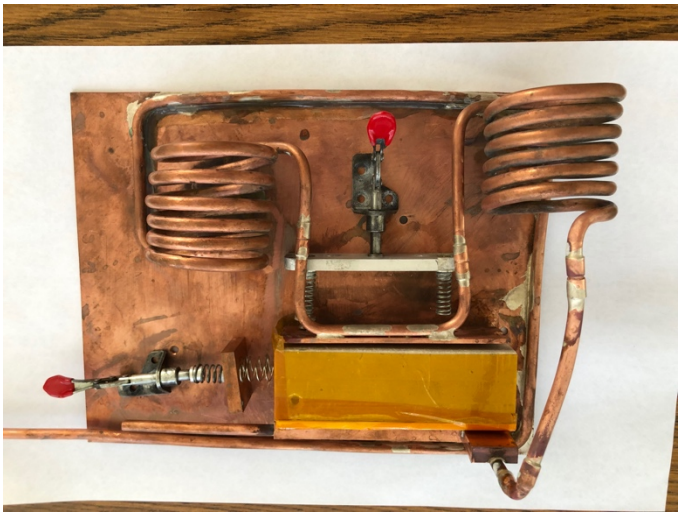
Areas of concern or consideration:

- All Documents should be uniquely identified at JLab.
- All Documents should be reviewed and approved for use (should be under version/revision control rather than date control). Not sure what the Accelerator Division policy is for this.
- No TOSP/THA posted for gallium handling into the crucible.
- No TOSP/THA for opening/closing/operating/setting up the target cell/radiator.
- No TOSP/THA for removing the crucible from the target cell. This also has a duplicate comment under the Run Plan. This document should be referenced in the Run Plan. Note the requirement to always have the crucible over something that will catch the contents should the crucible leak/break.
    - From the previous review – Pavel's presentation - Post-Irradiation Material Handling:
        - Quick release of the target copper coolers/holders.
        - Use the long-handled retrieval instrument to take the target (and the cover), place it onto the tray with adhesive Kapton sheet, and move to a convenient place away from the set.
        - Wrap the target together with the cover in the sheet, and use extra wrapping in adhesive Kapton tape.
        - Place the wrapped target in the container, tightly close it.
        - Take the container out to the measurement area to evaluate 67Cu activity.
        - Properly wrap and place the container into the shipping box.
        - Quick disconnect and release of the copper cooling station.
        - Place it into a shielded container and move it to the safe location (location TBD).
- No TOSP/THA for packing the specimen for shipping at JLab. This is the inverse process to the Package Opening Instructions. **Is there anything special about the Viking Shipping Container?**
- Risk Analysis for the Isotope run? Lessons Learned from previous experiment stated one should be developed, but none is listed.
- Property Transfer of specimen to VCU. Assume this is part of the shipping process, but question arose about someone at JLab "owns" the Ga specimen from the DOE. **How do we formally transfer ownership, knowing that we will not get the specimen back? JLab will write a new SDS for irradiated gallium to ship with the samples to VCU.**
- RWP for the Isotope Run in LERF. **Comments in Keith's talk about RWP with various procedural steps. May supersede some of the TOSP/OSP/THA documents mentioned above.**
- Is a JRRP (Radiation Review Panel) required for this unique running condition in the LERF?

Comments from Specific Documents: (note the document is identified first, basic text is from the document, **bold text is questions or comments**)

- From Isotope Proposal:
  - Gallium has a melting point of 29.8°C and a boiling point of 2204°C.
  - We estimate that it will take 4 hours to set the machine up for proper irradiation for each run at optimum energy and average current for isotope production. After that point the production rates of the desired isotope will be as projected in Section 3: ~31mCi of ^{67}Cu 24 hours after a 4 hour irradiation at 50kW beam power.
  - However, there are discrepancies between both FLUKA and TENDL-2014 and the much lower cross sections reported by Antonov *et al.* [1] and Segebade *et al.*[4]. These discrepancies must be resolved experimentally to validate the cost estimates presented in what follows. **Have the discrepancies been resolved in the initial experiment? Not sure if it just affects the cost estimates or fundamental capability. Was this the information presented by George Kharashvili in the first review?**
  - The fill/drain valves will be fitted with remotely controlled electric/pneumatic ball valves. A design goal for the target system is that the irradiated gallium can be retrieved remotely. **Are the valves satisfactory for the high radiation and high temperature environment? It isn't clear where they are located on the assembly. In the actual assembly to be used for low energy, it appears that spring loaded latches are used to apply the forces (not sure if this is the same thing – perhaps the statement in the document refers to the cooling water).**
- Quarterly Reports:
  - Radiation shielding calculations for targets up to 5 kW at 40 MeV (125 μA) and 1 kW at 18.5 MeV (54 μA) have been carried out and an initial shielding layout has been determined. **Several places throughout the documentation it mentions 5kW and 1kW. This review is for 1 kW. There have also been varying statements on what is to be run in the LERF (18.5 MeV, 25 MeV, and 40 MeV). Clarify the run specifics – Run Plan states 25 MeV. FY'19'Q2 report states 18.5 MeV for first run. It would also be beneficial to qualify statements about 5 kW analyses towards what its effect is for a 1 kW run.**
  - Target design was modified to simplify handling at VCU. We intend to make one or more crucibles in plastic and practice removing them from the target holder and opening them at VCU. When we are satisfied with the design, we will fabricate a target crucible from boron nitride for the first irradiations. **What has been changed on the target design? Is there any documentation to support the validation of the improvements or handling and opening at VCU?**
  - The cooling water will be attached rigidly to the rear shielding block and will not require disconnecting from the target cooling mechanism. **How is the cooling water both rigidly attached and able to move as the rear shielding block is extracted? Nothing in what has been received to date shows how the water lines will be run. How is the "raft" secured to the support structure? – ALARA asks for quick removal for storage after the run. Are the quick disconnects still used for the water lines?**

- Crucible Design Characteristics brainstorm detailed in Q2 report:
  - High thermal conductivity in 2 planes. **How is this communicated to the fabricator? How is this validated that it was done properly? What is the impact if it wasn't made correctly – will it still work for 1kW?**
  - Carbon plug – grounding and hex head for remote removal at VCU. **Grounding mechanism not defined anywhere – assume some electrical connection between head and earth ground – is it just the plunger/clamp?**
  - **Has the plug been demonstrated to seal for liquid Ga/Cu67? If not, how has a threaded feature been validated for sealing?**
  - Evaluation of contact pressure required for cooling. **Any validation of this? How tested? Use of tin as interface material – will it melt? What temperature will the specimen get up to in the 1 kW scenario?**
  - For the initial tests, spring-loaded clips will push the plates against the crucible; this is known to be sufficient for the initial low-power irradiations. **How is this known to be sufficient? What are the design requirement temperatures for the 1 kW application? Thermal analysis/test? Is this relying on the previous test results from CEBAF?**
  - With the new crucible, shipping container, pig and manipulator in hand, we will proceed with a series of transport tests… These tests will be carried out over the next two quarters. **Were the tests carried out? Any documentation of these tests? Were they successful or were there remediation actions?**
  - Gallium expands by about 3% when it freezes, so we need to take that into account. It seems impractical to try and ensure that the temperature never drops below 30°C, so we will ensure that there is sufficient space to allow for the expansion. **How is this validated/confirmed?**



  - Sealed raised edge on copper plate to prevent spillage in the event of hBN crucible failure (from previous CEBAF experiment review). **Feature not evident in this configuration. A recently received image shows additional copper tube barrier material being adhesively bonded to the plate.**
  - **Solder joints don't appear continuous on the movable plate. Is the thermal contact adequate? Has the assembly been tested or otherwise validated?**

        - **What is the availability of additional documents related to the actual crucible design, its cooling, and operation? This is a new design and is a scale up from the previous run. What thermal analysis has been done on the crucible? Mechanical engineering analysis done on the crucible design with a focus on maintaining mechanical integrity and associated test plans to verify novel design elements? Unexpected interactions between the beam and the containment have caused many issues at other isotope operations. What is the anticipated temperature profile? The thermal expansion coefficient between graphite and boron nitride is significant. What spec was used to cut the threads in the BN (are these pipe threads etc…)? What about torque requirements? Damage to the graphite during assembly? Have the appropriate tests been done and documented as noted in the FY19Q2 Quarterly Report?**
- From the TN-18-050 on LERF Layout:
    - The cryomodule that now sits in Zone 2 is an older module with limited gradient capability. No longitudinal manipulations are required for the isotope experiments so beam will be accelerated on-crest. To reach 40 MeV, the module will need to provide an energy gain of 32 MV (or, 4 MV/cavity) which is the upper limit of what it can provide. **Is the CM capable of providing the necessary beam energy or does the current need to increase to get the 1kW power on the target? It appears from the FY'19'Q2 report that only 31.1MV is available from FL02. There should be an additional 8 MeV from the booster/quarter CM – totaling 39.1 MeV (correct?).**
    - "The importance of being able to do a quadrupole scan cannot be overstated." Listed issues with Quadrupole Scan and not having the SW SME on the Beamanizer tool. **How is this being addressed to get the LERF tuned properly for the run? I don't see detail of this captured in the run plan or commissioning plan.**
- From TN-18-054: An initial analysis concluded that a 4 mm diameter uniform beam would be sufficiently large so as to avoid damage to the 0.015" thick window [3]. [3] J. Gubeli, e-mail correspondence October 24, 2018. **Is a copy of the e-mail available for reviewing the thermal and stress performance of the window? Should this analysis be represented in a Document(ed) report such as a TN?**
- Isotope Production Beamline Commissioning is listed as EES-01-005, Rev 2, January, 2014.
    - **Quad scan is listed as an issue in TN-018-050 but not mentioned anywhere in the Commissioning Plan. Some discussion about quad adjustments in section 2.0, but no mention of the Beamanizer SW tool. Comments?**
    - **Is this adequate for our Crew Chiefs and Operators?**
    - *From a brief discussion with Brian Freeman, the answer is yes, this is adequate. The commissioning plan was used for the setup to the 1G dump.*
- Isotope Production Run Plan:
    - Target system installed and operational with a tungsten radiator, gallium target, and graphite plug. **Look for other document which identifies how "operational" is qualified. Are there any ties from the target/radiator instrumentation/diagnostics to LERF machine protection? If so, what signals and limits?**
    - When 34 hours has elapsed, shut the beam down and Allsave the machine parameters. Log the time that the was shut off. **34 Hours operation, is assumed to be continuous.**

Also assumed the ops team will man the LERF for 34 straight hours – raise this, as LERF generally operates 1 shift per day.
    - **Definition of the term "weekend shutdown".**
    - **Is this adequate for our Crew Chiefs and Operators?**
    - There is a mention that after the 10 hour wait period, Step 5 of section *3.0 Perform Isotop* (sp) *Irradiation* states "After having received permission from Radcon, withdraw the target and quickly transfer the crucible to the lead pig." **This is an important and hazardous action, but there is no guidance how this step is to be performed. Is there a separate document on how extractions of the crucible/target are handled at this step which includes Radiation shielding/PPE and/or special tools for ALARA extraction?**
- Nomenclature between Layout Coordinate 1F and Layout Drawings 1F. Not significantly different, but the layout is simple enough that things should be easily made to match. Also, use of marked up drawings as the foundation for doing major layout changes in the vault. **Is this an acceptable policy?**
- Shielding Requirement for 5kW Isotope Project Target/Dump. **Who did the analysis? Why not show the diagrams referred to by the analysis? Is this for 40 MeV? What if energy changed to 25 MeV, what would be different? Assume 1kW results in more conservative results.**
- Shielding Design and Review:
    - **Radiation limits for materials – specifically the plastic milk crates, limit switches, drive motor, and drive belt/chain? Email review of the design by Tim Whitlatch indicates a chain drive.**
    - **Is there any lubrication which can get activated and easily transferred?**
    - **What will be holding the water which is placed within the plastic milk crates? Reference somewhere (Whitlatch e-mail?) of using jugs of water (again, assumed plastic).**
- Shipping Container Assessment: **Who did the analysis?** Based on these values, the shipping container for the 5 kW run will require Yellow III labeling, but should have a Transport Index less than 10, allowing shipment in general commerce. However, due to other concerns (maintaining ground shipping, and expediting delivery) it is anticipated that custom, exclusive use transport will be used. **Is the shipping method consistent with the analysis? Since it is OK for 5kW sample, should be more than OK for 1kW sample. If 1kW, is there any downgrade to shipping marking and rating?**
- **Lessons Learned (many items have been addressed, others still have questions):**
    - There are lessons learned documents (Word and Excel formats). Feedback was given but it is unclear what feedback was addressed during the planning, design and installation phases of this run. **How was this handled and is there a check off of what was addressed?**
    - **While it appears there have been dry runs with the package to VCU, one of the Lessons Learned is including instructions indicating what can and cannot be done by authorized and unauthorized staff at VCU (and JLab for that matter).**
    - Lessons Learned: Documentation should be such that a different group of experimenters can successfully stage the experiment. **Is this a valid statement for this experiment? What level of familiarity with the target and LERF ops is required to**

duplicate this activity? Expectation this will be a result of what comes out of the review.

- Redundant monitoring systems, even in case of the failed pneumatic controls, would have allowed continuation of the experiment to its conclusion. **Where are the opportunities to implement this in the new experimental/target setup? Have they been addressed? The Lessons Learned matrix indicates, " There is no sensitive instrumentation within the hutch. The hutch shielding has been designed to reduce radiation in the LERF vault to levels that will not affect instrumentation (this is more stringent than is required at the ANL Isotope Irradiation Facility, which members of the Isotope Team visited to learn about their program."**
- Regardless of the first part of the experiment, the chemical separation part of the experiment would have failed. The key contributor is the failure to include VCU's RSO in establishing the packaging and shipment protocols. **This appears to be addressed by dry runs with VCU and inclusion of their RSO in the review process.**
- **Reference to the initial review: https://www.jlab.org/indico/event/212/**
- **No information on the mechanical design/thermal analysis/instrumentation of the target and cooling plate.**
- **Risk Analysis/Risk Matrix for the Isotope run? Lessons Learned from previous experiment stated one should be developed, but none is listed.**
- **What grounds the carbon plug of the crucible which is in contact with the Ga?**
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- ATLis for installation in the LERF: http://opsweb.acc.jlab.org/CSUEApps/atlis/atlis.php?load=Task&task_id=18121 The only reference to the Pressure Systems requirements is a comment by Neil Wilson in 9/6/19 in the comments/history part of the ATLis.
- COO Document:
  - **Is there a special RWP for this experiment? Yes – Keith discusses this.**
  - **There are outstanding comments in the document.**
  - **Accelerator Operations Coordinator vs Accelerator Operations Liaison**
  - **Equipment Labeling – are they labeled?**
- Package Opening Instructions:
  - **Should this be more like a TOSP/OSP – THA? Should it be a formal VCU document, since they are doing the work? Agreement from the VCU RSO.**
  - **Seems to be written from the VCU point of use, however, nothing within that procedure shows the handling beyond the Pig extraction from the shipping container. Are there directions for the VCU personnel on how to handle the crucible (extract from Pig, unscrew the threaded stopper, remove product from crucible, etc.)?**
- Dose Rates on Packaged Gallium Target 24 Hours After Irradiation
  - This is for 5 kW, 24 hour run. **Does it need to be updated for 1 kW, 34 hour run?**
  - It does say it scales linearly with energy for 1 kW run consideration. **What about time?**