SNS-OPM-ATT 2.B-10.a.
Unreviewed Safety Issue (USI) Evaluation Form

I. Title of USI Evaluation:

USI Evaluation for Interim Storage of Spent Target Module(s) within the Target Building

II. Description of Proposed Activity (or discovered condition) (use attachments if necessary):

1. Overview

It is proposed to store one of the spent mercury target modules (TGT 11) within the Target Building but outside of the Target Service Bay. Two candidate locations are presently considered; 1) the cask cart room located in the basement beneath the service bay bottom loading port and 2) the high bay.

This analysis specifically evaluates Target Module 11; however is applicable to other target modules provided the criteria stated in Section 6, *Summary and Conclusions* are met.

The Target Service Bay is equipped with two in-cell shielded storage casks; each designed to hold a single spent target module. The in-cell casks provide shielding to reduce ambient dose rates within the Service Bay with the goal of protecting radiation sensitive electronics (e.g. video cameras, cabling, etc.). Spent target module 10 (TGT 10) and 11 (TGT 11) are currently stored in the in-cell storage casks.

It is desired to conduct post-irradiation evaluations of the modules that would involve cutting sample regions from the modules for further evaluations. Should the target module currently in use for beam operations fail before one of the two stored modules can be sampled and shipped, there may be a need to remove one of the spent modules from the Service Bay. While the Service Bay can accommodate three spent modules; such an arrangement is not desired long-term as it adds congestion at the rear of the Service Bay area and would lead to an elevated dose environment within the Service Bay that could shorten the life of some electronic equipment/components.

The current thinking is to store spent TGT 11 outside of the Service Bay but within the target building for an interim period; perhaps on the order of one year. This would allow time for sampling and the subsequent shipment of a spent module(s) which would open up space within the Service Bay to return the spent module from interim storage.

The stainless steel target modules become highly radioactive from proton beam induced activation. In addition, a residue of residual radioactive mercury and spallation products is assumed to coat the inner module surfaces. The Target Module Storage Cask (TMSC) is designed to shield radiation from the module (and associated residue) to levels that can be safely managed under the provision of the ORNL SBMS for Radiological Protection.

The spent target module will be double contained within a carbon-steel inner liner assembly placed inside of a heavily shielded TMSC. The TMSC is made of stainless steel encased lead and is similar to the DOT approved TN-RAM shipping cask; however, the TMSC is not DOT approved and is simply regarded as an onsite storage container. SNS engineers designed the TMSC in-house. Two TMSCs (see Figure 1) have been procured and are stored onsite.

Figure 1. SNS Target Module Storage Casks

The process of loading a spent module into the liner and the subsequent loading of the liner through the Service Bay bottom loading port into the TN-RAM cask has been successfully performed many times in accordance with an approved procedure [1]. Because of dimensional differences between the TMSC and the TN-RAM cask, a new transfer procedure will be developed, reviewed and approved prior to use.

The basic spent module out-loading steps include:

1. The inner liner is loaded from the High Bay into the Service Bay through the top loading port using the High Bay 50-ton crane.
2. The spent target module is placed into the inner liner and the liner lid is bolted into place within the Service Bay.
3. The TMSC is raised up to mate with the bottom loading port of the Service Bay with the Cask Cart.
4. The Service Bay bottom port is opened and the inner liner lowered into the TMSC.
5. The TMSC is lowered from the bottom loading port with the cask cart.
6. RCT direct radiation and smear surveys are conducted.
7. The TMSC is driven into position underneath the 50-ton crane hook and the lid lowered into place and bolted on.
8. Radiological surveys are performed.
9. Testing to verify the TMSC lid O-ring functionality is performed.

The leak testing on the TMSC lid O-rings involves evacuating the interstitial region between the O-rings (to less than 10 mTorr) and then performing a rate-of-rise test. The goal is to achieve a rate-of-rise that equates to a leak rate of no more than 8x 10^-5 Torr-L/sec.

Figure 2. High Bay view of inner liner and open top loading port. Note the top loading port shielding plug in the foreground.

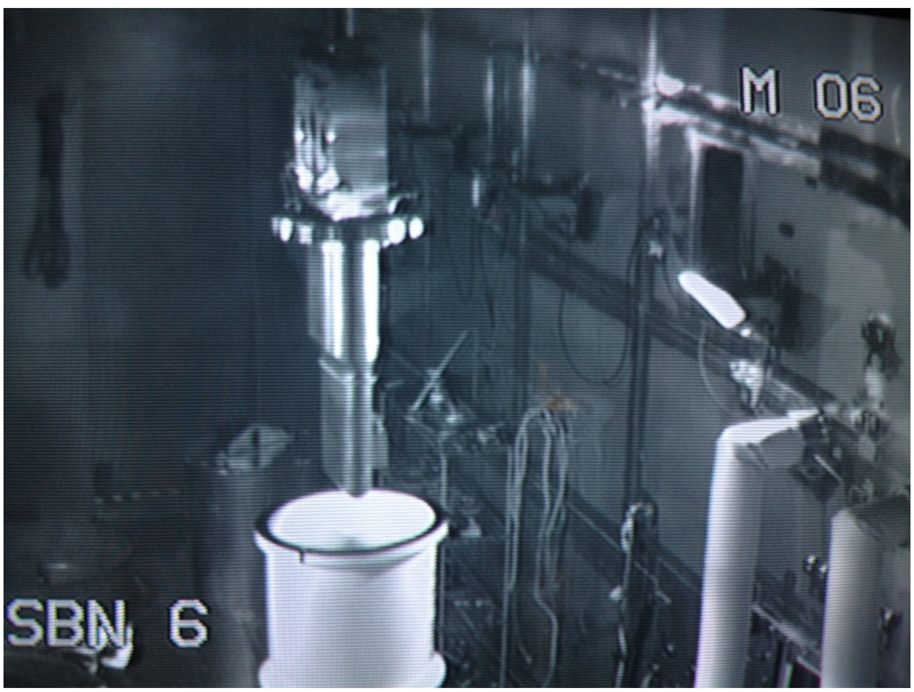

Figure 3. Service Bay view of a spent target module being lowered into the inner liner.

Figure 4. Service Bay view of the loaded inner liner being lowered down through the bottom loading port into the TN-RAM shipping cask. Unseen in the photograph is the TN-RAM cask which is mated at the underside of the bottom loading port.

The loaded TMSC could then be left on the cask cart for interim storage. Alternately, it may be desired to remove the TMSC from the cask cart should the need arise (e.g. use the cask cart for other purposes is desired). In such an instance, the TMSC could be lifted from the cask cart and lifted into the high bay with the 50-ton crane to a preapproved location with sufficient floor loading capacity.

The spent target module will ultimately be returned to the Service Bay for sampling. The process of loading a spent module into the Service Bay has not been performed before; however the process of loading an empty liner from the T-RAM cask into the Service Bay has been previously accomplished. The process of loading the spent module back into the Service Bay will be accomplished in accordance with approved written procedures. The basic in-loading steps include:

1. The TMSC returned to the Cask Cart (if removed);
2. The TMSC lid is removed using the 50-ton crane.
3. The TMSC is moved underneath and then raised up with the Cask Cart to mate with underside of the Service Bay bottom loading port.
4. The inner liner is lifted from the TMSC into the Service Bay using the in-cell crane with a special Ziplift feature through the bottom loading port.
5. Once inside of the Service Bay, the liner lid is removed and the target module removed from the liner for sampling.

After sampling, the spent module could then be stored or packed for shipment with the TN-RAM cask in accordance to already established approved procedures.

2. Cask Liner and Target Storage Cask (TMSC) Descriptions

2.1 Cask Liner

The drained target module will be loaded into a standard carbon steel shipping cask liner designed specifically for SNS spent module shipments in the NRC approved TN-RAM shipping cask. The liner is inspected and NQA-1 certified by the vendor. It should be noted that the liner lid provides 4 inches of lead shielding at the top of the liner. Figure 5 shows basic cask liner dimensions.

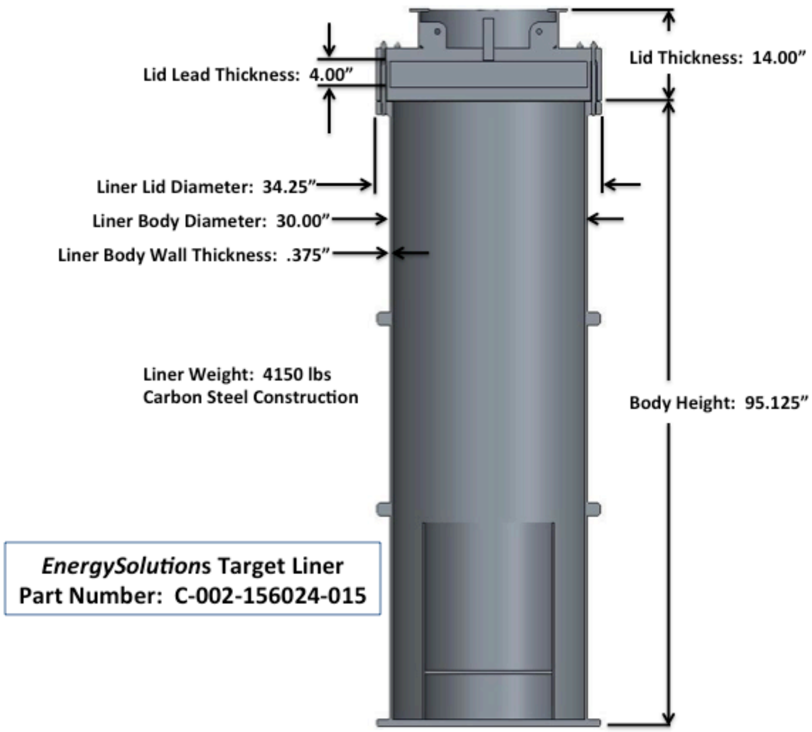

Figure 5. Target Module Cask Liner.

As can be noted from the figure, there are no penetrations in the liner. The liner is welded construction made from carbon steel. The design provides assurance that even if a fraction liquid residue were to spill from the nose of the drained module, it would be retained at the bottom of the liner with no leak path penetrations. By procedure, charcoal amalgam powder is poured into the bottom annulus of the liner prior to loading a spent target module for contamination control.

The liner is sealed with a neoprene gasket and bolt on lid. This feature confines the potentially contaminated atmosphere associated with the module within the liner. The liner is attached to the crane for handling with a special Ziplift connector designed for ease of remote access.

2.2 Target Module Storage Cask (TMSC)

The TMSC shown in Figures 6 and 7. The TMSC is welded construction made from stainless steel encased lead shielding with no penetrations in the cask cylinder (a penetration may be added to the lid to allow venting of the cask prior to opening). The TMSC is inspected prior to use. The TMSC lid is sealed with double concentric neoprene O-rings that trap an interstitial volume that can be accessed via a lid port for leak checking of the O-rings.

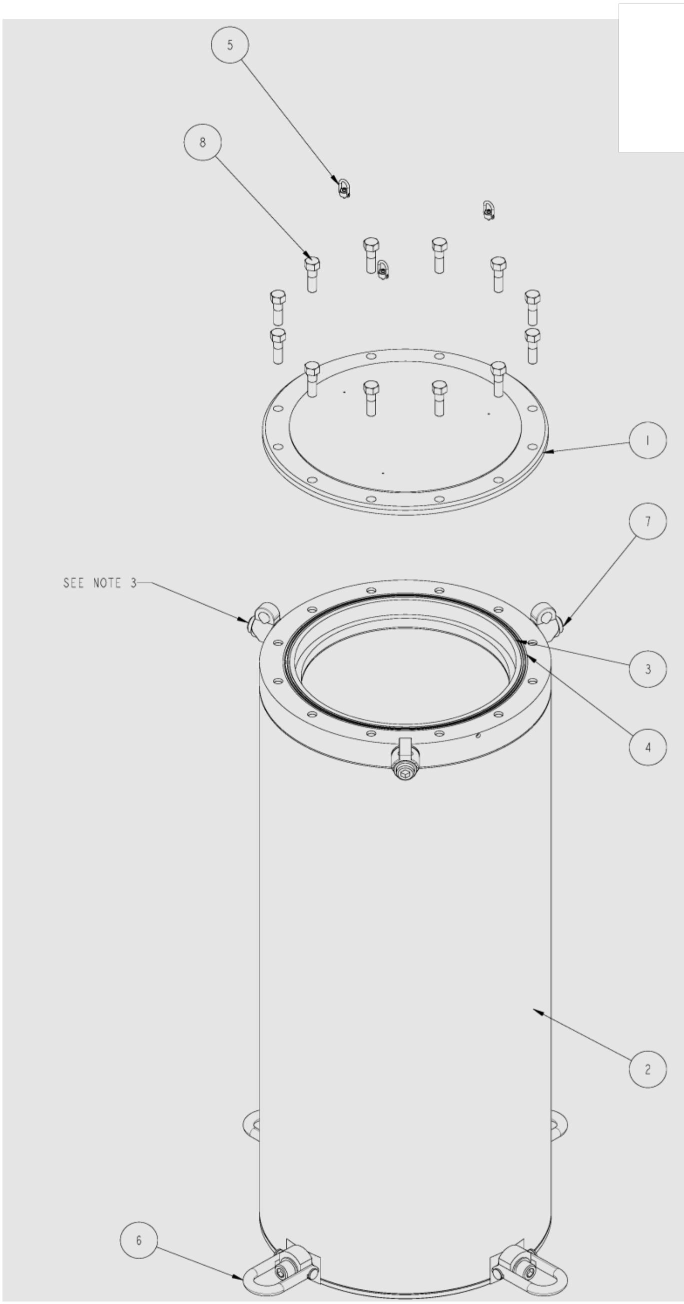

Figure 6. Target Module Storage Cask (TMSC)

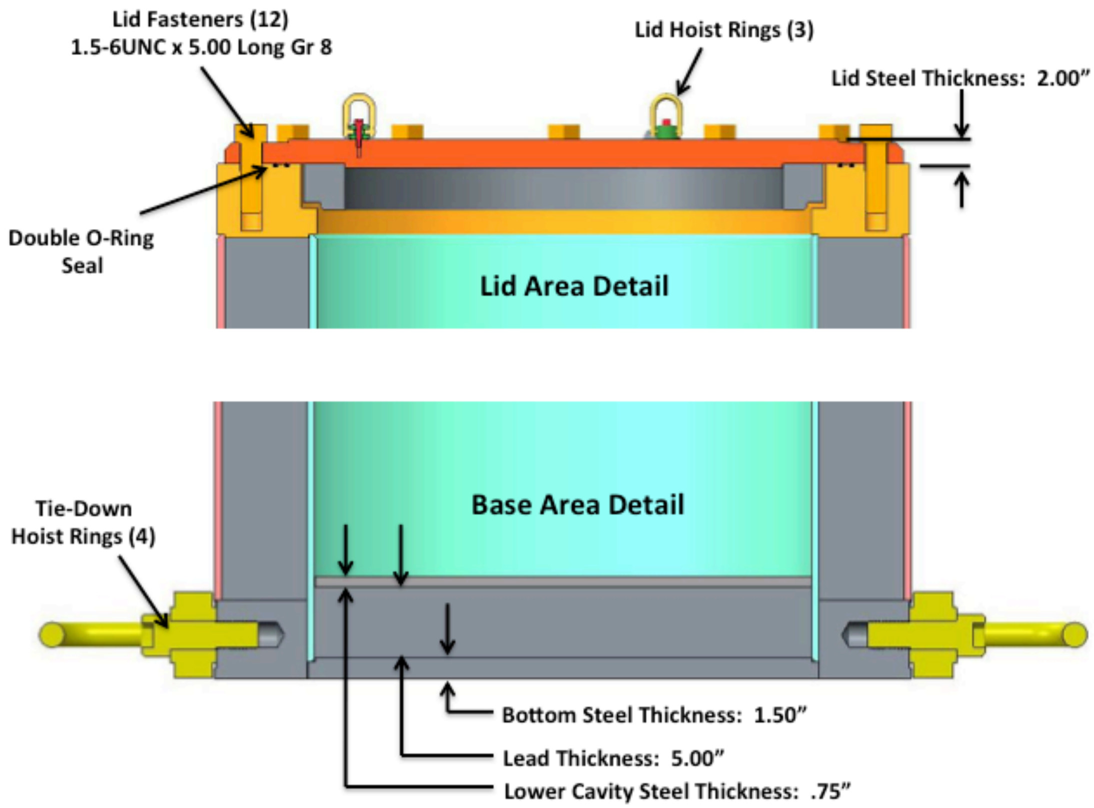

Figure 7. Some Dimensions and Detail for the TMSC.

The TMSC design is similar to that of the TN-RAM cask and provides similar shielding materials/thicknesses for the bottom and sides of the cask. A notable exception is that the TN-RAM lid provides ~ 6 inches of lead shielding while the TMSC lid provides 2 inches of steel with no lead. Expected dose rates outside of the TMSC are addressed below.

A comparison of some key dimensions and materials for the TN-RAM and TMSC is provided in Table 1. Figure 8 depicts the target module loaded within the liner and the liner loaded within the TMSC.

Table 1. TN-RAM Shipping Cask Comparison with TMSC

Parameter	**TN-RAM**	**Target Module Storage Cask**
Overall Height	129.375"	120.125"
Shell Outside Diameter	52.00"	49.00"
Cavity Inside Diameter	35.00"	35.00"
Cavity Inside Height	111.00"	109.813"
Lead Thickness, Sides	5.88"	6.00"
Steel Thickness, Sides	2.25"	1.00"
Lead Thickness, Bottom	6.00"	5.00"

Steel Thickness, Bottom	3.00”	2.25”
Lead Thickness, Lid	5.94”	0”
Steel Thickness, Lid	3.00”	2.00”
Weight, Empty	61350 lbs	44662 lbs

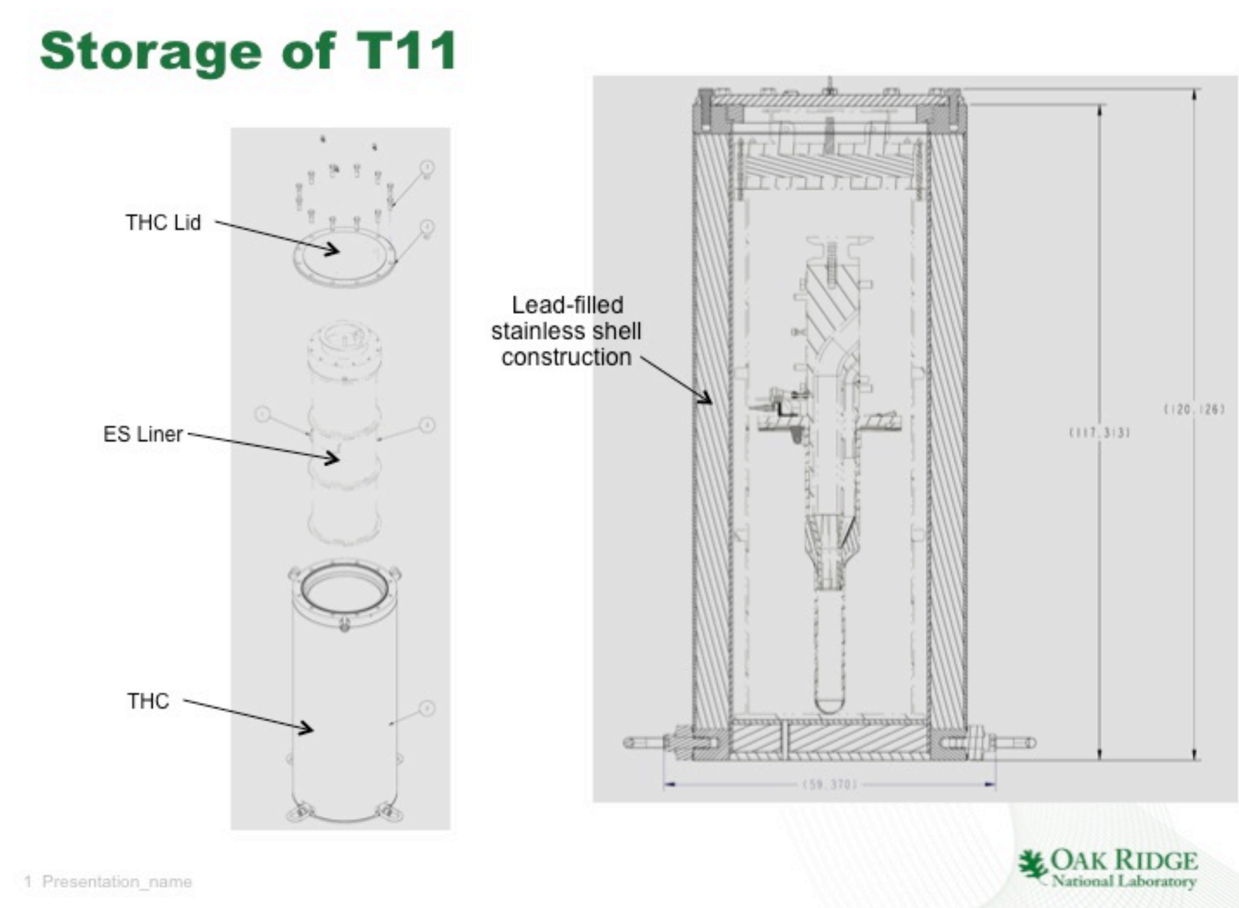

Figure 8. Depiction of target module loaded within liner and liner loaded into TMSC.

3. Spent Target Module 11 and Bounding Target Module Characteristics (Radionuclide Inventory, In-Air Dose Rates and Decay Heat)

The stainless steel target module becomes highly radioactive from proton beam induced activation. Upon removal from the beam, radionuclides within the module decay exponentially with nuclide-specific half-lives.

For shipping purposes, a residue of radioactive material from the process loop consisting of 200 grams of process mercury and a fraction of mercury spallation products is conservatively assumed to remain within the inner module. A fraction of 0.416 % of the entire process mercury loop spallation product inventory (with the exception of gold and noble gas isotopes) is assumed to adhere to the inner surfaces of the target module. This value is based on the assumption that 10 % of the spallation product inventory adheres to the inner surfaces of the mercury process loop and the relative inner surface area of the target module compared to that of the entire loop [2, 3]. The spallation product residue is assumed to be fixed to the inner surface [4] and not removable due to mechanical vibration/stress.

Measures are employed to ensure free liquids are removed from the module to the fullest extent possible. By procedure (TS-IOP-014 *Target Change Out – Removal and Installation* Revision 2, February 19, 2013), the target is tipped upon removal from the target cart seal plate to induce drainage of residual liquid back into the process loop through the manifold plate openings. After the module is removed from the carriage, it is transported to the rear of the service bay in a nose-down orientation and holes are bored into the nose of the target which allows accumulated liquids to drain into a designated catch basin. Subsequently, spent modules are stored within the in-cell Target Storage Casks in the nose down position. Observation of the floor of the in-cell target storage cask shows only droplets of mercury indicating that the draining of the module is effective.

TGT11 was removed from service on October 2014 after only 167 MW-hr of beam. Analyses specific to TGT 11 are presented below as well as analyses for a bounding spent target module. A bounding spent target module has been analyzed in support of establishing an envelope for compliant shipping within the TN-RAM cask. The bounding target module case assumes the module is irradiated at a beam power of 2 MW for 2,500 hours over a 1-year period. The bounding target case further assumes that residual mercury and spallation products within the module are representative of maximum activity levels reached after an assumed 40-year operation at 2 MW for 5,000 hours per year.

The expected in-air dose rate from the unshielded target module estimated by the SNS Neutronics Team is about 300 R/hr at a distance of 30 cm from the nose [5]. Predicted in-air dose rates associated with the bounding target case are on the order of ~15,000R/hr [6].

Target 11 radionuclide activities for the stainless steel module combined with the residual mercury and spallation products have been calculated by the SNS Neutronics Team and are presented in Reference 7 for decay times ranging from 1 day to 10 years. Neutronics analysis also estimates TGT 11 decay heat production to be ~ 5 Watts (60 day decay) [8]. It should be noted that the DOT license for the TN-RAM cask sets a limit of 300 Watts for cask shipments.

Radionuclide activities associated with the bounding target case are presented in Reference 2. Heat generation for the bounding target case is calculated to be ~125 W after a 30 day decay [8] which is a factor of two lower than the allowable heat loading for a TN-RAM cask shipment.

4. SNS Safety Assessment

4.1 Hazards Associated with Planned Interim Storage Spent Module Handling

SNS has significant experience in the loading of spent modules within the cask liner, inserting the liner into the TN-RAM shipping cask and lifting the shipping cask with the 50-ton crane. Nine spent modules have been shipped to date. Hazards associated with loading the spent module into the TMSC will be the same as those associated with a routine spent module shipment except that the TMSC provides less shielding than the TN-RAM cask.

Predicted dose rates associated with the storage of TGT-11 within the TMSC have been calculated to be less than 10 mrem/hr at a distance of 30 cm by the SNS Neutronics Team [9]. For the bounding target case, dose rates as high as 350 mrem/hr at a distance of 30 cm are predicted [9]. Hazards associated with external dose rates of this magnitude are safely and routinely managed under the provisions of ORNL SBSM Radiological Protection Program using controls such as area postings, RWPs, and Rad Worker Training.

The process of lifting the cask to high bay has inherent risk that are minimized by 1) use of the Credited NOG-1 50-ton High Bay crane and 2) following SBMS on Hoisting and Rigging which includes provisions for lift plan reviews, equipment validation and the use of trained operators. Lifting the cask will be considered a Critical Lift as defined in the ORNL SBMS.

For High Bay storage, the module will be stored in a pre-approved location near the crane airlock doors well away from the floor region covering the mercury process loop and core vessel (see Figure 9). Placing the cask at the airlock end of the High Bay ensures that any postulated accidental dropping or tipping of the cask could not possibly impact the mercury loop components. The High Bay floor is designed for a static loading of 4,000 lb/ft^2 [9c, 9d]. An engineering review shows that the loaded cask floor loading is 3,962 lb/ft^2 [9e] based on a loaded weight of 51,412 lbs. While the cask loaded with a spent module just meets the static floor loading requirement, should the cask be loaded to its maximum capacity (9,500 lb), the floor loading would be 4,240 lb/ft^2. To ensure sufficient floor loading margin, dunnage or other suitable load-distributing structure that distributes the cask weight over a minimum of 13.75 ft^2 is required [9f].

The High Bay Floor forms the ceiling of the Service Bay and serves as both a fire barrier and as a separation barrier to prevent combustibles from entering the Service Bay area during a seismic event. The High Bay floor (Service Bay ceiling) is designed to remain in place following a PC-3 seismic event for the purpose of preventing combustible material in the High Bay from entering the Service Bay. A seismic stability analysis has been completed [9d] that shows the loaded cask could be expected to slide laterally (~ 3 inch distance) but would not tip over during a PC-3 seismic event. It is therefore concluded that locating the cask in the high bay in the general region indicated on Figure 9 does not create the potential to interfere with ability of the High Bay Floor to perform its isolation function during a PC-3 seismic event.

As captured in the cask handling steps outlined in Section 1 above, the TMSC lid will be installed and removed from the loaded TMSC using the 50-ton crane with the TMSC on the basement cask cart. Dose rates near the open cask lid will be surveyed by RCTs prior to allowing worker access and are predicted to be ~ 90 mrem/hr for TGT 11 and as high as 2,800 mrem/hr for the bounding target case [10]. Because the inner linear is sealed with a neoprene gasket, it is expected that vapors will be contained within the liner. However, it could be postulated that the liner gasket fails and allows Hg vapor to come in equilibrium within the cask volume.

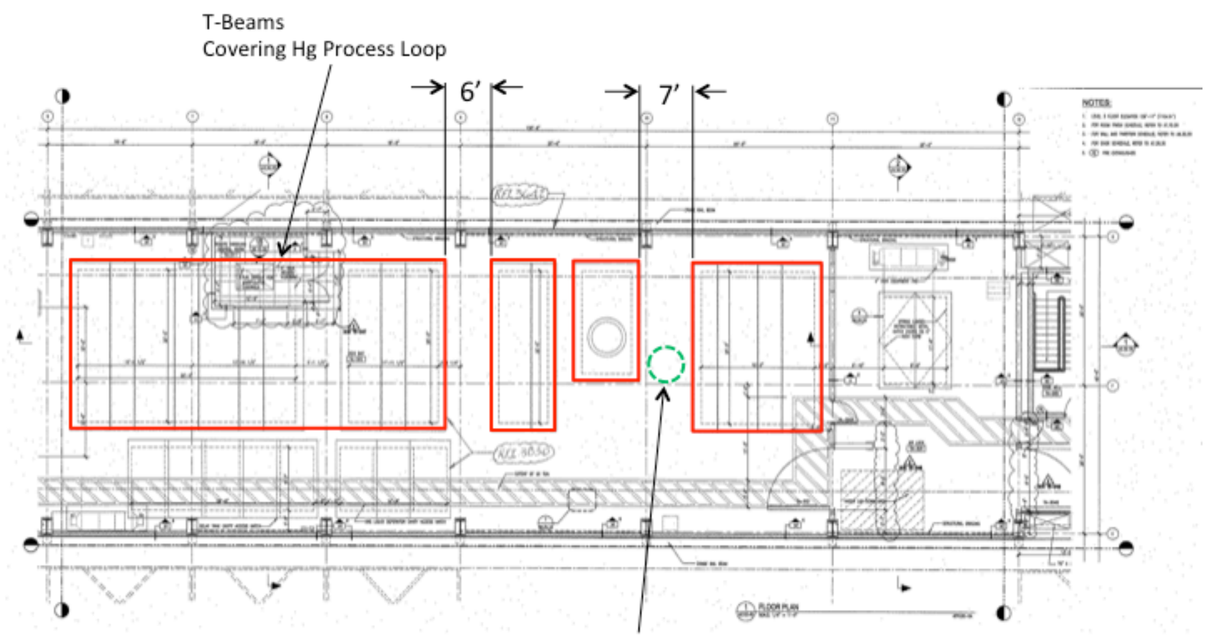

Figure 3. Proposed High Bay Storage Location

Figure 9. Proposed High Bay Storage Location

Equilibrium mercury vapor concentration inside of the liner/storage cask can be estimated based on a mercury vapor pressure of 0.284 Pa at 300K [11] using the Ideal Gas Law:

$$PV=nRT$$

where:

P = 0.284 Pa
V = Volume (m3)
n = # of moles of Hg
R = 8.314 J/K-mol
T = Absolute temperature = 300K

Rearranging the equation and using Hg atomic mass = 200.59 amu, 1 Pa = 1kg/m-sec^2, and 1 J = 1 kg-m^2/sec^2 , we obtain the following:

$$\frac{P}{RT} = \frac{n}{V}$$

$$\frac{P}{RT} = \frac{0.284\,Pa}{8.314\frac{J}{K-mol}\cdot 300K} = 1.14x10^{-4}\frac{Pa\cdot mol}{J}\cdot\frac{1\,J}{\frac{1kg\cdot m^2}{sec^2}}\cdot\frac{\frac{1kg}{m\cdot sec^2}}{1\,Pa}$$

$$= 1.14x10^{-4}\frac{mol}{m^3}\cdot\frac{200.59\,g}{mol} = 0.023\ \frac{g}{m^3}$$

Conservatively assuming that the inner liner and target module only occupy ~25% of the volume within the inner cask cavity, we can estimate the amount of Hg vapor within the TMSC at equilibrium:

$$Free\ Vol_{TSC} = (1-25\%)\cdot\pi\cdot R^2\cdot H = 0.75\cdot\pi\cdot\left(\frac{35in}{2}\right)^2\cdot 110in\cdot\frac{1.64x10^{-5}m^3}{in^3} = 1.3m^3$$

The total amount of Hg vapor present within the TMSC at equilibrium would be 0.03g.

Any such release from the cask would quickly disperse within the volume of the cask cart room volume of ~14,511.4 ft^3 (411 m^3) [12]. Assuming no ventilation (room normally well ventilated under negative pressure from SCE) and no plating or condensation, equilibrium vapor concentrations within the cask cart room could reach about 0.07 mg/m^3 which is well below FSAD ERPG-3 criteria of 4 mg/m^3 and below the OSHA ceiling of 0.1 mg/m^3 [13]. Levels of this magnitude are safely and routinely managed under the provision or the ORNL SBMS. None-the-less, it would be prudent to monitor for mercury vapor as the lid is lifted to ensure worker protection.

4.2 Accidents

Radiological hazards associated with the interim storage of the spent module includes direct exposure to the activated module and/or the residual Hg and Spallation Products and exposure to airborne residual Hg and/or spallation products. Such radiological exposures could occur from various scenarios that can be postulated leading to a release from the cask. Fire is considered the only credible means to drive a significant fraction of the material airborne.

Handling of a spent target module outside of the Service Bay is part of the normal workflow associated with SNS operations and is addressed in the FSAD-NF. The FSAD addresses release of radiological material within the building due to a transfer cask leak (Event HB3-1), transfer cask leak caused by dropping the cask (Event HB3-2) and direct exposure from inadvertent removal of shielding from highly activated component (HB4-3). The ORNL SBMS Hoisting and Rigging Program and Radiological Protection Program are credited with mitigating risk associated with these events.

The FSAD-NF provides a limit of 19.4 kg of process mercury stored outside of the Service Bay but within the Target Building (FSAD-NF Sections 4.3.1 and 4.4.3.14) based on potential Hg toxicity (not radiological) hazards to staff associated with a facility fire (based on Event TS1-3 and TS1-6). The spent target module is conservatively assumed to contain 200 grams of mercury residue, which is well within the FSAD-NF assumed 19.4 kg limit. The 19.4 kg process mercury limit established in the FSAD-NF is assumed to have a maximum process mercury activity (activation and spallation products) after an assumed 40-year facility lifetime of 2 MW operations.

4.2.1 Fire - Accidental Release of Radioactive Material

Fire hazards within the Target Building are mitigated by the building Fire Detection/Suppression System (Credited Engineered Control) and by the SNS Combustible Material Control Program (Credited Administrative Control). With these controls in place, a fire of sufficient magnitude to significantly heat the spent module within the massive cask and liner (48,000 lbs of steel and lead) is not credible. None-the-less the relative hazards associated with a fire engulfing the TSMC can be compared to those analyzed in the FSAD-NF for a fire event involving 19.4 kg of process Hg.

It is assumed that the residual mercury and spallation products could potentially vaporize if sufficiently heated; however, the activated stainless steel module is not expected to significantly vaporize in such a fire. The relative radiological hazard potential associated with a release of radioactive material from the spent module can be compared to that associated with the inventory of 19.4 kg of process mercury assumed in the FSAD-NF by using Hazard Category 3 (HC3) nuclide specific threshold activity values presented in DOE Standard 1027 [14].

While DOE Standard 1027 is not applicable to the SNS accelerator facility, its nuclide specific threshold values may serve as a useful tool for comparing relative potential radiological hazards associated with different radionuclide inventories. Nuclide specific HC3 threshold values represent levels of material which, if released, would result in a 10 Rem dose to an individual located 30 meters downwind based on EPA methodology presented 40 CFR 302.4. The relative potential hazard of a single isotope (i) can be assessed by taking the ratio of the radionuclide present to the HC3 threshold activity value. The relative radiological hazard figure of merit of an inventory with multiple (n) nuclides can be measured by summing the HC3 ratios for the individual nuclides:

$$Relative\ Radiological\ Hazard\ Figure\ of\ Merit = \sum_{i}^{n} \frac{A_i}{HC3_i}$$

where:

A_i = Activity of nuclide i in the inventory, and

$HC3_i$ = DOE Standard 1027 HC3 threshold activity for nuclide i

The relative radiological hazard figure of merit has been calculated as described above for 60 day and 120 day decay times for Target 11 based on nuclide inventories and nuclide specific $HC3_i$ ratios provided by the SNS Neutronics Team [15]. Table 2 show an example determination of the relative radiological hazard figure of merit for the 200 g mercury associated with TGT 11. Isotopes that make up 99 % of the relative radiological hazard figure of merit HC3 are presented. Table 3 provides a summary of relative radiological hazard figures of merit for the residual mercury and spallation products associated with TGT-11 after 60 and 120 day decay times.

Table 2. Example figure of merit determination for 200 g Hg associated with TGT-11

Isotope	Activity, A_i (Ci)	$HC3_i$ (Ci)	Ratio (A_i / $HC3_i$)
GD-148	9.16E-05	8.20E-02	1.12E-03
Hg-203	6.09E-02	3.60E+02	1.69E-04
I-125	5.40E-05	5.60E-01	9.64E-05
Hf-172	6.72E-03	9.40E+01	7.15E-05

Hg-194	4.97E-04	1.16E+01	4.29E-05
Au-195	6.34E-02	3.20E+03	1.98E-05
Lu-172	6.79E-03	4.80E+02	1.41E-05
		Total	**1.53E-03**

Table 3. Target Module 11 Relative Radiological Hazard Figure of Merit

Target 11 Module	60 day decay	120 day decay
Residual Process Mercury (200g)	0.0015	0.0014
Spallation Product Residue	0.60	0.57

The stainless steel module does not significantly contribute to any airborne release scenario (e.g. facility fire, dropping of the cask, cask leak, etc.). Therefore the relative radiological hazard figure of merit for a potential release associated with the spent module TGT11 is obtained by summing the ratios associated with the residual mercury and spallation products; 0.0015 + 0.60 = 0.6015.

The value can be compared to the relative radiological hazard figure of merit associated with the 19.4 kg of process mercury assumed in the FSAD-NF with its maximum activity at end of facility life (40 years of operations and 30 minute decay). The relative radiological hazard figure of merit for the 19.4 kg of 40-yr mercury has been calculated to be 3.06 based on nuclide inventories and nuclide specific $HC3_i$ ratios provided by the SNS Neutronics Team [16].

Therefore; the relative radiological hazard potential associated with a release from the TGT-11 is below that associated with the 19.4 kg of 40-yr process mercury by a factor of 0.6015/3.06 = 0.20.

An identical analysis was performed for the bounding target case. The assumed residual mercury and spallation products within the bounding target case are significantly more radioactive for TGT 11 because the bounding target module is assumed to occur at end-of-facility life, after 40 years of SNS operations. The mercury and associated spallation products within the mercury loop continue to increase in activity over years of SNS operations. At end-of-life, the process mercury loop is assumed to have an integrated beam of 40yrs x 2 MW x 5,000 hr/yr = 4.0 x 10^5 MW-hrs. By contrast, the process mercury loop for the TGT 11 case had an integrated beam of 2.4 x 10^4 MW-hr. The relative radiological hazard figure of merit for the bounding case has been calculated to be 7.87 after a 30 day decay; more than a factor of two higher than the 3.06 value associated with the 19.4 kg of Hg assumed in the FSAD-NF.

The analysis presented here applies to the storage of future spent target modules with mercury and spallation product residue having relative radiological hazard figure of merit of less than 3.06. Since the bounding module case exceeds this value, this analysis does not extend to the bounding case. The radiological hazard figure of merit must be assessed for each future target prior to interim storage to determine applicability of this USI Evaluation. Additional analysis under the USI Process will be required to address interim storage of modules whose residual mercury and spallation product figure of merit exceeds 3.06.

4.2.2 Cask Damage (e.g. Crane Drop, impact knocks over cask, etc.)

A Cask drop could potentially lead to a breach of the cask/liner potentially exposing the bare target module. As with the TN-RAM cask, such an event would be immediately recognized as an emergency and personnel in affected areas would be quickly evacuated from the affected area and appropriate response planning would ensue. A crane drop of a loaded transfer cask has been analyzed in the FSAD-NF (High Bay event HB3-2) and deemed to require the following credited controls: 1) High Bay Crane Design and 2) adherence to the ORNL SBMS Hoisting and Rigging Program. The High Bay Crane is designed in compliance with ASME NOG-1 and has been constructed and Tested in accordance with the requirements of NUREG 0554, Single Failure Proof Cranes for Nuclear Power Plants. The ORNL Hoisting and Rigging Program addresses review of lifts, use of lifting equipment and use of properly trained operators. As with the TN-RAM shipping cask, lifting of the TMSC would be handled as a Critical Lift as defined in the ORNL SBMS. These same credited controls are in place and provide assurance against a crane drop accident when lifting the TMSC.

4.2.3 Cask Leak

A cask leak could be postulated due to factors leading to a degraded condition cause by mechanical shock (e.g. striking cask with moving crane load, impact, topple-over, etc.) or corrosion and/or lid gasket failure. The spallation products are assumed to plate out on the inner surface of the module and are assumed fixed. The mercury within the module is assumed to adhere to the inner surface. Due to the all welded robust construction of both the liner and the TSCM, spontaneous leakage of mercury from the module into the liner and from the liner into the cask and with a resultant leak outside of the cask is not deemed credible.

A significant mechanical shock could cause some fraction of the assumed 200 g Hg within the module to be displaced from the module. Liquid mercury expelled from the module would fall into the liner which is pre-loaded with carbon amalgamation adsorbent powder. Mercury contacting the powder would be captured. A small fraction of the Hg assumed to reach the liner could be further be assumed to escape from the liner into the TSCM. Subsequent leakage of a small fraction of Hg that reaches the TSCM could also be assumed to leak for TSCM via a failed lid seal. The fraction of Hg that could credibly leak from the TSCM, even assuming significant mechanical shock is assumed to be low.

Rather than attempt to quantify the fraction of Hg that might be released from the cask in a credible accident scenario, the unrealistic but bounding case of assuming the entire 200 grams of Hg being spilt onto the floor is examined. Direct radiation levels from such a spill from TGT-11 would be on the order of 1 R/hr at 30 cm (based on 60 day decay) [17]. Dose rates associated with the a spill from the bounding target module case can be estimated based on the relative source strength photon intensity for Hg associated with the bounding target module which is a factor of 7 seven higher than that of TGT-11 [18]. The resulting dose rate estimate associated with a bare 200 gram Hg puddle from the bounding target module is 7 x 1 R/hr = 7 R/hr at a distance of 30 cm (30 day decay). Radiation hazards associated with dose rates in this range (1 to 10 R/hr) are safety and routinely managed by the provisions of ORNL SBMS on Radiological Safety.

As described above, a spontaneous leak from the cask is not assumed to be credible; it assumed that an energetic event would be required for leakage and that the energetic event would be quickly identified and timely remedial actions taken which would include area evacuation upon discovery of a breach of the cask. Mercury has an evaporation rate of 0.056 mg/hr-cm^2 [19] and both candidate storage locations are maintained at a negative pressure and ventilated through the Secondary Confinement Exhaust System. Assuming a 200 gram (14.8 cm^3) Hg spill, the amount of Hg that would evaporate in an hour assuming a puddle depth of 0.1 cm (FSAD-NF Section 4.4.1.2.2 assumes 1 cm depth for fire analysis); the rate of Hg evaporation would be (0.056 mg/hr-cm^2) x (14.8 cm^3/0.1 cm) = 8.2 mg/hr. If we conservatively assume the spill to be located in the Cask Cart room (free volume = 14,511 ft3 = 411 m^3 [12]); and assume no ventilation or air exchange, it would take about over 5 hours before the OSHA level of concern of 0.1 mg/m^3 [13] could be reached and 8.3 days before levels approaching 4 mg/m^3 (ERPG-3) could be reached. Therefore ample time exists to allow proper response to the event before Hg vapor could reach levels of concern.

4.2.4 Inadvertent Removal of Shielding – Removal of Cask Lid

Planned handling of the TMSC involves the eventual removal of the cask lid with the 50-ton crane just prior to mating the TMSC to the bottom loading port and the subsequent lifting of the liner into the Service Bay with the in-cell crane. Inappropriate removal of the TMSC cask lid could be postulated while the cask is in interim storage either in the High Bay or in the Cask Cart Room, however, such an action would require 1) the deliberate act of unbolting the lid, 2) an approved lift plan, 3) approved radiation work permit, 4) authorized use of the crane control pendant, and 5) the use of qualified crane operators to perform the lift. Even in the highly unlikely case that inadvertent removal of the cask lid is postulated, dose rates would be mitigated by the shielding provided by the liner lid and would be highly collimated out the top of the cask. It is not deemed credible to further assume that the liner would be removed from the cask (except when lifting into the Service Bay).

Installed radiation monitors in the area include a gamma radiation monitor located on the wall above the Gas/Liquid Separator tank cavity and two Chipmunks located in the RTBT area near the CMS cold box. These monitors would alarm on excessive radiation levels.

Estimated dose rates above the liner with the TMSC lid removed are less than 90 mrem/hr for TGT 11 and about 2,800 mrem/hr for the bounding target case [10]. Dose rates above the liner will be measured by RCTs after the liner has been loaded into the cask and prior to installing the cask lid; therefore the measured dose rates will be known prior to storing the cask.

As noted above, the FSAD-NF addresses inappropriate removal of shielding from highly activated components (HB4-3) and credits the ORNL Radiological Protection Program for providing the needed protections. Heavily shielded components with dose rates of this magnitude are safety managed under the provision of the ORNL SBMS Radiological Protection Program.

5. Summary of TGT 11 and Bounding Spent Module Assumptions

A bounding spent target module case has been analyzed for shipping purposes. It is assumed that the bounding spent target module undergoes 2,500 MW-hrs irradiation at 2 MW followed by a 30 day decay with a residual 200 gram Hg and Spallation Products calculated at their maximum activities associated with the end of facility life (40 yr operations) [2]. Table 4 below provides a listing of some parameters of interest for the TGT 11 and the bounding target module.

Table 4. TGT 11 and Bounding Target Parameter Comparison

Parameter	TGT 11 (60 day decay)	Bounding Target Module (30 day decay)

Integrated Module Exposure	167 MW-hr	10,000 MW-hr
Integrated Exposure of Mercury Process System	2.4×10^4 MW-hr	4.0×10^5 MW-hr
Bare Module In-Air Dose Rate	300 R/hr @ 30 cm	15,000 R/hr @ 30 cm
Bare 200 gram Hg Puddle In-Air Dose Rate	1 R/hr @ 30 cm	7 R/hr @ 30 cm
Maximum Dose Rate External to TMSC	9 mrem/hr @ 30 cm	350 mrem/hr @ 30 cm
Dose Rate above cask liner lid	90 mrem/hr	3.5 Rem/hr
HC-3 Figure of Merit (Hg + SPs)	0.602	7.87
Heat Generation	5 W	125 W

6. Summary and Conclusions

The analysis above considered potential hazards associated with both the specific case of TGT 11 and the bounding target module case. Hazards associated with planned handling of the spent target module and accident scenarios including fire, dropping the cask from the 50-ton crane, and direct exposure to the target module and spilled Hg have been evaluated. The analysis above shows that interim storage of the interim spent target module is bounded by the existing accident analysis presented in the SNS FSAD-NF. This analysis specifically evaluates Target Module 11; however is applicable to other target modules drained of mercury as described in Section 3 above and the relative radiological hazard figure of merit (per Section 4.2.1) total for assumed residual Hg and Spallation Products must be less than 306 %; this could include more than one drained target module provided the sum totals remain below 306 %. As determined in Section 4.1, dunnage or other suitable load-distributing structure that distributes the cask weight over a minimum of 13.75 ft^2 is required for storage of casks in the designated area of the high bay.

The bounding target module case is not covered by the existing analysis because the relative radiological figure of merit for the associated mercury and spallation products exceeds the criteria. It should be noted that several more years of high power operations will be required before the relative activity of the process Hg and spallation products associated with target modules will begin to approach a relative radiological hazard figure of merit nearing 300 %.

Because of the potential to release Hg vapor when removing the lid from the TSMC in preparation for unloading of the cask, it would be prudent to measure mercury vapor levels as the lid removed. As stated in Section 1, a written procedure that specifically addresses loading/unloading and handling of the TMSC is to be approved for use prior to loading the TMSC.

III. Does the proposed activity or discovered condition affect information presented in the FSAD-NF or FSAD-PF, e.g. regarding equipment, administrative controls, or safety analyses. If so specify the applicable FSAD and relevant sections.

The FSAD-NF addresses information relative to the presence and handling of a spent target module within a transfer cask within the building but outside of the Service Bay in Sections 4.3.1 and 4.4.3.14. The FSAD-NF addresses potential accidents leading to the release of radioactive material from a transfer cask. Interim storage of a spent target module within the Target Building is consistent with information provided in the FSAD-NF as shown above.

Handling of a spent target module outside of the Service Bay is part of the normal workflow associated with SNS operations and is addressed in the FSAD-NF. The FSAD addresses release of radiological material within the building due to a transfer cask leak (Event HB3-1), transfer cask leak caused by dropping the cask (Event HB3-2) and direct exposure from inadvertent removal of shielding from highly activated component (HB4-3). The ORNL SBMS Hoisting and Rigging Program and Radiological Protection Program are credited with mitigating risk associated with these events.

No FSAD-NF revisions are required to support the proposed interim storage of the target module. During the next revision of the FSAD-NF, consideration should be given to the merits of adding a statement addressing spent module storage within the building.

IV. Does the proposed activity or discovered condition affect any of the requirements of the ASE. If so, list the affected sections

Interim storage of a spent target module within the Target Building but outside of the Service Bay does not affect any of the ASE requirements. The ASE addresses requirements for the Target Building Fire Suppression System, the High Bay Crane, the facility Combustible Material Control Program; and the ORNL SBMS Radiological Protection Program all of which provide protections beneficial to the safe handling and storage of a target module/cask within the facility.

V. USI Evaluation Criteria:

1. Could the change significantly increase the probability of occurrence of an accident previously evaluated in the FSADs? Yes __ No_x_
   Justification: (use attachment if necessary)

   The proposed interim storage of a spent target module within the above described cask liner and TMSC does not significantly increase the probability of accidents evaluated in the FSAD. Related accidents addressed in the FSAD-NF include fire that could vaporize process Hg, crane drop of the cask, cask leak, and direct radiological exposure from inadvertent removal of shielding. The probability of these accidents occurring is not significantly affected by the proposed interim storage of a target module. The probability of fire is unaffected as the TMSC does not increase combustible loading or provide any ignition source. The probability a cask mishandling accident leading to a material release or the inadvertent removal of shielding is not increased over that already assumed for the TN-RAM. Credited Controls already in place (Target Building Fire Suppression System, the High Bay Crane, the facility Combustible Material Control Program; and the ORNL SBMS Radiological Protection Program) serve to protect against potential accidents involving interim storage of a target module as described above.

2. Could the change significantly increase the consequences of an accident previously evaluated in the FSADs? Yes__ No _x_
   Justification: (use attachment if necessary)

   The proposed interim storage of a spent target module as described above does not significantly increase the consequences of any accident evaluated in the FSAD. Related accidents addressed in the FSAD-NF include fire that could vaporize process Hg, crane drop of the cask, cask leak, and direct radiological exposure from inadvertent removal of shielding. The potential consequences of a fire event as shown above are bounded by the SNS fire accident involving 19.4 kg of process mercury for spent target modules with relative radiological hazard figure of merit less than 3.06. Potential consequences associated with a cask drop, cask leak or direct radiological exposure from the inadvertent removal of the cask lid of these accidents occurring are not significantly increased by the proposed interim storage of a target module. Credited Controls already in place (Target Building Fire Suppression System, the High Bay Crane, the facility Combustible Material Control Program; and the ORNL SBMS Radiological Protection Program) serve to protect against potential accidents involving interim storage of a target module as described above.

3. Could the change significantly increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the FSADs?

Yes__ No _x_
Justification: (use attachment if necessary)

The probability of a malfunction of equipment important to safety as evaluated in the FSAD is not significantly increased. Equipment important to safety related to the proposed interim storage of a spent target module includes the Target Building Fire Suppression System, the High Bay Crane; all of which are credited controls. The probability of a malfunction of one of these systems is not affected by the proposed interim storage of a spent target module.

As addressed above, if the TMSC is to be stored in the High Bay, it will be located on the available floor towards the rear of the High Bay near the airlock doors, well away from the floor area above the mercury process loop. FSAD-NF Section 5.2.12 *High Bay Floor* addresses the removable T-beams that cover the Service Bay and Core Vessel. The High Bay floor serves as a credited control with the purpose of resisting failure modes that would allow a dropped load to fall on the mercury process system. The probability of damaging the High Bay Floor with a crane drop is not increased significantly beyond that already considered to be associated with the lifting of other loads (e.g. TN-RAM cask) within the High Bay. Additionally, the TMSC will only be handled (lifted) and stored at the rear of the High Bay, well away from the mercury process system such that even in the highly unlikely event that the cask is dropped or tipped over by a crane load, it could not affect the mercury process system. Following the provisions of the credited ORNL Hoisting and Rigging Program minimizes the probability of a crane accident.

FSAD-NF Section 5.2.3 *Target Service Bay/Core Vessel Fire Barrier - Isolation Function* addresses the credited fire barrier and separation function of the Service Bay. The High Bay Floor forms the ceiling of the Service Bay and serves as both a fire barrier and as a separation barrier to prevent combustibles from entering the Service Bay area during a seismic event. The High Bay floor (Service Bay ceiling) is designed to remain in place following a PC-3 seismic event for the purpose of preventing combustible material in the High Bay from entering the Service Bay. The seismic stability analysis [9b] shows that storage of the TMSC in the High Bay will not compromise the ability of the High Bay Floor to perform its isolation function is required to ensure TMSC storage does not put the High Bay floor at risk during a PC-3 event.

4. Could the change significantly increase the consequences of a malfunction of equipment important to safety previously evaluated in the FSADs?

Yes__ No _x_
Justification: (use attachment if necessary)

Consequences associated with a malfunction of equipment important to safety as evaluated in the FSAD-NF are not significantly impacted by the proposed interim spent module storage. Equipment important to safety related to the proposed interim storage of a spent target module includes the Target Building Fire Suppression System and the High Bay Crane; both of which are credited controls. Consequences associated with failure of the FSS within the bounds of fire accidents already evaluated in the FSAD-NF. Consequences associated with failure of the High Bay Crane are within the bounds of transfer cask crane drop accidents already evaluated in the FSAD-NF.

5. Could the change create the possibility of a different type of accident than any previously evaluated in the FSADs that would have potentially significant safety consequences? Yes__ No _x_
   Justification: (use attachment if necessary)

   No new accidents scenarios are introduced by the proposed interim spent module storage. Accidents associated with facility fires and transfer cask activities including crane drops, cask leaks and inadvertent removal of shielding are presently evaluated in the FSAD-NF.

6. Could the change increase the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the FSADs?

   Yes__ No _x_
   Justification: (use attachment if necessary)

   No new types of malfunctions to equipment important to safety are introduced by the proposed interim spent module storage. Equipment important to safety related to the proposed interim storage of a spent target module includes the Target Building Fire Suppression System, High Bay Crane and the High Bay Floor. No new types of malfunctions are introduced to this equipment is introduced by the proposed spent module interim storage.

VI. USI Determination: A USI is determined to exist if the answer to any of the 6 questions above (Section V) is "Yes." If the answer to all 6 questions is "No", then no USI exists.

a. Does the proposed activity (or discovered condition) constitute a USI?

__ Yes – DOE approval required prior to implementing
_x_ No – Proposed activity may be implemented with appropriate internal review.

______________________________ ______________
David Freeman, Qualified Preparer Date

______________________________ ______________
Mike Harrington, Qualified Reviewer Date

______________________________ ______________
Steve Trotter, Reviewer Date

______________________________ ______________
Mike Dayton, Reviewer Date

______________________________ ______________
Franz Gallmeier, Reviewer Date

______________________________ ______________
Don Gregory, Reviewer Date

Approvals: ______________________________ ______________
Signature of SNS Operations Manager or Designee Date

5. Could the change create the possibility of a different type of accident than any previously evaluated in the FSADs that would have potentially significant safety consequences? Yes__ No _x_
   Justification: (use attachment if necessary)

   No new accidents scenarios are introduced by the proposed interim spent module storage. Accidents associated with facility fires and transfer cask activities including crane drops, cask leaks and inadvertent removal of shielding are presently evaluated in the FSAD-NF.

6. Could the change increase the possibility of a different type of malfunction of equipment important to safety than any previously evaluated in the FSADs?

   Yes__ No _x_
   Justification: (use attachment if necessary)

   No new types of malfunctions to equipment important to safety are introduced by the proposed interim spent module storage. Equipment important to safety related to the proposed interim storage of a spent target module includes the Target Building Fire Suppression System, High Bay Crane and the High Bay Floor. No new types of malfunctions are introduced to this equipment is introduced by the proposed spent module interim storage.

VI. USI Determination: A USI is determined to exist if the answer to any of the 6 questions above (Section V) is "Yes." If the answer to all 6 questions is "No", then no USI exists.

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__ Yes – DOE approval required prior to implementing

_x_ No – Proposed activity may be implemented with appropriate internal review.

David Freeman, Qualified Preparer	March 20, 2015 Date
Mike Harrington, Qualified Reviewer	3/20/2015 Date
Steve Trotter, Reviewer	3/27/2015 Date
Mike Dayton, Reviewer	3-23-2015 Date
Franz Gallmeier, Reviewer	3-26-2015 Date
Don Gregory, Reviewer	30 MARCH 2015 Date

Approvals: Signature of SNS Operations Manager or Designee — 31 MARCH 2015 Date

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