UNIVERSITY of MISSOURI

RESEARCH REACTOR CENTER

January 16, 2018

U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Mail Station P1-37
Washington, DC 20555-0001

REFERENCE: Docket 50-186
University of Missouri-Columbia Research Reactor
Renewed Facility Operating License No. R-103

SUBJECT: Written communication as specified by 10 CFR 50.4(b)(1) regarding responses to the "University of Missouri at Columbia - Request for Additional Information RE: License Amendment Request to Implement Selective Gas Extraction Target Experimental Facility at the University of Missouri Research Reactor (CAC A11010/05000186/L-2017-LLA-0227)," dated November 1, 2017

By letter dated May 3, 2017, the University of Missouri Research Reactor (MURR) submitted a license amendment request (LAR) to the U.S. Nuclear Regulatory Commission (NRC) in order to conduct an experiment that would produce molybdenum-99 (Mo-99) in large quantities as part of its role in supplying critical medical radioisotopes to the domestic and international community. The experiment would utilize General Atomics' (GA) Selective Gas Extraction (SGE) process, which consists of irradiating target rods containing low-enriched uranium (LEU) pellets in the reactor graphite reflector region in order to produce fission product Mo-99. The Mo-99 would then be extracted from the LEU in dedicated hot cells using the SGE technology. Included with the LAR submittal was eight (8) attachments, six (6) of which contained proprietary information which was withheld from public disclosure pursuant to 10 CFR § 2.390.

By letter dated June 19, 2017, MURR submitted two (2) additional attachments (Attachment 9 – GA Design Report 30441R00038, "Computational Fluid Dynamics Analysis of Target Housing Design Calculation Report," and Attachment 10 – GA Design Report 30441R00041, "Critical Heat Flux Testing at the University of Wisconsin Final Report") to supplement the May 3, 2017 submittal to further assist the NRC in review of the LAR. One version of each attachment contained proprietary information which was withheld from public disclosure pursuant to 10 CFR § 2.390.

By letter dated September 7, 2017, the NRC requested additional information and clarification regarding the proposed LAR in the form of thirty-eight (38) questions (numbered 1 through 38).

A020
NRR

1513 Research Park Drive Columbia, MO 65211 Phone: 573-882-4211 Fax: 573-882-6360 Web: http://web.missouri.edu/~murrwww

By letter dated October 17, 2017, MURR submitted one (1) additional attachment (Attachment 11 – GA Design Report No. 30441R00045, "Target Cooling System Flow Test Report") to supplement the May 3, 2017 submittal to further assist the NRC in review of the LAR. One version of the attachment contained proprietary information which was withheld from public disclosure pursuant to 10 CFR § 2.390.

By letter dated November 1, 2017, the NRC requested additional information and clarification regarding the proposed LAR in the form of eighteen (18) questions (numbered 39 through 57).

By letter dated December 6, 2017, MURR responded to the September 7, 2017, request for additional information (Questions 1 through 38).

Below are MURR's responses to the November 1, 2017, request for additional information (Questions 39 through 57), including enclosures of supporting documentation. Additionally, there is a correction to the response to RAI No. 3.3, which was submitted to the NRC by letter dated December 6, 2017.

If there are questions regarding these responses, please contact me at (573) 882-5118. I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

Bruce Meffert
Reactor Manager

ENDORSEMENT:
Reviewed and Approved

Matthew R. Sanford
Interim Director

xc: Reactor Advisory Committee
Reactor Safety Subcommittee
Isotope Use Subcommittee
Dr. Mark McIntosh, Vice Chancellor for Research, Graduate Studies and Economic Development
Mr. Alexander Adams Jr., U.S. Nuclear Regulatory Commission
Mr. Geoffrey A. Wertz, U.S. Nuclear Regulatory Commission
Mr. Johnny Eads, U.S. Nuclear Regulatory Commission

Enclosures:

1. General Atomics Report 30441R000030, "*Mo-99 Target Cooling System Seismic Analysis Design Report*," Rev. A, 11 January 2017

State of Missouri
County of Boone
Subscribed and sworn to before me this 16 day of January, 2018

JACQUELINE L. MATYAS, Notary Public
My Commission Expires: March 26, 2019

NOTARY PUBLIC
NOTARY SEAL
STATE OF MISSOURI

JACQUELINE L. MATYAS
My Commission Expires
March 26, 2019
Howard County
Commission #15634308

LAR Attachment 1

39. *LAR, Attachment 1, Section 3.4.3, "Structural Performance During a Seismic Event," provides analyses of the target experimental facility (TEF) response to two seismic events. The results of the analyses imply that the integrity of the TEF piping and components will be maintained during the analyzed seismic events. However, the description of the analyses does not provide an overall conclusion as to the operability of the TEF to a seismic event, or the consequences of any accident from a seismic event. Furthermore, the NRC staff did not find any discussion of any other external events which could impact the operation of the TEF, such as fire, floods, high winds, or human-created events such as toxic releases or explosions.*

    The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, NUREG-1537, Part 1, Chapter 3.4, "Seismic Damage," provides guidance that the applicant should provide reasonable assurance that the reactor, and TEF, can be shutdown, and maintained in a safe condition, and that all potential consequences from a seismic event are bounded by the results of the safety analysis or within NRC limits. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 13, "Accident Analyses," states that the facility design should be able to accommodate any postulated external events.

    39.1. *Provide a description indicating that the seismic design of the TEF can provide reasonable assurance that both the reactor and TEF can be shutdown and remain in a safe condition, or justify why no additional information is needed.*

Based on the seismic design of the Target Cooling System (TCS) [Refs. 39-1, 39-2 (Enclosure 1)] and the reactor pool biological shield [Ref. 39-3], the Target Experimental Facility (TEF) and its TCS should remain intact following a seismic event. Should a seismic event cause a loss of electrical power to the TCS pumps, the consequences would be the same as the Loss of Pump Flow analysis presented in Reference 39-4. In the extremely unlikely case that a seismic event does cause a break in the TCS piping, the consequences are the same as the Loss of Coolant Accidents discussed in Reference 39-5. In all cases, the TEF would shut down and be in a safe shutdown condition following the seismic event. Note: Reference 39-3 concluded that the MURR reactor pool/biological shield would remain structurally intact and filled with pool water following a seismic event as defined by the response spectrum methodology of Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants;" therefore, the reactor fuel elements and SGE target rods would remain covered by pool water after the design seismic event.

Reference 39-3 also states that the NRC concluded that the ground motion response spectra (GMRS) developed in the staff assessment is enveloped by the Safe Shutdown Earthquake (SSE) up to 16 Hz. The GMRS exceeds the SSE above this frequency; however, ground motions at higher than approximately 10 Hz are not damaging to the structures, systems, and components of a nuclear reactor except the functional performance of components sensitive to vibration, such as electrical relays. Every safety feature of the reactor and TEF has been designed to fail in "fail safe" mode. The relays would disengage due to high frequency vibration, similar to a loss of electrical power event, resulting in a

reactor scram and insertion of the control blades. The reactor will scram regardless of where the input signal to the reactor safety system is generated from; either parameters monitoring the reactor or the TEF.

The TEF is designed such that no TEF structures or components would prevent the reactor from shutting down and maintaining it in a safe condition during a seismic event. The reactor control blades are in a gap between the outer reactor pressure vessel and beryllium reflector. An electromagnet engages the control blade to its drive mechanism. A loss of electrical power or minor vibration will cause the control blades to disengage and scram the reactor well before any damage to the TEF would occur during a seismic event.

39.2. Provide a description that the potential consequences from a seismic event have been analyzed and the consequences are bound by the SAR, or within NRC limits, or justify why no additional information is needed.

As stated above, if a seismic event results in a loss of electrical power to the TCS pumps, the consequences will be the same as the Loss of Pump Flow analysis presented in Reference 39-4. In the extremely unlikely case that a seismic event does cause a break in the TCS piping, the consequences are the same as the Loss of Coolant Accidents discussed in Reference 39-5. Neither of these accident scenarios pose dose consequences greater than that analyzed for the TEF Maximum Hypothetical Accident (MHA) – a Total Effective Dose Equivalent of 428.38 mrem and 2.50 mrem in the restricted and unrestricted areas, respectively.

39.3. Provide the evaluation of any external events (other than seismic, such as fire, floods, high winds, or human-created events such as toxic releases or explosions.) which could impact the TEF operation. If not evaluated, provide a justification why no additional information is needed.

Chapter 2 and Section 13.2.8 of the MURR Safety Analysis Report (SAR) addresses the evaluation of external events for the facility. Since the TEF is located in the reactor containment building where the reactor is situated, the same conclusions can be reached for the TEF as for the reactor. SAR Section 13.2.8.3, Conclusions, states, "Based on meteorological, seismic and other characteristics of the region, it can be concluded with reasonable assurance that there are no geographic or demographic features that render the MURR site unsuitable for operation of the facility, and no accidents with consequences even approaching the MHA will be caused by external events related to the site or the region."

Additionally, Reference 39-3 provides an NRC staff assessment of the potential for damage of the reactor core from a wind-related phenomenon at the MURR reactor site using current tornado information given in Regulatory Guide 1.76, "Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants." The NRC staff concluded that it is unlikely that the reactor at the MURR facility will experience any substantial damage from a rigid tornado missile strike even from an extremely rare one.

References:

39-1 LAR Part 1, Attachment 1, "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor*," Section 3.4.3

39-2 General Atomics Report 30441R000030, "*Mo-99 Target Cooling System Seismic Analysis Design Report*," Rev. A, 11 January 2017

39-3 "University of Missouri at Columbia – Staff Assessment of Applicability of Fukushima Lessons Learned to University of Missouri - Columbia Research Reactor," ML15161A387, dated December 8, 2016

39-4 LAR Part 1, Attachment 1, "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor*," Section 10.7

39-5 LAR Part 1, Attachment 1 "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor*," Sections 10.5 and 10.6

40. *LAR, Attachment 1, Section 3.4.9, "Electrical Power System Supporting the TCS [Target Cooling System]," provides information on the electrical power distribution to the TCS. However, the NRC staff did not find any information describing any other auxiliary systems needed to support the TEF operation, changes to existing auxiliary systems needed to support the TEF operation, or if the installation or operation of the TEF affected auxiliary systems needed to operate the reactor.*

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. Furthermore, NUREG-1537, Part 1, Chapter 9, "Auxiliary Systems," provides guidance that the LAR should provide information on auxiliary systems that are important to the safe operation and shutdown of the reactor and to the protection of the health and safety of the public, the facility staff, and the environment.

40.1. Discuss or describe any auxiliary systems that are needed to support the operation of the TEF, or justify why no additional information is needed.

The air actuators on the Target Experimental Facility (TEF) Target Decay Heat Removal Valves (TDHRVs) – TDHRV-1A, TDHRV-1B, TDHRV-2A and TDHRV-2B – will require compressed air to operate. As described in Section 9.14.4, Valve Operation Air System, of the MURR Safety Analysis Report (SAR), the Valve Operation Air System supplies compressed air to the air-operated valves of the reactor plant. This same system will supply compressed air to the TDHRV air-actuators (air-operated-to-close, spring-to-open). The valve operation air compressor will automatically start when system pressure reduces to approximately 100 psig (689 kPa above atmosphere). The compressor will then automatically secure when pressure in the valve operation air system increases to approximately 115 psig (793 kPa above atmosphere). Since the Main Air System (See Section 9.14.2 of the SAR) is set to operate at a higher pressure, the valve operation air compressor does not typically run and is essentially a backup air supply to the Valve Operation Air System. However, should the Main Air System become inoperable or system pressure decrease below the set points of the Valve Operation Air System, the valve operation air compressor will assume the valve operation compressed air load and force shut a check valve in the air supply line from the Main Air System, isolating the Main Air System from the Valve Operation Air System. The check valve ensures that the valve operation air compressor will supply compressed air to only the Valve Operation Air System.

The TDHRVs will be located in the reactor pool, as are the current anti-siphon isolation valves V543A and V543B (See SAR Section 6.3.4) and the reactor's in-pool heat exchanger automatic isolation valves V546A and V546B (See SAR Section 5.8.3), at the refuel deck level approximately six (6) feet (1.8 m) below the pool surface.

No other MURR auxiliary systems other that the Valve Operation Air System and the Normal Electrical Power System will be needed to support TEF operation.

40.2. Discuss changes to any other auxiliary systems than the electrical system, needed to support the TEF operation, or justify why no additional information is needed.

As described in the response to RAI No. 40.1 above, operation of the Target Decay Heat Removal Valves (TDHRVs) will require compressed air from the Valve Operation Air System. Piping upstream of VOP-54 will be connected to the header that supplies compressed air to the reactor anti-siphon isolation valves V543A and V543B and in-pool heat exchanger automatic isolation valves V546A and V546B. Figure 40-1 shows the compressed air flow path from the existing Valve Operation Air System, and the solenoid-operated valves that will control compressed air to the TDHRV air-actuators.

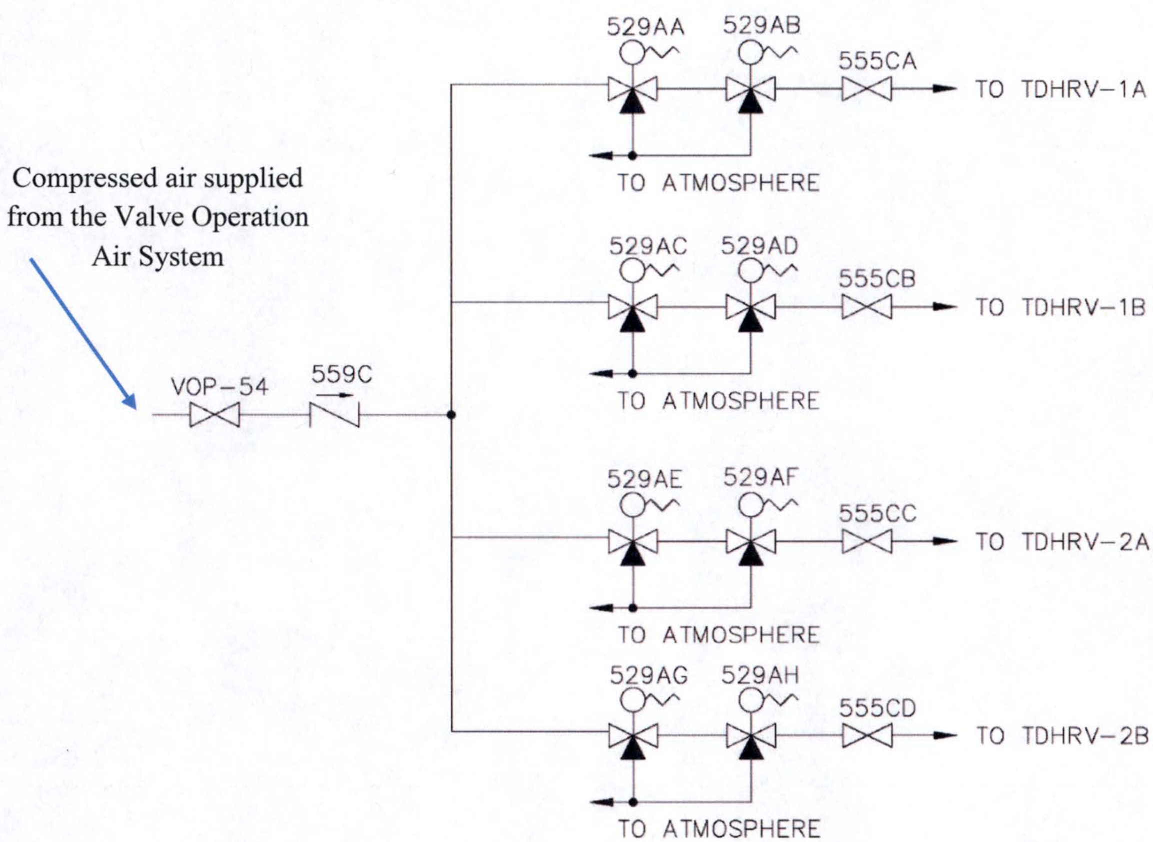

Figure 40-1
Target Decay Heat Removal Valves Air Supply System

No other MURR auxiliary systems other that the Valve Operation Air System and the Normal Electrical Power System will be needed to support TEF operation.

40.3. Discuss if the installation of the TEF impacts any of the auxiliary systems needed to support the operation of the reactor, or justify why no additional information is needed.

As described in the responses to RAI No. 40.1 and 40.2, and Section 3.4.9 of Attachment 1 to LAR Part 1, the only auxiliary systems that will be required for TEF operation are the Valve Operation Air

System and the Normal Electrical Power System. Installation of the TEF will not impact any other MURR auxiliary system needed to support operation of the reactor. Modifications to these systems will be performed in accordance with administrative procedure AP-RO-115, "Modification Records." This procedure provides instructions for documenting changes that alter the facility as it is described in the MURR SAR, or, for documenting changes that are determined to be significant enough to warrant the issuance of a Modification Record. Additionally, proper plant configuration control will be used when performing the modifications including post maintenance testing, as required.

41. *LAR, Attachment 1, Section 7, "In-Pool Target Transfer System," presents a description of the equipment and process to move target rods from/to the target storage and to/from the target cartridge at the cartridge loading/unloading station. However, the NRC staff review identified the need for additional information as listed below.*

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. The regulations in 10 CFR Part 20 require that doses to workers and members of the public be limited. Furthermore, NUREG-1537, Part 1, Chapter 9.2, "Handling and Storage of Reactor Fuel," provides guidance that the LAR should provide information on how subcriticality is ensured under all conditions of fuel handling and storage, and descriptions of procedures and systems for the storage and handling of irradiated fuel, including shielding, protection from physical damage, physical control, and cooling to prevent overheating, and surface corrosion.

41.1. *Provide the detailed calculations that support the analyses for the k-effective values provided in the LAR, Section 7.1.1, "Cartridge Loading/Unloading Station Description," and the results of analyses for any other k-effective values reported in the LAR, or justify why no additional information is needed.*

Since submittal of LAR Part 1, the design of the Target Experimental Facility (TEF) cartridge loading/unloading station has been slightly modified to reduce its overall size. The station is now designed to only load/unload/store one (1) target cartridge at a time. The original submittal design allowed two (2) cartridges to be loaded/unloaded/stored at a time. A further explanation of the loading/unloading station will be included in the response to RAI No. 43. The new station design is shown in Figures 41-1 and 41-2. During a normal unloading/loading sequence, 11 fresh (unirradiated) target rods will be stored in the new target rod bank and 11 irradiated target rods will be in either the cartridge or the transfer cask (reactor pool to hot cell) quiver. However, to calculate the most conservative (highest) k-effective value for the unloading/loading station, the k-effective calculation assumed 33 fresh target rods were stored in the station; filling all possible target rod positions in the new target rod bank, the cartridge, and the transfer cask quiver.

The cartridge unloading/loading station criticality calculation was conducted using MCNP5 KCODE with the geometry and dimensions shown in Figure 41-2 with all 33 target rod positions filled with fresh (unirradiated) target rods. This calculation assumed the area around the entire station was flooded and surrounded by reactor pool water, which is the normal condition. The KCODE utilized 20 million source particles after rejecting the first 2 million particles. All cross-sections were acquired from the ENDF-V11.0 data sets. The results of the simulation for this configuration is a k-effective = 0.44309 with a standard deviation of 0.00018.

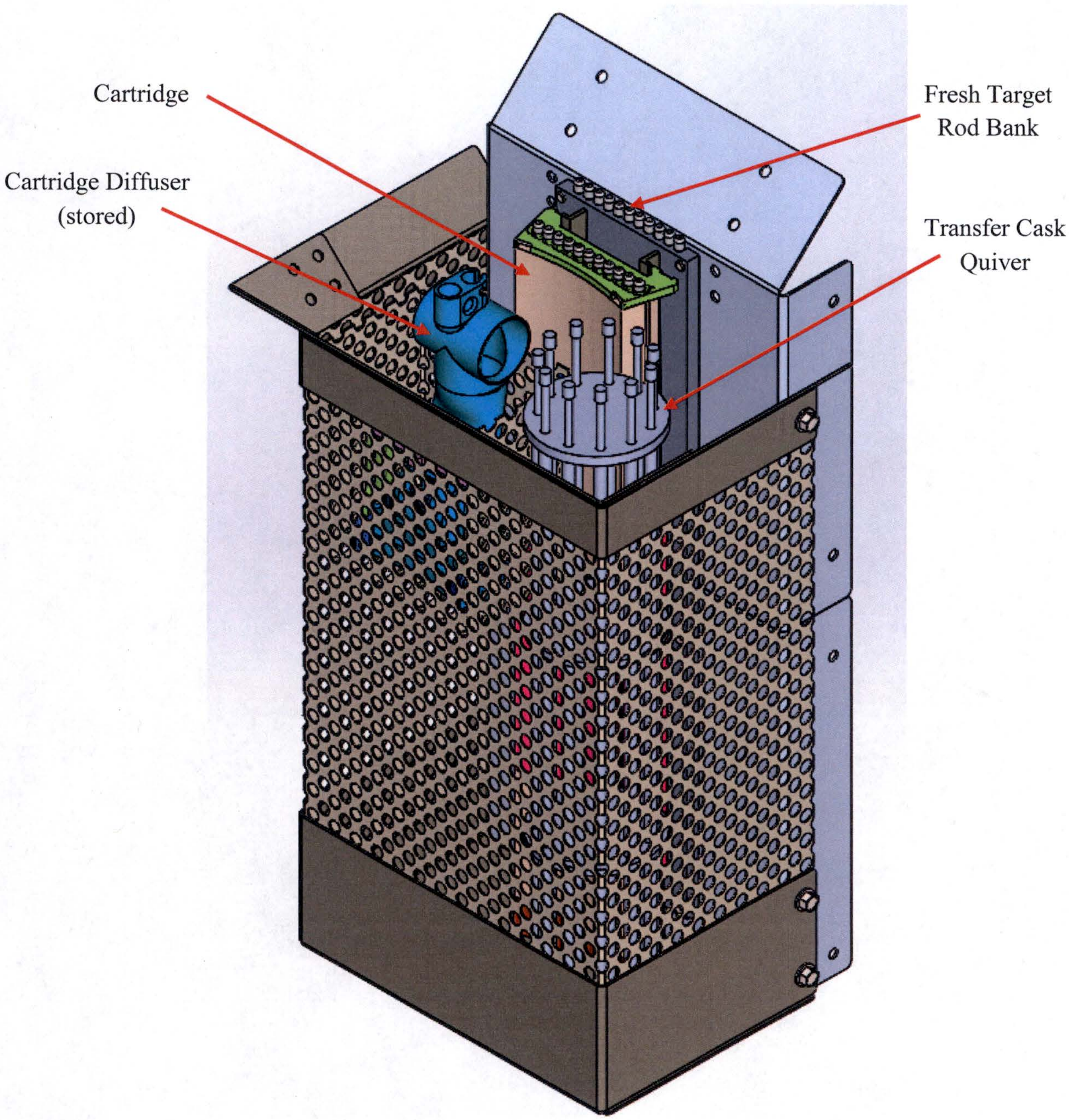

Figure 41-1
Target Experimental Facility Cartridge Loading/Unloading Station (Side View)

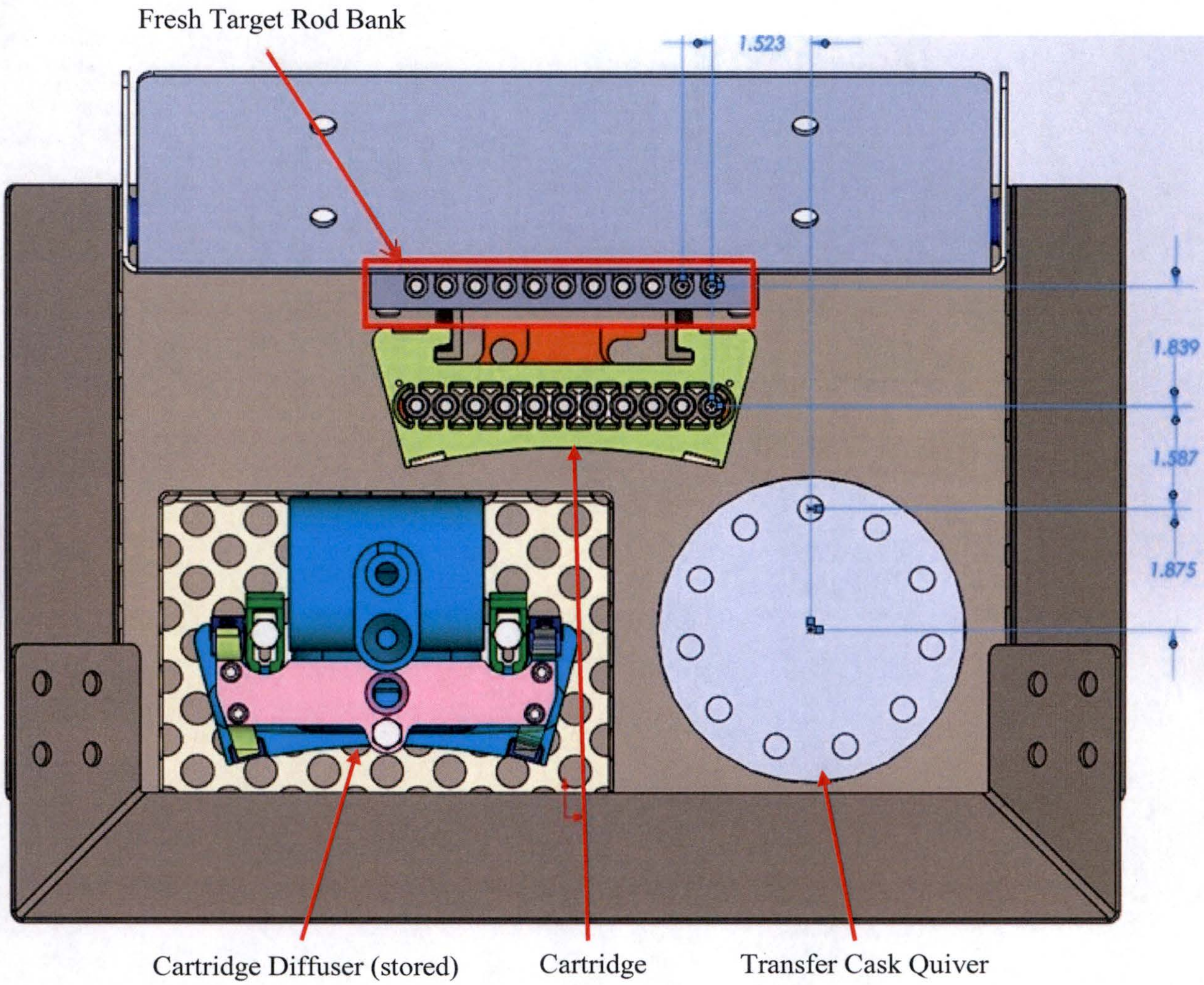

Figure 41-2
Target Experimental Facility Cartridge Loading/Unloading Station (Top View)

41.2. *Provide a description of any accident scenarios involving physical damage to the target assemblies (TAs) during the in-pool transport process, possibility of a mishandled TA or cartridge, or justify why no additional information is needed.*

There are no credible accident scenarios that can cause damage to the target housings; when either installing or removing them, during in-pool transport, or during normal operation. The target housings are designed to have a 10-year lifetime, so once initially installed, they will remain in position for at least 10 years. When installed, the target housings are on the west side of the reactor pressure vessel, in the graphite reflector region, within the upper reflector tank (See MURR Safety Analysis Report, Section 4.2.3 and Figures 4.1 and 4.4) and well protected due to the physical constraints surrounding them. Additionally, when the target housings are being installed and removed, the target cartridge will not be inserted into the housing so there will not be any irradiated target rods being transported/handled during these evolutions. Note: As described in proposed Technical Specification 1.1B and Section 2.1

of LAR Part 1, Attachment 1, a single target assembly consists of a target housing and target cartridge, and associated equipment and components such as the coolant diffuser, coolant piping and instrumentation.

A target rod or target cartridge handling accident is discussed in detail in the responses to RAI No. 7.1 and 10.

41.3. Provide the dose assessment performed to indicate that the irradiated TAs in the cartridge loading/unloading station have adequate biological shielding (concrete wall) to protect the workers, or justify why no additional information is needed.

As stated in the response to RAI No. 41.1, the cartridge loading/unloading station has been slightly modified since LAR Part 1 was originally submitted. Now only one irradiated target cartridge will be transferred at a time from the target housings to the loading/unloading station after a minimum of a one (1) hour decay period after the end of irradiation. The dose rates noted below in Table 36-1 at the surface of the reactor pool were reduced by a factor of 2 from the original analysis since the source term is half of what it was previously when storing only one target cartridge. The exposure rates at the biological shield increased slightly when compared to the previous analysis because of the physical changes to the loading/unloading station. Additionally, some added conservatism was built into the Microshield® calculations, which MURR believes is more representative of the actual station design and its proximity to the reactor pool wall liner. No credit has been taken for the shielding effect of the 11 fresh (unirradiated) target rods, which are positioned directly behind the irradiated rods at a distance approximately two (2) inches closer to the pool wall liner than the irradiated target rod location.

No changes were needed to the analysis and subsequent calculations at the surface of the reactor pool other than reducing the initial two (2) target cartridge source term to one (1), as noted above.

Table 36-1
Dose Rates at Pool Surface and Biological Shield

Dose Location	Surface Exposure Rate (mR/hr)	1 foot Exposure Rate (mR/hr)	1 meter Exposure Rate (mR/hr)
Reactor Pool	64	50	30
Biological Shield at Handling Station Level	26	17	8.6

It should be noted that access to the biological shield location directly opposite the cartridge loading/unloading station is a controlled area with access only available via a controlled key lock issued by the Control Room to authorized personnel only. This area has the appropriate signage designating this area as a radiation area, thus MURR believes the above noted doses and controls are appropriate and consistent with other radiation areas that occur at the MURR facility.

41.4. Provide a description of the proximity of the TEF Cartridge Loading/Unloading Station to the reactor fuel in-pool storage locations, if any storage locations are the same for the reactor fuel

and TAs, and if any potential for a dropped TEF TA or cartridge could adversely impact stored reactor fuel, or justify why no additional information is needed.

The reactor fuel storage locations are described in detail in the response to relicensing RAI No. 2 [Ref. 41-1]. The reactor fuel storage locations are situated in three (3) areas within the reactor pool and are designated as the "X," "Y" and "Z" storage baskets. The "Z" storage basket contains 48 fuel element storage locations; consisting of two (2) levels, referred to as "upper" and "lower," of 24 locations per level. The "X" and "Y" storage baskets each contain 20 fuel element storage locations. The "X" and "Y" reactor fuel storage baskets are located at the bottom of the deep section (30 feet) of the reactor pool whereas the "Z" storage basket is located on the east end of the "weir" area of the reactor pool. The "Z' storage basket also has a swinging protective grate over it that is closed when reactor fuel is not being transferred into or out of the basket. All of these reactor fuel storage baskets are of robust design, as described in Attachments 2 through 6 to the October 1, 2015 letter.

The SGE target rods and reactor fuel do not share any storage locations. The only locations that the target rods will be placed are in the cartridges installed in the target assemblies, the loading/unloading station and the cask when the target rods are removed from the reactor pool for transport to the SGE hot cells. The cartridge loading/unloading station is not located near, or directly above, any of the reactor fuel storage locations.

The TEF target housings are designed for a 10-year lifetime. The target housings are located in the graphite reflector region, on the west side, a significant distance from the reactor fuel storage locations. During installation and removal activities (See target housing handling in response to RAI No. 41.5), the target housings will not pass anywhere near a reactor fuel storage location. Target cartridges will be transported back and forth from the target housings to the loading/unloading station to load and remove target rods; however, they will not be transported over any reactor fuel storage baskets.

Therefore, no potential exists for a dropped TEF target housing or cartridge to adversely impact stored reactor fuel.

41.5. Provide a description of the tools needed for handling the target rods and cartridges, and the TAs (e.g., are the tools identical to the current fuel handling tools), or justify why no additional information is needed.

SGE Target Rod-Handling Tool

The SGE target rod-handling tool and step-by-step procedure for insertion/removal of the target rods into the cartridge are illustrated and described in LAR Part 1, Attachment 1, Section 7.1.2 and Figure 74, and the response to RAI No. 43 below. The design is based on the fuel element-handling tool commonly used at all TRIGA® research reactors, which is designed to work on a ball-detent principle [Ref. 41-2]. This ball-detent mechanism has proven to be reliable in providing positive control of TRIGA fuel rods over many decades of use. The SGE target rod-handling tool cannot be confused with the MURR reactor fuel-handling tool due to differences in size and operation.

SGE Target Cartridge-Handling Tool

The SGE cartridge-handling tool (See Figure 41-3) has been designed to operate in a manner similar to MURR's existing graphite reflector element installation/removal tool. The main difference is the thread size. MURR's existing tool utilizes a 1/2-inch-13 thread. The SGE target cartridge tool has a 3/8-inch-16 threaded stud since the lifting weight for a cartridge is much less than a typical MURR graphite reflector element.

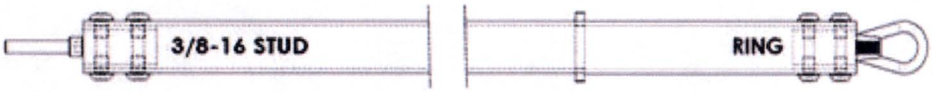

Figure 41-3
Selective Gas Extraction Target Cartridge-Handling Tool

As shown in Figure 41-3, the upper end of the lifting tool has a ring as an attachment point to be secured to the overhead crane by a rope. The procedure (also See LAR Part 1, Attachment 1, Section 7.2.2, pp. 127-128) will require the operator to manually thread in the studded portion of the handling tool into the diffuser. Once this tool is securely threaded into the diffuser, the cartridge is then unlocked from the housing using a second, similar tool with a 3/8-inch socket, by turning the bolt-connected levers. Once unlocked, the cartridge can then be transferred underwater from the housing to the cartridge loading/unloading station.

SGE Target Housing-Handling Tool

The SGE target housing-handling tool is designed to brace and attach on to the target housing and to secure the flexible bellows section of the piping (See Figure 41-4). For installation of the target housing, the tool is attached to the housing outside of the reactor pool in the same position normally occupied by the cartridge. The clamps are then engaged to the welded rings on the inlet pipe both below and above the flexible bellows section to secure and brace the flexible section. Using the crane, the target housing is then gently lowered into the pool adding the rest of the piping sections in succession as the housing is lowered. Once the target housing is safely installed in the graphite reflector region, the inlet pipe is secured to the refuel (lower) bridge of the reactor.

For removal of the target housing, the cartridge is first removed. Then, the same tool used for installation is lowered in the space normally occupied by the cartridge. Using the same guiderails used by the cartridge for alignment, the tool centers itself to the housing assembly. Once in position, the bolt that engages the clamps is actuated to grab the lifting welded rings on the target housing piping. At this point, the housing is secured to the lifting tool such that the piping is released from the bridge brace. The target housing is then slowly lifted out of the reactor pool removing the piping as the flanges come out of the water.

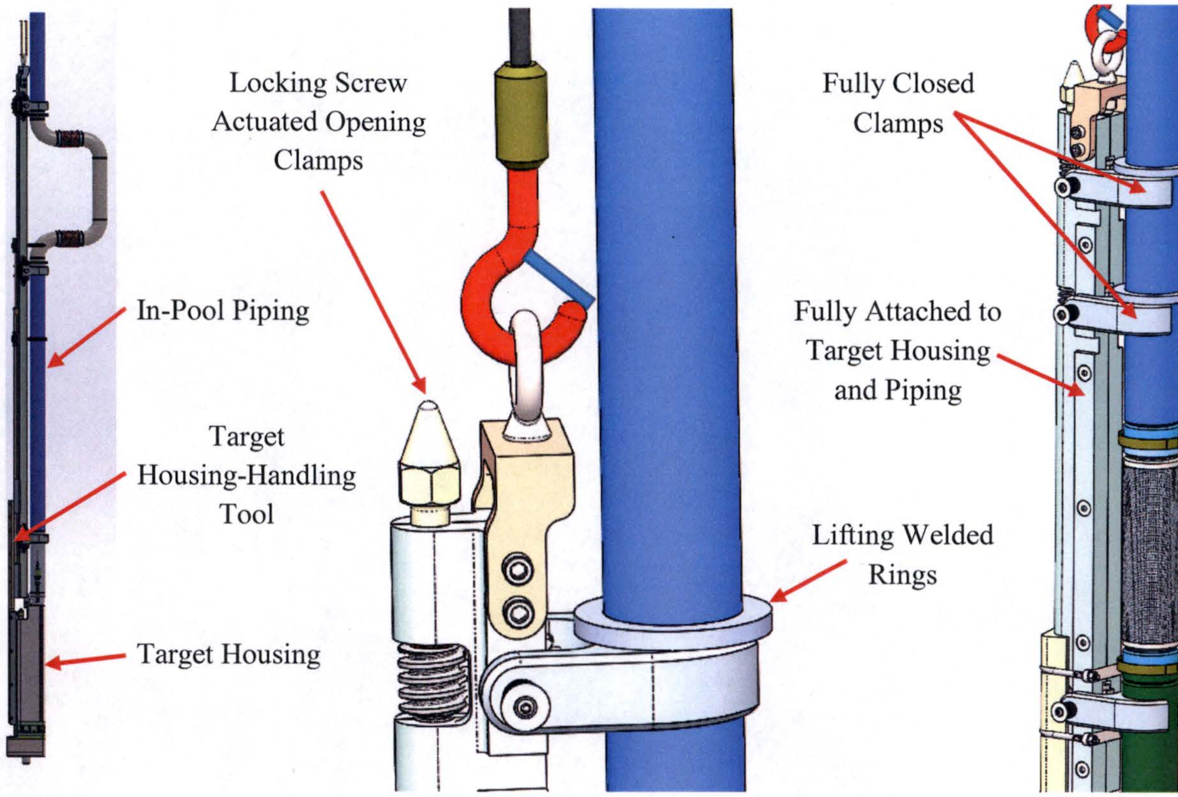

Figure 41-4
Selective Gas Extraction Target Housing-Handling Tool

References:

41-1 Letter to NRC, dated October 1, 2015, in response to "University of Missouri at Columbia - Request for Additional Information Regarding the Renewal of Facility Operating License No. R-103 for the University of Missouri at Columbia Research Reactor (TAC No. ME1580)," dated April 17, 2015

41-2 "Common Reactor Tools," in *General Atomics Reactor Operator Training Manual*, Section 1.13, pp. 1-52 to 1-53, November 1992

42. *LAR Attachment 1, Section 7.1.1, "Cartridge Loading/Unloading Station Description," states that no more than 22 target rods will be either in a cartridge or in target storage at the cartridge loading/unloading station during normal operations. Furthermore, of those 22 target rods, only 11 of them will be fresh (unirradiated). LAR Section 1.2, "Normal Operation," states that during normal operation, one (1) or two (2) target cartridge(s) are loaded with fresh (unirradiated) target rods in the loading station. The NRC staff is not clear if the LAR is limiting the irradiation to only 11 fresh (unirradiated) target rods or 22 fresh (unirradiated) target rods.*

    The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. Furthermore, the guidance in NUREG-1537, Part 1, Chapter 4, Section 4.5, "Nuclear Design," provides guidance that the LAR should include all necessary information on the nuclear parameters and characteristics of the reactor core.

    Provide a description of the fresh (unirradiated) target rods (11 or 22) which may be irradiated in the reactor, and if a limit is imposed on the irradiation of fresh (unirradiated) target rods, if a corresponding TS is required, or justify why no additional information is needed.

    Enclosure 1 of the December 6, 2017, submittal to the NRC, as part of the responses to the Request for Additional Information, by letter dated September 7, 2017, provides the most recent version of the proposed Technical Specifications (TSs) for LAR Part 1.

    Limiting Conditions for Operations (LCO) TS 3.1B.a states:

    > "a. Each SGE target cartridge shall contain eleven (11) SGE target rods."

    Definition TS 1.B states:

    > "**Selective Gas Extraction (SGE) Target Assembly** - The Selective Gas Extraction (SGE) Target Assembly consists of (1) a water inlet section, (2) a target housing, (3) a lower plenum, (4) a target cartridge, (5) an outlet diffuser, and (6) a target cartridge locking mechanism."

    Definition TS 1.3B states:

    > "**Selective Gas Extraction (SGE) Target Experimental Facility (TEF)** - The Selective Gas Extraction (SGE) Target Experimental Facility (TEF) is designed to (1) provide forced cooling to the target rods during normal operation, (2) provide natural circulation cooling during shutdown periods, (3) transfer and reject heat to the secondary coolant system, (4) maintain sufficient cooling flow and temperature conditions to ensure a Critical Heat Flux Ratio of greater than 2.0, and (5) provide instrumentation to assure cooling flow rates, temperatures, and pressures are within specified conditions for operation.
    >
    > The SGE TEF consists of the following major components: two (2) coolant pumps, two (2) coolant heat exchangers, (2) target assemblies plus all associated instrumentation, piping and valves. One (1) coolant pump and one (1) coolant heat exchanger shall be designed to provide the necessary cooling for either one (1) or two (2) operating target assemblies; the other coolant pump and heat exchanger are installed spares."

Definition TS 1.5B states:

> "**Selective Gas Extraction (SGE) Target Rod** - The Selective Gas Extraction (SGE) Target Rods consist of upper and lower Zircaloy-4 end caps, Zircaloy-4 cladding, a stainless steel spring, and low-enriched uranium dioxide pellets nominally enriched to 19.75% in the isotope uranium-235 with a nominal active length of 600 millimeters."

LCO TS 3.2B.a, "Reactor Safety System," allows operation with both, either one ('A' or 'B'), or no Target Assembles if the SGE TEF is secured.

LCO TS 3.1B.b states:

> "b. Each SGE target rod shall not be irradiated for greater than 480 hours at full power operation."

Therefore, depending on Mo-99 production needs, the reactor may operate with two (2), one (1), or no target assemblies (cartridges installed) in operation. If both cartridges are installed, then 22 target rods will be irradiated – all 22 may be fresh (unirradiated) target rods.

43. *LAR, Attachment 1, Section 7.1.2, "Cartridge Loading/Unloading Station Operation," and Section 7.2.2, "Cartridge Installation and Removal into/From the Target Housing Operation," provide a description of the operational sequence for each specified activity. However, the NRC staff is not completely clear as to the overall process for loading, unloading, installation, storage, and removal of the TA cartridges. The NRC staff needs additional description, detail, drawings, illustrations, etc., to ensure a comprehensive understanding of the process.*

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, NUREG-1537, Part 1, Chapter 9, "Auxiliary Systems," provides guidance for the handling and storage of reactor fuel, which would include the TEF TAs.

Provide additional description, detail, drawings, illustrations, etc., of the TA cartridge loading and unloading station operation, and the cartridge installation and removal into and from the target housing, and storage, or justify why no additional information is needed.

Description of SGE Target Rod-Handling Tool Operation

When an SGE target rod is to be handled, the SGE target rod-handling tool release lever is actuated by the operator's hand overcoming the compression spring force to allow the female end to slide over the end of the target rod with the captive locking ball disengaged (See Figure 74 in LAR Part 1, Attachment 1, and Figure 43-1 below). The SGE target rod-handling tool is then lowered over the target rod. Once the tool is fully engaged on the target rod, the release lever is released. The compression spring then forces the captive locking ball to be lodged such that the inner male end of the SGE target rod-handling tool is locked to the inside surface of the target rod. The captive locking ball maintains positive engagement of the SGE target rod-handling tool to the target rod until the release lever is again actuated.

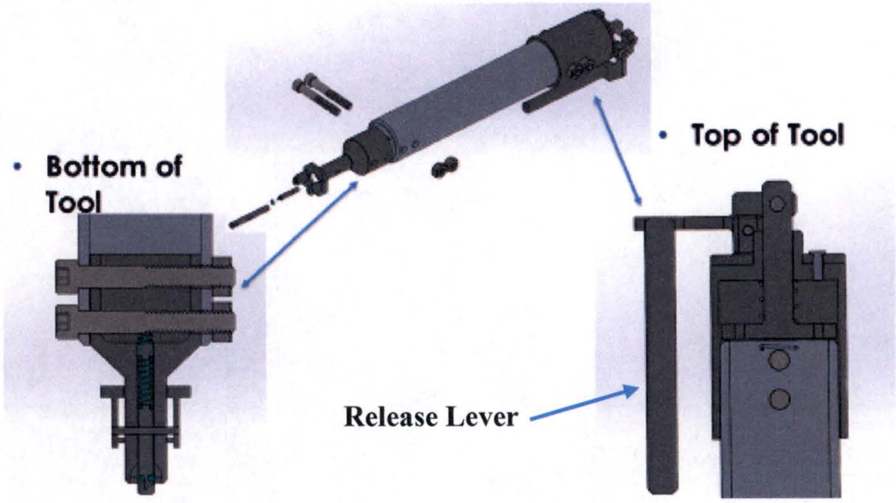

Figure 43-1
SGE Target Rod-handling Tool

Description of Cartridge Locking Mechanism Operation

The cartridge locking mechanism secures the target cartridge to the target housing. Using a socket tool, the actuator for cartridge locking mechanism is turned forcing the cartridge locking mechanism under a recess in the target housing. To release the cartridge from the housing, the actuator is turned in the opposite direction to lower the cartridge locking mechanism away from and free of the housing recess (See Figure 43-2 below).

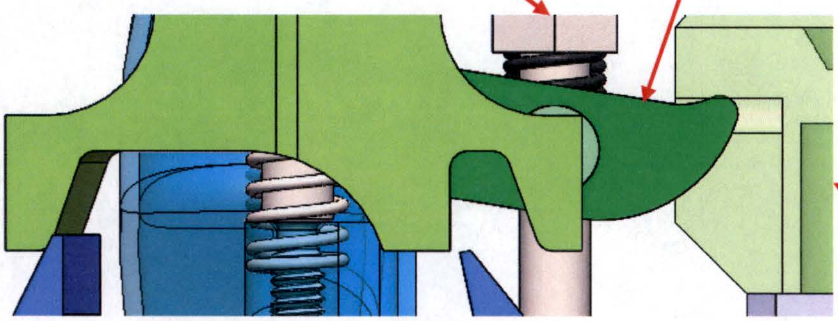

Figure 43-2
Cartridge Locking Mechanism

Description of Diffuser Locking Mechanism Operation

The diffuser locking mechanism secures the diffuser to the top of the target cartridge and holds the target rods inside the cartridge. To install the diffuser onto the cartridge, the SGE target cartridge-handling tool is used to place the diffuser just above the cartridge. Then, while holding the diffuser with the SGE target cartridge-handling tool, the diffuser unlock tool is placed in the hole and the diffuser locking bar is pushed downward, opening the diffuser locking mechanism. The diffuser is then lowered onto the cartridge and the downward force on the locking bar is released. The diffuser locking mechanism spring force positions the locking tabs in place. To ensure the locking bar is secure during cartridge/diffuser movement to the target housing and during irradiation, a socket tool tightens the locking bolt against the backside of the diffuser securing the diffuser-locking bar in the up, locked position (See Figure 43-3).

To release the diffuser from the cartridge, the operator must first use a socket tool to move the locking bolt away from contact with the diffuser. Then, the operator will push down on the locking bar to release the diffuser lock while at the same time lifting the diffuser off the cartridge with the SGE target cartridge-handling tool.

Figure 43-4 provides an illustration on how the diffuser is mechanically locked to the cartridge.

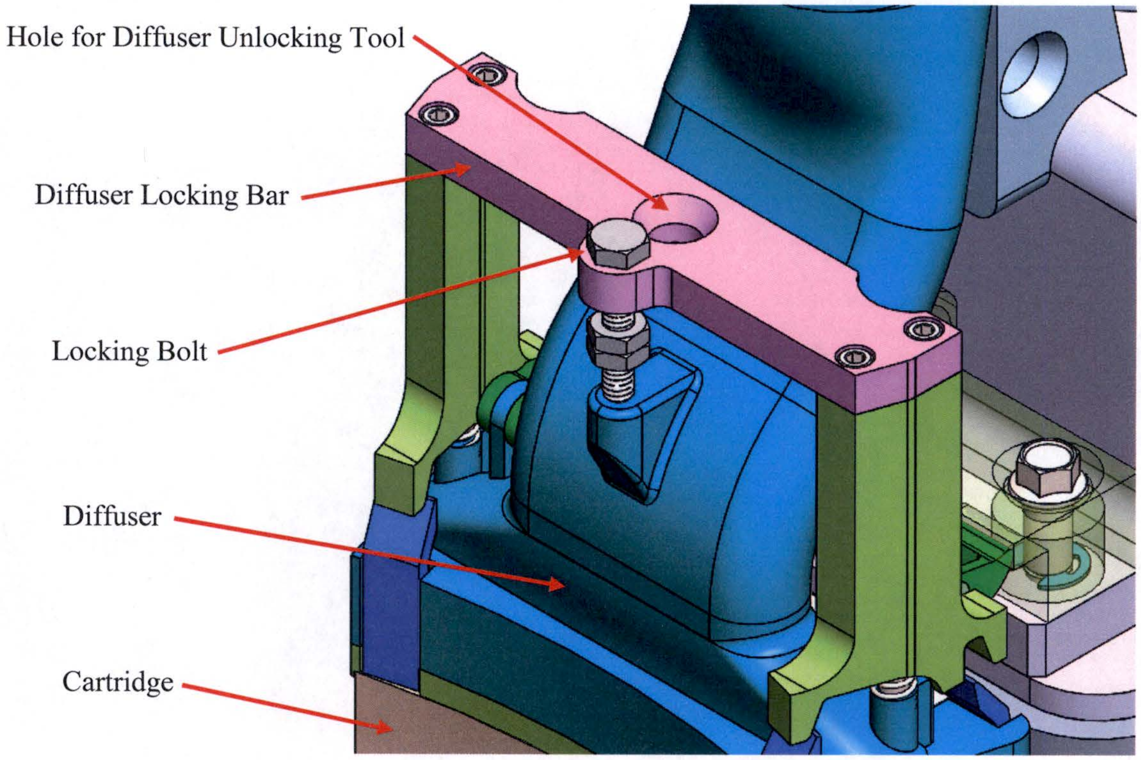

Figure 43-3
Cartridge Locking Mechanism

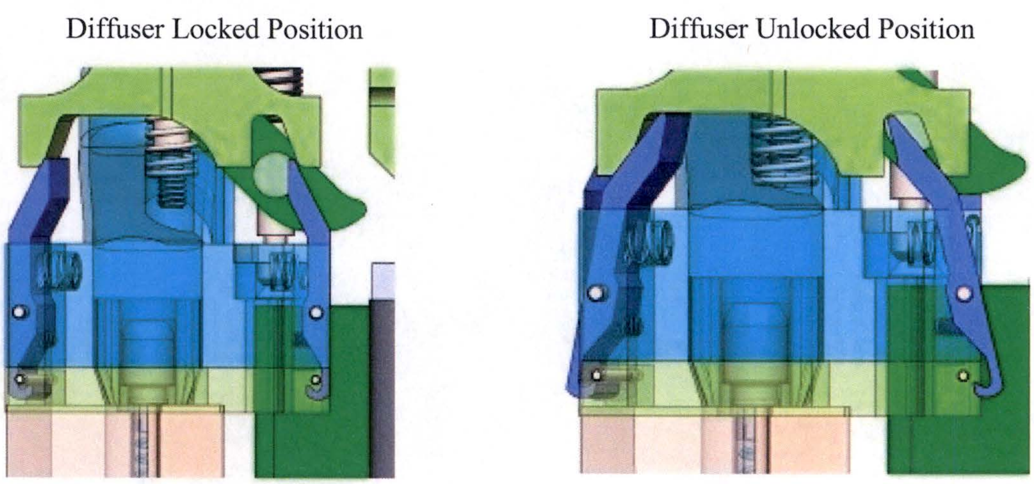

Figure 43-4
Diffuser Locked/Unlocked Positions

Detailed Description of Target Cartridge and Target Rod Handling Process

The initial conditions of this description are:

a. 11 target rods are being irradiated in the reactor; and

b. No cartridge, diffuser, cask quiver, or target rods are in the cartridge loading/unloading station.

Steps:

1. Review the paperwork for the upcoming target rod and cartridge movements.
2. Remove the target rods to be lowered into the reactor pool from the long-term fresh target rod storage to the target rod transfer basket. Document a two-party verification of each of the target rod's identification numbers removed from long-term storage.
3. Transfer the target rods to the pool edge.
4. Using the SGE target rod-handling tool, lower each target rod one at a time into the fresh target rod bank on the cartridge loading/unloading station to the exact position designated by the SGE target rod map. Document a two-party verification of each target rod's identification number and the fresh target rod bank position in which each target rod is placed.
5. Place the empty transfer cask quiver into the cartridge loading/unloading station.
6. Shut down the reactor.
7. Maintain TEF cooling water flow for a minimum of one (1) hour after shutdown and prior to removing a target cartridge from the housing.
8. Ensure reactor containment integrity exists.
9. Review the paperwork for the upcoming movement and have both operators agree which target cartridge is to be removed.
10. Using the SGE target cartridge-handling tool, thread the studded portion of the handling tool into the diffuser.
11. Using a socket tool, unlock the cartridge from the housing by turning the bolt-connected levers.
12. Once the levers are fully unlocked, vertically lift the SGE target cartridge-handling tool removing the target cartridge and the diffuser from the target housing.
13. Transfer the target cartridge and diffuser assembly up and over the reactor ensuring the RTD cable does not catch on other equipment.
14. Set the target cartridge and diffuser assembly so that the cartridge engages into the cartridge rails in the unloading/loading station.
15. Using a socket tool, unlock the locking bolt on the diffuser lock.
16. While pushing down on the locking bar with the diffuser unlock tool, vertically lift the SGE target cartridge-handling tool until it is clear of the cartridge.

17. Place the diffuser in the cartridge loading/unloading station basket.
18. Review the paperwork for the upcoming target rod movements.
19. Using the SGE target rod-handling tool, move each irradiated target rod one at a time into the transfer cask quiver to the exact position designated by the SGE target rod map. Document a two-party verification of each target rod's identification number and the irradiated rod position in the quiver.
20. Using the SGE target rod-handling tool, move each fresh target rod located in the fresh target rod bank one at a time into the target cartridge to the exact position designated by the SGE target rod map. Document a two-party verification of each target rod's identification number and the fresh rod position in the target cartridge.
21. Lift the SGE target cartridge-handling tool and place the diffuser over the cartridge.
22. While pushing down on the locking bar with the diffuser unlock tool, lower the diffuser onto the cartridge.
23. Release the locking bar.
24. Using a socket tool, turn the locking bolt to secure the locking bar in the up, locked position.
25. Transfer the target cartridge and diffuser assembly up and over the reactor ensuring the RTD cable does not catch on other equipment.
26. Set the target cartridge and diffuser assembly so that the cartridge engages into the cartridge rails in the housing.
27. Ensure the target cartridge is aligned properly in the housing.
28. Using a socket tool, lock the cartridge to the housing by turning the bolt-connected levers.
29. Unthread the SGE target cartridge-handling tool from the diffuser portion of the cartridge.
30. Ensure the RTD cable is properly positioned for reactor operation.
31. Visually inspect all in-pool target rod storage positions to ensure the current situation matches the final movement target rod map.

44. *LAR, Attachment 1, Section 8.2, "Liquid Sources," states, in part, that "By utilizing existing reactor-related cooling and decay systems for the reduction of N-16, the addition of any N-16 produced by the TAs will not add any appreciable source term to the overall inventory of N-16 that must be decayed and/or shielded in order to protect reactor staff." However, the NRC staff is not clear as to the expected dose rates and worker doses due to the Target Cooling System piping when the TEF is in operation.*

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. The regulations in 10 CFR Part 20 require that doses to workers and members of the public be limited. Furthermore, NUREG-1537, Part 1, Section 11.1, "Radiation Protection," provides guidance that the applicant should describe the radiological consequence of normal operation of the facility.

Provide a description of the expected dose rates and worker doses from the Target Cooling System piping to the workers in the vicinity, or justify why no additional information is needed.

The reactor pool water source term and resulting radiation doses from the three (3) Target Experimental Facility (TEF) Target Cooling System (TCS) lines – one suction and two return – were analyzed using Microshield, Version 8.03, a commercially available nuclear industry-accepted computer program used in performing shielding calculations. MURR used this program to analyze the dose rates at three (3) different distance points near the TCS lines in order to assess dose rates and cumulative doses that Reactor Operations staff may incur while working in areas near the TCS. The three (3) main constituent isotopes commonly found in the MURR pool water that were used in the analysis are: Mg-27, Mn-56 and Na-24. These isotopes and their activity concentrations were chosen at their worst-case values after reviewing weekly pool water sample analysis reports over the past several years. N-16 was not considered during this review, as the source of the water (TCS pump suction) is in an area of the reactor pool where the pool coolant system water return is located. The returning pool water has gone through the pool hold-up tank (N-16 decay tank) and pool demineralizer beds, thus N-16 will not be present at the analyzed location to contribute to staff dose. Dose rates were analyzed on contact with each pipe, 1 foot (0.3 m) and 9 feet (2.7 m) away from an 18-foot (5.5-m) section of piping. The dose rates are summarized in the Tables 44-1, 44-2 and 44-3 below.

Table 44-1
Dose Rate per Pipe

Distance	**Unshielded Dose Rate (mR/hr)**	**Shielded Dose Rate – 1-inch of Pb (mR/hr)**
Contact	42	4
1 foot	5.3	0.7
9 feet (working area)	0.4	0.07

Note: It should be noted that the contact dose rate provided by Microshield is the least statistically reliable dose rate estimate due to the geometric limitations of the computer program and in all likelihood greatly exceeds the actual dose rate that will be present on the piping. The program produces a warning when using a close distance to alert the user of exactly this limitation.

Table 44-2
Dose Rate in Piping Area

Distance	Unshielded Dose Rate (mR/hr)	Shielded Dose Rate – 1-inch of Pb (mR/hr)
Contact	126	12
1 foot	15.9	2.1
9 feet (working area)	1.2	0.21

Note: This table overestimates cumulative dose rates due to spatial considerations and is only provided for reference purposes. It should also be noted that the measured dose rate immediately above the reactor pool surface is about 25 mR/hr and 12 mR/hr at 4 feet (1.2 m) above the pool, thus validating the note provided by the Microshield program manual.

Table 44-3
Estimated Dose to Workers

Unshielded Dose (mrem/yr)	Shielded Dose – 1-inch Pb (mrem/yr)
201.6	35.3

Note: The above dose estimates assume the worker works at the 9-foot (2.7-m) working area 1 hour per 12-hour shift on average of 3.5 days per week for 48 weeks per year. In all likelihood, this overestimates dose by at least a factor of 2 but is used for comparison purposes.

MURR Reactor Health Physics and Reactor Operations will assess the doses that are generated by the TEF TCS piping once the system is operational to determine what shielding, if any, is necessary to ensure doses are ALARA and meet the standards of the MURR Radiation Protection Program.

45. LAR, Attachment 1, Section 8.3, "Solid Sources," provides general information on the solid radioactive sources expected from the proposed LAR. However, the NRC staff is interested in the potential for the activation and generation of additional solid radioactive sources from the operation of the TEF, such as cobalt-60.

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. Furthermore, the guidance in NUREG-1537, Part 1, Chapter 11, "Radiation Protection Program and Radioactive and Waste Management," Section 11.1.1.3, "Solid Radioactive Sources," provides guidance that the LAR should identify all expected solid radioactive sources.

Provide a description of the potential for the activation and generation of solid radioactive sources, including cobalt-60, as a result of the operation of the TEF, or justify why no additional information is needed.

Operation of the Target Experimental Facility (TEF) will generate the following solid radioactive sources:

1. Two (2) activated target cartridges with a 1-year design life;
2. Two (2) activated diffusers with a 10-year design life;
3. Two (2) activated target housings with a 10-year design life; and
4. Dry Active Waste (DAW) that contains such items as disposable gloves, coveralls, shoe covers, etc., which are routinely produced in and around the reactor bridge area where routine sample handling occurs.

Table 45-1 summarizes the solid radioactive sources associated with the normal operation of the TEF. The information presented in Table 45-1 is only an estimate of annual and once every 10-year solid radioactive source production in support of LAR Part 1, the "in-pool" portion of the project.

Although solid waste is included in Table 45-1, additional information on waste classification, storage, packaging, and shipment is included in the response to RAI No. 46.

Table 45-1
Representative Target Experimental Facility Solid Radioactive Sources

Source Description	Radionuclide(s)	Nominal Activity After One (1)Year of Decay (Ci)	Physical Characteristics	Estimated Volume (ft^3)
Two (2) Activated Target Cartridges per year	Co-58 Co-60 Cr-51 Fe-55 Fe-59 Mn-54 Ni-63 S-35 Zn-65	1.1 580 0.86 980 0.54 3.8 6.5 0.022 31	Two metal pieces made of various aluminum and stainless steel components	0.64
Two (2) Activated Target Diffusers per 10 years	Co-58 Co-60 Cr-51 Fe-55 Fe-59 Mn-54 Ni-63 S-35 Zn-65	1.1 7.0 0.11 530 0.072 0.90 8.7 0.0032 0.41	Two metal pieces made of various aluminum, titanium, and stainless steel components	0.77
Two (2) Activated Target Housings per 10 years	Co-58 Co-60 Cr-51 Fe-55 Fe-59 Mn-54 Ni-59 Ni-63 S-35 Zn-65	0.56 8550 2.4 11000 1.5 19 0.38 17 0.059 110	Two metal pieces made of various aluminum, Inconel, and stainless steel components	3.57
Dry Active Waste	Co-60, Zn-65, Mn-54, and other mixed activation products	0.11	55-gallon barrels and B-25 containers; Total annual dry waste activity and volume for the TEF has been estimated as about 5% MURR's current dry waste activity and volume.	63

46. *LAR, Attachment 1, Section 8.4, "Radioactive Waste Management Program," indicates that no changes are needed to the MURR Health Physics (HP) monitoring and surveying program as a result of the TEF. Furthermore, the LAR states, in part, that "Little additional equipment is anticipated to be needed in order to support the addition and operation of the SGE TEF." The NRC staff is not clear as to the extent of any additional equipment needed to provide HP monitoring and surveying to ensure that the worker's radiation exposures are maintained below the limits in 10 CFR 20.*

Additionally, the NRC staff finds that the MURR SAR, Chapter 11, "Radiation Protection Program and Waste Management," (ADAMS Accession No. ML092110597), provides a description of the radiation protection programs at the MURR facility, including the MURR Radioactive Waste Management Program, ALARA Program, Radiation Monitoring and Surveying, the Radiation Exposure Control and Dosimetry, Contamination Control, and Environmental Monitoring. The NRC staff is not clear if any changes to these programs are required to ensure effective HP monitoring of the TEF operation, or if any changes to the quantity or type of radioactive waste is expected as a result of the TEF operation.

Note: Attachment 1, Section 8.3, Table 35, Column titled "Wt% Uranium," does not appear to correct based on the information provided. The NRC staff finds that the table column would more appropriately titled "U-235 Enrichment."

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. The regulations in 10 CFR Part 20 require that doses to workers and members of the public be limited. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 11, "Radiation Protection Program and Waste Management," indicates that the LAR should provide information on radiation protection and waste management.

46.1. Provide a description of any changes to the HP monitoring and surveying equipment needed to support the operation of the TEF, or justify why no additional information is needed.

The only changes that will be necessary to the MURR Reactor Health Physics monitoring and survey program, and related equipment, regarding the irradiation of the SGE target rods in the Target Experimental Facility (TEF) will be those directly related to the transfer of the target rods to the cartridge loading/unloading station. It is anticipated that during initial startup irradiation of the target rods, Reactor Health Physics staff will be present to assess any additional doses, which may occur during the process of moving the target cartridge up from the target assembly to the cartridge loading/unloading station for eventual transfer of the target rods from the reactor pool. This practice is consistent with any new project that MURR undertakes with regards to personnel exposure assessment. Additionally, the Health Physics equipment required to perform these tasks are the same that are currently used to provide Reactor Health Physics support to Reactor Operations staff during the movement of reactor fuel or experimental samples. Thus, at this point, it is not anticipated that additional Health Physics equipment used for monitoring or surveying will be required at this phase of the project as the MURR Reactor Health Physics staff maintains an equipment inventory sufficient for these evolutions.

Additionally, regarding the note above concerning Table 35 of LAR Part 1, Attachment 1, Section 8.3, the NRC is correct; the table column should have stated "U-235 Enrichment."

46.2. Provide a description of any changes to the:

46.2.1. Radiation Protection Program,

The MURR Radiation Protection Program (RPP) is a broad policy document that outlines how radiation protection is organized and performed at MURR [Ref. 46-1]. It covers areas such as the Reactor Health Physics Group organization, duties of the Reactor Health Physics Manager, Control of Radioactive Materials, General Radiation Worker Training, Radiation Monitoring, the MURR ALARA Program and Waste Management. It is designed to provide an overall overview of how radiation protection is practiced at MURR and what responsibilities are designated to specific groups and positions. Section 4, "Control of Radioactive Material and Radiation Sources," of the MURR RPP directs the use of procedures to implement the specific areas of this program. Thus with regards to the TEF, it is not anticipated that changes need to be made at this time to the MURR RPP due to its overview nature as related to radiation protection at MURR. If members of MURR Management or the Reactor Health Physics Manager assess that specific areas of TEF operation warrant inclusion into the MURR RPP at a future date then this inclusion can easily occur as the Reactor Health Physics Manager reviews the RPP at least annually. Thus, at this time, MURR does not believe that changes to the RPP are necessary for LAR Part 1 submittal.

46.2.2. Radioactive Waste Management Program,

The MURR Radioactive Waste Management Program falls under Section 8, "Waste Management," of the MURR Radiation Protection Program, as described above. The operation of the TEF will generate waste similar to that generated by the normal operation of the reactor; mainly Dry Active Waste (DAW) that contains such items as disposable gloves, coveralls, shoe covers, etc., which are routinely produced in and around the reactor bridge area where routine sample handling occurs. The only other items that would require routine disposal as Low Level Radioactive Waste (LLRW) are the two (2) target housings and the two (2) target rod cartridges. The target housings are designed for a 10-year life span and would be disposed of as higher activity radioactive waste in a DOT Type A or B shipment, most likely as Class A or B radioactive waste. Additionally, the two (2) target rod cartridges would be shipped as described above; however, they are designed to have a one to two year life and thus would be generated at a higher frequency than the target housings. Both items described above would most likely be disposed of along with other radioactive irradiated reactor hardware generated at MURR, which is shipped periodically from MURR to an approved LLW disposal sight. Thus, MURR believes that no project specific changes are required for the MURR Radioactive Waste Management Program.

46.2.3. ALARA Program,

The MURR ALARA Program falls under Section 7, "MURR ALARA Program," of the MURR Radiation Protection Program, as described above. While the operation of the TEF may result in increased doses to staff that handle the irradiated target rods prior to transfer for processing, any doses received will be evaluated under the guidance of the current MURR ALARA Program. Any improvements that can lead to dose reduction will be evaluated and implemented by adjusting staff handling technics or by equipment improvements through the use of engineered controls. Thus, MURR believes that the existing ALARA Program is sufficient to evaluate doses and implement changes as it relates to the irradiation and handing of target rods in the TEF and thus no changes are needed at this time.

46.2.4. HP Radiation Monitoring and Surveying Program,

The Health Physics Radiation Monitoring and Surveying Program falls under Section 6, "Radiation Monitoring," of the MURR Radiation Protection Program, as described above. With regards to potential changes to the Monitoring and Surveying Program, the response to RAI No. 46.1 indicates that no changes are anticipated to this program with regards to operation of the TEF.

46.2.5. Radiation Exposure Control and Dosimetry Program,

The Radiation Exposure Control and Dosimetry Program falls under Section 6, "Radiation Monitoring," of the MURR Radiation Protection Program, as described above. Operation of the TEF and associated post irradiation target rod handling described in LAR Part 1, Attachment 1, does not pose any additional sample handling risks that are outside of what is currently performed by Reactor Operations staff when handling new experiments or irradiated reactor fuel elements. No dosimetry changes will be needed to handle items that result from the use of the TEF. All staff involved with handling or monitoring the TEF or its operations will wear National Voluntary Laboratory Accreditation Program (NVLAP-certified) dosimetry, including whole body and extremity rings. Additionally, MURR staff involved in such operations routinely wear Electronic Personnel Dosimetry (EPD), which provides instantaneous feedback related to dose conditions that the staff may be operating under. Thus, MURR believes that its current Radiation Exposure Control and Dosimetry Program is sufficient to provide an adequate level of safety to those personnel involved in the operation of the TEF and thus no changes are required for this program.

46.2.6. Contamination Control Program, and

The MURR Contamination Control Program falls under both Section 4, "Control of Radioactive Material and Radiation Sources," and Section 6, "Radiation Monitoring," of the MURR Radiation Protection Program, as described above. Section 4 describes the general radioactive contamination control philosophy and practice. Section 6 describes how contamination control surveys are used as an assessment method to evaluate the potential for loose contamination to become airborne and how the MURR Reactor Health Physics group can proactively evaluate

grossly contaminated areas for the potential to become airborne and recommend airborne monitoring methods to help assess potential internal dose. Procedures are also available to assist staff in performing the above Health Physics operations. MURR believes that the current Contamination Control Program is adequate to address the use of the TEF and thus no additional changes are required for this program.

46.2.7. Environmental Monitoring Program, needed to support the operation of the TEF, or justify why no additional information is needed.

MURR Technical Specification (TS) 3.7.c contains the requirements for an Environmental Monitoring Program at MURR. TS 3.7.c(1) specifies three (3) types of routine samples for collection and analysis, which include soil, surface water and vegetation. When analyzed, these samples provide data, which helps confirm that MURR is not emitting radionuclides in a manner that is detrimental to the environment. Additionally, sub-surface soil samples are collected and analyzed which provide further data to substantiate that MURR is not releasing longer-lived isotopes, which could be detrimental to the environment. All environmental samples have been collected and analyzed over the past 50 years of operation with the exception of the sub-surface soil samples, which were added within the past 10 years.

Additionally, TS 3.7.c(2) requires that thermoluminescent dosimeters or other appropriate monitoring devices be strategically placed around the MURR facility to identify areas where background radiation may be increased due to any radiological activities conducted at MURR. To date, areas monitored have shown that MURR does not release activity that would cause a dose to a member of the general public to exceed the 100 mrem per year public dose limit as specified in 10 CFR Part 20.1301, "Radiation Dose Limits for Individual Members of the Public." Additionally, the target rods will be fabricated under an NRC-approved quality control program in such a manner to preclude potential leakage from the target rods. Thus, MURR believes that the current Environmental Monitoring Program TSs provide an adequate margin of safety with regards to the current level of monitoring for environmental releases and that no additional changes need to be made at this time.

46.3. Provide a description of any changes to the quantity or type of radioactive waste as a result of the TEF operation, or justify why no additional information is needed.

The MURR Radioactive Waste Management Program falls under Section 8, "Waste Management," of the MURR Radiation Protection Program, as described in the response to RAI No. 46.2.2 above. The operation of the TEF will generate waste similar to that generated by the normal operation of the reactor; mainly Dry Active Waste (DAW) that contains such items as disposable gloves, coveralls, shoe covers, absorbent paper etc., which are routinely produced on and around the reactor bridge area where routine in-pool sample handling occurs. The only other items that would require routine disposal as Low Level Radioactive Waste (LLRW) are the two (2) target housings and the two (2) target rod cartridges. The target housings are designed for a 10-year life span and would be disposed of as higher activity radioactive waste in a DOT Type A or B shipment, most likely as Class A or B radioactive waste. Additionally, the two (2) target rod cartridges would be shipped as described earlier; however, they are

designed to have a one to two year life and thus would be generated at a higher frequency than the target housings. Both items described above would most likely be disposed of along with other radioactive irradiated reactor hardware generated at MURR, which is shipped periodically from MURR to an approved LLRW disposal sight. Thus, MURR believes than no program specific changes are required for the MURR Radioactive Waste Management Program once the commencement of the TEF begins for irradiation of the SGE target rods.

References:

46-1 POL-3, "*MURR Radiation Protection Program*," May 2017

47. LAR Attachment 1, Section 9.3, "Material Control & Accounting," states, in part, that "Irradiated target rod material control will be discussed in the Part 2 License Amendment application." However, LAR Section 1.1, "Proposed Experiment Description," states that the target material will be irradiated in the graphite reflector region of the reactor. The NRC staff is not clear why the control of target material would not apply to material irradiated in the LAR Part 1.

The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, the regulations in 10 CFR Part 74, "Material Control and Accounting of Special Nuclear Material, require licensees of special nuclear material to establish controls, as applicable.

Provide a description of the material controls required for the irradiated targets as described within the scope of the activities proposed in the LAR, Part 1, or justify why no additional information is needed.

The entire Special Nuclear Material (SNM) Material Control and Accounting (MC&A) program for this project spans both LARs Part 1 and Part 2. Therefore, it is planned to have a single MC&A program that covers the entire process.

Figure 47-1 below is the LAR Part 1 flow path from when the SGE target rods are received at MURR, through the irradiation process, and to the point when they are placed in the pool-to-hot cell cask for their transfer from the reactor pool to the processing hot cells.

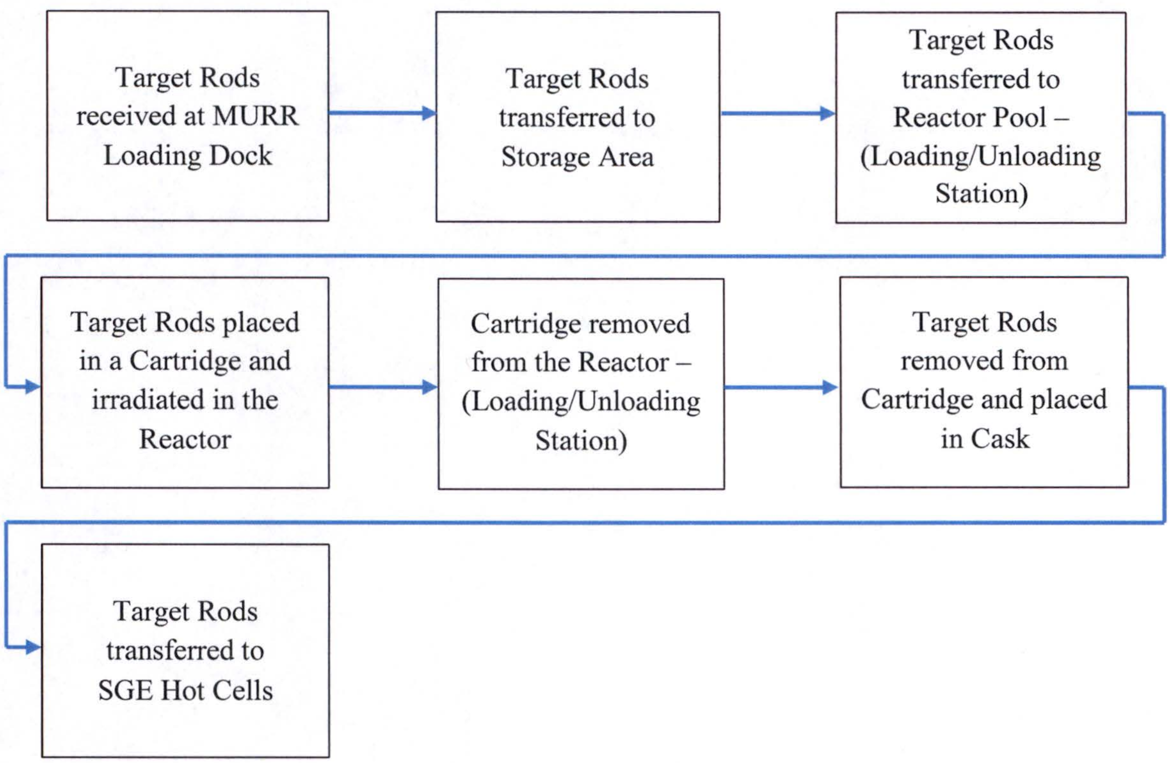

Figure 47-1
LAR Part 1 Flow Path for the SGE Target Rods

On receipt, the target rods will be inspected and inventoried prior to storage. As the target rods are removed from storage in preparation for irradiation, their IDs will be tracked until they are removed from the reactor post irradiation and transferred to the hot cells for processing via the pool-to-hot cell transfer cask. Beyond this point, in LAR Part 2, the MC&A program will be tracking LEU pellets, UO_2 and U_3O_8 powders, and not individual target rods. The MC&A portion outlined in LAR Part 2 will be more involved and complex. Therefore, the intent is to submit the complete MC&A program as part of LAR Part 2 submittal.

Additionally, as discussed in the responses to RAI No. 5 and No. 6, irradiation of SNM leased from the U.S. Department of Energy (DOE) under this project [Ref. 47-1] cannot be performed unless a LEU take-back contract between MURR and DOE is executed. This restriction is documented in the MURR/DOE LEU Lease Agreement. The SNM in the target rods must be processed and placed in a form that a DOE site will eventually accept, most likely U_3O_8 powder after the SGE process is performed on the UO_2 pellets to extract Mo-99.

Finally, as discussed during the NRC public meeting on February 2, 2017, MURR is not requesting irradiation of any target rods under LAR Part 1 unless LAR Part 2 is approved.

References:

47-1 "Lease Contract for the Supply of Low Enriched Uranium for Domestic Molybdenum-99 Production," Contract No. NNSA-LC16-Y12-1001, University of Missouri-Columbia, June 2016.

48. LAR, Attachment 1, Section 10, "Target Experimental Facility Accident Analysis," provides accident analyses for various accidents associated with the TEF. However, the NRC staff review did not find an accident analysis for 1) a potential flow blockage of the TA; or 2), a potential loss of secondary cooling.

The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 13, indicates that the LAR should also describe how equipment will work when needed in accident situations.

48.1. Provide an analysis for the potential flow blockage of the TA assembly accident, or justify why no additional information is needed.

The potential for flow blockage has been addressed in the response to RAI No. 3. An inlet screen upstream of the Target Cooling System Module (TCSM) pump suction limits the largest piece of debris that could enter the pump to 0.221 inches (0.561 cm). A secondary fine mesh screen with a maximum particle size of 0.045 inches (0.114 cm) limits the debris that could flow through it and into the target housing. Particles of this size will not cause a flow blockage within the target assembly. A flow blockage of the pump inlet screen has also been analyzed in response to RAI No. 33.

48.2. Provide an analysis for the potential loss of secondary cooling accident, or justify why no additional information is needed.

An analysis to determine the consequences from a loss of secondary cooling was performed to assess the adequacy of the resistance temperature detector (RTD) response time, and has been discussed in the response to RAI No. 4.4. This analysis starts with the reactor at 10.0 MW, the target power at 100% nominal, and Target Cooling System (TCS) at 100% nominal flow rate. The secondary cooling flow rate is then ramped down to zero in one (1) second. During this ramp down, the reactor pool is assumed to be at its Technical Specification limit of 120 °F [Ref. 48-1] (normal value is 100 °F), and the RTD at the TCS skid outlet starts at 102 °F (Ref. 48-2). The maximum delay in the RTD is 60 seconds, thus the reactor does not scram until 65 seconds after the limit is reached. By this time, the target assembly inlet temperature has increased to the reactor pool temperature. This is not an immediate safety concern since the Bernath critical heat flux ratio (CHFR) is still above 2.0, at a value of 2.57. Even if TCS flow rate was at 85% of nominal, the Bernath CHFR is still above 2.0, at a value of 2.31. A reactor scram is only needed because the target assemblies are adding additional heat to the reactor pool, which is not permitted.

Note: The above analysis assumes 11 target rods in a target assembly, which is a Technical Specification (TS) requirement – TS 3.1B.a. The response to RAI No. 15.1 is based on operation with only three (3) target rods in a cartridge (worst-case). Although the most limiting analysis was performed, MURR will not operate in that configuration.

References:

48-1 "*Technical Specifications for The University of Missouri Research Reactor*," Appendix A, Renewed Facility Operating License No. R-103, Specification 3.5.b.3

48-2 LAR Part 1, Attachment 1, "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor*," Section 6.1.4

49. *LAR, Attachment 1, Section 10, "Target Experimental Facility Accident Analysis," provides accident analyses for various accidents associated with the TEF. However, the NRC staff is not clear if other experiments will be performed concurrent with TEF TA irradiation. If multiple experiments are performed concurrent with TA irradiation, the LAR does not appear to discuss any accident scenarios involving multiple experiments, or the impact of other experiments on the TA in the reactor or stored in the reactor pool.*

    The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 13, indicates that the LAR should also describe how equipment will work when needed in accident situations.

    Provide an analysis or description of any accident scenarios which involve concurrent or multiple experiment failures occurring during TA irradiation, or while TAs are stored in the reactor pool, or justify why no additional information is needed.

    The justification limiting the Maximum Hypothetical Accident (MHA) to a single target rod was provided in the response to RAI No. 7.1. The hypothetical failure mode of the target rod is independent of the other target rods.

    Loss of cooling to both target assemblies was analyzed for both a loss of pump flow and a pipe break before the wye where the target cooling water flow is divided between the two (2) target assemblies (TAs). The loss of pump flow accident was presented in Reference 49-1 and further analyzed in the response to RAI No. 33. The pipe break before the wye was presented in response to RAI No. 32.1.

    MURR will be irradiating other experiments concurrent with the operation of the Target Experimental Facility (TEF); however, none of these other experiments will be in close proximity to the TAs and none have energetic failure modes that could impact operation of the TAs. All other experiments that could run concurrent with TEF operation have been evaluated by MURR analyses to demonstrate that failure of that experiment will not impact other experiments or the safety of the reactor, including the reactor's ability to shut down and maintain a safe shutdown condition.

    Additionally, the experiment review process is described in detail in Section 10.4 of the MURR Safety Analysis Report and in the response to relicensing RAI No. 10.3.a. [Ref. 49-2]. The mechanism used to verify that each experiment, or single experiment sample, complies with all of the applicable Technical Specifications (TSs), and other limitations based upon good operating, engineering, and Health Physics practices, is called the Reactor Utilization Request (RUR). This formalized process, which is detailed in administrative procedure AP-RO-135, "Reactor Utilization Requests," specifically requires that a safety analysis be prepared, reviewed and approved by both the Reactor and Reactor Health Managers before an experiment can be conducted.

Each safety analysis includes, but is not limited to, the following major criteria: criticality and/or reactivity considerations; heat generation considerations; shielding considerations; and off-gassing and/or chemical reactions. It also includes all credible accident and transient scenarios, which also involve concurrent or multiple experiment failures, to ensure that the experiment does not jeopardize the safe operation of the reactor or constitute a hazard to the safety of the facility staff and general public.

References:

49-1 LAR Part 1, Attachment 1, "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor*," Section 10.7

49-2 Letter to NRC, dated March 11, 2011, in response to "University of Missouri at Columbia - Request for Additional Information Re: License Renewal, Safety Analysis Report, 45-Day Response Questions (TAC No. MD3034)," dated June 1, 2010

50. *LAR, Attachment 1, Section 10.1, "Target Experimental Facility Maximum Hypothetical Accident," provides a description of the maximum hypothetical accident (MHA) associated with the TEF (known as the TEF MHA versus the SAR MHA which results from the Failed Fueled Experiment accident). The NRC staff review of the TEF MHA did not identify any discussion as to the adequacy of the existing engineered safety features (ESFs), or whether additional ESFs were needed for the operation of the TEF MHA, in order to ensure that radiation doses to the workers and public remain below the limit in 10 CFR Part 20. Additionally, the NRC staff didn't find any discussion describing which MHA was considered the bounding MHA (Failed Fueled Experiment MHA or TEF MHA).*

The regulations in 10 CFR Part 20 require that doses to workers and members of the public be limited. Furthermore, NUREG-1537, Part 1, Chapter 6, "Engineered Safety Features," Section 6.1, "Summary Description," provides guidance that the applicant should describe all the ESFs in the facility design and summarize the postulated accidents whose consequences could be unacceptable without mitigation.

50.1. Provide a description of the adequacy of the existing ESFs, and whether additional ESFs were needed for the operation of the TEF MHA, in order to ensure that radiation doses to the workers and public remain below the limit in 10 CFR Part 20, or justify why no additional information is needed.

No new Engineered Safety Features (ESFs) are required for the Selective Gas Extraction (SGE) Target Experimental Facility (TEF). As described in Chapter 6 of the MURR Safety Analysis Report (SAR), MURR has two (2) ESFs: the Containment System and the Anti-Siphon System. These systems are designed to mitigate the consequences of certain identifiable accidents – Maximum Hypothetical Accident (MHA) and the reactor Loss of Coolant Accident (LOCA) – and to keep radiological exposures to the operating staff and the general public within the limits of 10 CFR 20. The containment system is designed to completely isolate the reactor containment building, thereby preventing or mitigating any uncontrolled release of radioactive materials to the environment during an accident. Redundancy is incorporated into the system to ensure that no single component or circuit failure will render any portion of the containment system inoperative.

As discussed in Section 10.1 of LAR Part 1, Attachment 1, and in the responses to RAI No. 7.1 through 7.10, the Containment System is assumed to initiate during the TEF MHA. The same assumptions regarding containment free volume, designed leakage rate, differential pressure, etc. are used in the TEF MHA analysis as they are used in the three (3) primary MURR accidents with radiological consequences: (1) Fuel Failure During Operation, (2) Fuel Handling Accident, and (3) Fueled Experiment Failure. Therefore, the Containment System is more than adequate to keep radiological exposures to the operating staff and general public within the limits of 10 CFR 20 during a TEF MHA.

50.2. Provide a description of which MHA provides the bounding analysis for MURR, or justify why no additional information is needed.

The Target Experimental Facility Maximum Hypothetical Accident (MHA) – failure of a single SGE target rod after 480 hours of operation at 10 MW and the subsequent release of the entire target rod gap

fission product inventory – results in a Total Effective Dose Equivalent of 428.38 mrem and 2.50 mrem in the restricted and unrestricted areas, respectively. These values were calculated for the response to RAI No. 7.8.

The current MURR MHA – Fueled Experiment Failure – results in a Total Effective Dose Equivalent of 1180.33 mrem and 1.12E-02 mrem in the restricted and unrestricted areas, respectively.

51. *LAR, Attachment 1, Section 10.2.1, "Rapid Insertion of Positive Reactivity," states, in part that "The target rod analysis for the positive reactivity step insertion examines the maximum powered target rod at the beginning and end of a three-week irradiation." The NRC staff review noted that LAR, Attachment 1, Section 6.1.4, "Target Assembly Steady-State Operation," states the minimum loaded TA (3 target rods) results in the most severe target rod operating conditions. The NRC staff review also finds that the assessment of the Rapid Insertion of Positive Reactivity emphasizes the calculated maximum fuel temperatures and acceptance criteria to fuel melt. The NRC staff assumes that the calculated target rod transient fuel temperature is maximized when the target rod initial fuel temperature is maximized. The NRC staff review further notes that both Attachment 1, Section 6.1.4, "Target Assembly Steady-State Operations," Table 30, "Predicted Thermal Performance for 11 Active Target Rods, 11.5 MWt Reactor Power, 85% Flow," and Table 32, "Predicted Thermal Performance for 3 Active Target Rods, 11.5 MWt Reactor Power, 85% Flow," provide an initial target rod fuel centerline temperature of 2,204.7 degrees Celsius.*

The NRC staff is not clear if the analysis described in Section 10.2.1, is initiated from the maximum powered target rod assuming a TA loaded with 3 target rods, or from the maximum powered target rod assuming a complete TA of 11 target rods. Additionally, the NRC staff is not clear if sensitivity analyses were done using a combination of target rods (1 through 11) which demonstrate the limiting TA composition associated with the Rapid Insertion of Positive Reactivity transient analysis.

The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 13, indicates that the LAR should also describe how equipment will work when needed in accident situations.

51.1. *Provide a description of the TA composition (i.e., number of target rods in the TA) used in the analysis in Section 10.2.1, and which composition of target rods is considered the limiting TA configuration, or justify why no additional information is needed.*

The target assembly (TA) composition used in the analysis in Section 10.2.1 consists of eleven (11) SGE target rods, as defined by proposed Technical Specification 3.1B.a [Ref. 51-1]. It was initially considered possible to operate with fewer than 11 SGE target rods, especially during system commissioning (Ref. 51-2), but that option has been subsequently eliminated in favor of always operating with a full target cartridge of 11 SGE target rods.

51.2. *Provide the results of the sensitivity study performed to establish the limiting TA composition, or justify why no additional information is needed.*

The limiting TA composition consists of eleven (11) SGE target rods. Other TA loading schemes [Ref. 51-2] have been eliminated in favor of always operating with a full target cartridge.

References:

51-1 Enclosure 1, "*Revised, proposed Technical Specification Pages,*" submitted to USNRC on December 6, 2017 as part of the responses to the Request for Additional Information, by letter dated September 7, 2017

51-2 LAR Part 1, Attachment 1, "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor,*" Section 6.1.4

52. *LAR, Attachment 1, Section 10.2.1, "Rapid Insertion of Positive Reactivity," states, in part, "The target rod analysis for the positive reactivity step insertion examined the maximum powered target rod at the beginning and end of a three week irradiation." LAR, Attachment 6, Section 2.1, "Design Requirements," states that the number of hours of irradiation in a 1 week irradiation cycle is 152 consecutive hours. Furthermore, LAR, Attachment 2, Section 3.11, "Selective Gas Extraction Target Experimental Facility," proposed TS, Specification d., states, each SGE target rod shall not be irradiated for greater than 480 hours at 10 megawatts, and the TS bases states the thermal steady-state and transient analyses are based on an SGE target rod being irradiated for no greater than 480 hours at 10 megawatts. However, the NRC staff review did not find the analyzed target rod irradiation time.*

The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 13, indicates that the LAR should also describe how equipment will work when needed in accident situations.

Provide the maximum target rod irradiation time in hours used in the rapid insertion of positive reactivity analysis, or justify why no additional information is needed.

The maximum target rod irradiation time in hours for a rapid positive reactivity insertion accident (RIA) analysis was originally performed for 450 hours at 10 MW. This value is consistent with the neutronics design [Ref. 52-1], and includes midweek shutdowns of approximately 4 hours and end of week shut downs of approximately 16 hours. Also, the daylong 11.5 MW irradiation times at the beginning and end of irradiation for the RIA analyses have been converted to equivalent 10 MW irradiation times to arrive at this value.

A FRAPCON/FRAPTRAN analysis was also performed to investigate the effect of irradiation time (480 hours vs. 450 hours) on temperatures and strains for the 600 pcm RIA. For the 480 hours case, the peak temperature increased by 17 °C, from 2743 °C to 2760 °C, for a 64 um gap, and this peak temperature now occurs at end-of-life (EOL) as compared to beginning-of-life (BOL) for the 450 hour case. This provides an 80 °C margin to the melting temperature of 2840 °C. Maximum hoop strains in the 36 um gap case increase slightly, from 0.79% to 0.80%. The increase in temperatures/strains is due to decreased gap conductance from an increase in released fission product gases.

References:

52-1 LAR Part 1, Attachment 6, General Atomics Report 30441R00031, "*Mo-99 Target Assembly Nuclear Design for Once-Through Operation*," Section 2.1, Rev. B, 19 January 2017

53. *The NRC staff review did not identify any changes proposed to the MURR Organization as a result of the proposed LAR.*

The regulations in 10 CFR 50.90 require that the applicant submit an application fully describing the changes desired, and following as far as applicable, the form prescribed for original applications. Furthermore, the guidance in NUREG-1537, Part 2, Chapter 12.1, "Organization," states that the organization should be specified.

Provide a description of any organization changes at MURR as a result of the proposed LAR, or justify why no additional information is needed.

The MURR Organization is described in Section 6 of the Technical Specifications (TS), specifically TS 6.1.a through g and Figure 6.0. Implementation of LAR Part 1, the "in-pool" portion of the project, will not require any changes to Chapter 12 of the MURR Safety Analysis Report or Section 6 of the TSs.

The MURR Organization required for implementation of LAR, Part 2, the "ex-pool" portion of the project will require training and certification of the process operators as prescribed in NUREG-1537, ISG, Section 12.1.4, "Selection and Training of Personnel." The required changes to the MURR Organization for the "ex-pool" portion of this project will be provided in the LAR Part 2 submittal.

LAR Attachment 2

54. *LAR Attachment 2, proposed TS 3.8, Specifications f, n, r, and t, describe exceptions for the SGE target rods. The NRC staff noted that the corresponding TS bases for TS 3.8, Specifications f, n, r, and t, generally provided a reference to the applicable SAR section. However, the NRC staff could not find a justification which explained the reason for each TS exception.*

    The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. NUREG-1537, Part 2, Chapter 14, provides guidance that the TSs should be supported by their respective safety analysis.

    Provided justification which explains the reason for each exception listed in TS 3.8, Specifications f, n, r, and t, or justify why no additional information is needed.

    Specification 3.8.f:

    A failure analysis of an SGE target rod during reactor operation has been performed. The total iodine-131 through iodine-135 inventory that is released into the reactor pool at the time of target rod failure is listed in Table 39 of LAR Part 1, Attachment 1. This inventory is much greater than the 150 Curie limit of current Technical Specification 3.8.f. The current bases states that an analysis of a fueled experiment containing inventories greater than 150 Curies has not been completed and therefore their use is not permitted. In the case of the SGE TEF, an analysis has been completed and the doses to a worker and public based on 5-minute (restricted area) and 16.5-hour (unrestricted area) exposures, respectively, have been calculated. Failure of a single SGE target rod after 480 hours of operation at 10 MW and the subsequent release of the entire fission product inventory within the target rod gap results in a Total Effective Dose Equivalent of 428.38 mrem and 2.50 mrem in the restricted and unrestricted areas, respectively (See response to RAI No. 7.8). Therefore, since an analysis has been performed and the dose consequences calculated, SGE target rods should be excepted from this Specification.

    Specification 3.8.n:

    As stated above, a failure analysis of an SGE target rod during reactor operation has been performed and dose consequences have been calculated, such as they have been completed for the other two exceptions to this Specification: fueled experiments that produce iodine-131 through iodine-135 and non-fueled experiments that are intended to produce iodine-131. Therefore, since an analysis has been performed and the dose consequences calculated, SGE target rods should be excepted from this Specification.

    Specification 3.8.r:

    To prevent accidental voiding and failure of the SGE target assembly, the SGE target rods cooling system is designed to maintain sufficient cooling water flow rate and temperature conditions at all times such that a large critical heat flux margin is maintained, and any subcooled nucleate boiling will have a negligible impact on the safe operation of the target rods. The design provides a critical heat flux

ratio (CHFR) of >2.0 under all operating conditions, and was obtained using the most conservative heat flux correlation (Bernath) for the SGE target rod conditions (LAR Part 1, Attachment 1, Section 6). In addition, experimental testing of the system has confirmed the calculated critical heat flux analyses [Ref. 54-1]. The results show that measured critical heat fluxes agree within 10% with the values obtained using the Groeneveld correlation, which are less conservative than critical heat fluxes calculated using the Bernath correlation.

Specification 3.8.t:

A detailed safety analysis has been performed on the SGE target rod system that shows no fuel melting, including any centerline melting, or cladding breach is expected from a number of accident conditions that have been analyzed (LAR Part 1, Attachment 1, Section 10). Additionally, post-irradiation examination of test capsules irradiated at representative operating conditions has shown that under conditions more limiting (higher steady-state heat generation rate) that the fuel shows no signs of melting and that the cladding maintains its structural integrity [Ref. 54-2]. While the factor of 2.0 below melting temperature is not maintained for the UO_2 in the SGE target rod, analysis and experiment predict that experimental failure is unlikely.

References:

54-1 LAR Part 1, Attachment 10, General Atomics Report 30441R00041, "*Critical Heat Flux Testing at the University of Wisconsin Final Report*," Rev. A, 14 April 2017

54-2 CNL Test Report, "*Irradiation and PIE of UO_2 Target Pellets at Canadian Nuclear Laboratories: Final Report*," to be issued January 2018

55. *LAR Attachment 2, proposed TS 3.11, "Selective Gas Extraction Target Experimental Facility," Specification c, states "Each SGE target cartridge shall contain eleven (11) SGE target rods." Furthermore, proposed TS 4.11, "Selective Gas Extraction Target Experimental Facility," Specification a, states "Each SGE target cartridge shall be verified to consist of eleven (11) SGE target rods...." However, LAR Attachment 1, Section 2.1.4, "Target Cartridge," states, in part, that "During commissioning operations, it will be necessary to load fewer than 11 [uranium dioxide] UO_2 filled target rods in a cartridge." The NRC staff is not clear how the proposed TS 3.11.c and TS 4.11.a, support operation with less than 11 UO2 target rods.*

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. NUREG-1537, Part 2, Chapter 14, provides guidance that the TSs should be supported by their respective safety analysis.

Provide a safety analysis for operation with less than 11 UO_2 target rods and revise proposed TS 3.11.c and TS 4.11.a accordingly, or justify why no additional information is needed.

The safety analysis for operation with less than 11 target rods is provided in Section 5.3.5 of LAR Part 1, Attachment 1, and Section 4.3.3 of LAR Part 1, Attachment 6 (Ref 55-1). The most limiting case is operation with three (3) target rods. As discussed in the response to RAI 51.1, it was initially considered possible to operate with fewer than 11 active SGE target rods, especially during system commissioning (Ref. 55-2), but that option has been subsequently eliminated in favor of always operating with a full target cartridge of eleven (11) SGE target rods. As discussed in the response to RAI No. 42, each SGE target cartridge shall contain eleven (11) SGE target rods (Proposed Technical Specification 3.1B.a).

References:

55-1 LAR Part 1, Attachment 6, General Atomics Report 30441R00031, "*Mo-99 Target Assembly Nuclear Design for Once-Through Operation*," Rev. B, 26 August 2016

55-2 LAR Part 1, Attachment 1, "*License Amendment Request to Implement SGE TEF at the University of Missouri Research Reactor*," Section 6.1.4

56. *In the NRC staff-issued SER for license renewal (ADAMS Accession No. ML16124A887), TS 5.3, "Reactor Core and Fuel," Specification l, describes the experimental facilities. Although TS 5.3, Specification l.3, describes a portion of the graphite reflector, the NRC staff noted that the TEF was not listed in TS 5.3.*

The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. NUREG-1537, Part 2, Chapter 14, Section 3.8, "Experiments," provides guidance that the experimental facilities should be described in TS Section 5, "Design Features."

Provide a description of the TEF in TS 5.3, or justify why no additional information is needed.

MURR initially felt that Technical Specification 5.3.l.3, "A portion of the graphite reflector;" was sufficient in the way it is worded since the target assemblies will be located within the graphite reflector region. However, since a significant portion of the TEF is not within the graphite reflector region, TS 5.3.l will be revised to read:

"l. The reactor shall have the following experimental facilities:

1. Six (6) beam tubes which penetrate the graphite reflector;
2. A center test hole located in the flux trap;
3. A portion of the graphite reflector;
4. A bulk pool consisting of the water region above and outside the graphite reflector;
5. A thermal column; and
6. A Selective Gas Extraction Target Experimental Facility."

Additionally, the bases for Specification 5.3.l will be revised to read:

"l. Specification 5.3.l assures that the reactor consists of the experimental facilities as required by design (Ref. Chapter 10 of the SAR and Amendment No. 38)."

LAR Attachment 3

57. *LAR Attachment 3, Section 3.1.1, "Selective Gas Extraction Target Experimental Facility QAL 1 Components," states that, "As the result of the engineering determination and assessment to identify all of the equipment required for the SGE TEF, the following components are considered to meet the QAL 1 designation: the target rods' cladding, endcaps (upper and lower) and welding of the endcaps; the target pellets; the flow meters in the target cooling system; and the temperature sensor downstream of the heat exchanger in the target cooling system, including its signal conditioner." However, the NRC staff is not clear if these constitute SGE TEF system, structures or components (SSCs), or if they are considered ESFs.*

    The regulations in 10 CFR 50.9 require that information provided to the Commission by a licensee shall be complete and accurate in all material respects. Furthermore, the guidance in NUREG-1537, Part 1, Chapter 3, "Design of Structures, Systems, and Components," states that the licensee should discuss the SSCs required to ensure reactor facility safety and protection of the public, and Chapter 6, "Engineered Safety Features," states that the license should discuss ESFs.

    Provide a description of any SGE TEF SSCs or ESFs needed as a result of this LAR, or justify why no additional information is needed.

All of the Quality Assurance Level I (QAL I) designated components listed above are SSCs. As explained in the response to RAI No. 50, there are no new ESFs associated with the SGE TEF.

SSCs which are needed to perform essential safety functions for the operation of the TEF are designated as QAL I under the Quality Assurance Program for the analysis, design, procurement and fabrication activities associated with the SGE TEF (LAR Part 1, Attachment 3, Section 3). The QAL I designation is applied to SSCs, related items or design characteristics which prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. For the SGE TEF, these SSCs are:

1. Target rod cladding, endcaps and welds: Form a hermetic barrier against release of fission products to the reactor pool.
2. Target pellet design and manufacture: Shape, size and fissile content.
3. Flow meters in the Target Cooling System: These components safely shut down the reactor should a reduction or loss of target coolant flow occur.
4. Temperature sensors downstream of the Target Cooling System heat exchanger: These sensors and associated signal conditioning equipment indicate when the temperatures are outside of the normal operating range and cause a reactor shutdown should this event occur.

The basis for the selection of these SSCs as QAL I components is given in Table 57-1; additional technical bases for their selection and classification as QAL I is provided in Reference 57-1.

Table 57-1
Basis for Identifying Safety-Related Components

Safety Function	**Target rod cladding, endcaps and welds**	**Target pellets**	**Flowmeters in Target Cooling System**	**Temp sensor/conditioner in Target Cooling System**
1. Maintain integrity of radionuclide barrier	X		X	X
2. Safe reactor shutdown			X	X
3. Assure essential heat removal from the target rods	X	X	X	X
4. Safety design bases event analyses/assumptions	X	X	X	X

References:

57-1 General Atomics Report 30441R00040, "*MURR Pool and Target Cooling System QAL I Components: Technical Evaluation Report*," Rev. A, 26 April 2017

Correction to the response to RAI No. 3.3, by letter dated December 6, 2017:

3.2. *A description if there is any protection from debris entering the target decay heat removal valves when they are open.*

Currently, there is no protection from debris entering the Target Decay Heat Removal Valves when they are open as they take in clean water from the reactor pool. Additionally, natural convection flow is upward and out through the valves when they are open to remove decay heat from the Target Assemblies when shut down. Reactor Operations administrative procedure AP-RO-110, "Conduct of Operations," contains strict guidance regarding "Foreign Material Exclusion" when working on or near systems where foreign material could be introduced, especially around the reactor pool.

The natural convection flow was incorrectly stated as upward and out through the valves. The response should have stated:

"Additionally, natural convection flow is downward and in through the valves when they are open to remove decay heat from the Target Assemblies when shut down."