SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING AMENDMENT NO. 23 TO

RENEWED FACILITY OPERATING LICENSE NO. R-106

OREGON STATE UNIVERSITY

OREGON STATE TRIGA REACTOR

DOCKET NO. 50-243

1.0 INTRODUCTION

By letter dated April 13, 2012 (Ref. 1), as revised and supplemented by letters dated January 8, 2013 (Ref. 2), August 23, 2013 (Ref. 4), April 14, 2014 (Ref. 6), March 2, 2015 (Ref. 13), July 13, 2015 (Ref. 14), and email dated January 4, 2016 (Ref. 15), the Oregon State University (OSU or the licensee) submitted a license amendment request under the provisions of Section 50.90 of Title 10 of the *Code of Federal Regulations* (10 CFR) to the U.S. Nuclear Regulatory Commission (NRC or Commission) to amend the Oregon State TRIGA® Reactor (OSTR) renewed Facility Operating License No. R-106 and Technical Specifications (TSs). The licensee stated the proposed changes are for the "explicit purpose of demonstrating the production of [molybdenum-99 (^{99}Mo)] in a small reactor" (Ref. 1). The requested license and TS changes would allow the irradiation of up to three medical isotope production targets (hereinafter targets) containing fissionable material in the OSTR. The irradiation period would be no longer than 6.5 effective full-power days (EFPD) or 7.15 megawatt-days (MWD), after which the targets would be removed from the reactor for measurements and isotopic evaluation.

By correspondence dated April 22, 2013 (Ref. 3), and February 7, 2014 (Ref. 5), the NRC staff requested additional information from the licensee. By letters dated August 23, 2013, April 14, 2014, March 2, 2015, July 13, 2015, and email dated January 4, 2016, the licensee responded to these requests.

The original license amendment request, the NRC staff requests for additional information (RAIs), and licensee responses to the RAIs contain proprietary information and, therefore, contain information that is withheld from public disclosure in accordance with 10 CFR Section 2.390, "Public inspections, exemptions, requests for withholding." Publicly-available portions (i.e., non-sensitive and non-proprietary) of the foregoing correspondence are listed in the References section and may be accessed in the NRC's Agencywide Documents Access and Management System (ADAMS) public document collection at http://www.nrc.gov/reading-rm/adams.html.

The NRC staff is also reissuing the TSs in their entirety to correct pagination and font conversion errors introduced by the NRC staff as discussed in Section 3.9 of this Safety Evaluation (SE).

2.0 REGULATORY EVALUATION

The NRC staff reviewed the licensee's application to ensure that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) activities proposed will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public. The NRC staff considered the following regulatory requirements, guidance, and licensing and design basis information during its review of the proposed changes.

Part 20, "Standards for Protection Against Radiation," of 10 CFR, establishes standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC.

Part 50, "Domestic Licensing of Production and Utilization Facilities," of 10 CFR, provides the regulatory requirements for licensing of non-power reactors.

Section 50.92, "Issuance of amendment," of 10 CFR, paragraph(a), states, in part, that: "[i]n determining whether an amendment to a license […] will be issued to the applicant, the Commission will be guided by the considerations which govern the issuance of initial licenses […] to the extent applicable and appropriate."

Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions," of 10 CFR, provides regulatory requirements for the protection of the environment.

Section 182a of the Atomic Energy Act of 1954, as amended, requires applicants for utilization facilities to include TSs as a part of the license. The regulatory requirements related to the content of the TSs are contained in 10 CFR 50.36, "Technical specifications." The TSs requirements in 10 CFR 50.36 include the following categories: (1) safety limits, limiting safety systems settings and limiting control settings, (2) limiting conditions for operation (LCOs), (3) surveillance requirements (SRs), (4) design features, (5) administrative controls.

NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria," (Ref. 8), provides guidance to NRC staff on the conduct of licensing action reviews for non-power reactor licensing applications. Chapters referenced in the conduct of this review include: Reactor Description (Ch. 4), Auxiliary Systems (Ch. 9), Experimental Facilities and Utilization (Ch. 10), Accident Analysis (Ch. 13), and Technical Specifications (Ch. 14).

Regulatory Guide (RG) 2.2, "Development of Technical Specifications for Experiments in Research Reactors," (Ref. 7) provides guidance on developing TS for experiments and includes a regulatory position statement regarding irradiation of fissionable material. Aside from fuel element assemblies described in the TS, the RG states that irradiation of fissionable material is considered an unreviewed safety question and requires Commission review and approval of safety analysis and establishment of specifications in support of those experiments. The existing OSTR license and TS do not currently address experiments involving irradiation of fissionable material. Therefore, the licensee submitted a license amendment request and supporting safety analysis in order to irradiate these targets.

3.0 TECHNICAL EVALUATION

The NRC staff reviewed the license amendment request (Ref. 1), as well as the safety analysis report (SAR) submitted for conversion in 2007 (Ref. 9). The reactor performance and accident analysis methodology used in the 2007 conversion SAR formed part of the basis for this license amendment request. The request was reviewed in accordance with the guidance of NUREG-1537.

3.1. Reactor Description Summary

The OSTR is located at the OSU campus in Corvallis, Oregon. The OSTR is a natural convection, water-cooled, Mark-II TRIGA® pool-type reactor built by General Atomics. The OSTR can be operated at a maximum steady-state thermal power level of 1.1 megawatt (MW(t)), pulsed up to a peak power of about 2,500 MW(t), or operated in a square-wave mode.

The OSTR core consists of six concentric rings of fuel or graphite element locations surrounding a central aluminum slug. These concentric rings are referred to by letters, starting with the innermost B-ring to the outermost G-ring. The reactor core is surrounded by a graphite reflector.

The reactor is fueled with LEU TRIGA® fuel elements. These elements have a nominal enrichment of 19.75 percent uranium-235 (^{235}U), nominal uranium content of up to 30 weight percent (w/o), erbium poison content of 1.1 w/o, and zirconium hydride ($ZrH_{[1.5-1.65]}$) as the balance of the fuel.

The OSTR core is located near the bottom of a water-filled aluminum tank. For personnel shielding, the tank is shielded radially by ordinary concrete, water, lead, and graphite. Approximately 16 feet of water above the reactor core provides shielding at the top of the reactor tank. Four control rod drives (three motor-driven and one pneumatic electro-mechanical driven) are mounted at the top of the tank on a bridge structure spanning the tank. Irradiated fuel elements and targets may be moved within the core or to/from designated storage racks located under water in the tank (also known as in-tank storage racks).

3.2. Target Design

According to Section I of its analysis (Ref. 2), the licensee states that up to three aluminum-clad targets containing fissionable material are proposed to be irradiated in the outermost ring (G-ring) of the core in locations G32, G33, and G34. Each target is designed with the same exterior dimensions as a TRIGA® fuel element and contains uranium nominally enriched to 19.75 percent ^{235}U. The target has welded end fittings that will fit the top and bottom grid plates of the OSTR.

In Section III of its analysis (Ref. 2), the licensee described the neutronic analysis that modeled the OSTR core containing both fuel and targets, which is discussed further in Section 3.3, “Nuclear Design.”

In Section VI of its analysis (Ref. 2), the licensee proposed to modify the TSs to provide a LCO (TS LCO T4) for the target fabrication requirements, which is discussed further in Section 3.8.2, "Proposed Changes to Technical Specifications." According to the licensee's RAI responses (Ref. 4), the targets will be subject to configuration control and manufactured under a quality assurance plan to ensure consistency between the analysis and end product.

The NRC staff reviewed the license amendment application and supplemental information, which described the target. The NRC staff finds that the licensee adequately discussed the constituents, materials, and components for the targets. The NRC staff finds that the target design (e.g. dimensions, cladding material) is compatible with the existing OSTR core design. Because the target fabrication requirements will ensure adherence to the design bases and safety-related requirements as described in the license amendment application, the NRC staff concludes the target design is acceptable.

3.3. Nuclear Design

3.3.1. Calculational Methodology

In Section III of its analysis (Ref. 2), the licensee states that a Monte Carlo N-Particle (MCNP) model was developed to carry out the neutronic analysis of the core containing the targets. The licensee analyzed the core configuration changes (e.g., targets, fuel, graphite, water, and irradiation locations) in order to demonstrate that the overall power level of the reactor will remain within the OSTR license limit of 1.1 MW(t).

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR to compare the licensee's current calculational methodology to the calculational methodology previously approved by the NRC staff. The NRC staff previously reviewed and accepted the calculational methodology proposed by the licensee (Ref. 10, Enclosure 4). Because the licensee used documented codes that are well-accepted and have been validated against data for TRIGA® reactors, including the OSTR, the staff concludes that the calculational methodology used by the licensee is acceptable.

3.3.2. Reactivity Worth, Excess Reactivity, Shutdown Margin

Reactivity Worth and Excess Reactivity

In Section III of its analysis (Ref. 2), the licensee provided calculated values for the individual and combined reactivity worth of the targets in the specified core locations.

In Section III of its analysis (Ref. 2), the licensee states prior fuel movement experience has shown addition of reactivity in the G-ring does not significantly affect reactivity worth of control rods. However, the licensee's analysis showed that the overall reactivity worth of the reactor core would change by more than $0.25. The licensee states control rod worth will be measured after installation of targets to verify shutdown margin before full-power operation is allowed. The NRC staff finds this action is required by TS 4.1.b, which requires total reactivity worth of each control rod to be measured following a change in reference core reactivity greater than $0.25. Because the TS continues to provide assurance that shutdown margin is maintained before full-power operation, the NRC staff finds the changes in reactivity worth to be acceptable.

In Section III of its analysis (Ref. 2), the licensee calculated core excess reactivity using various initial conditions and core configurations at the beginning of life (BOL). However, the

2007 conversion SAR indicated that the highest core excess reactivity occurs at middle of life (MOL), or around 1,600 MWD (about 14 years from the date of this license amendment), with the lowest shutdown margin due to the production of fissionable material and the reduction of burnable poisons in the fuel elements. In RAI responses (Ref. 6), the licensee provided justification for basing calculations on the conditions at BOL due to the OSTR's low number of MWDs of operation since 2007. As of June 2014, the current OSTR core had 293.8 MWD of operation with 30-70 MWD added annually. Further, the anticipated changes in core excess reactivity during MOL core conditions is operationally controlled by fuel management, as was previously demonstrated at OSTR with the fuel lifetime improvement program fuel from 1976-2008. Because the license amendment application proposes a one-time irradiation of the targets in the near future (i.e. one to three years, not 14 years), the NRC staff finds that the revised initial condition assumption of BOL used in the analysis is acceptable.

During its review of Section III of the license amendment application, the NRC staff noted that the calculated BOL core excess reactivity in the application was different from the reactivity value submitted in the 2007 conversion SAR. The NRC staff concluded that value submitted in the license amendment application was based on a measurement of actual core excess reactivity in the initial LEU operating core from 2008 that the licensee included in Section IV.B. of its Post Conversion Startup Report (Ref. 11). The licensee also published a paper in a peer-reviewed journal that explained the potential reasons for the difference between the calculated value and measured values for core excess reactivity (Ref 12, pp141-142). These reasons included: 1) the initial assumption to use HEU core model bias when modeling the LEU core; 2) changes in initial LEU core configuration from what was modeled; and 3) differences in material composition and trace element contaminants between analyzed and manufactured LEU fuel elements. Additionally, the values submitted for BOL core excess reactivity in Section III of the analysis (Ref. 2) are also based on the current OSTR core configuration. The NRC staff finds the measured value for core excess reactivity is more representative of the current OSTR core and, therefore, is acceptable.

In Section III of its analysis (Ref. 2), the licensee provided calculated values for core excess reactivity based on the target reactivity worth. The combined reactivity worth of the three targets would increase the core excess reactivity; however, core excess reactivity remains below the TS 3.1.3, "Core Excess Reactivity," maximum limit of $7.55. Therefore, the NRC staff finds the values for target reactivity worth and core excess reactivity are acceptable.

Shutdown Margin

In Section III of its analysis (Ref. 2), the licensee provided calculated values for shutdown margin using various initial conditions and core configurations at BOL. The current OSTR limiting shutdown margin in a normal configuration is $1.62. With the targets installed, the shutdown margin would be reduced; however, shutdown margin remains greater than the TS 3.1.2, "Shutdown Margin," minimum limit of $0.55. Therefore, the NRC staff finds the value for shutdown margin is acceptable.

Conclusions

The NRC staff reviewed the license amendment application, supplemental information, 2007 conversion SAR, and the licensee's current TSs. Following any significant change (>$0.25) from a reference core, TS 4.1b, TS 4.1c, and TS 4.1d require control rod worth, excess reactivity, and shutdown margin to be measured. The NRC staff finds TS 4.1b, TS 4.1c, and TS 4.1d will continue to ensure the ability to safely shutdown the reactor after target installation. Based on the information discussed above, the NRC staff finds that the ability to shutdown the reactor with the targets installed in the core will be maintained.

3.3.3. Dynamic Parameters

In Section III of its analysis (Ref. 2), the licensee states that the installation of the targets should not appreciably change the global core neutronic parameters (e.g. neutron lifetime, delayed neutron fraction, coefficients of reactivity). The licensee bases this statement on the relative low neutron flux at the periphery of the core at the proposed target locations and the small mass of fissionable material in target (less than 3.5 percent of core mass).

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. Dynamic parameters are based on the neutronic behavior of the entire core. Since the targets represent less than 3.5 percent of core mass, the NRC staff finds that the global neutronic parameters will not appreciably change. Therefore, the NRC staff finds the irradiation of the targets will not unacceptably change the basic behavior of the core.

3.3.4. Thermal Power

In Section III of its analysis (Ref. 2), the licensee states the addition of the targets to the periphery of the core thins out the flux and power density with the core operating at the same licensed power of 1.1 MW(t). This reduces the power produced in each fuel element. The licensee also stated that it used MCNP5 and the same methodology described in the 2007 conversion SAR to reach these conclusions. The licensee calculated a maximum fuel element thermal power of 16.69 kW ± 0.02 kW for the LEU core at BOL in a Normal core configuration. The licensee also calculated a maximum target thermal power. The maximum fuel element thermal power and maximum target thermal power are both below the 18.52 kW maximum fuel element thermal power evaluated in the 2007 conversion SAR.

In Section VI of its analysis (Ref. 2), the licensee proposed to modify the TSs to add an LCO (TS LCO T1) to limit the addition of the targets to the positions analyzed (G32, G33, and G34), which is discussed further in Section 3.8.2, "Proposed Changes to Technical Specifications."

The NRC staff reviewed the license amendment application and the 2007 conversion SAR. The NRC staff finds the calculated values for maximum thermal power of both the fuel elements and targets are below the maximum previously evaluated and are, therefore, bounded by the existing analysis contained in the conversion SAR.

3.3.5. Conclusions

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. The NRC staff finds that the neutronic parameters of the OSTR core have been calculated using established methods and take into account the proposed TSs and limited duration of the target irradiation (less than seven (7) EFPD). Based on the information discussed above, the NRC staff concludes that the changes in nuclear design due to the addition of the targets are acceptable.

3.4. Thermal-Hydraulic Analysis

3.4.1. Calculational Methodology

In Section IV and Appendix A of its analysis (Ref. 2), the licensee performed thermal-hydraulic analysis using a similar methodology as the 2007 conversion SAR. The licensee developed a RELAP5-3D model to carry out the analysis. The parameters that were calculated include: target core and cladding temperatures, coolant flow rate, bulk coolant temperature, and departure from nucleate boiling ratio (DNBR).

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR to compare the licensee's current calculational methodology to the calculational methodology previously approved by the NRC staff. The NRC staff previously reviewed and accepted the use of RELAP5-3D as proposed by the licensee (Ref. 10, Enclosure 4). Because the licensee used a documented code that is well-accepted and has been validated at other reactors, including the OSTR, the staff concludes that the calculational methodology used by the licensee is acceptable.

3.4.2. Results of the Thermal-Hydraulic Analysis

In Section IV and Appendix A of its analysis (Ref. 2), the licensee states that the thermal hydraulic analysis utilized bounding initial conditions that correspond to TS limits, the target element at maximum thermal power, and a hypothetical coolant flow channel modeled after the smallest channel locations in the core. Consistent with the thermal-hydraulic analysis in the 2007 conversion SAR, the licensee modeled the hypothetical coolant flow channel for the targets based on the smallest channel locations in the core. Use of this hypothetical coolant flow channel would provide bounding thermal-hydraulic conditions (e.g. target temperature, coolant temperature, coolant flow). As discussed in Section 3.3.4, "Thermal Power," of this SE, thermal power produced in each fuel element is decreased. The expected maximum target temperatures decreases correspondingly and, therefore, is bounded by the 2007 conversion SAR thermal hydraulic analysis. The licensee calculated a maximum coolant temperature of 74.4 degrees Celsius (degrees C), maximum fissionable target material temperature of 122.8 degrees C, and maximum target cladding temperature of 113.6 degrees C. In its RAI responses (Ref. 6), the licensee presented a sensitivity study on thermal conductivity of the target region containing fissionable material. The sensitivity study used more conservative values for thermal conductivity based on available published research. Using the study, the licensee calculated a maximum fissionable target material temperature of 384.2 degrees C and a maximum target cladding temperature of 116.1 degrees C. The licensee also calculated that the average fissionable target material temperature would be approximately 300 degrees C. In Section V of its analysis (Ref. 2), the licensee states that the target cladding temperatures will remain below 600 degrees C; above this temperature the target cladding approaches its melting point. The NRC staff finds the maximum cladding temperature of the target is below temperatures that would challenge the integrity of the target's aluminum cladding. The NRC staff also finds the initial conditions for the thermal-hydraulic analysis are bounded by the analysis in the 2007 conversion SAR and the OSTR TS limits on power (TS 3.1.1), pool level (TS 3.3a), and pool temperature (TS 3.3b) will maintain target cladding integrity.

In Section IV and Appendix A of its analysis, the licensee calculated the critical heat flux (CHF) and the minimum departure from nucleate boiling ratio (MDNBR) for the hypothetical coolant flow channel. The licensee calculated MDNBR values of 16.049 using the Groeneveld Look-up Tables and 9.479 using the Bernath Correlation. The NRC staff finds the 9.479 MDNBR value calculated is greater than the 2.0 MDNBR guidance value provided in NUREG-1537 and is, therefore, acceptable. The NRC staff also finds the 9.479 MDNBR value calculated provides sufficient margin to CHF conditions within the target coolant flow channel.

In Section VI of its analysis, the licensee proposed to modify the TSs to add an LCO (TS LCO T2) to prohibit pulse or square wave mode operations while the targets are installed in the core. This is because the licensee did not analyze pulse or square wave mode operations with targets in the core. TS LCO T2 is discussed in Section 3.8.2, “Proposed Changes to Technical Specifications.”

3.4.3. Conclusions

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. The NRC staff finds the analyses were conducted using previously benchmarked computer codes, justified and reasonable assumptions, and methodology utilized in the conversion SAR. The NRC staff also finds the use of a hypothetical coolant channel modeled after the smallest coolant channel conditions in the core is conservative given the larger actual coolant channel conditions in the G-ring where the targets will be located. Based on the information discussed above, the NRC staff concludes that the thermal hydraulic analysis of the OSTR with targets installed adequately demonstrate that the targets do not decrease the core safety margins in regards to thermal hydraulic conditions.

3.5. Experimental Activities

In Section V of its analysis, the licensee stated that, other than changing the neutron flux in the core, the targets will not affect other experiments in the core. The OSTR conducts research activities through experiments that include the use of beam ports, vertical irradiation tubes, a thermal column, a thermalizing column, a pneumatic transfer system, a central thimble, an argon production facility, and a rotating rack. The licensee has not proposed any restrictions on the conduct of specific experiments when targets are located in the reactor.

The NRC staff reviewed the license amendment application, supplemental information, and existing TSs. Because the OSTR is used to conduct research and development activities, the NRC staff considered whether the target irradiation would affect other OSTR experiments. Based on the target location and limited affect on neutron flux in the core, the NRC staff finds that the licensee’s analysis demonstrates that presence of targets in the analyzed G-ring locations will not affect the ability to conduct other experimental activities in the OSTR and will not adversely affect continued safe operation.

3.6. Target Storage

In Section VII of its analysis (Ref. 2), the licensee provided information on the storage of targets. The licensee stated that the three targets would be stored in the existing fuel storage racks. The licensee provided calculated values for the effective neutron multiplication factor (k_{eff}) based on storage of three targets, which are less than the TS 5.4(a), “Fuel Storage,” maximum value for k_{eff} of 0.9. Since the targets and TRIGA fuel elements are both similar in dimension and will be stored based on a similar geometry, the NRC staff finds keeping k_{eff} less than the TS 5.4(a) value to be acceptable.

In Section VI of its analysis, the licensee proposed to modify the TSs to add an LCO (TS LCO T3) to limit the k_{eff} of stored targets to less than 0.9, which is discussed further in Section 3.8.2, “Proposed Changes to Technical Specifications.”

However, the licensee did not analyze interactions between targets and fuel elements in the storage racks. In order to address this configuration, the licensee proposed to modify the TSs to add an LCO (TS LCO T3) that prohibits storage of other items in any storage rack containing targets, which is discussed further in Section 3.8.2, “Proposed Changes to Technical Specifications.”

The NRC staff reviewed the license amendment application, supplemental information, and existing TSs. The NRC staff finds the analyses were conducted using a previously approved methodology that demonstrates that k_{eff} will be appropriately maintained, provided the storage array is limited to analyzed configurations. Based on the information discussed above, the NRC staff concludes that the ability to safely store targets and fuel in a subcritical array will be maintained.

3.7. Accident Analysis

In Section V of its analysis (Ref. 2), the licensee identified and evaluated nine hypothetical accident scenario consequences for target irradiation using a similar methodology as the 2007 conversion SAR.

3.7.1. Target Cladding Failure

Accident Description

In Section V of its analysis, the licensee analyzed the cladding rupture of one irradiated target with no radioactive decay followed by the instantaneous release of volatile fission products outside the cladding in water. Boundary conditions and assumptions included a limited target irradiation time, released fission products uniformly distributed in the reactor room air, and 100 percent of noble gases and 2.5 percent of halogens become instantaneously released and airborne. Boundary conditions for similar accident scenarios involving in-pool experiments containing fissionable material typically only consider a release in water. However, in a letter dated July 13, 2015 (Ref. 14), the licensee also provided calculated radiation doses from releases in air and water after a 24-hour decay period in the unlikely event a release were to occur during post-irradiation measurements. The NRC staff finds the assumptions and boundary conditions consistent with accepted nuclear industry practices and representative of the proposed targets.

Source Term Determination

In Section V of its analysis and RAI responses (Ref. 6), the licensee calculated the fission product inventory in a target based on methodology used in the 2007 conversion SAR using uranium-235 fission yields. The fission product yield was scaled based on the maximum power generation of a target. Initially, the licensee chose a 365-day irradiation time to determine fission product yield, which is consistent with their existing accident methodology for the reactor fuel. Because the licensee only plans on irradiating the targets for 6.5 EFPD (Ref. 2), the NRC staff identified this year-long timeframe as conservative and requested the licensee present a bounding estimate based on target irradiation time. According to the licensee's RAI responses (Ref. 6), the licensee recalculated the inventory for the planned target irradiation time of 6.5 EFPD. Use of this realistic assumption significantly reduced the available radioactive material in the target and results in the primary contributors for dose being nuclides with short half-lives. The NRC staff reviewed the methodology and calculation of the target source term inventory and finds the calculated source term inventory acceptable.

The licensee determined the quantity of volatile fission products available for release to the reactor building atmosphere. To further support the dose calculations in the license amendment application, an irradiation experiment consisting of a small sample of target material was performed at the University of Missouri-Columbia research reactor. By letter dated March 2, 2015 (Ref. 13), the licensee provided experimental results showing that the dose calculation from potential cladding breaches bound the results obtained by experiment.

The licensee's methodology for determining the release under accident conditions used the best available research in the field. Further, the NRC staff reviewed the experimental methodology used to provide supplemental information which used target material identical to that proposed to be irradiated in the Oregon State Reactor. Because the licensee's methodology used the best available research in the field and is complemented by a specific experiment, the NRC staff finds the method to determine fission products available for release acceptable.

Dose Result Calculations

In Section V of its analysis (Ref. 2), RAI responses (Ref. 6), and letter dated July 13, 2015 (Ref. 14), the licensee calculated radiation doses consistent with methodology used in the 2007 conversion SAR. The licensee used a number of scenarios in order to determine the most limiting or bounding potential radiation doses to staff or to the general public in an unrestricted area. As described above, the licensee analytically generated a radionuclide inventory for the target cladding failure. Using these inventories, the licensee evaluated occupational and public doses based on three different scenarios.

- Scenario A assumes a ground level release with the reactor room air leaving at the mean wind speed (1 m s^{-1}) through the north wall of the reactor room, which instantaneously vanishes. Individuals outside the reactor room are exposed for the amount of time it takes for the entire volume of the reactor room air to be evacuated, which is 8.52 seconds.
- Scenario B assumes a ground level release with the reactor room air leaving at the stack ventilation rate (4.39×10^6 cm^3 s^{-1}) through an unspecified release path. Individuals

outside the reactor room are exposed for the amount of time it takes for the entire volume of the reactor air to be evacuated, which is 14.7 minutes.

- Scenario C assumes a ground level release with the reactor room air leaving at the leakage rate (1.69 x 10^4 cm^3 s^{-1}) through the walls due to the pressure differential between the reactor room and outside. Individuals outside the reactor room are exposed for the amount of time it takes for the entire volume of the reactor air to be evacuated, which is 63.7 hours.

Reactor room occupational doses were calculated for an individual in the reactor room. A five-minute building evacuation time was assumed for the OSTR staff. Calculations using Scenario C provided the most limiting reactor room occupational doses. The occupational total effective dose equivalent (TEDE) for a release in water at the end of irradiation was calculated to be 41 mrem (0.41 millisievert (mSv)). The occupational TEDE for a release in air 24 hours after the end of irradiation was calculated to be 46 mrem (0.46 mSv). These are both below the regulatory limit of 5 rem (0.05 sievert (Sv)), or 5,000 mrem (50 mSv), in paragraph (a)(1)(i) of 10 CFR 20.1201, “Occupational dose limits for adults.” The thyroid dose (sum of the deep-dose equivalent and the committed dose equivalent) was calculated to be 157 mrem (1.57 mSv). This is below the regulatory limit of 50 rem (0.5 Sv), or 50,000 mrem (500 mSv), in paragraph (a)(1)(ii) of 10 CFR 20.1201.

Public exposure doses were calculated at the nearest facility boundary and at varying distances from the reactor. The nearest facility boundary is 10 m from the reactor. Calculations using Scenario A provided the most limiting offsite TEDE of 36 mrem (0.36 mSv). However, the NRC staff finds the assumptions used in calculating doses based on Scenario A to be conservative (i.e. entire reactor room wall vanishes). The NRC staff finds Scenario C provides the most realistic set of assumptions and conditions. Using Scenario C, the offsite TEDE for a release in water at the end of irradiation was calculated to be 3 mrem (0.03 mSv). The offsite TEDE for a release in air 24 hours after the end of irradiation was calculated to be 26 mrem (0.26 mSv). Both calculated doses are below the regulatory limit of 100 mrem (1 mSv) in paragraph (a)(1) of 10 CFR 20.1301, “Dose limits for individual members of the public.”

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. The NRC staff reviewed the methodology to calculate occupational and public radiation doses and finds it is consistent with NUREG-1537 guidance. The NRC staff performed independent confirmatory accident dose calculations and the results are consistent with the dose results the licensee provided. While the calculated doses for the target cladding failure are slightly higher than the calculated doses for the maximum hypothetical accident (MHA) in the 2007 conversion SAR, the differences in assumptions between the two scenarios contribute to the difference in calculated dose. Because the doses from the postulated scenario continue to demonstrate that the maximum TEDE doses were below the occupational limits in 10 CFR 20.1201 and the public exposure limits in 10 CFR 20.1301, the staff finds the difference in dose does not represent a significant increase. Based on the information discussed above, and confirmed by the NRC staff’s independent calculations, the NRC staff finds the results of the licensee’s analysis of the target cladding failure doses are acceptable.

3.7.2. Insertion of Excess Reactivity

In Section V of its analysis (Ref. 2), the licensee evaluated an uncontrolled withdrawal of a control rod with the addition of the targets. Based on calculations in the 2007 conversion SAR, the maximum reactivity insertion from an uncontrolled withdrawal of a control rod is $0.96, which is less than the reactivity normally inserted during pulsing operations.

In RAI responses (Ref. 4), the licensee indicated further analysis of the excess reactivity transient is not possible due to limitations in the RELAP5-3D point reactor kinetics model. The limitations prevented the licensee from inputting separate material parameters for both the fuel element and target. Alternatively, the licensee indicated the worst-case scenario following a pulse would be the simultaneous failure of all three targets with any resulting doses within the occupational limits and public exposure limits of 10 CFR Part 20. The NRC staff used the doses from a target cladding failure in water at the end of irradiation as discussed in Section 3.7.1 above to calculate the resulting doses from this worst-case scenario. The occupational TEDE was calculated to be 123 mrem (1.23 mSv). This is below the regulatory limit of 5 rem (0.05 Sv), or 5,000 mrem (50 mSv), in paragraph (a)(1)(i) of 10 CFR 20.1201. The thyroid dose was calculated to be 471 mrem (4.71 mSv). This is below the regulatory limit of 50 rem (0.5 Sv), or 50,000 mrem (500 mSV), in paragraph (a)(1)(ii) of 10 CFR 20.1201. The offsite TEDE for a member of the public was calculated to be 9 mrem (0.09 mSv). This is below the regulatory limit of 100 mrem (1 mSv) in paragraph (a)(1) of 10 CFR 20.1301.

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. Because proposed TS LCO T2 prohibits the licensee from conducting pulse or square wave operations when targets are in the core, the NRC staff finds the worst-case scenario following a pulse transient to be conservative. However, the doses from the worst-case scenario demonstrate that the maximum TEDE doses were below the occupational limits in 10 CFR 20.1201 and the public exposure limits in 10 CFR 20.1301. The NRC staff finds the results of a reactivity insertion from an uncontrolled rod withdrawal consistent with previously accepted analysis. Based on the information discussed above, the NRC staff concludes that the results of the licensee's analysis on the insertion of excess reactivity are acceptable.

3.7.3. Loss-of-Coolant Accident (LOCA)

In Section V of its analysis (Ref. 2), the licensee evaluated the impact of a LOCA with the addition of the targets. The scenarios leading to the LOCA are not affected by the addition of targets and, therefore, the analysis previously done in the 2007 conversion SAR is still applicable. The analysis assumes all water is instantaneously lost from the pool. The aluminum-clad targets reach peak temperature at 25 seconds following reactor SCRAM and loss of coolant. The peak temperature reached is less than the target clad failure temperature of 600 degrees C.

The licensee also evaluated the gamma ray dose from the exposed core and targets following the instantaneous loss of coolant. The dose rates are based on the fission product inventory, which is dependent on power history. Because operation of the reactor is limited to the licensed power level of 1.1 MW(t) and the targets are irradiated for only 6.5 EFPD, the addition of targets does not change the gamma ray dose following a loss of coolant accident.

The NRC staff reviewed the license amendment application and the 2007 conversion SAR. The NRC staff finds natural convective air cooling of the target is found to be sufficient to keep the target temperature below the temperature for cladding failure. The NRC staff finds the doses resulting from the exposed core and target are bounded by previous analyses. Based on the information discussed above, the NRC staff concludes the results of the licensee's analysis on LOCA are acceptable.

3.7.4. Loss of Coolant Flow

In Section V of its analysis (Ref. 2), the licensee discussed how a loss of coolant flow to the targets is mitigated. In the licensee's RAI responses (Ref. 4), the licensee evaluated a reduction or loss of flow to the targets, assuming full power reactor operation. Results provided show the peak temperature reached is less than the target clad failure temperature of 600 degrees C.

The NRC staff reviewed the license amendment application and supplemental information. The NRC staff finds the target temperature will remain below the temperature for cladding failure for a reduction or loss of flow. Based on the information discussed above, the NRC staff concludes the results of the licensee's analysis on loss of coolant flow are acceptable.

3.7.5. Other Accidents

In order to address all of the accident categories described in NUREG-1537, the licensee discussed how these other accidents have been considered. In Section V its analysis (Ref.2) and RAI responses (Ref. 4), the licensee states that these accidents have all been shown to either lead to acceptable results, to be bounded by the MHA in the 2007 conversion SAR, to be bounded by the target cladding failure accident, or not to be possible. The events discussed in the application and supplemental information that fall into this category are:

- Mishandling or Malfunction of Target
- Experiment Malfunction
- Loss of Normal Electrical Power
- External Events
- Mishandling or Malfunction of Equipment

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. The NRC staff finds the postulated results of the above listed accidents continue to be bounded by previously approved analyses or are not possible and, therefore, are acceptable.

3.7.6. Conclusions

The NRC staff reviewed the license amendment application, supplemental information, and the 2007 conversion SAR. Review of the calculations, including assumptions, demonstrated that the inventory of radioactivity assumed and other boundary conditions for the target cladding failure accident are acceptable. While the radiological consequences to the public and occupational workers from the target cladding failure accident are slightly higher than the radiological consequences calculated for the MHA for the OSTR, the resultant doses remain well within the regulatory limits of 10 CFR Part 20. As a result of this review, the staff concludes that continued operation of the reactor poses no undue risk from a radiological standpoint to the public or the staff of the OSTR in the event of a target cladding failure accident.

The addition of the targets does not change the assumptions, analyses or consequences of a LOCA and hence, consequences are acceptable for the targets. The licensee did not identify any new reactivity addition accidents not previously analyzed for the OSTR reactor. The licensee also found that other accidents previously considered for OSTR reactor either lead to acceptable results, are bounded by the MHA in the 2007 conversion SAR, are bounded by the target cladding failure accident, or are not possible with the addition of targets. Therefore, the risk to the health and safety of reactor staff and the public from reactivity addition accidents or the list of accidents in Section 3.7.5 above does not increase above that previously found acceptable for the OSTR reactor.

3.8. Proposed Changes to License Conditions and Technical Specifications

The licensee has proposed changes to the license conditions for special nuclear material possession limits and the TSs.

3.8.1. Proposed Changes to License Conditions

In Section VII of its analysis (Ref.2) and RAI responses (Ref. 6), the licensee requested the addition of license condition 2.B.(2) f. to allow for possession of the targets.

Based on the proposed possession limit, the new license condition would read as follows:

> f. to receive, possess, and use, but not separate, in connection with operation of the facility, up to 0.5 kilograms of contained uranium-235 enriched to less than 20 percent in the form of molybdenum-99 production targets.

The staff reviewed the proposed license changes associated with the amendment. The staff finds the proposed possession limit in license condition 2.B.(2) f. is consistent with the number of targets analyzed and, therefore, is acceptable.

3.8.2. Proposed Changes to Technical Specifications

In its analysis (Ref. 2), RAI responses (Ref. 6), and supplemental information (Ref. 15), the licensee has proposed the addition of five LCOs, as discussed below.

Proposed TS 3.10, "Targets," LCO T1, "Permissible in-core target lattice positions," reads as follows:

> LCO T1, Permissible in-core target lattice positions.
>
> Applicability: Any time when targets are located in any core lattice position.
>
> Objective: To ensure assumptions made for the neutronic and thermal hydraulic analyses are not compromised.
>
> Specification: Permissible target locations are core positions G32, G33, G34. Targets shall not be placed in any other core lattice positions.

Basis: Analyzed target locations were G32, G33 and G34. Location G34 was found to produce the highest integrated power in a target. Thermal hydraulic analysis was based on power distribution in this hot target.

The proposed new LCO identifies the permissible target locations based on core grid plate positions to ensure the assumptions in neutronic and thermal hydraulic analysis are not compromised. Because the proposed TS limits target positions based on those analyzed in the amendment application and evaluated in Sections 3.3, "Nuclear Design," and 3.4, "Thermal-Hydraulic Analysis," of this SE, the NRC staff finds the addition of TS LCO T1 to be acceptable.

Proposed TS 3.10, LCO T2, "Pulse or square wave mode operation with targets located in any core lattice position," reads as follows:

LCO T2, Pulse or square wave mode operation with targets located in any core lattice position.

Applicability: Any time when targets are located in any core lattice position.

Objective: To prevent all pulse activity while targets are present in any core lattice position.

Specification: The reactor shall not be operated in pulse mode or square wave mode while targets are present in any core lattice position.

Basis: Target performance has not been analyzed under rapid transient pulse conditions, therefore pulsing shall not be allowed when targets are present in the core. Pulse mode operation is prohibited. Square wave mode operation is also prohibited because it is possible to add more than $1.00 of reactivity in square wave mode. A rod withdrawal accident will not introduce sufficient reactivity to pulse the reactor.

The proposed new LCO prohibits reactor operations that are not bounded by the 2007 conversion SAR or have not been analyzed in the license amendment application (Ref. 2). Because the proposed TS limits operations to those analyzed in the amendment application and evaluated in Sections 3.3, "Nuclear Design," and 3.4, "Thermal-Hydraulic Analysis," of this SE, the NRC staff finds the addition of TS LCO T2 to be acceptable.

Proposed TS 3.10, LCO T3, "Allowed Target Storage Locations," reads as follows:

LCO T3, Allowed Target Storage Locations.

Applicability: Any time targets are located in the reactor tank and not in transit or in an in-core lattice position.

Objective: To maintain k-effective of stored targets less than 0.9 under all conditions of moderation.

Specification: The targets shall be stored in the standard in-tank TRIGA® storage racks. No other items shall be present in any storage rack containing targets.

Basis: Storage racks are sufficiently far from the core such that the presence of targets in the core will not affect the criticality condition of targets in the storage racks. Criticality analysis assumes no other objects are present in the vicinity of the stored targets. The criticality analysis for the storage of the fuel assumed no other objects (i.e., fuel elements) were stored with the targets. The k-effective was calculated to be less than 0.9 when stored in the storage racks.

The proposed new LCO on target storage addresses a condition that is not analyzed in the license amendment application (Ref. 2): the storage of targets with other items that are usually stored in the in-tank TRIGA® storage racks. Because the proposed TS limits target storage configurations to those analyzed by the licensee and evaluated in Section 3.6, "Target Storage," of this SE, the NRC staff finds the addition of TS LCO T3 to be acceptable.

Proposed TS 3.10, LCO T4, "Target Fabrication Requirements," reads as follows:

LCO T4, Target Fabrication Requirements.

Applicability: This specification applies to any target that will be placed in the reactor tank.

Objective: To assure that targets placed in the core may be used with a high degree of reliability with respect to their physical and nuclear properties.

Specification:

a. The maximum enrichment of uranium in each target shall not exceed 19.75%.
b. The maximum mass of uranium in a target shall not result in a dose to a member of the general public in excess of 100 mrem from an accident involving a single target.
c. Cladding: aluminum, nominal thickness 0.32 cm.

Basis:

a. Targets must be fabricated with LEU (i.e., less than or equal to 19.75% enriched in ^{235}U). An enrichment of 20% was assumed for the neutronic and the thermal hydraulic analysis for the purpose of bounding the calculations.
b. The dose to the general public from the target cladding failure accident is a function of many variables. Provided all other variables remain constant, the predicted dose should be directly proportional to the mass of uranium in the target. Analysis has shown that the maximum dose to a member of the general public will not exceed 100 mrem given the assumptions made in the calculation of the target cladding failure accident. Therefore, the mass of uranium in each target is limited by the parameters of the analysis and the dose performance criteria.

c. Cladding of this type provides adequate structural integrity while minimizing parasitic neutron absorption.

The proposed new LCO requires targets to be manufactured as specified and analyzed in the license amendment application (Ref. 2). The proposed LCO specifies target parameters (e.g. uranium enrichment, uranium mass, cladding type, and cladding thickness) that are important to safety. TS T4 b. does not contain a direct mass limit because that parameter is considered proprietary information by the licensee. However, the use of a radiation dose limit accomplishes the same result as a mass limit because of their direct relationship to the source term. Therefore, the NRC staff finds it acceptable. Because the proposed fabrication requirements are to ensure that the targets perform consistent with the licensee's safety analysis and the staff's evaluation in Sections 3.3, 3.4, and 3.7, "Accident Analysis," of this SE, the NRC staff finds the addition of TS LCO T4 to be acceptable.

Proposed TS 3.10, LCO T5, "Mo-99 Target Irradiation," reads as follows:

LCO T5, Mo-99 Target Irradiation

Applicability: This specification applies to the irradiation of Mo-99 demonstration targets.

Objective: The objective is to assure that the time that the Mo-99 demonstration targets are irradiated is limited by reactor power history.

Specification: The Mo-99 demonstration targets shall be irradiated in a core lattice position for no more than 7.15-MW days (MWD).

Basis: The predicted radionuclide inventory was based upon a 6.5-day irradiation while the reactor is at full power (i.e., 1.1-MW). The multiple of these two numbers represents the effective full power days for the core while the targets are in the core lattice positions analyzed. This power history creates the source term inventory that was predicted for the accident analysis that could potentially be released from the uranium bearing material within the targets. Limiting the irradiation time to 7.15-MWD will ensure that the potential accident consequences are less than the dose limit for individual members of the general public identified in 10 CFR 20.1301.

The proposed new LCO limits the fission product inventory in the targets to ensure consistency with the assumptions used to determine the source term for the target cladding failure accident (Ref. 15). The licensee proposes to measure target irradiation time in terms of MWD instead of EFPD, to be consistent with its current operating practice. The NRC staff confirmed that an irradiation time of 6.5 EFPD is equivalent to 7.15 MWD, since 1 EFPD is equal to irradiation at the licensee's licensed power limit of 1.1 MW for a timeframe of 1 day. Because the proposed TS limits target fission product inventory to that analyzed by the licensee and evaluated in Section 3.7 of this SE, the NRC staff finds the addition of TS LCO T5 to be acceptable.

3.8.3. Conclusions

The NRC staff has reviewed the license amendment application and supplemental information. The NRC staff finds that the additions to the license and TSs are appropriate to ensure the safe irradiation and storage of the proposed targets. Also, the NRC staff finds the licensee has appropriately justified the technical bases for these changes as discussed above. The NRC staff also concludes that the proposed possession limit is appropriate based on the licensee's analysis and the NRC staff's evaluation. Therefore, the addition of the license condition is acceptable. The NRC staff concludes that the new TSs provides the functional capability required for safe operation and that the new TSs are, therefore, acceptable.

3.9. Corrections to Technical Specifications Made by the NRC Staff

In addition to the proposed changes in Section 3.8 above, the NRC staff is reissuing the OSTR TSs in their entirety to correct pagination, font conversion, and formatting errors introduced by the NRC staff when: 1) the renewed license and the order requiring the conversion from HEU- to LEU-fuel (implemented as Amendment No. 22) were issued in September 2008, and 2) the TSs were converted to Portable Document Format (PDF) for inclusion in ADAMS. Due to a difference in the effective date for each action, the errors were not identified by the staff until after both licensing actions became effective.

Page 6 of the TS should have been left blank. However, the page break was inadvertently removed when the document was converted to PDF for inclusion in ADAMS before issuance by the NRC staff. The words "Page Intentionally Left Blank" appear at the top of page 6 of the renewed license TS (ADAMS Accession No. ML082530509), which also contains TS 2.1. This error renumbered all of the pages following page 6 (i.e. page 7 became page 6, page 8 became page 7, etc.). Therefore, the NRC staff reinserted the page break on page 6 and renumbered subsequent pages to correct the pagination errors.

Amendment No. 22 included TS replacement pages (Ref. 10, Enclosure 3), however the change pages were numbered based on page 6 being intentionally left blank (the pagination for TS replacement pages for Amendment No. 22 was established before the renewed license TSs were converted to PDF for inclusion in ADAMS). If the instructions that accompanied Amendment No. 22 were followed, TS pages could be duplicated or TSs could be omitted. However, the licensee recognized the error, brought it to the NRC staff's attention, and maintained a coherent set of approved TSs. Therefore, the NRC staff repaginated and included the TSs that are currently in effect under the renewed license and Amendment No. 22.

In TS 2.2, 3.1.4, and 3.2.3, the symbol for a dash (-) used to hyphenate table numbers, figure numbers, or words was in a font (e.g., WP MathA) that was not recognized when the document was made an official agency record. These dashes were replaced by another character (□) when the document was converted to PDF by the NRC staff. Therefore, the NRC staff replaced the "□" symbols with a dash (-) to correct the errors.

In TS 5.3.3.1, a particular nuclide of uranium is referenced when discussing the uranium content of the fuel elements. In this case, the element symbol for uranium-235 is stated as 235U. Therefore, the NRC staff corrected the style convention used for the element symbol so the mass number appears in the left superscript position (e.g. ^{235}U).

In TS 6.1, the character "|" appears below Figure 1. This symbol has no meaning and was unintentionally introduced when the document was converted to PDF by the NRC staff. Therefore, the NRC staff removed the character.

Reissuing the TSs in their entirety, including the changes for Amendment No. 23, is an efficient and effective means to correct these errors. Reissuance of the TSs is administrative and corrective in nature, correcting pagination and font conversion errors inadvertently introduced by the NRC staff when: 1) the renewed license and the order requiring the conversion from HEU-to LEU-fuel (implemented as Amendment No. 22) were issued in September 2008, and 2) the TSs were converted to PDF. Therefore, the NRC staff concludes these changes are acceptable.

4.0 ENVIRONMENTAL CONSIDERATION

The NRC's regulations in 10 CFR 51.22(a) state that licensing actions may be found eligible for a categorical exclusion if the action does not individually or cumulatively have a significant effect on the human environment. The amendment involves changes in the installation or use of a facility component located within the restricted area, as defined in 10 CFR Part 20. Therefore, as required by 10 CFR 51.22(c)(9), an evaluation of the effect on the human environment is presented below:

(i) *The amendment or exemption involves no significant hazards consideration;* [10 CFR 51.22(c)(9)(i)]

The NRC's regulations in 10 CFR 50.92 state that the NRC may make a final determination that a license amendment involves no significant hazards consideration if operation of the facility, in accordance with the amendment, would not:

(1) involve a significant increase in the probability or consequences of an accident previously evaluated; or [10 CFR 50.92(c)(1)]

In Section V its analysis (Ref.2), the licensee states that the presence of targets does not increase the likelihood of an accident. As discussed in Section 3.7 of this SE, the staff considered accidents previously evaluated for the OSTR. The staff did not identify any significant increase in the probability of an accident previously evaluated. The target cladding failure accident dose consequences are slightly higher than the MHA dose consequences previously evaluated in the 2007 conversion SAR. However, the resultant dose remains well within the regulatory limits of 10 CFR Part 20. Therefore, the NRC staff finds this change does not significantly increase the consequences of an accident previously evaluated.

(2) create the possibility of a new or different kind of accident from any accident previously evaluated; or [10 CFR 50.92(c)(2)]

In Section V its analysis (Ref.2) and RAI responses (Ref. 4), the licensee analyzed the proposed amendment considering the nine credible accident scenarios identified in NUREG-1537. All nine of these credible accident scenarios have already been previously analyzed for the OSTR. As discussed in Section 3.7 of this SE, the NRC staff finds the results of the accident analysis to be acceptable. Existing TSs are unchanged by this amendment. Additional TSs have been proposed by the licensee to: 1) limit placement and storage of targets to analyzed locations; 2) limit modes of reactor operation to those analyzed; and, 3) require targets placed in the reactor pool to be fabricated consistent with the design analyzed. For these reasons, the presence of targets does not create the possibility of a new or different kind of accident from any accident previously evaluated.

(3) *involve a significant reduction in a margin of safety* [10 CFR 50.92(c)(3)]

As discussed in Section 3.3, the NRC staff finds existing TSs will continue to ensure the ability to safely shutdown the reactor after target installation. As discussed in Section 3.4, the NRC staff finds the analysis of thermal hydraulic conditions with the presence of targets to provide sufficient margin to CHF conditions and, therefore, is acceptable. For these reasons, the presence of targets does not involve a significant reduction in a margin of safety.

Based on the above, the NRC staff concludes that this amendment involves no significant hazards consideration.

(ii) *There is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite; and* [10 CFR 51.22(c)(9)(ii)]

The fission products generated by irradiation of the targets will not significantly change from the types of fission products generated by operation of the reactor and already present in the reactor fuel. The targets have a limited irradiation period and therefore, will not generate significant amounts of fission products. Also, the amendment does not change potential release paths from the facility. For these reasons, there is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite due to presence of the targets.

(iii) *There is no significant increase in individual or cumulative occupational radiation exposure.* [10 CFR 51.22(c)(9)(iii)]

The amendment will permit irradiation of up to three prototypical targets for demonstration purposes. The target cladding failure accident dose consequences are slightly higher than the MHA dose consequences previously evaluated in the 2007 conversion SAR. However, the resultant dose remains well within the regulatory limits of 10 CFR Part 20. Furthermore, the amendment will not change existing administrative controls or the radiation protection program at the OSTR for limiting individual or cumulative occupational radiation doses. Therefore, the NRC staff finds that there is no significant increase in individual or cumulative occupational radiation exposure.

The amendment also makes editorial, corrective, or other minor revisions to the TSs. Accordingly, this amendment meets the eligibility criteria for categorical exclusion as set forth in 10 CFR 51.22(c)(9) and 10 CFR 51.22(c)(10)(v). Pursuant to 10 CFR 51.22(b), no environmental impact statement or environmental assessment need be prepared in connection with the issuance of this amendment.

5.0 CONCLUSION

The Commission has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) there is reasonable assurance that such activities will be conducted in compliance with the Commission's regulations, and (3) the issuance of the amendment will not be inimical to the common defense and security or to the health and safety of the public.

6.0 REFERENCES

1. Oregon State University, "License amendment application for the purpose of demonstrating ^{99}Mo production capability in the OSTR," April 13, 2012 (ADAMS Accession No. ML12124A265).

2. Oregon State University, "Replacement redacted version of License amendment application for the purpose of demonstrating ^{99}Mo production capability in the OSTR" (redacted), January 8, 2013 (ADAMS Accession No. ML12124A266).

3. U.S. Nuclear Regulatory Commission, "Request for Additional Information Regarding Application for Fueled Experiment License Amendment" (redacted), April 22, 2013 (ADAMS Accession No. ML13106A010).

4. Oregon State University, "Answers to Request for Additional Information request by USNRC with respect to a license amendment application for the purpose of demonstrating ^{99}Mo production capability in the OSTR" (redacted), August 23, 2013 (ADAMS Accession No. ML13252A181).

5. U.S. Nuclear Regulatory Commission, "Request for Additional Information Regarding License Amendment Request for Fueled Experiment" (redacted), February 7, 2014 (ADAMS Accession No. ML14031A199).

6. Oregon State University, "Answers to Request for Additional Information request by USNRC with respect to a license amendment application for the purpose of demonstrating ^{99}Mo production capability in the OSTR" (redacted), April 14, 2014 (ADAMS Accession No. ML14106A379).

7. U.S. Atomic Energy Commission, "Development of Technical Specifications for Experiments in Research Reactors," Regulatory Guide 2.2, November 1973 (ADAMS Accession No. ML003740125).

8. U.S. Nuclear Regulatory Commission, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria," NUREG-1537, Part 2, February 1996 (ADAMS Accession No. ML042430048).

9. Oregon State University, “Safety Analysis Report for the Conversion of the Oregon State TRIGA® Reactor from HEU to LEU Fuel” (redacted), November 6, 2007 (ADAMS Accession No. ML080420546).

10. U.S. Nuclear Regulatory Commission, “Issuance of Order Modifying License No. R-106 to Convert from High- to Low-Enriched Uranium Fuel (Amendment No. 22) – Oregon State University TRIGA Reactor (TAC NO. MD7360),” EA-08-251, September 4, 2008 (ADAMS Accession No. ML082390775).

11. Oregon State University, “Reactor Startup Report for the Oregon State TRIGA® Reactor Using Low Enrichment Uranium Fuel,” April 16, 2009 (ADAMS Accession No. ML091110188).

12. M. R. Hartman, et al., “HEU-to-LEU Fuel Conversion in Oregon State TRIGA,” *Nuclear Science and Engineering*: Volume 174, pp 135-149, June 2013.

13. Oregon State University, “Supplementary information supporting the license amendment application,” March 2, 2015 (ADAMS Accession No. ML15063A428)

14. Oregon State University, “[Supplementary] information,” July 13, 2015 (ADAMS Accession No. ML15198A031)

15. Oregon State University, “Proposed TS for targets,” January 4, 2016 (ADAMS Accession No. ML16005A551)

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