ENCLOSURE 2

SHINE MEDICAL TECHNOLOGIES, LLC

SHINE MEDICAL TECHNOLOGIES, LLC APPLICATION FOR AN OPERATING LICENSE REVISION 1 OF SHINE RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION 3.4-12 PUBLIC VERSION

The NRC staff determined that additional information was required to enable the staff's continued review of the SHINE Medical Technologies, LLC (SHINE) operating license application (Reference 1). SHINE provided the response to the NRC staff's request for additional information (RAI) via Reference (2). SHINE has determined that the SHINE Response to RAI 3.4-12, provided via Reference (2), requires revision to correct an administrative error. Revision 1 of the SHINE Response to RAI 3.4-12 is provided below. SHINE has confirmed that the FSAR markups associated with the SHINE Response to RAI 3.4-12 do not include similar administrative errors.

Chapter 3 – Design of Structures, Systems, and Components

<u>RAI 3.4-12</u>

Section 1.3.3.3, "Facility Systems," of the SHINE OLA states that the neutron driver assembly system (NDAS) is an "accelerator-based assembly that accelerates a deuterium ion beam into a tritium gas target chamber. The resulting fusion reaction produces 14 million electron volt (MeV) neutrons, which move outward from the tritium target chamber in all directions."

Section 4a2.3, "Neutron Driver Assembly System," states that "[s]tructural support beams support the neutron driver in the IU cell, with components installed above and adjacent to safety-related equipment. Neutron driver components within the IU cell are classified as a Seismic Category II component." It also states that "[t]he target chamber generates up to 1.5E+14 neutrons per second (n/s) during operation."

Guidance documents such as NUREG-7171, "A Review of the Effects of Radiation on Microstructure and Properties of Concretes Used in Nuclear Power Plants," discussed in 4a2.5.3.2 "Radiation Damage," and referenced by the applicant in Chapter 4 of the SHINE OLA and the industry standard ACI 349.3R-18, "Report on Evaluation and Repair of Existing Nuclear Safety-Related Concrete Structures," provide radiation thresholds for concrete and insights beyond which the compressive strength of concrete appears to rapidly decline while its crack density increases.

To effectively accomplish their intended function, nuclear safety-related SSCs are designed to resist operating loads, severe environments such as seismic events, and postulated accidents. To prevent lifetime-radiation related degradation of concrete SSCs and maintain an acceptable level of serviceability, NUREG-7171 limits the lifetime reinforced concrete neutron fluence exposure of 0.1 (and above) MeVs to 1×10^{19} neutrons/cm^2 and for gamma dose to 10^{10} rads. ACI 349.3R-18, which is more relevant to long term operation of nuclear facilities, also states that neutron fluence can change the mechanical properties of carbon steel resulting in an increase in yield strength and a rise in the ductile to brittle transition temperature.

Given the projected hours of operation for the SHINE facility, the high neutron flux and gamma dose exposures at NDAS or at other locations exposed to intense radiation within the facility, it is not clear whether concrete or steel structural support members or components, such as the IU driver supporting beams, have been evaluated for neutron fluence and gamma dose damage for the life of the facility. It is also not clear whether conservatively a reduction in strength due to radiation for materials used in the construction of the facility was considered and factored where applicable in the concrete or structural steel designs for seismic, aircraft impact, blast loadings.

(1) Discuss whether the radiation limits provided in NUREG-7171 were used to determine that safety related concrete or steel support structures or SSCs exposed to radiation (e.g., the IU driver support beams) will maintain their safety function during seismic, aircraft impact, or blast loading scenarios during the intended licensing period. Provide a discussion of any relevant evaluations used to support a conclusion that irradiation will not affect the safety functions described above.

(2) If applicable, state what actions are taken to ensure that potential damage to safety related concrete or steel support structures or SSCs that have radiation exposure above the previously discussed radiation limits will not adversely affect safe facility operability and its defense-in-depth.

Update the FSAR as appropriate to reflect the above requested information.

SHINE Response

(1) The neutron fluence and gamma dose rate to the concrete support structures in the facility were calculated using Monte Carlo N-Particle Transport Code 5 (MCNP5) and were shown to be under the acceptance criteria provided in NUREG/CR-7171 (i.e., 10^{19} n/cm^2 and 10^{10} rad, respectively) (Reference 3). The neutron fluence to the concrete support structures were also under the limit provided by American Concrete Institute (ACI) 349.3R-18 (i.e., 10^{20} n/cm^2) (Reference 4), where steel reinforcement could experience reduced ductility. The incident energy flux was also calculated for the concrete and was compared to the American National Standards Institute/American Nuclear Society (ANSI/ANS)-6.4-2006 (Reference 5) acceptance criterion that nuclear heating shall be considered for concrete shields that are exposed to incident energy flux greater than 10^{10} MeV/cm^2-sec and that will operate at a temperature of 65°C or greater. The energy flux was calculated to be less than 10^{10} MeV/cm^2-sec in most cases, and where it was greater than 10^{10} MeV/cm^2-sec, the temperature of the concrete was determined to be less than 65°C. Because the radiation exposure to the concrete structures is below allowable limits during the intended licensing period, no damage affecting the safety function of the safety-related concrete structures during seismic, aircraft impact, blast loading, or other accident scenarios is anticipated.

Steel structures are outside the scope of NUREG/CR-7171. To support the conclusion that irradiation will not affect the safety functions of safety-related steel structures located in the irradiation unit (IU) cells, lifetime neutron fluence to steel components close to the target solution vessel (TSV) and neutron driver assembly system (NDAS) target chamber were calculated using MCNP5. The structural component with the highest lifetime neutron fluence is the subcritical assembly support structure (SASS), which includes both pressure vessel and structural elements (e.g., support legs) and is fabricated from austenitic stainless steel. The highest fluence to the SASS occurs at the pressure vessel portion of the SASS adjacent to the TSV and is up to approximately [ ]$^{\text{PROP/ECI}}$. The fluence to the SASS was compared to literature data (Reference 6), which indicates an increase in yield and ultimate tensile strength and a reduction in ductility of austenitic stainless steel. An increase of yield and ultimate tensile strength by itself does not affect the ability of a steel structure from performing its safety function. However, a decrease in ductility, if excessive, could lead to brittle fracture during normal or accident loadings. To determine if the loss of ductility could be excessive, literature data was consulted to determine if austenitic stainless steel retains adequate ductility when irradiated with comparable fluence. Literature data (Reference 6) indicates that irradiated austenitic stainless steel loses some ductility but still retains approximately twice the energy (60 lb.-ft) to fracture than the commonly accepted criterion of 30 lb.-ft and therefore remains ductile. Literature (References 6 and 7) also indicates that austenitic stainless steel SASS components will remain ductile for temperatures greater than -50°C throughout their service life. The SASS is applicable as the limiting case for safety-related steel structures within the IU cell because such structures are made of austenitic stainless steel. Because the limiting case of irradiated steel structural components indicates an increase in strength and retention of adequate ductility, no damage affecting the safety function of the safety-related steel structures is anticipated.

Radiation impacts on structural components of the IU cell concrete are summarized in Subsection 4a2.5.3.2.1 of the FSAR. Section 4a2.2.5 of the FSAR has been revised to provide additional details regarding the radiation impacts on the SASS. A mark-up of the FSAR incorporating these changes is provided in Reference 2.

(2) No actions are needed to ensure that radiation exposure will not adversely affect safety-related SSCs because radiation exposure is below applicable radiation limits. Radiation exposure of safety-related concrete or steel support structures or SSCs will not adversely affect safe facility operability and its defense-in-depth.

References

1. NRC letter to SHINE Medical Technologies, LLC, “Issuance of Request for Additional Information Related to the SHINE Medical Technologies, LLC Operating License Application (EPID No. L-2019-NEW-0004),” dated October 16, 2020

2. SHINE Medical Technologies, LLC letter to the NRC, “SHINE Medical Technologies, LLC Operating License Application Supplement No. 6 and Response to Request for Additional Information,” dated December 15, 2020 (ML21011A264)

3. U.S. Nuclear Regulatory Commission, “A Review of the Effects of Radiation on Microstructure and Properties of Concretes Used in Nuclear Power Plants,” NUREG/CR-7171, November 2013

4. American Concrete Institute, “Report on Evaluation and Repair of Existing Nuclear Safety-Related Concrete Structures,” ACI 349.3R-18, Farmington Hills, MI

5. American National Standards Institute/American Nuclear Society, “Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants,” ANSI/ANS-6.4-2006 (R2016), La Grange Park, IL

6. Radiation Effects Information Center, “The Effects of Neutron Radiation on Structural Materials,” REIC Report No. 45, Kangilaski, M., June 30, 1967

7. National Aeronautics and Space Administration, "Radiation Effects Design Handbook: Section 7. Structural Alloys", NASA CR-1873, Kangilaski, M., October 1971