8.0 ELECTRICAL POWER SYSTEMS

Electrical power systems are designed for operation of the SHINE Medical Technologies, LLC (SHINE, the applicant) irradiation facility (IF) and radioisotope production facility (RPF) (together, the SHINE facility). In addition to normal electrical service, emergency electrical service ensures that, given a loss of normal electric service, sufficient power will be available to mitigate accidents in order to: (1) shut down the facility and maintain it in a safe shutdown condition and (2) prevent or minimize the offsite release of radioactivity in excess of applicable regulatory requirements and guidance.

This chapter of the SHINE operating license application safety evaluation report (SER) describes the review and evaluation of the U.S. Nuclear Regulatory Commission (NRC, the Commission) staff of the final design of the SHINE IF and RPF electrical power systems, as presented in Chapter 8, “Electrical Power Systems,” of the SHINE Final Safety Analysis Report (FSAR) and supplemented by the applicant’s response to staff requests for additional information (RAIs).

8a Irradiation Facility Electrical Power Systems

SER Section 8a, “Irradiation Facility Electrical Power Systems,” provides an evaluation of the final design of SHINE’s IF electrical power systems as presented in SHINE FSAR Section 8a2, “Irradiation Facility Electrical Power Systems,” within which the applicant described the irradiation unit (IU) normal electrical power systems and emergency electrical power systems.

8a.1 Areas of Review

The NRC staff reviewed SHINE FSAR Section 8a2 against applicable regulatory requirements, using appropriate regulatory guidance and acceptance criteria, to assess the sufficiency of the final design of the SHINE IF electrical power systems. The staff assessed the final analysis of the normal electrical power systems to ensure the safe operation and shutdown of the SHINE IUs, including the response of the facility to interruptions of normal electrical service, and the ability of the facility to be maintained in a safe condition with and without the availability of normal electrical service. The staff examined the ranges of power required, schematic diagrams, design and performance specifications, deviations from guidance and their justifications, and SHINE’s proposed technical specifications (TSs).

The NRC staff also assessed the final design and analysis of the SHINE emergency electrical power systems, including the design and functions of the emergency electrical power systems and their support of related systems required for protecting the health and safety of the public.

As described in SHINE FSAR sections 8b.1, “Normal Electrical Power Systems,” and 8b.2, “Emergency Electrical Power Systems,” respectively, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. Therefore, the areas of review described below are applicable to both the SHINE IF and RPF.

8a.2 Summary of Application

As described in SHINE FSAR sections 8b.1 and 8b.2, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. Therefore, the summary provided below applies to both the SHINE IF and RPF.

8a.2.1 Normal Electrical Power Supply System

SHINE FSAR section 8a2.1, "Normal Electrical Power Supply System," and section 8a2.1.3, "Normal Electrical Power Supply System Description," provide details for the normal electrical power supply system (NPSS). This system is comprised of normal power service entrances from the electric utility at 480Y/277 volts alternating current (VAC) into separate feeds that provide power to the distribution system providing three utilization voltages, 480Y/277, 400Y/277, and 208Y/120 VAC, 3-phase, 60 hertz. The NPSS is used for normal operation and normal shutdown of the SHINE facility. SHINE FSAR figure 8a2.1-1, "Electrical Distribution System (Simplified)," provides a one-line diagram of the electrical power system of the SHINE facility, including the NPSS and the emergency electrical power system.

SHINE FSAR section 8a2.1.3 states, in part, that the "NPSS operates as five separate branches, each receiving utility power at 480Y/277 VAC. The branches automatically physically disconnect from the utility by opening the associated utility power (UP) supply breaker . . . on a loss of phase, phase reversal, or sustained overvoltage or undervoltage as detected by protection relays for each utility transformer." This function is not required for safe shutdown, as described in SHINE FSAR section 8a2.1.6, "Loss of Off-Site Power." The two branches serving loads in the main production facility and the nitrogen purge system (N2PS) structure can be cross-connected by manually opening one of the UP supply breakers and manually closing both bus tie breakers in the event of the loss of a single utility 480Y/277 VAC feed. This cross-connection would be administratively controlled to ensure that the remaining utility feed is not overloaded.

8a.2.2 Emergency Electrical Power Systems

SHINE FSAR section 8a2.2, "Emergency Electrical Power Systems," provides details for the emergency electrical power system. This system is comprised of a safety-related uninterruptible electrical power supply system (UPSS), a non-safety-related standby generator system (SGS), and non-safety-related local power supplies and unit batteries. The UPSS consist of a 125-volt direct current (VDC) battery subsystem, inverters, bypass transformers, distribution panels, and other distribution equipment. The UPSS provides power to both safety-related loads and non-safety-related loads.

The non-safety-related SGS consist of a natural gas-driven generator and associated circuit breakers and distribution equipment that provides power for the UPSS loads and emergency power to SHINE's facility physical security control systems and information and communications systems.

SHINE FSAR section 8a2.2.3, "Uninterruptible Electrical Power Supply System Description," states, in part, that the "safety-related UPSS provides a reliable source of power to the redundant divisions of AC [alternating current] and DC [direct current] components on the safety-related power buses. Each division of the UPSS consists of a 125 VDC battery

subsystem, 125 VDC to 208Y/120 volts alternating current (VAC) inverter, rectifier (battery charger), bypass transformer, static switch and a manual bypass switch, and 208Y/120 VAC and 125 VDC distribution panels." Each of the components of the UPSS are safety-related. SHINE FSAR figure 8a2.2-1, "Uninterruptible Power Supply System," provides a one-line diagram of the UPSS and connections with safety-related and non-safety-related loads. SHINE FSAR table 8a2.2-1, "UPSS Load List," provides the list of the loads connected to the UPSS, and table 8a2.2-2, "UPSS Battery Sizing," provides the Amp-hours required to provide power to the loads connected to the UPSS.

8a.3 Regulatory Requirements and Guidance and Acceptance Criteria

The NRC staff reviewed SHINE FSAR sections 8a2, and 8b, "Radioisotope Production Facility Electrical Power Systems," against the applicable regulatory requirements, using appropriate regulatory guidance and acceptance criteria, to assess the sufficiency of the final design and performance of the SHINE electrical power systems for the issuance of an operating license.

8a.3.1 Applicable Regulatory Requirements

The applicable regulatory requirements for the evaluation of the SHINE electrical power systems are as follows:

- Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.34, "Contents of applications; technical information," paragraph (b), "Final safety analysis report"
- 10 CFR 50.36, "Technical specifications"
- 10 CFR 50.40, "Common standards"
- 10 CFR 50.57, "Issuance of operating license"
- 10 CFR Part 20, "Standards for Protection Against Radiation"

8a.3.2 Applicable Regulatory Guidance and Acceptance Criteria

In determining the regulatory guidance and acceptance criteria to apply, the NRC staff used its technical judgment, as the available guidance and acceptance criteria were typically developed for nuclear reactors. Given the similarities between the SHINE facility and non-power research reactors, the staff determined to use the following regulatory guidance and acceptance criteria:

- NUREG-1537, Part 1, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content," issued February 1996.
- NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria," issued February 1996.
- "Final Interim Staff Guidance Augmenting NUREG-1537, Part 1, 'Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power

Reactors: Format and Content,' for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors," dated October 17, 2012.

- "Final Interim Staff Guidance Augmenting NUREG-1537, Part 2, 'Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Standard Review Plan and Acceptance Criteria,' for Licensing Radioisotope Production Facilities and Aqueous Homogeneous Reactors," dated October 17, 2012

As stated in the interim staff guidance (ISG) augmenting NUREG-1537, the NRC staff determined that certain guidance originally developed for heterogeneous non-power research and test reactors is applicable to aqueous homogenous facilities and production facilities. SHINE used this guidance to inform the design of its facility and to prepare its FSAR. The staff's use of reactor-based guidance in its evaluation of the SHINE FSAR is consistent with the ISG augmenting NUREG-1537.

As appropriate, the NRC staff used additional guidance (e.g., NRC regulatory guides, Institute of Electrical and Electronics Engineers (IEEE) standards, American National Standards Institute/American Nuclear Society (ANSI/ANS) standards, etc.) in the review of the SHINE FSAR. The additional guidance was used based on the technical judgment of the reviewer, as well as references in NUREG-1537, Parts 1 and 2; the ISG augmenting NUREG-1537, Parts 1 and 2; and the SHINE FSAR. Additional guidance documents used to evaluate the SHINE FSAR are provided as references in appendix B, "References," of this SER.

In addition, the SHINE design criteria discussed in SER section 8a.4.1 are applicable to the SHINE electrical power systems.

8a.4 <u>Review Procedures, Technical Evaluation, and Evaluation Findings</u>

The NRC staff performed a review of the technical information presented in SHINE FSAR sections 8a2 and 8b, as supplemented by the applicant's response to staff RAIs dated December 15, 2020 (Agencywide Documents Access and Management System Accession No. ML21011A264 and January 29, 2021 (ML21029A101).

to assess the sufficiency of the final design and performance of the SHINE electrical power systems for the issuance of an operating license. The sufficiency of the final design and performance is determined by ensuring that they meet applicable regulatory requirements, guidance, and acceptance criteria, as discussed in section 8a.3, "Regulatory Requirements and Guidance and Acceptance Criteria," of this SER. The findings of the staff review are described in section 8a.5, "Review Findings," of this SER.

As described in SHINE FSAR sections 8b.1 and 8b.2, the SHINE facility has one common normal electrical power system and one common emergency electrical power system that serve both the IF and the RPF.

8a.4.1 Normal Electrical Power Systems

The NRC staff evaluated the sufficiency of the final design of the SHINE normal electrical power systems, as presented in SHINE FSAR section 8a2.1, using the guidance and acceptance criteria from section 8.1, "Normal Electrical Power Systems," of NUREG-1537, Parts 1 and 2,

and section 8a2, “Aqueous Homogeneous Reactor Electrical Power Systems,” and section 8b, “Radioisotope Production Facility Electrical Power Systems,” of the ISG augmenting NUREG-537, Parts 1 and 2.

Section 8.1 of NUREG-1537, Part 2, provides the applicable acceptance criteria. The guidance states, in part, that, “Normal electrical power systems at non-power reactors are designed for safe operation and shutdown of the reactor, and to provide for reactor use.” It also states that, “The reactor design should use high-quality, commercially available components and wiring in accordance with applicable codes in the normal electrical systems.” The NRC staff evaluated the SHINE normal electrical power systems against the following acceptance criteria:

- The design and functional characteristics should be commensurate with the design bases.

- The facility should have a dedicated substation or a shared system designed to provide reasonable assurance that other uses could not prevent safe shutdown.

- The system should be designed to permit safe shutdown and to prevent uncontrolled release of radioactive material if offsite power is interrupted or lost.

- Electrical power circuits should be isolated sufficiently to avoid electromagnetic interference with safety-related instrumentation and control functions.

- Technical specifications should be provided to ensure operability commensurate with power requirements for shutdown and to prevent uncontrolled release of radioactive material.

The SHINE design criteria are provided in SHINE FSAR section 3.1, “Design Criteria,” table 3.1-3, “SHINE Design Criteria.” The following design criteria are applicable to the normal electrical power systems:

- Criterion 4, “Environmental and dynamic effects.”

  Safety-related SSCs [structures, systems, and components] are designed to perform their functions with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. These SSCs are appropriately protected against dynamic effects and from external events and conditions outside the facility.

- Criterion 27, “Electric power systems.”

  An on-site electric power system and an off-site electric power system are provided to permit functioning of safety-related SSCs. The safety functions are to provide sufficient capacity and capability to assure that:

  1) target solution design limits and primary system boundary design limits are not exceeded as a result of anticipated transients, and

2) confinement integrity and other vital functions are maintained in the event of postulated accidents.

The onsite uninterruptible electric power supply and distribution system has sufficient independence, redundancy, and testability to perform its safety functions assuming a single failure.

Provisions are included to minimize the probability of losing electric power from the uninterruptible power supply as a result of or coincident with, the loss of power from the off-site electric power system.

- Criterion 28, “Inspection and testing of electric power systems.”

  The safety-related electric power systems are designed to permit appropriate periodic inspection and testing of important areas and features, such as wiring, insulation, connections, and switchboards, to assess the continuity of the systems and the condition of their components. The systems are designed with a capability to test periodically:

  1) the operability and functional performance of the components of the systems, such as on-site power sources, relays, switches, and buses; and

  2) the operability of the systems as a whole and, under conditions as close to design as practical, the full operation sequence that brings the systems into operation, including operation of applicable portions of the protection system, and the transfer of power among the on-site and off-site power supplies.

The NRC staff reviewed the information in SHINE FSAR section 8a2.1 to verify the functional characteristics of the normal electrical power system. SHINE FSAR section 8a2.1.1, “Design Basis,” states, in part, that the “design of the NPSS provides sufficient, reliable power to facility and site electrical equipment as required for operation of the SHINE facility and to comply with applicable codes and standards.” SHINE applies National Fire Protection Association (NFPA) 70-2017, “National Electrical Code,” as adopted by the State of Wisconsin (Chapter SPS 316 of the Wisconsin Administrative Code, Electrical), for the design of the normal electrical power system.

In its response to NRC staff RAIs, SHINE provided clarification regarding the portions of NFPA 70-2017 that were used for the design of the electrical systems, including the NPSS, the UPSS, and the SGS. In addition, SHINE incorporated standards from the IEEE for the design of the NPSS. Safety-related breakers in the NPSS are designed in accordance with IEEE Standard C.37.13-2015, “Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures.” The staff finds that the use of appliable portions of these standards provides reasonable assurance that SHINE’s final design and the functional characteristics of the normal electrical power system are commensurate with the design bases of the facility.

SHINE FSAR section 8a2.1 states, in part, that the “NPSS is sized for safe operation of the facility. The largest loads on the NPSS are the process chilled water system (PCHS), neutron driver assembly system (NDAS), and the facility chilled water system (FCHS); however, those loads are not required for safe shutdown of the facility.” For the sizing of the NPSS, SHINE used

applicable portions of NFPA 70-2017, as described in its response to NRC staff RAI 8-10. In addition, in its response to RAI 8-1, SHINE stated that, "Equipment sizing studies for the NPSS are not performed by SHINE, as there is no explicit requirement for SHINE to perform such studies. NPSS equipment sizing is based on wire and bus sizing minimums established in NFPA 70-2017." The NRC staff performed a regulatory audit and confirmed that the electrical system design assumptions align with the recommended practices of NFPA 70-2017, as discussed in the audit report. Based on the above, the NRC staff concludes that the electrical system final design meets Criteria 27 and 28 of the SHINE design criteria.

SHINE FSAR section 8a2.1.1 states, in part, that the NPSS is designed such that it:

- Does not prevent the ability of safety-related SSCs to perform their safety functions;
- Provides for the separation or isolation of safety-related circuits from nonsafety-related circuits, including the avoidance of electromagnetic interference with safety-related instrumentation and control functions;
- Fails to a safe configuration upon a loss of offsite power (LOOP);
- Provides the normal source of power supply to the safety-related electrical buses;
- Provides the safety-related function of removing power from select components when demanded by the safety-related engineered safety features actuation system (ESFAS) or target solution vessel (TSV) reactivity protection system (TRPS); and
- Is able to be inspected, tested, and maintained to meet the above design bases.

The NRC staff reviewed other sections of the SHINE FSAR to confirm consistency with SHINE FSAR Chapter 8, such as Chapter 4, "Irradiation Unit and Radioisotope Production Facility Description," Chapter 5, "Cooling Systems," Chapter 7, "Instrumentation and Control Systems," Chapter 9, "Auxiliary Systems," and Chapter 13, "Accident Analysis." The staff performed a regulatory audit to confirm that the final design and functional characteristics are commensurate with the design bases. Based on the above, the staff finds that the final design of the components within each of the systems in these chapters is commensurate with the design bases and functional characteristics of the NPSS.

As described in section 8.1 of NUREG-1537, Part 2, the SHINE facility should have a dedicated substation or a shared system designed to provide reasonable assurance that other uses could not prevent safe shutdown. SHINE FSAR Section 8a2.1.2, "Off-Site Power Supply Description," provides a description of the SHINE facility substation. It states, in part, that the "SHINE facility is connected to two single power circuits from the off-site transmission electric network. The power circuits are shared with other utility customers. The two power circuits feed five local outdoor 12.47 kilovolt (kV) – 480Y/277 VAC 3-phase transformers." The NRC staff finds that the final design of the dedicated substation meets the related acceptance criterion in NUREG-1537, Part 2.

SHINE FSAR section 8a2.1.3 provides a list of safety-related equipment in the NPSS, which are the following:

- Two safety-related breakers for each instance of the NDAS to provide the redundant ability to disconnect power.

- Two safety-related breakers per vacuum pump to provide the redundant ability to disconnect power from each vacuum pump in the vacuum transfer system (VTS).

- Two safety-related breakers per extraction feed pump to provide the redundant ability to disconnect power from each (of three) extraction feed pumps in the molybdenum extraction and purification system (MEPS).

- Two safety-related breakers providing the redundant ability to disconnect power from the radiological ventilation zone 1 (RVZ1) exhaust fans, radiological ventilation zone 2 (RVZ2) exhaust fans, and RVZ2 supply air handling units.

SHINE FSAR section 8a2.1.3 states, in part, that the safety functions performed by the specified breakers are related to preventing actions that could initiate or increase the consequences of an accident. The equipment tied to these breakers does not perform an active safety function. Redundant breakers are provided to ensure that the safety function of the breakers can still be performed in the event of a single active failure. The NRC staff reviewed applicable portions of SHINE FSAR Chapter 13, to verify that the classification of the safety-related equipment supports the mitigation of an accident. SHINE FSAR section 13b.2.2, "Loss of Electrical Power," evaluates in the accident analysis an initiating event for a number of critical equipment malfunction scenarios. SHINE FSAR section 13b.2.2 states that, "A facility-wide LOOP results in automatic actuation of multiple facility engineered safety features, which act to ensure the risk associated with radiological or chemical releases is reduced to within acceptable limits. The facility-wide LOOP does not result in system or component failures within the RPF that result in unacceptable radiological or chemical consequences."

In its response to NRC staff RAI 8-2, SHINE stated that, "The NDAS breakers are opened as part of the sequence to reach a safe shutdown condition in an IU, as the unit is transitioned to Mode 3. The VTS, MEPS, and RVZ breakers are not involved in reaching a safe shutdown condition." SHINE stated that the safety function performed by the safety-related breakers is to prevent actions that could initiate or increase the consequences of an accident and that the equipment tied to these breakers does not perform an active safety function. The staff finds that the proposed safety-related breakers provide reasonable assurance that the final design will permit safe shutdown and prevent uncontrolled release of radioactive material if offsite power is interrupted or lost. Therefore, the staff finds that the final design of the normal electrical power systems provides reasonable assurance that use or malfunction of electrical power systems and controls for experiments could not cause IU damage or prevent safe shutdown.

SHINE applied the guidance in sections 6.1.2.1, 6.1.2.2, and 6.1.2.3 of IEEE Standard 384-2008, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits," for isolation and the guidance in section 5.1.1.2, table 1 of section 5.1.3.3, and table 2 of section 5.1.4 of IEEE Standard 384-2008 for physical separation between non-safety-related circuits and safety-related circuits. In its responses to NRC staff RAIs, SHINE explained that it has committed to portions of specific IEEE standards that are applicable to its facility in

order to meet Criteria 27 and 28 of the SHINE design criteria. The staff reviewed the standards to verify whether the portions committed to are sufficient to meet the isolation and physical separation necessary to permit safe shutdown and to prevent uncontrolled release of radioactive material if offsite power is interrupted or lost to the electrical equipment. Based on the acceptance criteria in NUREG-1537, Part 2 and the portions of IEEE Standard 384-2008 used, the staff finds that SHINE's commitments are sufficient to meet the isolation and physical separation necessary for the NPSS.

SHINE FSAR section 8a2.1.5, "Raceway and Cable Routing," provides the design and location of the electrical wiring, stating that there are four separation groups for cables and raceways for the SHINE facility: Group A, Group B, Group C, and Group N. Spatial separation between groups is in accordance with section 5.1.1.2, table 1 of section 5.1.3.3, and table 2 of section 5.1.4 of IEEE Standard 384-2008. Group A and Group B contain safety-related power circuits for UPSS Division A and Division B, respectively. Group C contains safety-related control circuits from TRPS and ESFAS Division C. SHINE provides electrical isolation between non-safety-related circuits and safety-related circuits by isolation devices in accordance with sections 6.1.2.1, 6.1.2.2, and 6.1.2.3 of IEEE Standard 384-2008. The NRC staff finds that meeting these sections of IEEE Standard 384-2008 provides reasonable assurance that isolation between safety-related and non-safety-related circuits is achieved. Therefore, the staff finds that the final design and location of the electrical wiring will prevent inadvertent electromagnetic interference between the electrical power service and safety-related instrumentation and control circuits and is acceptable.

The NRC staff reviewed SHINE FSAR section 8a2.1 to verify that the NPSS final design is commensurate with SHINE Design Criterion 4. SHINE follows applicable portions of IEEE Standard 323-2003, "Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," to ensure that the NPSS is in conformance with Design Criterion 4. SHINE FSAR section 8a2.1.3 states that safety-related NPSS equipment is located in a mild environment, is not subject to harsh environmental conditions during normal operation or transient conditions, and has no significant aging mechanisms. This equipment is designed and qualified by applying the guidance of sections 4.1, 5.1, 6.1, and 7 of IEEE Standard 323-2003 and is qualified to the environmental parameters provided in SHINE FSAR tables 7.2-2, "Facility Control Room Design Environmental Parameters," and 7.2-3, "RPF and IF General Area Design Environmental Parameters." SHINE FSAR Tables 7.2-2 and 7.2-3 provide the environmental parameters to be considered for the qualification of the NPSS electrical equipment.

The NRC staff evaluated the information related to SHINE's approach for considerations for environmental and dynamic effects and finds that the use of the specific portions of IEEE Standard 323-2003 provides reasonable assurance that the NPSS is in conformance with SHINE Design Criterion 4. The NPSS is located in a mild environment, and qualifying equipment for the specific environmental parameters provided in SHINE FSAR tables 7.2-2 and 7.2-3 provides reasonable assurance that SHINE Design Criterion 4 is met.

8a.4.2 Emergency Electrical Power Systems

The NRC staff evaluated the sufficiency of the final design of the SHINE emergency electrical power systems, as presented in SHINE FSAR section 8a2.2, as supplemented, using the guidance and acceptance criteria from section 8.2, "Emergency Electrical Power Systems," of NUREG-1537, Parts 1 and 2, and Section 8a2, "Aqueous Homogeneous Reactor Electrical Power Systems," and section 8b, "Radioisotope Production Facility Electrical Power Systems," of the ISG augmenting NUREG-1537, Parts 1 and 2.

The SHINE emergency electrical power systems are described in SHINE FSAR section 8a2.2. section 8.2 of NUREG-1537, Part 2, provides the applicable acceptance criteria for the emergency electrical power systems for non-power reactors. This guidance states, in part, that emergency electrical power systems will be required to ensure that power is available to maintain safe shutdown, to support operation of a required engineered safety feature, or to protect the public from release of radioactive effluents. The NRC staff evaluated the SHINE emergency electrical power systems against the following acceptance criteria:

- The functional characteristics of the emergency power system should be commensurate with the design bases, which are derived from analyses presented in other chapters of the SAR [safety analysis report]. In general, the minimum requirement of an emergency electrical power system should be to ensure and maintain safe facility shutdown and to prevent uncontrolled release of radioactive material.

- The source of electrical power (generator, batteries, etc.) should be capable of supplying power for the duration required by the SAR analysis.

- The system should be designed for either automatic or manual startup and switchover.

- The emergency electrical power system should not interfere with or prevent safe facility shutdown.

- Malfunctions of the emergency electrical power system during … operation with normal electrical power should not interfere with normal … operation or prevent safe facility shutdown.

- Any non-safety-related uses of an emergency electrical power system should not interfere with performance of its safety-related functions.

- Technical specifications should be based on the accident analyses, should include surveillance and testing, and should provide reasonable assurance of emergency electrical power system operability. The discussions in the SAR should identify the minimum design requirements, the minimum equipment required, and the power and duration of operation required.

The NRC staff reviewed SHINE FSAR section 8a2.2 to verify that the functional characteristics of the SHINE emergency electrical power systems are commensurate with the design bases. The safety-related portion of the SHINE emergency electrical power systems is comprised of the UPSS. In addition, the design provides defense-in-depth with a non-safety-related SGS that will provide power to the UPSS upon a LOOP. The staff finds that the UPSS design provides the necessary power to the safety-related loads in order to ensure safe shutdown of the SHINE facility. Therefore, the staff finds that the SGS is not required to ensure safe shutdown of the facility.

The NRC staff evaluated the final design of the UPSS as described in SHINE FSAR section 8a2.2.1, “Uninterruptible Electrical Power Supply System Design Basis,” and section 8a2.2.3, “Uninterruptible Electrical Power Supply System Description.” SHINE stated

that the UPSS provides power at a sufficient capacity and capability to allow safety-related SSCs to perform their safety functions. Further, SHINE used NFPA 70-2017 and portions of IEEE Standard 384-2008 for the design of the UPSS. Although IEEE Standard 384-2008 provides the criteria for independence of Class 1E equipment, the SHINE UPSS safety-related equipment is not classified as Class 1E.

SHINE FSAR section 8a2.2.3 states that the safety-related UPSS provides a reliable source of power to the redundant divisions of AC and DC components on the safety-related power buses. Each division of the UPSS consists of a 125 VDC battery subsystem, 125 VDC to 208Y/120 VAC inverter, rectifier (battery charger), bypass transformer, static switch and a manual bypass switch, and 208Y/120 VAC and 125 VDC distribution panels. Each division of UPSS is normally powered by an emergency 480 VAC NPSS transfer bus via a division-specific battery charger. The emergency 480 VAC NPSS transfer buses can also be powered by the SGS, providing an alternate source of power to the UPSS.

In its response to NRC staff RAI 8-7, SHINE stated, "SHINE does not classify the UPSS as a Class 1E system. The NRC has not endorsed conformance with IEEE standards related to Class 1E power systems in satisfying the NRC's regulations with respect to the design, operation, and testing of safety-related power systems at non-power production and utilization facilities, like the NRC has for nuclear power plants." Additionally, the applicant stated, "While SHINE does not classify the UPSS as a Class 1E system and apply the full-scope of Class 1E-related standards to the UPSS, portions of Class 1E-related standards are applied to the design of the UPSS in order to satisfy applicable SHINE design criteria." SHINE FSAR section 8a2.2.3 provides details of the applicable portions of IEEE Standard 384-2008, such as sections 6.1.2.1, 6.1.2.2, and 6.1.2.3 for isolation of each UPSS division, and section 5.1.1.2, table 1 of section 5.1.3.3, and table 2 of section 5.1.4 for the physical separation of the electrical system. The staff finds that applying applicable portions of IEEE Standard 384-2008 for the design of safety-related electrical equipment within the UPSS provides reasonable assurance that the system is capable of providing the required power to perform the safety-related functions.

Section 8.2 of NUREG-1537, Part 2 provides that the emergency electrical power system source of electrical power should be capable of supplying power for the duration required by the FSAR analysis and that any malfunctions of the emergency electrical power system during facility operation with normal electrical power should not interfere with normal operation or prevent safe facility shutdown. Malfunctions that could impact the operation of the emergency system can be created by subcomponents, such as cables and connectors, associated with the emergency system. The SHINE UPSS is designed using applicable portions of IEEE Standard 384-2008. The NRC staff reviewed SHINE FSAR Chapter 8 to verify that SHINE provides a description of the safety classification of subcomponents used as part of the UPSS safety-related system to provide assurance that a malfunction of a subcomponent does not affect the operation of the facility. The staff confirmed by a request for confirmatory information that the UPSS subcomponents that support safety-related functions are classified as safety-related.

Sections 5.2, 6.2, 6.5, 7.1, 7.3, table 2 of 7.4, 7.6, and 7.9 of IEEE Standard 946-2004, "Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations," are used for the design of the battery and the battery chargers for the UPSS. In its response to NRC staff RAI 8-9, SHINE stated that it follows "specific sections of IEEE standards to meet SHINE's facility-specific Design Criteria 4, 27, and 28. The specific portions of the standards used by SHINE are for the design, qualification, testing, installation, and maintenance

of safety related electrical equipment." SHINE provided justification of how the specific portions of the standard are sufficient to meet SHINE Design Criteria 27 and 28.

The NRC staff reviewed SHINE FSAR table 8a2.2-1 and compared the loads provided in the list with the design calculations and documents provided for the UPSS during the staff's regulatory audit to ensure that the emergency electrical power systems are designed in accordance with the applicable portions of IEEE Standard 384-2008. The staff reviewed the documentation to ensure that the UPSS is designed to provide the capacity and capability to perform its intended safety function. The staff finds that the safety-related load list is comprehensive and that the UPSS system is capable of providing the necessary range of safety-related services. In addition, the design and operating characteristics of the safety-related UPSS are reliable, ensuring availability if needed.

The safety-related UPSS is environmentally qualified in accordance with IEEE Standard 323-2003. IEEE Standard 323-2003 provides an acceptable methodology to provide qualification of the equipment within the UPSS. SHINE stated that safety-related UPSS equipment is located in a mild environment, is not subject to harsh environmental conditions during normal operation or transient conditions, and has no significant aging mechanisms. This equipment is designed and qualified by applying the guidance of sections 4.1, 5.1, 6.1, and 7 of IEEE Standard 323-2003 and is qualified to the environmental parameters provided in SHINE FSAR tables 7.2-2 and 7.2-3. The NRC staff determined that the SHINE facility does not have electrical equipment located in a harsh environment and, therefore, the staff finds that the applicable portions of IEEE Standard 323-2003 mentioned above provide an acceptable method to environmentally qualify the UPSS and meet SHINE Design Criterion 4.

The safety-related UPSS is seismically qualified in accordance with IEEE Standard 344-2013, "IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations." SHINE FSAR section 8a2.2.3 states that the UPSS is required to perform its safety function before, during, and after a seismic event, and is qualified by one of the testing methods described in sections 8 and 9.3 of IEEE Standard 344-2013. NRC regulatory guide (RG) 1.100, Revision 4, "Seismic Qualification of Electrical and Active Mechanical Equipment and Functional Qualification of Active Mechanical Equipment for Nuclear Power Plants" ML19312C677), endorses IEEE Standard 344-2013 as an acceptable method for meeting the seismic qualification requirements. Therefore, the NRC staff finds that SHINE's use of IEEE Standard 344-2013 provides an acceptable method for the seismic qualification of safety-related equipment. The staff concludes that the seismic qualification of the UPSS meets SHINE Design Criterion 4 and is acceptable.

SHINE FSAR section 8a2.2.3 states that the UPSS is isolated from the NPSS and SGS by isolating breakers feeding the battery chargers and the bypass transformers. Additionally, SHINE stated that the breakers monitor incoming power for voltage, phase, and frequency, and will trip when monitored variables are out of limits. SHINE used specific portions of IEEE Standard 384-2008 for the independence and separation of the safety-related electrical equipment. RG 1.75, Revision 3, "Criteria for Independence of Electrical Safety Systems" (ML043630448), endorses IEEE Standard 384-1992, which provides acceptable methods for independence of safety-related electrical equipment. The NRC staff reviewed IEEE Standard 384-2008 and finds that the content in section 4.5.2 of the 2008 version of the standard is consistent with section 5.5.2 of the endorsed 1992 version of the standard. Therefore, the staff finds SHINE's use of IEEE Standard 384-2008 acceptable. The staff finds that the final design of the emergency electrical power systems will not interfere with safe facility

shutdown or lead to damage if the systems malfunction during normal operation since the design meets the applicable portions of IEEE Standard 384-2008.

The NRC staff reviewed the separation of the safety-related bus from the non-safety-related bus connected to the UPSS. Each of the DC and AC safety-related loads and non-safety-related buses are described in SHINE FSAR section 8a2.2.3. The DC safety-related bus is separated using isolation overcurrent devices. SHINE categorized DC non-safety-related loads as associated equipment, as defined in section 4.5.2 of IEEE Standard 384-2008. For AC safety-related buses that provide power to non-safety-related loads, isolation from the safety-related portion of the bus is accomplished by isolation overcurrent devices. The staff finds SHINE's use of the applicable portions of IEEE Standard 384-2008 for the isolation and separation between safety-related and non-safety-related loads connected to the UPSS acceptable because the content in the 2008 version of the standard is consistent with the endorsed 1992 version of the standard.

The NRC staff evaluated the non-safety-related SGS as a defense-in-depth for the SHINE emergency electrical power systems. The SGS is described in SHINE FSAR section 8a2.2.4, "Standby Generator System Design Basis." SHINE stated that "the purpose of the SGS is to provide a temporary source of nonsafety-related alternate power to the UPSS and selected additional loads for operational convenience and defense-in-depth." The SGS functions are as follows:

- Will provide for the separation or isolation of safety-related circuits from nonsafety-related circuits, including the avoidance of electromagnetic interference with safety-related I&C [instrumentation and control] functions;

- Will provide an alternate source of power for the safety-related electrical buses;

- Will provide an alternate source of power to systems required for life-safety or important for facility monitoring;

- Will automatically start and supply loads upon a loss of off-site power; and

- Permits appropriate periodic inspection and testing to assess the continuity of the system and the condition of components.

The SGS is designed in accordance with article 700 of NFPA 70-2017. In its response to NRC staff RAI 8-10, SHINE described the specific portions within article 700 of NFPA 70-2017 used for the design of the SGS.

SHINE FSAR section 8a2.2.6, "Standby Generator System Description," states that, "The SGS consists of a 480Y/277 VAC, 60 Hertz (Hz) natural gas-driven generator, a 480 VAC switchgear, and transfer switches to allow the SGS switchgear to be connected to either or both 480 VAC NPSS transfer buses. Upon a loss of off-site power (LOOP) (i.e., undervoltage or overvoltage sensed on utility service), the SGS automatically starts, both non-vital breakers (NV BKR 1 and NV BKR 2) automatically open, and the transfer switches operate to provide power to the associated 480 VAC NPSS transfer bus." Although the SGS provides power upon LOOP, it is not required to provide safe shutdown of the SHINE facility. Based on the above, the NRC staff finds that the SGS provides additional defense-in-depth to the emergency electrical power systems of the SHINE facility.

8a.4.3 Proposed Technical Specifications

In accordance with 10 CFR 50.36(a)(1), the NRC staff evaluated the sufficiency of the applicant's proposed technical specifications (TSs) for the SHINE electrical power systems as described in SHINE FSAR Chapter 8.

The proposed TS 3.6, "Emergency Power," limiting condition for operation (LCO) 3.6.1 and surveillance requirement (SR) 3.6.1 state the following:

LCO 3.6.1	Two Divisions of the UPSS shall be Operable. A Division of UPSS is considered Operable if: 1. The battery, battery charger, inverter, alternating current (AC) distribution panel, and direct current (DC) distribution panel are Operable, 2. The inverter is supplied by the DC distribution panel and is supplying power to the AC distribution panel, and 3. The battery and battery charger are connected to the DC distribution panel.
Applicability	Facility not Secured
Action	According to Table 3.6.1
SR 3.6.1	1. UPSS battery voltage and specific gravity shall be checked semi-annually. 2. UPSS battery charger and inverter voltage shall be checked semi-annually. 3. UPSS AC and DC distribution panels shall be verified to be energized semi-annually. 4. UPSS discharge test shall be performed every five years.

The proposed TS Table 3.6.1, "UPSS Actions," states the following:

	Condition and Action	Completion Time
1.	If one Division of UPSS is inoperable, Restore the Division to Operable.	72 hours
2.	If both Divisions of UPSS are inoperable, OR Associated action and completion time of Condition 1 not met Place all IUs undergoing irradiation in Mode 3 AND Suspend all work involving special nuclear material AND	1 hour 12 hours

	Open the VTS vacuum pump breakers AND Open at least one VTS vacuum break valve AND Place tritium in all three trains of TPS process equipment in its storage location OR Initiate a TPS Train Isolation for gloveboxes containing tritium.	12 hours 12 hours 12 hours 12 hours

LCO 3.6.1 requires that two divisions of the UPSS be operable. Additionally, LCO 3.6.1 provides the conditions for the UPSS to be considered operable and the actions to be taken with completion times if one or two divisions are inoperable. The basis for the LCO 3.6.1 states, in part, "One Division of UPSS may be inoperable 72 hours to perform corrective or preventative maintenance. The 72-hour completion time is based on the availability of off-site power and the SGS. This provides a reasonable time to restore the UPSS to Operable status with an acceptably low risk. It also provides sufficient time to prepare and implement an orderly and safe facility shutdown if the UPSS is not restored to Operable status." The NRC staff finds that LCO 3.6.1 would ensure that the UPSS can supply power to safety-related loads upon loss of the normal electrical power systems. The staff also finds that the completion times would allow for corrective or preventative maintenance based on the availability of the normal electrical power systems and the SGS. Therefore, the staff finds that LCO 3.6.1 is acceptable.

SR 3.6.1 requires that the UPSS battery voltage and specific gravity be checked semi-annually, the UPSS battery charger and inverter voltage be checked semi-annually, the UPSS AC and DC distribution panels be verified to be energized semi-annually, and an UPSS discharge test be performed every five years. The NRC staff finds that SR 3.6.1 is consistent with section 4.6.2 of ANSI/ANS 15.1-2007, "The Development of Technical Specifications for Research Reactors." In addition, SHINE's UPSS batteries are maintained in accordance with section 5 of IEEE Std. 450-2010, "Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead- Acid batteries for Stationary Applications." The staff finds that these surveillances would ensure that the UPSS is operable to perform its safety function when the SHINE facility is not secured and, therefore, the staff finds SR 3.6.1 acceptable.

The proposed TS 3.6, LCO 3.6.2 and SR 3.6.2 state the following:

LCO 3.6.2	Safety-related breakers listed in Table 3.6.2-a shall be Operable. A breaker is considered Operable if: 1. The breaker is capable of tripping on demand from TRPS or ESFAS
Applicability	According to Table 3.6.2-a
Action	According to Table 3.6.2
SR 3.6.2	1. Safety-related breakers listed in Table 3.6.2-a shall be verified to trip on demand from TRPS or ESFAS, as applicable, annually.

The proposed TS Table 3.6.2, “Safety-Related Breakers Actions,” states the following:

	Action	Completion Time
1.	If one Division of breakers for a single load listed in Table 3.6.2-a is inoperable, Open at least one redundant breaker.	12 hours
2.	If both Divisions of breakers for a single load listed in Table 3.6.2-a are inoperable, Open at least one redundant breaker.	1 hour

The proposed TS Table 3.6.2-a, “Safety-Related Breakers,” states the following:

	Component	Required Divisions	Applicability
a.	RVZ1 exhaust blower breakers	2 (per train)	Associated RVZ1 exhaust train operating
b.	RVZ2 exhaust blower breakers	2 (per train)	Associated RVZ2 exhaust train operating
c.	RVZ2 supply blower breakers	2 (per train)	Associated RVZ2 supply train operating
d.	VTS vacuum transfer pump breakers	2 (per pump)	Solution transfers using VTS in-progress
e.	MEPS extraction feed pump breakers	2 (per train)	Target solution present in the associated MEPS extraction hot cell
f.	NDAS HVPS breakers	2 (per IU)	Associated IU in Mode 1, 2, 3, or 4

LCO 3.6.2 requires that safety-related breakers be operable by ensuring that the TRPS and ESFAS are capable of opening all safety-related breakers listed in TS table 3.6.2-a. TRPS and ESFAS are evaluated in Chapter 7 of this SER. The NRC staff finds that LCO 3.6.2 would ensure that the TRPS and ESFAS would perform their safety functions to secure the components in TS table 3.6.2-a. For a single division inoperable, the staff finds that the completion time of 12 hours is acceptable because the redundant breaker remains operable and remains capable of securing the load. For both divisions inoperable, the staff finds that 1 hour is a reasonable time to promptly secure the equipment. Therefore, the staff finds LCO 3.6.2 acceptable.

SR 3.6.2 requires that the safety-related breakers listed in TS Table 3.6.2-a be verified to trip on demand from TRPS or ESFAS, as applicable, annually. The functions of the safety-related breakers are described in SHINE FSAR sections 7.4, “Target Solution Vessel Reactivity Protection System,” and 7.5, “Engineered Safety Features Actuation System.” SHINE’s safety-related breakers are designed in accordance with IEEE C.37.13-2015. The NRC staff determined that this surveillance would ensure that the safety-related breakers listed in TS table 3.6.2-a are capable of securing the components in TS table 3.6.2-a upon demand from the

TRPS or ESFAS and is consistent with section 4.2.9 of ANSI/ANS 15.1-2007 to test control and safety system interlocks annually, therefore, the staff finds SR 3.6.2 acceptable.

8a.5 Review Findings

The NRC staff reviewed the descriptions and discussions of the SHINE electrical power systems, as described in SHINE FSAR Chapter 8, as supplemented, against the applicable regulatory requirements and using appropriate regulatory guidance and acceptance criteria. The staff determined that the final design and functional characteristics of the NPSS and the emergency electrical power systems are commensurate with SHINE Design Criteria 4, 27, and 28. The NPSS provides reasonable assurance that in the event of a loss or interruption of electrical power, the facility can be safely shutdown. In addition, the emergency electrical power systems provide reasonable assurance that in the event of a loss of the NPSS, the UPSS can maintain the SHINE facility in a safe shutdown condition. The staff finds that the applicant's use of specific codes and standards provides reasonable assurance that the NPSS and the emergency electrical power systems meet SHINE Design Criteria 4, 27, and 28.

Based on its review of the information in the SHINE FSAR and independent confirmatory review, as appropriate, the NRC staff determined that:

(1) SHINE described the facility electrical power systems and identified the major features or components incorporated therein for the protection of the health and safety of the public.

(2) The processes to be performed, the operating procedures, the facility and equipment, the use of the facility, and other TSs provide reasonable assurance that the applicant will comply with the applicable regulations in 10 CFR Part 50 and 10 CFR Part 20 and that the health and safety of the public will be protected.

(3) The issuance of an operating license for the facility would not be inimical to the common defense and security or to the health and safety of the public.

Based on the above determinations, the NRC staff finds that the descriptions and discussions of the SHINE electrical power systems are sufficient and meet the applicable regulatory requirements and guidance and acceptance criteria for the issuance of an operating license.

8b Radioisotope Production Facility Electrical Power Systems

SER section 8b, “Radioisotope Production Facility Electrical Power Systems,” provides an evaluation of the final design of SHINE’s RPF electrical power systems, as presented in SHINE FSAR section 8b, “Radioisotope Production Facility Electrical Power Systems.”

8b.1 Areas of Review

As described in SHINE FSAR sections 8b.1 and 8b.2, respectively, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. Therefore, the areas of review described in SER section 8a.1, “Areas of Review,” are applicable to both the SHINE IF and RPF.

8b.2 Summary of Application

As described in SHINE FSAR sections 8b.1 and 8b.2, respectively, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. Therefore, the summary of these systems provided in SER section 8a.2, “Summary of Application,” is applicable to both the SHINE IF and RPF.

8b.3 Regulatory Basis and Acceptance Criteria

As described in SHINE FSAR sections 8b.1 and 8b.2, respectively, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. Therefore, the regulatory basis and acceptance criteria provided in SER section 8a.3, “Regulatory Basis and Acceptance Criteria,” are applicable to both the SHINE IF and RPF.

8b.4 Review Procedures, Technical Evaluation, and Evaluation Findings

As described in SHINE FSAR sections 8b.1 and 8b.2, respectively, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. While the technical evaluation of these systems provided in SER section 8a.4, “Review Procedures, Technical Evaluation, and Evaluation Findings,” is specific to the SHINE IF, the NRC staff’s review considered the interface of these systems between the IF and the RPF as part of a comprehensive technical evaluation. The staff notes that SHINE FSAR section 8b has no unique content. The staff evaluated the content of SHINE FSAR section 8a2 as it pertains to the final design of functions and equipment necessary for RPF electrical power loads.

8b.4.1 Normal Electrical Power Systems

The NRC staff evaluated the sufficiency of the final design of the SHINE normal electrical power systems in the RPF, as presented in SHINE FSAR section 8a2.1, using the guidance and acceptance criteria from Section 8.1 of NUREG-1537, Parts 1 and 2, and Section 8a2 and section 8b of the ISG augmenting NUREG-1537, Parts 1 and 2. The staff review included the offsite power service; power distribution system; standby diesel generator and supported loads; distribution equipment; facility grounding system; lightning protection system; cathodic protection system; freeze protection; and cable and raceway components and routing. The

technical evaluation provided in SER section 8a.4.1, “Normal Electrical Power Systems,” applies to both the IF and RPF.

8b.4.2 Emergency Electrical Power Systems

The NRC staff evaluated the sufficiency of the final design of the SHINE emergency electrical power systems in the RPF, as presented in SHINE FSAR section 8a2.2, in part, by reviewing the UPSS; 250–VDC battery subsystem; nonsafety-related loads, maintenance, and testing; surveillance methods; seismic qualification; independence; single-failure criterion; and monitoring systems on the UPSS using the guidance and acceptance criteria from section 8.2 of NUREG-1537, Parts 1 and 2, and section 8a2 and section 8b of the ISG augmenting NUREG-1537, Parts 1 and 2. The technical evaluation provided in SER section 8a.4.2, “Emergency Electrical Power Systems,” applies to both the IF and RPF.

8b.4.3 Proposed Technical Specifications

As stated above and described in SHINE FSAR sections 8b.1 and 8b.2, respectively, the SHINE facility has one common normal electrical power system and one common emergency electrical power system, which serve both the IF and the RPF. Therefore, the evaluation of proposed technical specifications provided in SER section 8a.4.3, “Proposed Technical Specifications,” is applicable to both the SHINE IF and RPF.

8b.5 Review Findings

The NRC staff reviewed the descriptions and discussions of the SHINE electrical power systems in the RPF, including proposed technical specifications, as described in SHINE FSAR section 8a2. The review findings provided in SER section 8a.5, “Review Findings,” are applicable to both the SHINE IF and RPF.