UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

May 4, 2022

MEMORANDUM TO: Ronald G. Ballinger, Lead
SHINE License Application Review Subcommittee

FROM: Walter L. Kirchner, Subcommittee Member *Walter L Kirchner*

SUBJECT: INPUT FOR ACRS REVIEW OF SHINE OPERATING LICENSE - SAFETY EVALUATION FOR CHAPTER 6, "ENGINEERED SAFETY FEATURES"

In response to the Subcommittee's request, I have reviewed the NRC staff's safety evaluation report (SER) with no open items, and the associated section of the applicant's FSAR, for Chapter 6, "Engineered Safety Features". The following is my recommended course of action concerning further review of this chapter and the staff's associated safety evaluation.

Background-Kirchner

Chapter 6 of the SER documents the staff's review of the engineered safety features (ESF) of the SHINE operating license application in accordance with the requirements contained in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material." The staff's review was guided by NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Parts 1 & 2 (Format and Content, and Standard Review Plan and Acceptance Criteria). The staff reviewed design bases and functions of structures, systems, and components (SSCs) to determine that the facility can be operated for its intended purpose and within regulatory limits, that drawings and diagrams present a clear understanding of facility features and processes; and that associated technical specifications (TS) are sufficient.

Additional Background Information-Kirchner

The ESF systems for SHINE are divided among the Irradiation Facility (IF) and Radioisotope Production Facility (RPF). These include engineered passive design features (physical barriers such as concrete or steel boundaries, sealed access plugs, and sealed doors) and active systems and components (valve and damper isolation of penetrations, including process piping, cooling, and HVAC systems penetrating confinement boundaries) to mitigate the consequences of accidents and keep the radiological exposures to public, staff, and environment within acceptable values. Credited ESFs are described below.

The IF uses two confinement systems: (1) the primary confinement barrier for the irradiation unit (IU) cells, target solution vessel (TSV) off-gas system (TOGS) shielded cells, and the IU cell and TOGS cell HVAC enclosures; and (2) the tritium confinement barrier for the tritium purification system (TPS). The IF confinement systems remain operational during and following design basis accidents (DBAs), including seismic events and loss of off-site power. Active components which comprise portions of the confinement boundary are designed to fail safe on a loss of control or actuating power and maintain the integrity of the confinement boundary.

The IF combustible gas management systems perform mitigation functions for the primary system boundary (PSB). The combustible gas management system uses the nitrogen purge system (N2PS), PSB piping, and the process vessel vent system (PVVS) to establish an inert gas flow through the IUs. One of the functions of the TOGS is to maintain PSB hydrogen concentrations below values which could result in hydrogen deflagration and overpressure capable of rupturing the PSB during normal, shutdown, and initial accident conditions.

The RPF confinement systems include the (1) the supercell confinement, which includes the extraction, purification, and packaging hot cells, the iodine and xenon purification and packaging cell, and the process vessel ventilation system (PVVS) hot cell; and (2) the below grade confinement, which confines the PVVS delay beds, the target solution hold, storage, and waste tanks, the pipe trench and valve pits, and the waste processing tanks. The RPF PVVS is equipped with isolation valves that actuate to confine and extinguish fires, which may occur in the PVVS carbon guard beds or carbon delay beds.

The combustible gas management system performs mitigation functions for the RPF systems and components that may potentially contain hydrogen gas from radiolysis. The PVVS maintains the hydrogen concentration in these areas below the lower flammability limit (LFL) during normal operating conditions. For hydrogen gas mitigation during and after an accident, or if the PVVS is unavailable, the nitrogen purge system (N2PS) provides sweep gas to dilute the RPF tanks to maintain the hydrogen concentration below the LFL.

Nuclear Criticality Safety-Kirchner

The SHINE Nuclear Criticality Safety Program (6b.3) is designed to maintain fissile materials throughout the facility in a subcritical state during normal and credible abnormal conditions. It is consistent with applicable ANSI/ANS standards as endorsed by RG 3.71, Rev. 3, "Nuclear Criticality Safety Standards for Fuels and Materials Facilities," and nuclear criticality safety requirements of applicable sections of 10 CFR Part 70. The Program outlines organizational roles and responsibilities, training requirements, methods for nuclear criticality safety evaluations, and application of conservative criticality safety controls to systems and processes. It will be executed by qualified staff using written procedures.

SER Summary-Kirchner

The SER documents the staff's evaluation of the applicant's design for compliance with applicable regulations and standards. The NRC staff evaluated the descriptions and discussions of SHINE's IF and RPF ESFs, including technical specifications, as described in SHINE FSAR and found that the final design of SHINE's IF and RPF ESFs, including the principal design criteria; design bases; and information relative to confinement provides reasonable assurance that the final design will conform to the design basis, and meets all applicable regulatory requirements and acceptance criteria in NUREG-1537. Based on the above determinations, the NRC staff found that the descriptions and discussions of SHINE's

ESFs and TSs are sufficient and meet the applicable regulatory requirements and guidance, and acceptance criteria, for the issuance of an operating license.

Concerns-Kirchner

I did not identify any specific deficiencies in my review. I would observe that the application was well documented, and the staff's evaluation thorough. However, I would observe that there are *many repetitive process operations involving fissile solutions* to be conducted in producing the desired radioisotope product. Historically, nuclear processes involving solutions are potentially more likely to lead to criticality or radioisotope release accidents than other causes. Those processes that are not inherently safe by design, may require application of the double contingency principle (DCP), and/or require control of two or more parameters or diverse control of a single parameter. For example, the filling of the target solution vessel (TSV), the molybdenum eluate tank (MEPS), and the target dissolution tanks (TSPS), are worthy of further review should a cross-cut focus area review on nuclear criticality safety be conducted.

Recommendation-Kirchner

As lead reviewer for SHINE Chapter 6, I recommend that a single cross-cut review of nuclear criticality safety and conduct of operations be jointly completed by related chapter leads in a SHINE Subcommittee meeting, or by the full Committee, prior to drafting and issuing our final letter report on the SHINE OL application. This may require additional presentations by the applicant and/or staff on criticality safety controls and conduct of operations for key processes involving fissile solutions.

Additional Input-March-Leuba

The applicant identifies three main sources of risk in the design that need to be addressed via ESFs: (1) the creation of radiolytic hydrogen, which, if allowed to accumulate, could deflagrate and damage the TSV boundary; (2) the possibility of release of radioactive material, which includes tritium, should a breach of a boundary occur; and (3) tritium releases from either the accelerator or the tritium purification system. The applicant design includes ESFs to mitigate these risks during design basis accidents (DBAs).

A significant amount of hydrogen is produced in the uranyl solution by radiolysis of water (i.e., dissociation of water molecules when exposed to ionizing radiation). The hydrogen bubbles up and accumulates on top of the TSV. The applicant has provided a TSV off-gas system (TOGS) ESF to mitigate the consequences. The TOGS has an oxygen-rich atmosphere and a catalytic device that neutralizes the hydrogen. The staff SE finds the TOGS design acceptable to minimize the possibility of hydrogen accumulation that could reach deflagration concentrations.

A primary confinement boundary is provided for protection against the potential release of radioactive material to the environment during both normal conditions of operation and during and after DBAs. Passive confinement is performed by physical barriers such as concrete or steel boundaries, sealed access plugs, and sealed doors. The confinement systems provide active isolation of penetrations during and after certain DBAs that include process piping and heating, ventilation, and air conditioning systems penetrating confinement boundaries. The tritium confinement boundary ESF mitigates the consequences of tritium release from the tritium purification system. The staff SE has evaluated the design of these confinement boundaries and isolation system and found them to be adequate.

A customary area of concern is criticality safety. The applicant addresses it throughout the facility with a safe-by-design approach, and all volumes capable of containing uranyl solution (except the TSV) have geometries that guarantee subcriticality. TSV subcriticality is maintained via operator actions (i.e., solution filling procedures) and enforced by the protection system, which initiates a TSV solution dump if unsafe conditions are detected. Even though some individual reactivity feedback mechanisms are positive (e.g., water holdup in the off-gas system), the overall power reactivity coefficient is negative, which ensures subcritical operation of the TSV. The main criticality-safety-related ESF is the criticality accident alarm system (CAAS). The CAAS consists of detectors located throughout the main production facility at locations designated to provide sufficient coverage of areas in which SNM is used, handled, and stored. The staff SE has performed a thorough review of all criticality safety functions and finds them adequate. I concur.

Additional Input-Halnon

Review Finding in SER Chapter 6 review, section 6b.5, item 2:
This statement implies that the operating procedures have been reviewed as part of the SER Chapter review. Given that operating procedures have not been written, this boiler-plate description of a review finding could be misleading. It is recommended that the staff consider revising the statement of finding for each chapter where used (such as Chapters 5 and 6). Additionally, we should request a briefing on the most critical operations applicable to Chapter 6, specifically regarding criticality safety during operational evolutions.

References

1. US NRC, “Engineered Safety Features,” Chapter 6, Staff Safety Evaluation Report, March 14, 2022 (ML22073A208).

R. Ballinger

May 4, 2022

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