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Interfaces Between the IMSR® Core-unit and Reactor Auxiliary Building Structures and Systems

Abstract
This white paper contains a description of interfaces for structures, systems and components (SSCs) in the Reactor Auxiliary Building that interact directly with the structures, systems and components that comprise the IMSR® Core-unit. TEUSA plans to provide the detailed interface requirements and acceptance criteria in a subsequent white paper. TEUSA acknowledges that any future application for a combined license or Standard Design Approval under Part 52 or a construction permit under Part 50 will need to demonstrate that the interface requirements and acceptance criteria have been satisfied.

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I. Purpose

The purpose of this white paper is to identify and describe the interfaces for structures, systems and components (SSCs) in the Reactor Auxiliary Building that interact directly with the SSCs that comprise the IMSR® Core-unit.

This white paper supports the identification of interface requirements and boundary conditions necessary to establish the Core-unit as a "major portion" of the overall IMSR® power plant design in an application for a Standard Design Approval (SDA) for the Core-unit under 10 CFR Part 52, Subpart E.

Interface requirements are those requirements related to the interface and boundary conditions associated with the Core-unit. The interfaces will stem from the dependency of the SSCs that are within the scope of the application for a Core-unit SDA as well as on the functional and operational characteristics of SSCs that are not within the scope of the SDA.

Interfaces and boundary conditions can be distinct; however, they can also be used interchangeably. Nonetheless, together, they describe the limitations, constraints, assumptions, and conditions to define the relationship between the Core-unit and the remainder of the power plant.

An interface could include a programmatic requirement or an operational assumption about system performance of the Core-unit. Whereas, a boundary condition could be a physical constraint or an explicit limit on an interfacing system or component, or a similar restraint or limitation associated directly with the Core-unit. Additionally, a boundary condition may be a well-defined physical point of separation, or departure, between an interfacing system and the Core-unit.

The information requirements for a Core-unit SDA application is a subset of the information requirements supporting an application for a construction permit or combined license, thereby supporting the longer-term licensing goals associated with IMSR® deployment. Information that supports an SDA application for the IMSR® Core-unit includes information identifying, defining, or describing:

- the IMSR® Core-unit,
- the associated Core-unit engineering boundary conditions,
- the interfaces between the Core-unit and the remaining portions of the IMSR® power plant,
- the IMSR® Principal Design Criteria (PDC),
- the Core-unit interface requirements & acceptance criteria, and
- other regulatory requirements applicable to the IMSR® Core-unit.

II. Introduction

Terrestrial Energy USA, Inc. (TEUSA) is developing the Integral Molten Salt Reactor (IMSR®) design to provide electricity or process heat to U.S. industrial heat users. TEUSA is planning for the first commercial deployment of this technology in the late 2020s. The IMSR® is a Generation IV advanced reactor power plant that employs a fluoride molten salt reactor (MSR) design. The IMSR® nuclear power plant (I-NPP), consists of a nuclear island containing at least one, approximately 440 MWth IMSR® (IMSR400) Core-unit. The IMSR400 has the potential to generate up to 195 MWe of electrical power or to export 600 °C of heat for industrial applications, or some combination of both. The I-NPP includes an adjacent balance-of-plant building that contains non-nuclear-grade, industry-standard power conversion and generation equipment.

The IMSR® design builds upon pioneering work carried out at Oak Ridge National Laboratory (ORNL) from the 1950s to the 1980s, where MSR technology was developed, built, and demonstrated with two experimental MSRs. The first MSR was the Aircraft Reactor Experiment (ARE) and next, the Molten Salt Reactor Experiment (MSRE). Based on the demonstrated feasibility of MSR technology, ORNL commenced a commercial power plant program for MSR technology. This program led to the Denatured Molten Salt Reactor (DMSR) design in the early 1980s.

TEUSA has developed and submitted a Regulatory Engagement Plan (REP) (Reference 5) to the Nuclear Regulatory Commission (NRC). The REP outlines topics and schedules for interaction with the NRC to achieve early resolution of general technical or regulatory matters related to the IMSR® design. Specifically, the REP highlights technical and regulatory topics that directly support the development and submittal of a 10 CFR 52, Subpart E application for a Standard Design Approval (SDA) of the IMSR® Core-unit. This white paper [ ] support the TEUSA SDA application development efforts.

Company Background

TEUSA [ ]. TEUSA is a Delaware C-Corp founded in August 2014 that started active business operations in 2015. TEUSA is a U. S. majority-owned company with corporate offices in New York. [ ].

Canadian Nexus

TEUSA has [ ]. TEUSA leverages the ongoing engineering and regulatory work that TEI accomplishes as TEI currently advances its regulatory activities under Phase 2 of the Vendor Design Review (VDR) process with the Canadian Nuclear Safety Commission (CNSC). Leveraging the efforts of TEI's VDR activities is possible because most of the technical and engineering information used for both regulatory reviews is the same. Leveraging TEI effort eliminates duplicate technical work in the U.S., and the approach also provides substantial cost savings for TEUSA. The figure below provides [ ].

Figure 1: [ ]

[

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Licensing Strategy and Objective

The REP provided to the NRC outlines the regulatory strategy for TEUSA activities. [

] to support a commercial operation date for the first U.S. plant in the 2020s. During regulatory reviews, the NRC uses its understanding of the design and operating characteristics as well as the supporting research and engineering work to perform its review responsibilities efficiently. To support the NRC understanding, TEUSA has begun familiarizing the NRC with the IMSR® design as well as the scope of the available and planned analyses, testing, and operational experience in support of the design. By initiating the process of introducing the IMSR® design information to the NRC, TEUSA expects that the NRC can identify any issues that may require further testing or technical analyses. Additionally, the NRC will be more able to estimate the resource and schedule requirements necessary to conduct regulatory activities associated with IMSR® licensing.

TEUSA's long-term licensing objective for the commercial deployment of the IMSR® design in the U.S. is to first obtain an SDA for the IMSR® Core-unit under 10 CFR Part 52, Subpart E. The IMSR® Core-unit represents a significant technical portion of the IMSR® facility and includes many systems that perform important safety functions. The systems within the Core-unit are reasonably discernible from systems outside the boundaries of the Core-unit. Subsequent sections of this white paper provide additional details about the design envelope of the IMSR® Core-unit and its safety interfaces.

[ ]. The first technical document that TEUSA submitted to the NRC was a white paper that provided an overview of major plant buildings, structures, systems and components that make up the IMSR® facility. The first technical document also provided details on the important plant SSCs that comprise the IMSR® Core-unit. This white paper [ ] identifies the interfacing systems that provide important functions in support of the operation and safety of the IMSR® plant and that interact directly with the IMSR® Core-unit. More detailed recommendations for interface requirements and acceptance criteria will be presented in a later white paper and any application for a combined license or SDA under Part 52 or a construction permit under Part 50 will demonstrate that the interface requirements have been satisfied.

The TEUSA Regulatory Engagement Plan (Reference 5) provides additional details regarding TEUSA licensing activities and objectives.

III. Regulatory Envelope and Related Guidance

The regulations governing the application process for an SDA can be found in Subpart E, "Standard Design Approvals," to 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants." The regulatory precedent for 10 CFR Part 52, Subpart E is 10 CFR Part 50 Appendix O, was first created in January 1975. The process outlined in Appendix O of 10 CFR part 50 was used to review standard designs for nuclear steam supply systems (NSSS), balance of plant systems, a nuclear island, and a turbine island. However, there is no regulatory precedent for using an SDA process for smaller portions of a plant design. The previously approved NSSS designs were subsequently incorporated into construction permit applications for specific plant sites.

10 CFR 52.135(a), "Filing of applications," states:

"any person may submit a proposed standard design for a nuclear power reactor of the type described in 10 CFR 50.22 to the NRC staff for its review. The submittal may consist of either the final design for the entire facility or the final design of major portions thereof."

The current regulations do not define what constitutes a "major portion" of a design. Because of this, an applicant is free to identify and justify the scope of the design for which the approval is being sought. Such freedom affords potential applicants substantial flexibility to standardize different portions of new or innovative technologies. Under these regulations, an SDA could be developed for selected SSCs at a level of detail analogous to a design certification application and the interface requirements would describe significant conceptual design information. Alternatively, an SDA could be developed for major portions of a design including designs that are conceptual and novel relative to commercial nuclear technology currently licensed and deployed in the United States. In this latter case, the NRC approval would be less substantive, and a lesser degree of regulatory finality would likely occur.

Relevant Regulatory Guidance

In an effort to support technology developers interested in pursuing a staged licensing process, the Nuclear Innovation Alliance (NIA) developed two guidance documents that are relevant to developing an application for an SDA for a major portion of their design. In April 2017, NIA issued its first report "Clarifying 'Major Portions' of a Reactor Design in Support of a Standard Design Approval" which discussed the options for using an SDA as part of a staged licensing approach. This report provided information to assist a reactor developer in determining if pursuing an SDA would support their licensing development interests (Reference 1).

In September 2019, NIA issued its second report, "Establishing Interface Requirements for 'Major Portions' Standard Design Approvals," (Reference 2). While the NIA report discussed options available for reactor designers seeking a staged licensing process, a key element of this guidance was that in an SDA application for a major portion of a technology, the developer should explicitly list all assumptions regarding the major portion's connection to other parts of the design to facilitate NRC review and any future use in subsequent licensing processes. These assumptions are frequently referred to as system interface requirements. The NIA document also provided guidance on a process that a potential applicant could use for establishing these interface requirements in its application.

The September 2019 NIA report (Reference 2) provides a process which may be used by developers of advanced reactor technologies. [ ].

The process that TEUSA employed is briefly explained in the following section.

Process for Identifying Interfaces

For TEUSA, the definition of the scope of the Core-unit was presented in a white paper submitted to the NRC in March 2020 (Reference 4). Consistent with the TEUSA defined scope, TEUSA examined the interaction between the IMSR® Core-unit systems and other systems within the Reactor Auxiliary Building (RAB) to identify the types of interfaces that might exist, for which future interface requirements will be need to be established.

If an applicant should decide to submit an application for an SDA, interface requirements should be thought of as boundary conditions between the portion of the design for which the SDA is being sought and the rest of the facility. In fact, 10 CFR 52.47(a)(25) states that an applicant must provide interface requirements to be met by those portions of the plant for which the application does not seek approval.

Figure 1 of the NIA September 2019 report "Establishing Interface Requirements for "Major Portions" Standard Design Approvals" (Reference 2) depicts a process for establishing interface requirements in support of an SDA for a major portion of a design. The NIA process calls for the designer to develop design criteria and recommends that a designer examine the guidance contained in Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors." (Reference 3) The regulatory guidance can also be used as a tool to assess, at a macro level, whether there could be a need to define boundary conditions and interface requirements in conjunction with the design process. The need for interface requirements stems from the dependency of the SSCs that are within the scope of the SDA application on the functional and operational characteristics of SSCs that are not within the SDA application scope. The process depicted in Table 1 of the referenced NIA report (Reference 2), proposes using the Advanced Reactor Design Criteria (ARDC) as a substitute for design-specific principal design criteria.

In practice, interfaces can generally fall into one or more of the categories listed below:

1. Material requirements
2. System performance requirements
3. Heat removal requirements
4. Fuel design requirements
5. Analytical capabilities and assumptions
6. Structural requirements
7. Plant protection requirements, and
8. Radionuclide retention or removal requirements

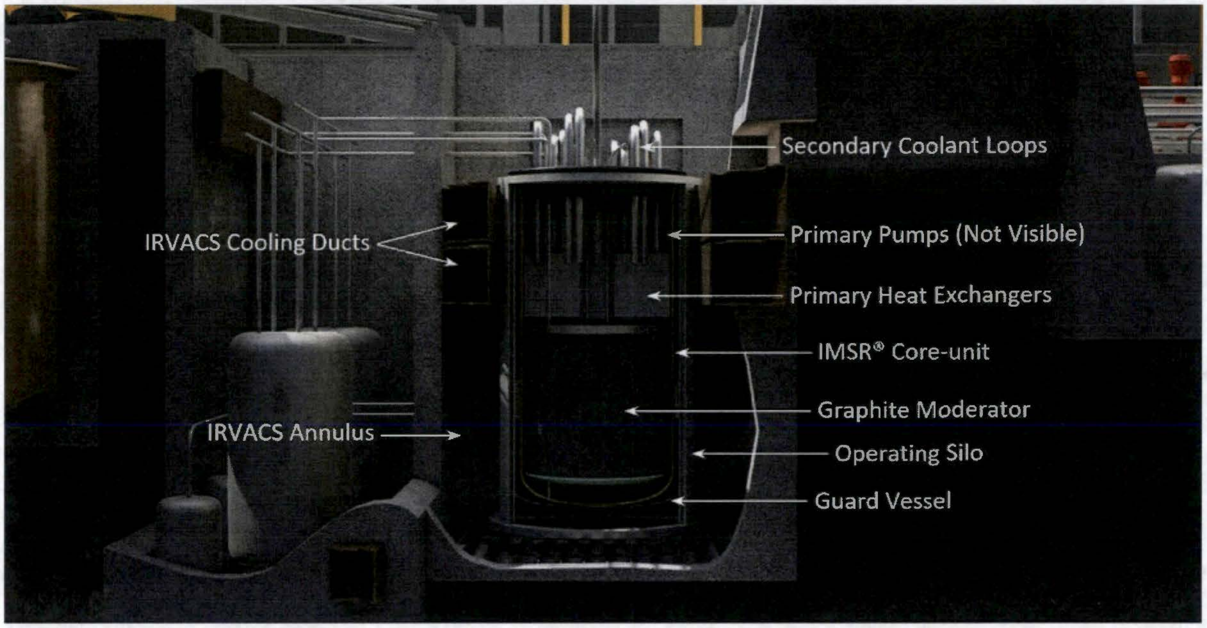
The scope of the IMSR® Core-unit and the systems included within it are summarized in the next section.

IV Structures, Systems and Components that Constitute the IMSR® Core-unit

For ease of reference, this section provides a brief summary of information about the SSCs that comprise the IMSR® Core-unit. Reference 4 provides greater detail about the IMSR® Core-unit SSCs.

Figure 2 below provides a more detailed picture of the internal structures and components of the IMSR® Core-unit and supporting systems.

Figure 2: IMSR® Core-unit and Supporting Systems



Reactor Vessel

The Reactor Vessel is an upright, [ ] cylinder. It contains the full inventory of liquid fuel salt and there are no external fuel salt piping loops associated with the Reactor Vessel. All the nuclear heat fission energy is generated within the Reactor Vessel. [ ], the Reactor Vessel forms the primary nuclear boundary during normal operation, anticipated events, and Design-Basis-Accidents (DBAs).

The Reactor Vessel boundary performs the following functions:

- Contains the fuel salt,
- Provides a flow circulation path for the fuel salt, and
- Provides a support (anchor point) for the core internals.

Liquid Fuel Salt

The IMSR® design operates by fissions of low-assay low enriched uranium (LEU) [dissolved in a molten primary coolant comprised of a fluoride salt-mixture. The primary purpose of the fuel salt-mixture is to deliver the low-enriched fissile uranium into the IMSR® graphite core for heat generation through a sustained fission chain reaction and subsequent transportation of the heat to the Primary Heat Exchangers. The [ ] over the 7-year lifetime. In any potential emergency involving a sudden temperature increase, the core negative temperature reactivity coefficient will inherently stabilize the reactor such that the Internal Reactor Vessel Auxiliary Cooling System (IRVACS) can passively remove the heat it produces.

Primary Pumping System

The Primary Pumping System performs the essential function to circulate the fuel salt through the Core-unit. Its purpose is to provide enough flow through the Primary Heat Exchangers and Moderator to facilitate full power operation without exceeding the material temperature limits of the Core-unit components. The Primary Pumping System is wholly contained within the sealed Core-unit.

Graphite Moderator

The purpose of the Graphite Moderator is to provide the medium for slowing down neutrons to promote the nuclear chain reaction. The core design provides fuel channels for the passage of fuel salt, using pumping force, through the moderator region, to the Primary Heat Exchangers. The graphite [

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Shutdown Rods

IMSR® reactor shutdown (i.e., sub-criticality) is not required to reach a safe end-state for any Anticipated Operation Occurrence (AOO) or DBA (a safe end-state for the IMSR® design is defined to be the reactor at low power, the Reactor Vessel temperature within acceptable limits, and no fuel (salt) boiling). However, as a defense-in-depth safety measure, and for operational purposes, the IMSR® design includes a Shutdown Mechanism (SDM) as an independent means of shutting down the reactor.

The purpose of the SDM is to bring the reactor to a sub-critical state. The SDM makes use of Shutdown Rods to bring the reactor to a shutdown sub-critical state, which would eventually result in cooldown to a cold condition as decay heat subsides.

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See Figure 4-22 of Reference 6 for more detail about Reactor Vessel internals.

Primary Heat Exchangers

The Primary Heat Exchangers (PHXs) provide heat transfer between the circulating Fuel Salt and a separate closed–loop coolant salt. The PHXs [

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Cover Gas & Off-gas Management System

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Additional details about the Cover Gas & Off Gas Management System is provided below.

This system [ ].

V. Identification of Structures, Systems and Components that Interface with the IMSR® Core-unit

This section identifies SSCs that are not contained within the Core-unit but connect directly to systems in the Core-unit. Section VI lists the interfacing systems and structures, identifies categories of interfaces for the selected system or structure identified, and provides references to potentially relevant principal design criteria associated with the selected system or structure.

Instrumentation and Control

In general, the control functions are not challenging in terms of complexity and performance due to the passive and inherent safety design features of the IMSR®. The I&C system's main functions deal fundamentally with integrated control of production, interlocks for safety coordination, and monitoring system status. Compared to conventional nuclear technology, some of the in-core instrumentation and process equipment for the salt systems operate in a higher temperature environment, [ ].

Makeup Fuel System (MFS)

The purpose of the MFS is to provide the initial fuel load for a new Core-unit and to periodically add fuel to the operating Core-unit during operation. Fuel additions are to maintain the reactivity of the core and maintain the fuel temperature at the desired value.

The system has a safety function to limit the rate and amount of reactivity that can be added to the Core-unit to ensure the fuel temperature does not increase in an uncontrolled manner. This system also ensures that fuel outside the Core-unit cannot go critical. Additionally, the design ensures the system meets safeguards requirements.

This system operates intermittently, is normally isolated from the Core-unit, and kept at, or near, atmospheric pressure.

Secondary Coolant System

The purpose of the Secondary Coolant System is to deliver heat from the Primary Heat Exchanger to the Secondary Heat Exchanger, where heat is transferred to the Tertiary Salt Loop. Figure 2 shows the relationship of Secondary Coolant System piping to the IMSR® Core-unit and other SSCs.

Internal Reactor Vessel Auxiliary Cooling System (IRVACS)

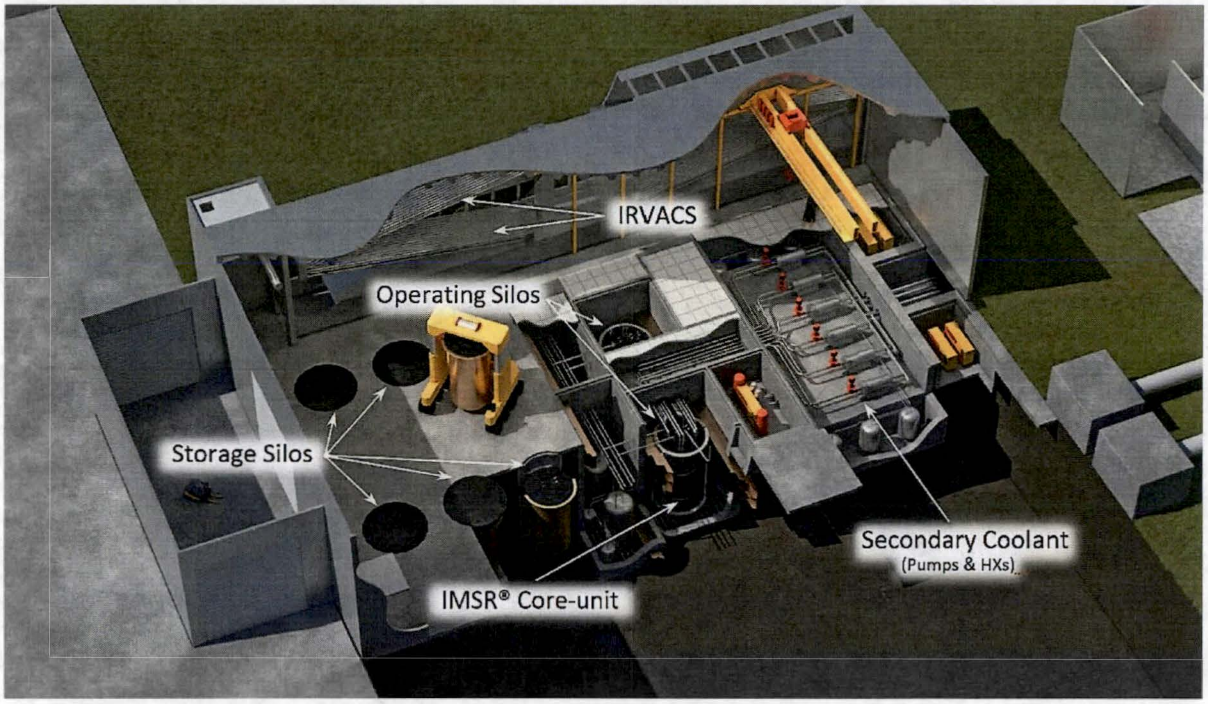
Under normal heat removal conditions, the fuel salt mixes convectively in the Core-unit and transfers heat out through the primary heat exchangers to the secondary heat exchangers. The IRVACS functions as an alternate emergency heat sink to passively remove heat generated within the Core-unit during transients, accidents, or whenever normal heat removal is unavailable.

IRVACS [ ] system that operates [ ] to transfer heat from the Core-unit to the atmosphere. The IRVACS is always operating and does not require any AC or DC electrical power. The system functions continuously irrespective of Core-unit status or plant state. The system has no actuation devices, no flow control mechanisms, nor any other type of control device. The heat removal capacity is sized to remove the maximum postulated decay-heat load, including situations where normal heat removal might not be available.

Reactor Auxiliary Building

The seismically qualified Reactor Auxiliary Building (RAB) houses, (i) the IMSR® Core-units and associated nuclear systems, (ii) various heat removal systems (excluding Steam Generators) and, where required, additional heat transfer equipment to supply process heat to industrial users, and (iii) electrical systems and various auxiliary systems required to safely control, and monitor the plant during all postulated operating conditions. Figure 3 below shows the arrangement of the storage silos, operating silos, a portion of the IRVACS (Internal Reactor Vessel Auxiliary Cooling System), and the location of the secondary coolant system, primarily the secondary coolant pumps and heat exchangers. Importantly, Figure 3 shows the physical relationship between the operating silos, storage silos, and the IMSR® Core-unit.

Figure 3: Reactor Auxiliary Building



Main Control Room and Secondary Control Area

The Main Control Room (MCR) is located in the Control Building and is the center for all plant operations. The Control Building is seismically qualified and is designed to withstand the effects of all postulated natural phenomena so that control room operators should not need to leave the control room during plant transients and postulated accidents. From the MCR, the operator can perform all plant control, monitoring, and safety functions. In the event the MCR is unavailable, operators would move to the Secondary Control Area (SCA) to monitor and ensure that the plant remains in a safe state. Local instrument rooms, which contain local monitoring and control capability, are distributed throughout the plant as needed.

Silos

There are eight silos included in the IMSR® facility. Two silos are for operating Core-units, and six are for Core-unit storage. One of either of these two operational silos houses the operating Core-unit for its 7-

year operational life; the second silo houses the previously operated (spent) Core-unit during its radioactivity decay cooldown period. Following cooldown, preparations are made for a new Core-unit by transferring the previously operated Core-unit from its operating silo into a storage silo. The six storage silos only house spent Core-units that have completed the required radioactivity decay cooldown period. The silos interface with the Reactor Vessel and Reactor Support Structure. Figure 2 shows the relationship of the Silo to the Guard Vessel, Core-unit, and SSCs.

Guard Vessel

The Guard Vessel is a stainless-steel vessel that is fitted around and supports the Reactor Vessel. The primary purpose of the Guard Vessel is to catch and retain any fuel salt leakage or radioactive release from the IMSR® Core-unit to protect from any unintended release from the Core-unit. In the event of a Beyond Design Basis failure of the Reactor Vessel, the Guard Vessel will catch and contain any leaked fuel salt. Unlike the Reactor Vessel, which is a component part of the replaceable Core-unit, the Guard Vessel is a component of the containment boundary. The Guard Vessel is designed to last for the operating life of the plant. Figure 3 (above) shows the relationship between the Guard Vessel, Silo, Core-unit, and other SSCs.

Reactor Support Structure

The Reactor Support Structure is a steel structure located in the silo. The Reactor Support Structure is used to support and provide alignment of the Guard Vessel inside the Silo. By extension, the Reactor Support Structure also provides support and alignment of the Core-unit. Figure 3 shows the relationship between the Reactor Support Structure, Silo, Guard Vessel, Core-unit, and other SSCs.

Containment

The Containment system forms a sealed, low-leakage envelope to house all systems that may contain highly radioactive material, specifically the Core-unit (active reactor), the off-gas lines/storage, irradiated fuel tanks, and any pipe transferring irradiated liquid fuel. In the event of a leak in any of these systems, the containment prevents the release of any radioactive materials to the Reactor Auxiliary Building. The Containment system also minimizes releases in the unlikely event of a severe accident. The Containment system includes the Guard Vessel and a common containment boundary that encloses the top plate of the Reactor Vessel, the off-gas and fuel transfer lines, and the irradiated fuel storage tanks.

Cover Gas & Off Gas Management System

Above the [ ]. It also accommodates [ ] over its 7-year operational life. A separate portion of the Cover Gas System provides [ ].

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The Cover Gas System [ ]. During critical power operation, the Cover Gas System [ ].

Irradiated Fuel System (IFS)

The primary purpose of the IFS is to remove the fuel from the Core-unit and transfer the fuel to storage tanks for long term on-site storage. This system [ ]. The system can store all of the irradiated fuel generated over the 60-year life of the plant. At [ ], this system [ ].

VI. IMSR® Core-Unit Interfaces

This section outlines the interfaces for each of the systems or structures that interact directly with the IMSR® Core-unit but are not part of the defined IMSR® Core-unit SDA application scope. Information for each interface is presented in a tabular format. In each table, the design functions for the interface are listed. [ ], the tables include examples of potentially relevant PDC for each of the listed Interface Categories. The listed "potentially relevant" PDC are not proposed as a comprehensive set and are provided only as illustrative examples.

The interface requirements for design, procurement, fabrication, and construction will be captured under an approved quality assurance plan. To reduce the redundancy within the tables, the interfaces to be governed by the quality assurance (QA) plan are simply listed once in the first interface category (Materials). TEUSA notes that for other interface categories, this relationship is implicit as it will be contained in the relevant standards used in the development of the detailed design of the interfacing SSCs and will also be prescribed in the overall QA program in the future.

The interface tables (Tables 1 through 12) refer to the PDCs presented in Appendix A, which are those listed for use for a sodium fast reactor in RG 1.232, Appendix B (Reference 3). Each of the RG 1.232 PDCs have been assigned a unique TEUSA number. No inference of applicability of the listed PDC in this paper or in Appendix B of RG 1.232 to the IMSR® design should be made at this time.

The IMSR® specific [ ] will be presented to the NRC as the subject of a separate white paper. The system and structure specific interface requirements and necessary acceptance criteria are also undergoing development and will be provided in a subsequent white paper.

Table 1. Interfaces for the Digital Instrumentation and Control System

Digital Instrumentation and Control System		
System Functions:	• Provide integrated control of production • Provide interlocks for safety coordination • Monitor system status • Provide capability for monitoring and operations in Main Control Room	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [ ]	[ ]
System performance	• [• • • • •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [ ]	[ ]
Plant protection	• [• •]	[ ]
Radionuclide retention or removal	• [ ]	[ ]

Table 2. Interfaces for the Makeup Fuel System

Makeup Fuel System (MFS)		
System Functions:	• Provides the initial fuel load for new Core-units • Periodically adds fuel during operation to maintain core reactivity and fuel temperature at the desired values • Ensures that fuel outside the Core-unit cannot go critical	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [• • • •]	[ ]
System performance	• [• • • • • • • • •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [• •]	[ ]
Structural	• [• •]	[ ]
Plant protection	• [• •]	[ ]
Radionuclide retention or removal	• [ ]	[ ]

Table 3. Interfaces for the Secondary Coolant System

Secondary Coolant System		
System Functions:	• Delivers heat from the primary heat exchanger to the secondary heat exchanger by using a secondary cooling salt loop • Forms the primary coolant boundary within the primary system heat exchangers	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [• • • •]	[ ]
System performance	• [• • • • • •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [•]	[ ]
Plant protection	• [• •]	[ ]
Radionuclide retention or removal	• [•]	[ ]

Table 4. Interfaces for the Internal Reactor Vessel Auxiliary Cooling System

Internal Reactor Vessel Auxiliary Cooling System (IRVACS)		
System Functions:	• Alternate emergency heat sink to remove heat generated in the IMSR® Core-unit during transients, accidents, or whenever normal heat removal paths are unavailable	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [• •]	[ ]
System performance	• [• •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [ ]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [ ]	[ ]

Table 5. Interfaces for the Reactor Auxiliary Building

Reactor Auxiliary Building		
System Functions:	• Houses (i) the IMSR® Core-units and associated nuclear systems, (ii) the heat removal systems before the steam generators and any additional heat transfer equipment to supply process heat to industrial users, and (iii) the electrical systems and various auxiliary systems required to operate safely, control, and monitor the plant during all postulated operating conditions	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [ ]	[ ]
System performance	• [ ]	[ ]
Heat removal	• [• • •]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [• • • •]	[ ]
Plant protection	• [• •]	[ ]
Radionuclide retention or removal	• [•]	[ ]

Table 6. Interfaces for the Control Building

Control Building		
System Functions:	• Houses the main control center, the security and operations staff, associated change rooms, and facilities required for the operation of the plant • Capability to operate all required safety systems when necessary	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [ ]	[ ]
System performance	• [•]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [•]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [ ]	[ ]

Table 7. Interfaces for the Silos

Silos		
System Functions:	• 2 silos are used for operating Core-units: one houses the operating Core-unit for its 7-year operational life; the other houses the previously operated (spent) Core-unit during its cooldown period • 6 silos are used for Core-unit storage	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [ ]	[ ]
System performance	• [ ]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [•]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [•]	[ ]

Table 8. Interfaces for the Guard Vessel

Guard Vessel		
System Functions:	• Supports the Reactor Vessel and by extension, the IMSR® Core-unit • Catch and retain any fuel salt leakage or radioactive release from the IMSR® Core-unit to protect from any unintended release as a result of a beyond design basis event	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [• •]	[ ]
System performance	• [ ]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [ ]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [ ]	[ ]

Table 9. Interfaces for the Reactor Support Structure

Reactor Support Structure		
System Functions:	• Supports and provides alignment of the guard vessel inside the silo, and by extension provides support and alignment to the IMSR® Core-unit	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [•]	[ ]
System performance	• [ ]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [•]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [ ]	[ ]

Table 10. Interfaces for the Containment

Containment		
System Functions:	• Houses all systems that may contain highly radioactive material, including the IMSR® Core-unit, the off-gas lines/storage, irradiated fuel tanks, and any pipe transferring irradiated liquid fuel • Provides a passive barrier for high activity sources within the plant to protect workers and the public from radiation doses during normal operations and accidents • Minimizes leakage to assure that normal operation release limits are met, and that AOOs and DBAs do not result in exceeding dose acceptance criteria	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [• •]	[ ]
System performance	• [• •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [•]	[ ]
Plant protection	• [• •]	[ ]
Radionuclide retention or removal	• [• • • •]	[ ]

Table 11. Interfaces for the Cover Gas & Off Gas Management System

Cover Gas & Off Gas Management System		
System Functions:	• [• • • • • •]	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [•]	[ ]
System performance	• [• • •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [ ]	[ ]
Structural	• [•]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [• • •]	[ ]

Table 12. Interfaces for the Irradiated Fuel System

Irradiated Fuel System (IFS)		
System Functions:	• Removes the fuel from the Core-unit and transfers the fuel to storage tanks for long term on-site storage	
Interface Category	**Interface**	**Principal Design Criteria**
Materials	• [• • •]	[ ]
System performance	• [• • • • • • •]	[ ]
Heat removal	• [ ]	[ ]
Fuel design	• [•]	[ ]
Structural	• [•]	[ ]
Plant protection	• [•]	[ ]
Radionuclide retention or removal	• [•]	[ ]

VI. Conclusion

This white paper identifies the interfaces between the IMSR® Core-unit and systems and structures located in the Reactor Auxiliary Building or Control Building that provide important functions in support of the operation and safety of the IMSR® plant. Interface requirements will be necessary for each of these interfacing systems or structures in an application for either a combined license or an SDA under Part 52, or a construction permit under Part 50. The specific proposals for interface requirements for the systems and components that support the IMSR® Core-unit will be presented in a future white paper.

Appendix A – Listing of Principal Design Criteria

Principle Design Criteria

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Abbreviations and Acronyms

AOO – Anticipated Operational Occurrence

ARDC – Advanced Reactor Design Criteria

ARE – Aircraft Reactor Experiment

BDBA – Beyond Design-Basis Accident

BeF_2 – Beryllium Fluoride

CFR – Code of Federal Regulations

CNSC – Canadian Nuclear Safety Commission

Cs - Cesium

DBA – Design Basis Accident

DMSR – Denatured Molten Salt Reactor

I&C – Instrumentation and Control

IFS – Irradiated Fuel System

I-NPP – IMSR Nuclear Power Plant

IMSR® – Integral Molten Salt Reactor

IRVACS – Internal Reactor Vessel Auxiliary Cooling System

KF – Potassium Fluoride

LEU – Low Enriched Uranium

LiF – Lithium Fluoride

MCR – Main Control Room

MFS – Makeup Fuel System

MW – Megawatt

MWe – Megawatt Electric

MWth – Megawatt Thermal

MSR – Molten Salt Reactor

MSRE – Molten Salt Reactor Experiment

NaF – Sodium Fluoride

NIA – Nuclear Innovation Alliance

NRC – Nuclear Regulatory Commission

NSSS – Nuclear Steam Supply Systems

ORNL – Oak Ridge National Laboratory

PDC – Principal Design Criteria

PHX – Primary Heat Exchanger

PSA – Probabilistic Safety Assessment

QA – Quality Assurance

R&D – Research and Development

RAB – Reactor Auxiliary Building

REP – Regulatory Engagement Plan

SCA – Secondary Control Area

SDA – Standard Design Approval

SDM – Shutdown Mechanism

SHX – Secondary Heat Exchanger

Sr - Strontium

SS – Stainless Steel

SSC – Structures, Systems, and Components

TEI – Terrestrial Energy, Inc.

TEUSA – Terrestrial Energy USA, Inc.

U.S. – United States

VDR – Vendor Design Review

Xe - Xenon

References

1. Nuclear Innovation Alliance, "Clarifying "Major Portions" of a Reactor Design in Support of a Standard Design Approval," April 2017.

2. Nuclear Innovation Alliance, "Establishing Interface Requirements for "Major Portions" Standard Design Approvals," September 2019.

3. Regulatory Guide 1.232, Revision 0, "Guidance for Developing Principal Design Criteria for Non-Light Water Reactors", April 2018, U.S. Nuclear Regulatory Commission

4. TEUSA, "IMSR® Core-unit Definition - Applicable Structures, Systems and Components," March 2020.

5. TEUSA, "Integral Molten Salt Reactor (IMSR®) – U.S. Regulatory Engagement Plan," March 2020.

6. IMSR-CSAR-000.00-00001-R00, CSAR Chapter 4, "Reactor", August 2016.

7. IMSR400-30000-PPS-001, Plant Performance Specification (PPS) for the IMSR400, December 2018