TERRESTRIAL
ENERGY USA

Principal Design Criteria

for IMSR® Structures, Systems and Components

Topical Report

Revision A

January 2023

Abstract
TEUSA's long term licensing objective is to obtain a Standard Design Approval (SDA) for the IMSR® Core-unit. A necessary component of a 10 CFR Part 52 SDA application for the IMSR® Core-unit is the identification and description of the principal design criteria for the IMSR® structures, systems, and components. This topical report contains the principal design criteria for those systems that provide important functions in support of the operation and safety of the IMSR® plant (also referred to as the IMSR400). The principal design criteria are developed based on the key design features of IMSR® technology and the guidance of Revision 0 of Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors."

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Table of Contents

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Executive Summary

This topical report provides the Principal Design Criteria (PDC) to be used with future license applications referencing the IMSR® (also referred to herein as the IMSR400). This topical report also summarizes the methodology that was used to determine the PDC. The PDC are application content requirements of future license applications and the specific content requirements are found at 10 CFR Part 50.34 for CP/OL applications, Part 52.79 for COL applications, and Part 52.137 for Standard Design Approval (SDA) applications. The PDC are developed based on the key design features of the IMSR400 technology and are established using the guidance of Regulatory Guide 1.232, "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors." The resultant PDC are comprehensive, reflect the key design features of IMSR400 technology, and provide future license applicants a set of PDC that will satisfy the application content requirements under 10 CFR 50 or 10 CFR 52. TEUSA is requesting Nuclear Regulatory Commission (NRC) review and approval of these PDC for the IMSR®.

I. Purpose

The purpose of this topical report is to establish a set of principal design criteria (PDC) for the IMSR® systems, structures, and components (SSCs) that provide important functions in support of the operation and safety of the IMSR® facility. Upon approval by the NRC, TEUSA intends for these PDC to be referenced in a subsequent application for a Standard Design Approval (SDA) for the IMSR® Core-unit or in future applications for licenses permitting construction and operation of an IMSR® facility.

The General Design Criteria (GDC) in 10 CFR 50, Appendix A provides the minimum requirements for the PDC for water-cooled NPPs. The PDC establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs important to safety. SSCs important to safety are those that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.

The requirements for the contents of an application for a construction permit specified in 10 CFR 50.34 (a) (3) include submittal of the PDC for the facility. It goes further to describe the information as the design basis and information relative to materials of construction, general arrangements, and approximate dimensions sufficient to provide reasonable assurance that the design will provide an adequate margin for safety. TEUSA licensing strategy is to initially pursue an application for an SDA. As part of the effort to develop the necessary information to incorporate into the future SDA application, TEUSA has developed the PDC contained in this topical report along with the supporting design detail to demonstrate how the PDC will be met in the IMSR facility.

II. Introduction

Terrestrial Energy USA, Inc. (TEUSA) is developing the Integral Molten Salt Reactor (IMSR®) (also referred to interchangeably herein as the IMSR400) design to provide electricity generation for domestic utilities or process heat to U.S. industrial heat users. The IMSR® is a Generation IV advanced reactor power plant that employs a fluoride molten salt reactor (MSR) design. The reference IMSR® nuclear power plant (I-NPP), consists of two Reactor Auxiliary Buildings (RABs) that produce a total of 884 MWth, (442 MWth per Core-unit) for about 390 MWe (195 MWe per steam turbine) of net electric output. This plant configuration is herein referred to as the IMSR400. The IMSR400 also has the potential to export 585 °C of heat (per RAB) for industrial applications, or some combination of both. The IMSR400 includes an adjacent steam plant and turbine buildings for each RAB. Each steam plant and turbine building contains non-nuclear-grade, industry-standard power equipment.

The IMSR400 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 2) 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 IMSR400 design. More 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 topical report supports the TEUSA SDA application development efforts.

Licensing Strategy and Objective

The TEUSA REP outlines the regulatory strategy for TEUSA licensing activities. The TEUSA licensing strategy is to incrementally advance the IMSR® licensing efforts in a purposefully planned and financially informed fashion to support a commercial operation date for the first U.S. plant in the early 2030s. To support the NRC understanding of the design and operating characteristics of the IMSR400, 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 IMSR400 design information to the NRC, TEUSA anticipates that the NRC would identify issues that may require further testing, technical analyses, or additional technical justification necessary to successfully submit its SDA application.

TEUSA has recently submitted Revision 1 of the IMSR® Core-unit Definition white paper that describes in large detail the characteristics of and performance requirements of the structures and systems that comprise both the IMSR® Core-unit and the IMSR400 facility. To avoid redundancy of review and to minimize future requirements for modification of this topical report in the event that the IMSR® design evolves, a substantial amount of the design details important to understanding the operation of the IMSR® are contained for reference in Revision 1 of the IMSR® Core-unit Definition white paper (Reference 19). While the Core-unit Definition white paper will serve as the foundational reference for the engineering details, the Core-unit Definition white paper is not incorporated by reference into this topical report nor is TEUSA requesting review or approval of the design details at this moment. Where additional information related to design or operation of the IMSR® is needed, the reviewer should consult Revision 1 of the Core-unit Definition white paper, or the system or component specific references listed at the end of this topical report.

III. IMSR® Power Plant Description - Overview

Historically, there have been primarily two different types of molten salt reactors that have been developed, were considered for development, or are under development. In one type, solid-fueled reactors use molten salt as a coolant. In the second type, the reactors use a liquid fuel, and the molten salt mixture circulates through a region where nuclear fission occurs to produce heat. In this situation, a reactor is considered a "liquid-fuel" MSR, and this liquid-fuel approach is the basis for the IMSR400.

The IMSR400 design achieves excellence in nuclear safety with the intrinsic properties of the design. Although both conventional reactors and the IMSR400 use Low Enriched Uranium (LEU), the IMSR400 uses LEU in a liquid form, not a solid form. The IMSR400 uranium fuel in the form of uranium tetrafluoride (UF_4), is [ ]. One benefit of this fuel salt composition selection is that it minimizes the production of tritium.

The molten salt (Fuel Salt) is an integral system – nuclear fuel, coolant, and heat transfer medium – providing the basis for a less complex reactor configuration and many safety attributes. In this context, it is noted that the term “Primary Fuel Salt Boundary” used in the TEUSA PDCs relates to the IMSR400 reactor Fuel Salt boundary, as there is only one Fuel Salt (i.e., there is no secondary Fuel Salt). The term “Primary” has been kept to align with the more traditional term used in LWRs and non-integral reactor types for their primary coolants.

Site Overview

The IMSR® site layout includes the buildings required within the site boundary to operate the plant safely and to meet the licensing, safeguards, and security requirements. A typical IMSR400 site includes 2 reactor units and has a small footprint [ ] and a small security perimeter [ ].

Each site includes two Reactor Auxiliary Buildings, two Steam Generation Buildings, two Turbine Buildings, and a shared Control Building. Also included are the plant support buildings and structures. These include the Maintenance Buildings, Rad Waste Building, Salt Storage Building, Emergency Mitigating Equipment Building, Main Pump House, Fire Water Pumphouse, Cooling Water Outlet Building, Electrical Switchyard, Main Security Building, and Auxiliary Security Building. A graphic showing a generic proposed site layout of a typical IMSR® site is provided as Figure 1 below.

Figure 1: Proposed Site Layout

[

]

Reactor Auxiliary Building

The RAB is a reinforced concrete structure, which consists of three floors below grade and two full floors above grade, with a large upper area to provide sufficient space for the [ ] located within it. This building is designed to 1) be seismically qualified, 2) be tornado proof, and 3) provide protection against large aircraft crashes.

Each RAB houses an IMSR® Core-unit within the reactor vault. There are two reactor vaults provided within each RAB to enable the replacement Core-unit to be installed in the adjacent vault before the first Core-unit is replaced after its 7-year operating lifetime. The used Core-unit will then be lifted into one of the six used Core-unit storage silos, using the large RAB overhead crane. There is a total of six used Core-unit silos provided to enable storage of all the used Core-units needed, during the design life of the IMSR400 Facility. There is also a central vault, known as the Fuel Salt Storage Tank (FSST) Vault, which is located between the two reactor vaults for placement of the FSST, and gas holding tanks (GHTs). It is not anticipated that these tanks will require replacement during the 60-year design life of the IMSR400 Facility, however a means of accessing them remotely is provided.

The major equipment associated with the following system designs have been considered in the latest RAB Layout:

a. Core-units,
b. Guard Vessels (GV),
c. Containment,
d. Reactor Support Structures (RSS),
e. Used Core Storage Silos,
f. Initial Fueling System (IFS),
g. Make-up Fueling System,
h. Irradiated Fuel System (IrFS),
i. Secondary Coolant System (SCS),
j. Tertiary Coolant System (TCS),
k. Internal Reactor Vessel Auxiliary Cooling System (IRVACS) and other safety support systems, located within the RAB,
l. Electrical Systems and Instrumentation and Control (I&C) Rooms
m. Major RAB HVAC Systems, and
n. Fire Protection Systems.

The RAB size is used as the basis for this overall facility layout. Both RAB#1 and RAB#2 are essentially identical in design and size, except the access routes to the interconnected buildings and structures are designed to allow the required access to the Control Building (CB) and each RAB.

Containment

The main functions of Containment are to:

1. Provide a passive barrier for high activity sources within the plant to protect workers and the public from radiation doses during normal

operations and accidents. The main sources of radioactivity in the plant are the Core-unit, off- gas storage, and irradiated fuel systems.

2. Control personnel access into containment to protect plant personnel from radiation. [ ].
3. Minimize leakage to assure that normal operation release limits are met, and AOOs and DBAs will not result in exceeding dose acceptance criteria defined in TEI Design Guides. (Note that the dose acceptance criteria will satisfy NRC regulatory requirements.)

Containment consists of the [ ] that houses radioactive materials. This includes radioactive materials (irradiated Fuel Salt and Off-gases) in the Core-unit, Fuel Salt Storage Tanks (FSSTs), Gas Holding Tanks (GHTs), and connecting piping. In the event of a leak in any of these systems, Containment provides an acceptable leak-tight boundary during DBA scenarios to limit the release of any radioactive materials to the Reactor Auxiliary Building (RAB) and surrounding environment. Containment must also assist in minimizing releases in the unlikely event of a severe accident (BDBA) to the extent practical.

Turbine Building

The turbine building (TB) is a conventional structural steel building with appropriate siding provided above ground and supported from a reinforced concrete basement. It consists of one level below grade and two levels above grade to house the turbine generator, the condenser, associated high pressure and low-pressure feedwater heaters, feedwater pumps and main and auxiliary steam systems required to produce the steam for each turbine. Both TB#1 and TB#2 are essentially the same design. Each TB is provided with its own overhead crane, sized to lift the loads associated with maintaining the major equipment of the proposed ~200 MWe turbine generator design. The laydown area and access door are also located at the end of the TB to provide sufficient space for the major equipment to be maintained and transported to and from each TB. The TB also houses the electrical and control equipment associated with the operation of the Turbine Generator power and control systems that connect back to the main control room, located in the control building.

The steam plant and the associated buildings have no safety function for the I-NPP and are therefore located outside of the protected area. IMSR® employs a conventional industrial electrical generator system with superheated and reheated steam capabilities, as well as multi-stage feedwater heating and a condenser unit.

Steam Generation Building (SGB)

The SGB is a conventional structural steel building with appropriate siding provided above ground and supported from a reinforced concrete basement. It consists of one (1) level below grade and four (4) levels above grade to house the various steam generating equipment and the associated Tertiary Coolant System (TCS) and steam piping connected to them.

The TCS piping, connected to the SCS heat exchangers, located in each RAB, transfers the heated tertiary coolant salt to the various steam generating vessels located in the SGBs. The TCS piping lines run
[

] This generates high pressure steam suitable for the turbines located in each of the adjacent Turbine Buildings and provides a separate steam supply to each Turbine Generator (TG), TG#1 and TG#2.

Control Building

The Control Building (CB) is a reinforced concrete structure, which consists of three floors below grade and four full floors above grade. This building is designed to be seismically qualified and tornado proof. The CB is located between the two RAB structures and provides support and services to both RAB units.

The CB houses the main control center, the security and operations staff, associated change rooms, and facilities required for the operation of the plant. Tunnels and access routes provide for personnel ingress/egress and for routing of auxiliary, electrical, instrumentation, and communication conduits between the buildings.

The CB is fully protected by automatic fire suppression systems, with the exception of the Common Control Room which is attended on a continuous basis. All electrical rooms and control equipment rooms are protected by gas suppression systems. The rest of the building is protected by a pre-action sprinkler system. In addition, the CB is served by a dedicated HVAC system which is separate from the HVAC system that services the rest of the building. This system maintains a small positive pressure with respect to the surrounding areas to reduce potential for ingress of smoke and contaminations.

Main Control Room and Secondary Control Areas (MCR and SCAs)

The IMSR400 Control Facilities include the MCR and SCAs. The MCR is located within the Control Building (CB) and is used for both units of a 2-unit plant. These control facilities are seismically qualified, as is the route between them to ensure safe passage in emergency scenarios. All operator control and monitoring can be assumed from the SCA if the MCR is unavailable. These facilities will have habitability systems, including uninterruptible power and breathing air for emergency scenarios, to ensure that at least one of the Control Facilities will operate during all plant states. Emergency operations lighting is powered by the AC Uninterruptible Power System and is provided in the control rooms and other critical areas to support the monitoring of the reactor by the operator. Shielding, air purification, and climate control systems will be in place in the Control Facilities.

Standby Diesel Generator Buildings

These buildings are located within the protected area and house the diesel generators that provide backup electrical power for building facilities and selected process systems in the nuclear island. There is one Diesel Generator building for each reactor unit. It is a stand-alone building detached from the RAB and the CB. Each building has two separate compartments, and each compartment contains a redundant, non-seismically qualified standby diesel generator system. They are located such that underground connections can be made to both RAB units and to the CB.

Main Security Building (MSB)

The MSB layout consists of a three-floor building, with a basement level and two (2) above ground levels to provide the following key facilities:

1. Basement: [ ]
2. Level 1: [ ]; and
3. Level 2: [ ]

Maintenance Building

The Maintenance Building is located within the protected area of the site and houses the various maintenance facilities required for nuclear island operations and maintenance of the various equipment located within it. It is a single floor steel frame building, sized to handle the largest size of equipment that may need to be serviced within the protected area, and has access doors provided at each end of the building. The Maintenance Building will contain typical mechanical, electrical and I&C workshops, welding shops, and storage rooms for spare parts, tools, and supplies. There may be small office rooms provided for control and inspection of the work performed within it.

Rad Waste Storage Building

This building is located within the protected area and is used to prepare and store the Intermediate-level radioactive waste (ILW) and Low-level radioactive waste (LLW) generated in the IMSR400 facility before shipment.

Emergency Mitigation Equipment Building

This building is located within the protected area to provide space for the various equipment associated with providing "Black Start Power", access route clearance and fire protection equipment/security vehicles.

IV. Regulatory Requirements and Related Guidance

Regulatory Requirements for Principal Design Criteria

The General Design Criteria (GDC) in 10 CFR 50, Appendix A provide the minimum requirements for the principal design criteria (PDC) for water-cooled NPPs. The PDC establish the necessary design, fabrication, construction, testing, and performance requirements for SSCs important to safety. The language of 10 CFR 50 Appendix A goes further to assert that the SSCs important to safety are those that provide reasonable assurance that the facility can be operated without undue risk to the health and safety of the public.

The requirements for the contents of an application for a construction permit specified in 10 CFR 50.34 (a) (3) include submittal of the PDC for the facility. It goes further to describe the information as the design basis and information relative to materials of construction, general arrangements, and approximate dimensions sufficient to provide reasonable assurance that the design will provide an adequate margin for safety. TEUSA is currently planning to apply for a Standard Design Approval (SDA) under Part 52. Content of an SDA application is governed by the requirements contained in 10 CFR 52.137 (a)(3).

Relevant Regulatory Guidance for Developing Principal Design Criteria

To support the development of new non-light water reactor designs, the U.S. NRC and U.S. Department of Energy (DOE) implemented a joint initiative to assess the GDC, determine the extent to which they apply to non-LWR designs and to propose amended or additional criteria that address non-LWR design features. The joint initiative resulted in the publication of Regulatory Guide 1.232, “Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors” in April 2018 (Reference 4).

Regulatory Guide (RG) 1.232 provides a set of advanced reactor design criteria (ARDC) that serve the same purpose for non-LWRs as the GDC serve for LWRs. In developing the ARDCs, the NRC considered different technologies including sodium fast reactors, lead-cooled fast reactors, gas-cooled fast reactors, modular high-temperature gas reactors, fluoride high-temperature reactors, and molten salt reactors. As developed, the ARDCs are intended to be generally inclusive for all the designs mentioned but the staff recognized that it would be difficult to be completely inclusive given the variety in technologies and designs. Therefore, the RG provides technology-specific non-LWR criteria for a sodium fast reactor (SFR-DC) and a modular high-temperature gas reactor (MHTGR-DC). As presented in the RG, the NRC intended that the ARDC apply to the technology types included in the DOE report; however, the NRC acknowledges that one or more of the criteria from the SFR-DC or the MHTGR-DC may be more applicable to other technologies being evaluated.

Relevant excerpts from the guidance for developing PDC using RG 1.232 are provided:

- “Applicants may use this RG to develop all or part of the PDC and are free to choose among the ARDC, SFR-DC, or MHTGR-DC to develop each PDC after considering the underlying safety basis for the criterion and evaluating the rationale for the adaptation described in this RG.”
- “(A) non-LWR applicant would not need to request an exemption from the GDC in 10 CFR Part 50 when proposing PDC for a specific design.”
- “Another example is the molten salt reactors (MSR) that use liquid fuel. An MSR designer may need to develop new PDC for liquid fuel and systems to support this design.”
- “In each case, it is the responsibility of the designer or applicant to provide not only the PDC for the design but also supporting information that justifies to the NRC how the design meets the PDC submitted, and how the PDC demonstrate adequate assurance of safety.”

The PDC in this report are provided for use by future license applicants seeking to license or construct the TEUSA IMSR® design and are intended to satisfy the regulatory requirements mentioned above for principal design criteria in a license application.

Other Related Industry Guidance Activities

ANS Design Criteria Initiative

The American Nuclear Society (ANS) has an initiative underway to develop design criteria for molten salt reactors. The ANS initiative is to develop a standard that will contain molten salt specific design criteria that would be applicable to all forms of liquid fuel molten salt reactors and would use much of the same structure as the design criteria guidance published as Regulatory Guide 1.232 discussed earlier. The initiative is captured as ANS 20.2, "Nuclear Safety Design Criteria and Functional Performance Requirements for Liquid-Fuel Molten Salt Reactor Nuclear Power Plants." The draft ANS standard will contain design criteria for liquid fuel molten salt reactors that match the safety intent of the 10 CFR 50 Appendix A General Design Criteria. The ANS Standard 20.2 design criteria are developed using a similar process to that was performed by the NRC in endorsing the ARDC in Regulatory Guide 1.232. The baseline reactor references that are being used are the criteria found in the common advanced reactor design criteria and adapted other design criteria using the relevant criteria developed for either modular high temperature gas reactors (MHTGR) or sodium fast reactors (SFR).

While the ANS 20.2 design criteria have not been submitted to the NRC for endorsement, TEUSA has considered the language of the draft design criteria of ANS 20.2 in developing its version of the PDC. Some language changes to the ARDC PDC have been made to better align the TEUSA PDC with the direction being developed in the ANS standard. TEUSA notes that its own process modified the common advanced reactor design criteria and those presented in RG 1.232 for SFRs as its baseline reference set, so the proposed PDC are flowing essentially from the same reference information as that used in the ANS development efforts. TEUSA states clearly that not all the ANS standard language is being adopted and that TEUSA acknowledges that it has the sole responsibility of providing the justification for each of its proposed PDC.

One TEUSA departure from the proposed standard is the decision to not use the term "Specified Acceptable System Radionuclide Release Design Limits" or SARRDLs in its PDC. TEUSA prefers to remain with its language of preserving the material, temperature, or reactivity design limits in its PDC. The logic for this variance is that material and temperature design limits are directly measurable as part of normal operating or post-accident conditions using plant monitoring equipment while SARRDLs are a conceptual term that flows from calculated results of releases after either normal operation or off-normal events using measured releases. In theory, the measurement of material and temperature limits would permit early intervention of normal or off-normal events to prevent the release of radionuclides, while the ANS standard would be an indirect means of establishing the material and temperature limits that would be needed to mitigate or prevent radionuclide releases.

Another departure is that the proposed ANS 20.2 design criteria are drafted with the assumption that the applicant will employ a functional containment design. In contrast, the IMSR400 employs a traditional leak-tight containment concept surrounding the Core-unit and other SSCs that contain potentially large quantities of radionuclides. Therefore, the IMSR400 is more aligned with the traditional containment design criteria that flows from previous LWR technologies and RG 1. 232.

TEUSA does not intend to justify its PDC by comparing them to the draft ANS criteria nor does it intend to justify areas where the TEUSA language may differ from that proposed in the draft standard. In providing this information, TEUSA intends to inform the NRC review and to demonstrate that the PDC development process considered all information available at the time. The TEUSA PDC are those that best reflect the IMSR400 technology and provide the appropriate level of safety necessary for licensing the IMSR400 in the U.S.

Limitations of the Design and Conditions

The IMSR® has completed its basic engineering phase so that the system design is reasonably well established. TEUSA acknowledges that some system and component design finalization will be necessary, however, TEUSA believes that the PDC given below will effectively represent the key systems and components of the IMSR® that will be used to establish that the IMSR® design will provide reasonable assurance of adequate protection of public health and safety.

TEUSA will revisit implementation of the proposed PDC to assure satisfactory agreement with the proposed criteria during preparation of the SDA application. Should TEUSA identify areas of the IMSR® design where changes to the PDC are necessary, these changes and their supporting basis will be discussed in a separate section within the SDA application.

V. Process for Developing Principal Design Criteria

This section discusses the process used by TEUSA to develop the principal design criteria (PDC) for the IMSR® design. The initial starting point for the assessment process was the set of ARDC listed in RG 1.232, Appendices A, B, and C (Reference 4). As noted earlier, RG 1.232 specifically stated that advanced reactor applicants may use RG 1.232 to develop all or part of the PDC and are free to choose among the ARDC, SFR-DC, or MHTGR-DC to develop each PDC after considering the underlying safety basis for the criterion and evaluating the rationale for the adaptation described in the RG.

The TEUSA process compared the general ARDC criteria to the systems and structures included as part of the IMSR400 facility. After comparing the ARDC to the IMSR400, TEUSA concluded that the set of ARDC that most closely represents IMSR® technology are those contained in Appendix B (SFR-DC) of the RG with some technology specific modifications. The basis for that conclusion is supported by a one-to-one comparison of the ARDC to the TEUSA IMSR® design and the determination that the systems, structures, and processes described in RG 1.232, Appendix B, with a few exceptions, are substantially aligned with the systems, structures and processes employed in the IMSR®. For that reason, the SFR-DC were used as the starting point for the PDC assessment process for an IMSR® facility.

The SFR-DC are written to be inclusive of different types of sodium reactors. The IMSR® is a fluoride molten salt reactor design. As mentioned above, the SFR-DC were selected for application to the IMSR® because they more closely represent the essential systems and processes that form the IMSR® design. TEUSA needed to modify certain provisions of the SFR-DC because some of the SFR-DC were not applicable to the IMSR®. [ ]. In such instances, the SFR-DC are either modified to be more specific to the IMSR® design or are not adopted. In either case, the basis discussion supporting the proposed PDC are discussed at a high level in the following section and in the supporting basis portion of the PDC table. Any PDC that were not adopted are specifically summarized at the end of this topical report along with the basis supporting the conclusion that the PDC would not apply, or that the underlying safety basis for the PDC is either not needed or met using an alternative process.

Where TEUSA is departing from some language provisions from the SFR-DC, TEUSA proposes alternative language and notes for the review that the language has been modified. The TEUSA basis and justification for each PDC are presented below as part of the discussion that describes how the proposed PDC are met for the IMSR400 as part of the TEUSA assessment process. As a reminder, more extensive details about the design of IMSR400 systems and components are provided in the TEUSA Core-unit white paper (Reference 19) as well as the references included in that document.

VI. Discussion of Principal Design Criteria Selection

This section provides a high-level discussion of the assessment of the criteria in RG 1.232 Appendix B and their applicability to the IMSR400. The discussion is presented following the outline given in RG 1.232:

Section I—Overall Requirements (Criteria 1–5)

Section II—Multiple Barriers (Criteria 10–19)

Section III—Reactivity Control (Criteria 20–29)

Section IV—Fluid Systems (Criteria 30–46)

Section V—Reactor Containment (Criteria 50–57)

Section VI—Fuel and Radioactivity Control (Criteria 60–64)

Section VII—Additional SFR-DC (Criteria 70–79)

Section I—Overall Requirements (SFR-DC Criteria 1–5)

These design criteria involve quality standards and records, design bases for protection against natural phenomena, fire protection, environmental and dynamic effects, and sharing of structures, systems, and components. There are five requirements in this category, and they are general non-design specific requirements. [ ].

Section II—Multiple Barriers (SFR-DC Criteria 10–19)

These criteria involve the barriers to the release of radioactivity, specifically reactor design, reactor inherent protection, suppression of reactor power oscillations, instrumentation and control, reactor coolant boundary, reactor coolant system design, containment design, electric power systems, inspection and testing of electric power systems, and control room. These criteria are more specific to the key design features of the technology. [ ].

In this group of criteria, the SFR-DC introduces the term 'specified acceptable fuel design limits' or SAFDLs. The current ANS effort in this area introduces the term 'specified acceptable radiological release design limits' or SARRDLs. In each case these terms are not presently defined and are left to the designer to describe or define. TEUSA notes that in each of those referenced cases, the values are derived from the material capabilities of the fuel, reactor vessel, and containment to survive and remain functional following design basis accident conditions.

As a molten salt fueled reactor, the IMSR400 does not have specific fuel design limits to prevent or mitigate fuel damage because the fuel is already in a molten state. Furthermore, the efforts to identify the functional capabilities of systems is directly related to the specific design conditions to which those systems are to be constructed and for which specific measurements can be obtained. If the as-measured conditions following a design basis accident are below the design specifications and licensing basis for which the systems are constructed, then there is a very high certainty that the design will prevent or mitigate any radiological release to values that will be less than the established regulatory criteria and would not endanger public health and safety. [ ]. The proposed limits are directly measurable by monitoring capabilities to be available in the IMSR400 design.

In this set of criterion, the SFR-DC use the term "primary coolant boundary" to define the scope of the PDC. In addition, the regulatory guide rationale states that the term "primary" indicates that the requirements are for the primary cooling system and does not apply to intermediate or tertiary cooling systems. Because the fuel salt in the IMSR400 is both fuel and the primary cooling process, the term primary coolant boundary is not generally applicable. [

].

Criterion 19 introduces language specifically identifying plant states such as for "prompt hot shutdown" or "hot shutdown." The plant states are holdovers from LWR operations that do not practically apply to the IMSR400. For example, the IMSR400 relies on the inherent properties of the fuel salt to take the reactor to a controlled safe state over a period of time. The IMSR400 does not use control rods to manage the fission reaction in the core but will have the capability of introducing prompt negative reactivity that will take the reactor to a subcritical condition should the condition of the reactor and the accident response require such action. However, it is important to note that use of the SDM is not part of a normal plant shutdown response following postulated transients or design basis accidents. [
].

Section III—Reactivity Control (SFR-DC Criteria 20–29)

These criteria involve protection system functions, protection system reliability and testability, protection system independence, protection system failure modes, separation of protection and control systems, protection system requirements for reactivity control malfunctions, reactivity control systems, combined reactivity control systems capability, reactivity limits, and protection against anticipated operational occurrences. There are nine requirements in this category. The regulatory guide design criteria are highly dependent on the technology and therefore the PDC proposed for the IMSR400 reflect the inherent protection provisions of the molten salt to minimize the requirements for protective systems to manage or respond to reactivity control during normal or off-normal transients.

Given the unique design of the IMSR400 and the inherent reactivity control processes, Criterion 20 was substantially modified. TEUSA modified the title from "Reactor Protection System" to "Means of Reactor Protection" [
].

The SFR-DC employs the use of "specified acceptable fuel design limits" as the criteria that are not to be exceeded. As stated above, [
] as a condition of normal operation or AOOs.

The IMSR® is designed with a strong negative reactivity coefficient of temperature, which provides for an inherent reactivity control capability to protect the reactor. This inherent design feature provides a self-governing and stable temperature regime that establishes the inherently safe operating profile of the IMSR® design. The fuel salt temperature reactivity coefficient is large and negative, due to consistently strong Doppler broadening and a small negative salt density term. This means that for any fuel temperature rise, there is an automatic and prompt negative reactivity response. Also, because the fuel salt is the cooling medium, heat transfer between the fuel and salt components is essentially instantaneous. This inherent design feature assures the reactor is automatically protected to avoid reactivity excursion and suppress reactor power oscillations.

A dedicated protection system is not required for IMSR400 because the reactor is inherently protected due to its design feature of strong negative reactivity coefficient of temperature. The safety function as required in the PDCs for a protection system is provided by this inherent design feature in IMSR400. IMSR® design is based on the view that a reactor protected by an inherent design feature is better than protection provided by an engineering design feature such as a mechanical protection system, considering the fact that an inherent design feature is more reliable and has a faster response compared to a physical protection system.

At the present time, there are no systems that are designated as protection systems for the IMSR400. [

] the inherent design features that provide the reactivity control and protection system functions.

Section IV—Fluid Systems (SFR-DC Criteria 30–46)

These design criteria relate to fluid systems used for advanced reactors. These criteria relate to the quality of reactor coolant boundary, fracture prevention of reactor coolant boundary, inspection of reactor coolant boundary, reactor coolant inventory maintenance, residual heat removal, emergency core cooling, inspection of the emergency core cooling system, testing of the emergency core cooling system, containment heat removal, inspection of the containment heat removal system, testing of the containment heat removal system, containment atmospheric cleanup, inspection of containment atmosphere cleanup, testing of containment atmosphere cleanup systems, structural and equipment cooling, inspection of structural and equipment cooling systems, and testing of structural and equipment cooling systems.

In LWRs, reactor coolant makeup in response to a loss-of-coolant transient was provided by systems that provided additional water to flood the reactor vessel and remove heat from the fuel. Similarly, containment cooling and atmospheric cleanup was performed by containment sprays, suppression pools, or ice condensers that removed substantial amounts of energy using water-based processes. Releases of radionuclides to the environment could occur through the introduction of filtered ventilation systems.

The regulatory guide criteria refer to the primary coolant boundary. Because the IMSR® is an integral reactor design with the fuel salt acting as both the fuel and the primary heat transfer fluid, the IMSR400 does not have a traditional primary coolant boundary as found in LWRs. [

] The concept behind the regulatory guide criterion remains as the primary fuel salt boundary being the initial barrier to release of any radionuclides and the integrity of that barrier is an essential safety function of the materials that form the boundary.

The IMSR400 is different in its approach to primary fuel salt inventory control and containment heat removal and cleanup processes when compared to other molten salt reactors. No additional fuel salt inventory is required to be added in response to potential transients that result in a breach of the reactor vessel. In fact, the addition of fuel salt would result in an unwelcome reactivity addition resulting in even greater temperature response. For those reasons, a guard vessel is provided to capture any releases resulting from a potential breach of the reactor vessel. Reactor vessel cooling occurs via passive cooling systems that are designed to be in continuous operation so that no active means are needed to initiate required cooling if a postulated accident should occur. Additionally, the containment will be externally cooled by a passive system to reliably maintain its integrity should a leak occur in both the reactor vessel and guard vessel. The IMSR400 contains systems that are provided to perform the functions expected by the RG 1.232 design criteria. However, not all those systems are necessary to achieve the safety functions needed for the IMSR400.

[ ]. The SFR-DC was constructed to assure that fuel and clad damage could not interfere with effective core cooling following postulated accidents. Because IMSR400 is a molten salt reactor, there is no fuel cladding to protect, nor would there be any cladding damage that would interfere with cooling the fuel, which in the case of the IMSR400 is all contained within the primary fuel salt boundary. [ ] to assure the continued integrity of the primary fuel salt boundary. If these limits are not exceeded, then component damage internal to the primary fuel salt boundary would not occur and effective cooling of the fuel in the reactor would be provided.

The IMSR® is an integral reactor design such that no fuel salt discharge from the reactor to the containment will happen for AOOs and DBAs. As such, the release of any radionuclides that may have escaped from the reactor vessel and entered the containment areas should be negligible for AOOs and DBAs. Liquid fuel salt is stable for retention of fission products and is able to limit fission product release from fuel salt to the containment following postulated accidents. IMSR400 is designed to remove fission gas online from the fuel salt by the off-gas system to minimize fission gas to be released to the containment following postulated accidents. As such, it is not necessary to design a system to control fission products in the containment following postulated accidents. IMSR400 is also designed to ensure that hydrogen and other non-condensable gases will not be generated following postulated accidents, as the stable salt is used as coolant, and water is eliminated inside containment. Therefore, there is no need to control the concentration of other substances in the containment atmosphere that may challenge the containment integrity following postulated accidents.

Section V—Reactor Containment (SFR-DC Criteria 50–57)

These design criteria relate to reactor containment structures. These criteria are very specific to a pressure retaining containment structure and include containment design basis, fracture prevention of the containment pressure boundary, capability for containment leakage rate testing, provisions for containment testing and inspection, piping systems penetrating containment, reactor coolant boundary penetrating containment, containment isolation, and closed system isolation valves.

See the earlier discussion about [ ]. The IMSR400 uses a pressure retaining containment concept. [ ].

Section VI—Fuel and Radioactivity Control (SFR-DC 60–64)

These design criteria relate to fuel and radioactivity control, including control of releases of radioactive material to the environment, fuel storage and handling and radioactivity control, prevention of criticality in fuel storage and handling, monitoring fuel and waste storage, and monitoring radioactivity releases. [ ].

Section VII—Additional SFR-DC (SFR-DC 70–79)

These design criteria are technology specific to SFRs and relate to the intermediate coolant system, primary coolant and cover gas purity control, sodium heating systems, sodium leakage detection and reaction prevention and mitigation, sodium/water reaction prevention/mitigation, quality of the intermediate coolant boundary, fracture prevention of the intermediate coolant boundary, inspection of the intermediate coolant boundary, primary coolant system interfaces, and cover gas inventory maintenance.

The IMSR400 employs a fluoride based molten salt as its primary coolant and employs secondary and tertiary cooling loops that employ salt as the heat transfer and cooling medium. [ ] expected safety functions would be performed. For example, there are no plans at this moment to have a molten salt purity control system. Leakage detection and heating systems [ ].

The SFR-DC uses the term "primary coolant boundary" to define the scope of the PDC. Because the fuel salt in the IMSR400 is both fuel and the primary cooling medium, [ ]. TEUSA will use the term "primary fuel salt boundary" to establish the scope of applicability for the regulatory requirements.

[ ] Further, as a molten salt reactor, the IMSR400 does not employ fuel design limits as would a reactor using more traditional fuel. TEUSA [ ].

TEUSA-79 describes [ ], would not result in unacceptable radiological consequences.

VII. Principal Design Criteria Assessment for the IMSR®

This section presents the TEUSA assessment of selected advanced reactor design criteria (ARDC) to the key features and design of the IMSR® facility. TEUSA will use the language of the ARDC as its PDC when the language of the ARDC can be directly applied to the IMSR® design. In instances where the ARDC are modified to reflect the IMSR® design, the exact language of proposed PDC will be presented followed by justification for the modified PDC.

The IMSR® design is a liquid fueled molten salt cooled reactor [ ]. As explained earlier, TEUSA has chosen to use the reference set of SFR-DC contained in Appendix B to RG 1.232 (Reference 4) as the initial starting point for developing its PDC. For ease of reference and discussion, the numbering in the TEUSA table below follows the design criteria numbering contained in Appendix B of RG 1.232. For example, SFR-DC–1 will be presented as TEUSA-1 in the table below.

The results are presented in tabular form for each PDC and are shown sequentially below.

Title of Principal Design Criteria	TEUSA-1: Quality Standards and Records
RG 1.232 SFR-DC PDC Criterion 1 Structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function. A quality assurance program shall be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions. Appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the nuclear power unit licensee throughout the life of the unit.	TEUSA -1 Quality Standards and Records [ ]
TEUSA Assessment	[ ]

TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-2: Protection Against Natural Phenomena
RG 1.232 SFR-DC PDC Criterion 2 Structures, systems, and components important to safety shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, floods, tsunami, and seiches without loss of capability to perform their safety functions. The design bases for these structures, systems, and components shall reflect: (1) Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area, with sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated, (2) appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena, and (3) the importance of the safety functions to be performed.	TEUSA-2: Protection Against Natural Phenomena [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-3: Fire Protection
RG 1.232 SFR-DC PDC Criterion 3 Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and fire-resistant materials shall be used wherever practical throughout the unit, particularly in locations with structures, systems, or components important to safety. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to ensure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.	TEUSA-3: Fire Protection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-4: Dynamic and Environmental Effects Design Basis
RG 1.232 SFR-DC PDC Criterion 4 Structures, systems, and components important to safety shall be designed to accommodate the effects of, and to be compatible with, the environmental conditions associated with normal operation, maintenance, testing, anticipated operational occurrences, and postulated accidents. These structures, systems, and components shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids that may result from equipment failures and from events and conditions outside the nuclear power unit. However, dynamic effects associated with postulated pipe ruptures in nuclear power units may be excluded from the design basis when analyses reviewed and approved by the Commission demonstrate that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping. Chemical consequences of accidents, such as sodium leakage, shall be appropriately considered for the design of structures, systems, and components important to safety, which must be protected.	TEUSA-4: Dynamic and Environmental Effects Design Basis [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-5: Sharing of Safety-Related SSCs
RG1.232 SFR-DC Criterion 5 SSCs important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown or safe operation of the remaining Units.	TEUSA-5: Sharing of Safety-Related SSCs [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	Language of Principal Design Criteria
ARDC 6-9 (reserved)	[ ]

Title of Principal Design Criteria	TEUSA-10: Reactor Design
RG 1.232 SFR-DC Criteria The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences.	TEUSA-10: Reactor Design [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-11: Reactor Inherent Protection
RG1.232 SFR-DC PDC Criterion 11 The reactor core and associated systems that contribute to reactivity feedback shall be designed so that, in the power operating range, the net effect of the prompt inherent nuclear feedback characteristics tends to compensate for a rapid increase in reactivity.	TEUSA-11: Reactor Inherent Protection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-12: Suppression of Reactor Power Oscillations
RG 1.232 SFR-DC PDC Criterion 12 The reactor core; associated structures; and associated coolant, control, and protection systems shall be designed to ensure that power oscillations that can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed.	TEUSA-12: Suppression of Reactor Power Oscillations [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-13: Instrumentation and Control
RG 1.232 SFR-DC PDC Criterion 13 Instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions, as appropriate, to ensure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, the primary coolant boundary, and the containment and its associated systems. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges	TEUSA-13: Instrumentation and Control [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[[

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Title of Principal Design Criteria	TEUSA-14: Primary Fuel Salt Boundary
RG 1.232 SFR-DC PDC Criterion 14 The primary coolant boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture.	TEUSA-14: Primary Fuel Salt Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–15: Primary fuel salt boundary design
RG 1.232 SFR-DC PDC Criterion 15 The primary coolant system and associated auxiliary, control, and protection systems shall be designed with sufficient margin to ensure that the design conditions of the primary system boundary are not exceeded during any condition of normal operation, including anticipated operational occurrences.	TEUSA–15: Primary fuel salt boundary design [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–16: Containment Design
RG 1.232 SFR-DC PDC Criterion 16 A reactor containment consisting of a low-leakage, pressure retaining structure surrounding the reactor and its primary cooling system shall be provided to control the release of radioactivity to the environment and to ensure that the reactor containment design conditions important to safety are not exceeded for as long as postulated accident conditions require. The containment leakage shall be restricted to be less than that needed to meet the acceptable onsite and offsite dose consequence limits, as specified in 10 CFR 50.34 for postulated accidents.	TEUSA–16: Containment Design [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–17: Electric Power Systems
RG 1.232 SFR-DC PDC Criterion 17 Electric power systems shall be provided when required to permit functioning of structures, systems, and components. The safety function for each power system shall be to provide sufficient capacity and capability to ensure that (1) the design limits for the fission product barriers are not exceeded as a result of anticipated operational occurrences and (2) safety functions that rely on electric power are maintained in the event of postulated accidents. The electric power systems shall include an onsite power system and an additional power system. The onsite electric power system shall have sufficient independence, redundancy, and testability to perform its safety functions, assuming a single failure. An additional power system shall have sufficient independence and testability to perform its safety function. If electric power is not needed for anticipated operational occurrences or postulated accidents, the design shall demonstrate that power important to safety functions is provided.	TEUSA–17: Electric Power Systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–18: Inspection and Testing of Electric Power Systems
RG1.232 SFR-DC PDC Criterion 18 Electric power systems important to safety shall be 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 shall be designed with a capability to test periodically (1) the operability and functional performance of the components of the systems, such as onsite 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 systems.	TEUSA–18: Inspection and Testing of Electric Power Systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–19: Control room
RG 1.232 SFR-DC PDC Criterion 19 A control room shall be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions. Adequate radiation protection shall be provided to permit access and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 rem total effective dose equivalent, as defined in § 50.2 for the duration of the accident. Adequate habitability measures shall be provided to permit access and occupancy of the control room during normal operations and under accident conditions. Adequate protection against sodium aerosols shall be provided to permit access and occupancy of the control room under accident conditions. Equipment at appropriate locations outside the control room shall be provided (1) with a design capability for prompt hot shutdown of the reactor, including necessary instrumentation and controls to maintain the unit in a safe condition during hot shutdown, and (2) with a potential capability for subsequent shutdown, subcritical condition, of the reactor through the use of suitable procedures.	TEUSA–19: Control room [ ]
TEUSA Assessment	[

TEUSA Supporting Basis for Assessment	

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Title of Principal Design Criteria	TEUSA–20: Means of Reactor Protection
RG 1.232 DFR-DC PDC Criterion 20 The protection system shall be designed (1) to initiate automatically the operation of appropriate systems including the reactivity control systems, to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences and (2) to sense accident conditions and to initiate the operation of systems and components important to safety.	TEUSA–20: Means of Reactor Protection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-21: Reliability and Testability of Means of Reactor Protection
RG 1.232 SFR-DC PDC Criterion 21 The protection system shall be designed for high functional reliability and in-service testability commensurate with the safety functions to be performed. Redundancy and independence designed into the protection system shall be sufficient to assure that (1) no single failure results in loss of the protection function and (2) removal from service of any component or channel does not result in loss of the required minimum redundancy unless the acceptable reliability of operation of the protection system can be otherwise demonstrated. The protection system shall be designed to permit periodic testing of its functioning when the reactor is in operation, including a capability to test channels independently to determine failures and losses of redundancy that may have occurred.	TEUSA-21: Reliability and Testability of Means of Reactor Protection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-22: Independence of Means of Reactor Protection
RG 1.232 SFR-DC PDC Criterion 22 The protection system shall be designed to assure that the effects of natural phenomena, and of normal operating, maintenance, testing, and postulated accident conditions on redundant channels do not result in loss of the protection function or shall be demonstrated to be acceptable on some other defined basis. Design techniques, such as functional diversity or diversity in component design and principles of operation, shall be used to the extent practical to prevent loss of the protection function.	TEUSA-22: Independence of Means of Reactor Protection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-23: Failure modes for Means of Reactor Protection
RG 1.232 SFR-DC PDC Criterion 23 The protection system shall be designed to fail into a safe state or into a state demonstrated to be acceptable on some other defined basis, if conditions such as disconnection of the system, loss of energy (e.g., electric power, instrument air), or postulated adverse environments (e.g., extreme heat or cold, fire, fuel mixture or cooling system leakage, pressure, steam, water, and radiation) are experienced.	TEUSA-23: Failure Modes for Means of Reactor Protection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-24: Separation of Means of Reactor Protection and Plant Control Systems
RG 1.232 SFR-DC PDC Criterion 24 The protection system shall be separated from control systems to the extent that failure of any single control system component or channel, or failure or removal from service of any single protection system component or channel which is common to the control and protection systems leaves intact a system satisfying all reliability, redundancy, and independence requirements of the protection system. Interconnection of the protection and control systems shall be limited so as to assure that safety is not significantly impaired.	TEUSA-24: Separation of Means of Reactor Protection and Plant Control Systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–25: Requirements of Means of Reactor Protection for Reactivity Control Malfunctions
TEUSA–25: Protection System Requirements for Reactivity Control Malfunctions The protection system shall be designed to ensure that specified acceptable fuel design limits are not exceeded during any anticipated operational occurrence accounting for a single malfunction of the reactivity control systems.	TEUSA–25: Requirements of Means of Reactor Protection for Reactivity Control Malfunctions [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-26: Reactivity Control Systems
TEUSA-26: Reactivity Control Systems A minimum of two reactivity control systems or means shall provide: (1) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the design limits for the fission product barriers are not exceeded and a safe shutdown is achieved and maintained during normal operation, including anticipated operational occurrences. (2) A means which is independent and diverse from the other(s) shall be capable of controlling the rate of reactivity changes from planned, normal power changes or fuel additions to assure that the design limits for the fission product barriers are not exceeded. (3) A means of inserting negative reactivity at a sufficient rate and amount to assure, with appropriate margin for malfunctions, that the capability to cool the core is maintained and a means of shutting down the reactor and maintaining, at a minimum, a safe shutdown state following a postulated accident is available. (4) A means for holding the reactor shutdown under conditions which allow for interventions such as fuel loading, inspection and repair shall be provided.	TEUSA-26: Reactivity Control Systems [ ]
TEUSA Assessment	[ ]

TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-27: Combined Reactivity Control Systems Capability
RG 1.232 SFR-DC PDC Criterion 27 [ ]	TEUSA-27: Combined Reactivity Control Systems Capability [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA-28: Reactivity Limits
RG 1.232 SFR-DC PDC Criterion 28 The reactivity control systems shall be designed with appropriate limits on the potential amount and rate of reactivity increase to ensure that the effects of postulated reactivity accidents can neither (1) result in damage to the primary coolant boundary greater than limited local yielding nor (2) sufficiently disturb the core, its support structures or other reactor vessel internals to impair significantly the capability to cool the core.	TEUSA-28: Reactivity Limits [ ]
TEUSA Assessment	[ ]

TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–29: Protection Against Anticipated Operational Occurrences
RG 1.232 SFR-DC PDC Criterion 29 The protection and reactivity control systems shall be designed to assure an extremely high probability of accomplishing their safety functions in the event of anticipated operational occurrences.	TEUSA–29: Protection Against Anticipated Operational Occurrences [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–30: Quality of primary fuel salt boundary
RG 1.232 DFR-DC PDC Criterion 30 Components that are part of the primary system boundary shall be designed, fabricated, erected, and tested to the highest quality standards practical. Means shall be provided for detecting and, to the extent practical, identifying the location of the source of primary system leakage.	TEUSA–30: Quality of primary fuel salt boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-31: Fracture Prevention of Primary Fuel Salt Boundary
RG 1.232 SFR-DC PDC Criterion 31 The primary coolant boundary shall be designed with sufficient margin to ensure that, when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures, service degradation of material properties, creep, fatigue, stress rupture, and other conditions of the boundary material under operating, maintenance, testing, and postulated accident conditions and the uncertainties in determining (1) material properties, (2) the effects of irradiation and coolant composition, including contaminants and reaction products, on material properties, (3) residual, steady–state, and transient stresses, and (4) size of flaws.	TEUSA-31: Fracture Prevention of Primary Fuel Salt Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–32: Inspection of Primary Fuel Salt Boundary
RG 1.232 SFR-DC PDC Criterion 32 Components that are part of the primary coolant boundary shall be designed to permit: (1) periodic inspection and functional testing of important areas and features to assess their structural and leak-tight integrity, and (2) an appropriate material surveillance program for the reactor vessel.	TEUSA–32: Inspection of Primary Fuel Salt Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA - 33: Primary Fuel Salt Inventory Maintenance
RG 1.232 SFR-DC PDC Criterion 33 A system to maintain primary coolant inventory for protection against small breaks in the primary coolant boundary shall be provided as necessary to ensure that specified acceptable fuel design limits are not exceeded as a result of primary coolant inventory loss due to leakage from the primary coolant boundary and rupture of small piping or other small components that are part of the boundary. The system shall be designed to ensure that the system safety function can be accomplished using the piping, pumps, and valves used to maintain primary coolant inventory during normal reactor operation.	TEUSA - 33: Primary Fuel Salt Inventory Maintenance [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-34: Residual Heat Removal
RG 1.232 SFR-DC PDC Criterion 34 A system to remove residual heat shall be provided. For normal operations and anticipated operational occurrences, the system safety function shall be to transfer fission product decay heat and other residual heat from the reactor core at a rate such that specified acceptable fuel design limits and the design conditions of the primary coolant boundary are not exceeded. Suitable redundancy in components and features and suitable interconnections, leak detection, and isolation capabilities, shall be provided to ensure that the system safety function can be accomplished, assuming a single failure.	TEUSA-34: Residual Heat Removal [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA-35: Emergency Heat Removal System
RG 1.232 SFR-DC PDC Criterion 35 A system to assure sufficient core cooling during postulated accidents and to remove residual heat following postulated accidents shall be provided. The system safety function shall be to transfer heat from the reactor core, during and following postulated accidents, such that fuel and clad damage with continued effective core cooling is prevented. Suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to ensure that the system safety function can be accomplished.	TEUSA-35: Emergency Heat Removal System [ ]
TEUSA Assessment	[ ]

TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–36: Inspection of Emergency Heat Removal System
RG 1.232 SFR-DC PDC Criterion 36 A system that provides emergency core cooling shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system.	TEUSA–36: Inspection of Emergency Heat Removal System [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–37: Testing of Emergency Heat Removal System
RG 1.232 SFR-DC PDC Criterion 37 A system that provides emergency core cooling shall be designed to permit appropriate periodic functional testing to ensure: (1) the structural and leak-tight integrity of its components, (2) the operability and performance of the system components, and (3) the operability of the system as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the system into operation, including operation of any associated systems and interfaces necessary to transfer decay heat to the ultimate heat sink.	TEUSA–37: Testing of Emergency Heat Removal System [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–38: Containment Heat Removal
RG 1.232 SFR-DC PDC Criterion 38 A system to remove heat from the reactor containment shall be provided as necessary to maintain the containment pressure and temperature within acceptable limits following postulated accidents. Suitable redundancy in components and features and suitable interconnections, leak detection, isolation, and containment capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure.	TEUSA–38: Containment Heat Removal [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–39: Inspection of containment heat removal system
RG 1.232 SFR-DC PDC Criterion 39 The containment heat removal system shall be designed to permit appropriate periodic inspection of important components to ensure the integrity and capability of the system.	TEUSA–39: Inspection of containment heat removal system [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–40: Testing of Containment Heat Removal System
RG 1.232 SFR-DC PDC Criterion 40 The containment heat removal system shall be designed to permit appropriate periodic functional testing to ensure (1) the structural and leaktight integrity of its components, (2) the operability and performance of the system components, and (3) the operability of the system as a whole, and under conditions as close to the design as practical, the performance of the full operational sequence that brings the system into operation, including the operation of associated systems.	TEUSA–40: Testing of Containment Heat Removal System [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA – 41: Containment atmosphere cleanup
RG 1.232 SFR-DC PDC Criterion 41 Systems to control fission products and other substances that may be released into the reactor containment shall be provided as necessary to reduce, consistent with the functioning of other associated systems, the concentration and quality of fission products released to the environment following postulated accidents and to control the concentration of other substances in the containment atmosphere following postulated accidents to ensure that containment integrity and other safety functions are maintained.	TEUSA – 41: Containment atmosphere cleanup [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–42: Inspection of containment atmosphere cleanup systems
RG 1.232 SFR-DC PDC Criterion 42 The containment atmosphere cleanup systems shall be designed to permit appropriate periodic inspection of important components, such as filter frames, ducts, and piping to assure the integrity and capability of the systems.	TEUSA–42: Inspection of containment atmosphere cleanup systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–43: Testing of Containment Atmosphere Cleanup Systems
RG 1.232 SFR-DC PDC Criterion 43 The containment atmosphere cleanup systems shall be designed to permit appropriate periodic functional testing to ensure: (1) the structural and leak-tight integrity of its components, (2) the operability and performance of the system components, and (3) the operability of the systems as a whole and, under conditions as close to design as practical, the performance of the full operational sequence that brings the systems into operation, including the operation of associated systems.	TEUSA–43: Testing of Containment Atmosphere Cleanup Systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–44: Structural and Equipment Cooling
RG 1.232 SFR-DC PDC Criterion 44 A system to transfer heat from structures, systems, and components important to safety to an ultimate heat sink shall be provided, as necessary, to transfer the combined heat load of these structures, systems, and components under normal operating and accident conditions. Suitable redundancy in components and features and suitable interconnections, leak detection, and isolation capabilities shall be provided to ensure that the system safety function can be accomplished, assuming a single failure.	TEUSA–44: Structural and Equipment Cooling [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–45: Inspection of Structural and Equipment Cooling Systems
RG 1.232 SFR-DC PDC Criterion 45 The structural and equipment cooling systems shall be designed to permit appropriate periodic inspection of important components, such as heat exchangers and piping, to ensure the integrity and capability of the systems.	TEUSA–45: Inspection of Structural and Equipment Cooling Systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–46: Testing of Structural and Equipment Cooling Systems
RG 1.232 SFR-DC PDC Criterion 46 The structural and equipment cooling systems shall be designed to permit appropriate periodic functional testing to ensure: (1) the structural and leaktight integrity of their components, (2) the operability and performance of the system components, and (3) the operability of the systems as a whole and, under conditions as close to design as practical, the performance of the full operational sequences that bring the systems into operation for reactor shutdown and postulated accidents, including the operation of associated systems.	TEUSA–46: Testing of Structural and Equipment Cooling systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–50: Containment Design Basis
RG 1.232 SFR-DC PDC Criterion 50 The reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from postulated accidents. This margin shall reflect consideration of: (1) the effects of potential energy sources that have not been included in the determination of the peak conditions, (2) the limited experience and experimental data available for defining accident phenomena and containment responses, and (3) the conservatism of the calculational model and input parameters.	TEUSA–50: Containment Design Basis [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–51: Fracture Prevention of Containment Pressure Boundary
RG 1.232 SFR-DC PDS Criterion 51 The boundary of the reactor containment structure shall be designed with sufficient margin to ensure that, under operating, maintenance, testing, and postulated accident conditions, (1) its materials behave in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized. The design shall reflect consideration of service temperatures and other conditions of the containment boundary materials during operation, maintenance, testing, and postulated accident conditions, and the uncertainties in determining (1) material properties, (2) residual, steady-state, and transient stresses, and (3) size of flaws.	TEUSA–51: Fracture Prevention of Containment Pressure Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–52: Capability of Containment Leakage Rate Testing
RG 1.232 SFR-DC PDC Criterion 52 The reactor containment structure and other equipment that may be subjected to containment test conditions shall be designed so that periodic integrated leakage rate testing can be conducted to demonstrate resistance at containment design pressure.	TEUSA–52: Capability of Containment Leakage Rate Testing [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–53: Provisions for Containment Testing and Inspection
RG 1.232 SFR_DC PDC Criterion 53 The reactor containment structure shall be designed to permit: (1) appropriate periodic inspection of all important areas, such as penetrations, (2) an appropriate surveillance program, and (3) periodic testing at containment design pressure of the leak-tightness of penetrations that have resilient seals and expansion bellows.	TEUSA–53: Provisions for Containment Testing and Inspection [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–54: Piping Systems Penetrating
RG 1.232 SFR_DC PDC Criterion 54 Piping systems penetrating the reactor containment structure shall be provided with leak detection, isolation, and containment capabilities that have redundancy, reliability, and performance capabilities necessary to perform the containment safety function and that reflect the importance to safety of preventing radioactivity releases from containment through these piping systems. Such piping systems shall be designed with the capability to verify, by testing, the operational readiness of any isolation valves and associated apparatus periodically and to confirm that valve leakage is within acceptable limits.	TEUSA–54: Piping Systems Penetrating Containment [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–55: Primary Fuel Salt Boundary Penetrating Containment
TEUSA–55: Primary Coolant Boundary Penetrating Containment Each line that is part of the primary coolant boundary and that penetrates the reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis: (1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or (2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or (3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or (4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment. Isolation valves outside containment shall be located as close to containment as practical and, upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety. Other appropriate requirements to minimize the probability or consequences of an accidental rupture of these lines or of lines connected to them shall be provided as necessary to ensure adequate safety. Determination of the appropriateness of these requirements, such as higher quality in design, fabrication, and testing, additional provisions for in-service inspection, protection against more severe natural phenomena, and additional isolation valves and containment, shall include consideration of the population density, use characteristics, and physical characteristics of the site environs.	TEUSA–55: Primary Fuel Salt Boundary Penetrating Containment [ ]

TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–56: Containment Isolation
RG 1.232 SFR DC PDC Criterion 56 Each line that connects directly to the containment atmosphere and penetrates the reactor containment structure shall be provided with containment isolation valves as follows, unless it can be demonstrated that the containment isolation provisions for a specific class of lines, such as instrument lines, are acceptable on some other defined basis: (1) One locked closed isolation valve inside and one locked closed isolation valve outside containment; or (2) One automatic isolation valve inside and one locked closed isolation valve outside containment; or (3) One locked closed isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment; or (4) One automatic isolation valve inside and one automatic isolation valve outside containment. A simple check valve may not be used as the automatic isolation valve outside containment. Isolation valves outside containment shall be located as close to the containment as practical and upon loss of actuating power, automatic isolation valves shall be designed to take the position that provides greater safety.	TEUSA–56: Containment Isolation [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–57: Closed System Isolation Valves
RG 1.232.SFR_DC PDC Criterion 57 Each line that penetrates the reactor containment structure and is neither part of the primary coolant boundary nor connected directly to the containment atmosphere shall have at least one containment isolation valve unless it can be demonstrated that the containment safety function can be met without an isolation valve and assuming failure of a single active component. The isolation valve, if required, shall be either automatic, or locked closed, or capable of remote manual operation. This valve shall be outside containment and located as close to the containment as practical. A simple check valve may not be used as the automatic isolation valve.	TEUSA–57: Closed System Isolation Valves [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–60: Control of Releases of Radioactive Materials to the Environment
RG 1.232 SFR_DC PDC Criterion The nuclear power unit design shall include means to control suitably the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences. Sufficient holdup capacity shall be provided for retention of gaseous and liquid effluents containing radioactive materials, particularly where unfavorable site environmental conditions can be expected to impose unusual operational limitations upon the release of such effluents to the environment.	TEUSA–60: Control of Releases of Radioactive Materials to the Environment [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–61: Fuel storage and Handling and Radioactivity Control
RG 1.232.SFR_DC PDC Criterion 61 The fuel storage and handling, radioactive waste, and other systems that may contain radioactivity shall be designed to ensure adequate safety under normal and postulated accident conditions. These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components important to safety, (2) with suitable shielding for radiation protection, (3) with appropriate containment, confinement, and filtering systems, (4) with a residual heat removal capability having reliability and testability that reflects the importance to safety of decay heat and other residual heat removal, and (5) to prevent significant reduction in fuel storage cooling under accident conditions.	TEUSA–61: Fuel storage and Handling and Radioactivity Control [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–62: Prevention of Criticality in Fuel Storage and Handling
RG 1.232 SFR_DC PDC Criterion 62 Criticality in the fuel storage and handling system shall be prevented by physical systems or processes, preferably by use of geometrically safe configurations.	TEUSA–62: Prevention of Criticality in Fuel Storage and Handling [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–63: Monitoring Fuel and Waste Storage
RG 1.232 SFR_DC PDC Criterion 63 Appropriate systems shall be provided in fuel storage and radioactive waste systems and associated handling areas: (1) to detect conditions that may result in loss of residual heat removal capability and excessive radiation levels and (2) to initiate appropriate safety actions.	TEUSA–63: Monitoring Fuel and Waste Storage [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–64: Monitoring Radioactivity Releases
RG 1.232 SFR-DC PDC Criterion 64 Means shall be provided for monitoring the reactor containment atmosphere, spaces containing components for primary system sodium and cover gas cleanup and processing, effluent discharge paths, and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.	TEUSA–64: Monitoring Radioactivity Releases [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–70: Intermediate Coolant System
RG 1.232 SFR_DC PDC Criterion 70 If an intermediate cooling system is provided, then the intermediate coolant system shall be designed with sufficient margin to assure that: (1) the design conditions of the intermediate coolant boundary are not exceeded during normal operations, including anticipated operational occurrences, and (2) the integrity of the primary coolant boundary is maintained during postulated accidents.	TEUSA–70: Intermediate Coolant System [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–71: Primary Fuel Salt Purity Control
RG 1.232 SFR-DC PDC Criterion 71 Systems shall be provided as necessary to maintain the purity of primary coolant sodium and cover gas within specified design limits. These limits shall be based on consideration of (1) chemical attack, (2) fouling and plugging of passages, and (3) radionuclide concentrations, and (4) air or moisture ingress as a result of a leak of cover gas.	TEUSA–71: Primary Fuel Salt Purity Control [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–72: Salt Fluid Heating Systems
RG 1.232 SFR-DC PDC Criterion 72 Heating systems shall be provided for systems and components that are important to safety, and that contain or could be required to contain sodium. These heating systems and their controls shall be appropriately designed to ensure that the temperature distribution and rate of change of temperature in systems and components containing sodium are maintained within design limits assuming a single failure. If plugging of any cover gas line due to condensation or plate-out of sodium aerosol or vapor could prevent accomplishing a safety function, the temperature control and the relevant corrective measures associated with that line shall be considered important to safety.	TEUSA–72: Salt Fluid Heating Systems [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA–73: Salt Leakage Detection and Reaction Prevention and Mitigation
RG 1.232 SFR-DC PDC Criterion 73 Means to detect and identify sodium leakage as practical and to limit and control the extent of sodium-air and sodium-concrete reactions and to mitigate the effects of fires resulting from these sodium-air and sodium-concrete reactions shall be provided to ensure that the safety functions of structures, systems, and components important to safety are maintained. Systems from which sodium leakage constitutes a significant safety hazard shall include measures for protection, such as inert enclosures or guard vessels.	TEUSA–73: Salt Leakage Detection and Reaction Prevention and Mitigation [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–74: Salt/Water Reaction Prevention/Mitigation
RG 1.232.SFR_DC PDC Criterion 74 Structures, systems, and components containing sodium shall be designed and located to avoid contact between the sodium and water and to limit the adverse effects of chemical reactions between the sodium and water on the capability of any structure, system, or component to perform any of its intended safety functions. If steam-water is used for energy conversion, to prevent loss of any plant safety function, the sodium-steam generator system shall be designed to detect and contain sodium-water reactions and limit the effects of the energy and reaction products released by such reactions, including mitigation of the effects of any resulting fire involving sodium.	TEUSA–74: Salt/Water Reaction Prevention/Mitigation [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–75: Quality of Intermediate Coolant Boundary
RG 1.232 SFR_DC PDC Criterion 75 Components that are part of the intermediate coolant boundary shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.	TEUSA–75: Quality of Intermediate Coolant Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–76 – Fracture Prevention of the Intermediate Coolant Boundary
RG 1.232 SFR DC PDC Criterion 76 The intermediate coolant boundary shall be designed with sufficient margin to ensure that, when stressed under operating, maintenance, testing, and postulated accident conditions, (1) the boundary behaves in a nonbrittle manner and (2) the probability of rapidly propagating fracture is minimized.	TEUSA–76 – Fracture Prevention of the Intermediate Coolant Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–77: Inspection of the Intermediate Coolant Boundary
RG 1.232 SFR-DC PDC Criterion 77 Components that are part of the intermediate coolant boundary shall be designed to permit (1) periodic inspection and functional testing of important areas and features to assess their structural and leak-tight integrity commensurate with the system's importance to safety, and (2) an appropriate material surveillance program for the intermediate coolant boundary.	TEUSA–77: Inspection of the Intermediate Coolant Boundary [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

Title of Principal Design Criteria	TEUSA–78: Primary Fuel Salt Interfaces
RG 1.232 SFR-DC PDC Criterion 78 When the primary coolant system interfaces with a structure, system, or component containing fluid that is chemically incompatible with the primary coolant, the interface location shall be designed to ensure that the primary coolant is separated from the chemically incompatible fluid by two redundant, passive barriers. When the primary coolant system interfaces with a structure, system, or component containing fluid that is chemically compatible with the primary coolant, then the interface location may be a single passive barrier provided that the following conditions are met: (1) postulated leakage at the interface location does not result in failure of the intended safety functions of structures, systems or components important to safety or result in exceeding the fuel design limits and, (2) the fluid contained in the structure, system, or component is maintained at a higher pressure than the primary coolant during normal operation, anticipated operational occurrences, shutdown, and accident conditions.	TEUSA-78 Primary Fuel Salt Interfaces [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[

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Title of Principal Design Criteria	TEUSA– 79: Cover and Off-Gas Inventory Maintenance
RG 1.232 SFR_DC PDC Criterion 79 A system to maintain cover gas inventory shall be provided as necessary to ensure that the primary coolant sodium design limits are not exceeded as a result of cover or off-gas loss due to leakage from the primary coolant boundary and rupture of small piping or other small components that are part of the primary coolant system boundary.	TEUSA– 79: Cover and Off-Gas Inventory Maintenance [ ]
TEUSA Assessment	[ ]
TEUSA Supporting Basis for Assessment	[ ]

VIII. IMSR® Principal Design Criteria Summary

This section summarizes the principal design criteria assessment for the IMSR400 design. For reasons presented earlier in this report, TEUSA developed its principal design criteria using the SFR-DCs listed in Appendix B of RG 1.232 for a sodium cooled fast reactor. TEUSA assessed the draft SFR-DC against the SSCs in the IMSR® design. The TEUSA specific IMSR400 PDCs were either SFR-DCs adopted without modification or modified to account for the unique features of the IMSR400 design.

The assessment process determined that thirty-four SFR-DCs could be directly adopted for the IMSR400 design without modification. Twenty-nine SFR-DCs could be adopted with some modification of the draft criteria to reflect the SSCs incorporated into the IMSR® design or the planned operational characteristics of the IMSR® design. One criterion [ ] was not adopted, and no alternative criterion was proposed because it was not necessary for the IMSR400 design. A table summarizing how each SFR-DC was categorized by TEUSA is shown below.

Upon approval by the NRC, TEUSA will adopt the set of principal design criteria for the IMSR400 design presented in Section VII above with the proposed modifications necessary for the IMSR® design.

TEUSA SFR-DC Categorization Summary Table

Adopted without Modification - 34	Adopted with Modification - 29	Not Adopted - 1
[		

Adopted without Modification - 34	**Adopted with Modification - 29**	**Not Adopted - 1**
		]

IX. Abbreviations & Acronyms

ANS – American Nuclear Society

AOO – Anticipated Operational Occurrence

ARDC – Advanced Reactor Design Criteria

ARE – Aircraft Reactor Experiment

BDBA – Beyond Design Basis Accident

BeF_2 – Beryllium Fluoride

CAS – Central Alarm Stations

CB – Control Building

CFR – Code of Federal Regulations

CNSC – Canadian Nuclear Safety Commission

Cs - Cesium

DBA – Design Basis Accident

DC – Design Criteria

DMSR – Denatured Molten Salt Reactor

DOE – Department of Energy

FSST- Fuel Salt Storage Tank

GDC – General Design Criteria

GV – Guard Vessel

GHT – Gas Holding Tank

HVAC – Heating, Ventilation and Air Conditioning

I&C – Instrumentation and Control

IFS – Initial Fuel System

IFACS – Irradiated Fuel Air Cooling System

IrFS – Irradiated Fuel System

IMSR® – Integral Molten Salt Reactor

I-NPP – IMSR Nuclear Power Plant

IRVACS – Internal Reactor Vessel Auxiliary Cooling System

KF – Potassium Fluoride

LIF – Lithium Fluoride

LLW – Low Level Waste

LWR – Light Water Reactor

MCR – Main Control Room

MFS – Makeup Fuel System

MHTGR – Modular High Temperature Gas Reactor

MSB – Main Security Building

MSR – Molten Salt Reactor

MSRE – Molten Salt Reactor Experiment

MW – Megawatt

MWe – Megawatt Electric

MWth – Megawatt Thermal

NaF – Sodium Fluoride

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

RV – Reactor Vessel

SAFDL- Specified Acceptable Fuel Design Limit

SCA – Secondary Control Area

SCS – Secondary Coolant System

SDA – Standard Design Approval

SDM – Shutdown Mechanism

SFR – Sodium Fast Reactor

SG – Steam Generator

SGB – Steam Generation Building

Sr - Strontium

SS – Stainless Steel

TB – Turbine Building

TCS - Tertiary Coolant System

TEI – Terrestrial Energy, Inc.

TEUSA – Terrestrial Energy USA, Inc.

TG – Turbine Generator

U.S. – United States

VDR – Vendor Design Review

Xe - Xenon

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