June 20, 2023

TP-LIC-LET-0084
Project Number 99902100

U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
ATTN: Document Control Desk

Subject: Reactor Stability Presentation Material

This letter provides the TerraPower, LLC presentation material for the upcoming Natrium™ advanced reactor[1] pre-application engagement meeting "Reactor Stability" (Enclosures 2 and 4).

The presentation material contains proprietary information and as such, it is requested that Enclosure 4 be withheld from public disclosure in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." An affidavit certifying the basis for the request to withhold Enclosure 4 from public disclosure is included as Enclosure 1. Proprietary materials have been redacted from the presentation provided in Enclosure 3; redacted information is identified using [[ ]]$^{(a)(4)}$.

This letter and enclosures make no new or revised regulatory commitments.

If you have any questions regarding this submittal, please contact Ryan Sprengel at rsprengel@terrapower.com or (425) 324-2888.

[1] a TerraPower and GE-Hitachi technology.

Sincerely,

Ryan Sprengel
Director of Licensing, Natrium
TerraPower, LLC

Enclosure:
1. TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))
2. "Reactor Stability" Presentation Material – Open Meeting – Non-Proprietary (Public)
3. "Reactor Stability" Presentation Material – Closed Meeting – Non-Proprietary (Public)
4. "Reactor Stability" Presentation Material – Closed Meeting – Proprietary (Non- Public)

cc: Mallecia Sutton, NRC
William Jessup, NRC
Andrew Proffitt, NRC
Nathan Howard, DOE
Jeff Ciocco, DOE

ENCLOSURE 1

TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure (10 CFR 2.390(a)(4))

Enclosure 1
TerraPower, LLC Affidavit and Request for Withholding from Public Disclosure
(10 CFR 2.390(a)(4))

I, George Wilson, hereby state:

1. I am the Vice President, Regulatory Affairs and I have been authorized by TerraPower, LLC (TerraPower) to review information sought to be withheld from public disclosure in connection with the development, testing, licensing, and deployment of the Natrium™ reactor and its associated fuel, structures, systems, and components, and to apply for its withholding from public disclosure on behalf of TerraPower.
2. The information sought to be withheld, in its entirety, is contained in Enclosure 4, which accompanies this Affidavit.
3. I am making this request for withholding, and executing this Affidavit as required by 10 CFR 2.390(b)(1).
4. I have personal knowledge of the criteria and procedures utilized by TerraPower in designating information as a trade secret, privileged, or as confidential commercial or financial information that would be protected from public disclosure under 10 CFR 2.390(a)(4).
5. The information contained in Enclosure 4 accompanying this Affidavit contains non-public details of the TerraPower regulatory and developmental strategies intended to support NRC staff review.
6. Pursuant to 10 CFR 2.390(b)(4), the following is furnished for consideration by the Commission in determining whether the information in Enclosure 4 should be withheld:
    a. The information has been held in confidence by TerraPower.
    b. The information is of a type customarily held in confidence by TerraPower and not customarily disclosed to the public. TerraPower has a rational basis for determining the types of information that it customarily holds in confidence and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application and substance of that system constitute TerraPower policy and provide the rational basis required.
    c. The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR 2.390, it is received in confidence by the Commission.
    d. This information is not available in public sources.
    e. TerraPower asserts that public disclosure of this non-public information is likely to cause substantial harm to the competitive position of TerraPower, because it would enhance the ability of competitors to provide similar products and services by reducing their expenditure of resources using similar project methods, equipment, testing approach, contractors, or licensing approaches.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on: June 20, 2023

George Wilson

George Wilson
Vice President, Regulatory Affairs
TerraPower, LLC

ENCLOSURE 2

“Reactor Stability”
Presentation Material – Open Meeting

Non-Proprietary (Public)

NATRIUM

Reactor Stability

a TerraPower & GE-Hitachi technology

TP-LIC-PRSNT-0004

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Table of Contents

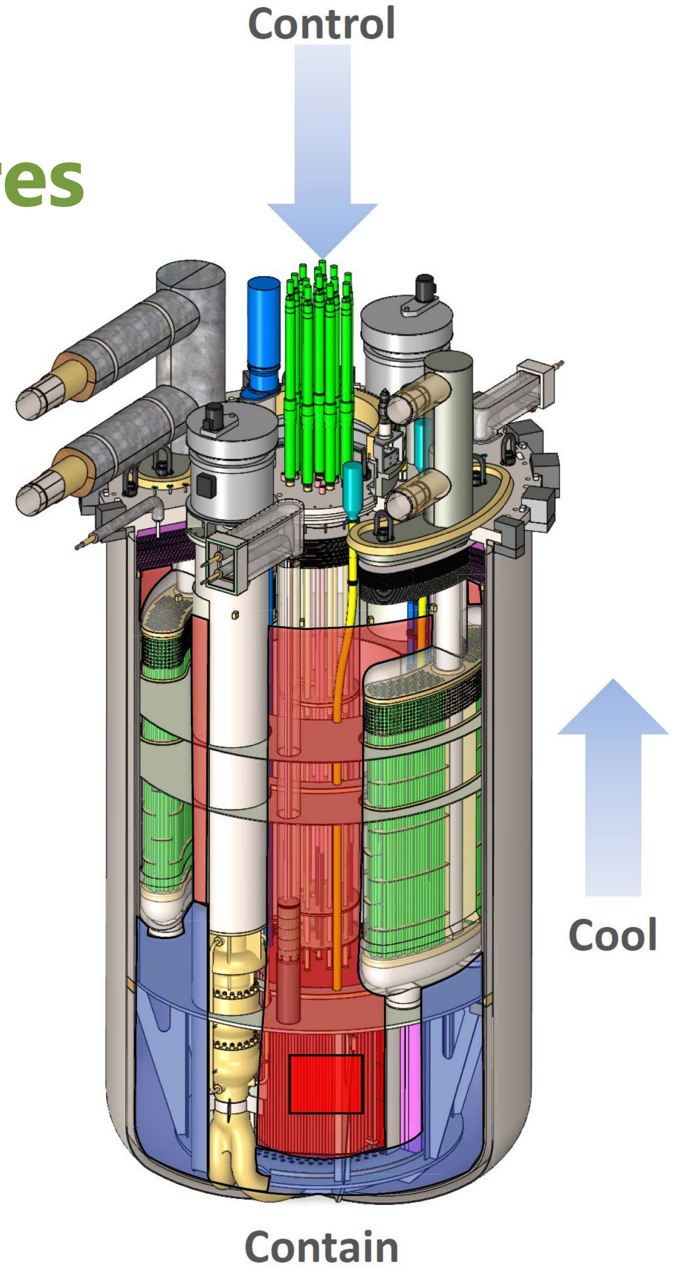
Natrium Reactor Overview

- The Natrium project is demonstrating the ability to design, license, construct, startup and operate a Natrium reactor.

- Pre-application interactions are intended to reduce regulatory uncertainty and facilitate the NRC's understanding of the Natrium design and its safety case.

Natrium Safety Features

- Pool-type Metal Fuel SFR with Molten Salt Energy Island
  - Metallic fuel and sodium have high compatibility
  - No sodium-water reaction in steam generator
  - Large thermal inertia enables simplified response to abnormal events
- Simplified Response to Abnormal Events
  - Reliable reactor shutdown
  - Transition to coolant natural circulation
  - Indefinite passive emergency decay heat removal
  - Low pressure functional containment
  - No reliance on Energy Island for safety functions
- No Safety-Related Operator Actions or AC power
- Technology Based on U.S. SFR Experience
  - EBR-I, EBR-II, FFTF, TREAT
  - SFR inherent safety characteristics demonstrated through testing in EBR-II and FFTF



Control

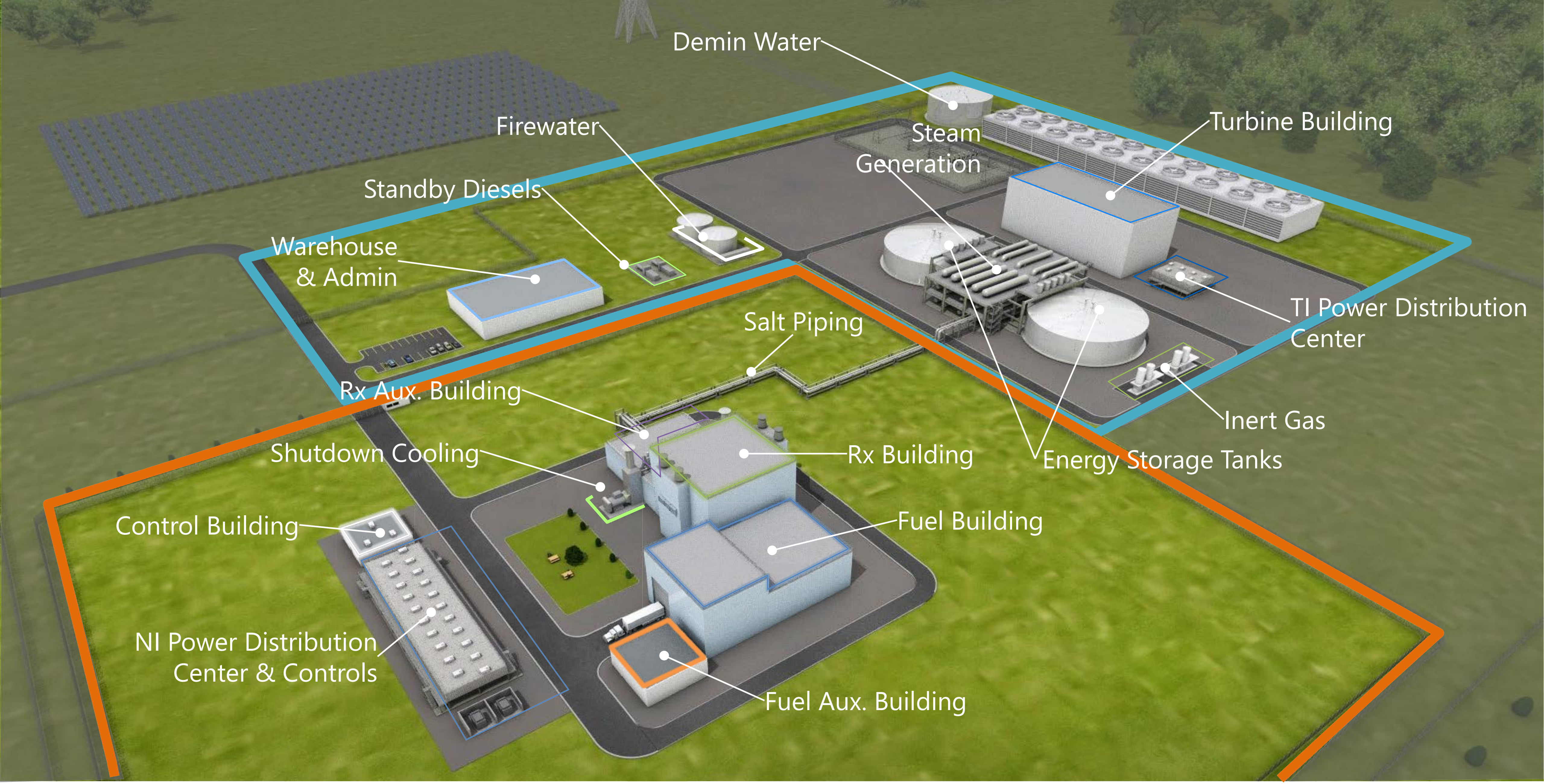
- Motor-driven control rod runback and scram follow
- Gravity-driven control rod scram
- Inherently stable with increased power or temperature

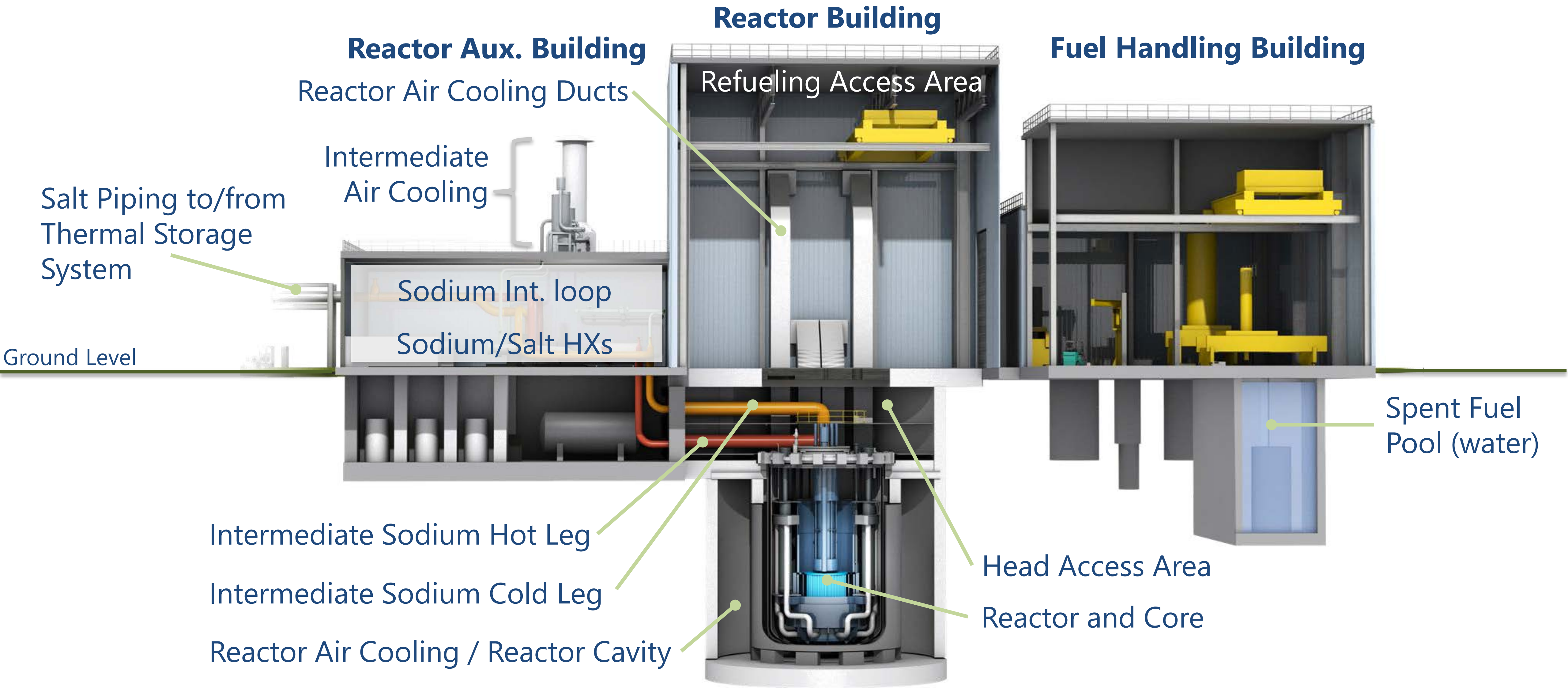
Cool

- In-vessel primary sodium heat transport (limited penetrations)
- Intermediate air cooling natural draft flow
- Reactor air cooling natural draft flow – always on

Contain

- Low primary and secondary pressure
- Sodium affinity for radionuclides
- Multiple radionuclides retention boundaries


Demin Water
Firewater
Steam Generation
Turbine Building
Standby Diesels
Warehouse & Admin
TI Power Distribution Center
Salt Piping
Rx Aux. Building
Inert Gas
Shutdown Cooling
Rx Building
Energy Storage Tanks
Control Building
Fuel Building
NI Power Distribution Center & Controls
Fuel Aux. Building


Reactor Building
Reactor Aux. Building
Fuel Handling Building
Reactor Air Cooling Ducts
Refueling Access Area
Intermediate Air Cooling
Salt Piping to/from Thermal Storage System
Sodium Int. loop
Sodium/Salt HXs
Ground Level
Spent Fuel Pool (water)
Intermediate Sodium Hot Leg
Intermediate Sodium Cold Leg
Reactor Air Cooling / Reactor Cavity
Head Access Area
Reactor and Core

Introduction to the Stability Methodology

Purpose

- Provide an overview of the Natrium stability methodology

Background

- Reactor stability is an analysis of the reactor's oscillatory response
  - Investigating whether the reactor is susceptible to diverging power oscillations in response to reactivity input
- Reactor stability not expected to be a challenge for modern US-style SFRs
- Similar to PWRs, SFRs do not have significant reactivity feedback effects from flow voiding, meaning thermal-hydraulic flow instabilities are not driving forces
- Accordingly, analyses generally revolve around ensuring proper representation of neutronic-dominant feedbacks

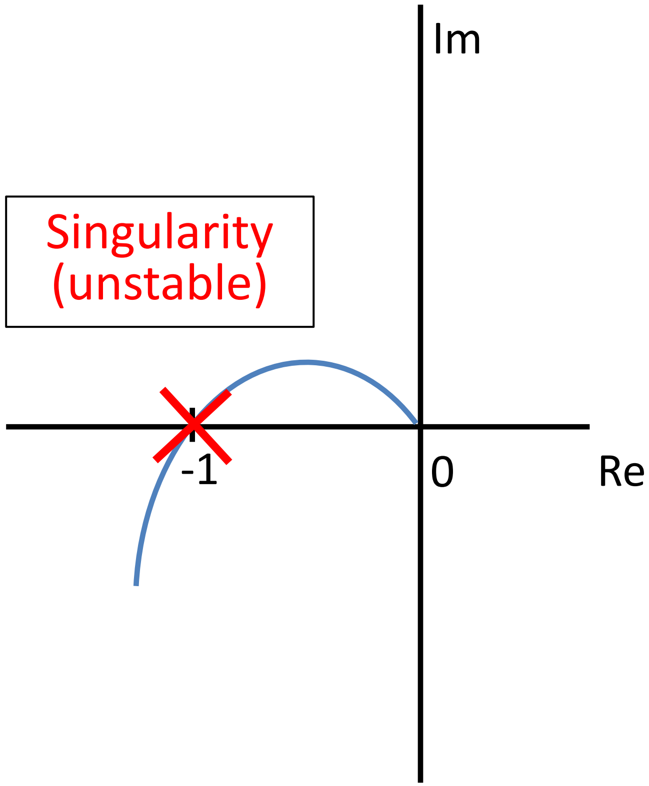
Stability Methodology Requirements

Method Requirements Flow Down From Regulatory Criteria

- Natrium PDC 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 system radionuclide release design limits are not possible or can be reliably and readily detected and suppressed.

Figure of Merit: Nyquist Stability Criterion

- Nyquist stability criterion:
  - System unstable when Nyquist result encircles or passes through the -1+0i point (plotted on the complex plane)
- Derived from the reactor's oscillatory power response to a sinusoidal reactivity input
- A 'frequency-domain' figure-of-merit
  - Criteria is derived from functions of frequency, $f(\omega)$



Important Phenomena

- Reactor kinetics
- System operating parameters
- Reactivity feedbacks

Stability Methodology Overview

Stability Methodology Overview

- Use in-house developed code to calculate reactor power response from a reactivity input
- Use this reactivity-to-power relationship to calculate Nyquist plot
- Include appropriate methods and input uncertainties
  - Benchmark assessment against available data (Fermi-I)

Stability Methodology Benchmark: Fermi-I

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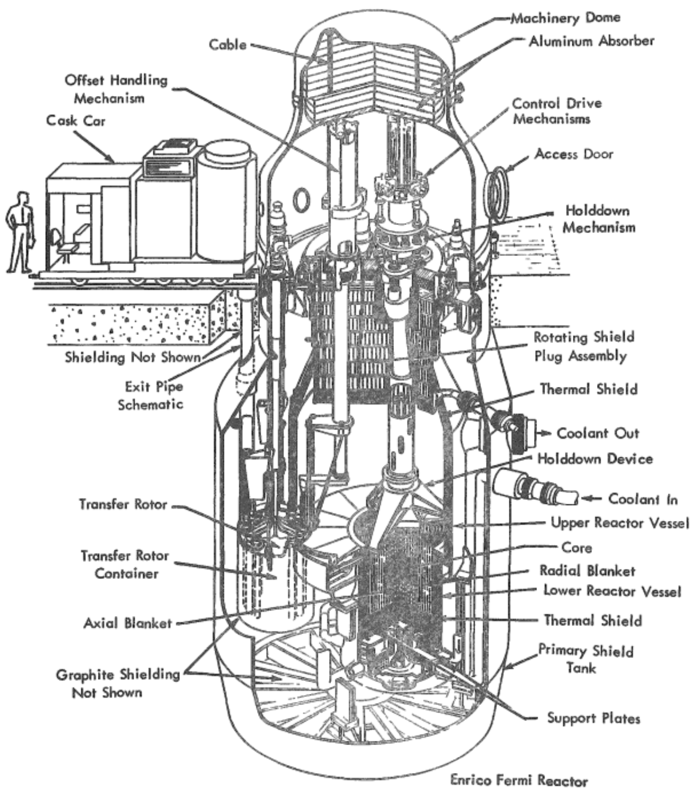
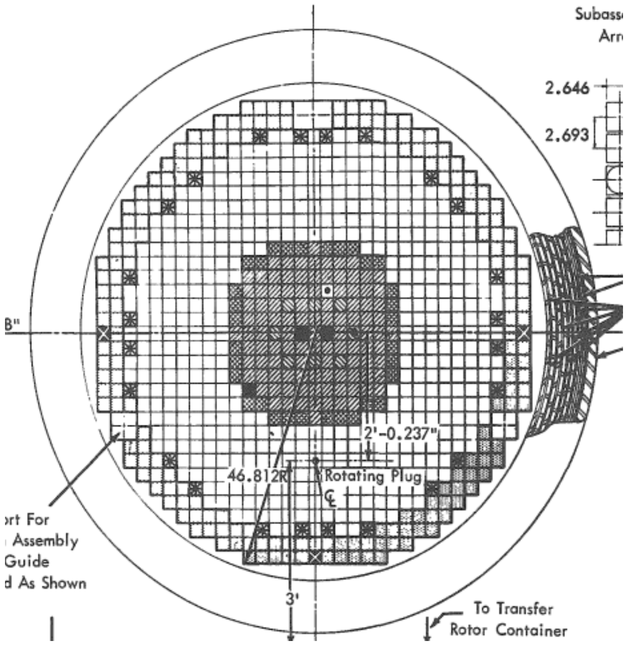
Benchmark: Fermi-I Reactor Overview

Images reference: A. Klickman et. al., "Oscillator Tests in the Enrico Fermi Reactor," Atomic Power Development Associates, Inc., APDA-NTS-11, 1967.

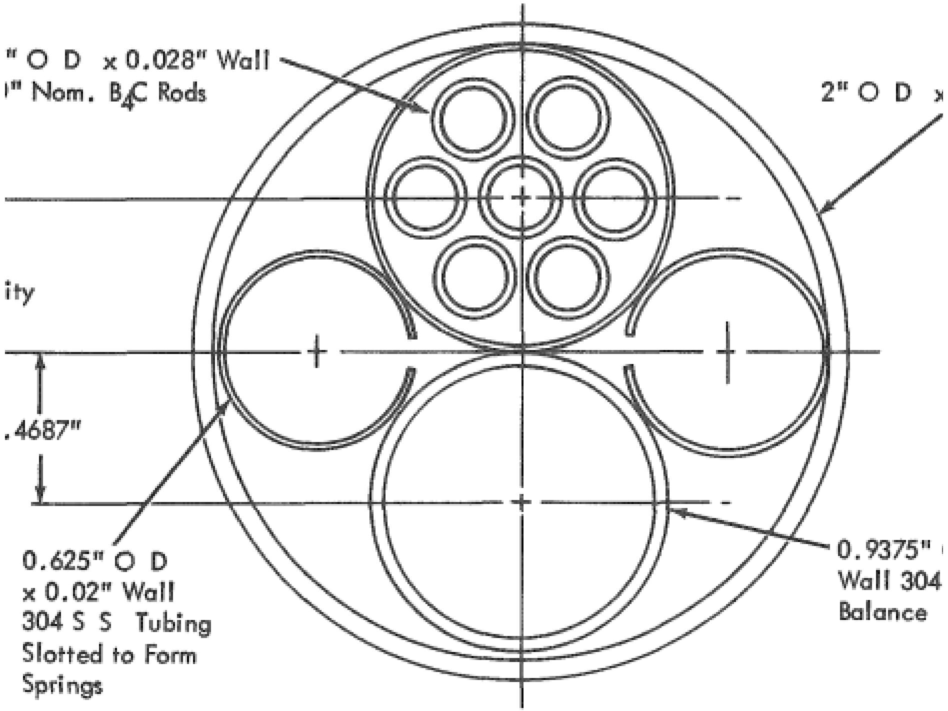


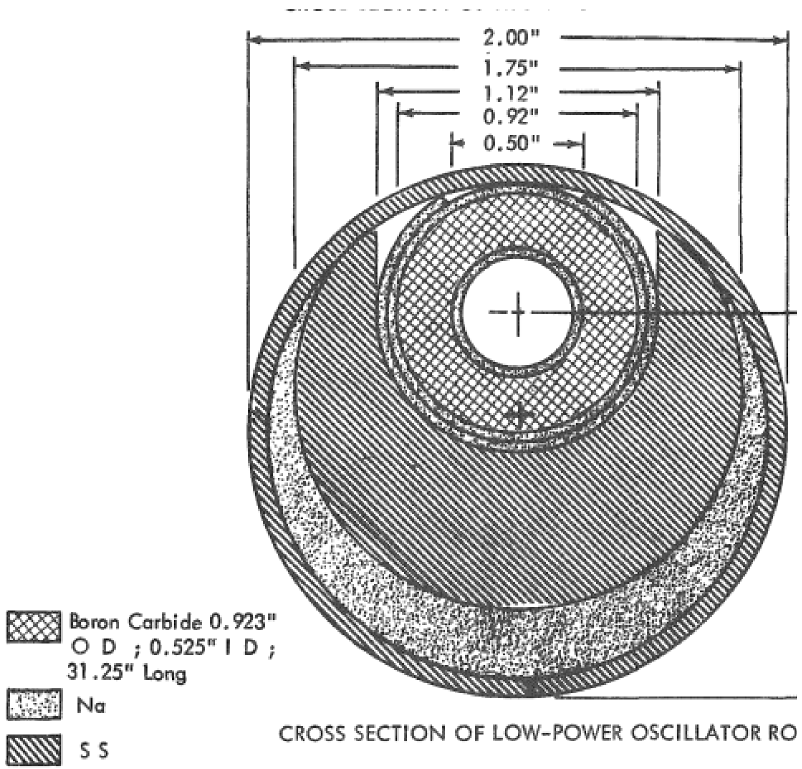


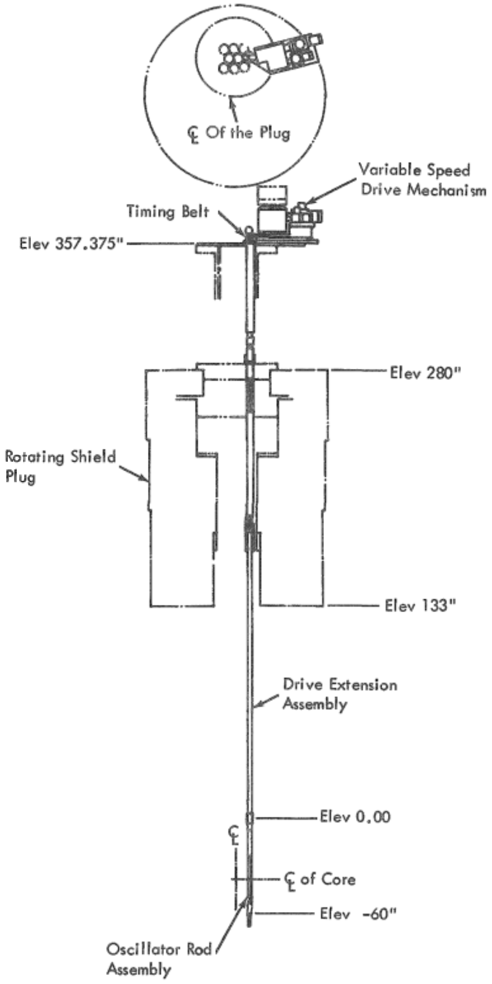
- Commercial power reactor (1960s)
- Similar to Natrium design: Metal fuel, sodium cooled, fast spectrum

Images reference: A. Klickman et. al., "Oscillator Tests in the Enrico Fermi Reactor," Atomic Power Development Associates, Inc., APDA-NTS-11, 1967.

Benchmark: Fermi-I Oscillator Tests







- Oscillator devices applied a sinusoidal reactivity input at frequencies from 5 Hz to 5e-3 Hz

Stability Methodology: Natrium Reactor Application

Natrium Reactor Stability Methodology Application

- Natrium reactor operating at rated conditions (100% power, 100% flow) analyzed using the stability methodology
- Nominal BOL result demonstrated significant margin to unstable behavior
- Treatment of input uncertainties and model uncertainties continued to demonstrate significant margins

Questions?

Acronym List

ARCAP – Advanced Reactor Content of Application Project
ARDC – Advanced Reactor Design Criteria
ARDP – Advanced Reactor Demonstration Program
BOL – Beginning-of-life
CFR – Code of Federal Regulations
DID – Defense-in-Depth
EBR – Experimental Breeder Reactor
FFTF – Fast Flux Test Facility
GDC – General Design Criteria
LBE – Licensing Basis Event
LMP – Licensing Modernization Project
PDC – Principal Design Criteria
PSAR – Preliminary Safety Analysis Report
PWR – Pressurized water reactor
RIPB – Risk-Informed, Performance-Based
SFR – Sodium Fast Reactor
SSC – Structures, systems, and components
TICAP – Technology Inclusive Content of Application Project
TREAT – Transient Reactor Test

ENCLOSURE 3

“Reactor Stability”
Presentation Material – Closed Meeting

Non-Proprietary (Public)

NATRIUM

Reactor Stability

a TerraPower & GE-Hitachi technology

TP-LIC-PRSNT-0005

SUBJECT TO DOE COOPERATIVE AGREEMENT NO. DE-NE0009054

Portions of this presentation are considered proprietary and TerraPower, LLC requests it be withheld from public disclosure under the provisions of 10 CFR 2.390(a)(4).

Nonproprietary versions of this presentation indicate the redaction of such information using [[ ]]$^{(a)(4)}$.

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Stability Methodology Requirements

Important Phenomena

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Important Phenomena

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Important Phenomena

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Important Phenomena

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Important Phenomena

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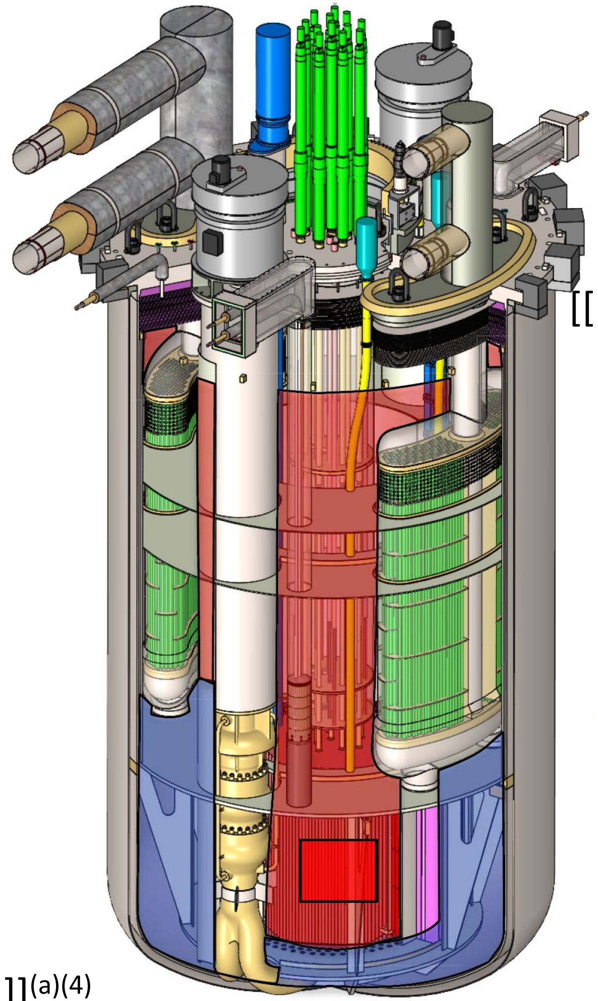

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Stability Methodology Overview

Figures of Merit Selected: Nyquist

- **Nyquist** selected as the figure-of-merit due to availability of relevant validation data
- Historical SFRs such as Fermi-I, FFTF, and EBR-II performed measurements to generate Nyquist plots
- Selecting Nyquist then drives what models/components will comprise the methodology

Methodology Overview: Approach

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]][(a)(4)]

- ZPTF is a measure of the system power response *gain* and *phase shift* relative to the sinusoidal input reactivity in the **absence** of reactivity feedback effects
- FPTF is the *gain* and *phase shift* of power relative to reactivity in the **presence** of reactivity feedback effects

Model Components: Reactivity Input and ZPTF

- Define a small sinusoidal external reactivity insertion to the reactor
  - Use to quantify the behavior of the oscillatory reactor power response
  - Set amplitude to small value (~1 cent) such that small perturbations are induced (~linear response)

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Model Components: FPTF

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Model Components: FPTF

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Model Components: FPTF

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Model Components: FPTF

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Stability Methodology Assessment: Fermi-I

Fermi-I Measured vs. Calculated

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Method Uncertainties Treatment

Model Uncertainty Treatment

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Input Uncertainties Treatment: Selected Approach

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Input Uncertainties Treatment: Parameters Included

Neutronic-related

Thermal-hydraulic related

[[

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Input Uncertainties Treatment: Number of Samples

- Number of samples: [[

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Stability Methodology: Natrium Reactor Application

Input Uncertainties Treatment: Natrium Application

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Nominal BOL HFP Natrium Nyquist Plot

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HFP Natrium Input Uncertainties Characterization

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Wrap-Up

Future Plans

- Update Natrium application calculations for final Natrium configuration
- Submit Licensing Topical Report on the Natrium stability methodology
- Perform additional methodology assessment using FFTF
- Iterate to finalize startup testing plan

Questions?

Acronym List

BOL – Beginning-of-life
CRDL – Control rod driveline
EBR – Experimental Breeder Reactor
FFTF – Fast Flux Test Facility
FPTF – Full-power transfer function
HFP – Hot full power
LWR – Light Water Reactor
OLTF – Open-loop transfer function
ODE – Ordinary differential equation
SFR – Sodium Fast Reactor
ZPTF – Zero-power transfer function

TerraPower NATRIUM