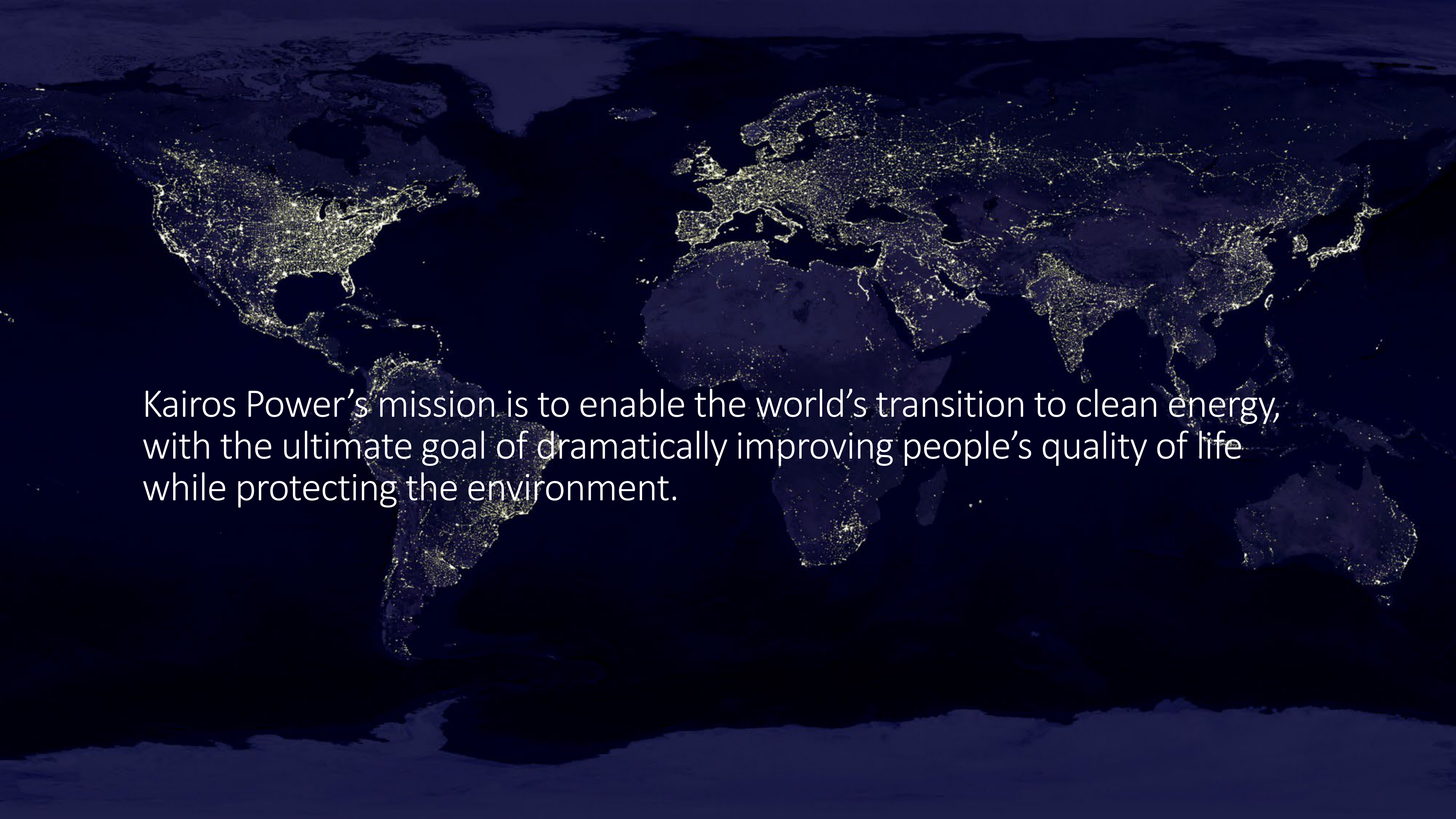
Enclosure 2
Presentation Materials for the January 12, 2023, ACRS Kairos Power Subcommittee Meeting
(Non-Proprietary)

Metallic Materials Qualification Topical Report

ACRS Kairos Power Subcommittee Meeting

January 12, 2023

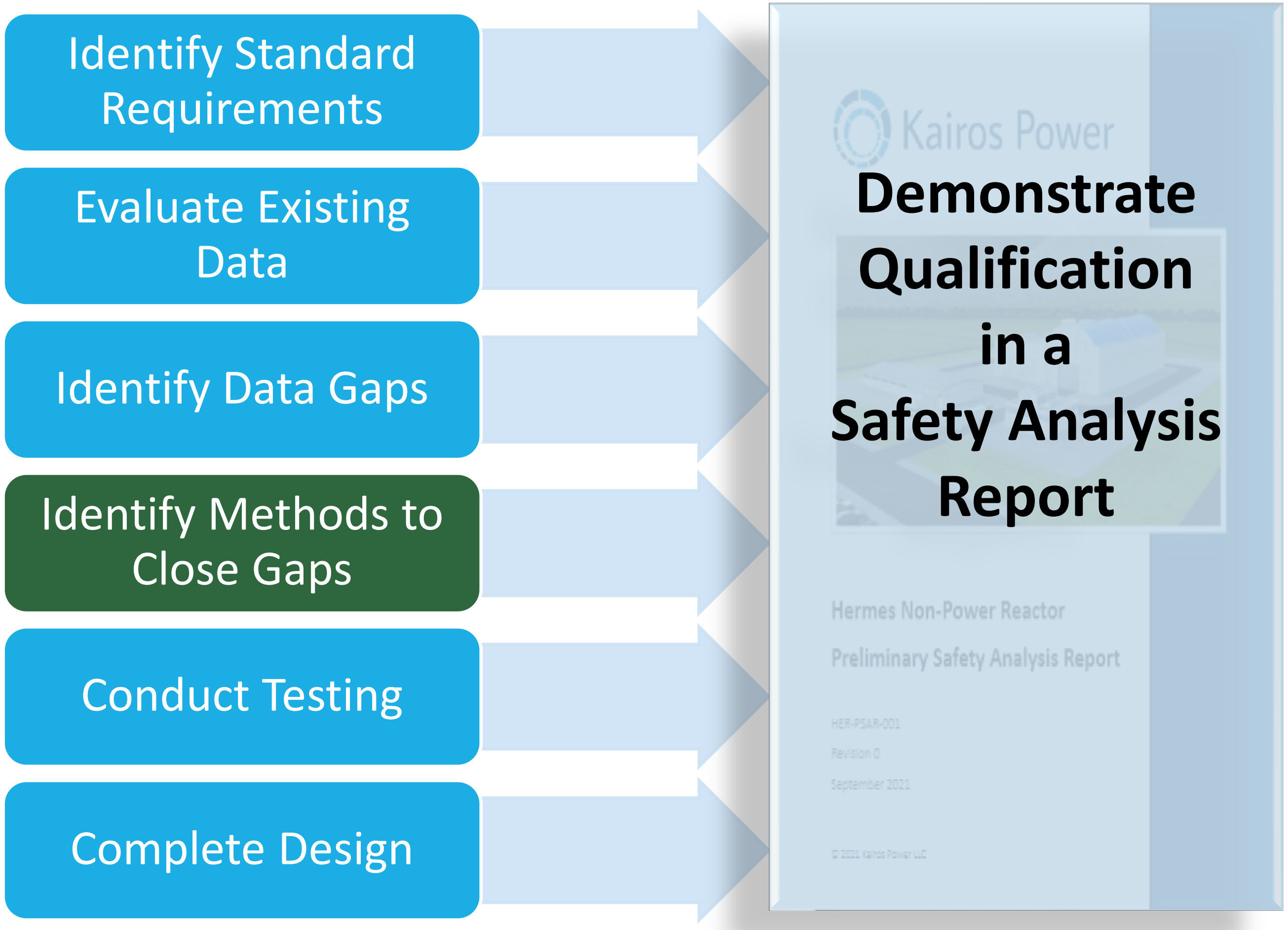
OPEN SESSION



Kairos Power's mission is to enable the world's transition to clean energy, with the ultimate goal of dramatically improving people's quality of life while protecting the environment.

Introduction

- This report presents the methods for qualifying metallic materials for use in KP-FHRs
  - Qualification is subject to the conditions in topical report
  - Uses KP-X PIRT test plan as a baseline but with reduced test durations for the shorter-lived Non-Power Test Reactor
- Demonstration of qualification will be documented in safety analysis report documents as part of licensing applications under 10 CFR Part 50 or Part 52
- This report is applicable to the Non-Power Test Reactor (Hermes) and to the Commercial Power (KPX) Reactor



Summary of Key Parameters in KP-FHR (Table 1)

Parameter	Power Reactor	Non-Power Test Reactor
Reactor Description	Low pressure, fluoride salt-cooled high temperature reactor (FHR)	
Core Configuration	Pebble bed core, graphite reflector, and enriched Flibe molten salt coolant	
Physical Dimensions	Reactor Vessel is ~4 m diameter, ~6 m height	Reactor Vessel is ~2.5 m diameter, ~4 m height
Reactor Thermal Power	320 MW_{th}	35 MW_{th}
Primary Heat Transport System	Flibe Salt, 550°C-650˚C, ~0.2 MPa, ~0.11-0.15 m/s	
Intermediate Heat Transport System	Intermediate Coolant, <0.2 MPa, 360°C-600°C	None. Primary Heat Transport System rejects heat to the (air) heat rejection subsystem
Power Conversion System	300°C-585°C, steam ~19 MPa	None. Primary Heat Transport System rejects heat to the (air) heat rejection subsystem
Material for Safety-Related Structures	Alloy 316H and ER16-8-2 (ASME Section III, Division 5, approved)	
Lifetime	[[ ]]	≤5 years (1 year commissioning + 4 years operation)
End of Life Irradiation of Reactor Vessel	<0.1 dpa	

Metallic Materials Topical Report Organization

- Introduction
  - KP-FHR Technologies
  - Regulatory Information
- Structural Alloys
  - Background
  - Structural Alloy Selection
  - Industrial Experience
- Air Testing and Finite Element Analysis
  - Testing Required for ASME Code Extension
  - Testing to Facilitate Reactor Designs
  - High Temperature Testing & Analysis to Support Potential Degradation
- Compatibility with Flibe and Irradiation
- Environmental Compatibility
- Conclusions and Limitations
- Appendix A: Coatings, Cladding, and Tritium Management
- Appendix B: Inspection and Aging Management
- Appendix C: Details of the Corrosion Data Analysis
- Appendix D and E: Not Used
- Appendix F Certified Material Reports

Chapter 2: Alloy 316H and Weld Filler Metal ER16-8-2

- Alloy 316H and Weld Filler Metal ER16-8-2 were chosen because of its qualification in high temperature applications. As the material is qualified, components can be designed for extremely low probability of abnormal leakage, resistance to rapidly propagating failure, and resistance to gross rupture.
- Alloy 316H and its weld metals exhibit desirable mechanical properties, have demonstrated compatibility with Flibe salt, and have an extensive experience base in nuclear applications.
- Alloy 316H and its weld metals are used in other industry applications near the time and temperature of the KP-FHR.

Chapter 3.1: Testing Required for ASME Code Extension

- Alloy 316H is qualified for 816°C and Weld Filler Metal is currently qualified to 650°C
- The weld filler metal will be tested to extend the ASME qualification of ER16-8-2 to match the base metal.
  - Elevated Temperature Tensile Testing
  - Creep-Fatigue Testing
  - Creep-Rupture Testing

Chapter 3.2: Testing to Facilitate Non-Power and Commercial Power Reactor Designs

- The types of tests being conducted for Alloy 316H stainless steel model calibration and validation of ASME design methodologies (all conducted in high temperature air)
  - Tensile Testing
  - Stress Relaxation Testing
  - Strain Rate Change (Stress Dip) Testing
  - Uniaxial Creep Testing
  - Creep-Fatigue Testing

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Chapter 3.3: High Temperature Testing & Analysis to Support Potential Degradation

- Stress Relaxation Cracking – testing program per discussion with NRC Staff
- Thermal Stresses & Thermal Striping – managed via design

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Chapter 4.2: Environmental Compatibility

- Use of the PIRT Data
- Corrosion
  - Corrosion Testing with Use of Compositional Analysis and Electrochemical Potential (ECP) Monitoring
- Environmentally Assisted Cracking
  - Slow Strain Rate Testing (SSRT)
  - Fracture Mechanics Based Testing – Corrosion Fatigue (CF) and Stress Corrosion Cracking (SCC)
  - Environmental Creep Testing
- Metallurgical Effects / Other
  - Stress Relaxation Cracking
  - Phase Formation Embrittlement
  - Thermal Cycling / Striping
- Irradiation Effects
  - Irradiation-Induced Embrittlement
  - Irradiation-Affected Corrosion
  - Irradiation-Assisted Stress Corrosion Cracking (IASCC)

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Some Major Comments that Have Been Addressed

- Testing at 750°C added to bound maximum expected transient temperature and time
- Heat affected zone (HAZ) samples added throughout EAC and Corrosion testing and these samples are priorities for Hermes Rx testing
- Direct testing for stress relaxation cracking added – comparison study between 347 HAZ and 316H HAZ
- Significant detail added to testing plans (e.g., numbers of samples, exposure times, etc. for corrosion tests, specific conditions for environmentally assisted cracking tests)

Summary

- Alloy 316H base metal and ER16-8-2 weld filler metal have been selected as the metallic structural alloys for use in safety-significant, high temperature, Flibe-wetted component designs.
- This testing is being conducted to support the design and licensing of both the non-power test reactor (Hermes) and the commercial power generation reactor (KP-X).
- This testing is focused on structural alloys 316H and ER16-8-2 for the reactor vessel, which was determined to be the primary safety-related component of interest, as it serves to retain the Flibe coolant (a fission product barrier) around the fuel pebbles.
- Testing to support design includes work to extend the code qualification of ER16-8-2 weld metal up to a temperature to match the current qualification of Alloy 316H base metal as well as testing and analyses required to support design per the ASME Code Section III, Division 5.
- The materials testing consists of two major efforts: (1) testing in high temperature air to support ASME design and (2) testing in molten Flibe salt to account for potential environmental degradation.

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