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Enclosure 1
Metallics Material Qualification Presentation Materials for the February 1, 2023,
ACRS Full Committee Meeting
(Non-Proprietary)

Kairos Power

Metallic Materials Qualification Topical Report

ACRS Kairos Power Full Committee Meeting

February 1, 2023

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.

Background

- Purpose: This report presents a materials testing plan methodology, including analysis and monitoring, for metallic structural materials used in Flibe-wetted safety-related high temperature components.
  - The materials include Alloy 316H and Weld Filler Metal 16-8-2. These materials were chosen because of existing qualification in high temperature applications and because they are provided by ASME Code, Section III, Division 5 and endorsed by Regulatory Guide 1.87.
  - 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.
  - Qualified materials provide assurance that components can be designed for extremely low probability of abnormal leakage, resistance to rapidly propagating failure, and resistance to gross rupture.
- Scope: The report is applicable to both the KP-FHR test reactor and power reactor designs, provided the limitations specified in the report are met.
  - The material qualification test results generated by this methodology will be used as a basis in future licensing actions to address materials reliability and environmental compatibility in KP-FHR reactor designs.

Codes and Standards Applicability

- ASME Code
  - Alloy 316H and Weld Filler Metal 16-8-2 are approved materials for high temperature reactors in ASME Code, Section III, Division 5
    - Alloy 316H is qualified for 816°C
    - Weld Filler Metal 16-8-2 is currently qualified to 650°C
  - The ASME qualification of weld filler metal 16-8-2 will be extended by testing to match the base metal temp for Alloy 316H:
    - Elevated Temperature Tensile Testing
    - Creep-Fatigue Testing
    - Creep-Rupture Testing
- Quality Assurance
  - The qualification for the power reactor will satisfy an NQA-1 based QA program
  - The qualification for the test reactor will satisfy an ANSI/ANS-15.8-1995 based QA program

Testing Program Overview

- A phenomena importance and ranking table (PIRT) was created for the metallic materials testing program
  - The PIRT review identified and ranked the appropriate environmental degradation phenomena that are applicable to the Flibe-wetted safety-related components of the KP-FHR.
    - The reactor vessel is the only safety-related structural metallic component which serves the function of retaining the coolant around the fuel.
  - The PIRT identified two potential accident scenarios that could affect the structural integrity of Flibe-wetted safety-related components (Note that these effects are mitigated via design features):
    - air ingress into the reactor
    - intermediate coolant ingress into the Flibe (power reactor only)
- The testing program is informed by the PIRT results and consists of two major efforts:
  - testing in high temperature air to support ASME design, and
  - testing in molten Flibe salt to account for potential environmental degradation.

Testing Program Overview (continued)

- The following tests are conducted for Alloy 316H stainless steel to support 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
  - Notch Bar Creep Testing
  - Creep-Fatigue Testing

Testing Program Overview (continued)

- The following potential degradation phenomena were assessed in detail and form the basis for the testing plans:
  - 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)

Summary

- Metallic materials qualification 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).
  - The scope of testing is limited to structural alloys 316H and 16-8-2 for the reactor vessel, which was determined to be the primary safety-related component of interest
    - The reactor vessel maintains an inventory of Flibe coolant around the fuel pebbles (fission product barriers).
  - Qualified materials provide assurance that the reactor vessel can be designed for extremely low probability of abnormal leakage, resistance to rapidly propagating failure, and resistance to gross rupture.
- The materials testing consists of two major efforts:
  - testing in high temperature air to support ASME design, ASME qualification extension, and
  - testing in molten Flibe salt to account for potential environmental degradation.