UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

February 15, 2023

Mr. Daniel H. Dorman
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT SAFETY EVALUATION OF KAIROS TOPICAL REPORT, KP-TR-013, "METALLIC MATERIALS QUALIFICATION FOR THE KAIROS POWER FLUORIDE SALT-COOLED HIGH-TEMPERATURE REACTOR"

Dear Mr. Dorman:

During the 702nd meeting of the Advisory Committee on Reactor Safeguards, February 1-3, 2023, we completed our review of the Kairos Topical Report, KP-TR-013, "Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor," and the associated NRC staff safety evaluation (SE). Our Kairos Subcommittee also reviewed this matter on January 12, 2023. During these meetings, we had the benefit of discussions with NRC staff and representatives from Kairos Power LLC (Kairos). We also had the benefit of the referenced documents.

Conclusions and Recommendation

1. The Kairos methodology to qualify structural alloys used in safety-related systems is technically sound.

2. The topical report methodology with the limitations and conditions imposed by the staff will ensure that high temperature metallic materials will be code-qualified and able to perform their safety function.

3. The staff SE should be issued.

Background

The topical report, KP-TR-013, describes the Kairos methodology for qualifying alloys used in safety-related metallic components in the Kairos non-power and power Fluoride High-Temperature Reactors (KP-FHRs). The approach addresses and augments, where necessary, the requirements in the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 5 (Rules for Construction of Nuclear Power Plant Components, High Temperature Reactors). For the power reactor, the data developed for safety-related metallic structural materials qualification will be in accordance with Nuclear Quality Assurance (NQA-1). For the non-power test reactor, Kairos is implementing a quality

assurance program based on ANSI/ANS-15.8-1995, “Quality Assurance Program Requirements for Research Reactors,” which is endorsed by Regulatory Guide 2.5, “Quality Assurance Program Requirements for Research and Test Reactors.”

Topical report KP-TR-003-NP-A, “Principal Design Criteria (PDC) for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor,” Revision 1, provides the PDCs for the KP-FHR. Two of the PDCs relevant to metallic materials are: “Reactor Coolant Boundary” (KP-PDC-14), and “Fracture Prevention of Reactor Coolant Boundary” (KP-PDC-31).

Kairos selected Type 316H austenitic stainless steel and its associated weld metal, ER16-8-2, for structural alloys in safety-related portions of the reactors. These materials are among the qualified high temperature materials in the ASME Code, Section III, Division 5. Division 5 provides minimum quality requirements that will result in extremely low probability of excessive leakage, unstable failure propagation or gross rupture. These requirements will satisfy, in part, KP-PDCs 14 and 31. The NRC has endorsed the use of ASME Section III, Division 5 in Regulatory Guide 1.87, “Acceptability of ASME Code, Section III, Division 5, High Temperature Reactors.”

Discussion

While Type 316H stainless steel and its weld metal (ER16-8-2) are ASME Section III, Division 5 qualified, additional weld metal testing is planned because the maximum accident temperature for the power and non-power reactors is predicted to exceed the current code limitations for the weld metal. Environmentally related degradation issues (corrosion, stress corrosion cracking (SCC), etc.) in Flibe[1] must be evaluated to meet the requirements of the code. The staff imposed several limitations and conditions in the safety evaluation to ensure the required data are obtained prior to operation and that a sufficient surveillance and inspection program is implemented.

An extensive program will be completed to extend the operating temperature for Type 316H and its weld metal and to provide for environmental degradation qualification. Environmental/mechanical testing will be conducted in the following areas:

- Corrosion (including general corrosion, crevice corrosion, thermal aging, erosion/wear, and cold leg occlusion)
- Environmentally assisted cracking (including SCC, environmental creep, and corrosion fatigue)
- Degradation of metallurgical properties (including stress relaxation cracking, phase formation embrittlement, and thermal cycling)
- High temperature effects on mechanical properties.

Additionally, potential effects of irradiation will be assessed via a combination of design, testing, and/or a materials surveillance system. The programs outlined in KP-TR-013 are extensive and thorough.

[1] Flibe is a eutectic mixture of LiF and BeF2.

Summary

The Kairos methodology to qualify structural alloys used in safety-related systems is technically sound. The topical report methodology with the limitations and conditions imposed by the staff will ensure that high temperature metallic materials will be code-qualified and able to perform their safety function. The staff SE should be issued.

No response to this letter is required.

Sincerely,

Signed by Rempe, Joy
on 02/15/23

Joy L. Rempe
Chairman

REFERENCES

1. Kairos Power LLC, "Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor," Topical Report KP-TR-013, Revision 4, September 30, 2022 (ML22263A456).

2. Kairos Power LLC, "Principal Design Criteria for the Kairos Power Fluoride-Salt Cooled High-Temperature Reactor," Topical Report KP-TR-003-NP-A, Revision 1, June 12, 2020 (ML20167A174).

3. U.S. Nuclear Regulatory Commission, Draft Safety Evaluation of Metallic Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor (KP-TR-013), Kairos Power, December 21, 2022 (ML23011A104).

4. NUREG-2245, "Technical Review of the 2017 Edition of ASME Code, Section III, Division 5, 'High Temperature Reactors'," August 31, 2021 (ML21223A097).

5. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.87, "Acceptability of ASME Code, Section III, Division 5, High Temperature Reactors," Revision 2, January 2023 (ML22101A263).

6. U.S. Nuclear Regulatory Commission, Regulatory Guide 2.5, "Quality Assurance Program Requirements for Research and Test Reactors," Revision 1, June 2010 (ML093520099).

7. ANSI/ANS-15.8-1995, "Quality Assurance Program Requirements for Research Reactors," American Nuclear Society, La Grange Park, IL, reaffirmed September 2005.

8. American Society of Mechanical Engineers, Rules for Construction of Nuclear Power Plant Components, High Temperature Reactors, Boiler and Pressure Vessel Code, Section III, Division 5, 2017 Edition.

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