UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 25, 2022

MEMORANDUM TO: William Kennedy, Acting Chief
Advanced Reactor Licensing Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

FROM: Samuel Cuadrado, Project Manager
Advanced Reactor Licensing Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Signed by Cuadrado de Jes on 02/25/22

SUBJECT: REPORT ON THE REGULATORY AUDIT OF KAIROS POWER LLC FLIBE THERMOPHYSICAL PROPERTIES

Kairos Power LLC (Kairos) began pre-application discussions with the U.S. Nuclear Regulatory Commission (NRC) staff on their Kairos Power Fluoride-Salt-Cooled, High-Temperature Reactor (KP-FHR) in October 2018. In December of 2020, Kairos announced that the Hermes test reactor would be used to support future development of the KP-FHR, and in early 2021 Kairos' communicated to the NRC staff its plans to submit an application for a construction permit (CP), including a preliminary safety analysis report (PSAR) for the Hermes test reactor. Over the past several years, Kairos has submitted several topical and technical reports that apply to both the Hermes test reactor, as well as the full-scale KP-FHR reactor. The NRC staff conducted an audit to gain a better understanding of Kairos' process to determine that referenced historical data regarding Flibe thermophysical properties is appropriate to use in safety analyses for the Hermes and KP-FHR reactor designs.

The audit plan is provided in the NRC's Agencywide Documents Access and Management System (ADAMS) under Accession No. ML21194A439 and the audit was conducted between the months of August and October 2021. Kairos provided the NRC staff access to the audited documents via its electronic reading room and meetings between the NRC staff and Kairos were held through video conferences.

Project No. 99902069

Enclosure:
Audit Report

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SUBJECT: REPORT ON THE REGULATORY AUDIT OF KAIROS POWER LLC FLIBE THERMOPHYSICAL PROPERTIES DATED: FEBRUARY 25, 2022

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ADAMS Accession Number: ML21364A106 **NRR-106**

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KAIROS POWER, LLC SUMMARY REPORT ON THE REGULATORY AUDIT OF

KAIROS POWER LLC FLIBE THERMOPHYSICAL PROPERTIES

August – October 2021

Project No. 99902069

1.0 BACKGROUND AND PURPOSE

Kairos Power LLC (Kairos) began pre-application discussions with the U.S. Nuclear Regulatory Commission (NRC) staff on their Kairos Power Fluoride-Salt-Cooled, High-Temperature Reactor (KP-FHR) in October 2018. In December of 2020, Kairos announced that the Hermes test reactor would be used to support future development of the KP-FHR. Over the past several years, Kairos has submitted several topical and technical reports that apply to both the Hermes test reactor, as well as the full-scale KP-FHR reactor. As discussed in meetings held on January 27, 2021, and March 3, 2021, Kairos planned to submit an application for a construction permit (CP), including a preliminary safety analysis report (PSAR), for the Hermes test reactor in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic licensing of production and utilization facilities." A key reference in the preliminary safety evaluation was expected to be the Reactor Coolant topical report (KP-TR-005, Revision 1) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20016A486) which provides key thermophysical properties for use in safety analyses. The NRC staff reviewed and approved this topical report subject to Limitations and Conditions (ADAMS Accession No. ML20140A147). One such condition is for Kairos to perform confirmatory analyses to ensure referenced data from the Oak Ridge National Laboratory Molten Salt Reactor Experiment (MSRE) is of appropriate quality and applicable to Kairos reactor designs. As per the Kairos presentation to the NRC staff dated January 27, 2021, it was expected that Kairos will reference this topical report in the PSAR for the Hermes test reactor. A copy of the January 27, 2021, presentation is available in ADAMS under Accession No. ML21021A364. Near the conclusion of this audit, by letter dated September 29, 2021 (ADAMS Accession No. ML21272A375), Kairos submitted the Hermes test reactor CP application and PSAR. The NRC staff accepted the Hermes test reactor CP application by letter dated November 29, 2021 (ADAMS Accession No. ML21319A354) and is currently reviewing the application, including the PSAR. Consistent with its plans, Kairos referenced the NRC staff approved Reactor Coolant topical report in the Hermes test reactor PSAR. This audit allowed the NRC staff to gain a better understanding of Kairos's process to determine that referenced historical data is appropriate to use in the safety analyses for the Hermes and KP-FHR reactor designs.

2.0 AUDIT REGULATORY BASES

The bases for the audit are the regulations in 10 CFR Part 50, Sections 50.34(a), "Preliminary Safety Analysis Report," and 50.35, "Issuance of construction permits."

3.0 AUDIT OBJECTIVES

The NRC staff audited supporting calculations and met with subject matter expert(s) to discuss details of the Kairos data corroboration effort to satisfy Limitations/Conditions from topical report KP-TR-005-P-A, "Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor."

4.0 SCOPE OF THE AUDIT AND AUDIT ACTIVITIES

The audit was conducted between the months of August and October 2021, via the Kairos electronic reading room. The NRC staff conducted the audit in accordance with the Office of Nuclear Reactor Regulation (NRR) Office Instruction NRR-LIC-111, Revision 1 "Regulatory Audits." Members of the audit team, listed below, were selected based on their detailed knowledge of the subject. Audit team members included:

- Alexander Chereskin, Technical Reviewer
- Jeffrey Schmidt, Technical Reviewer
- Boyce Travis, Technical Reviewer
- Odunayo Ayegbusi, Technical Reviewer
- Samuel Cuadrado, Project Manager
- Stewart Magruder, Project Manager

The NRC staff audited the following documents:

- KP-Q02-QAPL-002, "Qualification Methods for Existing (Legacy) Data," Revision 0.
- KP-Q03-QAPL-001, "Quality Assurance Plan for Flibe Thermophysical Properties Data Qualification," Revision 0.
- KP-RPT-000065, "Flibe Thermophysical Properties," Revision 0.
- KP-RPT-000078, "Review of Flibe Thermophysical Property Legacy Data: Density," Revision 0.
- KP-RPT-000079, "Review of Flibe Thermophysical Property Legacy Data: Viscosity," Revision 0.
- KP-RPT-000082, "Review of Flibe Thermophysical Property Legacy Data: Heat Capacity," Revision 0.
- KP-RPT-000083, "Review of Flibe Thermophysical Property Legacy Data: Thermal Conductivity," Revision 0.
- The American Society of Mechanical Engineers, ASME NQA-1-2019, "Quality Assurance Requirements for Nuclear Facility Applications," 2019.

5.0 SUMMARY OF OBSERVATIONS

The NRC staff's summary of observations listed below is based on the notes taken by the NRC staff during the audit. The NRC staff did not acquire any documents during the audit. The NRC staff examined the documents listed above. During this examination NRC staff noted the purpose of the document, identified key inputs and their sources, and noted the key results. In particular, NRC staff noted:

1. In general, the NRC staff believes that the reports reviewed are thorough, well-written, and cover the relevant topics for data corroboration of the specified properties.

2. The NRC staff observed the procedures and analyses listed, and it appears they are generally consistent with the data corroboration process described in Section 402 of Subpart 4.2.3, "Guidance on Qualification of Existing Data," in American Society of Mechanical Engineers (ASME) Code NQA-1-2019.

3. The NRC staff and Kairos discussed how new data that may be generated is considered in this process. It is important to have a process that identifies new data, which may

indicate potential non-conservatisms in the Kairos analyses, evaluates them, and takes corrective actions as needed. It appears that this information will be captured in the Kairos corrective action program to evaluate it, and recommend changes to property correlations, if necessary.

4. The NRC staff and Kairos discussed the impact of salt composition on the thermophysical property correlations. The NRC staff emphasized the importance of verifying the impact of composition on all property correlations and uncertainties even if the expected impact is small.

5. The NRC staff examined the reports provided to ensure the corroborating references covered the applicable range of operating conditions (e.g., temperature and salt composition). It wasn't clear whether all conditions are covered, and the NRC staff noted it is important to ensure conditions are bounded by the referenced data (e.g., minimum temperature).

6. The NRC staff noted that some of the data attributes from corroborating references didn't have strong attributes for certain aspects of the data (e.g., chemical composition of Flibe not analytically verified). The NRC staff discussed these attributes and noted that if there is a weak data attribute the analysis of the property should contain a justification for using data with potentially weak attributes.

7. The NRC staff noted that thermal conductivity had a relatively high uncertainty. It will be important to ensure uncertainties can be bounded by design for the KP-FHR.

8. For multiple analyses the NRC staff noted that theoretical calculations were used. While these may provide value to see if property behavior is as expected, calculations are not mentioned in the NQA-1 data corroboration process. The process relies on use of existing data to confirm correlations.

6.0 EXIT BRIEFING

The NRC staff conducted the audit closeout meeting on October 7, 2021. At the exit briefing the NRC staff reiterated the purpose of the audit and discussed their activities. Additionally, the NRC staff stated that they did not identify areas where additional information would be necessary to support the review.

7.0 REQUESTS FOR ADDITIONAL INFORMATION RESULTING FROM AUDIT

No requests for additional information were generated as a result of this audit.

8.0 OPEN ITEMS AND PROPOSED CLOSURE PATHS

Not applicable. There were no open items or deviations from the audit plan.