



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

December 18, 2019

MEMORANDUM TO: Benjamin G. Beasley, Chief
Advanced Reactor Licensing Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

FROM: Stewart L. Magruder, Senior Project Manager */RA/*
Advanced Reactor Licensing Branch
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Production and Utilization Facilities
Office of Nuclear Reactor Regulation

SUBJECT: REPORT FOR THE REGULATORY AUDIT OF KAIROS POWER
LLC TO SUPPORT PRE-SUBMITTAL INTERACTION ON
INSTRUMENTATION AND CONTROLS DESIGN

Kairos Power LLC (Kairos) began pre-application discussions with the NRC staff on their Kairos Power Fluoride-Salt-Cooled, High-Temperature Reactor (KP-FHR) in October 2018. Over the past year, Kairos has submitted several topical and technical reports and has met with the NRC staff on numerous occasions. During these meetings, Kairos informed the NRC staff that they have begun work on the instrumentation and controls (I&C) portion of their design. This audit allowed the NRC staff to review documents that provide a high-level overview of the Kairos I&C approach.

The audit took place at Kairos' offices in Alameda, CA on October 30, 2019.

Enclosure:
Audit Report

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SUBJECT: REPORT FOR THE REGULATORY AUDIT OF KAIROS POWER LLC TO
SUPPORT PRE-SUBMITTAL INTERACTION ON INSTRUMENTATION AND
CONTROLS DESIGN DATED: DECEMBER 18, 2019

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KAIROS POWER, LLC
SUMMARY REPORT OF AUDIT TO SUPPORT
PRE-SUBMITTAL INTERACTION ON INSTRUMENTATION AND CONTROLS DESIGN
October 30, 2019

1.0 BACKGROUND AND PURPOSE

Kairos Power LLC (Kairos) began pre-application discussions with the NRC staff on their Kairos Power Fluoride-Salt-Cooled, High-Temperature Reactor (KP-FHR) in October 2018. Over the past year, Kairos has submitted several topical and technical reports and has met with the NRC staff on numerous occasions. During these meetings, Kairos informed the NRC staff that they have begun work on the instrumentation and controls (I&C) portion of their design. This audit allowed the NRC staff to review documents that provide a high-level overview of the Kairos I&C approach.

2.0 AUDIT REGULATORY BASES

10 CFR 50.34(a)(3)(i) requires in part that an applicant for a construction permit to build a power reactor provide principal design criteria for the facility. Similar regulatory requirements exist for design certification, combined license, and standard design approvals (10 CFR 52.47(a)(3)(i), 10 CFR 52.79(a)(4)(i), and 10 CFR 52.137(a)(3)(i), respectively).

General Design Criterion (GDC) 13, "Instrumentation and control", requires that instrumentation shall be provided to monitor variables and systems over their anticipated ranges for normal operation, for anticipated operational occurrences, and for accident conditions as appropriate to assure adequate safety, including those variables and systems that can affect the fission process, the integrity of the reactor core, the reactor coolant pressure boundary, and the containment and its associated systems. Appropriate controls shall be provided to maintain these variables and systems within prescribed operating ranges. Although GDC 13 applies only to light water reactor (LWR) designs, the staff expects non-LWR designs to have a similar Principal Design Criteria (PDC). Kairos submitted their proposed PDC in a topical report on July 31, 2019 (ML19212A757).

3.0 AUDIT OBJECTIVES

An early engagement with the applicant on the Kairos I&C design concepts will allow the NRC staff to gain understanding of the automations and credited manual operator actions (if any) needed for safe operation of the plant. As stated in GDC 13, safety function of the I&C systems is to monitor variables and systems over their anticipated ranges (from normal operation to accident conditions) to assure adequate safety through automatic and/or manual controls. Any diversity and defense-in-depth measures being considered for the I&C system design will also be discussed during this audit. Past reviews have shown that such early engagements aid the applicant in providing a thorough and essentially complete I&C system design in their application. Subsequently, this results in a safety-focused, risk-informed and an efficient staff review process.

4.0 SCOPE OF THE AUDIT AND AUDIT ACTIVITIES

The audit was conducted on October 30, 2019 at Kairos' offices in Alameda, CA. 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 I&C designs; their experience supporting previous design reviews; and their knowledge of the regulatory framework regarding new approaches to I&C reviews. Audit team members included:

1. Joseph Ashcraft, Electronics Engineer (NRC)
2. Dinesh Taneja, Senior Electronics Engineer (NRC)
3. Dawnmathews Kalathiveetil, Electronics Engineer (NRC)
4. Benjamin Beasley, Branch Chief (NRC)
5. Stewart Magruder, Senior Project Manager (NRC)

The audit began with introductions and an overview of the KP-FHR design. Next the Kairos engineering team provided a series of presentations on the following topics:

- High level overview of I&C approach for KP-FHR (including overall I&C architecture)
- Reactor Protection System design overview
- Plant Control System design overview
- Health Monitoring System design overview
- Sensor Qualification plan
- Main Control Room concept
- Plan for Licensing Topical Reports and licensing reviews

After the presentations, the NRC staff were given a tour of Kairos' facilities and testing laboratory. Following the tour, an audit exit meeting was conducted. The NRC staff's summary of observations listed below is based on the notes taken by the staff during the audit. The NRC staff did not acquire any documents during the audit.

5.0 SUMMARY OF OBSERVATIONS

Based on the audit objectives, the NRC staff first reviewed the Kairos Power I&C architecture. Kairos provided a presentation of the overall KP-FHR I&C architecture (along with a large size drawing posted on the wall) and discussed the key parts with the NRC staff. Conceptual design for the KP-FHR has a robust non-safety plant control system that would maintain the plant well within the normal operating limits and to potentially prevent abnormal operating occurrences and accident conditions. The KP-FHR I&C architecture also includes a simplified independent safety-related reactor protection system whose main two functions are to (1) scram the plant, and (2) if needed, initiate passive residual heat removal without overcooling. Due to robust control system design the KP-FHR, use of the protection system is anticipated to occur only once during the life of the plant. NRC staff observed that at the I&C architecture level there is adequate independence between the safety and non-safety systems. KP-FHR I&C design also reflects sufficient diversity and defense-in-depth measures. Kairos Power also shared their concepts for using a health monitoring system and algorithms that include onboard diagnostics and constant monitoring of their systems and components. Any faulty system or instrument can thus be immediately identified, and appropriate rectifying measures be taken. To maintain independence between safety and non-safety systems, the conceptual KP-FHR design uses

separate sensors as inputs to the plant control system and reactor protection system. The NRC staff also observed the main control room design concept along with the control capabilities planned for the remote shutdown room.

Kairos Power staff provided the NRC staff with a tour of their testing laboratory facilities. The NRC staff observed several ongoing tests and noted that the tour provided a helpful visual perspective of the Kairos Power design.

Kairos Power's phased project development approach, where they incrementally prove plant design concepts, includes proving of the I&C design concepts in stages. The NRC staff should continue to engage Kairos Power periodically as they finalize the KP-FHR I&C design.