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

December 4, 2023

Mr. Scott Moore
Executive Director
Advisory Committee on Reactor Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: SUMMARY OF KEY DIFFERENCES BETWEEN KAIROS HERMES 1 AND HERMES 2 FACILITY DESIGNS AND REVIEW SCHEDULE FOR KAIROS HERMES 2 CONSTRUCTION PERMIT APPLICATON

Dear Mr. Moore:

By letter dated July 14, 2023, Kairos Power LLC (Kairos) submitted a construction permit (CP) application under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," for the Hermes 2 test reactor facility (Agencywide Documents Access and Management System (ADAMS) Accession No. ML23195A121). Similar to Kairos's proposed Hermes 1 test reactor facility[1], the two-unit Hermes 2 test reactor facility would employ Kairos's fluoride salt-cooled, high temperature reactor (KP-FHR) technology. The Hermes 2 facility would be located on the same site as the proposed Hermes 1 test reactor facility at the East Tennessee Technology Park in Oak Ridge, Tennessee.

The purpose of this letter is to provide the Advisory Committee on Reactor Safeguards (ACRS) staff with an overview of the key differences between Hermes 1 and Hermes 2 and an outline of the U.S. Nuclear Regulatory Commission (NRC) staff's review schedule for the Hermes 2 CP application. The NRC staff expects that this information can be used by the ACRS and its staff to plan for appropriate engagements with the NRC staff regarding the Hermes 2 CP application and related licensing activities.

ACRS engagements related to the KP-FHR technology

The ACRS received an informational subcommittee briefing on the KP-FHR technology on April 21, 2022 (ML22119A253). Over the course of four subcommittee meetings and one full committee meeting, the ACRS also reviewed the NRC staff's evaluation of the Hermes 1 CP application (ML21319A354). Further, the NRC staff and Kairos previously provided presentations to the ACRS regarding seven topical reports (TRs) that support licensing of

[1] The NRC staff issued its safety evaluation for the Kairos Hermes 1 construction permit application in June 2023 (ML23158A265).

Kairos's proposed test and commercial reactors.[2]

Key technical differences between Hermes 1 and Hermes 2

The Hermes 2 facility includes many of the same structures, systems, and components (SSCs) as the Hermes 1 facility and large portions of the Hermes 2 preliminary safety analysis report (PSAR) are identical to the Hermes 1 PSAR. In its Hermes 2 CP application, Kairos highlighted the differences between Hermes 1 and Hermes 2 using blue font in the Hermes 2 PSAR to identify any modified or new text. Kairos also provided a summary of the information that was not transferred from the Hermes 1 PSAR in the generation of the Hermes 2 PSAR (ML23195A132). Based on its previous review of the Hermes 1 CP application and the information provided by Kairos explicitly outlining the differences between Hermes 1 and Hermes 2, the NRC staff's review of the Hermes 2 CP application will focus on these differences.

The proposed Hermes 2 facility includes two test reactors powering a common turbine generator set to produce approximately 20 megawatts electric (MWe). Each Hermes 2 unit would use an intermediate heat transport system (IHTS) to transport heat from the primary coolant salt to a common power generation system (PGS). Each unit would have its own reactor protection system and reactivity controls and no safety-related systems would be shared between the two units. Hermes 2 will have the same core design and safety-related SSCs as Hermes 1. The proposed operational lifetime of Hermes 2 is 11 years, as compared to the 4-year operational lifetime of Hermes 1. This 7-year difference between the two facilities is a key focus area for the NRC staff's review of the Hermes 2 CP application. The NRC staff's review in this area will consider topics such as the impact of an extended operating life on component qualification, monitoring, and integrity.

The Hermes 2 IHTS and PGS are considered to be new systems in the sense that they were not included in the design of the Hermes 1 facility. The IHTS coolant is a eutectic mixture of sodium fluoride and beryllium fluoride (BeNaF). The Hermes 2 PSAR states that BeNaF has similar characteristics to the primary coolant salt (i.e., lithium fluoride and beryllium fluoride salt mixture or Flibe) in that it is thermodynamically stable, compatible with structural materials, and has analogous chemical properties to Flibe. The NRC staff will review supporting documentation to determine whether the IHTS coolant salt is similar to Flibe and to ensure key salt properties are adequate to support IHTS design and safety functions. The IHTS interfaces with the primary coolant through an intermediate heat exchanger (IHX). The Flibe primary coolant is maintained at a higher pressure than the BeNaF intermediate coolant to ensure the composition of the primary coolant system is maintained in the event of an IHX tube failure. There is only one safety-related function associated with the IHTS: providing system pressure relief in the event of a superheater tube leak or rupture event.

Similar to the Hermes 1 design, the proposed design for each Hermes 2 test reactor includes a heat rejection subsystem (HRS). However, the addition of the IHTS made the HRS a secondary heat rejection system for Hermes 2, as opposed to Hermes 1 where the HRS serves as the primary means of heat rejection. The Hermes 2 HRS provides for non-safety-related heat transfer from the reactor coolant system to the atmosphere at low power during plant startup

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[2] To date, the NRC staff has approved 11 TRs submitted by Kairos. Links to approved TRs can be found here: https://www.nrc.gov/reactors/new-reactors/advanced/licensing-activities/pre-application-activities/kairos.html

and normal shutdown conditions. The HRS heat rejection radiator (HRR) serves as the main heat transfer component and is in series with the IHX along the primary coolant flow path. To account for these new heat transfer pathways, Section 13.1.2, “Insertion of Excess Reactivity,” of the Hermes 2 PSAR includes five additional examples of events that could result in an increase in heat removal and reactivity beyond those that were included in the Hermes 1 PSAR.

The PGS is described in PSAR Section 9.9, “Power Generation System,” and includes three distinct subsystems: the steam system, the turbine generator system, and the condensate and feedwater system. The PGS interfaces with the IHTS for each unit and a majority of the PGS is shared by both units. These power conversion systems do not perform safety-related functions. The turbine generator would be located in the turbine building away from safety-related SSCs. As stated in Hermes 2 PSAR Chapter 9, “Auxiliary Systems,” the turbine will be favorably oriented with respect to the reactor building and safety-related SSCs such that it would not be able to strike a safety-related SSC or impair safety functions if a turbine missile is generated.

Hermes 2 also expands the tritium management system (TMS) to add two more functions: tritium capture from argon in the IHTS cover gas and tritium capture from air in the HRR enclosure. As described in Hermes 2 PSAR Section 9.1.3, “Tritium Management System,” tritium is anticipated to permeate through the IHX tubing and into the IHTS coolant during normal operation in the gaseous chemical form of hydrogen-tritium (HT) or tritium-tritium (T_2). Further permeation of tritium beyond the IHTS will be mitigated by collecting tritium in the cover gas after converting the HT/T_2 to tritium fluoride (TF). The conversion of HT/T_2 to TF is accomplished through isotopic exchange reactions with hydrogen fluoride (HF) that is added to the argon cover gas of the intermediate salt vessel (ISV), a component of the IHTS. A tritium capture subsystem in the ISV cover gas then sequesters tritium from the IHTS. As with the IHX, tritium is expected to permeate through the heat transfer surface of the HRR into the surrounding air. During startup and normal shutdown conditions, when the tritium generation rates are relatively low and the heat rejection blower is running, tritium permeation through the HRR will be discharged through the heat removal system as a gaseous effluent. At normal operating power, the tritium generation rate is increased, and the heat rejection blower is secured which isolates the air flow path. During this time, the isolated air within the HRR enclosure will be recirculated through a tritium capture subsystem to allow for mitigation of HRR permeation releases.

The accident analyses described in Hermes 2 PSAR Chapter 13, “Accident Analysis,” are largely the same as those in Chapter 13 of the Hermes 1 PSAR, with additions or changes to account for the differences in the design (e.g., additional heat removal postulated events). Hermes 2 PSAR Chapter 13 also describes a maximum hypothetical accident (MHA) which remains unchanged from that described in Hermes 1 PSAR. The MHA consequences are intended to bound all postulated accidents. Hermes 2 PSAR Table 13.1-1, “Acceptance Criteria for Figures of Merit,” is provided to ensure that the consequences of postulated accidents are bounded by the MHA offsite dose estimates. Although the MHA has not changed from that provided in the Hermes 1 PSAR, KP-TR-022, “Hermes 2 Postulated Event Methodology” (ML23195A131), which supports the PSAR Chapter 13 accident analyses and figures of merit, considers the effects of the Hermes 2 design. The NRC staff will evaluate the acceptability of the MHA for Hermes 2, and the figures of merit, to ensure that it is bounding for the Hermes 2 postulated events as part of its review of the Hermes 2 CP application.

Review schedule

The NRC staff accepted the Hermes 2 CP application for review on September 11, 2023

(ML23233A167). A separate letter outlining the estimated review schedule and resources was issued to Kairos on October 11, 2023 (ML23269A176). Similar to the Hermes 1 CP application safety review, the NRC staff plans to provide the ACRS with draft safety evaluation (SE) chapters on a rolling basis. The Hermes 2 CP application safety review schedule was developed based on the assumption that NRC staff review efforts would be focused primarily on the differences between Hermes 1 and Hermes 2 facility designs, as noted above. The NRC staff expects that similar efficiency gains can be realized for the Hermes 2 environmental review (ER) through the preparation of an environmental assessment (EA). Accordingly, the NRC staff informed the Commission in SECY-23-0080, “Environmental Review Approach for the Kairos Power, LLC, Hermes 2 Construction Permit Application,” (ML23214A164) that it would be preparing an EA as part of the Hermes 2 ER. The EA will be used to determine whether an environmental impact statement is necessary, or a finding of no significant impact is warranted.

Future ACRS engagements

As the Hermes 2 CP application review progresses, the NRC staff will work with the ACRS staff to develop timelines, schedules, and topics for meetings regarding the CP application review. The NRC staff also expects future interactions with the ACRS on (1) the Hermes 1 operating license application and (2) two technical reports that were referenced in the Hermes 1 and Hermes 2 CP applications that will be submitted to the NRC staff for review as TRs in preparation for the Hermes 1 operating license application. The NRC staff appreciates the coordination and looks forward to future interactions with the ACRS as the review progresses.

If you have questions regarding this matter, please contact Seamus Flanagan via email at Seamus.Flanagan@nrc.gov or Michael Orenak via email at Michael.Orenak@nrc.gov.

Sincerely,

Robert M. Taylor

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Robert Taylor, Deputy Director
for New Reactors
Office of Nuclear Reactor Regulation

Docket Nos.: 50-611
50-612

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