From: Samuel Cuadrado de Jesus
Sent: Friday, June 9, 2023 3:11 PM
To: Darrell Gardner; Drew Peebles
Cc: Matthew Hiser; Edward Helvenston; Candace de Messieres; Andrew Proffitt
Subject: General and Accident Analysis Audit Reports-Hermes Construction Permit PSAR (Docket Number 05007513)
Attachments: Kairos Kermes PSAR General Audit Report.pdf; Kairos Hermes PSAR Chapters 4 and 13 Accident Analysis Audit Report.pdf

Dear Darrell and Drew,

Attached are summaries of two audits conducted by U.S. Nuclear Regulatory Commission (NRC) staff (the staff) of the Hermes test reactor accident analysis and general topics from the Preliminary Safety Analysis Report (PSAR). By letter dated September 29, 2021, Kairos Power LLC (Kairos) applied for a construction permit (CP) under Title 10 of the Code of Federal Regulations (10 CFR) Part 50 for its Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes); the application included a preliminary safety analysis report (PSAR) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21272A375).

The attached audit summaries have been redacted to remove proprietary information. The full versions containing proprietary information will be provided to you via secure file sharing and added to non-public ADAMS.

These audits allowed the staff to gain a better understanding of Kairos's PSAR through review and discussion of underlying supporting documentation and aided in assessing the safety of the proposed test reactor. Enhanced understanding and communications provided detailed information to the staff and supported effective and efficient development of information needs. The staff reviewed information through the Kairos Electronic Reading Room (ERR) and held discussions with Kairos staff to understand and resolve questions. In many cases, Kairos updated the Hermes PSAR to resolve items discussed in the audit.

Regards,

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SUMMARY REPORT FOR THE REGULATORY AUDIT OF KAIROS POWER LLC HERMES CONSTRUCTION PERMIT PRELIMINARY SAFETY ANALYSIS REPORT GENERAL AUDIT

February 2022 – February 2023

1.0 BACKGROUND AND PURPOSE

By letter dated September 29, 2021, Kairos Power LLC (Kairos) applied for a construction permit (CP) under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 for its Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes); the application included a preliminary safety analysis report (PSAR) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21272A375). This audit enabled the U.S. Nuclear Regulatory Commission (NRC) staff (the staff) to gain a better understanding of Kairos's PSAR and CP application through review and discussion of underlying supporting documentation. Enhanced understanding and communications supported effective and efficient development of information needs.

2.0 AUDIT REGULATORY BASES

The bases for the audit are the regulations of 10 CFR 50.34, "Contents of applications; technical information," paragraph (a), "Preliminary safety analysis report" and 10 CFR 100.11, "Determination of exclusion area, low population zone, and population center distance."

3.0 AUDIT OBJECTIVES

The primary objective of the audit was to enable a more effective and efficient review of the Hermes PSAR through the staff's review of supporting documentation and discussion with Kairos. Gaining access to underlying documentation and engaging in audit discussions about various aspects of the Hermes design facilitated the staff's understanding of the Hermes CP application and aided in assessing the safety of the proposed test reactor.

4.0 SCOPE OF THE AUDIT AND AUDIT ACTIVITIES

The audit was conducted from February 2022 to February 2023, via the Kairos electronic reading room (ERR). The 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 ofthe subject. Audit team members included:

- Jeff Schmidt, NRR (Senior Reactor Systems Engineer, Lead Technical Reviewer)
- Jason Schaperow, NRR (Senior Reactor Systems Engineer)
- Andrew Bielen, RES (Senior Reactor Systems Engineer)
- Ben Adams, NRR (General Engineer)
- Tuan Le, NRR (Reactor Engineer)
- Meg Audrain, NRR (Materials Engineer)
- Alexander Chereskin, NRR (Materials Engineer)
- Sheila Ray, NRR (Senior Electrical Engineer)
- Vijay K Goel, NRR (Electrical Engineer)

- Amitava Ghosh, NRR (Physical Scientist)
- Jason White, NRR (Meteorologist)
- Suzanne Ani, NMSS (MC&A Physical Scientist)
- Shawn Harwell, NMSS (Financial Analyst)
- Kenneth Mott, NSIR (Emergency Preparedness Specialist)
- Ben Beasley, NRR (Lead Project Manager)
- Edward Helvenston, NRR (Project Manager)
- Sam Cuadrado, NRR (Project Manager)

Prior to the audit, the audit team reviewed the PSAR and defined the range of topics in the audit plan (ML22039A336) to be addressed and focused on during the audit. The following table documents dates that the staff transmitted audit questions and when audit meetings were held:

Audit Questions (ADAMS Accession No.)	Audit Meetings
January 13, 2022 (ML23019A050)	January 26, 2022
April 6, 2022 (ML22096A241)	April 13, 22, 25, and 28, 2022
April 8, 2022 (ML22098A305; ML22098A306; ML22098A082)	May 2, 4, 5, 9, 10, 13, 19, and 25, 2022
April 18, 2022 (ML22108A220; ML22108A293)	June 1, 13, 14, 21, and 28, 2022
April 26, 2022 (ML22117A223; ML22117A224; ML23138A403)	July 15, 26, and 29, 2022
May 2, 2022 (ML22122A032)	August 1, 12, and 29, 2022
May 26, 2022 (ML22152A268)	September 6, 12, 13, and 20, 2022
June 9, 2022 (ML22166A324)	December 16, 2022
June 24, 2022 (ML22175A150)	
July 19, 2022 (ML23150A251)	
July 29, 2022 (ML22224A240)	
August 9, 2022 (ML23138A403)	
September 9, 2022	
December 2, 2022 (ML23005A107)	
December 14, 2022 (ML23006A111)	
January 13, 2023 (ML23019A050)	

The staff reviewed the following documents via the ERR:

- "Engineering Report of Integral Worths-Differential Rod Worths and Control Element Heating"
- "Hot Pebble Factor Methodology for KP-SAM Transient Analysis"
- "Hermes Decay Heat Removal System Design Description"
- "Chemistry Control System (CCS) System Requirements Document"
- "Inert Gas System (IGS) System Requirements Document"
- "Hermes Demonstration Reactor Transient and Safety Analysis Methodology Technical Report"
- Screening effluent calculation information from a collection of analysis code input and output files and related spreadsheets referred to as the "February 11, 2022, Kairos Modeling Archive for the XOQDOQ and GASPAR II inputs and output"

- "Additional Information on the Impact of Thermal Effects on Plume Height" (supporting information providing the basis for the stack parameter values in PSAR Table 11.1-2)
- Information related to the statistical analysis used to address the basis of the construction cost

5.0 SUMMARY OF AUDIT OUTCOME

The staff's audit focused on the review of supporting documents associated with the topics identified in the audit plan and subsequently transmitted questions. The staff reviewed information through the Kairos ERR and held discussions with Kairos staff to understand and resolve questions. In many cases, Kairos updated the Hermes PSAR to resolve items discussed in the audit. The tables below replicate transmitted audit questions and summarizes the resolution of the questions.

Research and Development, and Compliance with the Nuclear Waste Policy Act of 1982 (PSAR Sections 1.3.9 and 1.7)

Question Number	Question	Resolution
1.3.9-1	The staff reviewed PSAR Section 1.3.9 and the Sections of the PSAR referenced therein for research and development and noted that it is not clear when the research and development activities listed in PSAR Section 1.3.9 will be completed. The staff would like to discuss the schedule for completion of research and development for Hermes SSCs prior to or at the completion of Hermes construction to satisfy 10 CFR 50.34(a)(8) which states in part that each application for a construction permit shall include a PSAR with the following information: "An identification of those structures, systems, or components of the facility, if any, which require research and development to confirm the adequacy of their design; and identification and description of the research and development program which will be conducted to resolve any safety questions associated with such structures, systems or components; and a schedule of the research and development program showing that such safety questions will be resolved at or before the latest date stated in the application for completion of construction of the facility."	In a letter dated December 8, 2022, (ML22342B282) Kairos stated that the research and development activities will be completed in advance of the completion of construction and that Enclosure 1 of the Hermes CP application states that the latest date for completion of construction is expected to be December 31, 2026.
1.7-1	The guidance in Section 1.7 of NUREG-1537 Part 1 states in part that: "The applicant should briefly discuss how it meets the requirements of Section 302(b)(1)(B) of the *Nuclear Waste Policy Act* of 1982 (NWPA) for disposal of high-level radioactive wastes and spent nuclear fuel." Based on its review of PSAR Section 1.7 it is not clear how the requirements of the NWPA are being met for the Hermes facility. The staff noted that to be in compliance at the CP stage, Kairos needs to submit documentation showing communications in good faith between Kairos and the Department of Energy to enter into a contract for the disposition of high-level waste and nuclear fuel.	In a letter dated November 15, 2022, (ML23019A360) Kairos provided documentation from the Department of Energy confirming that Kairos is actively and in good faith negotiating on a contract under section 302(b) of the Nuclear Waste Policy Act.

Siting Questions (PSAR Chapter 2; additional questions were included in the General Audit because the Site Characteristics audit was already closed.)

Question Number	Question	Resolution
2.2-6	PSAR Section 2.2.3 references NRC Regulatory Guide (RG) 1.91, Revision 1, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants," dated 1978. However, the staff notes that RG 1.91 was updated as Revision 2, "Evaluations of Explosions Postulated to Occur at Nearby Facilities and on Transportation Routes Near Nuclear Power Plants" (note different title) in 2013. (RG 1.91 was updated again as Revision 3 in November 2021.) Based on how RG 1.91 methodologies are discussed in the PSAR, it is not clear to the staff whether Kairos intended to reference Revision 1, or a later version.	Kairos confirmed by a revision to the PSAR that it is using Revision 2 of RG 1.91.
2.2-7	PSAR Section 2.2.3 references NRC RG 1.78, "Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release." However, the PSAR does not provide a version and it is not clear to the staff which version of this RG Kairos intended to reference.	Kairos confirmed by a revision to the PSAR that it is using Revision 1 of RG 1.78.
2.2-8	PSAR Section 2.2.3 references NRC RG 4.7, "General Site Suitability Criteria for Nuclear Power Stations." However, the PSAR does not provide a version and it is not clear to the staff which version of this RG Kairos intended to reference.	Kairos confirmed by a revision to the PSAR that it is using Revision 3 of RG 4.7.
2.2-9	PSAR Section 2.2, Reference 18, is "SHINE Medical Technologies, LLC, SHINE Medical Isotope Production Facility Preliminary Safety Analysis Report. June 2019." However, the staff notes that the final (NRC-approved) revision of the SHINE PSAR is dated October 2015 (ADAMS Accession No. ML15258A431). Please clarify which revision of the SHINE safety analysis report Kairos intended to reference.	Kairos confirmed that it intended to reference the final (NRC-approved) version of the SHINE PSAR. Kairos revised the Hermes PSAR to correct the date to August 2015 in the references. (The staff notes that the original audit question 2.2-9 included an incorrect October 2015 date for this document.)
2.3-1	PSAR Section 2.3.1.10 states that "Based on the data provided in American Society of Civil Engineers (ASCE) Standard No. 7-10 […], Figure 10.4-2, the specification for calculating the ice load on a structural element is: the 500-year mean recurrence interval of uniform ice thickness due to freezing rain for Roane	Kairos corrected the PSAR to reference Figure 10-2 of the ASCE standard and refer to a 50-year mean recurrence interval. Kairos also revised "1 inch" to "0.75 inches" based on Figure 10-2 of the ASCE standard.

	County is 1 inch with a concurrent 3-second wind gust of 30 mph." However, based on its review of ASCE Standard No. 7-10, the staff notes that the standard does not appear to include a Figure 10.4-2. It is not clear to the staff if Kairos intended instead to reference Figure 10-2 of the ASCE standard, and refer to a 50-year mean recurrence interval.	
Additional Chapter 2 items shared with Kairos (not part of a formal audit question)	The staff noted that: • PSAR Section 2.2.1.3 states the TN-327 and TN-58 intersection lies "approximately 2 miles (1.2 km)" east of the site, and that TN-327 is located "approximately 1 mile (0.6 km)" east of the site. It appears the kilometer conversions are incorrect. • PSAR Section 2.2.3.3, in the "Nearby Facilities" subsection, states that four facilities were evaluated in the Clinch River SSAR and lists four facilities, but then appears to discuss the evaluation of six different facilities in the SSAR. • PSAR Section 2.3.1.6 states "The maximum estimated annual precipitation is in the range of 47-53 inches." However, PSAR Table 2.3-1 uses a label "Normal Annual Rainfall" to describe the values in this range. The word "maximum" in the PSAR Section 2.3.1.6 appears to be an error. • PSAR Section 2.3.1.12 states that the section provides ambient temperature and humidity statistics to establish heat loads for the design of systems including "post-accident containment heat removal systems." This appears to refer to a system that would not be included in the Hermes design. • PSAR Section 2.3.2.6 and PSAR Table 2.3-20 appear to provide slightly different values for the probable maximum precipitation for the proposed Hermes site area.	Kairos corrected these items in the PSAR. As part of the PSAR revisions, Kairos also revised PSAR Section 2.2.3.3 PSAR Table 2.2-1 to clarify the distances between the proposed Hermes site and two nearby water treatment plants. (See PSAR change package Kairos submitted by letter dated February 3, 2023 (ML23034A212).)

Reactor Fuel Questions (PSAR Section 4.2)

Question Number	Question	Resolution
4.2-6	PSAR Table 4.2-1, Fuel Particle Properties, lists the pyrolytic carbon (PyC) Bacon Anisotropy Factor (BAF) values as less than or equal to 1.045 which is outside the range of the approved EPRI topical report, EPRI-AR-1-A (ML20336A052). As stated in the EPRI topical report, Section 4.3.1, "Sufficiently isotropic PyC layers (BAF <= 1.035) are able to perform well out to high fast neutron fluences because the irradiation-induced strains and stresses are relaxed to some extent by irradiation-induced creep." What is the basis for exceeding the EPRI topical report PyC BAF value?	Kairos stated that the higher value will be justified or revised in the final safety analysis report (FSAR) to be consistent with the Advanced Gas Reactor (AGR) program. Kairos maintains that a higher BAF value is not deleterious to TRISO particle performance. Kairos updated the PSAR in response to this audit question to point to typical or nominal values for fuel particle and pebble properties (ML22181B176).
4.2-7	Does the peak SiC temperature given in PSAR Table 4.2-6 include peaking factors (1.8 total in PSAR Table 4.5-4) and conservative boundary conditions (i.e., maximum coolant outlet temperature)?	Kairos stated during the audit that the answer to this question is yes.
4.2-8	KP-TR-018, Section 3.4.2.1 states, there is negligible failures for peak fuel temperatures up to 1600 °C.	Kairos affirmed this statement based on AGR safety case testing.
4.2-8a	Based on PSAR Table 4.2-5, the staff understands the 1600 °C to be the SiC coating layer temperature. Is the staff's understanding correct?	Kairos stated during the audit that the answer to this question is yes.
4.2-8b	Figure 7-15 of Reference 1 (EPRI-AR-1) indicates that SiC failures increase for temperatures above 1600 °C. Therefore, it is unclear to the staff what no incremental transient induced failures up to 1600 °C means. Please provide additional clarification regarding no incremental transient induced failures up to 1600 °C.	Kairos revised the PSAR to state that negligible transient failures above 1600 °C are expected (ML22224A201).
4.2-8c	KP-TR-018, Section 3.4.2.2 discusses two approaches to determine incremental fuel failures, the transient 1600 °C limit and the methodology described in KP-TR-018, Section 4.2 using KP-Bison. PSAR Section 4.2.1 seems to refer only to the KP-Bison methodology where transient induced failures are added to the normal operation in-service failures. Please clarify the intended approach.	Kairos updated KP-TR-018 Section 3.4.2.2 to state that postulated events will use event-specific power distributions and temperatures (ML22224A201).

4.2-8d	In KP-TR-018, Tables A1-1 and A4-3 show no increase in postulated event SiC failures. Do Tables A1-1 and A4-3 use the postulated event temperatures as given by Figures A1-2 and A4-1? If not, what temperatures or assumptions are used?	Kairos stated during the audit that the answer to this question is yes as event-specific temperatures are used instead of maximum hypothetical accident (MHA) values.
4.2-8e	Does Table A4-4 differ from Table A4-3 due to including manufacturing defects (in addition to in-service failures)?	Kairos stated during the audit that the answer to this question is yes.
4.2-9	Are the maximum TRISO temperatures given in KP-TR-018, Figures A1-2 and A4-1 the maximum kernel values? If not, what does the maximum TRISO temperature correspond to?	Kairos stated during the audit that the answer to this question is yes.
4.2-10	The initial maximum TRISO temperature in KP-TR-018, Figure A1-2 is approximately 1030 °C. The SiC temperature given in PSAR Table 4.2-5 is less than 830 °C. Using the kernel to SiC coating layer delta-T of 45 °C from KP-TR-011, Table 3-17, the estimated initial transient temperature would be approximately 875 °C which is well below 1030 °C. Please provide additional information as to why the Figure A1-2 initial maximum TRISO is higher than 875 °C?	Kairos clarified through audit discussions that there are conservatisms in the postulated event figures that increase the maximum event temperature.
4.2-11	On PSAR page 4-8 the peak SiC temp is described as provided in Figure 4.2-6 but the staff believe this should refer to Table 4.2-6.	Kairos updated the PSAR to make this editorial correction.
4.2-12	No confirmatory destructive testing is documented in the PSAR. Review of KP-TR-011, Section 3.9.3, Fuel Pebble Destructive Examination, notes that destructive confirmatory testing for the KP-FHR fuel will be performed. The staff understood that destructive confirmatory testing was being planned for the Hermes fuel. Is destructive testing of the Hermes fuel still planned? If so, why is it not included as confirmatory testing in the PSAR?	Kairos revised KP-TR-011 (ML23089A398) Section 3.9.3, which is referenced in PSAR Section 4.2.1, to clarify that destructive testing on Hermes fuel will be performed as stated in KP-TR-011.
4.2-13	1) Beyond that described in PSAR, Section 4.2.1.1, is there a description of the moderator pebble design? 2) Is there information in a licensing submittal which describe the specific graphite matrix material and end-state attributes of the pebble (e.g., grain size)? 3) Is there a testing program to ensure buoyancy, wear characteristics, crush and impact loading tests (e.g., due to	During the audit Kairos stated that the matrix material and grain size is the same as the outer matrix of a fuel pebble. PSAR Section 4.2.1 was revised to describe the moderator pebble testing (ML22230D047).

	shutdown element insertion) including the effects of irradiation? In short, is a document available for staff audit which has content similar to the fuel qualification topical report and addresses the moderator pebble, or does Kairos plan on evaluating the various failure modes in Chapter 13?	
4.2-14	KP-TR-018, Section 3.4.2.2., TRISO Failure Probability, references Section 4.2. The staff has the following questions: The staff understands the first paragraph to determine the failure fractions of the five states (and the fraction of intact particles) for both pre-transient (high and low temperature profiles) and transient using event specific power and temperatures. Is KP-BISON only used to determine failure fractions (weighing of cohorts) for the MHA or are KP-BISON transient particle releases (failed and intact) also determined for input into the MST?	Kairos stated that the MHA uses assumed values for the coating failure cohorts. The specific Chapter 13 events will use KP-BISON and the event specific releases will be compared to the MHA.
4.2-15	The second paragraph of Section 3.4.2.2 describes an alternative method. The staff takes "assuming MHA fuel temperature profiles" to mean setting the kernel temperature vs time to Figure 2.1 and setting the pebble surface (Tfilm) to a conservative value based on the Flibe MHA temperature profile plus various uncertainties. KP-BISON would be used to determine incremental, transient failure fractions. These KP-BISON determined incremental failure fractions will be bounding if postulated event temperatures stay below the MHA temperature-time curve. These are shown to be negligible to compared to the pre-transient failure fractions.	Kairos deleted this alternative method from KP-TR-018 and is only using KP-BISON with event-specific power distributions and temperatures remained (ML22224A201). Transient incremental failures, if any, will be determined using KP-BISON.

Reactor Vessel and Components Questions (PSAR Sections 3.0, 3.6, 4.1, 4.3, and 4.7)

Question Number	Question	Resolution
3.0-1	The Hermes application has proposed changes from topical report KP-TR-003 for the principal design criteria. The Hermes PSAR identifies that the term safety related is to be substituted for the term safety significant in the PDC developed in KP-TR-003 and that the SSC classification only uses two categories, safety related and non-safety related. Also, the terms abnormal operational occurrence and accident are not used because the frequency of events is not considered in the Hermes licensing methodology, and the term postulated events is used. Based on the phone call with Kairos Power on February 9, 2022, Kairos Power is of the opinion that anything that would be considered as important to safety is classified as safety related. This would adequately address any concerns of having any items unaccounted for in the classification scheme. We would like Kairos to make the statement in the PSAR that with the change in terminology, anything that would be considered as important to safety under a different classification methodology is classified as safety related for the Hermes non-power test reactor.	Kairos stated that it will not include this statement in the PSAR but thinks anything that would have been considered important to safety is classified as safety related.
3.6-1	PSAR Table 3.6-1 lists the "Reactor Vessel System" as safety related. However, the metallic material qualification topical report refers to the vessel as the only safety related metallic component. • The NRC staff requests clarification for which components in the reactor vessel system and internals are safety related. These include the fluidic diode device, reflector support structure, core barrel, top head, and other metallic components within the vessel. • If components other than the vessel are safety related, describe how the proposed testing in the metallic material qualification topical report will bound the conditions experienced (e.g. temperature and fluence) by these other components. For example, the fluidic diode will be in direct contact with the	Kairos stated that all wetted components in the reactor vessel system and internals are considered safety related. In addition, the testing in the metallics topical report will bound the conditions experienced by all metallic safety related components.

	graphite reflector. This can potentially cause increased corrosion rates of stainless steel. Although the metallic material qualification topical report includes graphite in the corrosion tests, it is not clear whether these will be designed to bound this specific part of the design.	
4.1-3	Graphite 1. Has an analysis been done on how graphite dust could impact components? Will there be limits on acceptable amount of dust? 2. Does graphite dust have an impact on graphite/metal interactions such as increased corrosion rates?	Kairos stated that there is no limit on acceptable graphite dust in the coolant and that it doesn't believe additional graphite dust from structural components is a credible source of additional corrosion. Kairos further stated that the testing performed in its graphite topical report (ML23108A317) would be bounding and any necessary in-service action will be addressed by an in-service inspection (ISI) program in the operating license application (OLA).
4.1-4	PSAR Section 4.1.3 mentions a fluidic diode in a bypass flow path to direct coolant to the downcomer region during natural circulation mode. The fluidic diode is identified in section 1.3.9 as component requiring research and development. By regulation (10 CFR50.34(a)(8)), Kairos is required to identify what testing will be done and how and provide a schedule to demonstrate that the safety questions will be answered before the latest date in the application for completion of construction of the facility. Staff has the following questions: • What type of research and development program will be conducted for the fluidic diode? What is the schedule for the research and development program? • What quantity of flow is required through the fluidic diode? • What testing will be completed to demonstrate the fluidic diode in conjunction with the decay heat removal system can provide sufficient heat removal from the system to prevent the core fuel from overheating under all required conditions?	Kairos stated that development and qualification testing for the fluidic diode would be included in their research activities. In addition, the conditions for the diode would be bound by the testing in the metallics topical report. Specific design details would be provided in the OLA.
4.3-4	PSAR Section 4.3.3 describes how the graphite reflector will meet PDC 74 to allow for insertion of reactivity elements. However, this section does not describe how the reflector design will ensure the coolant flow path is maintained during	Request for Additional Information (RAI) Package 350, Question 410 (ML22251A400) provides Kairos's response to this question.

	normal operations and natural circulation (e.g. PDCs 34 and 35). The Kairos graphite qualification topical report states that the reflector supports conformance, in part, to PDCs 34 and 35. Additionally, the PSAR states that the reflector blocks provide a heat sink for the core. • Describe how the design of the graphite reflector meets PDCs 34 and 35 related to maintaining coolant flow path and decay heat removal during natural circulation. • Clarify whether the reflector is needed to perform a safety related heat transfer function and if so, describe which PDC are applicable and how the reflector design meets these PDC.	
4.3-5	In the basis for KP-FHR PDC 14, Kairos stated that "…safety significant components of the reactor coolant boundary will be subject to leakage monitoring." Describe how the plant control system will perform leakage monitoring.	Kairos clarified that the design will have catch basins in the bottom of the reactor vessel. They updated the language in the PSAR to clarify that leakage from coolant carrying systems and the reactor vessel will be monitored (ML22250A680).
4.3-6	PSAR Section 4.3.3 states that coolant purity design limits are established with consideration of chemical attack and fouling to partially meet PDC 31. NUREG-1537 Section 5.2, "Primary Coolant System," states that the primary coolant system should maintain high quality coolant to limit corrosion of fuel cladding, control rods, the vessel, and other essential components. However, purity limits do not appear to be in Chapter 4 or 9 of the PSAR. Additionally, the testing described in the metallic material qualification report does not appear to consider fouling in any tests. Describe how purity limits will be established for the Hermes reactor and whether the limits will consider factors beyond chemical attack of 316H SS.	Kairos clarified that testing from the metallic material qualification program can be used to inform fouling considerations. Kairos also stated that specifications on salt purity will be operating conditions.
4.3-7	PSAR Section 4.3.3 states that no tensile or fracture toughness monitoring and testing programs are necessary to demonstrate compliance with PDC 32 as per the metallic material qualification topical report. However, the referenced topical report does not discuss whether monitoring programs are	Kairos stated that tensile and fracture toughness monitoring is not needed because of their design and low fluence. The NRC staff will confirm this during the OLA review.

	needed as it only discusses qualification testing. Therefore, provide the justification for why tensile or fracture toughness monitoring is not needed to demonstrate compliance with PDC 32.	
4.3-8	Section 4.3.3 states that coupons will be used to confirm irradiation-affected corrosion is non-existent or manageable. Appendix E of the metallic materials qualification topical report states that the non-power test reactor will use coupons to ensure materials performance with both metal and graphite samples exposed. • Will graphite coupons be utilized in Hermes? If so, what properties will these coupons be used to confirm? • Will the metallic coupons be examined for more than just irradiated assisted corrosion?	Kairos stated that metallic coupons will be examined for appropriate degradation based on testing and design and that details will be provided during the OLA. Kairos also stated that graphite coupons will not be used and no monitoring is currently planned. The NRC staff will determine acceptability upon review of the OLA.
4.3-9	Provide documents and/or data that describe vessel design relating to operating temperatures, fluence, and stresses.	Kairos stated that these design details will be provided in the OLA.
4.3-10	Provide piping arrangement and anti-siphon device drawings that show how the anti-siphoning works following a pipe break.	Kairos updated the PSAR to address this question (ML22237A326).
4.3-11	Describe how vessel integrity will be assured through design and monitoring programs. For example, is the vessel designed to be inspected? Will there be a monitoring program for indications in the vessel or in the weld between vessel and bottom head?	Kairos stated that design and in-service monitoring program details will be provided in the OLA. Kairos also stated that it is in the process of developing monitoring technologies for certain areas of the reactor. The NRC staff will determine acceptability of the design and ISI programs during the OLA review.
4.3-12	PSAR Section 3.1.1, "Design Criteria," of the PSAR references document KP-TR-003-NP-A, "Principal Design Criteria for the Kairos Power Fluoride-Salt Cooled, High Temperature Reactor," Revision 1, to provide the principal design criteria for the Hermes test reactor. KP-FHR PDC 32, "Inspection of the reactor coolant boundary," describes requirements to inspect portions of the reactor coolant boundary. The basis for this PDC states that "…the potential for flow blockages/restriction from failed internals (such as graphite reflector blocks) is addressed as part of compliance with PDC 35, 36, and 37, including inspections if appropriate." This indicates that PDCs 35, 36, and	Kairos provided a response to this question in RAI package 339 (ML22243A247).

	37 may be applicable to vessel internals as well as other components in the residual heat removal system. Section 4.3.3 of the PSAR describes how the components in the reactor vessel system meet specific PDC. However, it does not describe how certain components meet PDC 36. Therefore, the staff have the following questions: • It appears that a potential failure of graphite reflector blocks could cause flow blockages or restrictions of the natural circulation flow path. However, PSAR section 4.3.3 does not appear to describe how the graphite reflector design meets PDC 36. Indicate whether vessel internals need to meet PDC 36 and describe how the graphite reflector design allows for periodic inspections to meet PDC 36. • The fluidic diode device described in Section 4.3.3 appears to be safety related. The CP states it is used to establish the flow path for natural circulation but does not appear to describe how it meets PDC 36. Describe how the fluidic diode is designed to meet PDC 36.	
4.3-13	The Reactor Vessel System Requirements Document states that "the reactor vessel shall, where applicable, conform to the requirements of ASME BPVC Section XI, Division 2". PSAR Section 6.3.4 also indicates that Reliability and Integrity Management (RIM) will be used; however it is not mentioned in other sections of the PSAR. Clarify if/how a RIM program will be implemented. Provide the scope of components to be inspected as well as potential locations for inspection.	Kairos updated the PSAR to state that Hermes will not use a RIM program (ML22210A319). Kairos stated they will provide details of their ISI program with the OLA.
4.7-1	Neither Section 4.3 "Reactor Vessel System" nor Section 4.7 "Reactor Vessel Support System" of the Hermes PSAR include design information for load combination methodology. The load combination information is needed to provide reasonable assurance that structures and components will remain intact such that the reactor can be shut down and maintained in a safe condition and that PDC 1 will be satisfied. Additionally, the load combination information will also support PDC 2, "Design Bases for Protection Against Natural Phenomena," and PDC 4,	Kairos updated the PSAR to address this question and provide load combination methodologies in Tables 3.5-1, 4.3-2, and 4.7-1 (ML22259A141).

	"Environmental and Dynamic Effects Design Bases." The NRC staff requests that Kairos include the methodologies of load combination in either Section 4.3 or Section 4.7 of the Hermes PSAR. The methodologies of load combination can be tabulated in a manner similar to Table 3 of RG 1.143 "Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants." Another example may be found in Section 3.4.2.5 (page 3-28) of the SHINE facility PSAR (ML15258A371).	

Thermal-Hydraulic Design Questions (PSAR Section 4.6)

Question Number	Question	Resolution
4.6-1	a) The fluidic diode is identified as a research and development item in PSAR Section 1.3.9. Since the fluidic diode supports a key safety function, the staff needs to determine the feasibility of developing such a device for Hermes. Therefore, the staff is requesting additional information such as existing industry applications or research that would indicate there is reasonable assurance this device can be successfully developed to perform its Hermes safety function. b) In the PSAR, please provide a description of, and schedule for, the research and development program for the fluidic diode, as required by 50.34(a)(8).	Kairos provided additional information on the feasibility of the fluidic diode during audit discussions and revised the PSAR accordingly (ML22258A182). Kairos also provided a supplement confirming the schedule for a research and development program to satisfy 10 CFR 50.34(a)(8) (ML22342B282).
4.6-2	a) Staff has questions about how some of the heat transfer correlations fit together in the Hermes models. i. **[[ ]]** is discussed in KP-TR-017-P, Section 5.3.1, “Porous Media Modeling,” and **[[** 1. In KP-SAM, how do these correlations fit together to calculate the heat transfer from the fuel centerline to the bulk reactor coolant? The staff understands the KP-SAM model calculates core average coolant temperature. **[[** **]]** Is the staff’s understanding correct? To determine the average coolant conditions in KP-	Kairos provided clarifications on correlations used across the Hermes models, including why they were chosen and their consistent use between models. Kairos confirmed that the correlations discussed were consistent across all Hermes models. This discussion helped NRC staff gain a better understanding of the modeling choices made by Kairos.

	SAM how are pebble bed conduction, convection and pressure drop determined? 2. In KP-SAM, is **[[** **]]** the same **[[** **]]** from KP-TR-017-P? 3. In KP-SAM, is the **[[** **]]** used to account for pebble-to-pebble convective heat transfer? 4. In KP-SAM, how is heat transfer to the graphite reflector calculated (i.e radiative, conductive, and convective heat transfer from pebbles and coolant)? ii. Are these correlations in KP-SAM consistent across all Hermes thermal-hydraulic models (i.e., STAR-CCM+)? What modifications are made to the heat transfer correlations in SAM, if any? Please provide justifications for the heat transfer correlations used in KP-SAM, regardless of whether they are different or the same as the correlations in SAM.	
4.6-3	KP-TR-017-P, Section 5.3.1, “Porous Media Modeling,” states **[[** **]]** Is this **[[** **]]** used in all the Hermes models, and what is the justification for choosing it? What other **[[** **]]** if any, are used in the Hermes models, and what are the justifications for choosing them?	Kairos provided clarification and justification for an aspect of the Hermes porous media models. This discussion helped NRC staff gain a better understanding of the modeling choices made by Kairos.
4.6-4	In Section 4.6, “Thermal-hydraulic Design,” please reference discussions on computer codes and evaluation models. Staff would be satisfied with references to KP-TR-017 and KP-TR-018 (e.g., “Thermal-hydraulic computer codes and evaluation models are discussed in KP-TR-017 Sections 4 and 5 and KP-TR-018 Section 4”).	Kairos updated the PSAR to reference the discussion on computer codes and evaluation models (ML22237A326).

Reactor Coolant System Questions (PSAR Chapter 5)

Question Number	Question	Resolution
5.1-1	PSAR Section 5.1.1.5 indicates that auxiliary heating may be needed to prevent coolant freezing in certain areas of the plant where insulation alone may not be adequate. Describe where this auxiliary heating may be needed and whether Flibe freezing may impair the ability of a system, structure, or component (SSC), to perform its safety function. Additionally, describe scenarios in which auxiliary heating may be needed to prevent Flibe from freezing.	Kairos stated that heating is needed in external piping and is not safety related or credited in natural circulation. They also stated that the FSAR will show that freezing in the reactor vessel will not happen due to potential freezing in the primary heat transfer system (PHTS) piping.
5.1-2	What subsystem provides the thermal management function described in Section 5.1.1.3? The reactor auxiliary heating system described in Section 9.1.5.1.2 doesn't appear to include primary heat transfer system (PHTS) components such as the Heat Rejection Radiator (HRR).	Kairos stated that the sub-system in Section 5.1.1.5 is for external to vessel heating. The system in Section 9.1.5.1.2 is for in-vessel heating. There are two systems for heating.
5.1-3	The interface between the primary and intermediate system is now separating Flibe from air. Part of Principal Design Criteria (PDC) 73 states that a single barrier between the systems may be appropriate provided that postulated leakage doesn't result in failure of the safety function of safety related SSCs. Describe how air leakage through the HRR barrier may impact the safety functions of safety related SSCs and whether a single passive barrier is appropriate to meet PDC 73.	Kairos stated that Flibe is not incompatible to air, so PDC 73 is not applicable. Kairos updated the PSAR to incorporate a technical specification to limit the amount of air in the system (PSAR Chapter 14) during steady state operation (ML22049B555). The amount of air ingress will be within the testing envelope of the graphite topical report.
5.1-4	Section 5.1.3 states that significant air ingress is excluded by design basis. How much is 'significant' air ingress in this instance? Additionally, describe how trips of the primary salt pump and air blowers prevents a large quantity of air from reaching the PHTS. Section 5.1.1.3 states that this prevents forced air ingress but doesn't discuss natural convection air ingress. How will the upper bound limit for air in the reactor coolant be determined and measured?	Kairos provided a response to RAI Package 350, Question 410 to address this question (ML22251A400).

5.1-5	Section 5.1.3 states that design features such as trip of the primary salt pumps (PSPs) and air blowers help to meet PDC 33. However, PDC 33 is not cited in Section 5.1.2. Clarify whether this should be added to Section 5.1.2. Additionally, clarify whether the PSPs need to be tripped to maintain reactor coolant inventory in the event of a leak in the reactor coolant boundary, if only the anti-siphon feature is relied upon, or if a combination of both are needed to maintain coolant inventory.	Kairos updated the PSAR to address PDC 33 (ML22062B685).
5.1-6	NUREG-1537 Section 5.2, "Primary Coolant System," states that the primary coolant system should maintain high quality coolant to limit corrosion of fuel cladding, control rods, the vessel, and other essential components. The PSAR does not appear to state the required coolant purity to limit corrosion of SSCs other than the reactor vessel. Describe how coolant purity will be maintained to limit corrosion of SSCs other than the reactor vessel (e.g. TRISO, control rods, pump components).	Kairos clarified that metallic components that will be salt-wetted will be shown to be bound by qualification testing. This discussion provided the NRC staff clarification regarding the existing docketed information. While sufficient for the CP stage, the staff indicated that additional information on this topic may need to be docketed to support an OLA.
5.1-7	Section 5.1.1.1, "Reactor Coolant," states that a description of the reactor coolant can be found in KP-TR-005, "Reactor Coolant for the Kairos Power Fluoride-Salt Cooled High Temperature Reactor." However, the PSAR doesn't appear to state that the LiF to BeF_2 stoichiometry needs to be maintained in order to keep thermophysical properties within appropriate bounds. 10 CFR 50.36(c)(2)(ii)(B), "Criterion 2," states an operating restriction that is an initial condition for a DBE or transient analysis which could challenge integrity of a fission product barrier must be a technical specification (TS). Does Kairos plan to include a proposed TS in the OL to maintain the LiF:BeF_2 ratio for Flibe?	Kairos stated during the audit that reactor coolant will be maintained in an allowable range, as stated in PSAR Section 9.1. In addition, Kairos updated the PSAR (ML22284A156) to add a technical specification in PSAR Chapter 14 on allowable bounds of Flibe chemical composition.
5.1-8	Identify the materials of construction used in the PHTS in order to provide reasonable assurance that no significant galvanic corrosion of safety related SSCs will occur.	Kairos stated that the PHTS will be constructed of austenitic stainless steel, which can help minimize galvanic corrosion of the vessel. The staff will confirm this during the OL review.

5.1-9	Section 5.1.1 states that the PHTS system functions include "Provide for in-service inspection, maintenance and replacement activities". Clarify if this refers to ISI, maintenance and replacement activities for the PHTS or if this statement is referring to support for these activities for safety related systems.	Kairos confirmed that this statement is specific to PHTS system, not a safety related system
5.1-10	Section 5.1.1 states that the PHTS system functions include "Provide capability to drain the PHTS to reduce parasitic heat loss during over-cooling transients". A description of this does not appear to be included in Chapter 5. Provide a description of this capability and the cases when draining would be necessary.	Kairos updated the PSAR to state that this function will not be credited in the safety case (ML22159A360).
5.1-11	Section 5.1.1.3 provides a description of the HRR blower and states that the blower will be tripped concurrent with the primary salt pump to prevent air ingress. However, there is not a description of other potential blower malfunctions. Provide a description of potential malfunctions of the heat rejection subsystem blower and how under/over cooling events could affect the temperature of the Flibe and other system performance.	Kairos stated that the HRR blower does not perform safety related functions and is assumed to fail. The only safety related malfunction would be over-cooling and this is described in technical report KP-TR-018.
5.1-12	How will an appropriate in-service testing program for the active components in the PHTS be determined? Will the in-service inspection program be performed under a reliability and integrity management (RIM) program as discussed in Ch 6.3.4?	Kairos stated that information regarding in-service testing (IST) will be available in the OLA and any components that are determined to have a safety function would be included. The NRC staff will determine acceptability of ISI and IST programs in the OLA review. Kairos indicated that a RIM program will not be used for Hermes.
5.1-13	Section 5.1.1.1 of the Hermes PSAR references topical report KP-TR-005 for a description of the reactor coolant. Limitations and Conditions of that topical report require an applicant to perform work to ensure coolant properties are in the applicant's QA program which Kairos is pursuing (see the regulatory audit summary at ADAMS Accession No. ML21364A106). Provide	Kairos stated that this effort will be completed and described with the OL application. The NRC staff will review results of this effort at that time.

	and discuss the status of the thermophysical property data confirmation for the Flibe coolant.	

Decay Heat Removal System Questions (PSAR Section 6.3)

Question Number	Question	Resolution
6-1	PSAR Chapter 4 was revised to note a maximum design temperature for the reactor vessel of 750 °C. PSAR Section 6.3.3 indicates the DHRS components will be designed to operate up to 800 °C, while PSAR Table 6.3-3 indicates a thimble design temperature of 1500 °F (~816 °C). a. Please confirm on the docket that the design of the DHRS will be consistent with ASME BPVC Section III, Division 5 such that the Chapter 6 DHRS design temperature is consistent with the revision to the reactor vessel temperature in Chapter 4.	Kairos revised the PSAR (ML22353A625) to clarify the DHRS design temperature is consistent with the revision to the reactor vessel temperature in Chapter 4.
6-2	On September 1, 2022, Kairos provided a docketed response (KP-NRC-2209-003, ML22244A235) to an audit question related to the DHRS system, in which Kairos described the plans for DHRS qualification testing. a. In KP-NRC-2209-003, Kairos stated "Qualification testing for the safety-related portion of the DHRS will be defined in a test plan that includes appropriate acceptance criteria and demonstrates the system reliability and adequacy of performance under conditions that simulate the most adverse design basis conditions." While working to complete the SER input for Chapter 6, the staff noted several additional topics related to materials and mechanical performance of the DHRS system that could be addressed through the planned qualification testing: i. Thermal shock effects on material properties and component integrity from stress and thermal cycling during evolution from 550 °C to 100 °C upon DHRS startup at threshold power, ii. Flow-induced vibration effects on DHRS components during evolution from 550 °C to 100 °C upon DHRS startup at threshold power,	Kairos submitted a letter (ML22353A625) to clarify the DHRS design verification process will evaluate thermal shock, flow-induced vibration, and metal fatigue associated with DHRS startup.

	iii. Metal fatigue effects due to repeated stress and thermal cycling during evolutions from 550 °C to 100 °C upon DHRS startup at threshold power. Please address on the docket whether these topics will be addressed by the planned DHRS qualification testing or provide justification why testing is not needed for these items.	

Electrical Power Questions (PSAR Chapter 8)

Question Number	Question	Resolution
8-1	The Preliminary Safety Analysis Report (PSAR), Section 8.1 states that “Owing to the passive design of Hermes, safety related structures, systems, and components (SSCs) do not require electric power to perform safety related functions for a minimum of 72 hours following a design basis event. Therefore, AC power from off-site or backup power sources is not required to mitigate a design basis event.” Clarify whether any normal or backup power will be needed after 72 hours and include any relevant design information to support this clarification.	Power is not relied on for postulated events. A loss of power always results in a trip, as discussed in PSAR Section 8.3.3. No further information was required.
8-2	Please clarify which portions of electric power systems of Hermes (described in Section 8 of PSAR), will be designed and constructed to comply with KP-FHR-PDC-17 and KP-FHR-PDC-18. Further, please specify if the UPS power supplies are required for performing any safety related function for safe shutdown of the plant and to keep the plant in the safe shutdown condition. If power supplies are required for performing any safety related function, please explain whether the individual and collective loss of the power supplies was considered for design basis events, to determine safety significance, and any special treatment of these power supplies. If the UPS is not required to be available, please explain the means to verify the reactor is shutdown.	Hermes conforms PDC-17 because the design does not rely on safety related power. All electric power systems are non-safety. Power supplies will provide shutdown indication, but the indication is not needed for any safety related function so the indication is not safety related. Based on an internal follow-up discussion, the NRC staff concluded that PDC 17 is not applicable; however, an exemption to PDC 17 is not required.
8-3	In PSAR Section 8.2.1.1, the following is stated: “Each UPS provides a highly reliable power supply during normal operations and is automatically configured to provide backup power during a loss of normal electrical power event.” The staff is unclear on the configuration of the UPS as stated above, and as such, please clarify the configuration of the UPS and any connection to the DC batteries for backup power.	Normal power is from the grid and backup power is provided by a diesel generator or combustion gas turbine. The UPS is used to prevent spurious trip when transferring between power supplies. The UPS is used for very short duration (i.e., 20 seconds, as indicated in Figure 8.1-1) to provide power to systems that need power while power transfer occurs. DC power (from batteries) is converted to AC and stepped up to needed

		voltage. This information was sufficient on the use of the UPS.
8-4	In PSAR, Section 8.2.1.2, the following is stated: “AC electrical power is supplied to these cabinets [that require 24 VDC] via UPS to ensure continuous, failure-tolerant DC power during normal operation and for a specified minimum duty cycle following a total loss of AC electrical power.” Please explain the term “failure-tolerant" for the DC power system. Also clarify the minimum duty cycle; whether it is 20 seconds as indicated in PSAR Figure 8.1-1.	The system is tolerant of AC power fluctuations to prevent spurious trip. No additional information is needed regarding “failure-tolerant.” The reference to minimum duty cycle should be changed to maximum duty cycle. The UPS will carry the load for up to 20 seconds. The PSAR was revised to change the duty cycle from minimum to maximum.

Chemistry Control, Inert Gas and Tritium Management System Questions (PSAR Section 9.1)

Question Number	Question	Resolution
9.1-1	Please provide the Chemistry Control System (CCS) design requirements document for audit. The document may answer some of the other questions on Section 9.1.1.	Kairos provided the CCS design requirements document to the staff for review on the ERR.
9.1-2	Will the CCS sample from multiple locations in the Primary Heat Transport System or solely though connections with the Inventory Management System (IMS)?	The response to Request for Confirmation of Information (RCI) 349 (ML22231B228) states that Kairos will demonstrate that the CCS draws a well-mixed representative sample from the coolant in the FSAR.
9.1-3	Will operational limits and required actions for coolant purity be set in the operating license / FSAR?	Kairos clarified that any purity limits not previously stated would be included in the OLA or FSAR. Additionally, times to correct coolant chemistry (i.e., restore conformance to specification) would be included.
9.1-4	Please provide a drawing that shows the location of the CCS in relation to safety related SSCs. This will allow the NRC staff to verify whether potential failures of the CCS will affect safety related SSCs.	Kairos updated the PSAR (ML22160A689) to address PDC 4 and describe how it is met by ensuring appropriate measures to protect safety related systems.
9.1-5	Will a reducing agent be used to control redox potential or will coolant chemistry only be controlled through removing and replacing coolant? It appears that coolant chemistry will be controlled via removing and replacing coolant, however the NRC would like to verify this because additions of reducing agents can alter thermophysical properties of the coolant.	Kairos clarified the PSAR (ML22160A689) to reflect coolant chemistry control is currently conducted via removing and replacing the coolant in order to maintain it within specification.
9.1-6	PDC 70 states that a system shall be provided to maintain purity of the coolant within limits. However, the PSAR states that the CCS is used to monitor the coolant chemistry and the IMS may be used to restore conformance to the Flibe specification. Section 9.1.4 does not state coolant purity control as a function of the IMS. Clarify whether the CCS or IMS is used to maintain coolant purity within specified limits and provide a description of how the system will provide this function.	Kairos clarified the IMS is used to maintain coolant chemistry via removing and replacing Flibe coolant. Therefore, PDC 70 was added to IMS section of the PSAR (ML22160A689). Kairos also clarified the CCS does not interface with the reactor vessel, so any cleaning function (filtering) of the coolant would be through the IMS.
9.1-7	Section 9.1.1.3 states that the CCS will monitor reactor coolant chemistry to ensure the coolant is within specifications	Kairos clarified that graphite dust factors were due to compatibility issues with nitrate salt of the

	described in the reactor coolant topical report, KP-TR-005, or circulating activity technical specification limits. However, this topical report doesn't consider coolant specifications for impurities that may be introduced during operations, or the effect of coolant chemistry on components such as TRISO or control rods. Describe all of the coolant chemistry limits that will be monitored by the CCS.	intermediate coolant system, which is no longer a concern due to the removal of the intermediate coolant system from the design. Kairos clarified there are no other operational limits besides total impurity, circulating activity, and the specification in KP-TR-005.
9.1-8	Please provide the Inert Gas System (IGS) design requirements document for audit.	Kairos provided the IGS design requirements document to the staff for review on the ERR.
9.1-9	It is noted that the IGS is needed to ensure Flibe doesn't freeze in certain areas. How does the IGS achieve this function? If this function is lost and Flibe freezes, does it affect safety functions? Where are the vulnerable areas?	Kairos clarified the IGS prevents Flibe from freezing via gas flow to prevent long term deposits in various components exposed to the IGS such as internals of the RCSS, PSP internals, and pebble extraction machine.
9.1-10	Is the IGS capable of measuring air and moisture content for the cover gas? "Hermes Reactor Vessel System Requirements Document" notes that the IGS is required to remove air and moisture from the vessel prior to coolant loading.	The response to RCI 349 clarifies that the IGS will be able to measure both air and moisture content of the cover gas.
9.1-11	Section 13.1.10.9 states that release of radionuclides from Flibe can be affected by characteristics of the cover gas (e.g. purity of cover gas). How does the design of the IGS ensure assumptions made in Chapter 13 are bounded? Is this through the proposed technical specification to limit radioactive material at risk for release in the cover gas?	Kairos stated there will be a technical specification on IGS circulating activity to ensure release of radionuclides is within analyzed conditions. Although gas flow can affect mass transfer of radionuclides from Flibe, flow across the Flibe surface is restricted by graphite blocks. Kairos stated that the gas flow rate will be monitored to detect anomalies to ensure flow rate doesn't affect radionuclide mass transfer.
9.1-12	Section 9.1.2.4 states that the backup argon system will be periodically checked for leakage. Will other parts of the IGS also be checked for leakage?	Kairos clarified that the entire argon system will be monitored for leakage, not just the backup argon storage tank. This is clarified in the response to RCI 349.
9.1-13	NUREG-1537, Section 9.6 "Cover Gas Control in Closed Primary Coolant Systems," states that the NRC staff should review analyses of potential effects on reactor safety or operation if the characteristics of the gas mixture are changed.	Kairos clarified that the PHSS break bounds the IGS break based on MAR that can be mobilized. Therefore, the effects of changing the gas (i.e., air ingress) would be bounded by events analyzed in

	Has Kairos analyzed the impacts of changing characteristics of the gas mixture on other SSCs? If there is a break in the IGS that causes air ingress, will any safety related SSCs be impacted? For example, has potential air ingress been evaluated for the potential to oxidize TRISO in the Pebble Handling and Storage System? Chapter 13 includes an analysis of a break in the Pebble Handling and Storage System, but it isn't clear whether this bounds the potential for a break elsewhere in the IGS. Is the IGS needed to control pressure for any SSCs that could be affected by a change in the gas?	Chapter 13. Additionally, Kairos clarified that overpressure events are unlikely to have negative effects because the Flibe coolant is an incompressible fluid.
9.1-14	"Inert Gas System System Requirements Document" states that the IGS shall be able to vent cover gas to maintain core cooling. Clarify how venting of the cover gas maintains core cooling and if it is needed to maintain core cooling during a transient or postulated accident. Additionally, is the IGS needed to meet any of the PDC associated with this function?	Kairos clarified that venting of the cover gas is not needed to maintain core cooling or meet any PDC related to core cooling.
9.1-15	Section 4.1.2 of "Inert Gas System System Requirements Document" states the cover gas leak rate shall comply with acceptable contaminant levels allowed and leakage could spread radioactive materials and increase the site boundary dose. Clarify whether the IGS boundary is credited to meet PDCs 16 and/or 60.	Kairos clarified that the IGS is not credited to meet either PDC 16 or 60.
9.1-16	Section 4.1.1 of "Inert Gas System System Requirements Document" states the IGS uses gas pressure as the motive force for transfer of salt to/from the tanks to/from the vessel. If there is a malfunction in the pressure control part of the IGS, are there ways to prevent flow in the wrong direction (e.g. due to a sudden pressure drop)?	During the audit Kairos clarified that the design of the IGS will contain features such as check vales to ensure the gas motive force will not cause flow in the wrong direction.
9.1-17	During the previous audit discussion, Kairos noted that the IGS was analyzed for an overpressure event. Was the IGS analyzed to determine whether a high initial pressure during a postulated event can hinder natural circulation of the salt coolant?	During the audit Kairos clarified that natural circulation takes place below the Flibe free surface and that there is no place in the natural circulation flow path that is occupied by gas at the onset of a transient. Because the siphon is already broken in the event of a pipe break, the salt is only circulating in the vessel.

9.1-18	"Hermes Demonstration Reactor Transient and Safety Analysis Methodology Technical Report" assumes a PHSS hot cell temperature for the PHSS malfunction. Will the IGS have a TS to ensure the PHSS is maintained at the appropriate temperatures assumed for the transient analyses? Additionally, does the IGS need to maintain conditions (e.g. pressure, temperature) to support initial condition assumptions for any other transient analyzed?	In the response to RCI 349 Kairos clarified the IGS isn't needed to control the hot cell temperature during a PHSS malfunction event.
9.1-19	Section 9.1.3 of the PSAR states that the amount of tritium accumulated in the tritium mitigation system will be monitored to ensure that it is below the amount that is assumed to be released from the fuel and coolant included in the maximum hypothetical accident analysis. However, it is not clear how Kairos will assure that this assumption will be met. NUREG-1537 states that, for each auxiliary system, the applicant should provide required technical specifications and their bases, including testing and surveillance. Please explain how Kairos plans to ensure that the amount of tritium accumulated is monitored to ensure this assumption will be met.	Kairos stated that they will have administrative controls based on the amount of accumulated tritium in the tritium capture medium. They will measure upstream and downstream activity levels as well as volumetric flow rate to determine deposition in the tritium capture medium.

Other Auxiliary Systems (PSAR Chapter 9)

Question Number	Question	Resolution
9.2-1	Regarding PSAR Section 9.2.1, the PSAR states "Ventilation exhaust that is discharged to the atmosphere from portions of the Reactor Building (RB) that potentially contain contaminants during normal operation is monitored and utilizes appropriate filtration, including HEPA filters." Is all of the reactor building exhaust monitored and filtered or is there some portion of the reactor building that is not expected to contain contaminants and its exhaust is not monitored and filtered? If there are RBHVAC exhausts that are not monitored and filtered, is there monitoring or other feature to confirm that no contaminants are present?	Kairos stated that the design intent is to monitor all reactor building exhaust. Final details of the RBHVAC design will be provided with the FSAR.
9.2-2	Regarding PSAR Section 9.2, will the RBHVAC have the ability to isolate on a high radiation signal in the system? PSAR Section 11.1.5 and 11.2.2.1 describe monitoring and filtration in the RBHVAC but do not mention any action based on the monitoring. Is monitoring only for recordkeeping or does it contribute to automatic or manual control (contain or confine) of reactor facility atmospheres? If containment or confinement are a function of the RBHVAC, describe the features which serve that function. This response should be provided on the docket to support the finding in the safety evaluation.	Kairos stated that no containment or confinement capability is credited. PSAR Section 13.2.1.1 provides assumptions for the MHA. One assumption is that the entire volume of the reactor building is released. Kairos does expect to have manual isolation capability for maintenance of the system. Details of the design will be provided with FSAR and therefore additional information did not need to be provided on the docket.
9.2-3	Regarding PSAR Section 9.2 and 11.1.5, describe features of the RBHVAC and the reactor building that limit inadvertent or uncontrolled release of airborne radioactive material to areas outside the reactor building, controlled areas, and the environment. This response should be provided on the docket to support the finding in the safety evaluation.	Kairos stated that uncontrolled releases are limited by monitoring, HEPA filters in the flow paths, and the ability to isolate any flow path. Higher radiation areas will be sealed to avoid leakage. Flow from low to high hazard areas will manage radioactive material in controlled areas. High hazard areas will be fully contained within low hazard areas which will limit uncontrolled releases to the environment. Kairos will provide more details with the FSAR and therefore additional information did not need to be provided on the docket.

9.2-4	PSAR Section 9.2.1 states that ventilation flow is from areas of low hazard potential to higher hazard potential. Please confirm that, as part of the RBHVAC design, the reactor cell and PHSS cell are designed such that leakage will be from areas of low hazard potential to higher hazard potential. This response should be provided on the docket to support the finding in the safety evaluation.	Kairos confirmed that the design will cause flow and leakage to go from areas of low hazard to high hazard. The reactor cell and PHSS cell are anticipated to be the high hazard areas. Details of the design will be in the FSAR. Kairos revised PSAR Section 9.2.1 to include leakage in the fourth bullet of RBHVAC functions (ML22178A236).
9.3-1	Section 9.3.3 of the PSAR states that other portions of the PHSS that do not perform a safety function will be either seismically mounted or physically separated to preclude adverse interactions with other safety related SSCs during a design basis earthquake. Which portions of the PHSS do not perform a safety related function?	Kairos stated that the concrete structures associated with the storage bay, pool, and support restraints in the pool are safety related structures to ensure the geometry of the storage area is maintained to preclude an inadvertent criticality during a design basis earthquake. The pebble-extraction-machine trip function is safety related. Other portions of the PHSS are not safety related.
9.3-2	Section 9.3.3 of the PSAR states that the canister interior is designed to handle radiolysis products from spent fuel to ensure the integrity of the canister, seal, and weld precluding release of radionuclides from the canister. What radiolysis products are being referred to? How do the radiolysis products challenge the canister? Does Kairos plan modeling or testing to show canister robustness to radiolysis products?	Kairos stated that residual Flibe on the pebbles can react with moisture (H_2O) in the canister under a radiation field to form HF which can be corrosive to the stainless-steel canister. The detailed design of the canister will be available at the OLA stage and will address this issue.
9.6-1	PSAR Section 9.6 states that the CP application is intended to support applications for 10 CFR Parts 30, 40, and 70 licenses for the Hermes site, as well as the 10 CFR Part 50 CP application. In addition, PSAR Sections 9.6.1, 9.6.2, and 9.6.3 state that special nuclear material, source material, and byproduct material will be managed by compliance with 10 CFR Part 70, 40, and 30 licenses, respectively. The guidance in NUREG-1537, Part 1, Section 9.5, states that 10 CFR Part 50 non-power reactor licenses typically include material that is produced by the reactor or is required to operate the reactor, including byproduct, source, or special nuclear material. Please clarify whether Kairos intends to submit separate license applications for possession and use of radioactive material at	Kairos stated that its current plan is to apply for 10 CFR Part 30, 40, and 70 licenses with CP amendment(s), parallel with an OLA review. Kairos' plan is that possession of Part 30, 40, and 70 materials would eventually be subsumed in a 10 CFR Part 50 OLA. Kairos updated the PSAR (ML22144A397) to clarify PSAR Section 9.6.

	the Hermes site, or whether Kairos intends for all material associated with the Hermes reactor to be possessed under a 10 CFR Part 50 operating license (material under a 10 CFR Part 50 license would still be subject to applicable 10 CFR Part 30, 40, or 70 requirements).	
9.6-2	PSAR Section 9.6.3 states that tritium is present "throughout the primary system, in the secondary coolant, [and] in the graphite core of fuel pebbles." Should the reference to secondary coolant be removed, given that Kairos indicated by letter dated February 18, 2022, that it plans to eliminate the intermediate nitrate salt coolant loop from the Hermes design? (Kairos' letter provided PSAR updates to reflect the elimination of this loop, but did not appear to provide any edits for PSAR Section 9.6.)	Kairos updated the PSAR (ML22144A397)to correct PSAR Section 9.6.
9.7-1	The other water systems in section 9.7 state "The XXXX water system is also not credited with performing safe shutdown functions." Please confirm that the Service Water system will not perform any safe shutdown function.	Kairos confirmed that the Service Water System will not perform any safe shutdown function.
9.7-2	The introduction to PSAR Section 9.7 states that water systems which directly interface with systems containing radioactive material will be designed to meet the requirements of 10 CFR 20.1406. Section 9.7 and the subsections do not state which water systems are expected to interface with systems containing radioactive material. Figure 9.7-1 seems to indicate that only the Component Cooling Water System interfaces with systems containing radioactive material. Confirm that, among the auxiliary water systems, only the Component Cooling Water System will interface with systems that contain radioactive material.	Kairos stated that in the current design, only the Component Cooling Water System interfaces with systems containing radioactive material. If the design changes such that other water systems interface with a system containing radioactive material, the water systems will be designed to meet 10 CFR 20.1406.
9.8-1	Section 9.8.4.4 states that crane design will implement ASME B30.2. Will ASME B30.2 also be implemented for testing, inspection, operator training, operation, and maintenance of the crane and rigging?	Because of the short operating life of Hermes, the determination on the use of ASME B30.2 has not been made. The extent of B30.2 implementation will be provided in the FSAR.
9.8-2	Section 9.8.2 of the PSAR states that temperatures in and around the storage canisters and other SSCs served by the Spent Fuel Cooling System (SFCS) will be monitored and controlled by the plant control system such that the SFCS fans and piping maintain the	Kairos stated that the SFCS maintains the operating temperature in the storage bay. So, in addition to the storage canisters, the SFCS serves the following SSCs in the storage bay:

	temperatures within desired limits. What SSCs does the SFCS serve besides the storage canisters?	concrete structures, storage racks/restraints, and the heat exchanger piping for cooling the spent fuel pool.
9.8-3	PSAR Section 9.8.2 states, “In the event that normal power is not available, the SFCS is capable of passively cooling spent fuel storage canisters.” Please explain how the SFCS would provide cooling to the spent fuel storage canisters if power is lost. Does Kairos intend for the Pebble Handling and Storage System geometry to provide cooling if the SFCS fails to operate due a loss of power?	Kairos stated that the geometry of the system provides cooling via natural circulation of air for canisters outside of the pool and natural circulation of water for canisters in the pool. For the pool, the design target is for the water not to reach boiling for at least 7 days.

Experimental Facilities and Utilization (PSAR Chapter 10)

Question Number	Question	Resolution
10.1-1	PSAR Section 10.1 states that Hermes will not "include special facilities dedicated to the conduct of reactor experiments or experimental programs." However, PSAR Section 10.1 also states that the Hermes reactor vessel will be "equipped with a material surveillance system [MSS] to insert and remove material specimens to assess long term material performance." PSAR Section 4.3.1.1.1 states that the MSS, which is supported by the reactor vessel top head, "provides a remote means to insert and remove material and fuel test specimens into and from the reactor to support testing." PSAR Section 4.3.3 further states that the "MSS uses coupons and components monitoring to confirm that irradiation-affected corrosion is non-existent or manageable." Please clarify the purpose(s) for the MSS, and how it will be used, to help the NRC staff to understand whether the MSS could be an "experimental facility" which should be analyzed based on the guidance in NUREG-1537, Parts 1 and 2, Chapter 10. Will it be solely intended for collecting data to monitor the performance of Hermes SSCs? Or, does Kairos intend to use it for testing and evaluation of, for example, other various material and fuel test specimens that are not necessarily representative of Hermes SSCs? Could the MSS or materials that are placed [in] it affect reactor operation, or result in or contribute to an accident?	Kairos clarified that the MSS is only for collecting inspection and monitoring data for SSCs, and is not an experiment. Kairos stated that any material in the MSS will have its reactivity analyzed, calculated, and ensured to within overall TS limits; separate TSs are not needed as the MSS and any contents are part of the reactor design and not experiments. Kairos' current plan is that the MSS will not be used for irradiation and evaluation of novel fuels or foreign materials; if this plan changes, Kairos would revise PSAR Chapter 10 in an OLA to include appropriate information and analyses. Kairos confirmed that the MSS or materials placed in it would not contribute to an accident or change analyses beyond what is provided in Hermes PSAR Chapters 4 and 13. Kairos stated that it expects that samples would be in the reactor from the beginning (i.e., initial startup) and would stay in; Kairos would only evaluate changes during reactor shutdown. Kairos' plan is that most likely, nothing would be added or replaced over the reactor lifetime. Kairos revised the PSAR to clarify how the MSS will be used by deleting the "fuel test" wording from PSAR Section 4.3.1.1.1 (ML22210A317).

Radiation Protection Program and Waste Management (PSAR Chapter 11)

Question Number	Question	Resolution
11.1-1	Although shielding design details are left to the operating license application, did Kairos develop isotopic values for the sources for preliminary shielding design, including the biological shield described in PSAR Section 4.4? For any other shielding?	Kairos stated that preliminary isotopic data for radionuclide sources in fuel (inside the biological shield) and depleted Flibe (outside the biological shield) has been developed. Additional sources have been estimated for some other areas of the facility. The core design methodology topical report KP-TR-0017 provides information on methodology to develop the radionuclide sources in fuel and Flibe. Detailed evaluation of radiation shielding will be provided in the OLA.
11.1-2	Although shielding design details are left to the operating license application, did Kairos develop preliminary shielding design information (materials, dimensions, shielding effectiveness factors, etc.) for the biological shield described in PSAR Section 4.4? For any other shielding?	Kairos confirmed that preliminary shielding design information, such as preliminary shielding analyses and types of materials, has been developed. For example, they described the use of steel in in the biological shield. The applicant stated that preliminary shielding analysis have been done considering several different materials, but they have not yet made final design selections or bases. Staff asked if the preliminary design included identification of shielding effectiveness factors as a design goal or aid. Kairos stated they did not develop them for the CP application but will provide design details including shielding analyses in the OLA.
11.1-3	Provide the screening effluent calculation for audit, including any supporting calculations.	Kairos provided the staff access to the calculation and supporting information, including the dose analysis code output, on the ERR portal. The staff confirmed the description of the screening effluent calculation and results in the PSAR is accurate and reflects the Kairos calculation.
11.1-3a	Which version of NRCDose (GASPAR, XOQDOQ) was used?	By observation of the information in the ERR, the staff was able to confirm that Kairos used the NRCDose3 computer code for the analysis. Staff noted this is the most recent version of the code.
11.1-3b	Which dose conversion factors were used?	Kairos stated that the analysis used dose conversion factors from ICRP Publication No. 30 (ICRP-30). Staff further confirmed use of the ICRP-30 dose conversion factors in the GASPAR module of NRCDose3 through observation of the code output information in the ERR.
11.1-3c	Please describe other inputs and assumptions.	Kairos provided the staff access to the calculation and supporting information, including the dose analysis code output, on the ERR portal. This information sufficiently provided the other analysis inputs and assumptions and their bases for staff to understand the analysis and confirm that the description in the PSAR is consistent with the analysis.

11.1-4	What is the basis for the stack parameter values in PSAR Table 11.1-2?	Kairos stated that the stack parameter values were assigned as bounding values considering the limitations in the NRCDose3 module XOQDOQ with respect to the input range for plume energy. Kairos provided the staff access on the ERR portal to supporting information providing the basis for the stack parameter values in PSAR Table 11.1-2 considering the modeling of plume rise in XOQDOQ.
11.1-4a	How was the tritium generation rate of 62,500 Ci/yr, which was used in the bounding gaseous effluent tritium emission rate, estimated?	Kairos stated that the tritium generation rate was calculated using the methodology in the approved KP-FHR source term methodology topical report KP-TR-0012-A (ML22136A288).
11.1-4b	What is the basis for the assumed nominal stack height? Is this an effective release height accounting for topography?	Kairos stated that the assumed stack height is an effective release height that is based on a balance of visual and dispersion effects accounting for topography.
11.1-5	Although the PSAR states that tritium is expected to be the dominant routine radionuclide release, what is the potential effect of the other radionuclides in effluents? Will the doses from all the radionuclides in effluents be calculated in detail for the operating license application?	Kairos stated that the screening effluent analysis used information from the Clinch River Early Site Permit application effluent analysis as assumed input for radionuclides other than tritium. The staff confirmed that radionuclides other than tritium were included in the analysis by examination of the GASPAR input on the ERR module. Kairos stated that they plan to only revise the effluent calculation for FSAR if they expect that effluent dose will increase. In addition, the application referred to the response to RCI 12 for the environmental review (ML22115A206) dated April 22, 2022, for further information on the potential effluent releases.
11.1-6	The screening analysis described in PSAR Section 11.1.5 evaluated the consequences of gaseous effluent. What is the basis for not evaluating potential liquid effluent releases? Will liquid effluent consequences be calculated in detail for the operating license application?	Kairos stated that direct liquid effluent releases to the environment are not expected, and any release of liquid to the sanitary sewer system would be done in compliance with 10 CFR 20.2003, or it would be packaged for disposal as low-level radioactive waste.
11.2-1	It is unclear from the description of the Primary Heat Transport System in PSAR Section 5.1, the Inventory Management System in PSAR Section 9.1.5, or the discussion in PSAR Section 11.2.2	Kairos stated that there will be a process to replace Flibe during operation and noted that PSAR Subsection 9.1.1.1 describes that Flibe will be removed and replaced during operation. The PSAR describes that the inventory management system (IMS) removes/solidifies Flibe, while the environmental report (ER) describes storage of used Flibe in

	whether there would be periodic replacement of Flibe during operation. Clarify if there is a process that would result in handling and storage of radioactive Flibe over the operational life of the facility.	canisters in the Reactor Building until decommissioning or sent to disposal if necessary. Staff noted that the combination of information in the PSAR and ER addressed the topic.
11.2-2	Although radwaste system design details are left to the operating license application, did Kairos develop preliminary design information for the handling and storage of radioactive Flibe onsite?	Kairos stated that the preliminary design information can be found in PSAR Subsection 9.1.4, and ER Subsection 2.6.3.1.
11.2-3	Clarify whether there is a plan to periodically replace the Flibe during facility operation.	Kairos confirmed that there will be a process to periodically replace Flibe during the lifetime of the facility.
11.2-3a	Could this [Flibe replacement] be a major contributor to waste and difficult to deal with? If so, are there preliminary plans to address this need?	With regard to onsite handling of the waste Flibe, Kairos stated that their plans are that the Flibe will be solidified to avoid spills and for ease of handling. Kairos noted that PSAR Subsection 9.1.4.1.4 described transfer and solidification of the Flibe.
11.2-3b	Will the radioactive Flibe be disposed of as low-level waste?	Kairos stated that Flibe waste will be low-level waste within bounds of Class C. Kairos also stated that they have preliminary confirmation from a radwaste vendor that the vendor can receive Flibe waste for disposal.
Additional Ch 11 item shared with Kairos (not part of a formal audit question)	Noting that PSAR Subsection 11.1.7 states that the guidance in RG 4.1 and NUREG-1301 are generally relevant in development of environmental monitoring, will the Hermes radiological environmental monitoring program (REMP) include use of an Offsite Dose Calculation Manual (ODCM) and/or will they submit Annual Radiological Environmental Operating Reports?	Kairos stated that they are not committing to have an ODCM or submit Annual Radiological Environmental Operating Reports or any other specific report described in NUREG-1301, “Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors” (ML091050061), at this time, and they are not required by regulation for non-power reactors.

Conduct of Operations (PSAR Chapter 12)

Question Number	Question	Resolution
12.1-1	PSAR Section 12.1.2.8 states, “Radiation Protection has the authority to terminate unsafe activities pending review by management.” The guidance in NUREG-1537, Part 2, Section 12.1, states, “the radiation safety staff should encompass the clear responsibility and authority to interdict or terminate licensed activities that it believes are unsafe. This does not mean that the radiation safety staff possess absolute authority. If facility managers, the review and audit committee, and university or corporate upper management agree, the decision of the radiation safety staff could be overruled. However, the applicant should make clear that this would be a very rare occurrence that would be carefully analyzed and considered.” Please clarify what is meant by “pending review by management.” Does this mean that radiation safety staff would have to wait for management review and approval to terminate any activity? Or that management could subsequently overrule (following appropriate analysis and consideration) the radiation safety staff’s termination of an activity?	Kairos revised PSAR Section 12.1.2.8 to clarify that radiation protection staff can terminate activities and management could subsequently overrule (following appropriate analysis and consideration).
12.1-2	PSAR Section 12.1.4 states that ANSI/ANS-15.4-2007 “is used in the selection and training of personnel as applicable.” The NRC staff notes that there is a more recent version of this standard, ANSI/ANS-15.4-2016. Please clarify whether Kairos intended to refer to the 2007 or 2016 version.	Kairos revised PSAR Section 12.1.4 and the PSAR Chapter 12 references (i.e., PSAR Section 12.12) to reference the 2016 version of the standard.
12.2-1	PSAR Section 12.1.2.2 states that the Hermes Site Executive will be responsible for compliance with an OL and overall management of the Hermes facility. PSAR Section 12.2 states that the Hermes Plant Manager will establish a Review and Audit Committee, and the Plant Manager will ensure that appropriate technical expertise will be available for review and audit activities. PSAR Section 12.1.2.7 states that the Quality Manager, who reports to the Site Executive, is responsible for overseeing review and audit of plant operations by review and audit teams and is responsible for auditing for compliance with regulatory requirements and procedures. PSAR Figure 12.1-1 indicates “Quality Assurance” and “Review/Audit Committee” as separately reporting to the Site Executive. The guidance in NUREG-1537, Part 2, Section 12.2, states that “[review and/or audit] [c]ommitee members should be appointed by the highest level of upper	Kairos clarified that the Site Executive establishes the Review and Audit Committee. Kairos revised the PSAR to remove the statements suggesting that the quality manager and plant manager are responsible for the committee. Kairos also clarified that the Hermes Review and Audit Committee is independent of

	management." Furthermore, ANSI/ANS-15.1-2007, Section 6.2.1, recommends that TSs require that review and/or audit committee members be appointed by Level 1 management (i.e., the highest-level facility management, who is the individual responsible for the facility's license). Please clarify whether the Plant Manager, Quality Manager, or Site Executive will be responsible for appointing members of the Hermes Review and Audit Committee. In addition, please clarify the role of the Quality Manager and the review and audit teams that quality manager oversees; are the reviews and audits the Quality Manager is responsible for separate from those of the Review and Audit Committee discussed in PSAR Section 12.2?	the quality assurance function, and has oversight of it. The audits that are performed by the quality assurance function are separate from those performed by the Review and Audit committee. Kairos further clarified that "Quality Manager" as used in PSAR Chapter 12 and "Quality Assurance" used in PSAR Figure 12.1-1 have equivalent meaning; the figure is just a functional description.
12.2.7-1	As required in Title 10 of the Code of Federal Regulations (10 CFR) Part 50 Appendix E, Section II, "The Preliminary Safety Analysis Report" (PSAR), the PSAR shall describe the site layout and location, consideration of access routes, surrounding population distribution, land use, and jurisdictional boundaries. The guidance contained in NUREG-0849, "Standard Review Plan for the Review and Evaluation of Emergency Plans for Research and Test Reactors" (ADAMS Accession No. ML062190191), Section 1.0, "Introduction," calls for the emergency plan to briefly introduce items such as a description of the reactor facility access routes. The NRC staff was not able to identify reactor facility access route details and features such as site boundaries showing fences, gates, and parking lots on site in the Hermes PSAR, Chapter 12, Appendix A, "Description of the Emergency Plan," or in PSAR Figure 2.1-2," Prominent Features in Site Area," or Figure 2.1-3, "Project Site Area and Zones Associated with the Facility." Additional information is needed to meet the requirement of 10 CFR Part 50, Appendix E, Section II, and address the guidance of NUREG-0849, Section 1.0. Provide additional design descriptions, figures, or electronic copies of the Hermes reactor facility access route details and features.	The PSAR provided sufficient information for Appendix E.II that described the major features of the Hermes reactor site layout and location. During the audit Kairos stated that they will provide additional site details in the FSAR that will follow guidance.

12.2.7-2a	For non-power reactors, the need for compliance with 10 CFR Part 50, Appendix E is determined on a case-by-case basis. Appendix E, Section II.A, requests a description of the onsite and offsite organizations for coping with emergencies and the means for notification, in the event of an emergency, of persons assigned to the emergency organizations. The guidance contained in NUREG-0849, Section 3.0, "Organization and Responsibilities," and ANSI/ANS-15.16, Section 3.3, "Organization and Responsibilities," calls for the emergency plan to describe: • The reactor's emergency organization, including augmentation of the reactor staff to provide assistance for coping with the emergency situation, recovery from the emergency, and maintaining emergency preparedness. • The capability of the emergency organization to function around the clock for a protracted period of time following the initiation of emergencies that have or could have radiological consequences requiring around the clock emergency response. • A block diagram that illustrates the interrelationship of the facility emergency organization to the total emergency response effort. Interfaces between reactor and other onsite emergency organization groups and offsite local support organizations and agencies should be specified. Hermes PSAR, Chapter 12, Appendix A provides very short descriptions of the emergency organization and of the relationship with other support organizations. Please provide additional descriptions and/or figures that will address the guidance above.	The PSAR provided sufficient information for Appendix E.II that described the preliminary Hermes ERO structure and organization. During the audit Kairos stated that they will provide additional ERO organizational details in the FSAR that will follow guidance.
12.2.7-2b	The guidance contained in NUREG-0849, Section 2.0, "Definitions," states that terms that have a special meaning when used in the plan should be defined in the plan and that the emergency plan should include definitions of words or phrases with meanings specific or unique to the plan. Please provide the definitions of the emergency plan terms "normal staff" and "on-shift staff" and their relation to the emergency plan's descriptions of the responsibilities and duties of these emergency response staff members.	Kairos revised the PSAR to remove reference to normal staff (ML22125A270).
12.2.7-2c	The guidance contained in NUREG-0849, Section 3.0, "Organization and Responsibilities," and ANSI/ANS-15.16, Section 3.3, "Organization and	The PSAR provided sufficient information for Appendix E.II

	Responsibilities," calls for the emergency plan to: • Describe the 24-hour on-shift staff positions designated and trained to perform the initial responsibilities for the Emergency Director, Emergency Coordinator, Radiation Safety Officer, and Radiological Assessment Team positions, until these positions are filled by responding emergency personnel. • Describe the lines of succession for the senior individual on-shift if the senior individual on-shift is acting as the ED. • Describe a line of succession for the responsibilities of the Radiation Safety Officer including his/her responsibilities and authority for onsite and offsite dose assessments and recommended protective actions. Hermes PSAR, Chapter 12, Appendix A provides very short descriptions of organizational responsibilities. Please provide additional descriptions that will address the guidance above.	that described the key Hermes ERO personnel and their duties and responsibilities. During audit Kairos stated that they will provide additional ERO position and responsibility details in the FSAR that will follow guidance.
12.2.7-3	For non-power reactors, the need for compliance with 10 CFR Part 50, Appendix E is determined on a case-by-case basis. Appendix E, Section II.B, requests a description of contacts and arrangements made with local, State, and Federal governmental agencies with responsibility for coping with emergencies, including identification of the principal agencies. The guidance contained in NUREG-0849, Section 3.0, and ANSI/ANS-15.16, Section 3.3, calls for the emergency plan to describe the arrangements and agreements, confirmed in writing with local support organizations, to augment and extend the capability of the facility's emergency organization. Hermes PSAR, Chapter 12, Appendix A identifies local support organizations. However, contacts and arrangements with local support organizations that would augment and extend the capability of the facility's emergency organization have not been described. Submit or clarify whether confirmed agreements or letters of arrangements and agreements with local emergency response agencies that would augment and extend the capability of the Hermes facility's emergency organization have been made or would be submitted with the Kairos Hermes operating license application. Also identify any procedures developed for emergency response coordination.	The PSAR provided sufficient information for Appendix E.II that discussed the preliminary planned offsite emergency response support functions of federal, state, county, and local governmental agencies. During the audit Kairos stated that they will provide the documented offsite emergency response arrangements and agreement details in the FSAR that will follow guidance.

12.2.7-4	For non-power reactors, the need for compliance with 10 CFR Part 50, Appendix E is determined on a case-by-case basis. Appendix E, Part II.C, requests a description of protective measures to be taken within the site boundary and within each emergency planning zone to protect health and safety in the event of an accident and the procedures by which these measures are to be carried out (e.g., in the case of an evacuation, who authorizes the evacuation, how the public is to be notified and instructed, how the evacuation is to be carried out) and the expected response of offsite agencies in the event of an emergency. The guidance of NUREG-0849, Section 4.0, "Emergency Classification System," and ANSI/ANS-15.16, Section 3.4, "Emergency Classification System," state that the emergency plan should contain an emergency classification system that is consistent with the NUREG-0849, Section 4.0, planning standard. Please provide the Hermes emergency classification descriptions to address the NUREG-0849, Section 4.0, planning standard guidance or explain why this information is not necessary for a construction permit application.	The PSAR provided sufficient information for Appendix E.II that described and discussed the preliminary Hermes site protective steps and measures. During the audit Kairos stated that they will provide additional details of the site protective measures and the details of the Hermes emergency classification levels in the FSAR that will follow guidance.
12.13-1	While there is no mention of material control and accounting (MC&A) in the PSAR, the PSAR states that Kairos plans to request authorization to possess special nuclear material (SNM) pursuant to 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material". In accordance with 10 CFR 70.22(b), applicants requesting a license to possess SNM must submit a full description of their program for the control and accounting of SNM and show compliance with the applicable requirements in 10 CFR Part 74, "Material Control and Accounting of Special Nuclear Material." Please confirm if Kairos is deferring the description of its MC&A program until an application for a license requesting authorization to possess SNM (e.g., a Hermes operating license application).	Kairos confirmed that it will provide an MC&A plan with a Hermes OLA on other licensing submittal (e.g., a CP amendment) requesting authorization to possess SNM, as appropriate.

Technical Specifications (PSAR Chapter 14; an additional question (subsequently designated 14-1) was previously sent to Kairos by email dated February 3, 2022 (ML22034A991) and discussed in a public meeting on February 9, 2022.)

Question Number	Question	Resolution
14-2	In addition to ANSI/ANS-15.1-2007, will format and content of TS also be generally consistent with guidance in NUREG-1537, Part 1, Appendix 14.1, which clarifies some of what is in 15.1?	Kairos confirmed that the format and content of Hermes TSs will also be generally consistent with guidance in NUREG-1537, Part 1, Appendix 14.1. Following audit discussions, Kairos revised PSAR Table 14.1-1's first row, which provides an introduction to Kairos' list of safety limits (SLs) and Limiting Safety System Settings (LSSSs), to clarify that the list of SLs and LSSSs is a list of the proposed subjects rather than "examples of the proposed subjects," and that the first section of the table only includes SLs and LSSSs, not LCOs (ML22167A190).
14-3	Regarding safety limits: are core exit reactor coolant temperatures and core power more appropriate as LSSSs, versus SLs? Should fuel temperature (along with vessel temperature) be an SL, and should core exit temperature and core power be LSSSs? Should vessel temperature also be an LSSS (this is related/follow-up to question 14-1 that was sent to Kairos on 2/3/22 and discussed in a public meeting on 2/9/22)?	Kairos revised the PSAR (ML22167A190) to state that one of the SLs will be that fuel temperature shall not exceed the upper bound operating range. Kairos stated that reactor vessel surface temperature would remain an SL as currently written in PSAR. Kairos stated that core exit reactor coolant temperature would remain an LSSS in the PSAR. Kairos revised the PSAR (ML22167A190) to remove core power as an SL and make high power flux an LSSS. In addition to the PSAR revisions made in response to this question, Kairos also revised the PSAR (ML22167A190) to add flux rate (i.e., period) and coolant level as probable LSSSs. Kairos stated that it was adding the flux rate LSSS to ensure consistency with the fuel qualification topical report. Kairos stated that vessel temperature is not necessary as an LSSS, because the other LSSSs will ensure that unacceptable vessel temperatures will not be reached. Kairos stated that analyses provided in an OLA will demonstrate this.
14-4	In the proposed safety limits and LSSSs, why are coolant exit and	Kairos stated that Hermes will probably have multiple sensors for these parameters. Kairos stated that whether these LSSS TSs will be one value or

	vessel surface temperatures plural? Does Kairos plan to have multiple SL/LSSS values for these? (also related/follow-up to question 14-1)	multiple values will be determined in an OLA. Kairos revised the PSAR (ML22167A190) to put "(s)" after LSSS core exit reactor coolant temperatures to maintain flexibility about whether this could be one or multiple LSSSs. Kairos also revised the PSAR (ML22167A190) to make references to SL temperatures singular since its current intent is that the fuel and vessel temperature SLs will each be a single value. Kairos also separately noted that it does not consider minimum coolant temperature to be appropriate for an LSSS but it will likely be an additional LCO in an OLA. Regarding the core exit reactor coolant temperatures LSSS, Kairos confirmed that it understands that the outlet plenum may not necessarily have highest coolant temperature; it could potentially be higher in the defueling chute. Kairos confirmed that the exact location, number, and setpoint(s) of coolant temperature monitors will be based on a final thermal-hydraulic analysis in an OLA and will consider that measured location(s) may not necessarily include the highest temperature location.
14-5	What does Kairos mean by having reactor power as an LCO? Would this be a steady-state power limit and the power scram setting (above steady-state) would be an LSSS?	Kairos stated that a reactor power LSSS would likely be set at about 120 percent reactor power, and there would be a separate LCO that is lower than the LSSS. Additional details will be provided in an OLA.
14-6	Regarding reactor core parameters: what about shutdown margin, excess reactivity, and core reactivity (the NRC staff notes that the purpose of a core reactivity limit, and verifying core reactivity, might be to help identify issues like excessive damaged pebbles reducing reactivity)?	Kairos stated that Hermes will either have a comprehensive reactivity limit (which ensures reactivity is in the expected band so operators will know if anything unexpected is happening), or an LCO for PHSS operability written such that it would cover this. For other items in the audit question, Kairos confirmed that Hermes will have these, and this is covered by Kairos' general commitment to ANSI/ANS-15.1 in the PSAR. Additional details will be provided in an OLA.
14-7	Regarding reactor control and safety system LCOs: what about control rods	Kairos confirmed that Hermes will have appropriate LCOs for these items, and these are covered by Kairos' general commitment to ANSI/ANS-15.1 in

	(e.g., LCOs for shutdown and control element operability and insertion ability), and scram channels/functions (e.g., LCOs for high level RPS functionality)?	the PSAR. Additional details will be provided in an OLA. Kairos also revised PSAR Chapter 14 (ML22049B555) to explicitly list reactor protection system operability as a probable LCO as part of its separate secondary loop elimination PSAR update.
14-8	Under coolant systems LCOs in PSAR Table 14.1-1, should “inlet gas system pressure” be “inert gas system pressure”?	Kairos corrected the PSAR (ML22167A190) to “inert.”
14-9	Under Engineered Safety Features (ESF) LCOs, what is meant by having reactor vessel integrity as an LCO? Is reactor vessel integrity (which Kairos says will be measured/determined by design temperature operating limit) more appropriate as SL/LSSS? Also, does Hermes need other LCO TSs on ESFs to capture the “functional containment” concept? Or would these possibly be worked into design features TSs? (also related/follow-up to question 14-1)	Kairos revised the PSAR (ML22167A190) to remove as reactor vessel integrity as an LCO. Kairos stated that TSs related to the reactor vessel will likely be added as Design Features TSs in an OLA. In addition, other functional containment aspects will also be in Design Features TS, as needed (to be provided in an OLA.)
14-10	Is not having TSs on emergency power justified? Confirm that there are no safety related emergency power systems. (related to some questions that will be sent separately for Chapter 8)	Kairos confirmed that there are no safety related emergency power systems, and therefore Hermes will have no TSs on emergency power.
14-11	Is not having TSs on experiments justified? Confirm that Hermes will not have any experimental facilities, and discuss whether there may be any TSs associated with the MSS. (related to question 10.1-1)	Kairos confirmed that Hermes will have no experiments or experiment facilities, so no TSs on this are needed. Kairos stated that any reactivity limits related to the MSS would work into other reactivity TSs they would have. Kairos stated that it does not consider the MSS to need separate TSs because the MSS and coupons it would contain or other monitoring features it would include are considered part of the vessel.

Financial Qualifications (PSAR Chapter 15)

Question Number	Question	Resolution
15.1-1	For the NRC staff to determine the adequacy of Kairos Power's estimated construction costs, additional information is needed on the bases for the overnight capital cost, coolant cost, and fuel costs for initial core. Please provide the bases from which the estimates were derived.	Staff analyzed information placed on the Kairos portal related to the statistical analysis used to address the basis of the construction cost to make its finding and estimate to resolve this question.
15.1-2	What is the equity/grant mix? How much of the DOE award amount is applied to construction? Please identify sources of contingency funds and the amount of contingency funds.	Kairos provided information on the ERR portal resolved this and follow-up questions related to the adequacy of the 2020 valuation confirmation letter and any foreign funding.
15.4-1	Financial information provided with the application does not identify a board of directors. However, Section 15.4 of the Preliminary Safety Analysis Report states, in relevant part, "…the members of Kairos Power's Board are also United States citizens or United States permanent residents…." The regulation at 10 CFR 50.33(d)(3)(ii) requires the submission of the names, addresses and citizenship of directors and principal officers. After consultation with the NRC Office of the General Counsel, staff has determined that more information is needed. Is there a board of directors for Kairos Power LLC? If so, provide the name, address, and citizenship of each Director. Additionally, the names, addresses, and citizenship of the trustees should be provided because their role and influence can be equated to that of directors. Corporate addresses are acceptable.	Kairos provided the appropriate information in the ERR portal and revised the application to address the corporate and FOCD information required by the regulations. The information provided informed the staff's FOCD finding in the safety evaluation.

General

Question Number	Question	Resolution
Gen-1	Hermes PSAR Section 12.9, “Quality Assurance,” states that the Quality Assurance Program Description for Hermes design and construction is based on ANSI/ANS-15.8-1995, “Quality Assurance Programs Requirements for Research Reactors.” However, the PSAR, including in Chapters 3, 4, 6, and 13, indicates that safety related Hermes components, specifically pressure vessels (including the reactor vessel), the reactor vessel internals, core support structures, control and shutdown elements and drive mechanisms, and the decay heat removal system, will be designed and constructed in accordance with ASME Code, Section III, “Rules for Construction of Nuclear Facility Components.” The NRC staff notes that ASME Code, Section III, requires, in part, that components be designed, manufactured, and/or constructed under a Quality Assurance Program meeting 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants.” Recognizing that compliance with 10 CFR Part 50, Appendix B, is not required for non-power reactors such as Hermes, please clarify this apparent discrepancy.	Kairos clarified that it plans to consider ASME Boiler and Pressure Vessel Code (BPVC) Section III guidance in its design, but is not committing to all of the standard, including the QA parts. Kairos stated that, essentially, it is using the technical components (although not necessarily all of them; this will be determined in the OLA) of ASME BPVC Section III, but with ANSI/ANS-15.8 QA instead. Kairos noted that accordingly, it will not be able to apply a “stamp” to its design per ASME BPVC Section III. However, Kairos stated it will have its own “nameplate” it will use instead. (Kairos noted that Tennessee law provides provisions for it to do this for owner-built pressure vessels.) Kairos revised the PSAR (ML22256A299) to reflect this information, including by adding “Note 6” to PSAR Table 3.6-2 to clarify use of Section III.

6.0 EXIT BRIEFING

The staff conducted an audit closeout meeting on February 10, 2023. At the exit briefing the staff reiterated the purpose of the audit and discussed their activities. Additionally, the staff stated that they did not identify areas where additional information would be necessary to support the review.

7.0 ADDITIONAL INFORMATION RESULTING FROM AUDIT

Two RAIs (ML22251A400; ML22243A247) and one RCI (ML22231B228) were generated as a result of this audit. In addition, Kairos voluntarily updated the Hermes PSAR, submitting Revision 2 (ML23055A672) to address several items discussed during the audit.

8.0 OPEN ITEMS AND PROPOSED CLOSURE PATHS

Not applicable. There were no deviations from the audit plan.

SUBJECT: SUMMARY REPORT FOR THE REGULATORY GENERAL AUDIT OF KAIROS POWER LLC HERMES CONSTRUCTION PERMIT PRELIMINARY SAFETY ANALYSIS REPORT
DATED: JUNE 2023

OFFICE	PM: NRR/DANU/UAL1	BC: NRR/DEX/EXHB	BC: NRR/DEX/EEEB
NAME	MHiser	BHayes*	WMorton (SWyman for)*
DATE	5 / 12 /2023	5 / 26 /2023	5 / 26 /2023
OFFICE	BC: NSIR/DPR/RLB	BC: NMSS/DFM/MCAB	NMSS/REFS/FAB
NAME	JQuichocho*	JRubenstone (ESastre for)*	FMiller*
DATE	5 / 16 /2023	5 / 23 /2023	5 / 23 /2023
OFFICE	BC: NRR/DANU/UTB2	BC: NRR/DANU/UAL1	
NAME	Cde Messieres*	AProffitt*	
DATE	06/01/2023	5 / 20 /2023	

*concurred by email

SUMMARY REPORT FOR THE REGULATORY AUDIT OF KAIROS POWER LLC HERMES CONSTRUCTION PERMIT PRELIMINARY SAFETY ANALYSIS REPORT CHAPTERS 4 AND 13 (ACCIDENT ANALYSIS)

February 2022 – October 2022

1.0 BACKGROUND AND PURPOSE

By letter dated September 29, 2021, Kairos Power LLC (Kairos) applied for a construction permit (CP) under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50 "Domestic Licensing of Production and Utilization Facilities" for its Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes); the application included a preliminary safety analysis report (PSAR) (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21272A375). PSAR Chapter 4, "Reactor Description" provides a description of reactor features (e.g., reactor core, reactor vessel and reactor vessel internals, thermal hydraulic design). PSAR Chapter 13, "Accident Analysis," describes the analyses associated with postulated Hermes reactor accidents. Technical report KP-TR-017, "KP-FHR Core Design and Analysis Methodology," (ML21272A383) is referenced in PSAR Chapter 4, including Section 4.5, "Nuclear Design," and KP-TR-018, "Postulated Event Analysis Methodology," (ML21272A384) is referenced in Chapter 13. Because many of the assumptions and inputs used in the analyses in Chapter 13 are derived from Section 4.5 (e.g., reactivity coefficients, shutdown margin) the U.S. Nuclear Regulatory Commission (NRC) staff (the staff) conducted a joint audit of Chapters 4 and 13.

This audit enabled the staff to gain a better understanding of Kairos's PSAR Chapters 4 and 13 through review and discussion of underlying supporting documentation. Enhanced understanding and communications supported effective and efficient development of information needs.

2.0 AUDIT REGULATORY BASES

The bases for the audit are the regulations in:

- 10 CFR 50.34, "Contents of applications; technical information," paragraph (a), "Preliminary safety analysis report."
- 10 CFR 100.11, "Determination of exclusion area, low population zone, and population center distance."

3.0 AUDIT OBJECTIVES

The primary objective of the audit was to enable a more effective and efficient review of PSAR Chapters 4 and 13 through the staff's review and discussion of supporting documentation with Kairos. Gaining access to underlying documentation and engaging in audit discussions about accident analysis and nuclear design facilitated the staff's understanding of the Hermes application and aided in assessing the safety of the proposed test reactor.

4.0 SCOPE OF THE AUDIT AND AUDIT ACTIVITIES

The audit was conducted from February to October 2022, via the Kairos electronic reading room (ERR). The staff conducted the audit in accordance with the Office of Nuclear Reactor

Regulation (NRR) Office Instruction NRR-LIC-111, “Regulatory Audits,” Revision 1.

Members of the audit team, listed below, were selected based on their detailed knowledge of the subject. Audit team members included:

- Jeffrey Schmidt, NRR (Senior Reactor Systems Engineer, Lead Technical Reviewer)
- Ben Adams, NRR (General Engineer)
- Andrew Bielen, RES (Senior Reactor Systems Engineer)
- Alexander Chereskin, NRR (Materials Engineer)
- Michelle Hart, NRR (Senior Reactor Engineer)
- Jason Schaperow, NRR (Senior Reactor Systems Engineer)
- Alexandra Siwy, NRR (Nuclear Engineer)
- Edward Helvenston, NRR (Project Manager)
- Samuel Cuadrado, NRR (Lead Project Manager)

Prior to the audit, the audit team reviewed PSAR Chapters 4 and 13 and defined the range of topics in the audit plan (ML22041B665) to be addressed and focused on during the audit. The following table documents dates that the staff transmitted audit questions and when audit meetings were held:

Audit Questions (ADAMS Accession No.)	**Audit Meetings**
February 28, 2022 (ML23052A213)	March 1, 7; 16, and 30; April 6; May 5; and June 28, 2022
March 10, 2022 (ML23052A213)	March 16 and 30; April 28; May 5; July 7; and August 4, 2022
March 21, 2022 (ML23052A213)	March 28; April 19; May 5, 10; June 14, August 1; and July 8, 2022
April 6, 2022 (ML23052A213)	April 13, 2022
May 4, 2022 (ML23052A213)	May 5, 2022
July 7, 2022 (ML23052A213)	July 7 and August 4, 2022
August 8, 2022 (ML23052A213)	August 26 and September 6, 2022
September 6, 2022 (ML23052A213)	September 12, 2022
September 8, 2022 (ML23052A213; ML22255A236, ML23157A330)	September 12, 2022
September 14, 2022 (ML23157A330)	September 16 and 23, 2022
September 16, 2022 (ML23157A331)	September 20 and 23, 2022
September 26, 2022 (ML23157A330)	September 27, 2022
September 29, 2022 (ML23157A330)	October 4, 2022
October 18, 2022 (ML23157A330)	October 20, 2022

The staff reviewed the following documents via the ERR:

- Hermes PSAR pages indicating changes proposed by Kairos in response to various audit questions
- Hermes maximum hypothetical accident (MHA) calculation, **[[ ]]** “Hermes Maximum Hypothetical Accident Analysis”

- Tritium inventory and release calculation methodology, **[[ ]]** “Tritium Inventory and Release Calculation Methodology for the Maximum Hypothetical Accident and Postulated Events”
- **[[ ]]** technical memorandum re: “Argon-41 Inventories in Reactor System and Resulting Dose”
- **[[ ]]** “Transport and Release of Radionuclides from TRISO Fuel Particles Hand Calculation”
- **[[ ]]** “Hermes Decay Heat Removal System Design Description”
- **[[ ]]** “Performance Predictions for the DHRS During Postulated Event Conditions”
- **[[ ]]** “Engineering Report of Integral Worths-Differential Rod Worths and Control Element Heating”

5.0 SUMMARY OF AUDIT OUTCOME

The staff’s audit focused on the review of supporting documents associated with the scope identified in the audit plan. The staff reviewed information through the Kairos ERR and held discussions with Kairos staff to understand and resolve questions. In many cases, Kairos updated the Hermes PSAR to resolve items discussed in the audit. The table below replicates transmitted audit questions and summarizes the resolution of the questions.

Question Number	Question	Resolution
1	What is the MHA assumed release path? The MHA refers to three releases, (1) Radionuclide Transport in Fuel, (2) Structural radioactive material at risk of release (MAR) Transport from the Structural Materials, and (3) Transport of MAR from Flibe to Gas Space. The structural MAR is understood to be released into the gas space which is released to the reactor building. The Flibe-cover gas interface is also released directly to the reactor building. It's unclear to the staff how the transient fuel release is treated. Is the transient fuel released MAR transported to the Flibe coolant and then released via evaporation at the Flibe-cover gas interface as a function of time?	During the audit, Kairos responded that the staff's understanding is correct and the transient fuel released MAR is transported to the Flibe coolant and then released via evaporation at the Flibe-cover gas interface as a function of time.
2	The term "defective" fuel is used in PSAR Section 13.1.1.1. The staff believes the term defective fuel refers to manufactured defective coating layers and layers which have failed during normal operation as no additional (transient) failures are assumed. Is the staff's interpretation of defective fuel correct? a. Are the manufactured and normal operation in-service defects determined as a function of a specific coating layer failure (e.g., fraction of defect SiC [Silicon carbide] coating	a. Kairos confirmed during the audit that yes, this is the case. b. Kairos indicated during the audit that the staff's understanding is correct and no additional coating failures due to transients are assumed. This is based on engineering judgement; no KP-BISON runs have been performed to support this assumption.

	layer, fraction of defective IpyC [inner pyrolytic carbon] + SiC layers, etc.)? b. The staff believes that no additional coating failures have been assumed to occur due to the transients (events). Is the staff's understanding correct and, if so, have limiting, preliminary KP-BISON analysis been performed to support this assumption? c. How is transient fission product generation of dispersed uranium addressed? If only kernel retention is assumed, how is the equivalent radius "a" determined? d. How are transient intact particle releases addressed?	c. Kairos indicated during the audit that fission products are assumed to be deposited in the Flibe. d. Kairos stated during the audit that these releases are calculated using International Atomic Energy Agency (IAEA) correlations – this is different than the KP-BISON.
3	It's stated that Serpent 2 calculation will be used to determine the fuel MAR inventory. What is the assumption for the core average burnup used to determine the fuel MAR? Is the equilibrium core average burnup used?	Kairos indicated during the audit that this information is available in the MHA calculation posted in the ERR. The MHA calculation of fuel MAR does not assume one core average burnup. Instead, the analysis uses average burnup for **[[ ]]** pebble subgroups - modeled equilibrium core with assumed pebble fuel cycle of **[[ ]]** passes through core with an **[[** **]]** burnup as determined by Serpent 2 **[[ ]]** to

		determine the fuel MAR for that subgroup.
4	A bounding Flibe circulating activity is assumed. How is the bounding Flibe activity determined and what relationship, if any, is there to an applicable technical specification?	The MHA calculation posted in the ERR shows the Flibe circulating activity is an analysis assumption to bound the expected evaporative behavior of radionuclides in the system. PSAR Chapter 14 includes a commitment to include a technical specification (TS) limiting condition for operation (LCO) with respect to the upper bound limit of Flibe circulating activity.
5	Is the assumed 10% Flibe coolant void fraction only due to entrained cover gas? Is that the 10% void fraction used in equation 6 of KP-TR-018?	Kairos indicated during the audit that the staff's understanding is correct, that a conservatively high value of 10% is used to bound the other transients.
6	For the structural material release, how is the associated surface area determined? a. Graphite is a porous material, what is the basis for the surface only area absorption? b. It's the staff understanding that assuming a puff release of tritium from the pebbles is conservative relative to assuming a release as a function of temperature. Is the staff's understanding correct?	a. Kairos indicated during the audit that its modeling assumptions consider the Flibe-facing surface area of graphite geometry of components in the current core design. The graphite is considered to be a perfect adsorber to bound three-dimensional effects **[[** **]]** b. Kairos indicated during the audit that the

	c. Is there an estimate of the structural graphite mass loss due to oxidation? Is this available in a document the staff could audit? d. Clarify the time when the Ar-41 puff release from graphite structures occurs. e. The referenced Mechanistic Source Term (MST) topical report (TR), Section 5, “Evaluating Radionuclide Retention in Graphite Structures,” has a detailed description of tritium retention, but does not describe specifics for Ar-41. The TR states that “Although other activation products and fission products may be absorbed by the graphite reflector structures, they are assumed to be negligible.” Provide bases and justification for the modeling of Ar-41 in structural MAR.	staff’s understanding is correct and a puff release assumption is conservative. c. Kairos indicated during the audit that no oxidation of the structural graphite is assumed in the MHA. Oxidation is only assumed for air ingress transients, and since the MHA does not have air ingress, there is no graphite mass loss. d. Kairos indicated during the audit that Ar-41 is puff released from all the fuel and moderator pebbles and the structural graphite at the start of the event, **[[** **]]** e. Kairos provided additional information (**[[** **]]** technical memorandum re: “Argon-41 Inventories in Reactor System and Resulting Dose”) describing Ar-41 modeling assumptions. The staff notes the methodology described in the technical memo is based on trapping of the argon cover gas in the closed pores of Flibe-wetted graphite surfaces, with subsequent neutron activation. The method uses the known closed pore fraction for the ETU-10

		structural graphite as an assumption for the closed pore fraction for the pebble carbon matrix, which is unknown. f.
7	Are any explicit uncertainties consisted in the MHA radionuclide release determinations? If not, are the consideration of uncertainties included in the other transients (events) to ensure the MHA remains bounding (e.g., Flibe spill analysis)?	Kairos indicated during the audit that explicit uncertainties were not used, but rather conservative bounding assumptions.
8	Does the MHA radiological consequence analysis implement all aspects of the referenced MST TR methodology? Describe any differences from the methodology.	Kairos indicated during the audit that the MHA radiological consequence analysis does have deviations from KP-TR-012, "KP-FHR Mechanistic Source Term Methodology Topical Report" (MST TR) (ML22136A291)The Hermes MHA calculation identifies specific models that reference the MST TR.
9	Verify use of the SNAP/RADTRAD code to calculate radiological consequences, as discussed in the referenced KP-TR-012, "KP-FHR Mechanistic Source Term Methodology Topical Report."	Kairos indicated during the audit that they used SNAP/RADTRAD and the staff verified this in the Hermes MHA calculations.
10	Provide other dose calculation values/verify which values in SNAP/RADTRAD used (e.g., dose conversion factors (DCFs),	Kairos indicated during the audit that there are only one set of default DCFs and breathing rates

	breathing rates).	in SNAP/RADTRAD and the DCFs were taken from Federal Guidance Report (FGR), FGR-11 (U.S. Environmental Protection Agency (EPA), "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," EPA 520/1-88-020, Federal Guidance Report 11, Washington, DC, 1988), and FGR-12 (U.S. EPA, "External Exposure to Radionuclides in Air, Water, and Soil," EPA-402-R-93-081, Federal Guidance Report 12, Washington, DC, 1993). This is also described in the Hermes MHA calculations.
.11	Does the MHA consequence analysis model aerosol deposition in the Reactor Building, as described in the MST TR methodology? If so, considering that the MHA is not a break scenario what is the assumed release height for the Henry Correlation model for aerosol removal in SNAP/RADTRAD?	Kairos indicated during the audit that the Hermes MHA consequence analysis models aerosol deposition in the Reactor Building as described in the MST TR methodology. The model and inputs are also described in the Hermes MHA calculations. The aerosol release height for input to the aerosol deposition correlation is assumed to be from a location slightly above **[[ ]]** the vessel head, considering that any leakage from the intact system would be from the vessel head.

.12	Provide the MHA airborne release fraction (ARF) values to be used as acceptance criteria for certain figures of merit in Table 13.1-1 and describe how the MHA ARFs are determined for this use. Are there pathway-specific release ARFs, and if so, are different pathway-specific values relevant to a specific applicable event?	Kairos indicated during the audit that the MHA ARF values are in the Hermes MHA calculations and the staff verified this. Kairos indicated that no other postulated event ARFs are considered in the CP application.
.13	Clarify whether dose events such as salt spill or PHSS [pebble handling and storage system] event have been performed for the PSAR and compared to the acceptance criteria for the figures of merit in PSAR Table 13.1-1.	Kairos indicated during the audit that other dose events have not been performed for the CP application but will be performed for the operating license (OL) application.
.14	Provide the MHA radiological consequence analysis and supporting calculations for staff audit. Include calculations for transport through each barrier (fuel kernel, pebble, other graphite structures, Flibe, gas space, other sources of MAR).	Kairos provided the requested information by providing the staff access to the Hermes MHA calculation, tritium source calculation method, Ar-41 method memo, and TRISO fuel particle radionuclide transport and release hand calculation.
.15	Provide the initial radionuclide inventory in the fuel, listed per isotope. Describe the assumptions and input used in the calculation.	Kairos provided the requested information in the Hermes MHA calculation.

.16	Provide the isotopic bounding values for the Flibe circulating activity. Describe the methods, assumptions, and input used in the calculation, or if not based on a calculation, provide basis for the bounding Flibe circulating values.	Kairos provided the requested information in the Hermes MHA calculation.
.17	Provide the bounding values for retained tritium and activated argon available for release from the graphite. Describe the methods, assumptions, and input used in the calculations, or if not based on a calculation provide basis for the initial condition values. (Provide calculations for staff audit).	Kairos provided the requested information in the Hermes tritium source calculation method and Ar-41 method memo.
.18	Over the short term (mins) other transient (e.g., loss of forced flow, reactivity insertion) will have a higher system temperature but over the long term (hours) the salt spill analysis should have a higher average fuel and coolant temperatures due to the loss of coolant assuming all other conditions are equal (e.g., decay heat, heat removal). It's not clear if the MHA bounds the salt spill analysis long-term temperature. Please provide additional information to support that determination.	Kairos provided additional information on the docket (ML22243A253) to address this question and confirm that the MHA bounds a salt spill event.
.19	In KP-TR-018, the coefficient for the SMD [Sauter mean diameter] in equation 15 is slightly different than that given in the MST TR. Please clarify which coefficient for the SMD in	Kairos indicated during the audit that the coefficient is intended to be the same in both locations. The slight difference is due to rounding and truncation of decimal places, but the

	equation 15 is the correct one.	difference does not affect the analysis results.
20	In KP-TR-018, page 42 of 97 states, a conservatively low value of the entrainment coefficient E is assumed. Should that be a conservatively high value of E to maximize $Q_{A,sp}$ in equation 17?	Kairos indicated during the audit this is a typo; it should say a conservatively high value. This was corrected in a revision to the Hermes CP application dated September 29, 2022 (ML22272A595).
21	How is the surface area of the spilled Flibe determined by the mass? Is there a surface area to volume assumed to maximize the evaporation release?	Kairos indicated during the audit that the surface area was assumed to be the floor area of the reactor cavity. Also, the releases from the spill pool are dominated by the volatile puff releases and off-gassing and change to evaporation area versus pool volume is not important to longer-term releases.
22	For the same Flibe MAR, which release mechanism aerosol or evaporation is the dominate dose contributor?	Kairos indicated during the audit that the aerosol from spilled salt is a larger dose contributor as compared to evaporation, but noted that both are far outweighed by the volatile and off-gas releases from the vessel.
23	When the surface temperature reaches the freezing	Kairos provided the following reference to support

	temperature diffusion release is assumed to be negligible. Is there data to support this statement?	this statement: Thomas, S., Jackson, J., "Testing to evaluate processes expected to occur during MSR salt spill accidents," ANL/CFCT-21/22, ANL, Argonne, IL, September 22, 2021.
24	Upon a pipe break, air, which now could be pumped, will enter the cover gas space. This will release cover gas radionuclides (should be the same as the MHA) but it will now oxidize the exposed graphite material. Is the graphite area the same as used in the MHA (is this the same area as used in the MHA for structural release)? Is the heat rejection loop pump trip safety-related?	Kairos indicated during the audit that the MHA does not assume oxidized graphite. The spill analysis assumes oxidized graphite for the uncovered areas of the graphite structures and no pebbles are uncovered. The staff noted that no graphite oxidation model was used to support CP analyses. However, Kairos committed to developing a model for the OL application. Kairos indicated during the audit that the pump trip is credited and the trip will be safety related.
25	KP-TR-018, Section 4.5.1, Transient Analysis Methods, seems to indicate vacuum breakers are activated to all allow air to enter to prevent syphoning the Flibe out the break. Previous discussions indicated that the anti-syphoning device was based on the primary pump design. Please clarify the anti-syphoning design features as they will limit the Flibe mass release.	Kairos provided a response during the audit and a PSAR revision (ML22062B684) in response to another staff question that also addressed this question.
26	Please confirm the staff's understanding of releases as modeled	Staff reviewed audit documents and confirmed

	for the MHA and salt spill events: **Release -** Fuel **MHA -** Short and long term defective and intact release modeled. No additional TRISO barrier failures due to transient. **Salt Spill -** No additional release by the fuel.	the MHA uses the methodology in MELCOR and the International Atomic Energy Agency (IAEA)-TECDOC-1645, “High Temperature Gas Cooled Reactor Fuels and Materials,” to model fuel releases as a function of the MHA temperature versus time profile. Kairos will use KP-BISON to determine pre-transient fuel failure fractions but no additional failures are expected as a large temperature increase is not expected.
27	Please confirm the staff’s understanding of releases as modeled for the MHA and salt spill events: **Release -** Cover Gas **MHA -** Radionuclides that enter the cover gas are transported with no holdup to the reactor building. **Salt Spill -** The same as MHA. Radionuclides in the cover gas are assumed to go out the break and into the reactor building.	Kairos confirmed during the audit that the release from the cover gas space is the same for the salt spill as the MHA except the salt spill is expected to have a lower Flibe free-surface temperature.
28	Please confirm the staff’s understanding of releases as modeled for the MHA and salt spill events:	Kairos indicated during the audit that the methodology for bubble burst and the formation of

	Release - Bubble burst (from Flibe circulating activity in reactor vessel) **MHA -** Assumes conservative Flibe aerosol formation and release of circulating activity which is a function of cover gas entrainment. Occurs before transient release from fuel to Flibe. Bounding vessel void fraction of 0.1 assumed to facilitate release of low volatility species. **Salt Spill -** Same as MHA? Assume the initial void fraction and bubble burst assumptions (mass flow rate and particles per bubble volume are the same as MHA).	aerosols from the flibe free surface is the same between the MHA and salt spill analysis.
29	Please confirm the staff's understanding of releases as modeled for the MHA and salt spill events: **Release -** Break/Spill **MHA -** Not assumed **Salt Spill -** Assumed radionuclide release is a function of Flibe aerosol and evaporation from spilled Flibe pool until top surface is solidified. Total mass of Flibe spilled limited by design.	From a combination of reviewing the PSAR and audit discussions the staff determined the MHA does not model a spill. The MHA assumed the spill amount is limited as described in PSAR Table 13.1-1 (e.g., it's a figure of merit with an acceptance criteria). The criteria ensures the spilled salt mass is limited such that the MHA remains bounding. No Flibe water or concrete interactions are assumed.
30	Please confirm the staff's understanding of releases as modeled for the MHA and salt spill events:	From information provided in the audit about the various system heat capacities and the

	Release - Flibe-reactor vessel headspace evaporation (to cover gas) **MHA -** Assumes bounding radionuclide evaporation, driven by conservative MHA temperature curve. Gases and high volatility noble metals in Flibe circulating activity assume instantaneous puff release at beginning of transient. **Salt Spill -** Less as temperatures are based on KP-SAM which are assumed to be less than the MHA bounding values.	percentage of Flibe spilled, the releases from the Flibe free surface are expected to be higher in the MHA due to the use of the higher temperature used in the MHA. From a combination of auditing the MHA analysis and reviewing the PSAR, in both analyses (MHA and salt spill) the gases and highly volatile noble metals are assumed to instantaneous release.
31	Please confirm the staff's understanding of releases as modeled for the MHA and salt spill events: **Release -** Graphite/structural tritium **MHA -** What is the assumed release area and mass? The worst exposed graphite area? If so, what transient yields the highest area? No loss of graphite or pebble carbon matrix due to oxidation. **Salt Spill -** Less than MHA. Only the graphite/structures exposed are assumed? Temps are based on KP-SAM. KP-TR-018 spilled analysis wording does not note a difference between the spilled analysis and MHA.	From reviewing the tritium analysis during the audit, the tritium uptake into the pebbles and graphite structure is based on the generation rate in the Flibe (but not, currently, impurities in the graphite) and transferred via mass transfer correlations into the graphite. The graphite is assumed (conservatively) to absorb all the tritium that is generated (i.e., a perfect absorber). Release from oxidation of structural graphite is considered but the surface area is not known. Kairos indicated the surface area is a design detail that will be considered as part of analyses used to support the Hermes OL. The graphite

	What is mass loss of structural graphite loss due to oxidation? Section 3.4.2.8 of KP-TR-018 refers to pebble mass due to oxidation. The Flibe liquid level is assumed to remain above the active fuel. What location and number of pebbles are anticipated to experience oxidation loss?	testing (as described in KP-TR-014 “Graphite Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor” (ML23108A3170)) will determine a graphite oxidation correlation or determine that an existing one is conservative. The temperature of the graphite which is oxidized will be determined by KP-SAM. No oxidation of the pebbles is assumed in the salt spill analysis as the Flibe stays above the active fuel.
32	Please confirm the staff’s understanding of releases as modeled for the MHA and salt spill events: **Release -** Volatile products from chemical reactions **MHA -** Not modeled **Salt Spill -** Modeled? FOM [Figure of Merit] Acceptance criterion is negligible amount of additional volatile products formed.	Kairos confirmed during the audit that as described in PSAR Table 13.1-1 not volatile species are assumed by chemical interactions with water or concreate.
33	The PHSS break has a unique figure of merit “amount of	Kairos indicated in the audit that the total dose

	materials at risk released," which has the acceptance criterion of "less than limit derived to bound total releases of the postulated event to less than the MHA." What is the limit for the MAR released from the PHSS break analysis, and how is it derived?	from all pathways for the PHSS line break would be shown to be less than the total dose for the MHA, and to see the models in the postulated event methodology technical report (KP-TR-018).
34	Are you modeling releases from pebbles which remain in the PHSS, beyond those assumed to spill (i.e., does the analysis include fuel MAR and tritium releases from all affected pebbles)?	Kairos indicated in the audit that they would clarify the modeling in Section 3.2.2.5 of KP-TR-018.
35	What pebble burnup is assumed or will be assumed for the criticality analysis? Is water or other means of moderation evaluated to preclude criticality (i.e., an optimal moderation criticality calculation for 30 pebbles) or are the transfer lines located in areas designed to preclude additional moderation?	Kairos indicated in the audit that burnup is not credited in the criticality analysis, and that optimal moderation is assumed, which depends on design to exclude water or other moderators.
36	Is there a limit on the initial room temperature such that TRISO temperatures are maintained below 700 C? Is room HVAC needed to maintain an acceptable room temperature vs time? If no HVAC is needed to maintain initial room temperature to maintain the pebble surface temperature below 700 C, is that stated in the PSAR?	Kairos indicated in the audit that the room temperature will be limited and maintained mostly based on other considerations to ensure safety. Kairos had not determined if room temperature was going to be a TS safety limit. Kairos indicated in the audit that HVAC is not credited during the transient, as discussed in PSAR 9.3.3, regarding

		Principal Design Criteria (PDC) 62.
37	Based on the level of detail in the PSAR, the staff is unable to judge if a significant amount of graphite structural material will be uncovered during a transfer line break. Please provide additional details on the expected amount of potentially oxidized structural graphite surface area.	Kairos indicated in the audit that only the structural graphite above the Flibe can be exposed and oxidized and that is less than for the salt spill. Kairos described that for this event the break is above the Flibe liquid level, there is no Flibe spill, and air cannot enter the vessel through the PHSS extraction line. Air from the break can enter the pebble extraction machine and insertion line to enter the vessel head space.
38	Appendix A5 of KP-TR-018, Analysis Results, the following two key assumptions are stated, • Ar-41 this is held up in closed graphite pores is conservatively released in a puff at time zero and, • High volatility noble metals and dissolved gases in the Flibe are conservatively puff released at time zero For the Ar-41 release does the graphite include pebble matrix and structural graphite? For the highly volatile noble metals and dissolved gases does the puff release include the spilled/PHSS as well as in-vessel Flibe?	Kairos indicated in the audit that the Ar-41 release modeling includes all the pebble matrix and structural graphite. For the highly volatile noble metals and dissolved gases, Kairos indicated that there is no release from frozen Flibe at the interface of the pebble handling machine with the Flibe free surface in the vessel (surface inside the tubes).

39	Is a Flibe-concrete interaction, which may generate radionuclide chemical species that have a higher vapor pressure than those which already exist in the Flibe, precluded by design for the PHSS events? Is that stated in either the PSAR or technical report KP-TR-018?	Kairos indicated in the audit that Flibe-concrete interaction will be precluded by design, considering break location. The staff noted that while these interactions are assumed to be precluded by the design, final confirmation of this assumption is dependent on final design as described in the final safety analysis report (FSAR) for the OL application
40	Is a Flibe-water interaction, which may generate radionuclide chemical species that have a higher vapor pressure than those which already exist in the Flibe, precluded by design for a PHSS event? Is that stated in either the PSAR or technical report KP-TR-018? Does this consider a common cause event (e.g., seismic event) induced failure of two non-safety systems (water and Flibe containing)?	Kairos indicated in the audit that Flibe-water interaction will be precluded by design, considering break location. The staff noted that while these interactions are assumed to be precluded by the design, final confirmation of this assumption is dependent on final design as described in the FSAR for the OL application
41	KP-TR-018, Table A5-2, includes activities for selected elements in the graphite matrix with the highest burnup. Is the basis for selecting these based on holdup capability of the graphite matrix?	Kairos indicated during the audit that Table A5-2 activity values are based on a conservative assumption of perfect holdup within the pebble matrix. Kairos further indicated that the limited list of elements in the table were selected as examples for historically important fission products, but the total value in the table includes

		all TRISO-generated radionuclides.
42	It's unclear how the radioactive decay of the accumulated graphite dust is accounted for over the lifetime of the facility. Is the dust accumulated divided into specific quantities based on deposition time and an average decay time per deposition time used to determine the change in concentration?	Kairos indicated during the audit that they are evaluating a lifetime radioactive decay for dust using Equations 28 and 29 in KP-TR-018 (postulated event methodology technical report). They will model a constant dust generation rate over the lifetime of the facility with a continuous analytical solution to model the radioactive decay of accumulated graphite dust.
43	Equation 27 of KP-TR-018 does not seem to include a dust generation from in-core pebble movement. Is this term assumed to be negligible or is there no mechanism to transport in-core dust to the PHSS break location?	Kairos indicated in the audit that because the pebbles are in a Flibe-wetted environment, any graphite dust generated cannot be mobilized to transport to the break location.
44	The accumulated dust may also have some adsorbed tritium. How is the dust tritium release addressed for the PHSS event?	Kairos indicated in the audit that the tritium is retained in the dust and released as aerosol, but the amount is a magnitude smaller than tritium release from the vessel and is therefore trivial.
45	Should words "cut-off" diameter in the last sentence of the first paragraph on page 51 of KP-TR-018 be replaced with the "critical" diameter? The staff understands the cut-off diameter to be the maximum diameter to be considered an aerosol. It's	Kairos indicated in the audit that the cut-off diameter is the critical diameter, that the cut-off diameter determines the aerosol resuspension minimum, and that particles above a 50 micron

	unclear how the critical diameter in equation 32 is determined.	upper limit are not aerosols. Kairos further stated that this information is consistent with the aerosol model in the MELCOR code.
46	The Figures of Merit in PSAR Table 13.1-1 are different than those described in KP-TR-018, Section 3.2.2.5, “Pebble Handling and Storage System Malfunction.” Specifically, a figure of merit for mobilized Flibe and graphite dust released in the PHSS does not appear to be in PSAR Table 13.1-1. Please clarify this discrepancy.	Kairos indicated in the audit that the PSAR PHSS break has a figure of merit for the amount of materials at risk released to ensure that the total dose from all pathways is less than the total MHA dose. Models for the estimation of release from the PHSS break are in KP-TR-018.
47	PSAR Section 13.1.2, “Insertion of Excess Reactivity,” states that the reactor trip occurs as a result of a high flux or high coolant temperature RPS signal. However, the NRC staff was under the impression that the list of RPS signals would also include flux rate, which was a condition to preclude TRISO transient testing. Please confirm whether high flux rate will be an RPS signal.	Kairos indicated during the audit that flux rate is an RPS signal, but it is not modeled in PSAR Chapter 13 currently due to uncertainties at the preliminary design stage.
48	Please explain the assumption described in PSAR Section 13.1.2 and KP-TR-018-P Section 4.5.2.2, “Transient Analysis Methods,” that the limiting reactivity insertion event will be associated with the highest reactivity insertion rate. For example, could a slower transient result in a greater overall	Kairos stated during the audit that the OL application will provide analyses for a range of insertion rates for insertion of excess reactivity scenarios and provided associated changes to KP-TR-018 on the docket (ML22244A248).

	positive reactivity insertion, higher temperatures, or longer time at elevated temperatures? (This might be possible if the transient proceeded at a rate such that the high coolant temperature and high power signals were reached around the same time.)	
49	Please define "limiting reactivity rod worth per length," as described in KP-TR-018-P section 4.5.2.2.	Kairos clarified during the audit that this term refers to the control element with the highest differential rod worth (i.e., the control element expected to provide the highest amount of overpower during the event).
50	Related to PSAR section 13.1.2.1, "Initial Conditions Assumptions," what are the assumed initial positions of the other control elements? Is any uncertainty in control rod position considered?	Kairos stated during the audit that the assumed initial position of the shutdown elements and other control elements is the fully withdrawn position. The current example analysis does not consider control element position uncertainty or deadband. However, it would use a conservative insertion time that would bound the effects of a deadband.
51	In PSAR Section 13.1.2.2, the sentence "the shutdown and control elements are assumed to have sufficient worth to shut down the reactor and maintain long term shutdown" could be misinterpreted to mean that the reactivity worth of the elements	Kairos indicated during the audit that the staff's understanding is correct that the transient analyses will demonstrate the adequacy of the design shutdown and control element worth with

	is arbitrarily defined such that they will fulfill their safety function. This seems contrary to the expectation that the transient analyses should demonstrate the adequacy of the design shutdown and control element worth (appropriately accounting for uncertainties). Please clarify the statement.	appropriate accounting for uncertainties.
52	Please explain the hot channel analysis approach described in KP-TR-018-P Section 4.5.2.2. In particular, why is using a hot channel and one average channel appropriate, and how is it conservative?	Kairos stated that the hot channel factor accounts for both flow maldistributions and power peaking and clarified that there was an error in KP-TR-018, Section 4.5.2.2. Kairos provided changes to KP-TR-018 on the docket (ML22224A199) with the accurate description of the methodology.
53	KP-TR-018-P Section A.1, "Insertion of Excess Reactivity," states that there is "very little change in the Flibe temperature" during the excess reactivity insertion event, and Table 4-4, "Initial conditions for Insertion of Excess Reactivity," shows that Flibe temperature is biased at +3% °C as the initial condition. Would a lower initial average coolant temperature ever be more limiting by delaying the trip on high coolant temperature?	Kairos stated that it is possible that a lower initial average coolant temperature could be more limiting if the reactor tripped on high coolant temperature, but that was not true for the example case. The NRC staff communicated a broader concern that the methodology as written did not indicate that a range of initial conditions and assumptions would be investigated to ensure the most limiting cases would be identified for each postulated event. To address this broader concern

		of how uncertainties and conservative assumptions are handled in transient analyses, Kairos provided changes to KP-TR-018 on the docket (ML22244A248).
53-1	Flibe properties: KP-TR-018, Section 4.5.3.2 states, in part, that the uncertainties in material properties of the Flibe coolant are addressed conservatively for the loss of forced circulation event. a. Are the uncertainties consistent with, or do they bound, the uncertainties in topical report KP-TR-005-P-A, “Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor”? i. If so, can something to that effect be explicitly stated, and KP-TR-005-P-A be referenced in KP-TR-018 and PSAR Chapter 13? b. Are uncertainties in Flibe material properties applied throughout the postulated event methodology/Chapter 13 (not just loss of forced circulation events)? If so, please clarify this in KP-TR-018.	a. Kairos stated during the audit that the uncertainties will at a minimum be consistent with KP-TR-005-P-A. Kairos is focused on uncertainties for the Flibe properties that would affect the outcome of the analysis. i. Kairos indicated it would consider referencing KP-TR-005-P-A in KP-TR-018 and PSAR Chapter 13 but would need to evaluate implications of linking the references. Ultimately Kairos elected not to make reference updates. b. Kairos modified KP-TR-018 to address this and other audit questions (ML22244A248). These modifications included creating a new Table 4-4, “Input Parameters Considered for Postulated Events,” that indicates material properties will be ranged with consideration of uncertainties, such that “Uncertainty in material properties for coolant

	c. Have the most conservative Flibe material properties been assumed for the example calculations in Appendix A?	and structures treated on an event specific basis." c. Kairos stated during the audit that they tried to assume conservative properties that would accurately capture the greatest challenges to the figures of merit, but these calculations are based on the preliminary design. The final safety analysis will consider the most limiting properties.
53-2	Section 4.5.3.2 also specifically mentions RPS setpoints and time delays. This type of assumption should be universal to Chapter 13, not just a loss of forced circulation event. The NRC staff recommends clarifying this in KP-TR-018.	Kairos provided changes to KP-TR-018 on the docket (ML22244A248) that addressed this and other questions involving how uncertainties and conservative assumptions are handled in transient analyses.
53-3	KP-TR-018 Table 4-5 explicitly states that 75% of the decay heat capacity is assumed to be available. a. Is this assumption used for other events? If so, can this be stated as a universal part of the methodology (except for the overcooling event)? b. Does this 75% include/bound performance reductions due to operational considerations such as fouling?	a. Kairos stated during the audit that this assumption is used for other events and captures the limiting single failure criterion of a failure of one decay heat removal system (DHRS) train. b. Kairos stated during the audit that this does account for fouling.

	c. Will Hermes routinely be allowed to operate with DHRS thimbles out of service?	c. Kairos indicated during the audit that this level of detail for the Tech Specs is still being worked out. Kairos modified KP-TR-018 to address this and other audit questions (ML22244A248).
53-4	How are plant controls treated in the postulated event analyses at the time of event initiation? E.g., are plant controls assumed to remain operational if they would cause a worse transient, and are they assumed unavailable if they would mitigate the transient?	Kairos stated during the audit that it is likely that if a control system logic would have the system remain operational, and that system's operation would make a transient worse, they would model it. The Hermes RPS is designed to inhibit any kind of effect on any non-safety system that could affect an event. Kairos modified KP-TR-018 to address this and other audit questions (ML22244A248).
53-5	Is the single failure considered in the postulated event analyses universally the failure of a single DHRS train?	Kairos stated during the audit that this is their current working assumption because there are no other safety systems in operation, so no other single failure criterion to address. Instrumentation and controls will consider single failures in their design. Kairos is still evaluating the single failure criterion with respect to the overcooling event and

		would consider any single failures if they impacted figures of merit.
53-6	How is the limiting axial power distribution applied in the analyses determined?	Kairos stated during the audit that the limiting axial power distribution would be the axial shape that would present the greatest challenge to the figure of merit. For fuel, this would be the most skewed shape where the maximum power is, but there could be different limiting axial shapes for different figures of merit. Kairos modified KP-TR-018-NP to address this and other audit questions (ML22244A248). These modifications included adding this text: "A conservative treatment is applied to address the impact of a dynamic change in power shape associated with the control element movement."
53-7	How is the hot channel model integrated into KP-SAM?	Kairos stated during the audit that the hot channel model is a post-processor within KP-SAM. It uses multipliers from the hot pebble model for coolant temperature and film temperature with no feedbacks to KP-SAM.

53-8	Will aspects of the methodology described in KP-TR-018 (not just the example calculations in Appendix A) be updated when the FSAR is submitted?	Kairos stated during the audit that the current technical report will be updated and elevated to a topical report with the OL application.
54	KP-TR-018-P Section A.1 states that a decrease in system flow rate has notable impacts on heat transfer throughout the system during the entire simulation. Given this importance of flow rate, is uncertainty in initial coolant flow rate considered in the calculation?	Kairos explained during the audit that the effect of variations in mass flow rate are captured by biasing the reactor coolant temperature. Kairos modified KP-TR-018-NP to address uncertainties in general (ML22244A248).
55	KP-TR-018-P Section 4.1.1.1 states that decay heat power can be calculated form a user-provided decay heat curve or from a model based on a standard decay heat curve (the underlying documentation mentions ANSI/ANS-5.1-2005). It also states that a sensitivity factor can be applied to the decay heat fraction to conservatively account for uncertainties. However, it is unclear what approach is applied in the methodology. Has the decay heat curve been chosen, and has a sensitivity factor been determined? The NRC staff would expect at least some details committing to conservative decay heat modeling (e.g., maximum decay heat assumptions will be applied to undercooling events) to be provided in the CP application.	Kairos stated during the audit that the OL application will provide a justification for the conservatism of the decay heat methodology used as part of the postulated event analysis methodology and Chapter 13 calculations. The decay heat methodology was not reviewed in the safety evaluation for the construction permit and will be reviewed during the OL.
56	KP-TR-018-P Section A.1 states, “The short deviation (i.e., on	Kairos and the staff discussed this item during the

	the order of a few minutes) of the reflector temperature slightly above the MHA temperature is acceptable due to the time-at-temperature nature of diffusion of tritium out of graphite grains." Table 3-2, "Derived Figures of Merit and Acceptance Criteria for Postulated Events," shows that the acceptance criteria for many of the temperature-related figures of merit are that the temperatures are generally bounded by temperature-time curves from the assumed MHA. At what point is a deviation above the MHA temperature no longer considered to be generally bounded? If calculated temperatures were to increase in length of time or magnitude due to design changes or different initial conditions or assumptions, how would one determine whether the MHA is still bounding?	audit and the staff indicated that deviations such as this will need to be addressed and justified case-by-case in the OL application.
57	It is unclear how the nominal nuclear parameters (peaking factors, reactivity coefficients, control rod reactivity worths, etc.) described in Section 4.5 relate to the assumptions used in event-specific safety analysis simulations presented in Chapter 13. It is also unclear how these relate to the TRISO operational envelope presented in Table 4.2-5. Provide an explicit mapping between nuclear design, fuel performance, and safety analysis assumptions such that reasonable assurance of safe operation can be established.	Kairos provided the nuclear calculations report for the staff to review and referenced a technical report, **[[ ]]** "CRBRP Core Assemblies Hot Channel Factors Preliminary Analysis" (ML19211A749). This information increased the staff's understanding of how the parameters in PSAR Section 4.5 relate to the simulations in Chapter 13 and the TRISO operational envelope. While sufficient for the CP stage, the staff indicated that additional information on this topic may need to be docketed

		to support an OL application.
58	The evaluation of vessel fluence requires additional information to ensure safety limits will not be exceeded during the operational life of the facility. Provide the current estimated values of fluence to the vessel and the proposed acceptance criteria (based on ASME Code requirements) to demonstrate expected margin.	Kairos revised PSAR Chapter 4 to provide additional information on the vessel fluence calculations, including the preliminary best estimate with uncertainties (ML22272A595).
59	Additional details are required regarding the sensitivity of the packed bed geometry to statistical variations in pebble loading and their effects on core power and temperature distributions. Provide an assessment of limiting loading scenarios (e.g., a cluster of fresh pebbles adjacent to the radial reflector) and the resulting impact on safety parameters and the controls in place that give confidence that the scenarios analyzed are indeed the limiting cases.	An assessment was not provided, but Kairos discussed the statistical variations on pebble loading. This discussion provided the NRC staff clarification regarding the existing docketed information. While sufficient for the CP stage, the staff indicated that additional information on this topic may need to be docketed to support an OL application.
60	The description of the nodalization and interaction between different physics fields in KP-TR-017 is not sufficient for the staff to come to a reasonable assurance finding that the fuel isotopics, neutron transport, and thermal-fluidic feedback are adequately calculated and appropriate for follow-on safety	Kairos discussed nodalization in the Hermes models. This discussion provided the NRC staff clarification regarding the existing docketed information. While sufficient for the CP stage, the staff indicated that additional information on this

	calculations. Provide a more detailed description of how the physics fields are represented in core design models and how data is passed from model to model. Of specific interest is the **[[** **]]**.	topic may need to be docketed to support an OL application.
61	In Section 5.2.4 of KP-TR-017, Kairos describes the concept of **[[** **]]**	Kairos discussed this concept during the audit. This discussion provided the NRC staff clarification regarding the existing docketed information. While sufficient for the CP stage, the staff indicated that additional information on this topic may need to be docketed to support an OL application.
62	In Section 5.2.6 of KP-TR-017, Kairos states **[[**	Kairos discussed details regarding Section 5.2.6 of KP-TR-017 during the audit. The discussion increased the NRC staff's understanding of this section. While sufficient for the CP stage, the staff indicated that additional information on this topic may need to be docketed to support an OL application.

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63	Appendix A of KP-TR-017 provides a sample nuclear analysis for a Hermes-like reactor core. a. [[ ]] b. [[ ]] c. [[ ]] d. In Table A-10, [[ ]]	Kairos discussed the Hermes core sample analysis during the audit. The discussion increased the NRC staff's understanding of this topic. While sufficient for the CP stage, the staff indicated that additional information on this topic may need to be docketed to support an OL application.
64	PSAR Section 4.2.2, "Reactivity Control and Shutdown System," (page 4-12) states, "[t]he control and shutdown element insertion versus time will be provided in the application for an Operating License." Is this reactivity insertion versus time? Also, is this the same analysis described in KP-TR-018 Section 4.5.2.2, "Transient Analysis Methods," that will be provided in	Kairos clarified that this was reactivity insertion versus time and that this was the same analysis described in KP-TR-018 Section 4.5.2.2, "Transient Analysis Methods."

	the FSAR?	
65	PSAR Section 4.5.3.1, "Evaluation of Design Bases," (page 4-43) states that the control elements provide a means to control the rate of reactivity changes that is independent and diverse from the shutdown elements because they are in different locations, receive different signals to trip, and each of them have two independent and diverse release mechanisms, which would be consistent with PDC 26. NRC staff is concerned that, if the elements use an identical mechanical system, they are not diverse and independent. Do control and shutdown elements use a mechanical system that is identical to one another?	Kairos revised PSAR Section 4.5.3.1 to clarify the diversity of the control and shutdown elements and the consistency of the Hermes design with PDC 26 (ML22272A595).
66	PSAR Section 4.5.3.1, "Evaluation of Design Bases," (page 4-42) states that neutron flux distributions will be verified during startup using excore detectors. Are these the same detectors that will monitor neutron flux and burnup during operation?	Kairos revised PSAR Chapters 4 and 7 to include a detailed discussion on excore detectors. The revision clarified that the excore detectors are the same.
67	How is pebble peaking monitored? If the pebble peaking factor is monitored, will the peak particle power be inferred?	Kairos discussed pebble peaking and peak particle power monitoring. The discussion increased the NRC staff's understanding of this topic. While sufficient for the CP stage, the staff indicated that additional information on this topic

		may need to be docketed to support an OL application.
68	Provide Reference 13 in the eRR: **[[ ]]** “Transport and Release of Radionuclides from TRISO Fuel Particles Hand Calculation.”	Kairos provided the staff access to the document in the ERR. Kairos indicated in the audit a caveat that the calculation described in the document was done at the time of their preparation of the MST TR (not to support the PSAR) and used a very early version of KP-SAM. Kairos further indicated that the document was referenced in the MHA calculation only for the correlation described within.
69	Run through the analysis to show how to take information from the MHA calculation package to develop inputs to RADTRAD and the RADTRAD model. a. Inventory b. Radionuclide (RN) grouping c. Apply release fractions (RFs) d. RN re-grouping e. Species f. RADTRAD analysis model	Kairos provided an explanation of the MHA analysis and the modeling of radionuclide transport across barriers, using transport of Cs as an example. The presentation covered all the staff’s requested topics and questions and helped increase the staff’s understand the MHA calculation. The staff noted the following from the discussion of the example:

		• In MHA calculation Table 4.2, the Cs group is the **[[ ]]** in each RN group and how they act in Flibe. • All RN regroupings (fuel to Flibe to gas space) are done before input to RADTRAD. • Input sources in RADTRAD are evaporation or degas from Flibe as release to gas space. • MHA calculation Table 4.3.1 Flibe fuel RF correlations are not a function of initial inventory but are a function of temperature. • Calculation uses pure matter vapor pressures. • IAEA fuel diffusivities are used, same as in the MST TR, KP-TR-012.
70	In Section 6, Assumption 7 is that MAR originating in the cover gas is considered *de minimis* in the MHA analysis. a. What would be the estimated cover gas equilibrium MAR inventory? b. PSAR Table 14.1-1 indicates TS 3.3 will include an LCO or condition to maintain the quantity of MAR in the gas space of the primary heat transport system (PHTS) within an upper bound. Will this be an activity limit? What will be the basis for the TS value if not the MHA? c. Will the OL application MHA analysis explicitly verify the	Kairos provided the following answers during the audit: a. Cover gas equilibrium inventory to be determined and provided in OL application. b. The TS basis will be informed by the MHA analysis but will also use information from postulated events with mobilization and other information (e.g., conservative assumptions, added margin). Gas space

	de minimis assumption for cover gas MAR? If it will not, why not? d. Is this assumption in the modeling also supported by other MHA analysis conservatisms?	activity will consider activity in Flibe, diffusion from fuel, and activation of impurities in Flibe, etc. c. Kairos intends to keep the OL MHA analysis the same, including the MHA margin to dose criteria. The OL application will indicate any changes. d. Yes, see also item b.
71	On pg. 29 of 138, regarding the Ar-41 isotopic activity in closed graphite pores – the amount is much higher (2.86x) than in Reference 8, **[[ ]]** Why the difference?	Kairos indicated in the audit that the methodology technical memo, **[[ ]]** is older, and the MHA calculation used a revised **[[ ]]** cross section. The remainder of the method used to calculate the Ar-41 activity is the same as in the technical memo.
72	Table 7.1 – explain the values for Flibe cumulative RF for gases, low volatility noble metals (LVNM), and oxides. The values do not appear to be the sum of Flibe interval RFs up to that point.	Kairos indicated in the audit that the Flibe cumulate RF is a release of F, Li, and Be, not radionuclide release from the Flibe. This information addressed the staff's concern regarding Table 7.1, clarified that the Flibe cumulative RF is not a sum of the radionuclide release fractions.

73	Table 7.3 – what is "marginal release fraction?" What is "fraction of core" modifying? Is it the total of core inventory of the RN group constituents on a per activity basis? On a per mass basis? Something else? How is this table used?	Kairos indicated in the audit that "fraction of core" is the fraction of TRISO particles that are assumed to have a specific failure mode (e.g., exposed kernel) same as Table 4.3 TRISO configurations. The "marginal release fraction" is describing fraction of the core inventory released for the case where all TRISO particle failures were that one configuration. Kairos further indicated that the basis (activity, mass, or atoms) depends on the barrier. Kairos indicated that Section 7 tables could be thought of as interim calculation results and used for input to downstream calculations.
74	MHA Analysis **[[ ]]** Figure 4.4 – what is meant by **[[ ]]**? It isn't clear what scenario would cause **[[ ]]**.	Kairos clarified that the species described in this figure would transport with the faster vaporizing species.
75	MHA Analysis **[[ ]]** Equation 4.1 – the calculation states that the **[[ ]]**. However, the equation doesn't appear to have the	Kairos clarified that the equation contains an error, but the actual calculation that supports the corresponding figure is correct.

	[[ ]] in either the numerator or denominator. Is this a typo?	
76	In PSAR Section 4.5.4.2, “Testing and Monitoring,” please discuss the location and number of any axial, radial, and azimuthal excore detectors.	Kairos revised the PSAR to provide additional description of the excore detectors in PSAR Section 7.3.1, which is referenced in PSAR Section 4.5.4.2.
77	**[[ ]]** Figure 5.1, Cumulative Fuel Release Fractions, show Ag has a maximum fractional release of approximately **[[ ]]**. This seems several orders of magnitude lower than the Ag fractional inventory demonstrated by the AGR program as given in Figures 7-1, 7-2 and 7-3 of EPRI-AR-1 TR. What is the reason for the difference in the Kairos predicted vs. AGR measured Ag fractional release inventories? This question also applies to Cs and Sr but the staff notes the differences are less than observed for Ag.	Kairos stated during the audit that the figures in EPRI-AR-1 TR (7-1, 7-2 and 7-3) are for steady-state operation which is hundreds of days which allow the Ag to diffuse out. In the staff’s review of the MHA analysis, this calculation is for transient release as it assumes all the steady state release has already entered the coolant or cover gas. This is obviously also true for the other isotopes such as Cs and Sr.
78	The calculation of fractional fuel releases in **[[ ]]** appear to use **[[ ]]** parameters for diffusivity coefficients (Table 4.4), dimensions for the TRISO particles (Table 4.5) and an assumed failure fraction by configuration (Table 4.3). Are there any uncertainties or conservatisms in determining the element specific cumulative releases? If so, what are the conservatisms?	Kairos stated during the audit that the diffusivity coefficients are based on those already approved in the MST TR. The staff determined from reviewing the MHA analysis that the failure fraction (especially the TRISO failure fraction) is estimated to be conservative and largely determined by comparison to the AGR program

		manufactured failure fraction. The coating thicknesses is not a dominant factor as the fuel release is dominated by the exposed kernel which assumes no intact coating layers.
79	On page 26 of 138 of **[[ ]]** Table 4.1 shows the atoms per fuel species for an equally weighted **[[ ]]** pass core. Are those determined using **[[ ]]**?	From the audit review of **[[ ]]** the staff determined these are equally weighted at the highest expected burnup for each of the **[[ ]]** passes.
80	For longer postulated events, which take time to reach a trip setpoint (e.g., a slow element withdrawal), how is the additional nuclide generation and diffusion out of the kernel accounted for? Would a time dependent fuel source term be used in KP-BISON for such events?	Kairos stated during the audit that the nuclides generated during the transient are assumed to be negligible for any transient time. This is consistent with the MTS Section 2.1.
81	Equations 12.22a and 12.22b in TECDOC 1645 provide fractional release of irradiated (in-reactor), long lived or stable fission products, assuming little decay during irradiation. Equations 12.24a and 12.24b in TECDOC 1645 show the out-of-reactor releases. What is the basis for using the out-of-reactor equations? Is there a reference which compares the kernel long and short-term releases to measured fractional releases?	During the audit Kairos stated that out-of-pile is used as it ignores radioactive decay consistent with MTS Section 3.3.2.2. The staff verified this is consistent with the MELCOR modeling practice. The stated verified that ignoring radioactive decay and using IAEA equations 12.22a and b is industry practice.

		The staff reviewed IAEA TECDOC 1645, Figure 64 and noted that it shows that using out-of-pile core fractional releases are higher than irradiation (in-core) releases and hence the applicant's choice is conservative.
82 (MHA)	PSAR Section 13.2.1.1 seems to refer to TF while the MST refers to T2. Please clarify.	The staff reviewed a tritium calculation performed during the audit where both TF and T2 tritium inventories were calculated and found that TF was more limiting. The calculation review clarified the docketed references to TF and T2.
82 (ASME code)	In the draft NRC staff endorsement of ASME Code Section III Division 5 (DG 1.87, Revision 2), there are proposed limitations on stress rupture values for 316H at certain times and temperatures. The staff is currently resolving public comments regarding the draft guide and is considering the public comments that suggest relaxing the proposed limitations. However, the staff notes that certain statements in Chapters 4 and 13 of the Hermes PSAR do not appear to include consideration of the limitations in the staff's endorsement. The staff also notes that the information in the PSAR is not consistent with the current accident scenarios provided in the metallic materials topical report. Please clarify or justify the use	Kairos changed PSAR Chapter 4 and the proposed vessel temperature Safety Limits (ML22272A595) to reflect a maximum vessel temperature of 750 °C 316H limit consistent with the NRC endorsed value (ML22101A263). The vessel temperature in the MHA was not modified as it presents a conservative value to calculate radiological release.

	of stress rupture values for 316H SS at temperatures and times that may not be consistent with the planned Staff endorsement of Division 5 or the metallic materials topical report.	
83	PSAR Section 13.2.1.1 states "The tritium transport through the graphite pores is assumed to be instantaneous, and all graphite grains are exposed to the same tritium uptake conditions." Is the tritium in the graphite grains diffused out using the diffusivities given on page 47 of 138 of the MHA calc?	Kairos indicated during that audit that the tritium in the pebbles is assumed to be instantly released. Tritium in the structural graphite is diffused out as a function of time and temperature of the structure. Two tritium diffusivities were evaluated and the most limited one used in the PSAR evaluation.
84	What is the reference or basis for these tritium graphite uptake and release model inputs?	During the audit Kairos clarified that the uptake models are simplified based on mass transfer from the flibe to the graphite and pebbles (i.e., no uptake diffusivity is used). **[[** **]]** The release model is based on simply **[[** **]]** model of graphite grains whose size is based on the average grain size of ET-10 graphite.
85	Is the graphite perfect absorber true of the pebbles and structural graphite?	Kairos stated during the audit that the answer to this question is yes.

86	Is all the retained tritium of the pebbles released in the **[[ ]]**?	Kairos stated during the audit that the answer to this question is yes.
87	**[[ ]]**, page 15 states, **[[ ]]** On page 18 the statement is made that **[[ ]]** There is a similar statement on page 19, for **[[ ]]** a. **[[ ]]** b. **[[**	Kairos provided the following answers during the audit: a. **[[ ]]** b. **[[**

	]] c. Is equation 5.5 or 5.6 used for both uptake and release? If so, does the diffusivity, D, for uptake correspond to the diffusivity in Flibe or graphite? For the release does D correspond to tritium transport in graphite? d. The perfect absorber means mass transfer from the Flibe to graphite is not limited by tritium diffusion into graphite. How is this represented in the various diffusion equations?	]] c. D is diffusivity of tritium within a graphite grain. **[[** **]]** d. **[[** **]]** e. **[[** **]]**
88	Table 13 shows the release fractions are **[[** **]]** for	Kairos indicated in the audit that for the

	the pebbles. **[[** **]]**	temperature profile in Figure 13 of **[[** **]]** the high temperature for a 10-minute period for pebbles is **[[** **]]** The release is monotonically increasing with complete release within **[[** **]]** for pebbles. **[[** **]]**
89	**[[** **]]** If not, how is the pebble inventory **[[** **]]** release determined?	Kairos indicated in the audit that Figure 14 of **[[** **]]**shows what they used in the MHA. They searched the entire 10-year period considering changing inventory and release fractions. The analysis didn't separate pebbles from reflector in the model. Kairos said they picked point of time over life of facility for accumulated tritium in pebbles and reflector to be bounding for initial inventory. Tables 16 and 17 of Appendix 1 to **[[** **]]** shows the values used in MHA. **[[** Table 14 is evolution through time. Instead, Kairos finds the maximum value by interpolation.
90	The reflector inventory corresponds to **[[** **]]** Are the release fractions from Table 17 of **[[** **]]**	Kairos indicated in the audit that the MHA calculation used the reflector inventory at the peak

	used for the MHA release as a function of time **[[** **]]** Are the release fractions based on the **[[** **]]**	of Figure 14 of **[[** **]]** The analysis did not use the peak of reflector inventory because release fraction decreases over time. The **[[** **]]** tritium methodology is different than MHA. Instead, the method looks for the time when tritium buildup times release leads to highest offsite dose.
91	**[[** **]]** assumes a **[[** **]]** Flibe TS which equates to a total Flibe tritium concentration of **[[** **]]** The staff is expecting the OL Chapter 14, Section 3.3 coolant system activity limit to include an upper bound Flibe activity. Is the staff's understanding correct?	Kairos indicated in the audit that the staff's understanding is correct. Section 9.1.1 of the PSAR has some detail; however, Kairos is still evaluating the relationship to future development of TS bases.
92	For the PHSS accident, the oxidation mass loss rate is given by equation 23 in KP-TR-018. The correlation by Zhou is said to be from Reference 23 but I can't find that correlation (Zhou) in Reference 23 (MELCOR liftoff model). Is Reference 23 the correct reference?	Kairos corrected the relevant reference to be Reference 28.
93	Regarding the statement in 13.1.6, "Limiting the amount of MAR in subsystems and components obviates the need for a more detailed safety analysis for this category of events":	Kairos revised PSAR Section 13.1.6 in response to this audit question (ML23055A672).

	Does this statement mean for the CP or does it also apply to the OL? The statement sounds like a design commitment as the various MARs are not yet determined. It’s the staff opinion this will need to be evaluated at the OL to ensure the MHA continues to bound the releases associated from all non-safety systems due to a single initiating event (e.g., seismic). This would require some type of evaluation (safety-analysis) that the subsystem MAR amounts are set correctly and a summary of this evaluation described in the OL application. Therefore, the wording “obviates the need for a more detailed safety analysis” is difficult to understand.	
94	Regarding the MHA fuel radionuclide release: Per the MHA calc **[[ ]]**, the full radionuclide inventory of the fuel is retained and hence the fuel source term is independent of pre-transient, in-service failures or manufacturing defects. 1. Does “Inservice Failures” in Figure 3.1 of the MHA calc mean a TRISO failure (i.e., complete failure of all coating layers)? 2. Does the MHA transient assume a bounding combination of in-service (pre-transient) and	1. Based on the MHA analysis reviewed during the audit, in-service failure is by coating failure cohort. The most significant release is from exposed kernels where all coating layers are assumed to be failed. 2. Yes, the staff reviewed MHA analysis assumed in-service (pre-event) failures and manufacturing defect values. The failed in-service values are expected to be very conservative and the manufactured values were compared to those observed during the

	manufacturing defects by cohort type? 3. Are the MHA assumed in-service failures (pre-transient) by cohort compared against the steady-state (pre-transient) KP-BISON results to ensure they are conservative?	AGR program. The MHA uses assumed in-service cohort failure fractions which will be compared to the KP-BISON calculated values once the code has been approved.

6.0 EXIT BRIEFING

The staff conducted an audit closeout meeting on October 20, 2022. At the exit briefing, the staff reiterated the purpose of the audit and discussed their activities. Additionally, the staff stated that they did not identify areas where additional information would be necessary to support the review.

7.0ADDITIONAL INFORMATION RESULTING FROM AUDIT

One request for additional information (RAI), RAI 348 (ML22227A180) was generated as a result of this audit. In addition, Kairos voluntarily updated the Hermes PSAR (ML22060A272, ML22062B684, ML22224A202, ML22230D065, ML22286A243); a technical report (ML22224A201, ML22244A248, ML22286A242); and submitted additional information on the docket (ML22243A254) to address several items discussed during the audit.

8.0 OPEN ITEMS AND PROPOSED CLOSURE PATHS

Not applicable. There were no deviations from the audit plan.

SUBJECT: SUMMARY REPORT FOR THE REGULATORY AUDIT OF KAIROS POWER LLC HERMES CONSTRUCTION PERMIT PRELIMINARY SAFETY ANALYSIS REPORT CHAPTERS 4 AND 13 (ACCIDENT ANALYSIS)
DATED: JUNE 2023

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