NRC Staff Exhibit NRC-004

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

SAFETY EVALUATION

Related to the Kairos Power LLC Construction Permit Application for the Hermes 2 Test Reactor Facility Dockets 50-611 & 50-612

Completed: July 2024

Office of Nuclear Reactor Regulation

ABSTRACT

This safety evaluation (SE) documents the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review of the construction permit application submitted by Kairos Power LLC (Kairos) on July 14, 2023. The application is for the Hermes 2 test reactor facility, which is proposed to be built in Oak Ridge, Tennessee.

The test reactor facility will support development of Kairos's fluoride salt-cooled, high-temperature reactor technology. The Hermes 2 test reactor facility will contain two 35-megawatt thermal reactors using tristructural isotropic (TRISO) fuel particles embedded in a carbon matrix pebble. The fuel particles will contain high assay low enriched uranium. The reactors will be configured as a pebble bed with molten fluoride salt coolant. The reactors will use a functional containment implemented principally by the high temperature TRISO particle fuel. The reactors will have an intermediate molten-salt heat transfer loop and a common turbine to support demonstration of electrical power generation.

The NRC accepted this application for review and the application was docketed on September 11, 2023. To determine compliance with regulatory requirements in Title 10 of the *Code of Federal Regulations* (10 CFR), the staff used acceptance criteria in NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors" issued in February 1996.

The NRC's Advisory Committee on Reactor Safeguards independently reviewed those aspects of the application that concern safety and provided the results of its review to the Commission in a report dated July 17, 2024. Appendix C to this SE includes a copy of the report.

This SE presents the staff's review of the Hermes 2 construction permit application based on information submitted by Kairos. On the basis of its review of the construction permit application, the staff has determined that the preliminary design and analysis of the Hermes 2 facility, including the principal design criteria; design bases; information relative to materials of construction and general arrangement; and preliminary analysis and evaluation of the design and performance of structures, systems, and components of the facility: (1) provides reasonable assurance that the final design will conform to the design basis; (2) includes an adequate margin of safety; (3) describes the structures, systems, and components which will provide for the prevention of accidents and the mitigation of consequences of accidents; and (4) meets applicable regulatory requirements and satisfies applicable NRC guidance. Therefore, the staff recommends that the Commission make the necessary findings with respect to the safety of the construction permits in accordance with 10 CFR 50.35, "Issuance of construction permits"; 10 CFR 50.40, "Common standards"; and 10 CFR 50.50, "Issuance of licenses and construction permits."

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ABBREVIATIONS AND ACRONYMS

AC	Alternating current
ACI	American Concrete Institute
ACRS	Advisory Committee on Reactor Safeguards
ADAMS	Agencywide Documents Access and Management System
AEA	Atomic Energy Act
AGR	Advanced Gas-Cooled Reactor
AISC	American Institute of Steel Construction
ALARA	As low as is reasonably achievable
ANSI/ANS	American National Standards Institute/American Nuclear Society
AOO	Anticipated operational occurrence
ASCE	American Society of Civil Engineers
ASCE/SEI	American Society of Civil Engineers/Structural Engineering Institute
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BeF_2	Beryllium fluoride
BLEVE	Boiling Liquid Expanding Vapor Explosion
BPS	Backup Power System
BPVC	Boiler and Pressure Vessel Code
CCS	Chemistry control system
CCWS	Component Cooling Water System
CFR	*Code of Federal Regulations*
CP	Construction permit
DBE	Design basis earthquake
DC	Direct current
DHRS	Decay heat removal system
DOE	Department of Energy
DRG	Design Review Guide
DSRS	Design Specific Review Standard
EAB	Exclusion area boundaries
EA	Environmental assessment
EIS	Environmental impact statement
EPRI	Electric Power Research Institute
ER	Environmental Report
ESCS	Equipment and structural cooling subsystem
ESF	Engineered safety feature
ESP	Early Site Permit
ETTP	East Tennessee Technology Park
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FOCD	Foreign Ownership, Control, or Domination
FOM	Figure of merit
FONSI	Finding of no significant impact
FR	*Federal Register*
FSAR	Final safety analysis report
GDC	General Design Criteria
HEU	Highly enriched uranium

HFE	Human factors engineering
HRCS	Heat rejection control system
HRR	Heat rejection radiator
HRS	Heat rejection subsystem
HTGR	High-temperature gas-cooled reactor
I&C	Instrumentation and Control
IBC	International Building Code
IDCOR	Industry Degraded Core Rulemaking
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGS	Inert gas system
IHTCS	Intermediate heat transport control system
IHTS	Intermediate heat transport system
IHX	Intermediate heat exchanger
IMS	Inventory management system
ISP	Intermediate salt pump
ISV	Intermediate salt vessels
KP-FHR	Kairos Power fluoride high temperature reactor
LCO	Limiting Condition for Operation
LEU	Low-enriched uranium
LiF	Lithium fluoride
LPZ	Low population zone
LSSS	Limiting Safety System Setting
LWR	Light water reactor
MAR	Material at risk for release
MC&A	Material control and accounting
MCR	Main control room
MHA	Maximum hypothetical accident
MSRE	Molten Salt Reactor Experiment
MSS	Material surveillance system
MW	Megawatt
NEPA	National Environmental Protection Act
NESC	National Electrical Safety Code
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
OCC	Overnight capital cost
OL	Operating license
ORNL	Oak Ridge National Laboratory
PBR	Pebble bed reactors
PCS	Plant control system
PDC	Principal design criteria
PDR	Public Document Room
PEER	Pacific Earthquake Engineering Research
PGS	Power generation system
PHSS	Pebble Handling and Storage System
PHTCS	Primary heat transport control system
PHTS	Primary heat transport system
PLTMS	Primary loop thermal management system
PMF	Probable maximum flood
PSAR	Preliminary Safety Analysis Report
PSHA	Probabilistic seismic hazard analysis

PSP	Primary salt pump
QA	Quality assurance
QAPD	Quality Assurance Program Description
R&D	Research and development
RAHS	Reactor auxiliary heating system
RAI	Request for additional information
RBHVAC	Reactor building heating, ventilation and air conditioning
RCACS	Reactor coolant auxiliary control system
RCI	Request for confirmation of information
RCS	Reactor control system
RCSS	Reactivity control and shutdown system
RG	Regulatory Guide
ROSP	Remote onsite shutdown panel
RP	Radiation protection
RPS	Reactor protection system
RTMS	Reactor thermal management system
RTS	Reactor trip system
RV	Reactor vessel
RVSS	Reactor vessel support system
SDC	Seismic design category
SE	Safety evaluation
SFCS	Spent Fuel Cooling System
SMR	Small modular reactor
SNM	Special nuclear material
SSC	Structures, systems, and components
TEDE	Total effective does equivalent
TMS	Tritium Management System
TR	Topical Report
TRISO	Tristructural isotropic
TS	Technical specification
TVA	Tennessee Valley Authority
UCO	Uranium oxycarbide
UPS	Uninterruptible power supplies

1 THE FACILITY

This chapter of the safety evaluation (SE) provides a general introduction to the Hermes 2 test reactor facility and an overview of the topics covered in detail in other chapters of this SE, including areas of review, regulatory criteria and guidance, review procedures and findings, and conclusions.

1.1 Introduction

This SE documents the results of the U.S Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review of the construction permit (CP) application submitted by Kairos Power LLC (Kairos) under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," for a two-unit test reactor facility. The test reactor facility is referred to as Hermes 2. An environmental review was also performed for the Hermes 2 CP application. The staff's evaluation and conclusions for the environmental review are proposed to be issued in August 2024.

By letter dated July 14, 2023 (ML23195A122), Kairos submitted its application for CPs, which, if granted, would allow Kairos to construct Hermes 2 in Oak Ridge, Tennessee. The staff acknowledged receipt of Kairos's application for CPs in the *Federal Register* (FR) (88 FR 51876) on August 4, 2023. Kairos submitted the following in its CP application:

- Description and safety assessment of the site required by 10 CFR 50.34(a)(1).
- Environmental report (ER) required by 10 CFR 50.30(f).
- General information required by 10 CFR 50.33, "Contents of applications; general information."
- Agreement limiting access to classified information required by 10 CFR 50.37, "Agreement limiting access to Classified Information."

The staff conducted a docketing acceptance review of Kairos's application and, by letter dated September 11, 2023 (ML23233A167), determined that Kairos's CP application was complete and acceptable for docketing. The application was assigned Docket Nos. 50-611 and 50-612 for Hermes 2 Unit 1 and Unit 2, respectively. A notice of docketing of Kairos's CP application was published in the FR on September 15, 2023 (88 FR 63632). A notice of a 60-day opportunity to request a hearing and petition for leave to intervene was published in the FR on November 22, 2023 (88 FR 81439). No petitions were filed in response to the notice.

The safety review of the Hermes 2 CP application is based on information in the application, as revised and supplemented. Unless otherwise stated, this SE evaluates the information contained in the original application dated July 14, 2023 (ML23195A121); the information in Revision 1[*] of Kairos's Preliminary Safety Analysis Report (PSAR), dated May 23, 2024 (ML24144A092), which supersedes the PSAR Revision 0 included in the original application; the information in Revision 1 of technical report KP-TR-017-NP, "KP-FHR [Kairos Power fluoride salt-cooled high temperature reactor] Core Design and Analysis Methodology," dated September 29, 2022 (ML22272A598); the information in Revision 1 of technical report KP-TR-022-NP, "Hermes 2 Postulated Event Analysis Methodology," dated May 23, 2024 (ML24144A094); and the information in the following application supplements:

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[*]Revision 1 of the Hermes 2 PSAR, submitted May 23, 2024, incorporated all previously submitted changes to PSAR chapters.

- Kairos Power Response to Hermes 2 General Audit Question 1.5-1, dated October 27, 2023, ML23300A143.
- Kairos Power Response to Hermes 2 General Audit Question 1.5-2, dated October 27, 2023, ML23300A144.
- Kairos Power Additional Information Related to Hermes 2 CP Application – PSAR chapter 1, dated October 31, 2023, ML23304A312.
- Kairos Power Response to Request for Confirmation of Information 1 and 2 for the Hermes 2 PSAR, dated April 12, 2024, ML24103A243.
- Kairos Power Changes to Financial Information and PSAR Chapter 15, dated April 12, 2024, ML24103A245.
- Kairos Power Response to Request for Confirmation of Information 3 for the Hermes 2 PSAR, dated May 14, 2024, ML24135A382.

Kairos currently has an active construction permit, number CPTR-6, for the Hermes test reactor, which was issued on December 14, 2023. Hermes 2 is proposed to be built on the same site as the Hermes test reactor, and each Hermes 2 reactor unit is proposed to be of similar size and design as the Hermes reactor. For clarity on distinguishing between the two facilities, the Hermes test reactor will be referred to as Hermes 1 throughout this SE.

1.1.1 Areas of Review

The Hermes 2 CP application review consisted of two concurrent reviews: (1) a safety review of the Hermes 2 PSAR and (2) an environmental review of the Hermes 2 ER. The staff reviewed the Hermes 2 PSAR against applicable regulatory requirements using appropriate regulatory guidance and standards, as discussed below, to assess the sufficiency of the preliminary design of Hermes 2. As part of this review, the staff evaluated descriptions and discussions of the Hermes 2 structures, systems, and components (SSCs), with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. The preliminary design of Hermes 2 was evaluated to ensure the sufficiency of principal design criteria (PDC), design bases, and information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases. In addition, the staff reviewed Kairos's identification and justification for the selection of those variables, conditions, or other items that are determined to be probable subjects of technical specifications for the facility, with special attention given to those items that may significantly influence the final design. The SSCs were also evaluated to ensure that they would adequately provide for the prevention of accidents and the mitigation of consequences of accidents. The staff considered the preliminary analysis and evaluation of the design and performance of the Hermes 2 SSCs with the objective of assessing the risk to public health and safety resulting from operation of the facility.

The staff completed an environmental review in accordance with the National Environmental Policy Act (42 [United States Code] USC § 4321 *et seq.*,) (NEPA) to determine the potential impacts of the proposed action on the human environment and reasonable alternatives to Kairos's proposal. Based on a review of the ER submitted as part of the Hermes 2 CP application and the results of the environmental impact statement (EIS) recently issued for Hermes 1, the staff concluded that it would be prudent to first prepare a draft EA to determine whether preparation of an EIS would be necessary or whether a FONSI could be issued for the Hermes 2 CPs based on factors unique to the Hermes 2 CP application. These factors include, among others, the similar design of Hermes 2 and Hermes 1 and the staff's final EIS for

Hermes 1 covering the same site as Hermes 2 and documenting the environmental impacts from the proposed Hermes 1 CP as all SMALL impacts. The staff prepared a draft EA and draft FONSI for the Hermes 2 CP application in accordance with the requirements in 10 CFR 51.30, “Environmental assessment,” 10 CFR 51.31, “Determinations based on environmental assessment,” and 10 CFR 51.32, “Finding of no significant impact.” Consistent with 10 CFR 51.33, “Draft finding of no significant impact; distribution,” the staff offered a 30-day public comment period in the FR on April 26, 2024 (89 FR 32462). The staff is currently reviewing the public comments and the final evaluation and conclusions are proposed to be issued in August 2024.

1.1.2 Regulatory Basis and Acceptance Criteria

In accordance with 10 CFR 50.35(a), a CP (in this situation, two CPs) authorizing Kairos to proceed with the construction of the Hermes 2 facility may be issued if the staff makes the following findings:

1. The applicant has described the proposed design of the facility, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.
2. Such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the final safety analysis report (FSAR).
3. Safety features or components, if any, which require research and development have been described by the applicant and a research and development program will be conducted that is reasonably designed to resolve any safety questions associated with such features or components.
4. On the basis of the foregoing, there is reasonable assurance that: (i) such safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility, and (ii) taking into consideration the site criteria contained in 10 CFR Part 100, “Reactor Site Criteria,” the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.

As provided in 10 CFR 100.2, “Scope,” the siting requirements in 10 CFR Part 100 “apply to applications for site approval for the purpose of constructing and operating stationary power and testing reactors pursuant to the provisions of [10 CFR Part 50] …” Kairos submitted a CP application for a testing facility. Therefore, the staff evaluated the Hermes 2 site-specific conditions using the applicable criteria in 10 CFR Part 100, in addition to those in 10 CFR Part 50. The staff’s review evaluated the geography and demography of the site; nearby industrial, transportation, and military facilities; site meteorology; site hydrology; and site geology, seismology, and geotechnical engineering to ensure that issuance of CPs will not be inimical to public health and safety. The staff’s review also evaluated SSCs and equipment designed to ensure safe operation, performance, and shutdown when subjected to extreme weather, floods, seismic events, missiles (including aircraft impacts), chemical and radiological releases, and loss of offsite power. A detailed review of the Hermes 2 site can be found in chapter 2, “Site Characteristics,” of this SE.

The CPs, if issued, would constitute an authorization for Kairos to proceed with construction of the Hermes 2 facility. The staff’s evaluation of the preliminary design and analysis of the Hermes 2 facility does not constitute approval of the safety of any design feature or specification, nor did Kairos request such approval for any part of the Hermes 2 design. Such approval will be made following the evaluation of the final design of the facility, as described in the FSAR as part of Kairos's operating license (OL) application for Hermes 2.

In addition to the findings listed in 10 CFR 50.35, "Issuance of construction permits," a CP application must also provide sufficient information to allow the Commission to make the following determinations in accordance with 10 CFR 50.40, "Common standards," and 10 CFR 50.50, "Issuance of licenses and construction permits":

1. There is reasonable assurance: (i) that the construction of the facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission's regulations.
2. The applicant is technically qualified to engage in the construction of its proposed facility in accordance with the Commission's regulations.
3. The applicant is financially qualified to engage in the construction of its proposed facility in accordance with the Commission's regulations.
4. The issuance of a permit for the construction of the facility would not be inimical to the common defense and security or to the health and safety of the public.
5. After weighing the environmental, economic, technical and other benefits of the facility against environmental and other costs and considering reasonable available alternatives, the issuance of these CPs, subject to the conditions for protection of the environment set forth herein, is in accordance with Subpart A of 10 CFR Part 51 of the Commission's regulations and all applicable requirements have been satisfied.
6. The application meets the standards and requirements of the Atomic Energy Act and the Commission's regulations, and that notifications, if any, to other agencies or bodies have been duly made.

The staff's evaluation of Hermes 2's preliminary design and analysis was based primarily upon the following 10 CFR requirements:

- 10 CFR 50.2, "Definitions."
- 10 CFR 50.21, "Class 104 licenses; for medical therapy and research and development facilities."
- 10 CFR 50.33(f)
- 10 CFR 50.34(a)
- 10 CFR 50.35
- 10 CFR 50.40
- 10 CFR 50.41, "Additional standards for class 104 licenses."
- 10 CFR 50.50
- 10 CFR 50.55, "Conditions of construction permits, early site permits, combined licenses, and manufacturing licenses."
- 10 CFR 50.58, "Hearings and report of the Advisory Committee on Reactor Safeguards."
- 10 CFR Part 50, appendix C, "A Guide for the Financial Data and Related Information Required to Establish Financial Qualifications for Construction Permits and Combined Licenses."
- 10 CFR Part 50, appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities."
- 10 CFR 100.10, "Factors to be considered when evaluating sites."
- 10 CFR 100.11, "Determination of exclusion area, low population zone, and population center distance."

The regulations of 10 CFR 50.40 require that:

> … the processes to be performed, the operating procedures, the facility and equipment, the use of the facility, and other technical specifications, or the proposals, in regard to any of the foregoing collectively provide reasonable assurance that the applicant will comply with the regulations in this chapter, including the regulations in part 20 of this chapter, and that the health and safety of the public will not be endangered.

With respect to 10 CFR Part 20, "Standards for Protection Against Radiation," which is referred to in 10 CFR 50.40, the staff assessed whether Kairos had identified the relevant requirements for an operating facility and provided descriptions of the preliminary facility design to determine whether the PSAR provides an acceptable basis for the development of SSCs and whether there is reasonable assurance that Kairos will comply with the regulations in 10 CFR Part 20 during Hermes 2 operation. Because Kairos has not applied for licenses to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material, the staff did not evaluate whether requirements in 10 CFR Part 20 would be met for the construction of the two Hermes 2 reactors.

As required by 10 CFR 50.34(a)(3)(i), Kairos must describe the PDC for its Hermes 2 facility in the PSAR. However, for the Hermes 2 test reactors, Kairos is not required to follow 10 CFR Part 50, appendix A, "General Design Criteria [GDCs] for Nuclear Power Plants," which applies only to water-cooled nuclear power reactors. Section 3.1.1, "Design Criteria," of the Hermes 2 PSAR states the following regarding the PDC for Hermes 2:

> Kairos Power has also developed a set of principal design criteria (PDC) applicable for the KP-FHR technology which has been reviewed and approved by the NRC in "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor." [ML20167A174] The application of these criteria to the SSCs of the test reactor are shown in Table 3.1-2 ["Principal Design Criteria"]. Note that while the facility contains two reactor units, no safety-related SSCs are shared between the reactor units, which satisfies PDC 5. Therefore, PDC 5 is not further discussed within this safety analysis report. Specific details regarding how the other PDC are met by the design are described in the individual sections throughout this safety analysis report as summarized in Table 3.1-2.

The staff reviewed Kairos's description of the Hermes 2 PDC, as described in the PSAR sections identified in table 3.1-2 and in the NRC-approved topical report (TR) KP-TR-003-NP-A, "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor," as applicable to the test reactor facility.

The staff used established guidance and acceptance criteria that it determined to be relevant to the review of the Hermes 2 CP application, noting that much of this guidance was originally developed for completed designs of water-cooled nuclear reactors. In order to determine the acceptance criteria necessary for demonstrating compliance with regulatory requirements in 10 CFR, the staff used the following:

- NUREG-1537, Part 1, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content," issued February 1996

- NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria," issued February 1996

As appropriate, the staff used additional guidance (e.g., NRC regulatory guides, Institute of Electrical and Electronics Engineers standards, American National Standards Institute/American Nuclear Society standards, and NRC office instructions) in its review of the Hermes 2 CP application. The additional guidance was used based on the technical judgment of the reviewer, as well as references in NUREG-1537, Parts 1 and 2; and the Hermes 2 CP application.

1.1.3 Review Procedures

The staff's review of the Hermes 2 application was informed by NUREG-1537, the Hermes 1 SE (ML23158A265), as well as other relevant guidance cited therein, cited in the application, or used based on the staff's technical judgment. In particular, Kairos's Hermes 2 CP application only seeks authorization to construct the proposed Hermes 2 facility. Therefore, the level of detail needed in the application and the staff's corresponding SE is different than that needed for an OL application and corresponding SE. For the purposes of issuing a CP, the Hermes 2 facility may be adequately described at a functional or conceptual level in the PSAR. As such, Kairos has deferred providing some design and analysis details until the submission of its FSAR with its OL application.

The objective of the staff's evaluation was to assess the sufficiency of information contained in the Hermes 2 application for the issuance of CPs in accordance with the requirements of 10 CFR Part 50. An in-depth evaluation of the Hermes 2 final design will be performed following the docketing of an OL application and its accompanying FSAR.

1.1.3.1 Use of Docketed Information

The staff's review of the Hermes 2 CP application was informed by the Hermes 1 CP application review. The Hermes 2 facility includes many SSCs that are identical to those that would be used in the Hermes 1 facility. Accordingly, large portions of the Hermes 1 PSAR are identical to the Hermes 2 PSAR. In the July 14, 2023, CP application submittal, Kairos highlighted the differences between the Hermes 1 and Hermes 2 PSARs in two ways. First, Kairos used blue font in the Hermes 2 PSAR to identify any modified or new text. Second, Kairos provided a summary of the information deleted from the Hermes 1 PSAR to generate the Hermes 2 PSAR (ML23195A132). In addition, Kairos identified the docketed information and audit information from Hermes 1 that is applicable to the Hermes 2 CP application in two letters dated October 27, 2023 (ML23300A141 and ML22300A144). This information is considered docketed information for the Hermes 2 CP application and was used to inform the staff's review.

1.1.3.2 Format and Content of Hermes 2 Safety Evaluation Sections

Based on the consistencies between the Hermes 1 and Hermes 2 PSARs described above, the staff leveraged the Hermes 1 SE to the greatest extent possible to support its review of the Hermes 2 CP application. Accordingly, applicable contents of the Hermes 1 SE were incorporated by reference into this SE. To determine which Hermes 1 SE content could be incorporated by reference, the staff reviewed the differences between the Hermes 1 and Hermes 2 PSARs. Where the Hermes 2 PSAR only contained minor deviations (e.g., minimal or no effect on the NRC SE or editorial changes, as compared to the Hermes 1 PSAR), the staff's SE was largely limited to incorporating by reference applicable portions of the Hermes 1 SE.

Similarly, where the Hermes 2 PSAR contained a limited number of significant but discrete changes, but was otherwise identical to the Hermes 1 PSAR, the staff's SE was likewise limited to an evaluation of the variances between the two PSARs. In this case, the balance of the staff's SE also incorporated by reference applicable portions of the Hermes 1 SE. Based on this approach, many of the Hermes 2 SE sections are organized using the following structure:

- Brief introduction summarizing the Hermes 2 PSAR content with a focus on any changes in comparison to the Hermes 1 PSAR.
- Regulatory evaluation section that, in most cases, incorporates by reference the regulations and guidance from the corresponding section of the Hermes 1 SE due to the similarities between the Hermes 1 and Hermes 2 facility designs.
- Technical evaluation that:
    - Identifies the consistent and modified Hermes 2 PSAR information, as compared to the Hermes 1 PSAR.
    - Incorporates by reference, as appropriate, content from the Hermes 1 SE for PSAR information that is consistent between Hermes 1 and Hermes 2.
    - Evaluates the new design information and non-editorial changes (i.e., minor and/or few significant changes), as compared to the Hermes 1 SE. The depth of the staff review provided for each change is dependent on the significance of that change.
- A full conclusion specific to the Hermes 2 review.

For Hermes 2 PSAR sections that contain entirely new information and/or several significant changes when compared to the Hermes 1 PSAR, the staff performed its evaluation without incorporation by reference from the Hermes 1 SE. One example of a section which reflects such an evaluation by the staff is section 5.2, "Intermediate Heat Transport System," of this SE related to the intermediate salt loops. These systems are not in the design of the Hermes 1 test reactor; therefore, the staff did not evaluate them in its review of the Hermes 1 CP application. Accordingly, the staff evaluated this system in this SE without incorporation by reference of the Hermes 1 SE.

1.1.4 Resolving Technical Issues

For those technical areas that require additional information, the staff has several options:

1. The staff may determine that such technical issues must be resolved prior to the issuance of a CP.
2. The staff may determine that such information may be left until the submission of the OL application.
3. The staff may require that such technical issues be resolved prior to the completion of construction, but after the issuance of a CP.

Technical issues that fall within the scope of the first option require additional information to be provided in order to establish PDC and/or design bases so that the staff may have confidence that the final facility design will conform to the design basis. The staff resolves such technical issues through audits, requests for confirmation of information (RCIs), and requests for additional information (RAIs).

In the second and third options, the staff may also use audits or issue RCIs and RAIs to resolve identified technical issues. These types of technical issues include those that require a design maturity beyond what is required by 10 CFR 50.34(a) to issue a CP. Although determining what constitutes a preliminary versus a final design may be somewhat subjective, according to 10 CFR 50.34(a), a preliminary design must include PDC, the design bases, and general facility arrangement and approximate dimensions. This information should be sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety. The staff may use audits or issue RCIs and RAIs if it determines that doing so is necessary for the applicant to acknowledge certain technical deficiencies that could impact the final design. Appropriate responses include commitments to resolving these deficiencies either in the FSAR or before the completion of construction.

Audits are designed to maximize the efficiency of the staff's review. During an audit, the applicant can respond to questions, the staff can readily evaluate the applicant's responses, and the need for formal correspondence between the staff and the applicant is reduced, resulting in improved review efficiency. As part of its review of the Hermes 2 CP application, the staff conducted a general audit of the Hermes 2 PSAR. In this audit, Kairos supplemented the PSAR and provided clarifications through its responses to the staff's questions during audit meetings and in docketed correspondence. The staff documented the results of the Hermes 2 general audit in a report issued on July 11, 2024 (ML24193A214). The staff also issued requests for confirmation of information on April 12, 2024 (ML24103A176) and May 14, 2024 (ML24135A260) and received responses from Kairos on April 12, 2024 (ML24103A243) and May 14, 2024 (ML24135A382).

Additionally, appendix A, "Post Construction Permit Activities - Construction Permit Conditions and Additional Items for the Operating License Application," of this SE contains a listing of those elements of design, analysis, and administration identified as requiring additional research and development or resolution by Kairos. The staff determined that resolution of these items is not necessary for the issuance of CPs, but that Kairos should ensure that these items are fully addressed in the FSAR supporting a Hermes 2 OL application. The staff is tracking these items to ensure they are considered during the review of an OL application for Hermes 2.

1.1.5 Ongoing Research and Development

The provisions of 10 CFR 50.34(a)(8) allow for ongoing research and development (R&D) to confirm the adequacy of the design of SSCs to resolve safety questions prior to the completion of construction. In accordance with 10 CFR 50.34(a)(8), and as described in section 1.3.9, "Research and Development," of the Hermes 2 PSAR, Kairos has identified the following ten ongoing research and development activities:

- Perform a laboratory testing program to confirm fuel pebble behavior (section 4.2.1, "Reactor Fuel")
- Develop a high temperature material surveillance sampling program for the reactor vessel[s] and internal[s] (section 4.3.4, "Testing and Inspection")
- Perform testing of high temperature material to qualify Alloy 316H and ER16-8-2 (section 4.3, "Reactor Vessel System")
- Perform analysis related to potential oxidation in certain postulated events for the qualification of the graphite used in the reflector structure[s] (section 4.3)
- Development and validation of computer codes for core design and analysis methodology (section 4.5, "Nuclear Design")
- Develop and perform qualification testing for a fluidic diode device (section 4.6, "Thermal-Hydraulic Design")

- Justification of thermodynamic data and associated vapor pressure correlations of representative species (section 5.1.3, "System Evaluation")
- Complete compatibility evaluations of the intermediate coolant and reactor coolant chemical interaction (section 5.1.3)
- Develop process sensor technology for key reactor process variables (section 7.5.3, "System Evaluation")
- Develop the reactor coolant chemical monitoring instrumentation (section 9.1.1, "Chemistry Control System")

In support of these activities, Kairos has provided descriptions of the affected SSCs and identified the additional development that is needed. By letter dated October 27, 2023 (ML23300A144), Kairos stated that these research and development activities will be completed in advance of the completion of construction of Hermes 2, Unit 1. Enclosure 1, "General Information," of the CP application states that the latest date for completion of construction of Hermes 2 Unit 1 is expected to be December 31, 2027, with construction of Hermes 2, Unit 2, expected to be completed by December 31, 2028. As described in appendix A to this SE, the staff is tracking these activities and will verify that they are resolved prior to the completion of construction.

1.1.6 Advisory Committee on Reactor Safeguards Review

To support the Advisory Committee on Reactor Safeguards (ACRS) in providing an independent review and report to the Commission regarding the Hermes 2 CP application, the staff presented the findings and conclusions of this SE to the ACRS subcommittee on May 16, 2024, and June 4, 2024. The staff presented the results of its Hermes 2 CP application review to the ACRS full committee on July 10, 2024. After the meeting, the ACRS issued a letter to the Commission with their recommendations regarding the Hermes 2 CP application to meet the requirements of 10 CFR 50.58, "Hearings and report of the Advisory Committee on Reactor Safeguards." The ACRS letter is provided in appendix C of this SE.

1.1.7 Application Availability

Publicly available documents related to the Hermes 2 CP application may be obtained online in the Agencywide Documents Access and Management System (ADAMS) Public Documents collection at https://www.nrc.gov/reading-rm/adams.html. To begin the search, select "ADAMS Public Documents" and then select "Begin Web-based ADAMS Search." For problems with ADAMS, please contact the NRC's Public Document Room (PDR) reference staff at 1-800-397-4209 or by email to PDR.Resource@nrc.gov.

The versions of the Hermes 2 PSAR, submitted July 14, 2023, and May 23, 2024, are publicly available in ADAMS. Other public documents and correspondence related to this application may be found by searching Hermes 2's docket numbers, 50-611 and 50-612, in ADAMS (input 05000611 and 05000612 into ADAMS, respectively). Portions of the application or correspondence containing sensitive information (e.g., proprietary information) are being withheld from public disclosure pursuant to 10 CFR 2.390, "Public inspections, exemptions, requests for withholding."

1.1.8 NRC Staff Contact Information

The project manager for this SE was Michael Orenak, Senior Project Manager, Division of Advanced Reactors and Non-power and Utilization Facilities, U.S. Nuclear Regulatory Commission. Mr. Orenak may be contacted regarding this SE by telephone at 301-415-3229 or via email at Michael.Orenak@nrc.gov. Appendix B, “Principal Contributors,” to this SE provides a listing of principal contributors, including areas of technical expertise and chapters of authorship.

1.2 Summary and Conclusions on Principal Safety Considerations

The staff evaluated the descriptions and discussions of the proposed Hermes 2 facility, as described in Kairos’s CP application. Based on its review, the staff makes the following findings:

1. Applicable standards and requirements of the Atomic Energy Act and Commission regulations have been met.
2. The acceptance criteria in or referenced in NUREG-1537 have been satisfied for a preliminary design supporting a CP application where the criteria were found to be applicable to the design.
3. Required notifications to other agencies or bodies related to this licensing action have been duly made.
4. Based on the preliminary design of the facility, there is reasonable assurance that the final design will conform to the design basis with adequate margin for safety.
5. There is reasonable assurance that the facility can be constructed in conformity with the permit, the provisions of the Atomic Energy Act, and the Commission’s regulations.
6. Kairos has considered the expected consequences of several postulated credible accidents and a maximum hypothetical accident, emphasizing those that could lead to a release of fission products. The staff has evaluated the accident analyses presented by Kairos in the PSAR and determined that the calculated potential radiation doses outside the Hermes 2 site are not likely to exceed the guidelines of 10 CFR Part 100. Furthermore, SSCs have been designed to provide for the prevention of accidents and the mitigation of consequences of accidents.
7. Releases of radioactive materials and wastes from the facility are not expected to result in concentrations outside the limits specified by 10 CFR Part 20, Subpart D, “Radiation Dose Limits for Individual Members of the Public,” and are as low as is reasonably achievable (ALARA).
8. The financial information, technical analyses and programs, and organization as described in the application, as supplemented, demonstrate that Kairos is financially and technically qualified to engage in the construction of its proposed facility in accordance with the Commission’s regulations.
9. The preliminary emergency plan provides reasonable assurance that Kairos will be prepared to assess and respond to emergency events.
10. The application presents information at a level of detail that is appropriate for general familiarization and understanding of the proposed facility.
11. The application describes the relationship of specific facility design features to reactor operation.
12. Issuance of the CPs will not be inimical to the common defense and security or to the health and safety of the public.

Therefore, the staff finds that, subject to certain conditions, the preliminary design and analysis of the Hermes 2 facility, as described in the PSAR, is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs in accordance with 10 CFR 50.35.

Further technical information or design information required to complete the safety analysis in support of operation can reasonably be left for later consideration in the FSAR. Appendix A to this SE identifies certain permit conditions that the staff recommends the Commission include if the CPs are issued. Additionally, appendix A contains a listing of those elements of design, analysis, and administration identified as requiring additional development, description, or resolution by Kairos to support an OL application. The staff has determined that while resolution of these items is not necessary for the issuance of CPs, it is the responsibility of Kairos to ensure that these items have been fully addressed in the Hermes 2 FSAR supporting an OL application. The staff is tracking these items and will verify their implementation during the staff's review of a Hermes 2 OL application.

In addition, as discussed in PSAR section 1.3.9 and section 1.1.5 of this SE, Kairos has identified several ongoing R&D activities to confirm the adequacy of the design of SSCs to resolve safety questions prior to the completion of construction. The staff is tracking these activities, which are also listed in appendix A to this SE and will verify that they are resolved prior to the completion of construction.

Based on these findings as documented in this SE, and subject to the permit conditions identified in appendix A of this SE, the staff recommends that the Commission make the following conclusions for the issuance of CPs for Hermes 2 in accordance with 10 CFR 50.35, 10 CFR 50.40, and 10 CFR 50.50:

1. Kairos has described the proposed design of Hermes 2, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.
2. Such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the FSAR.
3. Safety features or components that require R&D have been described by Kairos and an R&D program will be conducted that is reasonably designed to resolve any safety questions associated with such features or components.
4. On the basis of the foregoing, there is reasonable assurance that: (i) such safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility, and (ii) taking into consideration the site criteria contained in 10 CFR Part 100, the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.
5. There is reasonable assurance: (i) that the construction of the Hermes 2 facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission's regulations.
6. Kairos is technically qualified to engage in the construction of its proposed Hermes 2 facility in accordance with the Commission's regulations.
7. Kairos is financially qualified to engage in the construction of its proposed Hermes 2 facility in accordance with the Commission's regulations.
8. The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

9. After weighing the environmental, economic, technical, and other benefits of the facility against environmental and other costs and considering reasonable available alternatives, the issuance of the CPs, subject to the conditions for protection of the environment set forth therein, is in accordance with Subpart A, “National Environmental Policy Act—Regulations Implementing Section 102(2),” of 10 CFR Part 51 of the Commission’s regulations and all applicable requirements have been satisfied.
10. The application meets the standards and requirements of the Atomic Energy Act and the Commission’s regulations, and notifications to other agencies or bodies have been duly made.

1.3 General Description

The staff evaluated the sufficiency of the general description of the Hermes 2 facility, as presented in section 1.3, “General Description of the Facility,” of the Hermes 2 PSAR, in part using the guidance and acceptance criteria from section 1.3, “General Description,” of NUREG-1537, Parts 1 and 2.

In section 1.3.1, “Geographical Location,” of the Hermes 2 PSAR, Kairos states that Hermes 2 will be located within the East Tennessee Technology Park in Oak Ridge, Tennessee. The property is at the site of the former Oak Ridge Gaseous Diffusion Plant and is approximately 185 acres (74.8 hectares). From the 1950s through the mid-1980s, uranium enrichment operations occurred at the plant. Since then, the site has been restored to a brownfield by the U.S. Department of Energy (DOE).

In section 1.3.3.2, “Operating Characteristics,” of the Hermes 2 PSAR, Kairos states that the Hermes 2 reactors will each operate at a power of 35 megawatts thermal (design rated thermal power) and the combined electrical power output will be 20 megawatts electric for a licensed lifetime of 11 years. Kairos stated that the Hermes 2 facility will be considered a Class 104(c) test reactor because Kairos will not recover more than 50 percent of its annual cost of owning and operating the Hermes 2 facility through energy for sale or commercial distribution in accordance with the regulations in 10 CFR 50.21(c) and 10 CFR 50.22 “Class 103 Licenses; for Commercial and Industrial Facilities.” The staff will confirm at the OL stage that Hermes 2 will meet 10 CFR 50.21(c) and 10 CFR 50.22. A description of the PDC for the facility is provided in PSAR section 3.1.1. The PDC are based on NRC-approved Kairos Power Topical Report KP-TR-003-NP-A.

In addition to the brief descriptions provided in section 1.3 of the Hermes 2 PSAR, more detailed descriptions of the facility design features are provided for the following:

- Safety systems (PSAR chapter 4, “Reactor Description,” chapter 5, “Heat Transport System,” and table 3.6-1, “Structures, Systems, and Components”)
- Engineered safety features (PSAR chapter 6, “Engineered Safety Features”)
- Instrumentation, control, and electrical systems (PSAR chapter 7, “Instrument and Control Systems,” and chapter 8, “Electric Power Systems”)
- Reactor coolant, power generation system, and other auxiliary systems (PSAR chapter 9, “Auxiliary Systems”)
- Radioactive waste management provisions or system and radiation protection (PSAR chapter 11, “Radiation Protection Program and Waste Management”)

As described in subsequent SE chapters, the design of Hermes 2 includes engineered safety features to mitigate design-basis events or accidents, control and protection systems, equipment and processes related to handling and storage of byproduct material and special nuclear material, a power generation system, and fire protection systems. Additional controls are also provided by the Hermes 2 radiation protection program, ALARA program, radioactive waste management program, quality assurance program, fire protection program, and other programs that are described in the PSAR.

1.4 Shared Facilities and Equipment

The staff evaluated the sufficiency of the evaluation of shared facilities and equipment, as presented in section 1.4, "Shared Facilities and Equipment," of the Hermes 2 PSAR, using the guidance and acceptance criteria from section 1.4, "Shared Facilities and Equipment," of NUREG-1537, Parts 1 and 2. The acceptance criteria state that a non-power reactor (e.g., test reactor) facility should be designed to accommodate all uses or malfunctions of the shared facilities without degradation of the facility, and the reactor should be designed to avoid the spread of contamination to any shared facilities or equipment.

Due to the unique nature of the two-unit test reactor facility, the staff reviewed the shared systems (equipment) between Unit 1 and Unit 2. Consistent with the review procedures of NUREG-1537, Part 2, section 1.4, the staff confirmed that all facilities or equipment shared by the Hermes 2 facility are discussed in the PSAR. The shared systems and equipment are all non-safety related and summarized as follows:

- Plant control system (PCS): The PCS is a non-safety related control system which controls reactor startup, changes in power levels, reactor shutdown, heat transport, and the power generation system. Because it is a non-safety related system, failure of the PCS would not affect the safety-related features of Hermes 2. A detailed review of the PCS can be found in section 7.2, "Plant Control System," of this SE.
- Main control room: The main control room contains operator and supervisor workstation terminals that provide alarms, annunciations, personnel and equipment interlocks, and process information. There are no operator actions performed nor safety-related SSCs located in the main control room that are credited for mitigating the consequences of postulated events. A detailed review of the main control room can be found in section 7.4 "Main Control Room and Remote Shutdown Panel," of this SE.
- Normal and backup power: The electrical system is a non-safety related system which provides power to support internal operation of plant equipment. Following a postulated event, SSCs do not require electrical power to perform safety-related functions due to the passive plant design. A detailed review of the electrical systems can be found in chapter 8, "Electrical Power Systems" of this SE.
- Power generation systems: The power generation system consists of the steam system, turbine generator system, and feedwater and condensate system. The majority of the power generation system is shared between Unit 1 and Unit 2, with the exception of unit-specific steam superheaters and associated piping and components. The power generation system does not perform any safety-related functions. A detailed review of the power generation system can be found in section 9.9, "Power Generation System," of this SE.
- Plant communication systems: The communication systems are common to both units and facilitate communications during normal and emergency conditions between essential areas of the facility and between locations remote to the facility. The

communication systems are not safety-related. A detailed review of the communication systems can be found in section 9.5, "Communication," of this SE.

- Service water system: The service water system draws water from municipal sources and provides the water to other water systems and supports general facility services (e.g., potable water). The service water system is not safety-related and is not credited for the mitigation of postulated events. A detailed review of the service water system can be found in Section 9.7.1, "Service Water System," of this SE.
- Treated water system: The treated water system provides chemistry control and supplies make-up water to the component cooling water system, the chilled water system, and the safety-related decay heat removal system, and the power generation system deaerator. The treated water system is not a safety-related system and is not credited for the mitigation of postulated events. A detailed review of the treated water system can be found in section 9.7.2, "Treated Water System," of this SE.
- Auxiliary site services: Auxiliary site services include non-safety related systems and equipment that support operation of the plant, such as machine shops, chemistry laboratory, sewers, lighting, warehousing, and storage. The auxiliary services are not credited for the mitigation of postulated events and will be built so that they will not interfere with the ability of safety-related SSCs to perform their safety function(s). A detailed review of the auxiliary site services can be found in section 9.8.5, "Auxiliary Site Services," of this SE.
- Facility physical security: Section 12.8, "Security," of the Hermes 2 PSAR states that a description of the security plan for the facility will be provided during the Hermes 2 OL application. In table 3.6-1, "Structures, Systems, and Components," the physical security system is stated to be non-safety related. A detailed review of the physical security system will be performed by the staff during the Hermes 2 OL application review.
- Sensors: Sensors will be used to provide information about temperature, pressure, neutron count rates, level, flow of the primary coolant and area radiation levels as input to multiple control and protection subsystems. Section 7.1 "Instrumentation and Controls Overview," of the Hermes 2 PSAR states that safety-related sensors are not shared between Unit 1 and Unit 2. Non-safety related sensors that control and monitor shared systems are shared between Unit 1 and Unit 2. A detailed review of the sensors can be found in section 7.5, "Sensors," of this SE.
- Fire protection: The fire protection systems are designed to detect, control, and extinguish fires so that a continuing fire will not prevent safe shutdown or result in an uncontrolled release of radioactive material that exceeds acceptance criteria. The Hermes 2 fire protection systems consist of unit-specific systems that serve each reactor building and common systems that serve the shared turbine building and the shared main control room. The fire protection systems do not perform safety-related functions. A detailed review of the fire protection system can be found in section 9.4, "Fire Protection Systems and Programs," of this SE.
- Radiation monitoring: Section 11.1.4, "Radiation Monitoring and Surveying," of the Hermes 2 PSAR states that details of radiation monitoring and surveying, including a description of the equipment, methods, and procedures will be provided during the Hermes 2 OL application. In table 3.6-1 of the Hermes 2 PSAR, the radiation monitoring system is stated to be non-safety related. A detailed review of radiation monitoring and surveying will be performed by the staff during the Hermes 2 OL application review.

Since the Hermes 2 preliminary design identifies all shared systems as non-safety related and the Hermes 2 non-safety related SSCs are designed such that failures will not impact safety-related SSCs, a malfunction or a loss of function of these shared systems would not degrade the facility's safety features. Additionally, the Hermes 2 design includes multiple barriers and a tritium management system to limit and manage the spread of contamination to shared systems. The staff finds that the loss of the shared systems would not damage the reactors or their capability to be safely shutdown or lead to uncontrolled release of radioactive material to unrestricted areas. In addition, the staff evaluation of PDC 5 related to shared systems is discussed in section 3.1.3.1 of this SE.

On the basis of its review of PSAR section 1.4 and other relevant PSAR chapters, the staff finds that the level of detail provided regarding the Hermes 2 shared systems demonstrates an adequate basis for preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 1.4. Therefore, the staff concludes that the information in section 1.4 of the Hermes 2 PSAR on shared facilities and equipment is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs in accordance with 10 CFR 50.35.

1.5 Comparison with Similar Facilities

The staff evaluated the sufficiency of Kairos's comparison of Hermes 2 with other similar facilities[1], as presented in section 1.5, "Comparison with Similar Facilities," of the Hermes 2 PSAR, using the guidance and acceptance criteria from section 1.5, "Comparison with Similar Facilities," of NUREG-1537, Parts 1 and 2.

Section 1.5 of the Hermes 2 PSAR states that the two Hermes 2 reactors will use pebble-based tristructural isotropic (TRISO) fuel with molten fluoride salt coolant. Kairos states that there are no existing or historical reactors that have used this specific fuel and coolant technology combination. However, Kairos states that the use of molten fluoride salt coolant was demonstrated in the Molten Salt Reactor Experiment (MSRE) at Oak Ridge National Laboratory.[2] In addition, the use of pebble-based fuel designs with pebbles containing graphite moderator and TRISO fuel particles has been demonstrated in high-temperature gas-cooled pebble bed reactors (PBRs), which have been designed, constructed, and operated internationally. Kairos states that Hermes 2 fuel is similar to the PBR fuel, but has slightly smaller pebbles, is cooled by a molten fluoride salt coolant instead of an inert gas, is buoyant in the coolant, and includes an annular fuel layer within the pebble. TRISO particle fuel in stationary (non-pebble) particle form, (similar to the particles that would be contained within Hermes 2 fuel pebbles) has been used in other high-temperature gas-cooled reactor (HTGR) designs, including the Peach Bottom Unit 1 and Fort St. Vrain power reactors that were constructed and operated in the United States.[3]

Section 1.5.2.2, "Graphite," of the Hermes 2 PSAR states that the two Hermes 2 reactors will use graphite as a moderator, which is similar to several other operating designs such as the Advanced Gas-Cooled Reactor (AGR) type reactors designed and operated in the United

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[1] As noted in section 1.1, the Hermes 1 facility is similar to the proposed Hermes 2 facility. However, the Hermes 1 final design was not completed, nor was construction of Hermes 1 completed, before the finalization of this SE. Because the NUREG-1537, Part 2, section 1.5, criteria are focused on comparison to existing facilities, Hermes 1 was not included for comparison in this section.
[2] The MSRE, which operated from 1965 to 1969 at power levels up to approximately 8 megawatts-thermal, utilized fuel dissolved in the salt coolant.
[3] Peach Bottom Unit 1, which operated from 1967 to 1974, was a 200 megawatt-thermal helium-cooled graphite moderated power reactor. Fort St. Vrain Nuclear Power Plant, which operated from 1979 until 1989, was a 842 megawatt-thermal helium-cooled graphite moderated power reactor.

Kingdom. For comparison, the Hermes 2 reactors will use a primary coolant containing a molten salt that is a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF_2) (commonly referred to as Flibe) in addition to graphite reflector assemblies on the bottom, top, and sides of the active core to provide neutron moderation, while the AGRs used graphite for neutron moderation and carbon dioxide as coolant. Section 1.5.3, “Comparison of Support Systems,” of the Hermes 2 PSAR states that the Hermes 2 reactors’ auxiliary systems, such as inventory control and chemistry monitoring, while Flibe-based, are functionally similar to conventional systems used at other reactors. In addition, other Hermes 2 auxiliary systems, including ventilation, cooling water, electrical power, power generation system, and instrumentation and control systems, are also generally conventional in nature.

The staff found that Kairos identified a number of similar facilities covering key aspects of the Hermes 2 design. MSRE provides relevant experience with molten fluoride salt coolant, while PBR experience is relevant to the use of pebbles with TRISO fuel particles. In addition, TRISO particle fuel has been used in previously operating HTGRs. Finally, AGR experience is relevant to the use of graphite as a neutron moderator as is planned in the Hermes 2 reactors’ design. The staff determined that this collective experience of safe operation from multiple other reactor technologies with a number of key Hermes 2 design features provides additional confidence in the inherent safety of those design features.

Consistent with the review procedures of NUREG-1537, Part 2, section 1.5, the staff confirmed that the characteristics of any facilities compared with the proposed facility were similar and relevant. The staff also verified that the operating history of facilities cited by Kairos generally demonstrated consistently safe operation, use, and protection of the public.

Based on its review, the staff finds that the level of detail provided on comparisons with similar facilities satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 1.5 (considering that Hermes 2 would use a novel design that, while different from that of any existing or historical reactors, includes several key design features that are similar to those of other reactors), allowing the staff to make the following findings:

1. Kairos has compared the design bases and safety considerations of Hermes 2 with similar facilities, as practicable. The history of these facilities and their design features relevant to the Hermes 2 demonstrates consistently safe operation that is acceptable to the staff.
2. Aspects of the Hermes 2 design that are similar to features in other facilities that have been found acceptable to the staff, or otherwise demonstrated successful operation, should be expected to perform in a similar manner to these comparable features in other facilities.
3. Kairos is using test data and operational experience from facilities with similar components and design features in designing Hermes 2 components, as practicable.

Therefore, the staff concludes that the comparisons with similar facilities, as described in PSAR section 1.5, are sufficient and meet the applicable regulatory requirements and guidance for the issuance of a CP in accordance with 10 CFR 50.35.

1.6 Summary of Operations

The staff evaluated the sufficiency of the summary of Hermes 2 operations, as presented in section 1.6, “Summary of Operations,” of the Hermes 2 PSAR, using the guidance and acceptance criteria from section 1.6, “Summary of Operations,” of NUREG-1537, Parts 1 and 2.

Consistent with the review procedures of NUREG-1537, Part 2, section 1.6, the staff verified that Kairos summarized the proposed operations of Hermes 2.

In section 1.6 of the Hermes 2 PSAR, Kairos states that the purpose of Hermes 2 will be to test and demonstrate the key technologies, design features, and safety functions of Kairos's KP-FHR technology, as well as to provide data and insights for the design and licensing of a KP-FHR commercial power reactor. Hermes 2 would operate over its full range of power during a 11-year lifetime and produce approximately 20 megawatts (MW) of electrical power. In chapter 4, "Reactor Description," of the Hermes 2 PSAR, Kairos states that the reactors will each be designed with the capability to achieve power levels up to 35 megawatts-thermal. Kairos states that further information regarding Hermes 2 operations and programs will be provided in an OL application.

Based on its review of the information in PSAR section 1.6 and other PSAR chapters, the staff finds that Kairos's information regarding the proposed operation of Hermes 2 is consistent with relevant assumptions and analyses in later PSAR chapters in which any safety implications of the proposed operations are evaluated. Therefore, the summary of operations satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 1.6. Accordingly, the staff concludes that the summary of operations, as described in PSAR section 1.6, is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs in accordance with 10 CFR 50.35. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration in an OL application.

1.7 <u>Compliance with the Nuclear Waste Policy Act of 1982</u>

The Nuclear Waste Policy Act of 1982 (42 USC § 10101) provides that the U.S. Government is responsible for the permanent disposal of high-level radioactive waste and spent nuclear fuel, but the cost of disposal should be the responsibility of the generators and owners of such waste and spent fuel. Section 1.7, "Compliance with the Nuclear Waste Policy Act of 1982," of the Hermes 2 PSAR states:

> Kairos Power intends to enter into a contract with the Department of Energy (DOE) for the disposition of high-level waste and spent nuclear fuel. The contract will provide that the DOE accept title to the fuel and the obligation to take the spent fuel and/or high-level waste for storage or reprocessing. This will be discussed further in the application for the Operating License, consistent with Section 302(b)(1) of the Nuclear Waste Policy Act of 1982.

The staff evaluated the sufficiency of Kairos's compliance with the Nuclear Waste Policy Act using the guidance and acceptance criteria from section 1.7, "Compliance with the Nuclear Waste Policy Act of 1982," of NUREG-1537, Parts 1 and 2. The staff determined that to be in compliance at the CP stage, Kairos needs to submit documentation showing communications in good faith between Kairos and the DOE to enter into a contract for the disposition of high-level waste and nuclear fuel. By letter dated October 31, 2023 (ML23304A312), Kairos provided documentation from the DOE that Kairos is actively and in good faith negotiating on a contract under section 302(b) of the Nuclear Waste Policy Act. Because Kairos has provided documentation of good faith negotiations with the Department of Energy, the staff finds that Kairos is in compliance with the Nuclear Waste Policy Act at the CP stage, consistent with NUREG-1537, Part 2, section 1.7.

1.8 Facility Modifications and History

The staff evaluated the sufficiency of Kairos's descriptions of facility modifications and history, as presented in section 1.8, "Facility Modifications and History," of the Hermes 2 PSAR, using the guidance and acceptance criteria from NUREG-1537, Parts 1 and 2, section 1.8, "Facility Modifications and History."

As stated in PSAR section 1.8, "This report is an application for the new construction of a non-power reactor facility. There are no prior operating histories of existing Nuclear Regulatory Commission licensed facilities nor modifications to existing licensed facilities to report." The staff determined that there are no existing facilities, there have been no modifications, and there is no history to report on the Hermes 2 test reactor facility.

Therefore, the staff concludes that Kairos's description of facility modifications and history in the PSAR section 1.8 is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs for a test reactor facility in accordance with 10 CFR 50.35.

1.9 References

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

-----. KP-TR-017-NP, "KP-FHR Core Design and Analysis Methodology," Revision 1, dated September 29, 2022, ML22272A598.

-----. "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1]), Revision 3," dated May 31, 2023, ML23151A743.

-----. KP-TR-022-NP, "Hermes 2 Postulated Event Methodology," Revision 2, dated June 30, 2023, ML23195A131.

-----. "Submittal of the Construction Permit Application for the Hermes 2 Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor," dated July 14, 2023, ML23195A121.

-----. "Enclosure 10: Summary of PSAR Deletions," dated July 14, 2023, ML23195A132.

-----. "Kairos Power LLC, Response to Hermes 2 General Audit Question 1.5-1," dated October 27, 2023, ML23300A143.

-----. "Kairos Power Response to Hermes 2 General Audit Question 1.5-2," dated October 27, 2023, ML23300A144.

-----. "Kairos Power LLC - Additional Information Related to Hermes 2 Construction Permit Application – PSAR Chapter 1," dated October 31, 2023, ML23304A312.

-----. "Kairos Power, LLC, Transmittal of Changes to Hermes 2 Construction Permit Application – PSAR Chapter 13 and KP-TR-022," dated December 22, 2023, ML23356A078.

-----. "Kairos Power, LLC, Response to NRC Request for Confirmation of Information for the Review of the Hermes 2 PSAR Chapter 5," dated April 12, 2024, ML24103A243.

-----. “Kairos Power, LLC, Response to NRC Request for Confirmation of Information for the Review of the Hermes 2 PSAR Chapter 5,” dated May 14, 2024, ML24135A382.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC). NUREG-1537, Part 1, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content,” dated February 1996, ML042430055.

-----. NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” dated February 1996, ML042430048.

-----. “Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes [1] Test Reactor,” dated June 16, 2023, ML23158A265.

-----. “Acceptance for Docketing of the Hermes 2 Non-power Test Reactor Construction Permit Application Submitted by Kairos Power LLC,” dated September 11, 2023, ML23233A167.

-----. “Hermes 2 General Audit Plan,” dated October 3, 2023, ML23268A446.

-----. “Hermes [1] Test Reactor Construction Permit,” dated December 14, 2023, ML23338A258.

-----. “Request for Confirmation of Information for Hermes 2 Preliminary Safety Analysis Report,” dated May 14, 2024, ML24135A260.

-----. “Request for Confirmation of Information 3 for Hermes 2 Preliminary Safety Analysis Report,” dated April 12, 2024, ML24103A173.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes 2 Construction Permit Preliminary Safety Analysis Report – General Audit,” dated July 11, 2024, ML24193A214.

-----. “Environmental Assessment and Finding of No Significant Impact for the Construction Permits for the Kairos Hermes 2 Test Reactors, Draft Report for Comment,” dated April 19, 2024, ML24103A002.

2 SITE CHARACTERISTICS

The purpose of evaluating the site characteristics of a proposed reactor facility is to determine whether the site selected is suitable for constructing and operating the proposed facility. Site characteristics include geography and demography; nearby industrial, transportation, and military facilities; meteorology; hydrology; and geology, seismology, and geotechnical engineering.

This chapter of the Hermes 2 construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary information on site characteristics provided in chapter 2, "Site Characteristics," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed PSAR chapter 2 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information on site characteristics for the issuance of CPs in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities."

2.1 Geography and Demography

2.1.1 Introduction

Section 2.1, "Geography and Demography," of the Hermes 2 PSAR describes the proposed Hermes 2 site and its surroundings, including population distributions for the area around the site.

2.1.2 Regulatory Evaluation

The staff reviewed section 2.1.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the site geography and demography between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 2.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 2.1.2 of the Hermes 1 SE.

2.1.3 Technical Evaluation

The staff reviewed section 2.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 2.1, "Geography and Demography"). The staff found that section 2.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few minor changes and a few significant changes, which are evaluated below in section 2.1.3.1 and section 2.1.3.2, respectively. The staff found that the following portions of section 2.1 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 2.1.1.1, "Specification and Location"
- Section 2.1.1.2, "Boundary and Zone Area Maps"

Since the Hermes 2 site geography and demography largely remain identical, apart from the differences evaluated below, section 2.1 of the Hermes 2 PSAR contains information consistent with section 2.1 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 2.1.3, “Technical Evaluation,” of the Hermes 1 SE.

2.1.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 2.1, as compared to the information in Hermes 1 PSAR section 2.1, include the following:

- The latitude and longitude, Universal Transverse Mercator coordinates, and Roane County State Plane coordinates for the location of the Hermes 2 reactor facility are provided.
- The Hermes 1 facility was added to the list of prominent natural and man-made features within approximately 5 miles (8 kilometers (km)) of the proposed Hermes 2.
- PSAR figures 2.1-2, “Prominent Features in Site Area,” and 2.1-3, “Project Site Area and Zones Associated with the Facility,” were updated to show the nearest full time resident and to show the Hermes 2 facility, respectively.

Kairos provided the coordinates of the proposed Hermes 2 facility in latitude and longitude, Universal Transverse Mercator, and Roane County State Plane. The staff confirmed that these coordinate values are accurate for the Hermes 2 facility. In addition, Kairos added the Hermes 1 facility to the list of prominent natural and man-made features within approximately 5 miles (8 km) of the proposed reactor facility (i.e., Hermes 2). The addition of the Hermes 1 facility to the list is appropriate because it will be a prominent feature when the Hermes 2 facility is being constructed and operated. Kairos updated figure 2.1-2 to identify that the nearest full time resident lives approximately ½ mile closer than previously known at the time that the Hermes 1 CP application was reviewed and updated figure 2.1-3 to include the Hermes 2 facility. The staff determined that the updates to figures 2.1-2 and 2.1-3 are appropriate because they account for the most recent knowledge about the proposed Hermes 1 and Hermes 2 sites and local area. Based on the above, the staff finds that the Hermes 2 coordinates, the addition of Hermes 1 facility to list of prominent and man-made features, and the updates to figures 2.1-2 and 2.1-3, are acceptable.

2.1.3.2 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in section 2.1 of the Hermes 2 PSAR, as compared to section 2.1 of the Hermes 1 PSAR, include information regarding the following:

- Revision to the distribution of resident population within 5 miles (8 km) from the proposed reactor facility site in both Roane and Morgan counties.

These changes are identified in:

- Section 2.1.2, “Population Distribution”
- Table 2.1-1, “Resident Population Distribution within 5 miles (8 km) of the Site in Roane County”
- Table 2.1-2, “Resident Population Distribution within 5 miles (8 km) of the Site in Morgan County”
- Figure 2.1-5, “Resident Population Distribution - 2020”
- Figure 2.1-6, “Resident Population Distribution - 2026”
- Figure 2.1-7, “Resident Population Distribution - 2031”

- Figure 2.1-8, “Resident Population Distribution - 2040”

The staff evaluated the sufficiency of this additional preliminary information regarding resident population distribution surrounding the proposed Hermes 2 site using the guidance and acceptance criteria from section 2.1, “Geography and Demography,” of NUREG-1537, Part 1, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content,” and Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” Section 2.1.2, “Population Distribution,” of the Hermes 2 PSAR describes the distribution of resident and transient populations within 5 miles (8 km) of the center point of the proposed site for the years 2026 (the beginning of the requested construction period), 2031, and 2040 (the approximate end of the requested 11-year license period), as described in Hermes 2 PSAR tables 2.1-1 and 2.1-2 and PSAR figures 2.1-5 through 2.1-8 using the 2020 decennial census data to project the population distribution. In these PSAR tables and figures, the projected population is presented in five distance bands, represented by concentric circles: 0 to 0.5 miles (0 to 0.8 km), 0.5 to 1 mile (0.8 to 1.6 km), 1 to 2 miles (1.6 to 3.2 km), 2 to 3 miles (3.2 to 4.8 km), and 3 to 5 miles (4.8 to 8 km). Each distance band is subdivided into 16 equal directional sectors. Kairos’s estimated population distributions for 2026, 2031, and 2041, are based on estimates for Roane and Morgan counties from the Boyd Center for Business and Economic Research, the demographer for the State of Tennessee. Because there are no schools or lodging facilities within 5 miles (8 km) of the proposed site, Kairos concluded that there is zero transient population in the area.

The staff finds the change in population distribution surrounding the proposed site for the Hermes 2 facility is acceptable as it is based on the most current (2020) census data. In addition, the population distribution for Roane and Morgan counties near the proposed site projected for 2026, 2031, and 2041, are based on estimates from the official demographer for the State of Tennessee using the 2020 census data. Based on the above, the staff finds the updated population distribution surrounding the proposed site for the Hermes 2 reactors acceptable.

Based on its review, the staff determined that the geographical and demographical information provided in the Hermes 2 PSAR is sufficiently detailed and accurate to provide the necessary bases to allow accurate assessments of the potential radiological impact on the public resulting from the siting and operation of the proposed Hermes 2 facility, including analysis (e.g., dose calculations) presented in other PSAR chapters. The staff also finds that no geographic or demographic characteristics of the Hermes 2 site render the site unsuitable for operation of the Hermes 2 facility, and that the information provided meets the applicable acceptance criteria of NUREG-1537, Part 2, section 2.1. Accordingly, the staff finds that the level of detail provided on geography and demography demonstrates an adequate design basis for the Hermes 2 facility.

2.1.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information in Hermes 2 PSAR section 2.1 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35, “Issuance of construction permits,” and 10 CFR 50.40, “Common standards.”

2.2 Nearby Industrial, Transportation, and Military Facilities

2.2.1 Introduction

Section 2.2, “Nearby Industrial, Transportation, and Military Installations,” of the Hermes 2 PSAR describes the present and projected future industrial, transportation, and military installations and operations in the area around the proposed Hermes 2 site.

2.2.2 Regulatory Evaluation

The staff reviewed section 2.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the nearby industrial, transportation, and military facilities between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 2.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 2.2.2 of the Hermes 1 SE.

2.2.3 Technical Evaluation

The staff reviewed section 2.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 2.2, “Nearby Industrial, Transportation, and Military Installations”). The staff found that section 2.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few significant changes, which are evaluated below in SE section 2.2.3.1. The staff found that the following portions of Section 2.2 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 2.2, “Nearby Industrial, Transportation, and Military Installations”
- Sections 2.2.1.1, “Description of Pipelines,” through 2.2.1.4, “Description of Railroads”
- Sections 2.2.2.1, “Identification of Air Traffic Near the Site,” through 2.2.2.3, “Evaluation of Airport Hazards and Helicopter Operations”
- Sections 2.2.3.2, “Flammable Vapor Clouds,” through 2.2.3.4, “Fires”

Since the Hermes 2 site location largely remains identical to Hermes 1, apart from the differences evaluated below, the discussion of nearby industrial, transportation, and military facilities in section 2.2 of the Hermes 2 PSAR contains information consistent with section 2.2 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 2.2.3, “Technical Evaluation,” of the Hermes 1 SE.

2.2.3.1 Significant Changes Compared to the Hermes 1 PSAR

The significant changes in Hermes 2 PSAR section 2.2, as compared to the information in Hermes 1 PSAR section 2.2, include the following:

- Effective area of the Hermes 2 facility
- Increased aircraft accident frequency for the site
- Addition of four facilities on the list of facilities within 5 miles (8 km) of the proposed site

These changes are identified in the following portions of the Hermes 2 PSAR:

- Table 2.2-7, “Calculated Effective Areas of Safety-Related Structures (square miles) by Aircraft Type Used for the Evaluation of Airways and Airport”
- Section 2.2.2.4, “Summary of Risks from Air Traffic” and table 2.2-9, “Total Crash Probability”
- Section 2.2.1, “Locations and Routes,” section 2.2.3, “Analysis of Potential Accidents at Facilities,” section 2.2.3.1, “Explosions,” table 2.2-1, “Nearby Facilities,” table 2.2-2, “Facilities Unable to Affect the Facility,” table 2.2-3, “Nearby Facility Chemical Storage,” and table 2.2-10, “Evaluation of Chemical Explosion Hazards Near the Site”

As Hermes 2 is a two-unit facility, compared to the single-unit Hermes 1 facility, the effective area of the reactor facility considered for evaluating aircraft crash hazards will be larger than that of the Hermes 1 facility, as reflected in PSAR table 2.2-7. Accordingly, since the footprint of each Hermes 2 reactor is the same as that of the Hermes 1 reactor, the effective area of the Hermes 2 reactor facility corresponding to each aircraft type is twice that assumed for Hermes 1. The staff finds that the estimated effective areas denoted in Hermes 2 PSAR table 2.2-7 for evaluating crash hazards from different types of aircraft flying in the vicinity of the proposed site are appropriate based on the size of the facility.

To assess the projected number of flights at the proposed Oak Ridge Airport, Kairos used the environmental assessment (EA) prepared by the U.S. Department of Energy (DOE) for transferring the property to develop the general aviation airport (DOE, 2016). Additionally, Kairos used the same air traffic information used for Hermes 1 of the Jet Route J46 and the Victor Route V16. The staff reviewed the EA prepared by the DOE for transferring the property and a draft EA of the proposed Oak Ridge Airport developed by the Federal Aviation Administration (FAA) (FAA, 2023). The runway of the proposed airport was shifted slightly to the southeast increasing the distance from the Hermes 2 facility, when compared to the evaluations performed for Hermes 1.

In addition, based on the airport master plan, the draft FAA EA indicates that there will be 14,796 forecasted annual operations by general aviation aircraft in 2025 and 15,906 in 2040. The forecasted number of operations at the proposed Oak Ridge Airport is smaller (approximately 32 percent) than that given in table 2.4, “Oak Ridge Local and Itinerant Operations Forecast,” of the DOE EA. The staff finds that the DOE EA has given the average of the operations at six nearby airports by the general aviation aircraft. As the number of operations given in the draft FAA EA is based on the airport master plan and would therefore be considered more specific to the proposed site, the staff used the number of operations forecasted in the draft FAA EA as the anticipated number of annual general aviation aircraft operations for the current hazard assessment.

Using the forecasted number of operations at the proposed Oak Ridge Airport from the draft FAA EA, the estimated annual crash frequency will be smaller than that provided in Hermes 2 PSAR table 2.2-9; “Total Crash Probability.” While the staff determined that the annual crash frequency estimated by Kairos is conservative, the estimated total annual crash frequency would still be above the credible hazard threshold. Therefore, Kairos stated that for all cases, the annual crash frequency criterion is exceeded due to general aviation aircraft use at the proposed Oak Ridge Airport. Consequently, in Hermes 2 PSAR sections 2.2.2.4 and 3.5, “Plant Structures,” Kairos stated that the safety-related portion of the two reactor buildings will be designed to withstand the impact of a general aviation aircraft. The staff will review the basis for selecting the “critical” aircraft type for designing the safety-related portion of the reactor buildings during a future review of the operating license (OL) application of the Hermes 2 facility.

In Hermes 2 PSAR section 2.2.3 and table 2.2-1, Kairos identified four additional nearby facilities at which an accident can potentially affect the proposed Hermes 2 reactor facility:

1. Hermes 1 Facility: This facility will be located within the site boundary. This facility has received a CP from the NRC. The Hermes 1 PSAR states that the offsite radiological impacts during routine operations and severe accidents of the facility would be within the regulatory limits. The Hermes 1 facility will have an on-site diesel fuel tank with the capacity of 21,555 gallons (81,595 liters). In addition, the Hermes 1 facility will have an inventory of 40,000 pounds (18,144 kilograms) of low-pressure molten salt coolant (Flibe); however, the quantities of other chemicals are not yet finalized. In addition, the locations of all on-site chemicals at the Hermes 1 facility are not yet finalized. Kairos analyzed the potential overpressure assuming the on-site diesel storage tank at its upper fire/explosion limit. The safe distance at which the overpressure is below 1 psi (6.7 kilopascals) is estimated to be 0.09 miles (0.14 km). Kairos will analyze the potential thermal radiation to be experienced by the safety-related structures, systems, and components at the Hermes 2 facility that could result from a fire at the Hermes 1 on-site diesel storage tank as part of the Hermes 2 OL application. Additionally, the staff will evaluate the potential thermal radiation during its review of the Hermes 2 OL application.

2. Kairos Power Atlas Fuel Fabrication Facility: This is a tristructural isotropic (TRISO)-based nuclear fuel fabrication facility that Kairos has proposed locating within the site boundary of the Hermes 2 facility. Kairos will analyze the potential hazards from this facility in the Hermes 2 OL application. The staff will evaluate the potential hazards from the Kairos Power Atlas Fuel Fabrication Facility during its review of the Hermes 2 OL application.

3. TRISO-X Fuel Facility: This is a TRISO-based nuclear fuel fabrication facility that would be located at the nearby Horizon Center, approximately 2.4 miles (3.9 km) northeast of the proposed Hermes 2 facility. Kairos will analyze the potential hazards from this facility in the OL application. The staff will evaluate the potential hazards from the TRISO-X Fuel Facility during its review of the Hermes 2 OL application.

4. Ultra Safe Nuclear Corporation Pilot Fuel Manufacturing Facility: This is a TRISO-based nuclear fuel fabrication facility located approximately 0.8 miles (1.3 km) southeast of the proposed Hermes 2 facility at the East Tennessee Technology Park (ETTP). The Hermes 2 PSAR does not have further information on this facility. Kairos is collecting information on this facility and potential hazards to the proposed Hermes 2 facility will be analyzed in the Hermes 2 OL application. The staff will evaluate the potential hazards from the Ultra Safe Nuclear Corporation Pilot Fuel Manufacturing Facility during its review of the Hermes 2 OL application.

The staff finds that these four facilities are sufficiently close to the location of the Hermes 2 reactors and an accident at any of these facilities can potentially affect the safe operation of the Hermes 2 facility. The inclusion of these nearby facilities for assessing potential hazards (i.e., effects of explosions, flammable vapor clouds, and toxic chemicals from onsite chemical storage at these facilities) to the Hermes 2 reactors presents a complete and current overview of facilities, activities, and materials located in the vicinity of the proposed reactor site and, therefore, is acceptable.

Based on its review, the staff determined that the level of detail and analyses provided on nearby industrial facilities, transportation routes, and military facilities demonstrate an adequate design basis and satisfy the applicable acceptance criteria of NUREG-1537, Part 2, section 2.2, allowing the staff to find that:

- The information in the PSAR is sufficiently detailed to provide an accurate description of the nearby facilities and transportation routes and hazards to the proposed facility posed by them.
- The description of the hazards and their assessments are adequate to determine potential radiological impact on the public resulting from the siting and operation of the proposed reactor facility.
- Potential hazards associated with nearby transportation routes and industrial and military facilities will pose no undue risk to the proposed facility as the facility is either designed against it (e.g., aircraft crash hazard) or the hazard is not a credible hazard to the proposed facility.

2.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information on nearby industrial, military, and transportation facilities in Hermes 2 PSAR section 2.2 is sufficient and meets the applicable guidance and regulatory requirements identified in this SE section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design details required to complete the safety analysis may reasonably be left for later consideration and the staff will confirm that the final design conforms to this design basis during the evaluation of the Hermes 2 OL application.

2.3 Meteorology

2.3.1 Introduction

Section 2.3, "Meteorology," of the Hermes 2 PSAR describes the general climate of the region around the proposed Hermes 2 site and meteorological conditions relevant to the design and operation of the Hermes 2 facility. PSAR section 2.3 also provides data and information used to determine the atmospheric dispersion conditions in the vicinity of the site. This information includes local and regional airflow and meteorological measurements used for dispersion estimates.

2.3.2 Regulatory Evaluation

The staff reviewed section 2.3.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the meteorology between Hermes 1 and Hermes 2 (i.e., the proposed sites are collocated), the staff finds that the regulations and guidance listed in section 2.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 2.3.2 of the Hermes 1 SE.

2.3.3 Technical Evaluation

The staff reviewed section 2.3, “Meteorology,” of the Hermes 2 PSAR and compared it to the equivalent material in the Hermes 1 PSAR (section 2.3, “Meteorology”). The staff found that the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few minor changes, which are evaluated below. The staff also verified that the Hermes 2 site meteorological data remain almost identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 2.3.3 of the Hermes 1 SE.

2.3.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 2.3, as compared to the information in Hermes 1 PSAR section 2.3, include the following:

- Changes in years of data collection, daily temperature (degrees Fahrenheit (°F)), relative humidity and precipitation for the Oak Ridge area
- Collection of thunderstorm data increased by one year
- Changes to years of reports for hail and increase on reported instances of severe hail for Knox County
- Increase in the number of lightning strikes and changes to the proximity of lightning strikes to the site
- Increase in years taken into consideration from the tornado events databases
- Description of tropical systems and hurricanes near the site for years 2021 and 2022
- The expected licensed period of operation for Hermes 2 is approximately 11 years; the expected period of operation for Hermes 1 is 4 years

In Hermes 2 PSAR section 2.3.1, “Regional Climatology,” Kairos provided changes to the data period used and the daily minimum and maximum temperature (°F), the data period and the regional average for relative humidity, and data related to annual precipitation and the wettest and driest seasons for the Oak Ridge area. The staff reviewed the information on the regional climatology of the proposed Hermes 2 site, including verification that Kairos obtained the information from appropriate sources and that the information is consistent with other available data. The staff determined the information appears reasonable for the geographic area and that Kairos’s assessment is sufficient for evaluation of the regional climatology to inform the design bases for the Hermes 2 facility. Based on the above, the staff finds that the assessment of the regional climatology is acceptable.

Hermes 2 PSAR section 2.3.1.2, “Thunderstorms,” states that the data collection period is from 2001-2021, which is an increase of 1 year from the Hermes 1 CP application. The staff reviewed the information on thunderstorms in the region of the proposed Hermes 2 site, including verification that Kairos obtained the information from appropriate sources and that the information is consistent with other available data. The staff determined that the information appears reasonable for the geographic area and that Kairos’s assessment is sufficient for the evaluation of potential thunderstorm impacts on Hermes 2 to inform the design bases for the Hermes 2 facility. Based on the above, the staff finds that the assessment of thunderstorms is acceptable.

Hermes 2 PSAR section 2.3.1.3, “Hail,” states that the data collection period is from 1950-2022, which is an increase of 2 years from the Hermes 1 CP application. During that period, the instances of severe hail in Knox County were updated to 94. The staff reviewed the information on hail in the region of the proposed Hermes 2 site, including verification that Kairos obtained the information from appropriate sources and that the information is consistent with other available data. The staff determined that the information appears reasonable for the geographic area and that Kairos's assessment is sufficient for the evaluation of potential hail impacts on Hermes 2 to inform the design bases for the Hermes 2 facility. Based on the above, the staff finds that the assessment of hail is acceptable.

Hermes 2 PSAR section 2.3.1.4, "Lightning," states that, during the review period, 7 of the 10 years had a lightning strike occurring within the proposed site boundary or within 500 feet (ft.) of the site. One of these years (2012) was a year with an exceptionally high number of cloud-to-ground lightning strikes. Eleven lightning strikes occurred within the site boundary with several more strikes occurring within 500 ft. of the site. The staff reviewed the information on lightning in the region of the proposed Hermes 2 site, including verification that Kairos obtained the information from appropriate sources and that the information is consistent with other available data. The staff determined that the information appears reasonable for the geographic area and that Kairos's assessment is sufficient for the evaluation of potential lightning impacts on Hermes 2 to inform the design bases for the Hermes 2 facility. Based on the above, the staff finds that the assessment of lightning is acceptable.

Hermes 2 PSAR section 2.3.1.7, "Tornadoes," states that the period of data review changed to a 73-year period of 1950-2022. The staff reviewed the information regarding tornadoes in the region of the proposed Hermes 2 site, including verification that Kairos obtained the information from appropriate sources and that the information is consistent with other available data. The staff determined that the information appears reasonable for the geographic area and that Kairos's assessment is sufficient for the evaluation of potential impacts from tornadoes on Hermes 2 to inform the design bases for the Hermes 2 facility. Based on the above, the staff finds that the assessment of tornadoes is acceptable.

Hermes 2 PSAR section 2.3.1.8, "Hurricanes," states that there have been 12 tropical storms within a 50-mile radius of the site. The PSAR states that in 2021, two tropical systems passed within a 50-mile radius of the site, but both were tropical depressions when they passed through the area. PSAR section 2.3.1.8 states that in 2022, a system which had been classified as a hurricane came within a 50-mile radius of the site, but by the time it reached the area, it was downgraded to a tropical depression, and dissipated over eastern Tennessee. The staff reviewed the information on hurricanes in the region of the proposed Hermes 2 site, including verification that Kairos obtained the information from appropriate sources and that the information is consistent with other available data. The staff determined that the information appears reasonable for the geographic area and that Kairos's assessment is sufficient for the evaluation of potential impacts from hurricanes on Hermes 2 to inform the design bases for the Hermes 2 facility. Based on the above, the staff finds that the assessment of hurricanes is acceptable.

Hermes 2 PSAR section 2.3.1.14, "Climate Change," states that the approximate license period for the facility is 11 years. The staff reviewed the information related to climate change and determined that Kairos's assessments of climate information to inform the design bases for Hermes 2 are sufficient given the 11-year planned operation period for the facility and because the staff does not expect climate changes over an 11-year period to significantly impact Hermes 2 operation or the design bases. Based on the above, the staff finds that the assessment of climate change is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 site meteorology demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 2.3, that the site area is sufficiently documented so that meteorological impacts on reactor safety and operation can be reliably predicted.

2.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information on meteorology in Hermes 2 PSAR section 2.3 is sufficient and meets the applicable guidance and regulatory requirements identified in this SE section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information on meteorology (e.g., details regarding long-term dispersion modeling) can reasonably be left for later consideration in the OL application since this information is not necessary to be provided as part of a CP application.

2.4 Hydrology

2.4.1 Introduction

Section 2.4, “Hydrology,” of the Hermes 2 PSAR describes postulated hydrological events and potential flood hazards for the proposed Hermes 2 site. Kairos references hydrological information from several flood hazard study reports. Kairos stated that information in PSAR section 2.4 supports the analyses and evaluations of the consequences of potential uncontrolled releases of radioactive material.

2.4.2 Regulatory Evaluation

The staff reviewed section 2.4.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the hydrology between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 2.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 2.4.2 of the Hermes 1 SE.

2.4.3 Technical Evaluation

The staff reviewed section 2.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 2.4, “Hydrology”). The staff found that section 2.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes, which are evaluated below. The staff also verified that the Hermes 2 hydrology is identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 2.4.3 of the Hermes 1 SE.

2.4.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 2.4, as compared to the information in Hermes 1 PSAR section 2.4, include the following:

- Increased proposed operating life from 4 years (Hermes 1) to 11 years (Hermes 2)
- Table 2.4-2, “Roane County FEMA FIS Flooding Elevation (Projected to Site),” adds to the (**) note the following statement, “…on plant grade El 765 NAVD 88.”

Section 2.4 of the Hermes 2 PSAR states that the intended licensing period is increased from 4 years to 11 years. The Hermes 1 SE describes staff's evaluation and findings with regard to dam safety during the facility's 4-year operating lifetime. The staff's findings are applicable to Hermes 2's longer operating lifetime of 11 years because the ongoing oversight and inspections carried out by the Tennessee Valley Authority (TVA) as part of its dam safety program will continue throughout the 11-year proposed licensing term of Hermes 2, providing the staff with reasonable assurance that a dam failure resulting in site flooding would be very unlikely. Additionally, as discussed in, "The Status of Methods for Estimation of the Probability of Failure of Dams for Use in Quantitative Risk Assessment," the probability of a "sunny day" dam failure is low, for both a 4-year operational life or the 11-year operational life of Hermes 2. Therefore, the associated flooding mechanism is not considered a credible hazard for a 4-year or a 11-year operating lifetime. Based on the above, the staff finds that the proposed 11-year operating lifetime is acceptable with regard to site hydrology.

The addition to the (**) note in Hermes 2 PSAR table 2.4-2 provides additional information on the basis for the numbers in the column, "Estimated Depth at Hermes 2." This addition does not change any of the technical information in the table, nor did the technical information in table 2.4-2 change from that provided in the Hermes 1 CP application. Based on the above, the staff finds that the addition to the note is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 hydrology demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 2.4, "Hydrology," that the site has been selected with due consideration of potential hydrologic events and consequences.

2.4.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information regarding hydrology in section 2.4 of the Hermes 2 PSAR is sufficient and meets the applicable guidance and regulatory requirements identified in this SE section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information on hydrology can reasonably be left for later consideration in the OL application since this information is not necessary to be provided as part of a CP application.

2.5 Geology, Seismology, and Geotechnical Engineering

2.5.1 Introduction

Section 2.5, "Geology, Seismology, and Geotechnical Engineering," of the Hermes 2 PSAR describes the geologic, geophysical, seismic, and geotechnical characteristics of the proposed Hermes 2 site and the surrounding region.

2.5.2 Regulatory Evaluation

The staff reviewed section 2.5.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the geology, seismology, and geotechnical engineering between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 2.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 2.5.2 of the Hermes 1 SE.

2.5.3 Technical Evaluation

The staff reviewed section 2.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 2.5, "Geology, Seismology, and Geotechnical Engineering"). The staff found that section 2.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a significant change, which is evaluated below in SE section 2.5.3.1. The staff found that the following portions of Hermes 2 PSAR section 2.5 contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 2.5.1, "Regional Geology"
- Section 2.5.2, "Site Geology"
- Section 2.5.2.2, "Site Subsurface Stratigraphy," through section 2.5.2.3.2, "Subsurface Stratigraphy"
- Section 2.5.3, "Vibratory Ground Motion" through section 2.5.3.4.6, "Enveloping Design Response Spectrum"
- Section 2.5.4, "Potential for Subsurface Deformation," through section 2.5.4.2, "Liquefaction Potential"
- Section 2.5.5, "Foundation Interface," and 2.5.5.1, "Site History"
- Section 2.5.6, "References"

Since the design and functionality of the Hermes 2 systems remain largely identical to those of Hermes 1, apart from the differences evaluated below, section 2.5 of the Hermes 2 PSAR contains information consistent with section 2.5 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 2.5.3, "Technical Evaluation," of the Hermes 1 SE.

2.5.3.1 Significant Change Compared to the Hermes 1 PSAR

A significant change contained in section 2.5 of the Hermes 2 PSAR, as compared to section 2.5 of the Hermes 1 PSAR, includes information regarding the following:

- Plant layout and foundation interface for the Hermes 2 reactors and their relative position to Hermes 1 and Borings B-1, B-3, and B-6.

This change is identified in the following Hermes 2 PSAR sections:

- Sections 2.5.2.1, "Karst," and 2.5.4.3, "Karst"
- Section 2.5.5.2, "Plant Layout and Foundation Interface"
- Figure 2.5-11, "Location of the Facility at K-33," and figure 2.5-22, "Foundation Interface"

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 geology and geotechnical engineering using the guidance and acceptance criteria from section 2.5, "Geology, Seismology, and Geotechnical Engineering," of NUREG-1537, Parts 1 and 2.

PSAR figure 2.5-11 provides a plan view of the facility with the location of Hermes 2, its position relative to Hermes 1, and the borings taken at the site. PSAR section 2.5.2.1 and section 2.5.4.3 provide a description of the location of Borings B-1, B-3, and B-6, relative to the Hermes 2 reactors stating that "[t]he location for the reactors is in the area of Boring B-3 and Boring B-6," and that “Boring B-1 is located more than 1000 ft. away from the proposed location of the reactors.” PSAR figure 2.5-22 provides a cross section of the reactors’ foundation interfaces. PSAR section 2.5.5.2 states that, “the bearing system for the safety-related structures is a foundation mat resting directly over sound rock or over a thin concrete fill. It is anticipated that sound bedrock will be very close to the elevation of the bottom of the basemat.”

The subsections in this SE below discuss the staff’s review of the effect of the changes to the layout and foundation interface for the Hermes 2 reactors and their relative position to Hermes 1 and Borings B-1, B-3, and B-6 as they relate to site geology (regional and local geology, and surface deformation) and geotechnical engineering (bearing capacity and settlements).

Regional and Local Geology

In PSAR section 2.5.2, Kairos describes the proposed site as underlain by three distinct bedrock formations: the Mascot Dolomite, Murfreesboro Limestone, and Pond Springs Limestone Formations. Each of these formations (i.e., bedrock units) trends northeast to southwest parallel to the regional trend of the Appalachian Valley and Ridge Physiographic Province. The formations are, to some degree, calcareous as discussed in PSAR section 2.5.2. As discussed in PSAR section 2.5.2.2 and section 2.5.2.3, Kairos developed the subsurface stratigraphy from the geotechnical boring program at the site, as shown in PSAR figure 2.5-23, “Foundation Interface,” and figure 2.5-24, “Profile A-A’ (Boring Data Summary).” As discussed in section 2.5.2.3, the geotechnical investigations of the proposed Hermes 2 site included soil borings and observation trenches, as well as laboratory testing.

PSAR section 2.5.2.3.2 states that the site subsurface includes fill, alluvial soils, and residual soils above the bedrock units. PSAR figure 2.5-2, “Subsurface Profile A-A’,” and figure 2.5-3, “Subsurface Profile B-B’,” illustrate the subsurface geologic profiles for the Hermes 2 site. Kairos did not identify the specific geologic unit that will be the foundation-bearing layer for the Hermes 2 reactors. The need to confirm the foundation-bearing layer and associated geological and geophysical properties is further discussed below in SE section, “Bearing Capacity and Settlements.”

The staff reviewed the changes between Hermes 1 and Hermes 2 for the Hermes 2 PSAR characterization of the regional and local geology at the proposed Hermes 2 site. Based on its review, the staff finds that the additional information provides an adequate description of the regional and local geology to sufficiently characterize the proposed site to support development of applicable design criteria for the Hermes 2 facility, and therefore, the staff finds that Kairos’s geology characterization is acceptable.

Surface Deformation

PSAR section 2.5.4 addresses subsurface deformation at the proposed site. With respect to surface faulting as a potential cause for subsurface deformation, Kairos stated that it will provide information on this topic in a Hermes 2 OL application.

PSAR section 2.5.2.1 discusses indications of karst activity that Kairos discovered during the geotechnical investigations, at depth, at the proposed Hermes 2 site. Although the geotechnical investigations encountered evidence of karst activity at depth, Kairos indicates that there was no evidence of sinkhole activity encountered at the surface. Kairos also addresses karst in PSAR section 2.5.4.3, in which Kairos stated that the Hermes 2 reactors foundation rock will be located at a depth at which no karstic dissolution is encountered. Kairos stated that the overburden soils and weathered rock will be removed to a depth of 30 ft. (9 meters (m)) and the exposed bedrock will be inspected (prior to the foundation preparation with either an engineered crushed stone or lean concrete fill) to ensure that the foundation rock has no evidence of karstic dissolution.

Based on the plant layout and foundation interface shown in figure 2.5-11 and figure 2.5-22, as well as the boring logs shown in figure 2.5-22, the staff observed the presence of karst features such as voids and clay-filled solution features in Boring B-6 at depths near the planned foundation level. To confirm that the exposed bedrock does not show signs of karstic dissolution when the excavations are complete and before the foundation is prepared, and to provide reasonable assurance that regulatory requirements and license commitments are adequately addressed during the construction of the Hermes 2 facility, the staff recommends that the CPs include the following condition:

> Kairos shall perform detailed geologic mapping of excavations for safety-related engineered structures; examine and evaluate geologic features discovered in those excavations, such as karst; and notify the Director of the Office of Nuclear Reactor Regulation, or the Director's designee, as specified in 10 CFR 50.4, once excavations for safety-related structures are open for examination by staff.

Following receipt of notification from Kairos, the staff will determine whether direct examination of open excavations is necessary as part of the NRC construction inspection program.

The staff reviewed the new information characterizing the potential for surface deformation at the proposed Hermes 2 site. Because Kairos plans to remove the upper 30 ft. of overburden soils and weathered rock to ensure the foundation rock shows no evidence of karstic dissolution subject to the permit condition referenced above, the staff finds that the surface deformation is sufficiently characterized to support development of applicable design criteria for the Hermes 2 facility. Therefore, the staff finds that Kairos's characterization of surface deformation potential is acceptable.

Bearing Capacity and Settlements

Kairos discussed the stability of each reactor's foundation at the proposed site in PSAR section 2.5.5. Kairos stated that the foundation layout for the Hermes 2 reactors and their auxiliary facilities was selected based on the subsurface conditions determined from both historical documentation and subsurface borings at the proposed site. PSAR figure 2.5-11 shows the proposed locations of the Hermes 2 reactors in the middle portion of the site, north of the Hermes 1 reactor location. PSAR section 2.5.5.2 states that the bedrock interface is just above the depth of the reactor foundation at this site location, which provides an adequate bearing stratum.

The staff reviewed information in the PSAR regarding the bearing capacity and settlement of the proposed reactors. As illustrated in PSAR figure 2.5-22, the safety-related portions of the Hermes 2 reactor buildings will be placed on a below-grade mat foundation on "sound bedrock limestone." Kairos did not identify the specific rock unit(s) (i.e., Pond Springs Formation or Murfreesboro dolomitic limestone) for foundation of each of the two reactors. Based on PSAR figure 2.5-11, the bedrock beneath both reactors or only the northern reactor close to Boring B-6 could be in Pond Springs limestone, which is medium bedded and medium jointed. Approximately, the top 5 ft. (1.5 m) of the Pond Springs limestone is weathered. It transitions quickly to fresh hard rock. The bedrock beneath the southern reactor close to Boring B-3 could be in the Murfreesboro dolomitic limestone, which is medium bedded and closely jointed with approximately 3 ft. (1 m) of weathering on top. Kairos did not observe any signs of sinkhole activity within the site but found karstic features, e.g., presence of solution cavities, as stated in PSAR section 2.5.2.1. PSAR section 2.5.5.2.1 states that additional details regarding characterization of the bedrock in the vicinity of the selected reactor location will be provided in a Hermes 2 OL application.

Boring B-6 encountered limestone at elevation 752.5 ft. Two clay-filled solution features and clay-filled fractures were observed below this elevation. The deeper clay-filled fracture extends at least to the elevation of 731 ft. (34.4 ft. below the grade), where the boring ended. The extent of this fracture below this elevation is currently unknown. A clay-filled fracture indicates that water flowed sometime in the past through the fracture and connection(s) with other karst feature(s) in this limestone stratum may exist. Because Boring B-3 did not extend into the limestone, the lateral extent of this karstic feature at the reactor location is currently unknown. Additionally, it is not known if the subsurface limestone stratum at the reactor foundation locations contains any more karstic features and/or other clay-filled fractures.

Kairos stated in PSAR section 2.5.4.3 that the “foundation rock for the reactor will be at depths at which no evidence of karstic dissolution is encountered.” Additionally, Kairos will over-excavate the zones (or areas) at which the bedrock is found to be “compromised.” Kairos further elaborated the process of selecting the foundation elevation of the reactors in PSAR section 2.5.5.2. The foundation surface will be “carefully examined” and inspected for any weathered zones. If found, these weathered zones will be over-excavated and backfilled with concrete to develop a foundation adequate for the reactors. In addition, Kairos stated in PSAR section 2.5.5.2 that a thin layer of concrete may be placed over the bedrock, if needed. The foundation of the safety-related structures will be mat foundation placed directly over sound bedrock or over this concrete layer. As shown in PSAR figure 2.5-22, engineered backfill will be placed over the foundation bedrock to construct the non-safety related structures. Kairos will provide additional details on the bearing capacity and settlement of the foundation of the Hermes 2 reactors in addition to the lateral pressure in the OL application, as stated in PSAR section 2.5.5.2.1.

As discussed in PSAR section 2.5.5.2, since the reactors and the associated safety-related structures will be placed on bedrock or concrete, Kairos expects that the bearing capacity provided by the bedrock will be adequate. In addition, as noted above, Kairos stated in PSAR section 2.5.4.3 that it will excavate and place the foundations at depths at which no karstic dissolution is present. Further, as noted in PSAR section 2.5.5.2, any small, weathered zones in the exposed bedrock will be over-excavated and filled with concrete. If necessary, a small layer of concrete fill will be placed over the exposed bedrock and the foundation mat of the safety-related structures will be placed over this concrete layer. The concrete layer is expected to increase the bearing capacity of the foundation and decrease the differential settlement. For these reasons, the staff finds that proposed foundation of both safety-related and non-safety related structures will be able to provide adequate bearing capacity as the proposed mat foundation will be placed over “sound” rock and will have engineering enhancement if needed. The staff also finds that the settlement of the reactor foundations will be limited only to immediate settlement because the foundation will be on rock or concrete, and therefore, the consolidation-related and secondary settlements will be negligible, if any.

As discussed in PSAR section 2.5.5.2, the foundations of the safety-related and non-safety related portions of the buildings are different. The safety-related portion will be placed on a concrete mat over the sound bedrock whereas the non-safety related portion will have engineered fill over the bedrock to support the lighter portion of the structure. As a result, a differential settlement between the safety-related and the non-safety related portions of the reactor buildings would be expected due to different stiffness properties of the engineered fill and the rock. As discussed in PSAR section 3.5.1, Kairos will provide a “moat” in the design of the reactor buildings between the safety-related and the non-safety portions to accommodate the differential settlement in addition to displacement during design basis seismic events. Based on the preceding discussion, the staff finds that Kairos adequately described the foundation of the proposed reactors and qualitatively discussed the expected bearing capacity and immediate settlement. The staff also finds that Kairos described adequately for the CP stage the subsurface geology that the reactor foundation is expected to encounter. As discussed, Kairos will provide detailed information on site characterization along with the calculations to demonstrate that adequate bearing capacity is available in a Hermes 2 OL application. Based on its review, the staff finds that the level of detail and analyses provided regarding Hermes 2 site geology, seismology, and geotechnical characteristics demonstrates an adequate design basis and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 2.5.

2.5.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information regarding geology, seismology, and geotechnical characteristics in Hermes 2 PSAR section 2.5 is sufficient and meets the applicable guidance and regulatory requirements identified in this SE section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40.

2.6 Summary and Conclusions on Site Characteristics

The staff evaluated the descriptions and discussions of the proposed Hermes 2 site characteristics, as described in chapter 2 of the Hermes 2 PSAR and finds that the information on Hermes 2 site characteristics: (1) provides reasonable assurance that the final design will conform to the design basis, (2) meets all applicable regulatory requirements, and (3) meets the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings and subject to the condition referenced above, the staff makes the following conclusions for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos described the proposed design of the facility, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.
- Such further technical or design information as may be required to complete the safety analysis of the site characteristics, and which can reasonably be left for later consideration, will be supplied in the OL application.
- There is reasonable assurance that, taking into consideration the site criteria contained in 10 CFR Part 100, the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.
- The issuance of permits for the construction of the facility would not be inimical to the common defense and security or to the health and safety of the public.

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3 DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

The purpose of the Hermes 2 test reactor facility's structures, systems, and components (SSCs) is to ensure the safety of the facility and the health and safety of the public. The material presented in chapter 3, "Design of Structures, Systems, and Components," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1, discusses the safety and protective functions and related design features of the SSCs that help provide protection against uncontrolled releases of radioactive material and related exposures. The bases for the design criteria for some of the SSCs discussed in this chapter may be developed in other chapters of the PSAR.

This chapter of the Hermes 2 construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary design of the Hermes 2 SSCs as presented in chapter 3 of the Hermes 2 PSAR. The Hermes 2 CP application is for a test reactor facility whose purpose is to test and demonstrate the key technologies, design features, and safety functions of the Kairos Power fluoride salt-cooled high temperature reactor (KP-FHR) technology and its SSCs. The facility will also provide data and insights for the safety analysis tools and computational methodologies used for the design and licensing of a KP-FHR commercial power reactor. The Hermes 2 reactors will use tristructural isotropic (TRISO) fuel, molten salt as a coolant, graphite as a moderator, and transfer heat generated by the TRISO fuel to a power generation system (PGS) through a primary heat transfer system (PHTS) and intermediate heat transport system (IHTS). In addition, each reactor's decay heat removal system (DHRS) provides the safety-related heat removal function.

The staff's findings and conclusions in this SE are limited to whether the Hermes 2 facility satisfies the Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," requirements for the issuance of CPs. Each of the sections below identify the applicable principal design criteria (PDC) for the SSCs being evaluated.

3.1 <u>Design Criteria</u>

3.1.1 Introduction

The PDC for the facility SSCs are described in section 3.1, "Introduction," of the Hermes 2 PSAR. The PDC are based on the NRC-approved topical report (TR), KP-TR-003-NP-A, "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor," Revision 1, dated May 22, 2020. Hermes 2 PSAR table 3.1-2, "Principal Design Criteria," identifies the PDC from KP-TR-003-NP-A that are applicable to the Hermes 2 facility and the PSAR sections that discuss how the PDC are met. In this section, the staff considered whether the four limitations and conditions identified in KP-TR-003-NP-A are satisfied. The staff evaluated the preliminary design information to determine whether the Hermes 2 design is consistent with the design aspects of the KP-FHR described in KP-TR-003-NP-A, and that any deviations from KP-TR-003-NP-A will lead to operation of the Hermes 2 facility without undue risk to the health and safety of the public.

3.1.2 Regulatory Evaluation

The staff reviewed section 3.1.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the design criteria between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 3.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 3.1.2 of the Hermes 1 SE.

3.1.3 Technical Evaluation

The staff reviewed section 3.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 3.1, “Introduction”). The staff found that section 3.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few significant changes, which are evaluated below in SE section 3.1.3.1. The staff found that the following portions of section 3.1 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 3.1.1, “Introduction,” through 3.1.3, “References”
- Table 3.1-3, “NRC Guidance Considered in the Design”

Since the design and functionality of the Hermes 2 systems remain largely identical, apart from the differences evaluated below, section 3.1 of the Hermes 2 PSAR contains information consistent with section 3.1 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 3.1.3 of the Hermes 1 SE except for the discussion of limitation and condition 1 from KP-TR-003-NP-A.

3.1.3.1 Significant Changes Compared to the Hermes 1 PSAR

Hermes 2 is a two-unit facility that is capable of electrical power production while Hermes 1 is a single unit with no electrical power production capability. Therefore, the IHTS and PGS are unique to Hermes 2 and are described in sections 5.2, “Intermediate Heat Transport System,” and 9.9, “Power Generation System,” of the Hermes 2 PSAR, respectively. The significant changes contained in section 3.1 of the Hermes 2 PSAR, as compared to section 3.1 of the Hermes 1 PSAR, include information regarding the following:

- In table 3.1-1, “Design Related 10 CFR Regulations Applicable to the Design,” 10 CFR 20.1406, “Minimization of Contamination,” is identified as one regulation to be addressed by the IHTS and PGS design.
- In table 3.1-2, “Principal Design Criteria,” PDC for the IHTS and PGS are identified.
- In section 3.1.1 and table 3.1-2, information is added stating that the two reactor units of Hermes 2 do not share safety-related SSCs and thus satisfy PDC 5.

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 design criteria using the guidance and acceptance criteria in NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,”, section 3.1, “Design Criteria,” 10 CFR 50.34(a)(3)(i) requirements on design criteria, and relevant guidance in Regulatory Guide 1.232, “Guidance for Developing Principal Design Criteria for Non-light-water Reactors.”

PSAR table 3.1-1 identifies 10 CFR 20.1406 as a regulation to be addressed by the IHTS and PGS design. The staff evaluated how the IHTS and PGS designs address 10 CFR 20.1406 in sections 5.2, “Intermediate Heat Transport System,” and 9.9, “Power Generation System,” of this SE. Based on the staff’s evaluation in SE sections 5.2 and 9.9, the staff finds that Kairos has appropriately identified 10 CFR 20.1406 as a regulation addressed by the IHTS and PGS design.

PSAR table 3.1-2 identifies the PDC for the IHTS and PGS designs. The staff evaluated how the IHTS and PGS designs meet these PDC in SE sections 5.2, “Intermediate Heat Transport System,” and 9.9, “Power Generation System.” Based on the staff’s evaluation in SE sections 5.2 and 9.9, the staff finds that Kairos has appropriately identified the applicable PDC for the IHTS and PGS based on their role and function within the overall Hermes 2 design.

PSAR section 3.1.1 and table 3.1-2 include additional information stating that the Hermes 2 reactors units satisfy PDC 5. PDC 5 states that safety significant SSCs shall not be shared among reactor units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions. The staff evaluated the preliminary design information for Hermes 2 and confirmed that no safety-related SSCs are shared between the reactor units. Therefore, the staff finds that the preliminary design for Hermes 2 is consistent with PDC 5.

Additionally, the staff evaluated the changes in table 3.1-2, “Principal Design Criteria,” against the SE in KP-TR-003-NP-A, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor,” particularly the four limitations and conditions. The staff found that the findings from the Hermes 1 SE associated with limitations and conditions 2, 3, and 4 identified in the SE for KP-TR-003-NP-A and the use of the terms “safety related” and “postulated events” remained applicable because the Hermes 2 PSAR had no relevant changes from the Hermes 1 PSAR in those areas. However, Hermes 2 has a key design feature that differs from Hermes 1 and is evaluated below for limitation and condition 1, which focuses on key design features for the KP-FHR.

Limitation and condition 1 states:

> As presented in the TR, there are key design features without which the proposed PDC would not be applicable or encompass the full set of necessary design criteria. Therefore, a KP-FHR design referencing the TR must have the following:
>
> - A “chemically stable molten fluoride salt mixture” coolant.
> - TRISO fuel particles and fuel pebbles that, combined with other design features as applicable, demonstrate functional containment performance criteria consistent with SECY-18-0096 and applicable regulatory dose requirements.
> - An intermediate coolant loop using a coolant that is compatible with reactor coolant, and that is demonstrated not to have a safety significant impact on the primary system.
> - “Near-atmospheric” primary coolant pressures.
> - The ability to ensure core cooling by maintaining coverage of the fuel within the reactor core with coolant.
>
> If other key design features are identified by the applicant that could necessitate additional PDC, those PDC would be subject to the staff’s review, independent of the TR.

For Hermes 2, the different key design feature from Hermes 1 is each unit contains an intermediate coolant loop (i.e., the IHTS) that is not present in the Hermes 1 design. All other key aspects of the Hermes 2 design, including chemically stable molten fluoride salt, TRISO fuel particles and fuel pebbles, “near-atmospheric” primary coolant pressures, and the ability to maintain coolant coverage of the fuel and core cooling, are the same as Hermes 1 and consistent with the KP-FHR design. Therefore, the PDC associated with those items remain valid. Limitation and condition 1 from KP-TR-003-NP-A states that a KP-FHR design must have “[a]n intermediate coolant loop using a coolant that is compatible with reactor coolant, and that is demonstrated not to have a safety significant impact on the primary system.” In section 5.1.3, “System Evaluation,” of the Hermes 2 PSAR, Kairos adds that the “compatibility of the primary to intermediate coolant interaction” will be addressed in the OL application. Similarly, in section 1.3.9, “Research and Development,” of the Hermes 2 PSAR Kairos states that completing compatibility evaluations of the intermediate coolant and reactor coolant chemical interaction is a research and development item.

The staff evaluated this addition and Kairos’s plan to address coolant compatibility in the OL application and found that it can be reasonably left for later consideration. Therefore, the staff finds that the information provided related to limitation and condition 1 is acceptable for a preliminary design. Consequently, the staff will confirm at the OL stage that limitation and condition 1 from KP-TR-003-NP-A is met by demonstrating compatibility between the primary and intermediate coolants and that the intermediate coolant does not have a safety significant impact on the primary system. Additional staff evaluation of intermediate coolant compatibility is provided in sections 4.3, “Reactor Vessel System,” and 5.1, “Primary Heat Transport System,” of this SE.

The staff concludes that the Hermes 2 PDC, as either approved in KP-TR-003-NP-A or modified where necessary as described in the PSAR, are acceptable, consistent with the relevant acceptance criteria in NUREG-1537, Part 2, section 3.1, “Design Criteria,” and meet the requirements in 10 CFR 50.34(a)(3)(i). Accordingly, the staff finds that the Hermes 2 design criteria provide reasonable assurance that the public will be protected from radiological risks that could result from operation of the reactor facility.

3.1.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information regarding the design criteria in Hermes 2 PSAR Section 3.1 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35, “Issuance of construction permits,” and 10 CFR 50.40, “Common standards.”

3.2 Meteorological Damage

3.2.1 Introduction

Section 3.2, “Meteorological Damage,” of the Hermes 2 PSAR describes the approach used to translate site meteorological parameters (e.g., normal wind speed, precipitation) into design loads used in the design of the safety-related portion of the reactor buildings. Section 3.2 of the Hermes 2 PSAR summarizes the methods for determining wind loads, including loads from hurricanes and tornadoes, and precipitation loads, including snow and ice loads. Relevant consensus design codes and design equations are identified, along with relevant NRC guidance.

3.2.2 Regulatory Evaluation

The staff reviewed section 3.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the design features for coping with meteorological damage between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 3.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 3.2.2 of the Hermes 1 SE.

3.2.3 Technical Evaluation

The staff reviewed section 3.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 3.2, “Meteorological Damage”). The staff found that section 3.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 meteorological design parameters and functionality of the safety-related portions of the reactor building remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 3.2.3, “Technical Evaluation,” of the Hermes 1 SE.

On the basis of its review, the staff finds a sufficient level of detail has been provided on the approach for determining meteorological design loads for the preliminary design of safety-related portions of the reactor buildings and it satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 3.2, “Meteorological Damage.” Accordingly, the staff finds that the design criteria and design for the protection from meteorological damage conditions are based on applicable local building codes, standards, and criteria that provides assurance that SSCs will continue to perform their safety functions as specified in the PSAR.

3.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the facility design features for coping with meteorological damage meet the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to this design basis during the evaluation of the Hermes 2 operating license (OL) application.

3.3 Water Damage

3.3.1 Introduction

Section 3.3, “Water Damage,” and section 3.5.3.2, “Conformance with PDC 2 for Internal and External Flooding,” of the Hermes 2 PSAR describe the approach taken to establish loads on the safety-related portion of each reactor building due to postulated internal and external flooding events. Section 3.5.3.1, “Conformance with PDC 2 for Meteorological Events,” of the Hermes 2 PSAR states that the safety-related portions of the reactor buildings are designed in accordance with industry codes and standards, including the American Concrete Institute (ACI) 349 and the American Institute of Steel Construction (AISC) N690. Section 3.5.3.2 of the

Hermes 2 PSAR states that the facility is a passively dry site and that the basemat of the safety-related portions of the structures are at grade level. Safety-related SSCs that are vulnerable to water damage from internal floods are elevated above the floors and water is directed away from SSCs via sloped floors and curbs.

3.3.2 Regulatory Evaluation

The staff reviewed section 3.3.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the approach taken regarding establishing loads from flooding events between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 3.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 3.3.2 of the Hermes 1 SE.

3.3.3 Technical Evaluation

The staff reviewed section 3.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 3.3, "Water Damage"). The staff found that section 3.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 approach taken regarding establishing loads from postulated internal and external flooding events on the safety-related portions of the reactor buildings remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 3.3.3, "Technical Evaluation," of the Hermes 1 SE.

Based on its review, the staff finds that the level of detail provided on establishing design loads from postulated internal and external flooding events is adequate for the preliminary design and meets the applicable acceptance criteria of NUREG-1537, Part 2, section 3.3, "Water Damage." The staff also finds that Kairos has adequately demonstrated that the safety-related portions of the reactor buildings are designed to withstand external flooding and are designed consistent with PDC 2 related to floods.

3.3.4 Conclusion

Based on the findings above, and as incorporated by reference from Hermes 1 SE, the staff concludes that the facility design features for coping with water damage meet the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to this design basis during the evaluation of the Hermes 2 OL application.

3.4 Seismic Damage

3.4.1 Introduction

Section 3.4, "Seismic Damage," of the Hermes 2 PSAR describes the design of SSCs that are required to remain functional in the event of an earthquake. Section 3.4 states that Kairos followed the graded approach of American Society of Civil Engineers (ASCE) 43-19, "Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities," for the seismic design of Hermes 2. The safety-related SSCs were identified by Kairos as Seismic Design Category (SDC) 3, consistent with ASCE 43-19, and the design response spectra were developed based on this category. PSAR section 3.4 also discusses how the structure was modeled and how the response analysis was performed.

3.4.2 Regulatory Evaluation

The staff reviewed section 3.4.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the design features for the protection against seismic damage between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 3.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 3.4.2 of the Hermes 1 SE.

3.4.3 Technical Evaluation

The staff reviewed Section 3.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (Section 3.4, "Seismic Damage"). The staff found that section 3.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for editorial changes and one significant change, which is evaluated below in SE section 3.4.3.1. The staff found that the following portions of section 3.4 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 3.4.1, "Seismic Design for Safety-Related SSCs," through 3.4.4, "References"

Since the Hermes 2 seismic design bases and methodology, as well as the functionality of the safety-related SSCs and non-safety related SSCs, largely remain identical to Hermes 1, apart from the differences evaluated below, section 3.4 of the Hermes 2 PSAR contains information consistent with section 3.4 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 3.4.3, "Technical Evaluation," of the Hermes 1 SE.

3.4.3.1 Significant Change Compared to the Hermes 1 PSAR

A significant change contained in section 3.4 of the Hermes 2 PSAR, as compared to section 3.4 of the Hermes 1 PSAR, includes information regarding the following:

- The safety-related rupture disks are not designed to Seismic Design Category (SDC) 3, consistent with ASCE 43-19. Instead, they are designed to the local building code.

This change is identified in the introduction to section 3.4.

Hermes 2 PSAR section 3.6.2.2, "Seismic Classification," (including table 3.6-1, "Structures, Systems, and Components," note 6) and section 5.2.3 "[IHTS] System Evaluation," identify that postulated failures of IHTS SSCs during a design basis earthquake (DBE) preclude their adverse interactions with safety-related SSCs and obviate the safety function of the IHTS rupture disks (i.e., to relieve IHTS pressure). Thus, the IHTS rupture disks are not relied upon to maintain their structural integrity during or following a DBE. Further, the rupture disks are designed and constructed to "Quality-Related" standards and located in a non-safety related plant area. The staff finds it acceptable for the IHTS rupture disks to be seismically designed to local building codes because it is not relied upon to maintain structural integrity during and following a DBE.

Based on its review, the staff finds that the level of detail provided on seismic design bases and methodology for seismic damage of SSCs is adequate for the preliminary design and supports the applicable acceptance criteria of NUREG-1537, Part 2, section 3.4, "Seismic Damage."

3.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the facility seismic design meets the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to this design basis during the evaluation of the Hermes 2 OL application.

3.5 Plant Structures

3.5.1 Introduction

Section 3.5, "Plant Structures," of the Hermes 2 PSAR describes the principal structural elements and general design of the reactor buildings, which also includes the primary and secondary biological shield structures as described in PSAR section 4.4, "Biological Shield." PSAR section 3.5 states that the reactor buildings are the only structures on the site that serve a safety function and that the structures are separated into safety-related and non-safety related portions by a seismic "moat." The safety-related portion of the reactor buildings is supported by a seismic base isolation system. This section of the PSAR also lists the safety functions of the reactor buildings and the applicable PDC, which are PDC 1, 2, 3, 4, 75, and 76. The PSAR summarizes how the design is consistent with these criteria and provides additional detail on how the reactor buildings meet PDC 2. Much of this information supports or repeats information contained in earlier PSAR sections, specifically sections 3.2, 3.3, and 3.4.

3.5.2 Regulatory Evaluation

The staff reviewed section 3.5.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the plant structures between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 3.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 3.5.2 of the Hermes 1 SE.

3.5.3 Technical Evaluation

The staff reviewed section 3.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 3.5, "Plant Structures"). The staff found that section 3.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for two minor changes and one significant change, which are evaluated below in SE sections 3.5.3.1 and 3.5.3.2, respectively. The staff found that the following portions of section 3.5 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 3.5.1, "Description of Plant Structures," 3.5.4, "Testing and Inspections," and 3.5.5, "References"

- Sections 3.5.3.1, “Conformance with PDC 2 for Meteorological Events,” 3.5.3.2, “Conformance with PDC 2 for Internal and External Flooding,” 3.5.3.3, “Conformance with PDC 2 for Earthquakes,” and 3.5.3.4, “Conformance with PDC 2 for Other Hazards”

Since the design and functionality of the Hermes 2 systems remain largely identical to those of Hermes 1, apart from the differences evaluated below, section 3.5 of the Hermes 2 PSAR contains information consistent with section 3.5 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 3.5.3, “Technical Evaluation,” of the Hermes 1 SE.

3.5.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 3.5**,** as compared to the information in Hermes 1 PSAR section 3.5, include the following:

- Figure 3.5-1 “Schematic of the Reactor Building” in the Hermes 2 PSAR was revised.
- In section 3.5.3.2.1, “External Flood Design Features,” Kairos clarified that no safety-related SSCs would be located below the basemat elevation of the safety-related portion of the reactor buildings.

In Hermes 2 PSAR section 3.5**,** figure 3.5-1 was revised. The revised figure is a mirror image of the Hermes 1 PSAR figure 3.5-1 with a change in the orientation of the Spent Fuel Storage in the Pebble Handling and Storage System cell and the arrangement of equipment in the reactor cell. The overall dimensions and general arrangement of the Hermes 2 reactor buildings remain essentially identical to that of Hermes 1; therefore, the change has no significant impact on the structural design methodology.

Additionally, in section 3.5.3.2.1, Kairos included a clarification in the following sentence (*emphasis* added*)*:

> The basemat of the safety-related portion of the reactor building, which is supported by the base isolators, as discussed in Section 3.5.1, is at grade level and there are no safety-related *SSCs in the safety-related portion of the reactor building* located below the basemat elevation that are classified as safety-related for flooding events.

The staff finds that the change provides completeness and clarity in describing that there are no SSCs classified as safety-related for flooding events that are located below the basemat elevation of the safety-related portion of the reactor buildings (see PSAR figure 3.5-1). The staff finds that the change is minor and involves no technical change to the Hermes 2 PSAR. Based on the above, the staff finds that the two minor changes are acceptable.

3.5.3.2 Significant Changes Compared to the Hermes 1 PSAR

A significant change contained in section 3.5 of the Hermes 2 PSAR, as compared to section 3.5 of the Hermes 1 PSAR, includes information regarding the following:

- Addition of PDC 4 to the design bases of the reactor building such that it is protected from and provides protection for other safety-related SSCs against environmental and dynamic effects associated with high-pressure steam system pipe leaks and breaks.

This change is identified in PSAR sections 3.5.2, “Design Bases,” and 3.5.3, “System Evaluation.”

The staff review determined that outside of this addition, the remaining portions of Hermes 2 PSAR sections 3.5.2 and 3.5.3 contain information consistent with the Hermes 1 PSAR. This addition is a conforming change consistent with the design bases in PSAR section 9.9.1.1, “Design Bases,” which includes PDC 4 to protect nearby safety-related systems against dynamic effects of high-pressure steam system pipe leaks related to the new Hermes 2 steam system described in the new section 9.9.1, “Steam System,” of the Hermes 2 PSAR. The steam system is one of several subsystems that make up the PGS. The staff evaluated the sufficiency of this additional preliminary information related to compliance with PDC 4.

PDC 4 states, in part, that:

> SSCs which are safety significant shall be designed to accommodate the effects of and be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents. These SSCs shall be appropriately protected against dynamic effects, including the effects of missiles, pipe whipping, and discharging fluids, that may result from equipment failures and from events and conditions outside the nuclear power unit.

Section 3.5.3, “System Evaluation,” of the Hermes 2 PSAR states that the safety-related portion of the reactor buildings is designed so they will be able to perform their physical protection safety function described in PSAR section 3.5.1 under the environmental and dynamic effects associated with high-pressure steam system pipe leaks and breaks, including if the non-safety related portion of the reactor buildings is damaged due to such effects. Further, PSAR section 9.9.1.2, “System Evaluation,” for the steam system states that safety-related SSCs located inside the safety-related portion of each reactor building are protected from the dynamic effects associated with high-pressure steam line breaks by either protective design features (e.g., barriers or blowout panels), are designed for the environmental conditions, are located sufficiently far enough away to avoid the hazards, or a combination of these measures.

The staff finds that the preliminary design basis of the safety-related portion of the Hermes 2 reactor buildings is consistent with PDC 4 because: (a) the safety-related portion of the reactor building will be designed to remain capable of performing its safety functions of protecting safety-related SSCs under the environmental conditions and dynamic effects associated with high-pressure steam system pipe leaks and breaks postulated to occur (i) outside the safety-related portion of the reactor building (i.e., in the non-safety related portion of the structure); and (ii) inside the safety-related portion of the reactor building structure; (b) the proposed design codes in the PSAR for the safety-related portion of the reactor building, namely ACI 349 and ANSI/AISC N690, include structural design provisions for impulsive and impactive load effects; and (c) the staff will verify that the reactor building final design conforms to PDC 4 during the Hermes 2 OL application review.

Based on its review, the staff finds that the level of detail provided on the general design of the reactor buildings is adequate for the preliminary design and the information provided adequately demonstrates that the structural design of the reactor buildings is consistent with PDC 1, 2, 3, 4, 75, and 76.

3.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the general reactor building design meets the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design details required to complete the safety analysis may reasonably be left for later consideration and the staff will confirm that the final design conforms to this design basis during the evaluation of the Hermes 2 OL application.

3.6 Systems and Components

3.6.1 Introduction

Section 3.6, "Systems and Components," of the Hermes 2 PSAR describes the design bases for the systems and components required to function for safe reactor operation and shutdown. PSAR section 3.6.1, "General Design Basis Information," describes the safety functions performed by safety-related SSCs and PSAR section 3.6.2, "Classification of Structures, Systems, and Components," describes how SSCs are classified.

PSAR section 3.6.1 identifies three fundamental safety functions provided by Hermes 2 SSCs: (1) prevent uncontrolled releases of radionuclides, (2) remove decay heat in a postulated event, and (3) control reactivity in the reactor core. The primary SSCs credited for preventing an uncontrolled radionuclide release are the reactor fuel, reactor vessel, reactor coolant, and reactor protection system. The SSCs used to ensure decay heat removal are the decay heat removal system with support from the reactor vessel, the reactor vessel support system, and the reactor protection system. The primary means of reactivity control is provided by the reactivity control and shutdown system and the reactor protection system with support from reactor vessel and nuclear design. The staff determined that the reactor buildings are designed to provide the necessary protection from external events for all of these SSCs. The staff evaluation of the reactor buildings is documented in SE section 3.5.

3.6.2 Regulatory Evaluation

The staff reviewed section 3.6.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the design of the systems and components between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 3.6.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 3.6.2 of the Hermes 1 SE.

3.6.3 Technical Evaluation

The staff reviewed section 3.6 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 3.6, “Systems and Components”). The staff found that section 3.6 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for one minor and a few significant changes, which are evaluated below in SE sections 3.6.3.1 and 3.6.3.2, respectively. The staff found that the following portions of section 3.6 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 3.6.1 and 3.6.2
- Table 3.6-2, “Design and Construction Codes and Standards for Fluid Systems”

Since the design and functionality of the Hermes 2 systems remain largely identical, apart from the differences evaluated below, section 3.6 of the Hermes 2 PSAR contains information consistent with section 3.6 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 3.6.3, “Technical Evaluation,” of the Hermes 1 SE.

3.6.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 3.6, as compared to the information in Hermes 1 PSAR section 3.6, includes the following:

- Section 3.6.1.1 states that the reactor protection system (RPS) also stops the intermediate salt pump (ISP) to ensure Flibe level remains constant during postulated events.

The ISP is a new component in the Hermes 2 design. Hermes 1 does not contain an ISP because it does not have an IHTS. The staff finds that the new ISP trip is appropriate because it reduces the chance of overcooling of the PHTS following an RPS actuation as described in section 7.3.1, “Reactor Protection System,” of the Hermes 2 PSAR. Therefore, the new ISP trip upon RPS actuation is acceptable.

3.6.3.2 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in section 3.6 of the Hermes 2 PSAR, as compared to section 3.6 of the Hermes 1 PSAR, include the information regarding the following:

- The following IHTS SSCs were added to table 3.6-1, “Structures, Systems, and Components”: intermediate heat exchanger (IHX), ISPs, intermediate piping, superheater, intermediate loop auxiliary heating subsystem, intermediate inert gas subsystem, intermediate coolant inventory management subsystem, intermediate coolant chemistry control subsystem, intermediate coolant.
- The following PGS SSCs were added to table 3.6-1: turbine generator system, steam system, condensate and feedwater system.

Hermes 2 is a two-unit facility that is capable of producing electrical power while Hermes 1 is a single unit facility with no electrical power production capability. Therefore, the IHTS and PGS are unique to Hermes 2 and are described in sections 5.2 and 9.9 of Hermes 2 PSAR, respectively. The additional components related to the IHTS and PGS are added to table 3.6-1, which summarizes the safety, seismic, and quality classification of the SSCs.

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 SSCs using the guidance and acceptance criteria in section 3.5, "Systems and Components," of NUREG-1537 Part 2, 10 CFR 50.2, and Regulatory Guide (RG) 1.29, "Seismic Design Classification for Nuclear Power Plants." Like Hermes 1, Hermes 2 uses the definition of 10 CFR 50.2 for "safety-related" SSCs to establish those SSCs that are classified as safety-related, with the exception of "integrity of the reactor coolant pressure boundary," which has been modified to state "integrity of the portions of the reactor coolant boundary relied upon to maintain coolant level above the active core."

The IHTS and PGS components are classified as non-safety related, except for the rupture disks in the intermediate inert gas subsystems. The rupture disks are used to prevent overpressure in the IHTS during a postulated superheater tube leak or rupture event. The rupture disk standpipes and vent lines would also provide a relief path for the steam from a superheater tube rupture to prevent the steam from reaching the IHX. While the IHX, including the IHX tubes, are classified as non-safety related, the staff noted that failure of one or more IHX tubes following a superheater tube rupture could lead to unanalyzed conditions due to potential Flibe-water interactions or higher than assumed levels of BeNaF ingress into the PHTS.

Recognizing the preliminary nature of the Hermes 2 design and that Kairos has not requested final approval of the safety of any design feature or specification in its application, the staff was unable to confirm that the IHX complies with the Hermes 2 definition of "safety-related" SSCs. To resolve this issue, Kairos confirmed in request for confirmation of information (RCI) 1 (ML24103A241) that the final design for Hermes 2 will demonstrate that the IHX tubes will not need to be classified as a safety-related SSC. Or, if the IHX tubes are relied upon to remain functional during and after a postulated event, Kairos will demonstrate that their failure is not credible considering all relevant factors. Based on the information identified in RCI 1 to be provided in the OL application, the staff finds that the classification for the IHTS and PGS components complies with Kairos's modified 10 CFR 50.2 definition, with the exception of the IHX for which the safety classification will be assessed as part of the OL application review.

RG 1.29 describes a method that the staff considers acceptable for the seismic classification of the SSCs for light water reactors (LWRs). While RG 1.29 is applicable to LWRs, it provides guidance related to the SSCs that should be designed in accordance with seismic design criteria that can also be useful for non-LWRs like Hermes 2. Based on the guidance from RG 1.29, the use of the local building code for the seismic design criteria of the non-safety related IHTS and PGS components is acceptable since they do not perform the safety functions to prevent uncontrolled release of radionuclides, remove decay heat during a postulated event, or control reactivity in the core. The staff also finds that it is appropriate to designate the non-safety related IHTS and PGS components as not quality-related. Table 3.6-1 of Hermes 2 PSAR shows that the rupture disks in the intermediate inert gas subsystems will be seismically designed to local building codes with the quality classification of quality-related. The staff finds these classifications appropriate because the rupture disks are safety-related components that are not relied upon to remain functional following a seismic event.

Based on its review, the staff finds that the level of detail provided regarding design bases for the systems and components that are required to function at the Hermes 2 facility is adequate for the preliminary design and supports the applicable acceptance criteria of NUREG-1537, Part 2, section 3.5, “Systems and Components.” Therefore, the staff finds that the design bases of the systems and components provide reasonable assurance that the facility systems and components will function as designed to ensure safe operation and safe shutdown of the reactors.

3.6.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the Hermes 2 facility systems and components meet the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to this design basis during the review of the Hermes 2 OL application.

3.7 Summary and Conclusions on Design of Structures, Systems, and Components

The staff evaluated the information in chapter 3 of the PSAR regarding the design of SSCs for Hermes 2 and finds that the preliminary information on, and design criteria of, the SSCs, including the PDC, design bases, and information relating to materials of construction, general arrangement, and approximate dimensions: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the SSCs, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information required to complete the safety analysis of the Hermes 2 SSCs, and which can reasonably be left for later consideration, will be provided in the final safety analysis report as part of the OL application.

- There is reasonable assurance: (i) that the construction of the facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission’s regulations.

- The issuance of permits for the construction of the facility would not be inimical to the common defense and security or to the health and safety of the public.

3.8 References

American Concrete Institute (ACI), ACI 349-13, “Code Requirements for Nuclear Safety related Concrete Structures.” American Concrete Institute, Farmington Hills, MI.

American Society of Civil Engineers (ASCE). ASCE 4-16, “Seismic Analysis of Safety related Nuclear Structures,” American Society of Civil Engineers, Reason, VA, 2017.

-----. ASCE 43-19, “Seismic Design Criteria for Structures, Systems and Components in Nuclear Facilities,” American Society of Civil Engineers, Reston, VA, 2019.

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U. S. Department of Energy (DOE). DOE-STD-3014-2006, “Accident Analysis for Aircraft Crash into Hazardous Facilities,” U.S. Department of Energy, Washington, DC, 2006.

IBC 2012, “International Building Code,” International Code Council, Country Club Hills, IL, 2011.

Kairos Power LLC. KP-TR-003-NP-A, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor,” Revision 1, dated June 2020, ML20167A174.

-----. “Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1]), Revision 3,” dated May 31, 2023, Pkg. ML23151A743.

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NEI 18-04, "Risk-Informed Performance-Based Technology-Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development,” Revision 1.

U. S. Nuclear Regulatory Commission (NRC), NUREG-1537, Part 1, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content,” dated February 1996, ML042430055.

-----. NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” dated February 1996, ML042430048.

-----. Regulatory Guide 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures, and Components Installed in Light-Water-Cooled Nuclear Power Plants,” Revision 2, dated November 2001, ML013100305.

-----. Regulatory Guide 1.76, “Design-Basis Tornado and Tornado Missiles for Nuclear Power Plants,” Revision 1, dated March 2007, ML070360253.

-----. Regulatory Guide 2.5, “Quality Assurance Program Requirements for Research and Test Reactors” Revision 1, dated June 2010, ML093520099.

-----. Regulatory Guide 1.221, “Design-Basis Hurricane and Hurricane Missiles for Nuclear Power Plants,” dated October 2011, ML110940300.

-----. Safety Evaluation for Kairos Power LLC Topical Report “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactors,” Revision 1, dated May 2020, ML20111A118.

-----. Regulatory Guide 1.233, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors,” Revision 0, dated June 2020, ML20091L698.

-----. Safety Evaluation for Kairos Power LLC Topical Report “Regulatory Analysis for the Kairos Power Salt-Cooled, High Temperature Reactor,” Revision 3, dated May 2022, ML22136A089.

-----. Regulatory Guide 1.29, “Seismic Design Classification for Nuclear Power Plants,” Revision 6, dated July 2022, ML21155A003.

-----. Regulatory Guide 1.87, “Acceptability of ASME Code, Section III, Division 5, High Temperature Reactors,” Revision 2, dated January 2023, ML22101A263.

-----. “Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes [1] Test Reactor,” dated June 16, 2023, ML23158A265.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report Site Characteristics (Chapter 2),” dated April 2023, ML23115A480.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes 2 Construction Permit Preliminary Safety Analysis Report – General Audit,” dated July 11, 2024, ML24193A214.

4 REACTOR DESCRIPTION

The reactor description addresses the principal features, operating characteristics, and parameters of the Hermes 2 test reactor facility. The Hermes 2 reactor cores generate heat by controlled fission of the tristructural isotropic (TRISO) fuel in a molten fluoride salt (Flibe) coolant that provides heat removal.

This chapter of the Kairos Power LLC (Kairos) Hermes 2 test reactor construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary information regarding the Hermes 2 reactors. This information is presented in chapter 4, "Reactor Description," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed PSAR chapter 4 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information Kairos provided regarding the Hermes 2 facility for the issuance of CPs in accordance with Title 10, *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." As part of this review, the staff evaluated information regarding the Hermes 2 facility, with special attention given to design and operating characteristics, unusual or novel design features, and principal safety considerations. The staff evaluated the preliminary design of the Hermes 2 facility to ensure the design criteria and information relative to construction are sufficient to provide reasonable assurance that the final design will conform to the design basis. In addition, the staff reviewed Kairos's identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of technical specifications (TSs) for the facility, with special attention given to those items which may significantly influence the final design.

In its review of areas relevant to Hermes 2 PSAR chapter 4, the staff considered the information in technical report KP-TR-017, "KP-FHR [Kairos Power fluoride salt-cooled high temperature reactor] Core Design and Analysis Methodology," Revision 1, dated September 30, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML23195A130), and technical report KP-TR-022, "Hermes 2 Postulated Event Analysis Methodology," Revision 2, dated June 30, 2023 (ML23195A131), which are both components of the Hermes 2 CP application (ML23195A121).

4.1 Summary Description

Section 4.1, "Summary Description," of the Hermes 2 PSAR provides a high-level overview of the reactor design. The Hermes 2 reactors are a fluoride molten-salt cooled pebble bed design that can each achieve a thermal power of up to 35 megawatts (MW). The reactor design employs a high-temperature graphite matrix coated TRISO particle fuel and a chemically stable, low pressure molten fluoride salt coolant (Flibe). The TRISO fuel and Flibe coolant constitute the functional containment. PSAR section 4.1 provides an overview of the key design parameters, such as reactor power, inlet and outlet temperature, operating pressure, and fuel materials and enrichment levels. PSAR chapter 4 describes various key aspects of the reactor design, including the reactor core (fuel, control and shutdown system, neutron startup source), reactor vessel and internals, biological shield, nuclear design, thermal-hydraulic design, and reactor vessel support system.

NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1, "Format and Content," and Part 2, "Standard Review Plan and Acceptance Criteria," section 4.1, "Summary Description," do not stipulate any specific review findings for the summary description of the reactor design. Therefore, the staff did not make any findings relative to PSAR section 4.1. PSAR sections 4.2 through 4.7 provide detailed descriptions of key aspects of the reactor design. The corresponding sections of this SE document the staff's review findings on these aspects of the reactor design.

4.1.1 Common Regulatory Evaluation for Reactor Systems

Common regulatory requirements for reactor systems evaluated in chapter 4 are identified below. Any additional requirements or guidance specific to a system are identified in the subsection for that system. The common regulatory requirements for the evaluation of the Hermes 2 reactor systems are:

- 10 CFR 50.34(a)(4), which requires, in part, "[a] preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…"
- 10 CFR 50.35, "Issuance of construction permits."
- 10 CFR 50.40, "Common standards."

4.2 <u>Reactor Core</u>

The subsections within section 4.2, "Reactor Core," of the Hermes 2 PSAR provide a description of the reactor cores, including the reactor fuel, reactivity control and shutdown, and neutron sources.

4.2.1 Reactor Fuel

4.2.1.1 Introduction

Section 4.2.1, "Reactor Fuel," of the Hermes 2 PSAR describes the fuel design, the qualification of the fuel, and the design bases that the fuel must meet. In addition, the section provides an overview of fuel manufacturing and a testing and inspection plan. The TRISO fuel particle, composed of a uranium oxycarbide fuel kernel encased in coating layers to limit fission product releases, is a key component of the functional containment and along with the reactor coolant, provide the credited barriers to the release of radioactivity to the environment.

4.2.1.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems in section 4.1.1 of this SE apply to the reactor fuel. Additionally, the staff reviewed section 4.2.1.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the reactor fuel design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.2.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.2.1.2 of the Hermes 1 SE.

4.2.1.3 Technical Evaluation

The staff reviewed section 4.2.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.2.1, "Reactor Fuel"). The staff found that section 4.2.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for editorial and a minor change, which is evaluated below. The staff also verified that the Hermes 2 reactor fuel design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 4.2.1.3, “Technical Evaluation,” of the Hermes 1 SE.

4.2.1.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 4.2, as compared to the information in Hermes 1 PSAR section 4.2, includes the following:

- Staff use of technical report KP-TR-022 instead of technical report KP-TR-018, “Hermes Postulated Event Analysis” to inform the evaluation.

For the review of Hermes 2 PSAR section 4.2.1, the staff used the information contained in technical report KP-TR-022 that details the postulated event methodology for Hermes 2. For the review of Hermes 1 PSAR section 4.2.1, the staff used the information contained in technical report KP-TR-018. The postulated event analysis results in KP-TR-018 used to review Hermes 1 PSAR section 4.2.1 remain the same in KP-TR-022 for the Hermes 2 design. Therefore, the staff finds the evaluation and findings from section 4.2.1.3 of the Hermes 1 SE are applicable to Hermes 2.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 reactor fuel demonstrates an adequate basis for a preliminary design; meets principal design criteria (PDC) 10, 16, 34, and 35; and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 4.2.1, “Reactor Fuel,” to support safety functions including functional containment.

4.2.1.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.2.1 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 reactor fuel can reasonably be left for later consideration at the operating license (OL) stage since this information is not necessary for the review of a CP application.

4.2.2 Reactivity Control and Shutdown System

4.2.2.1 Introduction

Section 4.2.2, “Reactivity Control and Shutdown System,” of the Hermes 2 PSAR describes the reactivity control and shutdown system (RCSS). The RCSS inserts and withdraws control and shutdown elements to control reactivity in the reactor core during normal operation and in response to abnormal conditions or postulated events to ensure safe shutdown. There are four control elements that insert into the graphite reflector and three shutdown elements that insert into the pebble bed. Control elements can be positioned throughout their range of travel and are non-safety related. Shutdown elements are safety-related and have two positions: (1) fully withdrawn or (2) fully inserted.

4.2.2.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems in section 4.1.1 of this SE apply to the RCSS. Additionally, the staff reviewed section 4.2.2.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the RCSS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.2.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.2.2.2 of the Hermes 1 SE.

4.2.2.3 Technical Evaluation

The staff reviewed section 4.2.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.2.2, "Reactivity Control and Shutdown System"). The staff found that section 4.2.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes, which are evaluated below. The staff also verified that the Hermes 2 RCSS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 4.2.2.3, "Technical Evaluation," of the Hermes 1 SE.

4.2.2.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 4.2.2 as compared to the information in Hermes 1 PSAR section 4.2.2, include the following:

- The RCSS SSCs are not shared between Unit 1 and Unit 2.
- The portion of the plant control system (PCS) that controls the RCSS is not shared between Unit 1 and Unit 2.

In Hermes 2 PSAR section 4.2.2, Kairos states that the RCSS SSCs and the portion of the PCS that controls the RCSS are not shared between Unit 1 and Unit 2. This design approach increases the degree of independence between the two units and reduces the potential for a postulated event in one unit affecting the safe operation of the other unit. The independence of the two units is important for demonstrating compliance with the requirements in 10 CFR 100.11(b) for determining the size of the exclusion area and low population zone boundaries. Further evaluation of how Kairos will comply with the requirements of 10 CFR 100.11(b) is provided in SE chapter 13. Based on the above, the staff finds Kairos's approach to not sharing RCSS SSCs, nor the portion of the PCS that controls the RCSS, to be acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 RCSS demonstrates an adequate basis for a preliminary design; is consistent with PDC 2, 4, 23, 26, 28, and 29; and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 4.2.2, "Control Rods," to support safety functions including reactivity control and reactor shutdown.

4.2.2.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.2.2 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of

CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of the Hermes 2 RCSS can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

4.2.3 Neutron Startup Source

4.2.3.1 Introduction

Section 4.2.3, "Neutron Startup Source," of the Hermes 2 PSAR discusses the neutron startup sources, which provide a neutron flux to the source range ex-core detectors for initial and subsequent startups. Each reactor unit has its own neutron startup source.

4.2.3.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems in section 4.1.1 of this SE apply to the neutron startup sources. There are no additional regulatory requirements applicable to the neutron startup sources.

The applicable guidance for evaluating the Hermes 2 neutron startup sources is as follows:

- NUREG-1537, Part 1 and Part 2, section 4.2.4, "Neutron Startup Source."

4.2.3.3 Technical Evaluation

The staff reviewed section 4.2.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (4.2.3, "Neutron Startup Source"). The staff found that section 4.2.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes, which are evaluated below. The staff also verified that the Hermes 2 neutron startup source design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 4.2.3.3, "Technical Evaluation," of the Hermes 1 SE.

4.2.3.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 4.2.3, as compared to the information in Hermes 1 PSAR section 4.2.3, includes the following:

- The neutron startup sources are not shared between Unit 1 and Unit 2.

In Hermes 2 PSAR section 4.2.3, Kairos states that the neutron startup sources are not shared between Unit 1 and Unit 2. Due to the radioactivity of the neutron startup sources, the staff views this as being consistent with as low as reasonably achievable principles for minimizing exposure. Additionally, the neutron startup sources do not perform any safety functions. Based on the above, the staff finds that not sharing neutron startup sources is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 neutron startup sources demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 4.2.4, "Neutron Startup Source."

4.2.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information in Hermes 2 PSAR section 4.2.3 is sufficient and meets the applicable guidance and regulatory requirements identified in this SE section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of the Hermes 2 reactor neutron startup sources can reasonably be left for later consideration at the OL stage since this information is not necessary for the approval of a CP application.

4.3 Reactor Vessel System

4.3.1 Introduction

Section 4.3, “Reactor Vessel System,” of the Hermes 2 PSAR states that the reactor vessel system contains the reactor core and provides for circulation of reactor coolant and pebbles as well as insertion of the RCSS elements in the reactor core. The reactor vessel consists of a shell, a flat top head, and a flat bottom head, and contains the reactor internals. The reactor internals include the graphite reflector blocks, fluidic diodes, the core barrel, and reflector support structure. The reactor vessel system is secured to the reactor vessel support system (RVSS), which is evaluated in section 4.7 of this SE. The top head of the reactor vessel system contains penetrations and is described in PSAR section 4.3.1.1.1, “Vessel Top Head.” PSAR section 1.3.3.2, “Operating Characteristics,” states that the planned operational lifetime of each reactor at 35 MW thermal power is 11 years.

4.3.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems in section 4.1.1 of this SE apply to the reactor vessel system. Additionally, the staff reviewed section 4.3.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the reactor vessel system between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.3.2 of the Hermes 1 SE.

4.3.3 Technical Evaluation

The staff reviewed section 4.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.3, “Reactor Vessel System”). The staff found that section 4.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for one minor change and a few significant changes, which are evaluated below in SE sections 4.3.3.1 and 4.3.3.2, respectively. The staff found that the following portions of section 4.3 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 4.3.1, “Description,” 4.3.2, 4.3.4, “Testing and Inspection,” and 4.3.5, “References”
- All information in section 4.3.3, “System Evaluation,” except for the change in operational life from 4 to 11 years; the discussions about table 4.3-3, “Testing Requirements to Extend the ASME [American Society of Mechanical Engineers]

Qualification of ER 16-8-2," through table 4.3-8, "Qualification Requirements for Graphite Irradiation;" and clarification of the reactor vessel system design for degradation.
- Tables 4.3-1, "Reactor Vessel Top Head Penetrations"; table 4.3-2, "Load Combinations for the Reactor Vessel System"; and figure 4.3-1, "The Reactor Vessel System," through figure 4.3-3, "The Reactor Vessel System Secondary Hold-Down Structure"

Since the Hermes 2 reactor vessel system design and functionality largely remain identical, apart from the differences evaluated below, section 4.3 of the Hermes 2 PSAR contains information consistent with section 4.3 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 4.3.3, "Technical Evaluation," of the Hermes 1 SE.

4.3.3.1.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 4.3, as compared to the information in Hermes 1 PSAR section 4.3, includes the following:

- In section 4.3.1, the intermediate heat transport system (IHTS) is mentioned as also unavailable along with the primary heat transport system (PHTS) during postulated events when the reactor vessel uses natural circulation to remove heat from the reactor core after an event.

This minor change accurately reflects the design of Hermes 2 having an IHTS and properly acknowledges that the IHTS would not be available during postulated events when the PHTS is not available, and the reactor vessel provides an alternative flow path to allow natural circulation of the reactor coolant to remove decay heat from the reactor core. Based on the above, the staff finds that the discussion of the IHTS as unavailable during certain events is acceptable.

4.3.3.1.2 Significant Changes Compared to the Hermes 1 PSAR

The significant changes contained in section 4.3 of the Hermes 2 PSAR, as compared to section 4.3 of the Hermes 1 PSAR, include information regarding the following:

- Operational lifetime of Hermes 2 is 11 years, compared to the 4 years of Hermes 1.
- Addition of tables 4.3-3 through 4.3-8 that describe plans for material qualification testing of a test reactor with a 11-year lifetime, which was not previously described in KP-TR-013-P-A, Revision 4, "Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor," and KP-TR-014-P-A, "Graphite Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor," Revision 4.

These changes are identified in:

- Section 4.3.3
- Tables 4.3-3 through 4.3-8

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 reactor vessel system against NUREG-1537, Part 2, section 4.3, "Reactor Tank or Pool," and PDC 14 and 31. Tables 4.3-3 through 4.3-6, "Irradiation Effects Testing of Metallic Materials," provide the qualification tests required for a test reactor with an 11-year operational lifetime for 316H stainless steel (SS) and weld materials. The staff reviewed the information in these tables to evaluate the qualification tests that will be performed to justify the ability of the reactor vessel system to withstand degradation over the 11-year lifetime. Table 4.3-7, “Qualification Requirements of Unirradiated Graphite Mechanical and Thermal Properties,” and table 4.3-8 provide the qualification tests required for graphite materials to support a 11-year operational lifetime.[4]

PSAR table 4.3-3 shows that qualification testing will be performed to extend qualification of the ER16-8-2 weld filler metal. Table 4.3-3 shows that the tests for creep-fatigue will increase the maximum test temperature for the 11-year lifetime when compared to the 5-year lifetime, and the creep test times will be extended up to 20,000 hours past the 10,000 hours testing planned for Hermes 1. The staff finds the preliminary information is consistent with PDC 14 and 31 and the guidance in NUREG-1537, Part 2, section 4.3, to ensure that the vessel can withstand applied stresses because the proposed tests were extended in time and temperature to align with the proposed Hermes 2 facility lifetime and operating temperatures. As described in the staff SE to KP-TR-013-P-A, the staff will review the data to extend qualification of ER16-8-2 to ensure it meets the requirements of the ASME Boiler and Pressure Vessel Code, Section III, Division 5, “High Temperature Reactors.”

PSAR table 4.3-4, “Testing Requirements for Reactor Design,” updates testing requirements for certain mechanical testing of metallic materials, including stress relaxation cracking. These tests are consistent with those proposed in KP-TR-013-P-A. Table 4.3-4 shows that the stress relaxation cracking tests in KP-TR-013-P-A for the commercial power reactor will be used for the design of Hermes 2. The staff determined that the modified qualification testing requirements to account for the longer plant life is conservative because it uses the previously approved qualification methodology for the longer lifetime reactor. The staff finds that the preliminary information is consistent with PDC 14 and 31 and the guidance in NUREG-1537, Part 2, section 4.3, and provides assurance that the vessel can withstand stresses it will experience over its proposed 11-year lifetime.

PSAR table 4.3-5, “Environmental Compatibility Testing of Metallic Materials,” updates the environmental compatibility testing originally listed in KP-TR-013-P-A to extend corrosion test times and add corrosion testing with postulated intermediate coolant contamination for Hermes 2. Additionally, table 4.3-5 shows that the full test matrix described in KP-TR-013-P-A for slow strain rate testing and for corrosion fatigue and stress corrosion cracking will be performed to support Hermes 2. This provides assurance that the final design will conform to the Hermes 2 design bases because the extended corrosion test times are reasonable to develop corrosion rates and the addition of intermediate coolant contamination tests account for the possibility of intermediate to primary contamination. Performing the full test matrix (i.e., for a commercial reactor lifetime) to support Hermes 2 is conservative as these tests were previously approved to support a reactor with a longer operating lifetime. Additionally, table 4.3-5 shows in-situ creep tests will be performed for Hermes 2 which is appropriate to determine effects of the Flibe environment on time-dependent material degradation (i.e., creep) for the proposed 11-year reactor lifetime. The staff finds the preliminary information consistent with PDC 14 and 31 because corrosion test times were increased to a duration commensurate with a longer plant lifetime and the full power reactor test matrix will be used for slow strain rate, corrosion fatigue,

[4] Tables 4.3-3 through 4.3-8 also include the qualification programs for a 5-year non-power reactor and a commercial power reactor; however, PSAR section 4.3.3 stated they are included for information purposes only. Therefore, the staff did not review the 5-year non-power reactor or commercial power reactor programs.

and stress corrosion cracking tests. This preliminary information is also consistent with guidance in NUREG-1537, Part 2, section 4.3, to ensure the vessel material is chemically compatible with the environment.

PSAR table 4.3-6 states that the test matrix from KP-TR-013-P-A will be used for Hermes 2 in conjunction with inspection and monitoring programs. This provides the staff with assurance that the final design will conform to the design bases as this is consistent with the prior staff approval of KP-TR-013-P-A. The staff finds that the preliminary information is consistent with PDC 14 and 31 because the irradiation qualification program will be implemented per KP-TR-013-P-A, ensuring the appropriate data is used to account for potential irradiation-induced corrosion, cracking, and embrittlement in the design of Hermes 2 reactor systems. This information is also consistent with the guidance in NUREG-1537, Part 2, section 4.3, for ensuring that the vessel material is resistant to irradiation effects.

PSAR tables 4.3-7 and 4.3-8 update graphite qualification requirements for an 11-year graphite component lifetime. PSAR table 4.3-7 does not reflect any changes from the unirradiated mechanical and thermal properties testing matrices found in KP-TR-013-P-A. This is acceptable because the qualification envelope for unirradiated properties does not change as a function of plant life. The changes in table 4.3-8 from the matrices found in KP-TR-013-P-A reflect that if basic irradiation property data exceed the qualification envelope, then new data will be collected. Table 4.3-8 also states that final design data and turnaround analysis will demonstrate that Hermes 2 graphite components will not reach turnaround, and if components exceed this point, then irradiation creep data will be obtained and used for analysis. These changes provide the staff with assurance that the final design will conform to the design bases because collecting new irradiation data if plant parameters exceed the qualification envelope is consistent with the NRC's approval of KP-TR-013-P-A. Additionally, ensuring graphite does not reach turnaround for a non-power reactor, or obtaining new irradiation creep data, is consistent with the NRC approval of KP-TR-013-P-A. The staff finds that the preliminary information consistent with PDC 10, 34, 35, 36, 37, and 74 because the changes in graphite properties will be accounted for to ensure a coolable core geometry, forming the natural circulation flow path, and allowing for insertion of reactivity elements. This preliminary information is also consistent with the guidance in NUREG-1537, Part 2, section 4.3, for ensuring that the graphite material is compatible with the chemical, thermal, mechanical, and radiation environments. Additionally, as described in appendix A to this SE, the staff will review the final design at the OL stage to ensure that graphite components will not reach turnaround as a function of temperature and fluence, or the staff will confirm that irradiation creep data that bounds the anticipated Hermes 2 conditions is collected.

In addition, as stated appendix A to this SE and discussed as part of Kairos's response to general audit question 4.3-3 (see general audit report at ML24193A214), the effects of thermal embrittlement of metallic materials on the mechanical performance of safety-related components in the proposed 11-year operational lifetime will be assessed by Kairos in the OL application.

Based on the evaluation above, the staff finds that the preliminary information on the reactor vessel system is consistent with PDC 14, 31, 34, 35, 36, 37, and 74. The staff also finds that the preliminary information is consistent with the NUREG-1537, Part 2, section 4.3, guidance in that it provides reasonable assurance of the reactor vessel system's reliability and integrity for its anticipated life.

4.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.3 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 50.40. Further information as may be required to complete the review of Hermes 2 reactor vessel system can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

4.4 Biological Shield

4.4.1 Introduction

Section 4.4, “Biological Shield,” of the Hermes 2 PSAR describes the preliminary design information on the biological shield, including its design bases. The biological shield functions to protect plant workers and the public from radiological exposure as well as to reduce radiation damage to plant equipment. The biological shield also reduces the potential exposure of plant workers to beryllium, should there be a coolant leak. The biological shield is made up of a primary biological shield, which surrounds the reactor vessel, and a secondary biological shield which encloses the primary to secondary heat transfer system and the inventory management system. The primary and secondary biological shields are composed of reinforced concrete.

4.4.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems in section 4.1.1 of this SE apply to the biological shield design. Additionally, the staff reviewed section 4.4.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the biological shield design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.4.2 of the Hermes 1 SE.

4.4.3 Technical Evaluation

The staff reviewed section 4.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.4, “Biological Shield”). The staff found that section 4.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few minor changes, which are evaluated below. The staff also verified that the Hermes 2 biological shield design and functionality remain similar to Hermes 1. Based on these consistencies, this section incorporates by reference section 4.4.3, “Technical Evaluation,” of the Hermes 1 SE.

4.4.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 4.4, as compared to the information in Hermes 1 PSAR section 4.4, include the following:

- The primary to intermediate heat transfer system is also enclosed in the secondary biological shield and the corresponding discussion in section 4.4.1 and figure 4.4-1, “Primary and Secondary Biological Shield,” are updated accordingly.

- Kairos states in section 4.4.1 of the Hermes 2 PSAR that the biological shield is not shared between Unit 1 and Unit 2.

In Hermes 2 PSAR section 4.4, Kairos states that the secondary biological shield will encase the primary to intermediate heat transfer system as well as the reactor vessel and inventory management systems. The change in the secondary biological shield boundary does not affect the biological shield design basis, which is evaluated in section 3.6 of this SE. Based on the above, the staff finds that enclosing the primary to intermediate heat transfer system within the secondary biological shield and having separate biological shields for Unit 1 and Unit 2 is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 biological shield demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 4.4, "Biological Shield," to support safety functions of protecting the health and safety of the facility staff and public.

4.4.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.4 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information, as may be required to complete the review of Hermes 2 biological shield, can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

4.5 <u>Nuclear Design</u>

4.5.1 Introduction

Section 4.5, "Nuclear Design," of the Hermes 2 PSAR describes the Hermes 2 nuclear design, including core design, fuel and moderator pebbles, reactor coolant, and graphite reflectors for neutron moderation and shielding. The reactor core is comprised of a packed bed of approximately a total of 36,000 spherical fuel pebbles and spherical moderator pebbles. The core is roughly 60 percent pebbles and 40 percent reactor coolant by volume. Neutron moderation is provided by a graphite reflector, which also increases neutron economy and shields the reactor structures from fast neutrons, moderator pebbles, graphite in the fueled pebbles, and the reactor coolant, Flibe. The core is slightly under-moderated during all operating conditions.

4.5.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems in section 4.1.1 of this SE apply to the nuclear design. Additionally, the staff reviewed section 4.5.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the nuclear design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.5.2 of the Hermes 1 SE.

4.5.3 Technical Evaluation

The staff reviewed section 4.5, "Nuclear Design," of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.5, "Nuclear Design"). The staff found that section 4.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 nuclear design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 4.5.3, "Technical Evaluation," of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 nuclear design demonstrates an adequate basis for preliminary design, is consistent with PDC 10, 11, 12, and 26, and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 4.5, "Nuclear Design," to support safety functions including controlling reactivity, ensuring shutdown margin, preventing power oscillations, and ensuring specified acceptable system radionuclide release design limits are not exceeded in any postulated events or normal operations.

4.5.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.5 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of the Hermes 2 nuclear design can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

4.6 Thermal-Hydraulic Design

4.6.1 Introduction

Section 4.6, "Thermal-Hydraulic Design," of the Hermes 2 PSAR, discusses the Hermes 2 thermal-hydraulic design. Hermes 2 includes a number of design features that ensure effective heat transport from the fuel pebble to the reactor coolant and ultimately to the heat rejection system.

4.6.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems apply to the thermal-hydraulic design. Additionally, the staff reviewed section 4.6.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the thermal-hydraulic design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.6.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.6.2 of the Hermes 1 SE.

4.6.3 Technical Evaluation

The staff reviewed section 4.6 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.6, "Thermal-Hydraulic Design"). The staff found that section 4.6 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1

PSAR, except for one minor and one significant change, which are reviewed below in SE sections 4.6.3.1 and 4.6.3.2, respectively. The staff found that the following portions of section 4.6 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 4.6.1.1, “Core Geometry,” through 4.6.4 “Testing and Inspection”
- Table 4.6-1, “Summary of Thermal Hydraulic Parameters”
- Figure 4.6-1, “Coolant Flow Path”

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, section 4.6 of the Hermes 2 PSAR contains information consistent with section 4.6 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 4.6.3, “Technical Evaluation,” of the Hermes 1 SE.

4.6.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 4.6, as compared to the information in Hermes 1 PSAR section 4.6, includes the following:

- Use of technical report KP-TR-022, Revision 0, instead of KP-TR-018, Revision 2, to evaluate the thermal-hydraulic design.

KP-TR-022 replaces KP-TR-018 in the Hermes 2 PSAR and addresses postulated events for Hermes 2, including new potential event initiators for the Hermes 2 design. The postulated events unique to Hermes 2 are further evaluated in chapter 13 of this SE. As discussed in KP-TR-022, the thermal-hydraulic computer codes and correlations used in the Hermes 2 model are identical to those used in the Hermes 1 model. Since the same thermal-hydraulic computer codes and correlations are used in both models, the insights and analysis results derived using KP-TR-018 are the same as those derived using KP-TR-022. Based on the above, the staff finds that the use of KP-TR-022 is acceptable.

4.6.3.2 Significant Change Compared to the Hermes 1 PSAR

The significant change in section 4.6 of the Hermes 2 PSAR, as compared to section 4.6 of the Hermes 1 PSAR, include information regarding the following:

- The IHTS is added to the list of systems that play a key role in the thermal-hydraulic design of the reactor system in PSAR section 4.6.1, “Description.”

In Hermes 2 PSAR section 4.6.1, Kairos states that the IHTS affects the thermal-hydraulic design of the facility. Due to the design of Hermes 2, the IHTS is thermally connected to the PHTS through the intermediate heat exchanger and will correspondingly affect the thermal-hydraulic design. A more detailed description of the IHTS design and its subsystems is available in PSAR section 5.2, “Intermediate Heat Transport System.”

The staff performed scoping calculations specific to the Hermes 2 design; these are discussed in chapter 13 of this SE. Based on these calculations, the staff concluded that the TRISO fuel is expected to maintain its integrity during postulated events. In addition, as discussed in chapter 13 of this SE, the maximum hypothetical accident (MHA) remains bounding for all postulated events applicable to the Hermes 2 design. Considering the results of the Hermes 2 scoping calculations and the bounding MHA, the staff determined that the relationship between power and flow of the Hermes 2 heat transport systems, as well as the thermal inertia of the coolant, ensures that heat transfer can be achieved at a rate that maintains the design conditions of the core. Therefore, the staff concluded that the Hermes 2 reactor system is designed with appropriate margin to ensure that specified acceptable system radionuclide release design limits are not exceeded during normal operations, transients, or accident conditions.

Based on the above, the staff finds that the preliminary information on the Hermes 2 thermal-hydraulic design is consistent with PDC 10, 34, and 35. The staff's review of PDC 12 is incorporated by reference from section 4.6.3.3 of the Hermes 1 SE because the thermal-hydraulic design characteristics that affect reactor power oscillations are consistent between Hermes 1 and Hermes 2. These characteristics include high thermal inertia and no two-phase flow in the coolant, and an atmospheric reactor pressure. Based on the above, the staff finds that the addition of the IHTS to the list of systems that play a key role in the thermal-hydraulic design is acceptable.

The staff is not approving the use of Kairos's thermal-hydraulic codes or correlations beyond their support for the staff's findings related to the issuance of CPs. While the staff reviewed uncertainties in the Hermes 2 Kairos Power Systems Analysis Module (KP-SAM) and STAR-CCM+ models, the staff did not make any findings regarding Kairos's validation and verification plan of codes or derivations of uncertainties in the KP-SAM and STAR-CCM+ models because it is not required or necessary for the issuance of CPs. Kairos's validation and verification plan of codes and derivations of uncertainties will be reviewed at the OL stage.

On the basis of its review, the staff finds that the level of detail provided regarding the thermal-hydraulic design demonstrates an adequate basis for preliminary design; is consistent with PDC 10, 12, 34, and 35; and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 4.6, "Thermal-Hydraulic Design," to support safety functions of providing sufficient heat removal and preventing power oscillations.

4.6.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.6 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of the thermal-hydraulic design can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

4.7 Reactor Vessel Support System

4.7.1 Introduction

Section 4.7, "Reactor Vessel Support System," of the Hermes 2 PSAR discusses the reactor vessel support system (RVSS) design. PSAR section 4.7.1, "Description," states that the RVSS provides structural support for the reactor vessel and the vessel internals. The RVSS supports the full weight of the vessel, fuel, coolant, vessel internals, and the head-mounted components. The RVSS is designed to transmit pressure, seismic, and thermal loads to the cavity structures and address thermal expansion during initial heat-up and postulated events.

4.7.2 Regulatory Evaluation

The requirements in the common regulatory evaluation for reactor systems apply to the RVSS. Additionally, the staff reviewed section 4.7.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the RVSS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 4.7.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 4.7.2 of the Hermes 1 SE.

4.7.3 Technical Evaluation

The staff reviewed section 4.7 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 4.7, “Reactor Vessel Support System”). The staff found that section 4.7 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a minor change, which is reviewed below. The staff also verified that the Hermes 2 RVSS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 4.7.3, “Technical Evaluation,” of the Hermes 1 SE.

4.7.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 4.7, as compared to the information in Hermes 1 PSAR section 4.7, includes the following:

- Section 4.7.1 states that the RVSS is not shared by Unit 1 and Unit 2.

Kairos states that the RVSS is not shared between Unit 1 and Unit 2. With the Hermes 2 facility design housing each reactor in a separate building, it is appropriate to have one RVSS for each unit. Based on the above, the staff finds that having a separate RVSS for each unit is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 RVSS demonstrates an adequate basis for a preliminary design; is consistent with PDC 2, 4, and 74; and with the acceptance criteria of NUREG-1537, Part 2, section 4.2.5 “Core Support Structure,” and section 4.3, “Reactor Tank or Pool,” to support safety functions to provide structural support for the reactor vessel and the vessel internals.

4.7.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 4.7 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 RVSS can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

4.8 Summary and Conclusions on the Reactor Description

The staff evaluated the information regarding the Hermes 2 reactor design, as described in PSAR chapter 4, and finds that the preliminary information on, and design criteria of, the reactors, including the PDC, design bases, and information relating to materials of construction, general arrangement, and approximate dimensions: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the reactors, including, but not limited to, the principal engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis of the reactors, and which can reasonably be left for later consideration, will be provided in the final safety analysis report as part of the OL application.

- Safety features or components which require research and development have been described by Kairos and a research and development program (see SE section 1.1.5, “Ongoing Research and Development”) will be conducted that is reasonably designed to resolve any safety questions associated with such features or components.

- There is reasonable assurance that safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed Hermes 2 facility.

- There is reasonable assurance: (i) that the construction of the Hermes 2 facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission’s regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

4.9 References

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5 REACTOR COOLANT SYSTEM

For the Hermes 2 test reactor facility, the reactor coolant system consists of the primary heat transport system (PHTS) that circulates coolant through the reactor core and an intermediate heat transport system (IHTS) that transfers the heat from the PHTS to the power generation system (PGS).

This chapter of the Kairos Power LLC (Kairos) Hermes 2 test reactor facility construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary information regarding the Hermes 2 PHTS and IHTS. This information is presented in chapter 5, "Heat Transport Systems," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed PSAR chapter 5 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information Kairos provided regarding the Hermes 2 facility PHTS and IHTS for the issuance of CPs in accordance with Title 10, *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." As part of this review, the staff evaluated information on the Hermes 2 PHTS and IHTS, with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. The staff evaluated the preliminary designs of the Hermes 2 PHTS and IHTS to ensure the design criteria, design bases, and information relative to construction are sufficient to provide reasonable assurance that the final designs will conform to the design basis. In addition, the staff reviewed Kairos's identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of technical specifications (TS) for the facility, with special attention given to those items which may significantly influence the final design.

5.1 Primary Heat Transport System

5.1.1 Introduction

Section 5.1, "Primary Heat Transport System," of the Hermes 2 PSAR describes the PHTS, which transfers heat from the reactor core by circulating reactor coolant between the reactor core and the IHTS during normal operations. The PHTS includes a primary salt pump (PSP), an intermediate heat exchanger (IHX), a heat rejection subsystem (HRS), and associated piping. The HRS includes a heat rejection radiator (HRR), heat rejection blower, and the associated ducting. The PHTS also includes thermal management features to maintain the reactor coolant in the liquid phase when the reactor core is not generating heat and the capability to drain external piping, the IHX, and the HRR to allow cooldown, inspection, and maintenance. The PHTS performs non-safety related functions as described in PSAR section 5.1.1, "Description." The PHTS interfaces with the IHTS as described in section 5.2, "Intermediate Heat Transport System." The PHTS also interfaces with various other systems, including the reactor thermal management system, inert gas system (IGS), tritium management system (TMS), and inventory management system as described in PSAR chapter 9, "Auxiliary Systems."

5.1.2 Regulatory Evaluation

The staff reviewed section 5.1.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the PHTS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 5.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 5.1.2 of the Hermes 1 SE.

5.1.3 Technical Evaluation

The staff reviewed section 5.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 5.1, "Primary Heat Transport System"). The staff found that section 5.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for several significant changes, which are evaluated below in SE section 5.1.3.1. The staff found that the following portions of section 5.1 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 5.1.1.1, "Reactor Coolant," and 5.1.1.2, "Primary Salt Pump"
- Sections 5.1.1.4, "Primary Loop Piping," and 5.1.1.5, "Primary Loop Thermal Management"
- Section 5.1.2, "Design Basis"
- Section 5.1.4, "Testing and Inspection"

Since the Hermes 2 PHTS design and functionality largely remain identical, apart from the differences evaluated below, section 5.1 of the Hermes 2 PSAR contains information consistent with section 5.1 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 5.1 of the Hermes 1 SE.

5.1.3.1 Significant Changes to the Hermes 1 PSAR

Significant changes contained in section 5.1 of the Hermes 2 PSAR, as compared to section 5.1 of the Hermes 1 PSAR, include information regarding the following:

- In section 5.1.1, the IHX is discussed as the component that transfers heat from the Flibe in PHTS to an intermediate molten slat (BeNaF) in IHTS. The IHX design is described in section 5.1.1.3, "Intermediate Heat Exchanger."
- In section 5.1.1.6, "Heat Rejection Subsystem," the discussion is updated for the changes in the HRR operation and the related changes in the tritium management.
- Section 5.1.3, "System Evaluation," discusses a postulated IHX tube failure.
- Section 5.1.3 states that tritium in the reactor coolant will normally permeate through the IHX and enter the IHTS.

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 PHTS using the guidance and acceptance criteria from 10 CFR 50.34, 10 CFR 50.35, 10 CFR 50.40, and NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria," section 5.2, "Primary Coolant System."

The design of Hermes 2 introduces an IHTS containing a different salt (BeNaF) for the intermediate coolant compared to the reactor coolant salt (Flibe). The IHX serves as the boundary between the reactor coolant and the intermediate coolant. In table 3.6-1 "Structures, System, and Components," of the Hermes 2 PSAR, the IHX, including the IHX tubes, are classified as non-safety related. As discussed in section 3.6.3.2 of this SE, the staff was unable to confirm that the IHX complies with the Hermes 2 definition of "safety-related" structures, systems, and components (SSCs). Kairos confirmed in the response to request for confirmation of information (RCI) number 1 (ML24103A241) that the final design for Hermes 2 will demonstrate that the IHX tubes will not need to be classified as a safety-related SSC or if the IHX tubes are relied upon to remain functional during and after a postulated event, Kairos will demonstrate that their failure is not credible considering all relevant factors. Based on the information identified in RCI 1 to be provided in the OL application, the staff will assess the safety classification of the IHX as part of the OL application review.

The staff reviewed the potential impact of an intermediate salt ingress into the reactor coolant because this event may impact the thermophysical and radionuclide retention properties of the reactor coolant. During the general audit (ML24193A214), the staff and Kairos discussed the consequences of BeNaF ingress into the reactor coolant. Kairos stated that any potential ingress scenarios would either introduce impurities within the allowable specification found in KP-TR-005-P-A, "Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor," (ML20219A591) or that Kairos would provide justification for exceeding the purity specification at the time of the OL application. This approach was confirmed by Kairos in the response to RCI 2 (ML24103A241). Additionally, PSAR section 5.1.1 states that the reactor coolant in the IHX is maintained at a higher pressure than the IHTS during normal operations. Therefore, during an IHX tube leak, the reactor coolant is driven into the IHTS and will maintain its specified chemistry within the PHTS. The staff finds the preliminary information related to potential ingress of the intermediate salt is consistent with PDC 10, 16, and 60 because the reactor coolant will remain within its specifications for the thermophysical and radionuclide retention properties. Kairos stated that it will provide justifications if the coolant purity specifications are exceeded at the OL stage. Further information related to potential ingress of the intermediate salt can reasonably be left for later consideration at the OL stage.

The staff also reviewed the potential impact of an intermediate salt ingress into the reactor coolant on its compatibility with the structural materials. As discussed in section 4.3, "Reactor Vessel System," of this SE, Kairos will perform material compatibility testing with a postulated BeNaF ingress. The proposed limiting condition for operation (LCO) on reactor coolant chemistry proposed in table 14.1-1, "Proposed Variables and Conditions for Technical Specifications," of the Hermes 2 PSAR also helps to ensure that the reactor coolant will remain within its specification during a IHX tube break event as the LCO would require facility actions to correct the reactor coolant chemistry if the intermediate salt infiltration exceeds the specified limit. The proposed material compatibility testing is consistent with PDC 14 and 31 because it addresses the effect of intermediate salt ingress on corrosion of safety-related components in the reactor vessel system. The proposed testing is further evaluated in section 4.3 of this SE. The preliminary information provided by Kairos in PSAR section 4.3 is consistent with PDC 70 because the proposed material compatibility testing addresses the reactor coolant purity necessary to mitigate chemical attack on safety-related metallic materials in the PHTS. Additionally, the chemistry control system (CCS) will be able to monitor and adjust Flibe purity as described in PSAR section 9.1.1 and evaluated in chapter 9 of this SE. This function of the CCS is consistent with NUREG-1537, Part 2, section 5.2, because there are means to maintain coolant chemistry and quality to limit corrosion of the fuel components, control rod cladding, vessel material, and other essential components in the primary system.

PSAR section 5.1.3 states that a postulated IHX tube failure could cause the reactor coolant to leak into intermediate coolant since the reactor coolant is maintained at a higher pressure than the intermediate coolant. PSAR section 5.1.3 states that the loss of reactor coolant inventory would be detected by the inventory management system discussed in PSAR section 9.1.4 and by the detection capability in the IHTS. Additionally, section 3.2.2.7, "Intermediate Heat Exchanger Tube Break," of the technical report KP-TR-022-NP, "Postulated Event Analysis

Methodology," (ML23195A131) states that the quantity of reactor coolant assumed to flow into the IHTS is the same or bounded by the volume of reactor coolant spilled during a postulated pipe break. The staff also notes that the anti-siphon design features on the hot and cold legs should maintain adequate reactor coolant inventory and mitigate any breaks outside the vessel. Accordingly, the staff finds that the preliminary design of the Hermes 2 PHTS is consistent with PDC 33 to maintain reactor coolant inventory to protect against small breaks in the safety related elements of the reactor coolant boundary. Additionally, the staff finds that this preliminary information for the PHTS design is consistent with the relevant guidance in NUREG-1537, Part 2, section 5.2, that the primary coolant system (of a forced-convection coolant flow) should be designed to prevent coolant loss.

PSAR section 5.1.1.6 states that during normal plant operations, the tritium permeating through the HRR is captured by a subsystem of the TMS that is discussed in PSAR section 9.1.3. During startup and normal shutdown conditions, tritium permeation losses through the HRR are released through the HRS as a gaseous effluent. Also, tritium in the reactor coolant will permeate through the IHX heat transfer surfaces and enter the intermediate coolant; tritium management in the IHTS is evaluated in section 5.2.3 of this SE. As stated in PSAR section 11.1.5, "Radiation Exposure Control and Dosimetry," facility effluents are monitored for radioactivity during normal operations and postulated events, and facility SSCs are designed to limit uncontrolled gaseous effluent releases to work areas or the environment, consistent with the goal of maintaining radiation exposures as low as reasonably achievable. Accordingly, the staff finds that the preliminary design of the Hermes 2 PHTS is consistent with PDC 60 to support the control of radioactive materials during normal reactor operation.

The staff reviewed the potential impact of feedback effect from the IHTS loop on the reactor power oscillations to evaluate compliance with PDC 12. The staff finds that the Hermes 2 design features, such as the small core height and diameter and long neutron diffusion length, limit the flow- and inlet temperature-induced power oscillations. Furthermore, the staff also finds that high coolant thermal inertia, the TS LCO that limits air in the reactor coolant, and the ability of instrumentation and control system to detect and suppress temperature and mass flow oscillations are important for suppression and/or prevention of power oscillations. Based on these inherent features and the proposed TS LCO, the staff finds that the preliminary design of the Hermes 2 PHTS is consistent with PDC 12.

On the basis of its review, the staff finds that the primary coolant system design will be able to accomplish the design functions of fuel integrity and sufficient heat removal, coolant loss prevention, conversion to passive natural-convection flow, limited corrosion of essential components, and sufficient radiation shielding for limiting personnel exposures. The staff finds that the preliminary information provided for the PHTS is adequate at this stage of the design and is consistent with PDC 2, 10, 12, 16, 33, 60, and 70 and with the acceptance criteria of NUREG-1537, Part 2, section 5.2.

5.1.4 Conclusion

Based on its findings above, the staff concludes the information in Hermes 2 PSAR section 5.1, as supplemented by the responses to RCI 1 and RCI 2 (ML24103A241), is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 PHTS can reasonably be left for later consideration at the OL stage since the information is not necessary for the review of a CP application.

5.2 Intermediate Heat Transport System

5.2.1 Introduction

Section 5.2 of the Hermes 2 PSAR describes the IHTS. The IHTS includes two intermediate salt pumps (ISPs), an intermediate heat exchanger (IHX), two intermediate salt vessels (ISVs), a superheater, and the associated piping. It transfers heat from the PHTS to the PGS by circulating intermediate coolant between the IHX and the superheater during normal operations. The IHTS contains several subsystems including intermediate coolant inventory management subsystem, intermediate inert gas subsystem, intermediate coolant chemistry control subsystem, and intermediate loop auxiliary heating subsystem. The IHTS performs primarily non-safety related functions as described in PSAR section 5.2.1, “Description.” The IHTS interfaces with the PHTS and PGS as described in sections 5.1 and 9.9, “Power Generation System,” respectively. The IHTS also interfaces with the tritium management system as described in section 9.3.1, “Tritium Management System.”

5.2.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of the Hermes 2 non-power test reactor IHTS design criteria are as follows:

- 10 CFR 50.34, “Contents of applications; technical information,” paragraph (a), “Preliminary safety analysis report.”
    - 10 CFR 50.34(a)(3)(ii) requires “The design bases and the relation of the design bases to the principal design criteria.”
    - 10 CFR 50.34(a)(3)(iii) requires “Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety.”
    - 10 CFR 50.34(a)(4) which requires “A preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…”
- 10 CFR 50.35, “Issuance of construction permits.”
- 10 CFR 50.40, “Common standards.”
- 10 CFR 20.1406, “Minimization of contamination.”

The applicable guidance for the evaluation of Hermes 2 IHTS is as follows:

- NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” chapter 5, “Reactor Coolant Systems.” Based on the role of the IHTS in the Hermes 2 design, the staff evaluated the system using the applicable acceptance criteria in section 5.3, “Secondary Coolant System” for a non-light water reactor.

5.2.3 Technical Evaluation

PSAR section 3.1.1, “Design Criteria,” describes the principal design criteria (PDC) that are applicable to the Hermes 2 reactor. These PDC were reviewed and approved by the staff in KP-TR-003-NP-A, Revision 1, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor.” PSAR section 5.2.2, “Design Basis,” identified the design bases for the IHTS. The PSAR states that the following PDC are applicable to the IHTS:

- PDC 2, “Design bases for protection against natural phenomena,” which requires safety related SSCs be designed to withstand the effects of natural phenomena.
- PDC 60, “Control of releases of radioactive materials to the environment,” which requires the plant design to control the release of radioactive materials, including during postulated events.
- PDC 64, “Monitoring radioactivity releases,” which requires means to monitor for radioactivity that may be released during operations, anticipated operational occurrences (AOOs), and postulated accidents.
- PDC 73, “Reactor coolant system interfaces,” which requires two passive barriers between the reactor coolant and any chemically incompatible fluid, or one passive barrier between the reactor coolant and a chemically compatible fluid provided postulated leakage doesn’t result in SR SSCs failing to perform their safety functions or result in exceeding specified acceptable system radionuclide release design limits.

PSAR section 5.2.3, “System Evaluation,” relates the design bases to the design criteria and identifies how the IHTS satisfies the PDC applicable to the design of the IHTS. In the following paragraphs, the staff addresses each PDC by summarizing the information presented in the PSAR and explaining the staff evaluation of the adequacy of the preliminary information in the Kairos PSAR relative to NUREG-1537, Part 2, section 5.3, acceptance criteria.

5.2.3.1 PDC 2, Design bases for protection against natural phenomena

PSAR section 5.2.3 states that the design of non-safety related IHTS SSCs is such that a failure of IHTS SSCs would not affect the performance of safety-related SSCs due to a design basis earthquake (DBE). The PSAR also states that the safety-related SSCs will be protected by either seismically mounting the relevant IHTS components, assuring sufficient physical separation from the IHTS components, or by the erection of protective barriers between the IHTS components and the safety-related SSCs to preclude any adverse interactions. Further, the PSAR states that the portions of the IHTS that cross the isolation moat around the safety-related reactor building are designed to accommodate differential displacement due to a DBE as discussed in PSAR section 3.5. PSAR section 3.5 states that this design feature minimizes the stresses on the components that cross the isolation moat and reduces the likelihood of their failure that would adversely affect the ability of safety-related SSCs during the DBE. Furthermore, as evaluated in section 13.1.4 of this SE, a postulated loss of normal heat sink due to failure of an IHTS component (e.g., ISP failure) would not lead to inadequate heat removal because the safety-related decay heat removal system (DHRS) or parasitic heat loss provides sufficient residual heat removal.

A novel safety-related component in the Hermes 2 design is the rupture disks of the intermediate inert gas system. PSAR section 5.2.1.2 states that these rupture disks preclude a gross failure of the IHX that could occur as a result of a postulated superheater tube leak or rupture event by relieving pressure in the IHTS and providing a steam relief path. These disks are in the gas space of the ISVs and, accordingly, are connected to the non-safety related IHTS.

PSAR table 3.6-1 shows that the rupture disks are seismically designed to the local building code despite being considered safety-related. The staff finds this acceptable because as stated in Note 6 of table 3.6-1, the IHTS SSCs are not relied upon to maintain their structural integrity during and following a DBE that may result in the loss of the IHTS pressure boundary. The loss of the pressure boundary during a DBE removes the need for the safety function of the IHTS rupture disks. Therefore, the IHTS rupture disks are not required to perform their safety function during a seismic event and the staff finds the preliminary seismic design of the safety-related rupture disks is consistent with PDC 2.

Because failures in the IHTS would not affect the ability of safety-related SSCs to perform their safety function, the staff finds that the preliminary design of the IHTS is consistent with PDC 2. The staff also finds that the preliminary design of the IHTS is consistent with the guidance provided in NUREG-1537, Part 2, section 5.3, that requires staff to ensure that the malfunction in secondary coolant system will not lead to reactor damage, fuel failure, or uncontrolled release of radioactivity to the environment.

5.2.3.2 PDC 60, Control of releases of radioactive materials to the environment

PSAR section 5.2.3 states that tritium will be present in the IHTS as it will diffuse through the IHX during normal operations. Kairos stated that anhydrous hydrogen fluoride will be used to convert tritium to the gaseous phase that will result in the tritium being removed from the IHTS by the TMS via the intermediate IGS.

The staff evaluated the ability of the IHTS to control tritium during normal operations against PDC 60. The staff finds the preliminary information provided in the PSAR consistent with PDC 60 because the IHTS has ability to control speciation of tritium to guide it to the tritium management system (TMS) for capture and removal. The radiation monitoring in the IHTS cover gas space will also provide assurance that tritium is being removed from the IHTS salt and transferred to the TMS via the intermediate IGS. The staff evaluation of the TMS and its ability to process and remove tritium is found in section 9.1.3 of this SE. Additionally, as described in PSAR chapter 14, there are proposed technical specifications to monitor the activity in the IHTS. This provides additional assurance that measures to control tritium in the IHTS will be in place to demonstrate that the final design of the IHTS will be consistent with PDC 60.

5.2.3.3 PDC 64, Monitoring radioactivity releases

The PSAR states that radiation monitoring is provided in the ISV cover gas space to monitor the radioactive material releases that might occur in the IHTS as result of an IHTS SSC failure. The staff finds this preliminary information consistent with PDC 64, which requires a means to monitor for radioactivity that may be released during operations, AOOs, or postulated accidents Further information can reasonably be left for later consideration at the OL stage.

5.2.3.4 PDC 73, Reactor coolant system interfaces

PSAR section 5.2.3 states that the Flibe primary reactor coolant is separated from water by two passive barriers, the IHX and the superheater. In addition, section 5.2.3 states that the PHTS is maintained at a higher pressure than the IHTS, so a leak or failure in the IHX could cause the IHTS coolant to be contaminated with Flibe. The PSAR also states that the reactor coolant and intermediate coolant are chemically compatible. In section 1.3.9, “Research and Development,” of the Hermes 2 PSAR Kairos states that completing compatibility evaluations of the intermediate coolant and reactor coolant chemical interaction is a research and development item to confirm the adequacy of the design. Consistent with similar findings in sections 3.1 and 5.1 of this SE, the staff finds that Kairos's plan to address coolant compatibility in the OL application can be reasonably left for later consideration. Therefore, the staff finds that the preliminary information for the IHTS design is consistent with PDC 73 for coolant compatibility and is acceptable for a preliminary design. The staff will confirm at the OL stage that the final design for the IHTS meets PDC 73 for coolant compatibility by demonstrating compatibility between the primary and intermediate coolants and that the intermediate coolant does not have a safety significant impact on the primary system.

An important postulated event for the IHTS design is a postulated superheater tube leak or rupture. The PSAR states that the IHTS includes safety-related rupture disks to mitigate the effects of a postulated superheater tube leak or rupture by relieving pressure in the IHTS and providing a relief path for the steam to prevent a gross failure of the IHX. PSAR section 13.1.10.11 states that the rupture disks prevent significant Flibe-water interaction in the PHTS that could result from a gross failure of the IHX due to steam over-pressurization of the IHTS during a postulated superheater tube leak or rupture event. The staff finding related to the safety classification of the IHX, including the IHX tubes that are the boundary between the PHTS and IHTS, can be found in sections 3.6.3.2 and 5.1.3 of this SE.

For the safety-related rupture disks, section 5.2.1.2, "Intermediate Inert Gas Subsystem," of the Hermes 2 PSAR states that the rupture disks are located in the gas space above the ISVs. The rupture disks will be made of 316H stainless steel with a maximum temperature during normal operations less than the maximum IHTS hot leg temperature (580 – 615 °C). The rupture disks will be designed in accordance with the 2017 version of American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section VIII, "Rules for Construction of Pressure Vessels," Division 2, "Alternative Rules," (Section VIII, Division 2). The PSAR states that Section VIII, Division 2, is more appropriate for the design and construction of the rupture disks than American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Facility Components," Division 5, "High Temperature Reactors," (Section III, Division 5) due to the absence of both a high irradiation environment and the need to maintain a safety-related pressure boundary. In addition, the rupture disks provide pressure relief for the IHTS, which is being designed to Section VIII, Division 2, as well.

The staff notes that all other safety-related SSCs in Hermes 2 will be designed in accordance with Section III, Division 5, which is endorsed by the staff for use in RG 1.87, "Acceptability of ASME Code Section III, Division 5, 'High Temperature Reactors'," Revision 2. The staff engaged in discussions with Kairos in the Hermes 2 general audit (ML24193A214) to understand the key differences between the use of Section VIII, Division 2, compared to Section III, Division 5, that may impact rupture disk reliability and ability to perform its safety function. The staff identified that 316H stainless steel is an approved material for high temperature applications within Section III, Division 5. Kairos provided supplemental information related to the design of the rupture disks in a submittal dated May 16, 2024 (ML24138A214) and confirmed their final design considerations in the response to RCI 3 (ML24135A382).

In the supplemental information, Kairos compared Section VIII, Division 2, and Section III, Division 5, provisions with respect to rupture disk design and observed the similarities between Section III, Division 5, and Section VIII, Division 2, for the rupture disk design. Further, in the response to RCI 3, Kairos confirmed that the final design of the IHTS and the rupture disks will justify that the overpressure protection safety function will be performed reliably with consideration for the system design, location of the rupture disks, operating environment, material aging or degradation due to environmental effects, potential salt vapor deposition impeding rupture disk function, and other design considerations such as redundancy and independence. The staff notes that the supplemental information on the similarities between Section VIII, Division 2, and Section III, Division 5, provisions with respect to rupture disk design and the additional information confirmed through RCI 3 provide a reasonable basis for developing the final design of the safety-related rupture disks for a non-power reactor. In addition, table 14.1-1 of the Hermes 2 PSAR identifies a probable TS LCO for IHTS pressure relief device operability, which provides additional assurance that provisions to identify conditions that may challenge the rupture disks' ability to perform their safety function will be implemented. Based on the information provided in the PSAR (including the use of 316H for the rupture disk material), the supplemental information, the RCI response, the proposed TS LCO, and Hermes 2's status as a non-power reactor, the staff finds the preliminary information related to the design of the safety-related IHTS rupture disks to perform the safety function to mitigate the effects of a postulated superheater tube leak or tube rupture event and prevent water-Flibe interaction is acceptable and further information can reasonably be left for later consideration at the OL stage.

Based on the findings above related to the coolant compatibility and the design of the rupture disks, the staff finds that the preliminary design information for the IHTS is consistent with PDC 73. Further information on the IHTS design related to PDC 73 can reasonably be left for later consideration at the OL stage.

5.2.3.5 10 CFR 20.1406, Minimization of contamination

PSAR section 5.2.3 states that the IHTS piping will be designed to the American Society of Mechanical Engineers (ASME) Standard B31.3, "Process Piping," and the superheater and ISVs will be designed to ASME Boiler and Pressure Vessel Code, Section VIII. The intermediate coolant can become contaminated with tritium or other radioactive materials from a postulated leak from the PHTS into the IHTS through the IHX. The staff evaluation of the TMS, which is designed to capture and remove the tritium from the IHTS, is provided in section 9.1.3 of this SE. As described in section 5.2.3.2 of this SE, the IHTS is also equipped with the capability to monitor the ISV cover gas environment for radioactive material releases from breaks and leaks in the piping system or via pressure relief equipment. In addition, table 14.1-1 of the Hermes 2 PSAR identifies a TS LCO that limits the quantities of material at risk for release (MAR) in the ISV cover gas space.

Based on the identification of the quality standards used to fabricate the IHTS, the radiation monitoring features of the IHTS, and the TMS to remove tritium from the IHTS, the staff finds the preliminary design of the IHTS is consistent with 10 CFR 20.1406. Further information on how the IHTS minimizes contamination and meets 10 CFR 20.1406 can reasonably be left for later consideration in the OL application.

5.2.3.6 Additional NUREG-1537 Criteria

As described in PSAR section 5.2.1, the IHTS performs non-safety related functions to remove heat from the PHTS during normal operations. There are no safety-related heat removal functions specified for the IHTS in section 5.2.1. Additionally, as described in PSAR chapters 6 and 13, the DHRS is the only safety-related means to remove heat from the reactor vessel.

The staff evaluated the preliminary IHTS design against applicable criteria in NUREG-1537, Part 2, section 5.3. These criteria require a secondary coolant system to have the ability to remove heat from the primary coolant system, as needed, to maintain fuel integrity and to support any conditions analyzed in PSAR chapters 6 or 13. The staff finds the preliminary information related to the IHTS design is consistent with the guidance from NUREG-1537, Part 2, section 5.3, because the Hermes 2 design does not rely on the IHTS for any safety-related heat removal. Further information regarding the need for heat removal capability by the IHTS can reasonably be left for later consideration at the OL stage and the staff will evaluate the final design to ensure that increases or decreases in heat removal rates from the IHTS are bound by chapter 13 analyses and will not impact fuel integrity.

PSAR section 5.2.1.4, "Intermediate Coolant Chemistry Control Subsystem," describes the chemistry control system for the IHTS. Additionally, PSAR chapter 14 indicates a proposed TS LCO that would limit the quantity of water in the IHTS to limit corrosion. The staff evaluated the preliminary design of the IHTS against applicable criteria in NUREG-1537, Part 2, section 5.3, which require a secondary coolant system to provide any necessary chemistry control to limit corrosion or degradation of the heat exchanger. The staff finds the preliminary information consistent with this guidance because the IHTS has a chemistry control system and there is a proposed TS LCO for the allowed amount of water in the IHTS to limit corrosion.

As described in PSAR section 5.2.1.5, the ISPs provide motive force for the circulation of intermediate salt in the IHTS. Hermes 2 PSAR section 7.3, "Reactor Protection System," adds a safety-related ISP trip resulting from RPS actuation. To limit overcooling during a postulated event, the ISP trips concurrently with the PSP and interlocks prevent the starting of the ISP with a secured PSP. As evaluated in sections 13.1.2 and 13.1.4 of this SE, the ISP trip plays critical role in mitigating the events initiated in the IHTS and PGS by significantly reducing the heat transfer between the PHTS, IHTS, and PGS. The ISP trip that reduces heat transfer between the PHTS, IHTS, and PGS provides additional assurance that the consequences of postulated events initiated from the IHTS and PGS remain within the bounds of the MHA. Therefore, the staff finds that the preliminary design of the IHTS is consistent with the guidance in NUREG-1537, Part 2, section 5.3, that states that secondary coolant system should include necessary instrumentation and control functions and be designed to respond as necessary to postulated events.

5.2.4 Conclusion

Based on its findings above, the staff concludes the information in Hermes 2 PSAR section 5.2, as supplemented by the submittal dated May 16, 2024, and response to RCI 3, is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 IHTS can reasonably be left for later consideration at the OL stage since the information is not necessary for the review of a CP application.

5.3 Summary and Conclusions on the Reactor Coolant System

The staff evaluated the information on the Hermes 2 reactor coolant system as described in PSAR chapter 5, as supplemented, and finds that the preliminary information on, and design criteria of, the reactor coolant system, including the PDC, design bases, and information relating to materials of construction, general arrangement, and approximate dimensions: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the reactor coolant system, including, but not limited to, the principal engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis of the reactor coolant system, and which can reasonably be left for later consideration, will be provided in the FSAR.

- Safety features or components which require research and development have been described by Kairos and a research and development program (see SE section 1.1.5 that reviews PSAR section 1.3.9) will be conducted that is reasonably designed to resolve any safety questions associated with such features or components.

- There is reasonable assurance that safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility.

- There is reasonable assurance: (i) that the construction of the facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission's regulations.

- The issuance of a permit for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

5.4 References

American Society of Mechanical Engineers (ASME) B31.3, "Process Piping," ASME: Two Park Avenue, New York, NY., dated June 2021.

-----. Section VIII, "BPVC [Boiler and Pressure Vessel Code] Section VIII-Rules for Construction of Pressure Vessels Division 1," ASME: Two Park Avenue, New York, NY, 2021.

Kairos Power LLC, "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," Revision 3, dated May 31, 2023, ML23151A743.

-----. KP-TR-003-NP-A, "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor," Revision 1, dated June 2020, ML20167A174.

-----. "Enclosure 2: Response to NRC Request for Additional Information 350," dated September 2022, ML22251A400 (redacted version).

-----. "Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor Topical Report," KP-TR-005-NP-A, Revision 1, dated July 2020, ML20219A591 (redacted version).

-----. "Mechanistic Source Term Methodology Topical Report," KP-TR-012-NP-A, Revision 3, dated March 2022, ML22136A2918 (redacted version).

-----. “Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor,” KP-TR-013-NP, Revision 4, dated September 2022, ML22263A456 (redacted version).

-----. “Graphite Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor,” KP-TR-014-NP, Revision 4, dated September 2022, ML22259A142 (redacted version).

-----. “Kairos Power, LLC, Response to NRC Request for Confirmation of Information for the Review of the Hermes 2 PSAR Chapter 5,” dated April 12, 2024, ML24103A243.

-----. “Kairos Power, LLC, Response to NRC Request for Confirmation of Information for the Review of the Hermes 2 PSAR Chapter 5,” dated May 14, 2024, ML24135A382.

-----. “Enclosure 2: Supplemental Information on Rupture Disk Design Code Evaluation,” dated May 16, 2024, ML24138A214.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

The U. S. Nuclear Regulatory Commission (NRC), NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” dated February 1996, ML042430048.

-----. “Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes [1] Test Reactor,” dated June 16, 2023, ML23158A265.

-----. “Request for Confirmation of Information for Hermes 2 Preliminary Safety Analysis Report,” dated April 12, 2024, ML24103A173.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes 2 Construction Permit Preliminary Safety Analysis Report – General Audit,” dated July 11, 2024, ML24193A214.

6 ENGINEERED SAFETY FEATURES

Engineered safety features (ESFs) are features designed to mitigate the consequences of accidents and to keep radiological exposures within acceptable values. For this reason, ESFs must be designed to function during a full range of conditions, from normal operation to accident conditions. The need for ESFs in a test reactor is design-specific and determined through an applicant’s accident analyses.

This chapter of the Kairos Power LLC (Kairos) Hermes 2 construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff’s (the staff’s) technical review and evaluation of the preliminary information provided in chapter 6, “Engineered Safety Features,” of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed chapter 6 of the Hermes 2 PSAR against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information on the Hermes 2 ESFs for the issuance of CPs in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, “Domestic Licensing of Production and Utilization Facilities.” As part of this review, the staff evaluated information on the Hermes 2 ESFs, with special attention given to design and operating characteristics, unusual or novel design features, and principal safety considerations. The staff evaluated the preliminary design of the Hermes 2 ESFs to ensure the design criteria, design bases, and information relative to construction is sufficient to provide reasonable assurance that the final design will conform to the design basis. In addition, the staff reviewed Kairos’s identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of technical specifications (TS) for the facility, with special attention given to those items which may significantly influence the final design.

In its review of areas relevant to PSAR chapter 6, the staff considered the information in technical report KP-TR-017, “KP-FHR Core Design and Analysis Methodology,” Revision 1, dated September 29, 2022, and technical report KP-TR-022, “Hermes 2 Postulated Event Analysis Methodology,” Revision 0, dated June 30, 2023. These technical reports were submitted as part of the Hermes 2 CP application and are referenced in the Hermes 2 PSAR.

The staff’s reviews and evaluations for areas relevant to PSAR chapter 6, including regulations and guidance used, a summary of the application information reviewed, and evaluation findings and conclusions, are discussed in the SE sections below for each specific review area. A summary and overall conclusions on the staff’s technical evaluation of the Hermes 2 ESFs are provided in SE section 6.4, “Summary and Conclusions on Engineered Safety Features.”

6.1 Summary Description

PSAR section 6.1, “Summary Description,” provides a high-level overview of the Hermes 2 ESFs. The ESFs for each of the Hermes 2 non-power test reactor units consist of the functional containment and the decay heat removal system (DHRS), both of which are credited in PSAR chapter 13, “Accident Analysis.” The functional containment includes the tristructural isotropic (TRISO) fuel particles and the Flibe coolant. The fuel design is the primary means of containing radionuclides for the Hermes 2 reactor units. Each unit’s DHRS removes heat from the reactor vessel (RV) to ensure RV and fuel integrity when the normal heat rejection system is not available.

NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1, "Format and Content," and Part 2, "Standard Review Plan and Acceptance Criteria," section 6.1, "Summary Description," do not stipulate any specific review findings for this section; therefore, the staff did not make any findings relative to Hermes 2 PSAR section 6.1. PSAR sections 6.2, "Functional Containment," and 6.3, "Decay Heat Removal System," provide detailed descriptions of the functional containment and DHRS, respectively. The corresponding sections of this SE document the staff's review findings on these ESFs.

6.1.1 Common Regulatory Evaluation for Engineered Safety Features

The staff reviewed section 6.1.1, "Common Regulatory Evaluation for Engineered Safety Features," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the ESF designs between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 6.1.1 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 6.1.1 of the Hermes 1 SE.

6.2 Functional Containment

6.2.1 Introduction

Section 6.2, "Functional Containment," of the Hermes 2 PSAR describes the approach of using a functional containment consisting of physical barriers, operating conditions, coolant design, and fuel form to limit the potential release of radioactive material instead of a traditional containment. The TRISO fuel particles retain most of the radioactive material at risk for release and the Flibe coolant in which the fuel pebbles are submerged is also credited for retaining radionuclides that are not aerosolized or evaporated during an event. In addition, the near-atmospheric primary system pressure precludes the type of high-energy releases associated with highly pressurized primary systems.

The individual components of the functional containment are described in PSAR chapter 4, "Reactor Description," and PSAR chapter 5, "Heat Transport System." PSAR chapter 13 describes accident analyses using the integral functional containment approach. In addition, PSAR chapter 14, "Technical Specifications," discusses variables and conditions that are probable subjects of TSs associated with the fuel, coolant, and reactor.

6.2.2 Regulatory Evaluation

The staff reviewed section 6.2.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the functional containment approach between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 6.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 6.2.2 of the Hermes 1 SE.

6.2.3 Technical Evaluation

The staff reviewed section 6.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 6.2, "Functional Containment"). The staff found that section 6.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 functional containment approach remains identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 6.2.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the design of the Hermes 2 functional containment demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, sections 6.2.1 and 6.2.2, to limit the potential release of radioactive material to the environment.

6.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 6.2 is sufficient, is consistent with the applicable guidance, and meets the regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. In addition, the staff concludes that the preliminary information on the functional containment approach is consistent with the approach described in SECY-18-0096, "Functional Containment Performance Criteria for Non-Light-Water Reactors," and the Staff Requirements Memorandum for SECY-18-0096. Further information as may be required to complete the review of the Hermes 2 functional containment (e.g., final safety analyses) can reasonably be left for later consideration at the OL stage since this information is not necessary to be provided as part of a CP application.

6.3 Decay Heat Removal System

6.3.1 Introduction

Section 6.3, "Decay Heat Removal System," of the Hermes 2 PSAR describes the DHRS, which is an ex-vessel system that removes decay heat from each reactor core during normal and off-normal conditions. Its safety function is to remove decay heat during and after postulated events, including the maximum hypothetical accident, that assume unavailability of the normal heat rejection system. There is one DHRS per unit and the DHRS does not share SSCs between the units. The DHRS includes four independent trains comprised of annular thermosyphon thimbles, steam separators, and water storage tanks. Heat is transferred from the reactor vessel to the water-based thermosyphons through thermal radiation and convection. Water in the thermosyphons, supplied by the water storage tanks, boils off and vents to the atmosphere.

6.3.2 Regulatory Evaluation

The staff reviewed section 6.3.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the DHRS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 6.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 6.3.2 of the Hermes 1 SE.

6.3.3 Technical Evaluation

The staff reviewed section 6.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 6.3, "Decay Heat Removal System"). The staff found that section 6.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1

PSAR, except for two minor changes, which are evaluated below. The staff also verified that the Hermes 2 DHRS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 6.3.3 of the Hermes 1 SE.

6.3.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 6.3, as compared to the information in Hermes 1 PSAR section 6.3, include the following:

- PSAR section 6.1, “Summary Description,” clarifies that for the Hermes 2 design, there is one DHRS per unit, and the DHRS does not share components between units. The design information in PSAR section 6.3 applies to both units.
- Use of technical report KP-TR-022, “Hermes 2 Postulated Event Methodology,” instead of technical report KP-TR-018, “Hermes Postulated Event Analysis Methodology”.

The staff determined that the Hermes 2 DHRS design did not change relative to the Hermes 1 DHRS design. The only difference related to the DHRS is that the Hermes 2 facility includes two reactor units instead of one and each unit has its own DHRS. Because there is no impact to DHRS design or functionality, the staff finds that having a separate DHRS for each unit is acceptable.

In Hermes 1 SE sections 6.3.3.2, “Staff Evaluation of DHRS Design,” and 6.3.3.7, “PDCs 10, 34, and 34, Reactor Design, Residual Heat Removal, and Passive Residual Heat Removal,” the staff references KP-TR-018 regarding overcooling Flibe and meeting temperature acceptance criteria, respectively. KP-TR-022 is largely identical to KP-TR-018, with the differences reflecting the addition of the intermediate heat transport system and power generation system to the Hermes 2 design. The staff confirmed that these differences do not impact DHRS design or the illustrative example calculations provided in the technical reports; therefore, the insights and analysis results derived using KP-TR-018 are the same as those derived using KP-TR-022. Thus, the staff’s references to KP-TR-018 in Hermes 1 SE sections 6.3.3.2 and 6.3.3.7 are also applicable for Hermes 2.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 DHRS designs demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, sections 5.3 and 6.2.3, and applicable principal design criteria (PDC) discussed in section 6.3.3 of the Hermes 1 SE to support the DHRS safety function of passive residual heat removal, in accordance with 10 CFR 50.34(a)(3).

6.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 6.3 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of the Hermes 2 DHRSs can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

6.4 Summary and Conclusions on the Engineered Safety Features

The staff evaluated the information on the Hermes 2 ESFs as described in PSAR chapter 6 and finds that the preliminary information on, and design criteria of, the ESFs, including the PDC, design bases, and information relating to materials of construction, general arrangement, and approximate dimensions: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the ESFs, including, but not limited to, the principal engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis of the ESFs, and which can reasonably be left for later consideration, will be provided in the final safety analysis report as part of the OL application.

- There is reasonable assurance: (i) that the construction of the Hermes 2 facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission’s regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

6.5 References

American Concrete Institute (ACI), ACI 349-13, “Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary,” 2014.

American Society of Mechanical Engineers (ASME). Boiler and Pressure Vessel Code, Section III, Division 5, “High Temperature Reactors,” ASME: New York, NY., 2017.

American Society of Civil Engineers (ASCE), ASCE 4-16, “Seismic Analysis of Safety-Related Nuclear Structures,” ASCE: Reston, VA., 2017.

American Society of Civil Engineers/Structural Engineering Institute (ASCE/SEI). ASCE/SEI 43-19, “Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities,” ASCE, Reston, VA., 2019.

Electric Power Research Institute (EPRI), “Uranium Oxycarbide (UCO) Tristructural (TRISO)-Coated Particle Fuel Performance,” Topical Report EPRI-AR-1(NP)-A, EPRI Report #3002019978, 2020, ML20336A052.

Kairos Power LLC. KP-TR-003-NP-A, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor,” Revision 1, dated June 2020, ML20167A174.

-----. “KP-FHR Fuel Performance Methodology,” KP-TR-010-NP-A, Revision 3, dated May 2022, ML22125A278 (redacted version).

-----. “Fuel Qualification Methodology for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor (KP-FHR),” KP-TR-011-NP, Revision 2, dated June 2022, ML22186A215 (redacted version).

-----. “Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor,” KP-TR-013-NP, Revision 4, dated September 2022, ML22263A456 (redacted version).

-----. “Graphite Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor,” KP-TR-014-NP, Revision 4, dated September 2022, ML22259A142 (redacted version).

-----. “Transmittal of Response to NRC Question on DHRS Testing from PSAR Section 6.3 Audit on Hermes [1] Preliminary Safety Analysis Report,” KP-NRC-2209-003, dated September 2022, ML22244A235 (redacted version).

-----. “Transmittal of Changes to Preliminary Safety Analysis Report Chapter 6 and Response to NRC Question on DHRS Testing,” KP-NRC-2212-003, dated December 2022, ML22353A625.

-----. “Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1]),” Revision 3, dated May 31, 2023, ML23151A743.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC). NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. SECY-18-0096, “Functional Containment Performance Criteria for Non-Light-Water-Reactors,” NRC: Washington, D.C., dated September 2018, ML18114A546.

-----. SRM-SECY-18-0096, “Staff Requirements – SECY-18-0096 - Functional Containment Performance Criteria for Non-Light-Water-Reactors,” NRC: Washington, D.C., dated December 2018, ML18338A502.

-----. Regulatory Guide (RG) 1.87, Revision 2, Acceptability of ASME Code Section III, Division 5, “High Temperature Reactors,” NRC: Washington, D.C., dated January 2023, ML22101A263.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report Decay Heat Removal System (Chapter 6, Section 6.3),” dated April 2023, ML23115A480.

-----. “Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes [1] Test Reactor,” dated June 16, 2023, ML23158A265.

7 INSTRUMENTATION AND CONTROL SYSTEMS

Chapter 7 of the Kairos Power LLC (Kairos) Hermes 2 construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary design of the Hermes 2 test reactor facility's structures, systems, and components (SSCs) as presented in chapter 7.0, "Instrumentation and Controls," of the Hermes 2 Preliminary Safety Analysis Report (PSAR), Revision 1.

As part of this review, the staff evaluated information regarding the Hermes 2 instrumentation and control (I&C) systems, with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. The preliminary design of the Hermes 2 I&C systems was evaluated to ensure the appropriate Principal Design Criteria (PDC) and design bases have been established and information relative to materials of construction, general arrangement, and approximate dimensions are sufficient to provide reasonable assurance that the final design will conform to the design basis.

Areas of review for this section included the plant control system (PCS), reactor protection system (RPS), main control room (MCR), remote onsite shutdown panels (ROSPs), display information, and sensors. Within these review areas, the staff assessed the preliminary design of the I&C systems needed to monitor key parameters and variables, maintain parameters and variables within prescribed operating ranges, alert operators when operating ranges are exceeded, and assure safety limits are not exceeded.

7.1 <u>Instrumentation and Controls Overview</u>

Section 7.1.1, "Summary Description," of the Hermes 2 PSAR states that the I&C systems monitor and control plant operations during normal operations and planned transients. The systems also monitor and actuate protection systems in the event of unplanned transients.

The Hermes 2 I&C architecture is comprised of four parts, described in the bulleted list below. Each of the four parts are described in further detail in subsequent subsections of this SE. The architectural design of the system accounts for interconnection interfaces for plant I&C SSCs. Hermes 2 PSAR figure 7.1-1, "Instrumentation and Controls System Architecture," provides an overview of the I&C system architecture.

- The PCS provides the capability to reliably control plant systems during normal, steady state, and planned transient power operations, including normal plant startup, power maneuvering, and shutdown. The power generation control system is the only portion of the PCS that is shared between Unit 1 and Unit 2. The PCS is evaluated in section 7.2 of this SE.
- The RPS provides protection for reactor operations by initiating signals to mitigate the consequences of postulated events and to ensure safe shutdown. The safety-related RPS is not shared between Unit 1 and Unit 2. The RPS is evaluated in section 7.3 of this SE. The MCR and ROSPs provide the capability for plant operators to monitor plant systems, control plant systems, and to initiate plant shutdown. Unit 1 and Unit 2 share a common MCR. Each unit is provided with a unit-specific ROSP. The MCR and ROSPs are evaluated in section 7.4 of this SE.
- Sensors provide input to multiple control and protection systems. Safety-related sensors are not shared between Unit 1 and Unit 2. Only non-safety related sensors that control

and monitor shared systems are shared between Unit 1 and Unit 2. Sensors are evaluated in section 7.5 of this SE.

As stated in the PSAR, the I&C system implements the Institute of Electrical and Electronics Engineers (IEEE) Standard 603-2018, “Standard Criteria for Safety Systems for Nuclear Power Generating Stations,” IEEE Standard 7-4.3.2-2003, “IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations,” and other consensus standards for safety related I&C functions. The I&C system is designed to incorporate the principles of independence, redundancy, and diversity. Features reflecting those principles are discussed in the specific subsystem descriptions.

The RPS is the safety related system credited for tripping the reactor and actuating engineered safety features. Accordingly, the RPS is isolated and independent from the other I&C systems and uses input signals from independent instrumentation. RPS instrumentation signals are provided to the PCS via a data diode, which is part of the RPS hardware platform. As described in PSAR section 7.3, “Reactor Protection System,” the RPS is isolated from other I&C systems, including the MCR and the ROSPs, using safety-related isolation hardware. Isolation is achieved through features built into the hardware platform or through separate isolation devices. The I&C system includes the capability for both manual and automatic control. The sensors for temperature, pressure, neutron count rates, level, flow, radiation level, and other analog and digital field detectors provide input to the RPS and PCS.

The PSAR states that the RPS includes sensors, trips, and interlocks to shut down the reactor when operating parameters exceed operational limits. This includes release of the control and shutdown elements within a set of defined parameters after the onset of a postulated event. As shown on PSAR figure 7.1-1, the RPS sensors are separate from the PCS sensors, which input into the PCS. Specific trips and interlocks are discussed in PSAR section 7.3. The PSAR states that RPS actuation setpoints, calculated in accordance with the guidance of ANSI/ISA 67.04.01-2018, “Setpoints for Nuclear Safety-Related Instrumentation,” for trips and interlocks are based on the following design approaches

- Simulation models: Time to reach operational limits based on system qualification (environments, process conditions, etc.) as demonstrated by actual empirical data collected during simulation testing.
- RPS Technical Specifications: Measurement time, process parameters as informed by safety case assumptions and bounded by Technical Specification limits.
- Mechanical design and testing - response time for actuation to complete: Time to detect, process, and actuate the required controls; this time should be less than the time between event onset and a parameter reaching a limiting condition for continued operation.
- Tiered (graded) approach to protection: The RPS utilizes highly reliable safety related parameters as the final level of protection for public health and safety.

The PDC for the facility SSCs are described in PSAR chapter 3, “Design of Structures, Systems and Components,” and are based on those specified in the NRC-approved Kairos topical report, KP-TR-003-NP-A, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor.”

7.2 Plant Control System

7.2.1 Introduction

Hermes 2 PSAR section 7.2.1, “Description,” states that the PCS is a non-safety related control system which controls reactor startup, changes in power levels, reactor shutdown, heat transport, and the power generation system. The PCS is made up of the following subsystems:

- reactor control system (RCS)
- reactor coolant auxiliary control system (RCACS)
- primary heat transport control system (PHTCS)
- intermediate heat transport control system (IHTCS)
- power generation control system
- auxiliary monitored systems

The PCS maintains plant and individual unit parameters within the normal operating envelope and provides data to the control consoles located in the main control room.

As described in the PSAR, the Hermes 2 PCS is a microprocessor-based distributed control system that individually controls plant systems using applicable inputs. The subsystems listed above are integrated into the PCS using non-safety related signal wireways which are terminated at local cabinets and use redundant, non-safety, real-time data highways. The RCS, RCACS, PHTCS, and IHTCS are unit-specific subsystems. The auxiliary monitored systems are also unit-specific. The power generation control system is shared between Unit 1 and Unit 2. The plantwide sensor inputs are used to verify interlock and permissive rules for the various plant states. The sensor data are also used to provide feedback and alarms to the operators via the control consoles. The PCS is powered by alternating current and direct current power supplies which are discussed in Hermes 2 PSAR chapter 8, “Electric Power System.” The PCS uses non-safety related sensor inputs as well as safety-related sensor inputs from the RPS, as described in PSAR section 7.3.3, “System Evaluation.”

7.2.2 Regulatory Evaluation

The staff reviewed section 7.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarity of the Hermes 1 and Hermes 2 facility designs and the consistency of the PCS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 7.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 7.2.2 of the Hermes 1 SE.

7.2.3 Technical Evaluation

Hermes 2 PSAR, section 3.1, table 3.1-3, “Principal Design Criteria” identifies PDC 13 as applicable to I&C systems.

7.2.3.1 Architecture

The PCS is made up of the following subsystems: RCS, RCACS, PHTCS, IHTCS, power generation control system, and auxiliary monitored systems. As shown in Hermes 2 PSAR figure 7.1-1, each of the subsystems are independent from one another. Subsystems RCS, RCACS, PHTCS, and IHTCS are independent from the MCR, isolated via a network switch, supervisory controller, and redundant switches. The auxiliary monitored systems and power generation control system are separate from the other subsystems and are also isolated using similar pathways. The PCS is independent and isolated from the RPS sensor inputs via a one-way data diode. The non-safety sensors provide input signals using non-safety related signal wireways that are terminated at local cabinets using redundant, non-safety, real-time data highways.

The staff reviewed PSAR section 7.2.1.1, “Reactor Control System,” which states that the RCS controls and monitors systems and components that support normal operation, planned transients, and normal shutdown of the reactor. The RCS controls the subsystems identified in figure 7.1-1 and supports the following capabilities: reactivity control and planned changes in power level, monitoring of core neutronics, pebble handling and storage, and monitoring and control of temperature in the reactor.

The RCS controls reactivity for normal operations and normal shutdown using reactor control elements and reactor shutdown elements in the reactivity control and shutdown system (RCSS). The RCS is capable of incrementally changing the position of reactor control elements and of releasing the control and shutdown elements. The RCS inputs include reactor outlet and inlet temperature sensors and source and power range neutron ex-core detectors. The RCS provides a reactor monitoring function to monitor plant components that are associated with reactor functions. The RCS uses source and power range sensors that are located outside the reactor vessel for reactor control. The RCS controls pebble insertion and extraction, in-vessel pebble handling, and ex-vessel pebble handling in the pebble handling and storage system (PHSS) and is capable of counting linearized pebbles external to the vessel, controlling the rate of pebble insertion and removal from the vessel, and controlling pebble distribution within the PHSS. Additionally, the RCS controls the reactor thermal management system (RTMS), which monitors the temperature of the primary system to maintain it within the normal operating envelope and to implement planned transients (e.g., power changes). The RCS also controls external heating elements in the RTMS to prevent overcooling. The RCS provides the capability for event monitoring and active actuation of the decay heat removal system (DHRS). Further evaluation of these subsystems is provided in section 6 and section 9 of this SE.

The staff reviewed PSAR section 7.2.1.2, “Reactor Coolant Auxiliary Control System,” which states that the RCACS controls the chemistry control system that monitors reactor coolant chemistry. The RCACS also controls the coolant inventory management system. The monitoring systems provide information to facilitate maintaining coolant purity and circulating activity within specifications for the system. The RCACS also controls the primary coolant loop’s inert gas system, tritium management system, and remote maintenance and inspection system monitoring and control. Further evaluation of these subsystems is in section 9 and section 11 of this SE.

The staff reviewed PSAR section 7.2.1.3, “Primary Heat Transport Control System,” which states that the PHTCS controls and monitors systems and components that support normal operation of the primary heat transport system (PHTS). The PHTCS supports the following capabilities: control of flow rate through the PHTS, PHTS thermal management, control of the heat rejection subsystem, and primary loop draining, filling, and piping monitoring, including PTS external piping. The purpose of the PHTCS is to control the transport of primary coolant through the PHTS, maintain the primary coolant in a liquid state, control the rejection of heat from the PHTS, and monitor the inventory of primary coolant in the PHTS. The PHTCS maintains the parameters in the PHTS within the normal operating envelope. The PHTCS controls the primary salt pump (PSP), primary loop thermal management subsystems, and heat rejection subsystem. The PHTCS does not provide a safety function; however, as discussed in section 7.3 of this SE, the RPS trips the PSP on a reactor trip as a protective feature for the reactor system related to the pump. Further discussion and evaluation for the PSP is in chapter 5 of this SE.

The staff reviewed PSAR section 7.2.1.4, “Intermediate Heat Transfer Control System,” which states that the IHTCS supports the following capabilities: control of the flow rate through the intermediate loop, intermediate loop heating, intermediate loop draining, filling, and piping monitoring, chemistry control in the intermediate loop, and maintaining a positive pressure differential between the PHTS and IHTS during normal operations.

The staff reviewed PSAR section 7.2.1.5, “Power Generation Control System,” which states that the power generation control system controls and monitors systems and components that support normal operation of the turbine generator. The power generation control system does not perform a safety-related function. The power generation control system maintains the parameters within the turbine generator, main steam, condensate, and feedwater systems within the normal operating envelope.

The PCS initiates automatic turbine generator trip signals if certain conditions are detected. In the event of a turbine generator trip, the PCS initiates runbacks of the RCSS, PSP, intermediate salt pump (ISP), and feedwater pumps on both units to decrease reactor thermal power and heat transport to a level that can be safely rejected using normal shutdown cooling if the condenser is available or using main steam power relief valves and/or main steam safety valves if the condenser is not available. In the event of a single unit reactor trip, the PCS will initiate signals to close the main steam isolation valve, open turbine bypass valves, regulate flow control valves through the unit-specific superheater and runback feedwater flow to the affected unit to maintain a minimum flow to the steam generator, ensure balanced steam supply to the turbine, and prevent overcooling of the intermediate loop, as discussed in PSAR section 9.9.

A turbine generator runback will also be initiated to establish turbine generator output within the capacity of a single unit’s superheater to allow the unaffected unit to remain online. Should the grid be unable to absorb the communicated power loss of a single unit trip, the turbine generator will lose grid synchronization and trip, in which case steam from the remaining unit will bypass the turbine while the reactor ramps down in power or grid connection is re-established. Further evaluation of these subsystems is in chapter 9 of this SE.

The staff reviewed PSAR section 7.2.1.6, “Auxiliary Monitored Systems,” which states that the auxiliary monitored systems control and monitor auxiliary systems to support normal operations. The auxiliary monitored systems supports the following capabilities: compressed air system, chilled water system, electric supply/loads, reactor building heating, ventilation, air conditioning (RBHVAC), and environmental monitoring. Further evaluation of these subsystems is in chapters 8, 9, and 11 of this SE.

NuScale Small Modular Reactor (SMR) design-specific review standard (DSRS) sections 7.1.2, 7.1.3, and 7.1.5 were used to evaluate I&C design principles of independence, redundancy, and diversity. Appendix B to the DSRS provides guidance for reviewing I&C architectures. While the DSRS was developed for the NuScale design, it contains updated guidance applicable to both Hermes 1 and Hermes 2. The architecture shown in figure 7.1-1 of the Hermes 2 PSAR, and the descriptions provided in section 7.2, “Plant Control System,” of the Hermes 2 PSAR shows appropriate electrical isolation and communication independence for demonstrating independence of systems shown in the architecture figure. The preliminary design contains multiple channels for safety related functions, providing appropriate redundancy. The preliminary design includes both functional and component diversity. Because of these preliminary design features, the staff finds that the information provided by Kairos demonstrates an adequate design basis for the preliminary design of the PCS to meet the I&C design principles of independence, redundancy, and diversity such that the design would adequately support normal operations, including planned transients. The staff also finds that the design of the PCS is consistent with the guidance found in the DSRS and appendix B to the DSRS. Further information on the Hermes 2 I&C architecture can reasonably be left for later consideration at the operating license (OL) stage.

7.2.3.2 Communications

As shown on PSAR figure 7.1-1 and described in PSAR section 7.2.1, the staff finds that there is no communication from the PCS to the RPS; communication is from the RPS to the PCS through safety related isolation and a data diode. The description of communication paths between the PCS and RPS provided by Kairos is consistent with the guidance in DSRS section 7.1.2 on independence because the proposed design exhibits communication independence between safety and non-safety systems. The staff finds the information to be adequate at this stage of the licensing process and that further information can reasonably be left for later consideration at the OL stage.

7.2.3.3 Codes and Standards

Hermes 2 PSAR table 7.2-2, “Standards Applicable to the Plant Control System,” states that the Hermes 2 software development process will follow annex C, “Dedication of Existing Commercial Computers,” sections C.2.2.2, “Software,” C.2.2.3, “Development Process Steps,” and C.2.3, “Demonstrating that the Characteristics are Acceptably Implemented,” of IEEE 7-4.3.2-2003, “IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations,” International Electrotechnical Commission (IEC) 61131, “Programmable controllers,” for the programable controllers, and IEC 62443, “Industrial communication networks - Network and system security,” for cybersecurity. The staff reviewed PSAR table 7.2-2, which lists the standards for the digital platform. The staff finds that the standards provided by Kairos are adequate for the design of the PCS because the standards listed provide sufficient guidance for software development, hardware/software for controllers, and cybersecurity and are consistent with the applicable acceptance criteria in NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” section 7.3, “Reactor Control System.” The staff finds the information to be adequate at this stage of the licensing process and that further information can reasonably be left for later consideration at the OL stage.

7.2.3.4 Technical Specifications

PSAR table 14.1-1, “Proposed Variables and Conditions for Technical Specifications,” states that the RCS “objective is to infer or calculate reactivity coefficients during normal plant operation to limit the severity of a reactivity transient.” The staff reviewed the information provided in PSAR section 7.2.1.1 that describes how the RCS controls reactivity for normal operations and limits rapid reactivity insertion via the reactor control elements. Additionally, PSAR section 7.2.3, “System Evaluation,” describes the PCS, which is designed to monitor plant parameters and maintain systems with normal operation and to control planned transients associated with anticipated operational occurrences. The staff finds that the information provided is adequate to support the preliminary development of the technical specifications and is consistent with the applicable acceptance criteria in NUREG-1537, Part 2, section 7.3, because setpoints are adjusted automatically based on plant modes or adjusted by operators to limit the severity of reactivity transients, thus maintaining reactivity coefficients within limits over the allowable range of operation. The staff finds the information to be adequate at this stage of the licensing process and that further information can reasonably be left for later consideration at the OL stage.

7.2.3.5 Logic, Displays, and Alarms

As stated in Hermes 2 PSAR section 7.2.1, the PCS includes trips, interlocks, and annunciations to monitor the operation of the PCS. The staff reviewed PSAR sections 7.2.1.1, 7.2.1.2, 7.2.1.3, 7.2.1.4, 7.2.1.5, 7.2.1.6, and tables 7.2-1 and 7.2-3. Because the trips, interlocks, and annunciations, as described in the PSAR, are able to monitor and maintain variables and systems over their anticipated ranges for normal operation and over the range defined in postulated events, the staff finds that the preliminary design is consistent with the applicable acceptance criteria in NUREG-1537, Part 2, section 7.3. The staff finds the information to be adequate at this stage of the licensing process and that further information can reasonably be left for later consideration at the OL stage.

7.2.3.6 Failure Modes

Hermes 2 PSAR section 7.2.3 states that the PCS is designed so that it cannot interfere with the RPS's ability to perform its safety functions. This is accomplished by isolating the RPS from the PCS and other non-safety SSCs through safety-related isolation and a data diode. Additionally, the PSAR states that, upon receipt of a reactor trip signal, the RPS deactivates non-safety related SSCs controlled by the PCS that would affect the RPS from performing its safety functions. The isolation and deactivation of non-safety SSCs are described and evaluated in section 7.3 of this SE. Because of these isolation and deactivation features, the failure modes of the PCS do not interfere with the RPS performance of its safety functions, and the staff finds that the preliminary design is consistent with the applicable acceptance criteria in NUREG-1537, Part 2, section 7.3. The staff finds the information to be adequate at this stage of the licensing process and that further information can reasonably be left for later consideration at the OL stage.

7.2.4 Conclusion

The staff finds that the level of detail provided on the PCS, including its RCS, is consistent with the applicable acceptance criteria in NUREG-1537, Part 2, section 7.3, "Reactor Control System," and demonstrates an adequate design basis for a preliminary design.

A more detailed evaluation of information (e.g., ranges of transient and steady-state conditions, requirements for multiple setpoints and trip criteria, PCS platform) will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to PDC 13 for the facility SSCs, based on topical report KP-TR-003-NP-A and applicable regulations.

Based on its review, the staff finds that the preliminary design of the Hermes 2 PCS, as described in Hermes 2 PSAR section 7.2, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.35, "Issuance of construction permits," and 10 CFR 50.40, "Common standards."

7.3 <u>Reactor Protection System</u>

7.3.1 Introduction

Section 7.3, "Reactor Protection System," of the Hermes 2 PSAR states that the RPS provides protection for reactor operations by initiating signals to mitigate the consequences of postulated events and to ensure safe shutdown. The RPS is the only portion of the I&C system that is safety related and that is credited for tripping the reactor and actuating engineered safety features. The purpose of the RPS is to actuate upon receipt of a trip signal in response to out-of-normal conditions and provide automatic initiating signals to protection functions. The RPS SSCs are unit-specific and not shared between Units 1 and 2.

7.3.2 Regulatory Evaluation

The staff reviewed section 7.3.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the RPS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 7.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 7.3.2 of the Hermes 1 SE.

7.3.3 Technical Evaluation

The staff reviewed section 7.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 7.3, "Reactor Protection System"). The staff found that section 7.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for one minor change and one significant change, which are evaluated below in SE sections 7.3.3.1 and 7.3.3.2, respectively. The staff found that the following portions of section 7.3 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 7.3.1.2, "Decay Heat Removal System," through 7.3.5, "References," and table 7.3-1, "Codes and Standards Applied to the Reactor Protection System"

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, section 7.3 of the Hermes 2 PSAR contains information consistent with section 7.3 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 7.3 of the Hermes 1 SE.

7.3.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 7.3, as compared to the information in Hermes 1 PSAR section 7.3, include the following:

- The RPS is described as being unit-specific and SSCs making up the RPS are not shared between units
- Addition of the heat rejection control system (HRCS) figure 7.3-1, "Reactor Protection System Trip Logic Schematic"

In Hermes 2 PSAR section 7.3.1, “Description,” Kairos states that the RPS is unit-specific and not shared between the units. Having an independent RPS for each unit is consistent with the dual unit design of Hermes 2. Safety-related systems should not be shared to avoid common cause failure. Additionally, Kairos updated figure 7.3-1 by adding the HRCS. The addition of this HRCS to figure 7.3-1 is consistent with the Hermes 2 design. Based on the above, the staff finds the inclusion of a separate RPS for each unit and the revised figure 7.3-1 is acceptable.

7.3.3.2 Significant Change Compared to the Hermes 1 PSAR

A significant change contained in section 7.3 of the Hermes 2 PSAR, as compared to section 7.3 of the Hermes 1 PSAR, includes information regarding the following:

- Reactor trip system (RTS) trip function for the ISP. The discussion of this trip displaces the discussion of the RPS trip of the heat rejection subsystem blower, which was originally described in the Hermes 1 PSAR.

This change is identified in:

- PSAR section 7.3.1
- Table 7.3-2, “Reactor Protection System Interlocks and Inhibits”

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 RTS trip of the ISP using the guidance and acceptance criteria in NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” section 7.4, “Reactor Protection System.” The ISP in the Hermes 2 design replaces the heat rejection subsystem blower that is incorporated in the Hermes 1 design as the SSC with an active function for normal heat removal from the PHTS. In Hermes 2, the ISP is secured to limit inadvertent overcooling of the PHTS. The trip removes power from the ISP, similar to the trip of other non-safety related subsystems and their components (i.e., the RCSS, PHSS, RTMS, PSP, PLTMS, and HRCS) as shown on figure 7.1-1 and figure 7.3-1. To limit overcooling, the ISP trips concurrently with the PSP and an interlock prevents starting the ISP if the PSP is not running, as described in section 7.3.1.1, “Reactor Trip System,” and table 7.3-2. The staff review of PSAR section 7.3.1, figure 7.1-1, figure 7.3-1 and table 7.3-2, finds that Kairos provided the necessary design basis information for the RPS trip of the ISP and meets the guidance of NUREG-1537, Part 2, section 7.4, and, therefore, is acceptable.

7.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the design of the Hermes 2 RPS, as described in Hermes 2 PSAR section 7.3, is sufficient to meet the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40.

A more detailed evaluation of information (e.g., ranges of transient and steady-state conditions, requirements for multiple setpoints and trip criteria, RPS platform) will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to the PDC 1, 2, 3, 4, 10, 13, 15, 20, 21, 22, 23, 24, 25, 28, and 29 for the facility SSCs, based on the topical report KP-TR-003-NP-A and applicable regulations.

7.4 Main Control Room and Remote Onsite Shutdown Panel

7.4.1 Introduction

Section 7.4.1, “Description,” of the Hermes 2 PSAR states that the MCR provides means for operators to monitor the behavior of each unit and the shared systems, control performance of each unit and the shared systems, and manage the response to postulated event conditions in each unit. The unit-specific ROSPs provides separate means to shut down each unit and monitor plant parameters in response to postulated event conditions.

Section 7.4.1.1, “Main Control Room,” of the Hermes 2 PSAR states that the MCR contains equipment related to normal operation of the plant. This equipment includes operator and supervisor workstation terminals, which provide alarms, annunciations, personnel and equipment interlocks, and process information. The MCR console displays plant parameters that allow operators to monitor conditions during and following postulated events. Dedicated consoles are provided to control and monitor each unit individually and to control and monitor shared systems.

Section 7.4.1.2, “Remote Onside Shutdown Panel,” of the Hermes 2 PSAR states that the ROSPs provide a human/system interface for plant staff to monitor unit-specific indications from the RPS including operating status of the RTS and the DHRS in the event that the MCR becomes inaccessible or uninhabitable. The ROSPs communicate (one-way, read-only) with the RPS instrumentation using a safety related isolation device, with the ability to initiate a trip signal from a manual trip button that actuates RTS. The ROSPs are not safety-related and are located in the safety-related portion of their respective reactor buildings.

7.4.2 Regulatory Evaluation

The staff reviewed section 7.4.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the MCR and ROSP designs between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 7.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 7.4.2 of the Hermes 1 SE.

7.4.3 Technical Evaluation

The staff reviewed section 7.4, “Main Control Room and Remote Onsite Shutdown Panel,” of the Hermes 2 PSAR and compared it to the equivalent material in the Hermes 1 PSAR (section 7.4, “Main Control Room and Remote Onsite Shutdown Panel”). The staff found that Hermes 2 PSAR section 7.4 contains information consistent with that in the Hermes 1 PSAR, except for three minor changes and two significant changes, which are evaluated below in SE sections 7.4.3.1 and 7.4.3.2, respectively. The staff found that the following portions of section 7.4 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 7.4.1, “Description” and 7.4.2, “Design Bases”

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, section 7.4 of the Hermes 2 PSAR contains information consistent with section 7.4 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 7.4 of the Hermes 1 SE.

7.4.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 7.4, as compared to the information in Hermes 1 PSAR section 7.4, include the following:

- Separate ROSPs for each unit
- Dedicated consoles provided to control and monitor each unit individually
- Removal of the “gateway” component discussed as part of the reactor trip path via manual trip switch

No changes to the individual Hermes 2 ROSPs’ designs are identified compared to the previously described Hermes 1 ROSP. Incorporation of an ROSP into the design of each unit is consistent with the dual unit design of Hermes 2. Based on the above, the staff finds that having individual ROSP for each unit to be acceptable.

No changes to the individual Hermes 2 control and display MCR console(s) design are identified compared to the Hermes 1 MCR. Incorporation of a MCR console into the design of each unit is consistent with the dual unit design of Hermes 2. Based on the above, the staff finds that each unit having dedicated consoles to be acceptable.

Section 7.4.1.1 of the Hermes 1 PSAR stated that a “gateway” lies in the reactor trip path between the trip switch and a safety-related isolation, but one was not present on Hermes 1 PSAR figures 7.1-1, “Instrumentation and Controls System Architecture,” and 7.4-1, “Architecture of the Main Control Room and the Remote Shutdown Onsite Panel.” Kairos did not identify a gateway on Hermes 2 PSAR figures 7.1-1 and 7.4-1 between the trip switch and the safety-related isolation in the reactor trip path, and a description of the gateway was not provided in the Hermes 2 PSAR. Removing discussion of the gateway in section 7.4.1.1 aligns the Hermes 2 PSAR text with figures 7.1-1 and 7.4-1. This gateway is not safety related for either Hermes 1 or Hermes 2; therefore, the staff finds that removal of the discussion of the gateway in section 7.4.1.1 of the Hermes 2 PSAR is acceptable.

7.4.3.2 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in section 7.4 of the Hermes 2 PSAR, as compared to section 7.4 of the Hermes 1 PSAR, include information regarding the following:

- Human factors engineering (HFE) consideration for the common MCR that is shared between Unit 1 and Unit 2
- Controls and monitoring are added to the dedicated consoles for each unit in the MCR for the two new shared PCS subsystems, “Power Generation Control System” and “Auxiliary Monitored Systems”

These changes are identified in:

- Section 7.4.1.1
- Figures 7.1-1 and 7.4-1

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 MCR using the guidance and acceptance criteria from NUREG-1537, Part 2, section 7.6, “Control Console and Display Instruments.” Specifically, it is stated in Hermes 2 PSAR section 7.4.1.1 that “[d]edicated consoles are provided to control and monitor each unit individually and to control and monitor shared systems.” This aspect of the Hermes 2 design warranted review to confirm that the detailed design of the MCR will incorporate the appropriate HFE-related considerations necessary to support human performance during dual unit operations.

NUREG-1537 Part 2, section 7.6, states that control room control console and display instruments should be based on good engineering practice and includes criteria that address, in part, (1) the observability and understandability of displays that show reactor status, rod position indication, and important parameters; (2) the accessibility of controls associated with important parameters and reactivity; and (3) providing clear alarms and annunciators to the operator. While not explicitly discussed under NUREG-1537, Part 2, section 7.6, good engineering practice within the context of operator observability, accessibility, and understandability entails the application of HFE. PSAR section 7.4.3.1, “Main Control Room,” includes the statement that “Human factor [sic] engineering principles will be considered in the MCR design,” and the staff evaluated this additional statement. The staff expects that application of HFE principles within the design of the MCR would lead to the HFE-related criteria of NUREG-1537, Part 2, section 7.6, being met in the finalized Hermes 2 design as submitted with the OL in a manner that supports human performance during dual unit operations. Therefore, the staff find that the consideration of HFE within the MCR design is appropriate for a test reactor CP application. Based on the above, the staff finds that the consideration of HFE to be acceptable.

Section 7.4.1.1 of the Hermes 2 PSAR also states that dedicated consoles are provided to control and monitor each unit individually and to control and monitor shared systems. These shared systems are the power generation control system and the auxiliary monitored systems, which are discussed in section 7.2 of this SE. Both systems are classified as non-safety. The control and monitoring for the power generation control system will allow the operators to regulate the steam supply from both reactors through common flow control valves to ensure balanced steam supply to the turbine as well as prevent coolant feedback from one system to the other. The control and monitoring for the auxiliary monitored systems will allow operators to control the balance of plant SSCs. Both systems were added to Hermes 2 PSAR figures 7.1-1 and 7.4-1. The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 consoles for controlling and monitoring these shared systems using the guidance and acceptance criteria of NUREG-1537, Part 2, section 7.6. The communication path for both subsystems shown in figure 7.1-1 and figure 7.4-1 is from unit console(s) in the MCR through network switches, plant-specific redundant real time data highways, redundant switches, system-specific switches, and then to the individual systems. This communication path provides sufficient preliminary information on the adequacy of the console design to allow the operators to perform the necessary control and monitoring of these systems. Based on the above, the staff finds that the addition of these systems on the MCR control boards and to figures 7.1-1 and 7.4-1 is acceptable.

7.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference form the Hermes 1 SE, the staff concludes that the preliminary design of the Hermes 2 MCR and ROSPs, as described in Hermes 2 PSAR section 7.4, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40.

A more detailed evaluation of information (e.g., ranges of transient and steady-state conditions, requirements for multiple setpoints and trip criteria, MCR and ROSP consoles) will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to PDC 19 for the facility SSCs based on the topical report KP-TR-003-NP-A and applicable regulations.

7.5 Sensors

7.5.1 Introduction

Section 7.5, “Sensors,” of the Hermes 2 PSAR describes the sensors used to provide information about temperature, pressure, neutron count rates, level, flow of the primary coolant and area radiation levels as input to multiple control and protection subsystems. Independent sensors are provided to the RPS and the PCS. sections in PSAR chapter 7 provide information on specific I&C subsystems, including a discussion of the sensors that support that subsystem and the type of sensor used (i.e., analog or digital).

Temperature, pressure, level, and flow sensors measure and monitor plant operating process parameters and are used to control operations and to initiate reactor protective actions. Neutron source range sensors provide indication of power level during the initial stages of startup. Gamma radiation monitors provide information about area radiation levels during all plant modes of operation.

7.5.2 Regulatory Evaluation

The staff reviewed section 7.5.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the proposed sensors between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 7.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 7.5.2 of the Hermes 1 SE.

7.5.3 Technical Evaluation

The staff reviewed section 7.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 7.5, “Sensors”). The staff found that section 7.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 sensor design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 7.5.3, “Technical Evaluation,” of the Hermes 1 SE.

7.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary design of the safety-related and non-safety related sensors, as described in Hermes 2 PSAR section 7.5, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40.

A more detailed evaluation of information (e.g., ranges of transient and steady-state conditions, requirements for non-safety and safety-related sensors) will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to PDC 1, 2, 3, 13, 21, 22, 24, and 29 for the facility SSCs based on the NRC-approved topical report KP-TR-003-NP-A and applicable regulations.

7.6 Summary and Conclusions on Instrumentation and Control Systems

The staff evaluated the information on the Hermes 2 I&C systems as described in PSAR chapter 7 and finds that the preliminary information on, and design criteria of, the I&C systems, including the PDC, design bases, and information relating to materials of construction, general arrangement, and approximate dimensions: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the I&C systems, including, but not limited to, the principal engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis of the I&C systems, and which can reasonably be left for later consideration, will be provided in the final safety analysis report as part of the OL application.

- Safety features or components which require research and development have been described by Kairos and a research and development program (see SE section 1.1.5) will be conducted that is reasonably designed to resolve any safety questions associated with such features or components.

- There is reasonable assurance that safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility.

- There is reasonable assurance: (i) that the construction of the facility will not endanger the health and safety of the public, and (ii) that construction activities will be conducted in compliance with the Commission’s regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

7.7 References

Institute of Electrical and Electronics Engineers (IEEE). Standard 7-4.3.2, “IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations,” New York, 2003.

-----. Standard 379, “IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems,” New York, 2014.

-----. Standard 1012-2017, “System, Software, and Hardware Verification and Validation,” New York, 2017.

-----. Standard 603, “Standard Criteria for Safety Systems for Nuclear Power Generating Stations,” New York, 2018.

American National Standards Institute, Instrument Society of America, ANSI/ISA-67.04.01, “Setpoints for Nuclear Safety-Related Instrumentation,” New York, 2018.

International Electrotechnical Commission (IEC). IEC 62443, “Cybersecurity,” Geneva, 2015.

-----. IEC 61131, "Programmable Controllers,” Geneva, 2020.

Kairos Power LLC. KP-TR-003-NP-A, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor,” Revision 1, dated June 2020, ML20167A174.

-----. “Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1]), Revision 3,” dated May 31, 2023, ML23151A743.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC), NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430048.

-----. Regulatory Issue Summary 2006-17, “The Staff Position on The Requirements of 10 CFR 50.36, ‘Technical Specifications,’ Regarding Limiting Safety System Settings During Periodic Testing and Calibration of Instrument Channels,” NRC: Washington, D.C., dated August 2006, ML051810077.

-----. “Design-Specific Review Standard for NuScale SMR Design,” NRC: Washington, D.C., dated June 2016, ML15355A295.

-----. “Design Review Guide (DRG): Instrumentation and Controls for Non-Light-Water Reactor (non-LWR) Reviews,” NRC: Washington, D.C., dated February 2021, ML21011A140.

-----. “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

8 ELECTRICAL POWER SYSTEMS

This chapter of the Hermes 2 construction permit (CP) safety evaluation (SE) describes the technical review and evaluation by the U.S. Nuclear Regulatory Commission (NRC) staff (the staff) of the preliminary design of the Kairos Power LLC (Kairos) Hermes 2 Test Reactor facility as presented in chapter 8, “Electric Power Systems,” of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed Hermes 2 PSAR chapter 8 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary design of the Hermes 2 facility. The following sections of the SE describe the areas reviewed as specified in NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 2, “Standard Review Plan and Acceptance Criteria.”

8.1 Electrical Systems

Hermes 2 PSAR section 8.1, “Summary Description,” states that the purpose of the electrical system is to provide power to plant equipment for operation and that the electrical system consists of the non-Class 1E normal power system and the backup power system (BPS). Further, Kairos states that, due to the passive design of Hermes 2, safety related structures, systems, and components (SSCs) do not require electric power to perform safety related functions following a design basis event. The design has no emergency electrical power systems, as described in NUREG-1537, Part 2, section 8.2, “Emergency Electrical Power Systems.” In addition, Kairos states that alternating current (AC) and direct current (DC) power from offsite or backup power sources is not required to mitigate a design basis event.

8.2 Normal Power System

8.2.1 Introduction

Hermes 2 PSAR section 8.2, “Normal Power System,” states that the normal power system is supplied by an offsite power source from the local utility, which provides a medium voltage feeder, or by the onsite turbine generator system via a 13.8 kilovolt (kV) feeder and associated 13.8 kV / 4.16 kV step down transformer. Voltage is stepped down further with 4.16 kV / 480 volt (V) transformers to support power distribution to plant loads at both units with 480 V and 120 V buses. A loss of voltage or a degraded voltage condition on the normal power system does not adversely affect the performance of safety related functions.

8.2.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of Hermes 2 normal power systems are as follows:

- Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.34, “Contents of applications; technical information,” including:
    - 10 CFR 50.34(a)(3)(ii) which requires “The design bases and the relation of the design bases to the principal design criteria.”
    - 10 CFR 50.34(a)(3)(iii) which requires “Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety.”

    - 10 CFR 50.34(a)(4), which requires “[a] preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…”; and
- 10 CFR 50.35, “Issuance of construction permits.”
- 10 CFR 50.40, “Common standards.”

The applicable guidance for the evaluation of the Hermes 2 normal power systems is as follows:

- NUREG-1537, Part 1, “Format and Content,” and Part 2, section 8.1, “Normal Electrical Power Systems.”

8.2.3 Technical Evaluation

The Principal Design Criteria (PDC) for the facility SSCs are described in Hermes 2 PSAR section 3.1 and are based on those specified in the NRC-approved Kairos Power Topical Report, KP-TR-003-NP-A, “Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor.” Hermes 2 PSAR, section 3.1, table 3.1-3, “Principal Design Criteria,” identifies PDC 2, 17, and 18 as applicable to chapter 8.

The normal power system is designed in accordance with National Fire Protection Association (NFPA) 70, “National Electrical Code 2020,” and Institute of Electrical and Electronics Engineers (IEEE), IEEE-C2, “National Electrical Safety Code (NESC) 2023,” as stated in PSAR section 8.2.3, “System Evaluation.”

In Hermes 2 PSAR section 8.2.1.1, “AC [Alternating Current] Electrical Power,” Kairos states that AC electrical power components include the following:

- A 4.16 kV / 480 V step down transformer connected to a single 4.16 kV offsite electrical power supply from the local utility,
- Incoming 13.8 kV feeder from the turbine generator system and associated 13.8 kV / 4.16 kV step down transformer,
- The low voltage AC electrical power distribution with nominal bus voltages of 480 V and 120 V, and
- A 13.8 kV / 161kV transformer from the turbine generator system to the onsite electrical switchyard.

Further, Kairos stated that selected loads are supplied with continual AC power via uninterruptible power supplies (UPS), which provide power during normal operations and backup power during a loss of normal electrical power.

In PSAR section 8.2.1.2, “DC Electrical Power,” Kairos states that 125 volts direct current (VDC) is provided to switchgear control power and 24 VDC is provided to instrumentation and control (I&C) functions during normal operations and for a specified maximum duty cycle following a loss of AC power. Kairos further states that DC electrical power is not shared between Unit 1 and Unit 2.

In PSAR section 8.2.2, “Design Bases,” Kairos states that the normal power system does not perform any safety related functions, is not credited for the mitigation of postulated events, and is not credited with performing safe shutdown functions. Further, Kairos states in PSAR section 8.2.3, “System Evaluation,” states that malfunction of the normal power system will not cause reactor damage or prevent safe reactor shutdown. section 8.2.3 also states that adequate independence is maintained between the non-safety normal power system and Class 1E I&C system. Therefore, section 8.2 discusses the design bases and provides a function description of the normal power systems consistent with the guidance in NUREG-1537, Part 2, section 8.1. The Hermes 2 I&C systems are evaluated in chapter 7 of this SE. In the staff's review of PSAR chapter 8 and, particularly, figure 8.1-1, "Electrical Configuration Diagram," the staff identified a dedicated connection from the local utility to the normal power system.

The staff reviewed the PDC listed in PSAR Chapter 8 against the Hermes 2 design. PDC 17, "Electric power systems," states that "electric power systems shall be provided when required to permit functioning of SSCs." PDC 18, "Inspection and testing of electric power systems," states that "electric power systems which are safety related shall be designed to permit appropriate inspection and testing." The staff's review found that there are no Class 1E electric power systems based on the PSAR statements that the normal power system is not credited for accident mitigation or safe shutdown; that the normal power system is classified as non-Class 1E or non-safety; and that no technical specifications for the normal power system are required. Based on these aspects of the design, the staff finds that PDC 17 and 18 are not applicable to the Hermes 2 facility.

Additionally, PSAR section 8.2.3, "System Evaluation" states that grounding and lightning protection will be implemented, and the switchyard protection scheme follows the design approach for protective devices, feeders, branch circuits, and transformers in accordance with IEEE Standard 242-2001, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)." Kairos further states that these features demonstrate conformance with PDC 2, "Design bases for protection against natural phenomena." The staff views grounding and lightning protection and switchyard protection to be a good engineering practice; however, PDC 2, as discussed in the TR KP-TR-003-NP-A, "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor," applies to SSCs which are safety significant. Hermes 2 PSAR section 3.1.1, "Design Criteria," clarifies that the term "safety significant" is replaced with "safety-related" for PDC 2 and other PDC. For the Hermes 2 design, the normal power system is not safety-related; therefore, the staff finds that PDC 2 is not applicable to the Hermes 2 normal power systems design.

The staff finds that the level of detail provided in the PSAR for the normal power system meets the applicable criteria of NUREG-1537, Part 2, section 8.1, and demonstrates an adequate design basis for a preliminary design, irrespective of the applicability of PDC 2, 17, and 18 to the normal power systems. Because AC power from offsite sources will not be required to perform safe shutdown functions, the reactor can be safely shut down in the event of a loss or interruption of the normal electrical power system.

8.2.4 Conclusion

Based on its review, the staff finds that the design of the Hermes 2 normal power system, as described in Hermes 2 PSAR section 8.2, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of construction permits in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff also finds that PDC 2, 17, and 18 are not applicable since there are no safety-related electrical power systems. A more detailed evaluation of the normal power system will occur during the review of the Hermes 2 operating license (OL) application, at which time the staff will confirm that the final design conforms to this design basis.

8.3 Backup Power System

8.3.1 Introduction

While there are no emergency electrical power systems in the Hermes 2 facility, Hermes 2 PSAR section 8.3, “Backup Power System,” states that the BPS’s design function is to provide AC electrical power to the essential facility loads when the normal AC power supply is not available. The BPS includes two backup generators, which are shared between the two units; three UPS per unit; two shared UPS; as well as electrical equipment and circuits used to interconnect the backup generators to the low voltage AC electrical power distribution systems. The PSAR further states that the facility is equipped with a plug-in connection for use with a portable 480 V generator to provide power to essential loads in the event the backup generators are unavailable.

8.3.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of Hermes 2 BPSs are as follows:

- 10 CFR 50.34, including:
    - 10 CFR 50.34(a)(3)(ii) which requires “The design bases and the relation of the design bases to the principal design criteria.”
    - 10 CFR 50.34(a)(3)(iii) which requires “Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety.”
    - 10 CFR 50.34(a)(4), which requires “[a] preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…”; and
- 10 CFR 50.35, “Issuance of construction permits.”
- 10 CFR 50.40, “Common standards.”

The applicable guidance for the evaluation of the Hermes 2 BPSs is as follows:

- NUREG1537, Parts 1 and 2, section 8.1, “Normal Electrical Power Systems.”

The staff notes that NUREG-1537 contains guidance for emergency electrical power systems in Parts 1 and 2, section 8.2, “Emergency Electrical Power Systems.” However, because Kairos’s BPSs are not emergency power systems and do not perform any safety related functions, but rather provides a backup to normal electric power for selected loads, as discussed below, the staff determined that NUREG-1537, Parts 1 and 2, section 8.1, “Normal Electrical Power Systems,” is the applicable guidance for the staff’s review of Hermes 2 BPSs.

8.3.3 Technical Evaluation

The PDC for the facility SSCs are described in PSAR section 3.1 and are based on those specified in the NRC-approved Kairos Power Topical Report, KP-TR-003-NP-A. Hermes 2 PSAR table 3.1-2, “Principal Design Criteria,” identifies the PDC 2, 17, and 18 as applicable to electrical power systems.

PSAR section 8.3.1.1, “Backup generators,” states that the backup generators are shared between the two units and automatically start in the event of a loss of offsite power to provide power to essential facility loads. Further, Kairos states that the backup generators are sized to simultaneously supply essential loads on both units. In addition, PSAR section 8.3.1.2, “Uninterruptible Power Supplies,” states that selected unit-specific loads are supplied with AC power via UPS and the UPS provides backup power during a loss of normal electrical power. Kairos further stated that the UPS are generally not shared between Unit 1 and Unit 2 unless the essential load is common to both units. Figure 8.1-1 indicates there are three UPS per unit and two additional that are shared between the units for emergency lighting and communications and for main control room power supplies.

Kairos stated in PSAR section 8.3.2, “Design Bases,” that the BPS does not perform any safety related functions, is not credited for the mitigation of postulated events, and is not credited with performing safe shutdown functions. The BPS, as stated in PSAR section 8.3.3, “System Evaluation,” is designed according to NFPA 70, National Electric Code 2020, so that postulated failures of SSCs in the system do not preclude a safety related SSC from performing its safety function. In the PSAR, Kairos addressed the classification and design attributes of the BPS, and the staff finds that PDC 2, 17, and 18 are not applicable to the BPS since there are no safety-related electric power systems. Therefore, the PSAR discusses the design bases and provides a function description of the BPS consistent with the guidance in NUREG-1537, Part 2, section 8.1.

The staff finds that the level of detail provided in the PSAR for the BPS satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 8.1, and demonstrates an adequate design basis for a preliminary design.

8.3.4 Conclusion

Based on the staff findings above, the staff concludes that the description of the Hermes 2 BPS, as described in Hermes 2 PSAR section 8.3, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of construction permits in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff also finds that PDC 2, 17, and 18 are not applicable since there are no safety-related electrical power systems. A more detailed evaluation of the BPS will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

8.4 Summary and Conclusions on Electrical Power Systems

The staff evaluated the information on the Hermes 2 electrical power systems as described in PSAR chapter 8 and finds that the preliminary information on, and design criteria of, the electrical power systems, including the PDC, design bases, and other design information: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff concludes the following regarding issuance of construction permits in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design for the electrical power systems, including, but not limited to, the principal engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis of the electrical power systems, and which can reasonably be left for later consideration, will be provided in the OL application.

- There is reasonable assurance: (i) that the construction of the facility will not endanger the health and safety of the public, and (ii) that construction activities will be conducted in compliance with the Commission's regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

8.5 References

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

-----. "Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1," dated May 23, 2024, ML24144A090.

National Fire Protection Association (NFPA) 70, "National Electrical Code," 2020.

U.S. Nuclear Regulatory Commission (NRC), NUREG-1537, Part 2, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors Standard Review Plan and Acceptance Criteria," NRC: Washington, D.C., dated February 1996, ML042430048.

Institute of Electrical and Electronics Engineers, IEEE-C2, "National Electrical Safety Code (NESC)," 2023.

IEEE Standard 242-2001, "IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book)."

9 AUXILIARY SYSTEMS

The auxiliary systems of the Hermes 2 test reactor facility consist of the reactor coolant auxiliary systems (the chemistry control system (CCS), the inert gas system (IGS), the tritium management system (TMS), the inventory management system (IMS), and the reactor thermal management system (RTMS)); the reactor building heating, ventilation and air conditioning system (RBHVAC); the pebble handling and storage system (PHSS); the fire protection systems; the communication system; facilities for possession and use of byproduct, source, and special nuclear material (SNM); the plant water systems (service water system, treated water system, component cooling water system (CCWS), chilled water system); other auxiliary systems (remote maintenance and inspection system, spent fuel cooling system (SFCS), compressed air system, cranes and rigging, and auxiliary site services); and the power generation system (PGS).

This chapter of the Hermes 2 construction permit (CP) safety evaluation (SE) describes the technical review and evaluation by the U.S. Nuclear Regulatory Commission (NRC) staff (the staff) of the preliminary design of the Kairos Power LLC (Kairos) Hermes 2 test reactor facility as presented in chapter 9, "Auxiliary Systems," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed Hermes 2 PSAR chapter 9 against the applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information on the Hermes 2 auxiliary systems for the issuance of CPs in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." The following sections of the SE describe the areas reviewed as specified in NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 2, "Standard Review Plan and Acceptance Criteria," as appropriate.

The principal design criteria (PDC) for the facility structures, systems, and components (SSCs) are described in section 3.1 of the PSAR. The PDC are based on the NRC-approved Kairos Power Topical Report, KP-TR-003-NP-A, "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor," Revision 1, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20167A174). Each of the sections below identify the applicable PDC for the system being evaluated.

9.1 <u>Reactor Coolant Auxiliary Systems</u>

The reactor coolant auxiliary systems are made up of five systems that provide support for the functionality and performance of the Flibe coolant. Each of the five systems is evaluated in a separate section below.

9.1.1 Chemistry Control System

9.1.1.1 Introduction

Section 9.1.1, "Chemistry Control System," of the Hermes 2 PSAR describes the CCS as being used to monitor coolant chemistry in the reactor vessel system and primary heat transport system (PHTS) for compliance with Flibe specifications found in KP-TR-005-P-A, "Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor Topical Report," Revision 1 (ML20219A591). The CCS allows for offline analysis of Flibe chemistry and can remove and replace a sufficient amount of coolant to restore conformance with the Flibe specification via the IMS. The CCS does not perform any safety-related functions, nor is it credited to mitigate postulated events. Each Hermes 2 unit has its own CCS and there are no shared components between the units.

9.1.1.2 Regulatory Evaluation

The staff reviewed section 9.1.1.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the CCS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.1.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.1.1.2 of the Hermes 1 SE.

9.1.1.3 Technical Evaluation

The staff reviewed section 9.1.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.1.1, “Chemistry Control System”). The staff found that section 9.1.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 CCS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.1.1.3, “Technical Evaluation,” of the Hermes 1 SE.

9.1.1.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.1.1, as compared to the information in Hermes 1 PSAR section 9.1.1, is the following:

- Each unit has its own CCS and there are no components shared between the units.

The CCS does not perform safety-related functions. Additionally, each unit having its own CCS will prevent one CCS failure from affecting both units. Based on the above, the staff finds that having a CCS for each unit is acceptable.

On the basis of its review, the staff finds that the CCS design will conform with guidance in NUREG-1537, Part 2, section 5.4, “Primary Coolant Cleanup System,” to monitor and maintain coolant purity in order to limit degradation of essential components in the primary system.

9.1.1.4 Conclusion

Based on staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information in Hermes 2 PSAR section 9.1.1 is sufficient and meets applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35, “Issuance of construction permits,” and 10 CFR 50.40, “Common standards.” The information provided gives the staff reasonable assurance that the CCS will not lead to radiation exposure or releases that exceed limits in 10 CFR Part 20, “Standards for Protection Against Radiation,” and that the CCS can support proposed technical specifications related to coolant chemistry.

Further information will be required before approving operation of the Hermes 2 CCS (e.g., basis of sampling location to provide a well-mixed and representative chemistry sample, ability of CCS to correct coolant chemistry within specified timeframes) and this information will be reviewed at the operating license (OL) stage.

9.1.2 Inert Gas System

9.1.2.1 Introduction

Section 9.1.2, "Inert Gas System," of the Hermes 2 PSAR describes the IGS. The design functions of the IGS are to:

- Maintain an inert environment for components using argon
- Provide inert gas purge flow
- Remove impurities from cover gas
- Provide transport of tritium for treatment
- Provide reactor coolant motive force during filling and draining

The PSAR also states that the IGS does not perform any safety-related functions. Each Hermes 2 unit has its own IGS and there are no shared components between the units.

9.1.2.2 Regulatory Evaluation

The staff reviewed section 9.1.2.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the IGS between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.1.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.1.2.2 of the Hermes 1 SE.

9.1.2.3 Technical Evaluation

The staff reviewed section 9.1.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.1.2, "Inert Gas System"). The staff found that section 9.1.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 IGS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.1.2.3, "Technical Evaluation," of the Hermes 1 SE.

9.1.2.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.1.2, as compared to the information in Hermes 1 PSAR section 9.1.2, is the following:

- Each unit has its own IGS and there are no components shared between the units.

The system does not perform safety-related functions. Additionally, each unit having its own IGS will prevent one IGS failure from affecting both units. Based on the above, the staff finds that having an IGS for each unit is acceptable.

On the basis of its review, the staff finds that the IGS will be consistent with 10 CFR 20.1406, "Minimization of contamination," based on its preliminary design, as there are systems provided to remove radioactive material from the IGS if necessary, and because the IGS can be monitored for leaks which would allow for action to limit release of radioactivity. The staff will verify the capability to monitor activity and releases with the design details provided in the OL application. Additionally, the staff finds that the IGS will be designed consistent with the guidance in NUREG-1537, Part 2, section 9.6, “Cover Gas Control in Closed Primary Coolant Systems,” to assess and maintain cover gas purity and meet any technical specification applicable to the IGS.

9.1.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information in Hermes 2 PSAR section 9.1.2 is sufficient and meets applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The information provided gives the staff reasonable assurance that the IGS can meet its design functions and will not lead to radiation exposure or releases that exceed limits in 10 CFR Part 20. Further information as may be required to complete the review of the Hermes 2 IGS (e.g., limit on circulating activity in the cover gas, details for allowable impurities, leakage detection) and can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

9.1.3 Tritium Management System

9.1.3.1 Introduction

Section 9.1.3, “Tritium Management System,” of the Hermes 2 PSAR describes a preliminary design for the TMS, which monitors and removes tritium from the vapor spaces of the reactor coolant system, the intermediate heat transport system (IHTS), the heat rejection radiator (HRR) enclosure, and the reactor buildings during normal operation. PSAR section 9.1.3 states that the systems do not perform safety-related functions. Each Hermes 2 unit has its own TMS and there are no shared components between the units.

9.1.3.2 Regulatory Evaluation

The staff reviewed section 9.1.3.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the TMS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.1.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.1.3.2 of the Hermes 1 SE.

9.1.3.3 Technical Evaluation

The staff reviewed section 9.1.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.1.3, “Tritium Management System”). The staff found that section 9.1.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for one minor and one significant changes, which are evaluated below in sections 9.1.3.3.1 and 9.1.3.3.2, respectively. The staff found that the following portions of section 9.1.3 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 9.1.3.2, “Design Bases”

- Section 9.1.3.3, “System Evaluation”
- Section 9.1.3.4, “Testing and Inspection”
- Section 9.1.3.5, “References”

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, the TMS, as described in section 9.1.3 of the Hermes 2 PSAR, is consistent with the information in section 9.1.3 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 9.1.3.3, “Technical Evaluation,” of the Hermes 1 SE.

9.1.3.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.1.3, as compared to the information in Hermes 1 PSAR section 9.1.3 is the following:

- Each unit has its own TMS and there are no components shared between the units.

The TMS does not perform safety-related functions. Each unit having its own TMS without any shared components will prevent one TMS failure from affecting both units. Based on the above, the staff finds that having a TMS for each unit is acceptable.

9.1.3.3.2 Significant Change Compared to the Hermes 1 PSAR

The significant change contained in section 9.1.3 of the Hermes 2 PSAR, as compared to section 9.1.3 of the Hermes 1 PSAR, includes information regarding the following:

- The addition of two primary system functions to the TMS: tritium separation from argon in the IHTS cover gas and tritium separation from dry air in the HRR enclosure.

These changes are identified in PSAR section 9.1.3.1, “Description.”

The staff evaluated the sufficiency of this additional preliminary information on the Hermes 2 TMS using the guidance and acceptance criteria from NUREG-1537, Part 2, section 9.7, “Other Auxiliary Systems.” Because the TMS does not perform safety-related functions, adding two locations in the plant for monitoring and removing tritium does not affect reactor safety and is appropriate considering the addition of the IHTS and the HRR to the Hermes 2 facility design, as compared to the Hermes 1 facility design. Based on the above, the staff finds that the addition of the two additional TMS primary functions is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 TMS demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, to prevent uncontrolled release of radioactivity, to limit potential radiation exposures to within 10 CFR Part 20 requirements, and for no function or malfunction of the TMS to interfere with or prevent safe shutdown of the reactor.

9.1.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information on the TMS in Hermes 2 PSAR section 9.1.3 is sufficient and meets applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff concludes that the preliminary design features intended to minimize contamination, support eventual decommissioning, and control releases to the environment will help ensure compliance with 10 CFR Part 20.

9.1.4 Inventory Management System

9.1.4.1 Introduction

Section 9.1.4, "Inventory Management System," of the Hermes 2 PSAR describes a preliminary design for the IMS, which adds and removes reactor coolant to maintain the desired level and volume within reactor-coolant-containing systems and components (e.g., reactor vessel, CCS). Each Hermes 2 unit has its own IMS and there are no shared components between the units. Hermes 2 PSAR section 9.1.4 states that the system does not perform safety-related functions.

9.1.4.2 Regulatory Evaluation

The staff reviewed section 9.1.4.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the IMS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.1.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.1.4.2 of the Hermes 1 SE.

9.1.4.3 Technical Evaluation

The staff reviewed section 9.1.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.1.4, "Inventory Management System"). The staff found that section 9.1.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes evaluated below. The staff also verified that the Hermes 2 IMS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.1.4.3, "Technical Evaluation," of the Hermes 1 SE.

9.1.4.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 9.1.4, as compared to the information in Hermes 1 PSAR section 9.1.4, include the following:

- Each unit has its own IMS and there are no components shared between the units.
- A change in the system description to reflect that the Hermes 2 design includes an intermediate heat exchanger (IHX).

The IMS does not perform safety-related functions. Each unit having its own IMS will prevent one IMS failure from affecting both units. The addition of the IHX to the system description is appropriate due to the IHX being a new SSC in the Hermes 2 design that is filled with reactor coolant on the shell side by the IMS. Based on the above, the staff finds that each unit having its own IMS and that the identification the IHX as being filled by the IMS are acceptable.

On the basis of its review, the staff finds that the preliminary design of the IMS satisfies the applicable acceptance criteria in NUREG-1537, Part 2, section 9.7, to prevent uncontrolled release of radioactivity and for no function or malfunction of the IMS to interfere with or prevent safe shutdown of the reactor.

9.1.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information on the IMS in PSAR section 9.1.4 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff concludes that the preliminary design features intended to minimize contamination and support eventual decommissioning will comply with the requirements of 10 CFR 20.1406.

9.1.5 Reactor Thermal Management System

9.1.5.1 Introduction

Section 9.1.5, "Reactor Thermal Management System," of the Hermes 2 PSAR describes a preliminary design for the RTMS which consists of two subsystems: the equipment and structural cooling subsystem (ESCS) and the reactor auxiliary heating system (RAHS). The purpose of the ESCS is to remove heat from SSCs in the reactor cavity to maintain the temperatures within operational limits. The purpose of the RAHS is to preheat the reactor vessel and to ensure Flibe in the vessel is maintained above a minimum operating temperature. Each Hermes 2 unit has its own RTMS and there are no shared components between the units. Hermes 2 PSAR section 9.1.5 states that the RTMS does not perform safety-related functions.

9.1.5.2 Regulatory Evaluation

The staff reviewed section 9.1.5.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the RTMS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.1.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.1.5.2 of the Hermes 1 SE.

9.1.5.3 Technical Evaluation

The staff reviewed section 9.1.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.1.5, "Reactor Thermal Management System"). The staff found that section 9.1.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 RTMS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.1.5.3, "Technical Evaluation," of the Hermes 1 SE.

9.1.5.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.1.5, as compared to the information in Hermes 1 PSAR section 9.1.5, is the following:

- Each unit has its own RTMS and there are no components shared between the units.

The RTMS does not perform safety-related functions. Additionally, each unit having its own RTMS will prevent one RTMS failure from affecting both units. Based on the above, the staff finds that each unit having its own RTMS is acceptable.

On the basis of its review, the staff finds that the level of detail regarding the RTMS demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria in NUREG-1537, Part 2, section 9.7, to not result in accidents or unacceptable radioactivity releases and for no function or malfunction of the RTMS to interfere with or prevent safe shutdown of the reactor.

9.1.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information on the RTMS in PSAR section 9.1.5 is sufficient and meets applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff concludes that the preliminary design features intended to minimize contamination and support eventual decommissioning are consistent with the requirements of 10 CFR 20.1406.

9.2 Reactor Building Heating, Ventilation, and Air Conditioning System

9.2.1 Introduction

Section 9.2, “Reactor Building Heating, Ventilation, and Air Conditioning System,” of the Hermes 2 PSAR describes the RBHVAC. The RBHVAC is not proposed to provide any safety-related function or support any safety-related SSCs. Although radiation monitoring and filtration will be provided, the RBHVAC is not needed to mitigate any postulated event. No technical specifications are proposed for the RBHVAC. Each Hermes 2 unit has its own RBHVAC and there are no shared components between the units. The RBHVAC performs the following non-safety related functions:

- Maintain environmental conditions (air quality, temperature, humidity, pressure, and noise levels) for personnel health, habitability, and for SSC operability
- Provide a means to control and monitor tritium, beryllium, and other controlled effluents
- Monitor exhaust air vented from the reactor building for controlled effluents
- Ensure ventilation flow from areas of low hazard to areas of higher hazard potential
- Minimize contamination of facility areas

9.2.2 Regulatory Evaluation

The staff reviewed section 9.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the RBHVAC design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.2.2 of the Hermes 1 SE.

9.2.3 Technical Evaluation

The staff reviewed section 9.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.2, “Reactor Building Heating, Ventilation, and Air Conditioning System”). The staff found that section 9.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 RBHVAC design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.2.3, “Technical Evaluation,” of the Hermes 1 SE.

9.2.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.2, as compared to the information in Hermes 1 PSAR section 9.2, is the following:

- Each unit has its own RBHVAC and there are no components shared between the units.

The RBHVAC does not perform safety-related functions. Additionally, each unit having its own RBHVAC will prevent one RBHVAC failure from affecting both units. Based on the above, the staff finds that each unit having its own RBHVAC is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 RBHVAC demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.1, “Heating, Ventilation, and Air Conditioning Systems,” to support the as low as reasonably achievable (ALARA) program, radiation monitoring, and contamination control functions.

9.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information in Hermes 2 PSAR section 9.2 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Additionally, the staff concludes that the design features and analyses described in the PSAR provide reasonable assurance that Kairos will meet 10 CFR 20.1101(b), 10 CFR 20.1101(d), and 10 CFR 20.1406.

9.3 <u>Pebble Handling and Storage System</u>

9.3.1 Introduction

Section 9.3, “Pebble Handling and Storage System,” of the Hermes 2 PSAR describes a preliminary design for the PHSS, which provides for handling and storing fuel and other pebbles. The system encompasses receipt and inspection of new fuel upon delivery, core loading, sensing, inspection and sorting during downstream circulation, re-insertion, core unloading, and removal and transfer to storage. Each Hermes 2 unit has its own PHSS and there are no shared components between the units.

9.3.2 Regulatory Evaluation

The staff reviewed section 9.3.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the PHSS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.3.2 of the Hermes 1 SE.

9.3.3 Technical Evaluation

The staff reviewed section 9.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.3, "Pebble Handling and Storage System"). The staff found that section 9.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for two minor changes and one significant change evaluated below in sections 9.3.3.1 and 9.3.3.2, respectively. The staff found that the following portions of section 9.3 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 9.3.1.1, "Pebble Extraction Machine," through 9.3.1.7, "PHSS Inert Gas Boundary"
- Sections 9.3.1.9, "New Fuel Pebble Introduction," and 9.3.2, "Design Bases"
- Section 9.3.4, "Testing and Inspection"

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, the PHSS design in section 9.3 of the Hermes 2 PSAR is consistent with the information in section 9.3 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 9.3.3 "Technical Evaluation," of the Hermes 1 SE.

9.3.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 9.3, as compared to the information in Hermes 1 PSAR section 9.3, include the following:

- Each of the Hermes 2 units will have its own PHSS.
- The storage bay will be sized sufficiently for the 11-year operating life of Hermes 2 rather than the 4-year operating life of Hermes 1.

Each unit having its own PHSS will prevent one PHSS failure from affecting both units. The increased size of the PHSS storage bay is appropriate due to the increased amount of spent fuel, and the air cooling for the storage bay is designed to effectively cool the increased amount of spent fuel under normal and postulated events. This increased size and proper cooling allows for geometrically safe configurations during storage. Based on the above, the staff finds that each unit having its own PHSS and the increased storage bay size are acceptable.

9.3.3.2 Significant Change Compared to the Hermes 1 PSAR

The significant change contained in section 9.3 of the Hermes 2 PSAR, as compared to section 9.3 of the Hermes 1 PSAR, includes information regarding the following:

- The addition of design and construction information regarding the spent fuel storage racks.

These changes are identified in PSAR section 9.3.1.8, “Pebble Storage” and PSAR section 9.3.3, “System Evaluation.”

The staff evaluated the sufficiency of this additional preliminary information regarding the Hermes 2 spent fuel storage racks using the guidance and acceptance criteria of NUREG-1537, Part 2, section 9.2, “Handling and Storage of Reactor Fuel.” In PSAR table 3.6-1, Kairos lists the air-cooled and water-cooled spent fuel storage racks as safety-related and quality-related and to be designed as seismic design category 3 structures. PSAR section 9.3.1.8 states that the safety function of the spent fuel storage racks is to store the fuel storage canisters in a configuration that precludes criticality and supports heat removal. The staff finds that the safety and seismic classification of spent fuel storage racks is consistent with the graded approach of the American Society of Civil Engineers (ASCE) 43-19, “Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities,” and the applicable guidance in NUREG-1537 and is, therefore, acceptable.

Kairos states the racks will be constructed of stainless steel meeting American Society for Testing and Materials (ASTM) A240, “Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications,” and the racks will be designed following American Institute of Steel Construction (AISC) N690-18, “Specification for Safety-Related Steel Structures for Nuclear Facilities,” and AISC 370-21, “Specification for Structural Stainless Steel Buildings.” AISC N690-18 has been endorsed by the staff with the exceptions and clarifications listed in NRC Regulatory Guide (RG) 1.243, “Safety-Related Steel Structures and Steel-Plate Composite Walls for Other than Reactor Vessels and Containments.” The staff considers the use of AISC N690-18 to be sufficient for designing the Hermes 2 spent fuel storage racks considering that AISC N690-18 is endorsed in RG 1.243. AISC 370-21, and its references to AISC Design Guide 27, “Structural Stainless Steel,” have not yet been reviewed by the staff for generic endorsement; however, the use of local building codes and standards for structural design (including spent fuel racks) is consistent with the guidance in chapter 3 of NUREG-1537, Part 2. The staff will perform a case-specific detailed review of the final design of the spent fuel storage racks during its evaluation of the OL application, including a review of the applicability of AISC 370-21 and it’s references to AISC Design Guide 27. This case-specific review will evaluate the ability of the structural design to adequately ensure the safety function of the racks, including any deviations of the structures from the typical structures addressed in AISC N690-18 and AISC 370-21.

Kairos evaluates the spent fuel storage racks’ designs in PSAR section 9.3.3 with additional details of the fuel handling and drop analysis being provided in PSAR section 9.3.1.8.2, “Fill, Sealing, and Movement.” The structural analysis of the spent fuel storage racks will use the load combinations in PSAR table 3.5-1 with the addition of an impact load from a dropped storage canister. Kairos did not identify a specific load combination for the impact load from a dropped storage canister but stated that it will provide it for as part of the drop analysis in the OL application.

Moving spent fuel canisters requires a fuel canister transporter, which contains one canister at a time, and a canister lifting device, which moves a canister between the transporter and the spent fuel storage racks. Kairos will analyze the impact of a storage canister dropped from the canister lifting device onto the spent fuel storage racks in the OL application. A drop of the fuel canister transporter or a canister from the transporter onto the spent fuel storage racks is not considered since the transporter complies with American Society of Mechanical Engineers (ASME) BTH-1-2017, “Design of Below-the-Hook Lifting Devices,” and is supported by a transporter crane designed as a Type I crane per ASME NOG-1-2020, “Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder).” The staff finds the use of these standards to be consistent with RG 1.244, “Control of Heavy Loads at Nuclear Facilities,” and constitutes a highly reliable (i.e., single-failure proof) handling system, which does not require a drop analysis to demonstrate adequate safety. Additionally, Kairos states that the storage canisters will be designed to preclude interference with the spent fuel storage racks during insertion and removal; therefore, Kairos does not consider an upward force on the racks can be caused by a stuck fuel canister. Based on its review, the staff finds that it is acceptable for Kairos to not analyze for upward loads on the spent fuel storage racks because the design of the storage canisters would prevent interference with the spent fuel storage racks during insertion and removal. A more detailed review of the spent fuel canister and spent fuel storage rack designs will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to the design basis.

Based on the above, the staff finds that the preliminary design information in the PSAR is sufficient to determine that the spent fuel storage racks should perform their safety functions of precluding criticality and supporting heat removal.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 PHSS demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.3, to support functions like maintaining subcriticality, preventing damage to pebbles, limiting radiation exposure, and material control and accounting.

9.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary design of the PHSS, as described in the Hermes 2 PSAR, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff also concludes that the preliminary design features related to criticality safety are consistent with the requirements of 10 CFR 70.24, “Criticality accident requirements,” and the preliminary design features intended to minimize contamination and support eventual decommissioning provide reasonable assurance that Kairos will meet the requirements of 10 CFR 20.1406(a) for the Hermes 2 facility. Further technical or design information required to approve operation of the PHSS will be evaluated in the review of the OL application.

9.4 Fire Protection Systems and Programs

9.4.1 Introduction

Section 9.4, “Fire Protection Systems and Programs,” of the Hermes 2 PSAR describes a preliminary design for fire protection systems and related programs. The fire protection program integrates components, procedures, analysis, and personnel used to define and carry out all activities of fire protection. The fire protection system is designed to detect, control, and extinguish fires so that a continuing fire will not prevent safe shutdown or result in an uncontrolled release of radioactive material that exceeds acceptance criteria. The Hermes 2 fire protection systems consist of unit-specific systems that serve each reactor building and common systems that serve the shared turbine building and the shared main control room. Kairos stated that a detailed description of the fire protection program and a fire hazards analysis will be provided with the application for an OL.

9.4.2 Regulatory Evaluation

The staff reviewed section 9.4.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the fire protection systems and programs between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.4.2 of the Hermes 1 SE.

9.4.3 Technical Evaluation

The staff reviewed section 9.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.4, "Fire Protection Systems and Programs"). The staff found that section 9.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes evaluated below. The staff also verified that the design and functionality of the Hermes 2 fire protection systems and programs remain similar to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.4.3, "Technical Evaluation," of the Hermes 1 SE.

9.4.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 9.4, as compared to the information in Hermes 1 PSAR section 9.4, include the following:

- There is one common fire protection program for the Hermes 2 site.
- The fire protection systems consist of unit-specific systems that serve each reactor building and common systems that serve the shared turbine building and the shared main control room.

In Hermes 2 PSAR section 9.4, Kairos states that Unit 1 and Unit 2 will have one common fire protection program and that there will be unit-specific systems for each reactor building and common systems for other areas. This approach is consistent with the facility having two units compared to the one unit of Hermes 1. The use of unit-specific systems for each reactor building, common systems that serve shared structures and systems, and a common fire protection program is an appropriate design and program structure for a two-unit facility. Based on the above, the staff finds that having unit-specific and common fire protection systems is acceptable.

Additionally, Hermes 2 PSAR section 7.4, "Main Control Room and Remote Onsite Shutdown Panel," contains changes that are applicable to fire protection systems and programs. The applicable minor changes, as compared to the information in Hermes 1 PSAR section 7.4, "Main Control Room and Remote Onsite Shutdown Panel," include the following:

- The main control room is shared between Unit 1 and Unit 2 and provides the means for operators to monitor each unit and shared systems, control the performance of each unit and the shared systems, and manage the response to postulated event conditions in each unit.
- Unit-specific remote onsite shutdown panels (ROSP) are now provided that separate the means to shut down each unit and monitor plant parameters in response to postulated

event conditions. Additionally, the ROSPs are located in the safety-related portion of the reactor building for each unit.

These changes provide the capabilities to monitor and control each unit inside and outside the control room in the event of a fire and the staff finds that the preliminary design is consistent with PDC 19, “Control Room.” Based on the above, the staff finds that having a common main control room and individual RSOPs to support the response to a postulated fire event is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 fire protection systems and programs demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.3, “Fire Protection Systems and Programs,” to support post-fire safe shutdown.

9.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 PSAR, the staff concludes that information provided in the PSAR meets the regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Based on the information provided in the PSAR, the staff also concludes that the preliminary description of the fire protection program and the fire protection systems demonstrate an adequate design basis for a preliminary design so that the requirements of 10 CFR 50.34(a) are met. Further programmatic, technical, or design information required to approve operation of the test reactor will be evaluated in the review of the OL application.

9.5 <u>Communication Systems</u>

9.5.1 Introduction

Section 9.5, “Communication,” of the Hermes 2 PSAR describes a preliminary design for the Hermes 2 communication systems. Hermes 2 PSAR, section 9.5.1, “Description,” states that the communication systems provide communications during normal and emergency conditions between essential areas of the facility and between locations remote to the facility. The communication systems are common systems shared between the Hermes 2 units. The communication systems are not safety-related, are not credited for mitigation of design basis events, and have no safe shutdown function.

9.5.2 Regulatory Evaluation

The staff reviewed section 9.5.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the communication systems between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.5.2 of the Hermes 1 SE.

9.5.3 Technical Evaluation

The staff reviewed section 9.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.5, “Communication Systems”). The staff found that section 9.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 communication systems design and functionality remain similar to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.5.3, "Technical Evaluation," of the Hermes 1 SE.

9.5.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.5, as compared to the information in Hermes 1 PSAR section 9.5, is the following:

- The communication systems are common systems shared between Unit 1 and Unit 2

The sharing of communication systems across the single facility is appropriate because personnel should be made aware of events and activities occurring in one unit or common areas that could affect the entire facility. Additionally, the sharing of communication systems in dual unit sites has been standard for the currently operating reactor fleet for decades. Based on the above, the staff finds that having shared communication systems is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 communication systems demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.4, "Communication Systems."

9.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the design of the Hermes 2 communication systems, as described in Hermes 2 PSAR section 9.5, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of this information will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.6 Possession and Use of Byproduct, Source, and Special Nuclear Material

9.6.1 Introduction

Section 9.6, "Possession and Use of Byproduct, Source, and Special Nuclear Material," of the Hermes 2 PSAR discusses radioactive materials, including byproduct material, source material, and SNM that will be present at the Hermes 2 facility. PSAR section 9.6 also discusses locations where these materials will be stored or used at the facility, systems that interact with these materials and controls for handling these materials. PSAR section 9.6 states that the design bases for systems interacting with byproduct, source, or SNM are to prevent uncontrolled releases of radioactive materials and to maintain any Kairos personnel exposures within 10 CFR Part 20 dose limits and ALARA objectives.

PSAR section 9.6 states that Kairos's Hermes 2 CP application does not request authorization to possess any radioactive material, and that amendments or applications for license(s) allowing such possession of such material would be submitted at later date(s). During the general audit for Hermes 1 (ML23115A480), Kairos stated that it planned to possess byproduct, source and SNM associated with operation under a 10 CFR Part 50 OL for Hermes 1, but that it might also request authorization to possess such materials prior to the issuance of an OL through a CP amendment request, for example. Possession of radioactive material by Kairos would be evaluated when an application is submitted to the NRC. Kairos confirmed that this same approach will be taken for Hermes 2 by letter dated October 27, 2023 (ML23300A144).

9.6.2 Regulatory Evaluation

The staff reviewed section 9.6.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the approach to possession of radioactive material between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.6.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.6.2 of the Hermes 1 SE.

9.6.3 Technical Evaluation

The staff reviewed section 9.6 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.6, "Possession and Use of Byproduct, Source, and Special Nuclear Material"). The staff found that section 9.6 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR except for the minor change evaluated below. The staff also verified that the Hermes 2 approach to the possession and use of byproduct, source, and SNM remains identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.6.3, "Technical Evaluation," of the Hermes 1 SE.

9.6.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.6, as compared to the information in Hermes 1 PSAR section 9.6, is the following:

- Hermes 2 PSAR section 9.6.3 added the IHTS and the PGS to the list of systems which may contain tritium.

The IHTS and PGS are new systems for the Hermes 2 design and may contain tritium. Hermes 2 PSAR sections 5.2, "Intermediate Heat Transport System," 9.1.3, and 9.6.3 state that the TMS manages the inventory of tritium in the reactor system, including the IHTS, to reduce environmental releases. Hermes 2 PSAR sections 9.9.1, "Steam System," and 9.9.3, "Condensate and Feedwater System," also discuss the control and monitoring of tritium releases from the PGS. The staff reviewed the information on the preliminary design of the IHTS, TMS, and PGS and found it acceptable for the issuance of CPs as discussed in SE sections 5.2, "Intermediate Heat Transport System," 9.1.3, and 9.9, respectively.

Additionally, as discussed in Hermes 2 PSAR section 13.2.1, "Accident Analysis and Determination of Consequences," the radioactive material at risk of release (MAR) calculation for the maximum hypothetical accident (MHA) accounts for a bounding initially generated amount of tritium in total for the reactor, not the amount of tritium in each individual system. The MHA analysis uses bounding estimates of the radionuclides in the circulating activity MAR and the structural MAR, and it also uses bounding estimates for the transport and release of those MAR sources. As discussed in Hermes 2 PSAR chapter 14, "Technical Specifications," MAR quantities will also be controlled by upper bound limits in the technical specifications (TS) to help ensure that the assumptions in the MHA remain bounding for all facility operating conditions. Therefore, the staff finds that the consequences of a potential release of tritium for Hermes 2, including in the IHTS and PGS, will be within the bounds of the MHA, and that routine operational releases of tritium will also be controlled to help ensure that any releases are within 10 CFR Part 20 dose limits and ALARA. Based on the above, the staff finds that accounting for tritium in the IHTS and PGS is acceptable.

On the basis of its review, the staff finds that the level of detail provided in Hermes 2 PSAR section 9.6 and other PSAR sections regarding the Hermes 2 possession and use of byproduct, source, and SNM demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.5, “Possession and Use of Byproduct, Source, and Special Nuclear Material.” Based on this review, the staff finds that: (1) the auxiliary facilities and systems are designed for the possession and use of source material, SNM, and byproduct material located at Hermes 2 and produced by the reactor and (2) the Hermes 2 design provides reasonable assurance that the uncontrolled release of radioactive material to the unrestricted environment and public will not occur. Because the design bases include limits on potential personnel exposures, the staff has reasonable assurance that Kairos will comply with the regulations in 10 CFR Part 20 and the ALARA program during Hermes 2 facility operation.

9.6.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information provided in the PSAR and the preliminary design of the Kairos program and auxiliary facilities for the possession and use of byproduct material, source material, and SNM at Hermes 2, as described in the PSAR, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff also concludes that the preliminary design and programs described in the PSAR provide reasonable assurance that Kairos will comply with 10 CFR Part 20 during operation. Further technical or design information required to approve operation of the test reactor will be evaluated in the review of the OL application.

9.7 Plant Water Systems

Section 9.7, “Plant Water Systems,” of the Hermes 2 PSAR describes four auxiliary water systems:

- Service water
- Treated water
- Component cooling water (CCWS)
- Chilled water

The auxiliary water systems do not provide any safety-related function or support any safety-related SSCs, are not needed to mitigate any postulated event, and are not credited with performing safe shutdown functions. No TS are proposed in the PSAR for these water systems. These water systems perform the following non-safety related functions:

- Supply, treat, and store water
- Distribute water for cooling and maintenance
- Remove heat from non-essential loads
- Remove heat from essential loads
- Discharge heat to the environment

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. As indicated by PSAR figure 9.7-1, “Plant Water System Process Flow Diagram,” only the CCWS interfaces with systems containing radioactive material in the current design. Kairos confirmed in the general audit that, in the final design, any auxiliary water systems that connect to a system containing radioactive material will be designed to meet the requirements of 10 CFR 20.1406.

9.7.1 Regulatory Evaluation for Auxiliary Water Systems

The staff reviewed section 9.7.1, “Regulatory Evaluation for Auxiliary Water Systems,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the auxiliary water systems design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.7.1 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.7.1 of the Hermes 1 SE.

9.7.2 Service Water System

9.7.2.1 Introduction

Section 9.7.1, “Service Water System,” from the Hermes 2 PSAR describes how the service water system draws water from municipal sources and provides the water to other water systems and supports general facility services (e.g., potable water). The service water system is not safety-related and is not credited for the mitigation of postulated events. The service water system is designed in accordance with local building codes. The service water system is a common system shared between Unit 1 and Unit 2.

9.7.2.2 Technical Evaluation

PDC applicable to the service water system are:

- PDC 2, "Design Bases for Protection Against Natural Phenomena"
- PDC 4, “Environmental and Dynamic Effects Design Bases”

Section 9.7.1 of the Hermes 2 PSAR describes the service water system as a supply system for other water systems and for general facility use. No portion of the service water system will be located in the proximity of safety-related SSCs. As described in PSAR section 3.5.3.2, “Conformance with PDC 2 for Internal and External Flooding,” the design of the safety-related portion of each reactor building includes features to protect vulnerable safety-related SSCs from the effects of potential internal flooding and water spray that may result from the failure of water systems outside the safety-related portion of the building, whether due to the effects of natural phenomena or other conditions. Additionally, the service water system conforms with PDC 4 because it is a low-pressure system and will not create pipe whip or jet impingement threats to safety-related SSCs. Thus, the staff finds that the preliminary design of the service water system is consistent with PDC 2 and PDC 4 regarding the effects of damage that could result from natural phenomena or other postulated events that involve failure of the service water system. Consistent with the guidance of NUREG-1537, Part 2, section 9.7, for auxiliary system operation and potential malfunctions, the Hermes 2 service water system has been designed such that it will not cause accidents affecting the reactor, uncontrolled releases of radioactivity, or interference with safe shutdown of the reactor.

9.7.2.3 Conclusion

Based on the findings above, the staff concludes that the preliminary design of the service water system is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the service water system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.7.3 Treated Water System

9.7.3.1 Introduction

Section 9.7.2, “Treated Water System,” of the Hermes 2 PSAR describes how the treated water system provides chemistry control and supplies make-up water to the CCWS and the safety-related decay heat removal system. Portions of the treated water system may be located in proximity to SSCs with safety-related functions, and portions of the system may cross the base-isolation moat that provides seismic protection for the reactor cell and PHSS cell. The treated water system is not safety-related and is not credited for the mitigation of postulated events. The treated water system is designed in accordance with local building codes. Portions of the treated water system are shared between Unit 1 and Unit 2.

9.7.3.2 Technical Evaluation

PDC applicable to treated water system are:

- PDC 2, “Design Bases for Protection Against Natural Phenomena”
- PDC 4, “Environmental and Dynamic Effects Design Bases”

Section 9.7.2, “Treated Water System,” of the Hermes 2 PSAR describes how the treated water system design features and features of the reactor building satisfy the above design criteria. Because portions of the treated water system may be located in proximity to SSCs with safety-related functions, those safety-related SSCs will be protected either by seismically mounting nearby treated water system components or installation of barriers to prevent adverse interactions. As described in PSAR section 3.5.3.2, the design of the safety-related portion of each reactor building includes features to protect vulnerable safety-related SSCs from the effects of potential internal flooding and water spray that may result from the failure of water systems within and outside the safety-related portion of the building, whether due to the effects of natural phenomena or other conditions. Additionally, the treated water system is a low-pressure system that will not create pipe whip or jet impingement threats to safety-related

SSCs. Thus, the staff finds that the preliminary design of the treated water system is consistent with PDC 2 and PDC 4 regarding the effects of damage that could result from natural phenomena or environmental or dynamic effects that could result from failure of the treated water system. Consistent with the guidance of NUREG-1537, Part 2, section 9.7, the treated water system satisfies guidance for auxiliary system malfunctions such that it would not initiate a reactor accident, initiate an uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.7.3.3 Conclusion

Based on the staff findings above, the staff concludes that the preliminary design of the treated water system is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the treated water system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.7.4 Component Cooling Water System

9.7.4.1 Introduction

Section 9.7.3, "Component Cooling Water System," describes how the CCWS provides cooling water for the RBHVAC, the ESCS, the SFCS, and the IGS. The CCWS is managed by the plant control system to maintain desired operational temperature limits. Heat from the CCWS is rejected to the environment. Each unit has its own CCWS and there are no shared components between the units. The CCWS does not perform safety-related functions and is not credited for the mitigation of postulated events. Portions of the CCWS may be located in proximity to SSCs with safety-related functions, and portions of the system may cross the base-isolation moat that provides seismic protection for the reactor cell and PHSS cell. As shown in PSAR table 3.6-1, "Structures, Systems, and Components," the CCWS is designed in accordance with local building codes.

9.7.4.2 Technical Evaluation

PDC applicable to the CCWS are:

- PDC 2, "Design Bases for Protection Against Natural Phenomena"
- PDC 4, "Environmental and Dynamic Effects Design Bases"
- PDC 44, "Structural and Equipment Cooling"
- PDC 45, "Inspection of Structural and Equipment Cooling Systems"
- PDC 46, "Testing of Structural and Equipment Cooling Systems"

Section 9.7.3 of the PSAR provides a description of the CCWS and identifies how the CCWS satisfies the above design criteria. Because portions of the CCWS may be located in proximity to SSCs with safety-related functions, those safety-related SSCs will be protected either by seismically mounting nearby CCWS components or installation of barriers to prevent adverse interactions. As described in PSAR section 3.5.3.2, "Conformance with PDC 2 for Internal and External Flooding," the design of the safety-related portion of each reactor building includes features to protect vulnerable safety-related SSCs from the effects of potential internal flooding and water spray that may result from the failure of water systems within and outside the safety-related portion of the building, whether due to the effects of natural phenomena or other conditions. Additionally, the CCWS is a low-pressure system that would not create pipe whip or jet impingement threats to safety-related SSCs. Thus, the staff finds that the preliminary design of the CCWS is consistent with PDC 2 and PDC 4 regarding protection of safety-related SSCs from the effects of damage that could result from natural phenomena or environmental or dynamic effects resulting from failure of the CCWS.

The CCWS transfers heat from safety significant SSCs such as the fuel storage pool under normal operating conditions but performs no safety-related heat transfer functions for accident mitigation. The CCWS design provides for periodic inspection and testing to ensure the integrity and capability of the system to cool SSCs and to adequately transfer heat to the ultimate heat sink. Based on this capability, the staff finds that the preliminary design of the CCWS is consistent with PDC 44, 45, and 46.

Based on its review, the staff finds that Kairos has adequately described the design bases of the CCWS in PSAR sections 9.7 and 9.7.3. In addition, the staff finds that the CCWS preliminary design, as described in the PSAR, is consistent with PDC 2, 4, 44, 45, 46, and the guidance of NUREG-1537, Part 2, section 9.7, with regard to performing heat transfer functions consistent with the system design basis and ensuring auxiliary system malfunctions would not initiate a reactor accident, initiate an uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.7.4.3 Conclusion

Based on the staff's findings above, the staff concludes that the preliminary design of the CCWS is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the CCWS design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.7.5 Chilled Water System

9.7.5.1 Introduction

Section 9.7.4, "Chilled Water System," of the Hermes 2 PSAR states that the chilled water system provides cooling water to the RBHVAC system and other facility SSCs that are not safety-related. The chilled water system is not safety-related and is not credited for the mitigation of postulated events. The chilled water system is designed in accordance with local building codes. Each unit has its own chilled water system and there are no shared components between the units.

9.7.5.2 Technical Evaluation

PDC applicable to chilled water system are:

- PDC 2, "Design Bases for Protection Against Natural Phenomena"
- PDC 4, "Environmental and Dynamic Effects Design Bases"

Section 9.7.4 of the PSAR provides a description of the chilled water system and identifies how the chilled water system satisfies the above design criteria. No portion of the chilled water system will be located in the proximity of safety-related SSCs. As described in PSAR section 3.5.3.2, the design of the safety-related portion of each reactor building includes features to protect vulnerable safety-related SSCs from the effects of potential internal flooding and water spray that may result from the failure of water systems outside the safety-related portion of the building, whether due to the effects of natural phenomena or other conditions. Additionally, the chilled water system is a low-pressure system, precluding pipe whip and jet impingement threats to safety-related SSCs. Thus, the staff finds that the preliminary design of the chilled water system is consistent with PDC 2 and PDC 4 regarding the effects of damage that could result from natural phenomena or other postulated events that involve failure of the chilled water system. Consistent with NUREG-1537, Part 2, section 9.7, the chilled water system satisfies guidance for auxiliary system malfunctions such that it would not initiate a reactor accident, initiate an uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.7.5.3 Conclusion

Based on the staff findings above, the staff concludes that the preliminary design of the chilled water system is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the chilled water system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.8 Other Auxiliary Systems

9.8.1 Remote Maintenance and Inspection System

9.8.1.1 Introduction

Section 9.8.1, “Remote Maintenance and Inspection System,” of the Hermes 2 PSAR describes how the remote maintenance and inspection system (RMIS) will provide the ability to remotely access, inspect, and handle components in the reactor system, the PHTS, and the PHSS. The RMIS is located in the reactor building and includes manipulators, tooling, cameras, monitors, cranes and rigging. The RMIS is not safety-related and does not perform safety-related functions. Portions of the system may cross the base-isolation moat that provides seismic protection for the reactor cell and PHSS cell. Each unit has its own RMIS and there are no components shared between the units.

9.8.1.2 Regulatory Evaluation

The staff reviewed section 9.8.1.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the RMIS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.8.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.8.1.2 of the Hermes 1 SE.

9.8.1.3 Technical Evaluation

The staff reviewed section 9.8.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.8.1, “Remote Maintenance and Inspection System”).

The staff found that section 9.8.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 RMIS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.8.1.3, "Technical Evaluation," of the Hermes 1 SE.

9.8.1.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.8.1, as compared to the information in Hermes 1 PSAR section 9.8.1, is the following:

- Each unit has its own RMIS and there are no components shared between the units.

The RMIS does not perform safety-related functions. Additionally, each unit having its own RMIS will prevent one RMIS failure from affecting both units. Based on the above, the staff finds that each unit having its own RMIS is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 RMIS demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, for auxiliary systems to not cause accidents to the reactor, uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.8.1.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary design of the RMIS is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff also concludes that the design features described in the PSAR help provide reasonable assurance that Kairos will comply with 10 CFR 20.1101(b) and 10 CFR 20.1406. A more detailed evaluation of the RMIS design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.8.2 Spent Fuel Cooling System

9.8.2.1 Introduction

Section 9.8.2, "Spent Fuel Cooling System," of the Hermes 2 PSAR describes a preliminary design for the SFCS, which cools spent fuel canisters in the spent fuel storage pool and storage bay. PSAR section 9.8.2 states that the system does not perform safety-related functions.

9.8.2.2 Regulatory Evaluation

The staff reviewed section 9.8.2.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the SFCS design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.8.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.8.2.2 of the Hermes 1 SE.

9.8.2.3 Technical Evaluation

The staff reviewed section 9.8.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.8.2, “Spent Fuel Cooling System”). The staff found that section 9.8.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes evaluated below. The staff also verified that the Hermes 2 SFCS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.8.2.3, “Technical Evaluation,” of the Hermes 1 SE.

9.8.2.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 9.8.2, as compared to the information in Hermes 1 PSAR section 9.8.2, include the following:

- The number of pebbles that each unit’s SFCS is sized to cool was increased to account for the higher number generated during 11 years of operation for Hermes 2 versus the 4 years of operation of Hermes 1.
- Each unit has its own SFCS and there are no components shared between the units.

Because the system does not perform safety-related functions, increasing the cooling capacity of the system does not affect reactor safety and is appropriate for the increased operational life of Hermes 2. Additionally, each unit having its own SFCS will prevent one SFCS failure from affecting both units. Based on the above, the staff finds that the increase in pebble (cooling) capacity and each unit having its own SFCS are acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 SFCS demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.2, “Handling and Storage of Reactor Fuel,” to support functions including preventing thermal failure and limiting radiation exposure.

9.8.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary design of the SFCS, as described in the PSAR, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The staff also concludes that the preliminary design features intended to minimize contamination and support eventual decommissioning will help ensure compliance with the requirements of 10 CFR 20.1406. Further technical or design information required to approve operation of Hermes 2 will be evaluated in the review of an OL application.

9.8.3 Compressed Air System

9.8.3.1 Introduction

Section 9.8.3, “Compressed Air System,” of the Hermes 2 PSAR states that the compressed air system provides compressed air for general facility services and for use in valve operation. The compressed air system is not safety-related and is not credited with performing safe shutdown functions. Each unit has its own compressed air system and there are no shared components between the units.

9.8.3.2 Regulatory Evaluation

The staff reviewed section 9.8.3.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the compressed air system design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.8.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.8.3.2 of the Hermes 1 SE.

9.8.3.3 Technical Evaluation

The staff reviewed section 9.8.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.8.3, “Compressed Air System”). The staff found that section 9.8.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 compressed air system design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.8.3.3, “Technical Evaluation,” of the Hermes 1 SE.

9.8.3.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.8.3, as compared to the information in Hermes 1 PSAR section 9.8.3, is the following:

- Each unit has its own compressed air system and there are no components shared between the units.

The compressed air systems do not perform safety-related functions. Additionally, each unit having its own compressed air system will prevent one compressed air system failure from affecting both units. Based on the above, the staff finds that each unit having its own compressed air system is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 compressed air system demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, for auxiliary systems to not cause accidents to the reactor, uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.8.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary design of the compressed air system is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the compressed air system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.8.4 Cranes and Rigging

9.8.4.1 Introduction

Section 9.8.4, “Cranes and Rigging,” of the Hermes 2 PSAR describes that each unit has a reactor building gantry crane to move equipment and support material receiving and shipping. Because of the heavy loads that would be lifted by the cranes, failure or mis-operation of the cranes could damage safety-related SSCs if a load was to drop. The reactor building cranes and associated rigging are not safety-related, perform no safety-related functions, and share no components between the units.

9.8.4.2 Regulatory Evaluation

The staff reviewed section 9.8.4.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the cranes and rigging design between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.8.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.8.4.2 of the Hermes 1 SE.

9.8.4.3 Technical Evaluation

The staff reviewed section 9.8.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.8.4, “Cranes and Rigging”). The staff found that section 9.8.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes evaluated below. The staff also verified that the Hermes 2 reactor building cranes and rigging design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.8.4.3, “Technical Evaluation,” of the Hermes 1 SE.

9.8.4.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 9.8.4, as compared to the information in Hermes 1 PSAR section 9.8.4, include the following:

- Each unit has its own reactor building cranes and rigging and there are no components shared between the units.
- A statement was modified in PSAR section 9.8.4.2, “Design Bases,” to state that “Consistent with PDC 4, safety-related SSCs are protected from the dynamic effects potentially created by the failure of the crane and rigging equipment.”
- A statement was modified in PSAR section 9.8.4.3, “System Evaluation,” to state that “Design features are include in the plant design so that failure of the lifting device does not interfere or preclude the ability of a safety-related system to perform a safety function.”
- A second statement was modified in PSAR section 9.8.4.3 to clarify that heavy loads would only be moved over safety-related equipment when the reactor is shut down and the consequences of a load drop had been determined to not pose a safety concern.

The above changes clarify that the overall plant design protects safety-related equipment from the potential effects of crane or rigging malfunctions. Since the cranes and associated rigging may be used to move heavy equipment in proximity to safety-related SSCs, protection against dynamic effects potentially created by the malfunction of the crane or rigging equipment is necessary to conform with PDC 4. The reactor building cranes and rigging do not perform safety-related functions, and the cranes and rigging do not include design features intended to prevent malfunctions that result in a heavy load drop. Rather, administrative controls and interlocks prevent the crane from moving heavy loads over safety-related SSCs except when (1) the reactor is shut down and (2) the consequences of a potential load drop have been determined to neither damage stored irradiated fuel to the extent that a significant off-site release would occur, nor preclude operation of sufficient equipment to achieve safe shutdown. The preliminary design of the facility conforms with PDC 4 by permitting the crane to be located where the dynamic effects of postulated crane or rigging failures would not affect safety-related SSCs. The proposed administrative controls and interlocks will be evaluated in conjunction with the OL application. Additionally, each unit having its own reactor building crane in separate reactor buildings will prevent one crane failure from affecting both units. Based on the above, the staff finds that each unit having its own cranes and rigging, and the changes to PSAR sections 9.8.4.2 and 9.8.4.3 described above, are acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 reactor building cranes and rigging demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, for auxiliary systems to not cause accidents to the reactor, uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.8.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary plant design is sufficient to protect safety-related equipment from dynamic effects that could result from crane operations and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the dynamic effects that could result from crane operations, and an evaluation of these effects against the final design, will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.8.5 Auxiliary Site Services

9.8.5.1 Introduction

Section 9.8.5, “Auxiliary Site Services,” of the Hermes 2 PSAR states that the Hermes 2 auxiliary site services include non-safety related systems and equipment that support operation of the plant, such as machine shops, chemistry laboratory, sewers, lighting, warehousing, and storage. The auxiliary services are not credited for the mitigation of postulated events and will be built so that they will not interfere with the ability of safety-related SSCs to perform their safety function(s). Some site services are proposed to be shared between Unit 1 and Unit 2. Warehouses, fire water storage, facility lighting, storm and sanitary sewers, and ground water monitoring wells are expected by Kairos to be shared by both the Hermes 1 and Hermes 2 facilities.

9.8.5.2 Regulatory Evaluation

The staff reviewed section 9.8.5.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the auxiliary site services between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 9.8.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 9.8.5.2 of the Hermes 1 SE.

9.8.5.3 Technical Evaluation

The staff reviewed section 9.8.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 9.8.5, "Auxiliary Site Services"). The staff found that section 9.8.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the minor change evaluated below. The staff also verified that the Hermes 2 auxiliary site services remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 9.8.5.3, "Technical Evaluation," of the Hermes 1 SE.

9.8.5.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 9.8.5, as compared to the information in Hermes 1 PSAR section 9.8.5, is the following:

- Some site services are shared between Unit 1 and Unit 2. Warehouses, fire water storage, facility lighting, storm and sanitary sewers, and ground water monitoring wells are expected to be shared across the site.

In Hermes 2 PSAR section 9.8.5, Kairos states that Unit 1 and Unit 2 will share some auxiliary site services and other auxiliary site services (e.g., warehouses, fire water storage, facility lighting, storm and sanitary sewers, and ground water monitoring wells). The auxiliary site services are not used to perform or support safety-related functions, so the sharing of these auxiliary services does not affect the safety of the facilities. Based on the above, the staff find that sharing of auxiliary services between the units and across the site is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 auxiliary services demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, for auxiliary systems to not cause accidents to the reactor, uncontrolled release of radioactivity, or interfere with safe shutdown of the reactor.

9.8.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary design of the auxiliary site services is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 50.40. A more detailed evaluation of the auxiliary site services will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.9 <u>Power Generation System</u>

The PGS consists of the following systems:

- Steam system
- Turbine generator system
- Feedwater and condensate system

The purpose of the PGS is to convert the heat energy contained within the IHTS into electrical energy. The PGS does not perform any safety-related functions and the majority of the PGS is shared between Unit 1 and Unit 2.

9.9.1 Steam System

9.9.1.1 Introduction

Section 9.9.1, "Steam System," of the Hermes 2 PSAR states that the steam system uses heat from the IHTS salt to generate superheated steam for the turbine generator system for power generation. Each unit contains a superheater in the portion of the reactor building that is not safety-related. The output of the superheater passes through a unit-specific isolation valve into a common steam header that supplies the turbine generator system and recirculated steam for evaporation of condensate. The turbine generator system, the feedwater and condensate system, and shared components of the steam system are outside the reactor buildings. Saturated steam from a shared evaporator feeds the superheater.

The steam system is not safety-related and is not credited for the mitigation of postulated events. The steam system provides heat removal during normal operations through the power conversion system. The unit-specific main steam isolation valves upstream of the common superheater outlet header support single unit operation as needed. The steam system is designed to handle a turbine trip without a corresponding reactor trip via the turbine bypass line, condenser (which is sized to handle 100% steam load), and steam relief valves (which have the capability to reject 100% load to the atmosphere). The steam system is designed in accordance with industry codes and standards for piping and pressure vessels.

9.9.1.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of the Hermes 2 facility steam system are:

- 10 CFR 50.34, "Contents of applications; technical information"
  - o 10 CFR 50.34(a)(3)(ii) requires that a CP application PSAR include, "The design bases and the relation of the design bases to the principal design criteria."
  - o 10 CFR 50.34(a)(3)(iii) requires that a CP application PSAR include, "Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety."
  - o 10 CFR 50.34(a)(4) which requires, in part, that a CP application PSAR include, "A preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…"

- 10 CFR 50.35, “Issuance of construction permits.”
- 10 CFR 50.40, “Common standards.”

As described in SE Section 1.1.2, the staff did not evaluate whether the requirements in 10 CFR Part 20 would be met for the construction of the Hermes 2 facility. Instead, the staff assessed whether Kairos identified the relevant requirements for an operating facility and provided descriptions of the preliminary facility design. The staff assessed this to determine whether the PSAR provides an acceptable basis for the development of systems and whether there is reasonable assurance that Kairos will comply with the regulations in 10 CFR Part 20 during Hermes 2 facility operation.

The applicable guidance for the evaluation of the Hermes 2 steam system is as follows:

- NUREG-1537, Parts 1 and 2, section 9.7, provides review criteria and procedures.

9.9.1.3 Technical Evaluation

The PDC applicable to the steam system are:

- PDC 4, “Environmental and dynamic effects design bases”
- PDC 60, “Control of releases of radioactive materials to the environment”
- PDC 64, “Monitoring radioactivity releases”

Section 9.9.1 of the PSAR provides a summary description of the steam system and identifies design features of the facility that support the system design function, prevent uncontrolled releases of radioactivity, and prevent interactions that could interfere with or prevent safe shutdown or cause a reactor accident. The steam system removes heat from the IHTS and transfers the superheated steam to the turbine generator for power generation or alternative heat rejection paths either directly to the main condenser or to atmosphere. Tritium produced in the reactor could propagate through the PHTS and IHTS to the steam system, and the steam system preliminary design includes features to control and monitor releases to the atmosphere. The proposed Hermes 2 facility includes design features that prevent steam system malfunctions from adversely affecting safety-related equipment, which reasonably ensures those malfunctions would not result in reactor accidents; uncontrolled releases of radioactivity; or interference with, or prevention of, safe shutdown of the reactor.

A portion of the steam system, including each unit’s superheater and steam isolation valve, are located in the non-safety related portion of each reactor building. The steam piping is not located near safety-related SSCs. Section 9.9.1 of the PSAR states that safety-related SSCs located inside the safety-related portion of the reactor building are protected from the effects of high-pressure steam line breaks by protective features (e.g., barriers or blowout panels), qualified for the environmental conditions, provided with sufficient separation, or a combination of these measures. Because of these design features, staff finds that the preliminary design of the facility is consistent with PDC 4 for ensuring that safety-related SSCs are able to withstand the effects of steam system malfunctions and accidents.

The steam system interfaces with the IHTS through the superheater. Tritium formed in the reactor and transported by the PHTS to the IHTS could migrate across the superheater tubes and remain present in the blowdown flow from the evaporator. This fluid, along with feedwater and condensate drains, is directed to the flash vessel where recirculated superheated steam evaporates the fluid for release to the atmosphere through a monitored vent. The preliminary steam system design also includes radioactivity monitoring capability at the steam system relief valves. Therefore, the design of the steam system conforms with PDC 60 and 64 with respect to controlling the release of tritium to the environment and monitoring releases of radioactive material. These design features support development of programs at OL application stage to satisfy the requirements of 10 CFR Part 20.

The staff observed that Kairos postulated multiple initiating events involving the rupture of steam system components. The potential positive reactivity insertion resulting from a steam line break is addressed in Hermes 2 PSAR section 13.1.2, "Insertion of Excess Reactivity" and SE section 13.1.2, "Insertion of Excess Reactivity." A rupture of a tube within the superheater that results in steam intrusion into the IHTS is discussed in Hermes 2 PSAR sections 5.2, "Intermediate Heat Transport System," and 13.1.10.11, "IHX Gross Failure Due to Superheater Tube Rupture or Leak." This superheater tube rupture event is evaluated by the staff in SE sections 5.2, "Intermediate Heat Transport System,"13.1.4, "Loss of Forced Circulation," and 13.1.10, "Prevented Events."

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 steam system demonstrates an adequate basis for a preliminary design; meets PDC 4, 60, and 64; and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, in that potential malfunctions should not result in reactor accidents, uncontrolled releases of radioactivity, or interfere with or prevent safe shutdown of the reactor.

9.9.1.4 Conclusion

Based on the staff's findings above, the staff concludes that the preliminary design of the facility is sufficient with respect to the steam system and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the steam system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.9.2 Turbine Generator System

9.9.2.1 Introduction

Section 9.9.2, "Turbine Generator System," of the Hermes 2 PSAR states that the turbine generator system converts thermal energy in the steam to electrical energy. One turbine generator building, and one turbine generator are shared between Unit 1 and Unit 2. The turbine generator system interfaces with the steam system and the condensate and feedwater system. The turbine generator system is not safety-related and is not credited for the mitigation of postulated events.

9.9.2.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of the Hermes 2 test reactor turbine generator system are:

- 10 CFR 50.34
    - 10 CFR 50.34(a)(3)(ii) requires that a CP application PSAR include, "The design bases and the relation of the design bases to the principal design criteria."

- 10 CFR 50.34(a)(3)(iii) requires that a CP application PSAR include, "Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety."
  - 10 CFR 50.34(a)(4) which requires, in part, that a CP application PSAR include, "A preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…"
- 10 CFR 50.35, "Issuance of construction permits"
- 10 CFR 50.40, "Common standards."

The applicable guidance for the evaluation of the Hermes 2 reactor turbine generator system is as follows:

- NUREG-1537, Parts 1 and 2, section 9.7, provides review criteria and procedures.

9.9.2.3 Technical Evaluation

The PDC applicable to the turbine generator is PDC 4, which specifies that safety-related equipment shall be appropriately protected from the dynamic effects of equipment malfunctions, including missiles.

Section 9.9.2 of the Hermes 2 PSAR describes that the turbine generator converts thermal energy in the steam to electrical energy in the turbine generator building. The turbine generator building is separate from the reactor buildings and the safety-related equipment located within those buildings. Also, the turbine generator is favorably oriented with respect to safety-related equipment located in the reactor buildings such that missiles resulting from postulated turbine generator malfunctions would not be able to adversely affect the ability of the safety-related equipment to perform their safety functions. Because of these design features, staff finds that the preliminary design of the facility is consistent with PDC 4 for safety-related SSCs to be appropriately protected against the dynamic effects of turbine generator system malfunctions. Therefore, these design features reasonably ensure that turbine generator system malfunctions would not result in reactor accidents, uncontrolled releases of radioactivity, or interference with or prevention of safe shutdown of the reactor.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 turbine generator system demonstrates an adequate basis for a preliminary design, meets PDC 4, and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, in that potential malfunctions should not result in reactor accidents, uncontrolled release of radioactivity, or interfere with or prevent safe shutdown of the reactor.

9.9.2.4 Conclusion

Based on the staff's findings above, the staff concludes that the preliminary design of the facility is acceptable with respect to design and location of the turbine generator system and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the turbine generator system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.9.3 Condensate and Feedwater System

9.9.3.1 Introduction

Section 9.9.3, "Condensate and Feedwater System," of the Hermes 2 PSAR states that the condensate and feedwater system returns condensed steam from the air-cooled condenser to the condensate tank, deaerates, reheats the water to feedwater temperature and pressure, and supplies feedwater to the evaporator. The air-cooled condenser is sized to handle 100 percent of the steam flow from the turbine bypass system, which permits the power conversion system to withstand a turbine trip without requiring corresponding reactor trips. The condensate and feedwater system includes radiation monitors on the air-cooled condenser and deaerator vapor vents which monitor tritium releases to the atmosphere during normal operations. The condensate and feedwater system is not safety-related and is not credited for the mitigation of postulated events. As shown in Hermes 2 PSAR table 3.6-2, "Design and Construction Codes and Standards for Fluid Systems," the condensate and feedwater system is designed in accordance with industrial standards for piping and pressure vessels.

9.9.3.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of the Hermes 2 condensate and feedwater system are:

- 10 CFR 50.34
    - 10 CFR 50.34(a)(3)(ii) requires that a CP application PSAR include, "The design bases and the relation of the design bases to the principal design criteria."
    - 10 CFR 50.34(a)(3)(iii) requires that a CP application PSAR include, "Information relative to materials of construction, general arrangement, and approximate dimensions, sufficient to provide reasonable assurance that the final design will conform to the design bases with adequate margin for safety."
    - 10 CFR 50.34(a)(4) which requires, in part, that a CP application PSAR include, "A preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…"
- 10 CFR 50.35, "Issuance of construction permits."
- 10 CFR 50.40, "Common standards."

As described in SE Section 1.1.2, the staff did not evaluate whether the requirements in 10 CFR Part 20 would be met for the construction of the Hermes 2 facility. Instead, the staff assessed whether Kairos identified the relevant requirements for an operating facility and provided descriptions of the preliminary facility design. The staff assessed this to determine whether the PSAR provides an acceptable basis for the development of systems and whether there is reasonable assurance that Kairos will comply with the regulations in 10 CFR Part 20 during Hermes 2 facility operation.

The applicable guidance for the evaluation of the Hermes 2 condensate and feedwater system is as follows:

- NUREG-1537, Parts 1 and 2, section 9.7, provides review criteria and procedures.

9.9.3.3 Technical Evaluation

PDC applicable to the condensate and feedwater system are:

- PDC 4, “Environmental and dynamic effects design bases”
- PDC 60, “Control of releases of radioactive materials to the environment”
- PDC 64, “Monitoring radioactivity releases”

Section 9.9.3 of the Hermes 2 PSAR provides a summary description of the condensate and feedwater system and identifies design features of the facility that support the system design function, prevent uncontrolled releases of radioactivity, and prevent interactions that could interfere with or prevent safe shutdown or cause a reactor accident.

The condensate and feedwater system is located in the turbine generator building, which is separate from the reactor buildings and the safety-related equipment located within those buildings. Because of these design features, staff finds that the preliminary design of the facility is consistent with PDC 4 for safety-related SSCs to be appropriately protected against the dynamic effects of pipe breaks and malfunctions affecting the condensate and feedwater system.

Tritium formed in the reactor and transported by the PHTS and IHTS to the steam system could be exhausted from the turbine into the condenser or be directed into the deaerator. These components include vents for controlled release of gases potentially containing tritium into the atmosphere. The preliminary feedwater and condensate system design includes radioactivity monitoring capability at the condenser and deaerator vents. Therefore, the preliminary design of the feedwater and condensate system conforms with PDC 60 and PDC 64 with respect to controlling the release of tritium to the environment and monitoring releases of radioactive material. These design features support development of programs at the OL application stage to satisfy the requirements of 10 CFR Part 20.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 condensate and feedwater system demonstrates an adequate basis for a preliminary design, meets PDC 4, 60, and 64; and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, in that potential malfunctions should not result in reactor accidents, uncontrolled releases of radioactivity, or interfere with or prevent safe shutdown of the reactor.

9.9.3.4 Conclusion

Based on the staff’s findings above, the staff concludes that the preliminary design of the facility is sufficient with respect to the condensate and feedwater system and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. A more detailed evaluation of the condensate and feedwater system design will occur during the review of the Hermes 2 OL application, at which time the staff will confirm that the final design conforms to this design basis.

9.10 Summary and Conclusions for Auxiliary Systems

The staff evaluated the information on the Hermes 2 auxiliary systems as described in PSAR chapter 9 and finds that the preliminary information on, and design criteria of, the auxiliary systems, including the PDC, design bases, and other design information: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2, allowing the staff to make findings that:

- Kairos's preliminary information and commitments to design the reactor coolant auxiliary systems, RBHVAC systems, PHSS, communication systems, water systems, other auxiliary systems, and PGS are sufficient and meet the applicable regulatory requirements and guidance for the issuance of CPs. Further information on these items can reasonably be left for later consideration in the OL application.

- The preliminary information on fire protection systems and programs is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs. Further information can reasonably be left for later consideration in the final safety analysis report, fire protection program, and fire hazards analysis that will be submitted with an OL application.

- The preliminary design of the Kairos program and auxiliary facilities for the possession and use of byproduct material, source material, and SNM at Hermes 2 is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs. Further information related to possession and use of byproduct material, source material, and SNM during operations and decommissioning can reasonably be left for later consideration during future reviews of a Hermes 2 OL application and proposed decommissioning plan, respectively.

Based on these findings referenced above, the staff concludes the following regarding the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the auxiliary systems, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the final safety analysis report.

- Safety features or components which require research and development have been described by Kairos and a research and development program (see SE section 1.1.5, "Ongoing Research and Development") will be conducted that is reasonably designed to resolve any safety questions associated with such features or components.

- There is reasonable assurance that safety questions will be satisfactorily resolved at or before the latest date stated in the application for completion of construction of the proposed facility.

- There is reasonable assurance: (i) that the construction of the Hermes 2 facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission's regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

9.11 References for Auxiliary Systems

American Institute of Steel Construction (AISC) N690-18, "Specification for Safety-Related Steel Structures for Nuclear Facilities," AISC: Randolph Street, Chicago, IL, dated June 2018.

-----. AISC 370-21, "Specification for Structural Stainless Steel Buildings," dated June 2021.

American Society of Civil Engineers (ASCE) 43-19, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities," Alexander Bell Drive, Reston, VA, dated January 2021.

American Society of Mechanical Engineers (ASME) BTH-1-2020, "Design of Below-the-Hook Lifting Devices," ASME: Two Park Avenue, New York, NY, dated January 2017.

-----. ASME NOG-1-2020, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)," dated December 2020.

-----. ASME B30.2-2016, "Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)," dated May 2017.

American Society for Testing and Materials (ASTM) A240, "Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications," ASTM: Harbor Drive, West Conshohocken, PA, dated December 2022.

Kairos Power LLC, "Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor Topical Report," KP-TR-005-P-A, Revision 1, dated July 2020, ML20219A591.

-----. "Principal Design Criteria for the Kairos Power Fluoride Salt-Cooled, High Temperature Reactor," KP-TR-003-NP-A, Revision 1, dated June 2020, ML20167A174.

-----. "Transmittal of Responses to NRC Requests for Confirmation of Information Hermes [1] Preliminary Safety Analysis Report, Section 9.1," dated August 2022, ML22231B228.

-----. "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," Revision 3, dated May 31, 2023, ML23151A743.

-----. "Kairos Power Response to Hermes 2 General Audit Question 1.5-2," dated October 27, 2023, ML23300A144.

-----. "Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1," dated May 23, 2024, ML24144A090.

U.S. Nuclear Regulatory Commission (NRC), NUREG-1537 Part 2, “Guidelines for Preparing and Reviewing Application for the Licensing of Non-Power Reactors, Parts 1 and 2,” NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. Regulatory Guide 4.20, “Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees Other Than Power Reactors,” Revision 1, dated April 2012, ML110120299.

-----. Regulatory Guide 1.243, “Safety-Related Steel Structures and Steel-Plate Composite (SC) Walls for other than Reactor Vessels and Containments,” dated August 2021, ML21089A032.

-----. Regulatory Guide 1.244, “Control of Heavy Loads at Nuclear Facilities,” dated December 2021, ML21006A346.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report – General Audit,” dated June 2023, ML23160A287.

-----. “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes 2 Construction Permit Preliminary Safety Analysis Report – General Audit,” dated July 11, 2024, ML24193A214.

10 EXPERIMENTAL FACILITIES AND UTILIZATION

Research and test reactors may have many experimental uses. Many such reactors have special experimental facilities, which may penetrate the core or reflector, be located near the core, or be an integral part of the reactor. Using these facilities, samples can be irradiated in the core or reflector, or neutron or other radiation beams can be extracted from the core region through the biological shield. In addition to these traditional experimental purposes, some research and test reactors may be operated primarily to gather information and data that could be useful for the purposes of licensing future prototype facilities and power reactors. Such non-power reactors may not include specific experimental facilities, but the reactor itself and/or specific structures, systems, and components (SSCs) could be considered experimental facilities to demonstrate technology for eventual prototype and commercial scale up.

Kairos Power LLC's (Kairos's) Hermes 2 preliminary safety analysis report (PSAR), Revision 1, chapter 10, "Experimental Facilities and Utilization," section 10.1, "Summary Description," states that Hermes 2 will not include special facilities dedicated to the conduct of reactor experiments or experimental programs. However, as discussed in Hermes 2 PSAR chapter 1, "The Facility," section 1.1, "Introduction," Kairos's purpose for Hermes 2 is to test and demonstrate the key technologies, design features, and safety functions of Kairos's fluoride salt-cooled, high temperature reactor (KP-FHR) technology and its associated SSCs for a two-unit facility including electrical power production. As part of its construction permit (CP) review, the U.S. Nuclear Regulatory Commission (NRC) staff (the staff) evaluated information on Hermes 2 SSCs in the PSAR, paying special attention to design and operating characteristics, unusual or novel SSCs being demonstrated by Hermes 2, and principal safety considerations. The preliminary design of unusual or novel SSCs, including special safety features for these SSCs and any added instrumentation or other features to monitor the performance of these SSCs, was evaluated to ensure the sufficiency of principal design criteria; design bases; information relative to materials of construction, general arrangement, and approximate dimensions; and high-level functional descriptions, to provide reasonable assurance that the final design will conform to the design bases. The information provided by Kairos in the Hermes 2 PSAR was also evaluated to determine whether it was adequate to provide reasonable assurance that a Title 10, *Code of Federal Regulations* (10 CFR) Part 50 CP for the Hermes 2 facility could be issued in accordance with applicable regulatory requirements and guidance on the basis that the facility could be constructed without undue risk to the health and safety of the public. The staff evaluations of unusual or novel Hermes 2 SSCs are found in other chapters of this safety evaluation (SE), particularly chapter 3, "Design of Structures, Systems, and Components," chapter 4, "Reactor Description," chapter 5, "Reactor Coolant System," chapter 6, "Engineered Safety Features," and chapter 9, "Auxiliary Systems."

In addition, the staff reviewed Kairos's Quality Assurance Program Description (QAPD) for ensuring the quality and performance of Hermes 2 SSCs during the design, construction, and operation of the facility. The staff documented its review of Kairos's QAPD in chapter 12, "Conduct of Operations," section 12.9, "Quality Assurance," of this SE.

The staff also reviewed Kairos's identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of technical specifications (TSs) for the facility, with special attention given to those items which may significantly influence the final design. The staff documented its review of Kairos's probable subjects of TSs for the facility in chapter 14, "Technical Specifications," of this SE.

Hermes 2 PSAR sections 4.3.1.1.1, 4.3.3, and 10.1 describe a material surveillance system (MSS), which is supported by the reactor vessel top head and provides a means to insert and remove material specimens (e.g., coupons) to support testing and assessment of material performance. During the general audit (ML23115A480) for the Hermes 1 CP application review, Kairos confirmed that, consistent with Hermes 1 PSAR section 10.1, the Hermes 1 MSS is not an experimental facility because the purpose of the MSS is to monitor and evaluate the performance of SSCs over the Hermes 1 operating life and Kairos does not plan to use the MSS to evaluate or irradiate other novel or experimental materials, i.e., which are not representative of Hermes 1 SSCs. Kairos also confirmed that any use of the MSS would not affect analyses of Hermes 1 operation or accidents in Hermes 1 PSAR chapters 4 and 13. By letter dated October 27, 2023 (ML23300A144), Kairos confirmed that this information from the Hermes 1 general audit is also applicable to Hermes 2.

The staff evaluated the information on the Hermes 2 facility in the Hermes 2 PSAR and found that the preliminary design of the facility does not include any facilities penetrating or located near the reactor that are specifically designated as experimental facilities. The staff notes that the Hermes 2 facility includes unusual and novel SSCs that are an integral part of the facility, including tristructural isotropic particle (TRISO) fuel, Flibe salt coolant, with others, and that the facility includes features to monitor the performance of these SSCs to demonstrate the key technologies, design features, and safety functions of Kairos's KP-FHR technology. However, these SSCs and features, as well as the QAPD and probable subjects of TSs that will help ensure the quality, performance, and safe operation of SSCs, are evaluated in other chapters of this SE, as discussed above. Therefore, the staff concludes that a separate evaluation using the guidelines of NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 2, "Standard Review Plan and Acceptance Criteria," chapter 10, "Experimental Facilities and Utilization," is not required. The staff will confirm that the final design conforms to the design basis, including that Hermes 2 will not include special facilities dedicated to the conduct of reactor experiments or experimental programs, during its review of a Hermes 2 operating license application.

10.1 References

Kairos Power LLC. "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," Revision 3, dated May 31, 2023, ML23151A743.

-----. Letter dated October 27, 2023, "Kairos Power Response to Hermes 2 General Audit Question 1.5-2," ML22300A144.

-----. "Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1," dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC). NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1, "Format and Content," and Part 2, "Standard Review Plan and Acceptance Criteria," NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. "Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report – General Audit," dated June 2023, ML23160A287.

-----. “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

11 RADIATION PROTECTION AND WASTE MANAGEMENT

The purposes of radiation protection and waste management programs and provisions are to ensure safety of a reactor facility and to provide protection to the facility staff, members of the public, and the environment.

This chapter of the Kairos Power LLC (Kairos) Hermes 2 test reactor construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary information on the radiation protection and waste management programs and design provisions at Hermes 2 as presented in chapter 11, "Radiation Protection and Waste Management," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed PSAR chapter 11 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information Kairos provided regarding facility radiation protection and waste management for the issuance of CPs in accordance with Title 10, *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities."

As part of this review, the staff evaluated information on the radiation protection and waste management programs and provisions for Hermes 2, with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. The staff evaluated the preliminary design of the Hermes 2 facility radiation protection program and waste management provisions to ensure the design criteria, design bases, and information relative to construction are sufficient to provide reasonable assurance that the final design will conform to the design basis. In addition, the staff reviewed Kairos's identification and justification for the selection of those variables, conditions, or other items which are determined to be probable subjects of technical specifications for the facility, with special attention given to those items which may significantly influence the final design.

The staff's reviews and evaluations for areas relevant to PSAR chapter 11, including regulations and guidance used, summaries of the application information reviewed, and evaluation findings and conclusions, are discussed in the SE sections below for each of the two major areas of review (radiation protection and waste management) covered in this SE chapter. A summary and overall conclusion on the staff's technical evaluation of radiation protection and waste management at Hermes 2 are provided in SE section 11.3, "Summary and Conclusions on Radiation Protection and Waste Management."

11.1 Radiation Protection

11.1.1 Introduction

Section 11.1, "Radiation Protection," of the Hermes 2 PSAR identifies the sources of radiation at the Hermes 2 facility and describes at a high level the programs and provisions for radiation protection and maintaining exposures to radiation as low as is reasonably achievable (ALARA), including preliminary facility design information relevant to radiation protection.

11.1.2 Regulatory Evaluation

The applicable regulatory requirements for the evaluation of radiation protection at Hermes 2 are as follows:

- 10 CFR 50.34, “Contents of applications; technical information,” including:
  - 10 CFR 50.34(a)(1)(i), which requires “[a] description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design”;
  - 10 CFR 50.34(a)(4), which requires “[a] preliminary analysis and evaluation of the design and performance of structures, systems, and components [SSCs] of the facility…”; and
  - 10 CFR 50.34(a)(6), which requires “[a] preliminary plan for the applicant's organization, training of personnel, and conduct of operations.”
- 10 CFR 50.35, “Issuance of construction permits.”
- 10 CFR 50.40, “Common standards.”

As provided in 10 CFR 20.1002, “Scope,” the regulations in 10 CFR Part 20, “Standards for Protection Against Radiation,” apply to persons licensed by the Commission to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material or to operate a production or utilization facility. Kairos applied for CPs and has not specifically requested approval of any design information. A CP does not provide a license to operate the facility. In its CP application, Kairos also did not apply for licenses to receive, possess, use, transfer, or dispose of byproduct, source, or special nuclear material at the facility. Therefore, the staff did not evaluate whether requirements in 10 CFR Part 20 would be met for the construction of the Hermes 2 reactor. Instead, the staff assessed whether Kairos had identified the relevant requirements for an operating facility and provided descriptions of the preliminary facility design and provisions for protecting the health and safety of the public, workers, and the environment in sufficient detail to determine whether the PSAR provides an acceptable basis for the development of the radiation protection programs and radioactive waste management, and whether there is reasonable assurance that Kairos will comply with the regulations in 10 CFR Part 20 during operation of the Hermes 2 facility. This is consistent with 10 CFR 50.40(a), which provides that in determining whether CPs may be issued, the Commission will be guided by consideration of reasonable assurance that Kairos will comply with the regulations, including the regulations in 10 CFR Part 20, and that the health and safety of the public will not be endangered.

The applicable guidance for the evaluation of Hermes 2 radiation protection is as follows:

- NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” section 11.1, “Radiation Protection.”

11.1.3 Technical Evaluation

11.1.3.1 Radiation Sources

PSAR section 11.1.1, “Radiation Sources,” identifies the radiation sources that present a potential hazard to workers and the public from operation of the Hermes 2 facility. The generation of the radiation sources is described in general terms. PSAR table 11.1-1, “Radiation

Sources," lists the SSCs or facility locations which contain fission products or other sources of radiation, with the specific contents identified (e.g., tritium, circulating activity in systems with liquid or gas flow, activation products in structures and components). PSAR section 11.1.1 states that additional details of radiation sources, including activity and external radiation fields in the facility, will be provided in an operating license (OL) application.

As described in PSAR section 11.1.5, "Radiation Exposure Control and Dosimetry," under subheading "Effluent Monitoring," and information from the Hermes 1 review that is applicable to and docketed for Hermes 2 (ML23300A141 and ML23300A144), Kairos performed a conservative screening analysis of gaseous tritium emissions from the Hermes 2 reactors. The screening analysis results yielded projected doses to the public from emissions of tritium from the facility which are well below the allowable limits in 10 CFR Part 20. Kairos used the XOQDOQ atmospheric dispersion model and GASPAR II gaseous effluent pathway model in the NRCDose3 computer code, with site-specific input on the release point, dose receptor locations, and 5 years of site-specific, validated meteorological data. The staff notes that NRCDose3 was developed by the NRC to implement the NRC's ALARA requirements for radioactive effluents from nuclear powerplants.

As described in PSAR section 11.1.5, analysis assumptions for the tritium effluent release were based on a conservative tritium release rate equal to the generation rate that does not account for retention in the reactor or engineered systems, which would reduce the effective tritium effluent rate. The assumed bounding effluent release quantities for gaseous radionuclide effluents other than tritium were taken from the Clinch River Early Site Permit (ESP) Environmental Report and were based on light-water small modular reactor preliminary design information. Kairos modeled the release as emanating from a single stack with a high-energy (>0.4 megawatts) plume at a 100-foot release height, which would bound the release height from the Hermes 2 reactors' radionuclide release pathways including the heat energy of the releases from each reactor. The calculated total effective dose equivalent (TEDE) gaseous effluent dose results for each Hermes 2 unit were added together to develop a Hermes 2 facility total, and also further combined with the gaseous effluent dose results for the Hermes 1 reactor to give the site total. The gaseous effluent doses were estimated at two locations: the maximally exposed individual in an unrestricted area and an analytical nearest resident. The estimated combined site total doses from gaseous effluent at these locations are well below the 10 CFR Part 20 public dose limits. The staff confirmed that Kairos's analysis assumptions and methods were consistent with the regulatory guidance identified by Kairos in PSAR section 11.1.5.

The staff evaluated the sufficiency of the preliminary information on Hermes 2 radiation sources, as described in PSAR sections 11.1.1 and 11.1.5, using the guidance and acceptance criteria from section 11.1.1 of NUREG-1537, Parts 1 and 2. The staff's review included a comparison of the bases for identifying potential radiation safety hazards with the process and facility descriptions to verify that such hazards were accurately and comprehensively identified.

Based on its review of the information in the PSAR and the information from Hermes 1 that is applicable to and docketed for Hermes 2, the staff finds that the high-level description of radiation sources and their bases, including the effluent screening analysis, is consistent with generation, transport, and cleanup of radionuclides, activation of materials, and radioactive waste production that would occur at the Hermes 2 facility. The staff finds that the results of the effluent screening analysis provide reasonable assurance that 10 CFR Part 20 limits will be met during Hermes 2 operation, including consideration of both the Hermes 1 and Hermes 2 facilities for site total effluent releases. The staff finds use of the Clinch River ESP effluent information for radionuclides other than tritium to be a reasonable assumption for a preliminary scoping analysis, considering the relative power levels and design differences. The staff will review the effluent analysis corresponding to the detailed design in the application for an OL. Based on its review, the staff finds the PSAR information on Hermes 2 radiation sources is adequate because it identifies the potential radiation safety hazards associated with the Hermes 2 reactors and provides an acceptable preliminary basis for the development of the radiation protection program. Further, the PSAR information meets the applicable acceptance criteria of NUREG-1537, Part 2, section 11.1.1.

11.1.3.2 Radiation Protection Program and ALARA Program

The staff reviewed sections 11.1.2, "Radiation Protection Program," and 11.1.3, "ALARA Program," of the Hermes 2 PSAR and compared them to the equivalent sections in the Hermes 1 PSAR (section 11.1.2, "Radiation Protection Program," and section 11.1.3, "ALARA Program"). The staff found that sections 11.1.2 and 11.1.3 of the Hermes 2 PSAR contain information consistent with that in the Hermes 1 PSAR. The staff also verified that the proposed Hermes 2 Radiation Protection Program and ALARA Program remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 11.1.3.2 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the proposed Hermes 2 radiation protection and ALARA programs demonstrates an adequate basis for a preliminary design and CP and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, sections 11.1.2 and 11.1.3, because it identifies applicable requirements and appropriate guidance and general features for implementation of the radiation protection and ALARA programs for the Hermes 2 facility.

11.1.3.3 Radiation Monitoring and Surveying

The staff reviewed section 11.1.4, "Radiation Monitoring and Surveying," of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 11.1.4, "Radiation Monitoring and Surveying"). The staff found that section 11.1.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the proposed Hermes 2 radiation monitoring and surveying programs remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 11.1.3.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the proposed Hermes 2 radiation monitoring and surveying programs demonstrates an adequate basis for a preliminary design and CP and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 11.1.4, because it identifies applicable requirements for radiation monitoring and surveying, and includes appropriate preliminary information on guidance, practices, and design features to help ensure that Hermes 2 radiation fields and effluents are monitored and sampled as necessary for the Hermes 2 facility.

11.1.3.4 Radiation Exposure Control and Dosimetry

The staff reviewed section 11.1.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 11.1.5, "Radiation Exposure Control and Dosimetry"). The staff found that section 11.1.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for the description of the gaseous effluent analysis, which is evaluated above in SE section 11.1.3.1, and minor changes that are evaluated below. The staff also verified that the Hermes 2 radiation exposure control and dosimetry remain similar to Hermes 1. Based on these consistencies, this section incorporates by reference section 11.1.3.4 of the Hermes 1 SE.

11.1.3.4.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 11.1.5, as compared to the information in Hermes 1 PSAR section 11.1.5, include the following:

- Kairos identified potential gaseous effluent release points for the Hermes 2 reactors that did not exist in the Hermes 1 design.

In Hermes 2 PSAR section 11.1.5, Kairos states that potential gaseous release points include the power generation system (PGS) evaporator, flash vessel, deaerator, and condenser vent pipe, with a reference to Hermes 2 PSAR section 9.9, "Power Generation System." Hermes 2 PSAR section 9.9 provides preliminary design information, including sufficient information to confirm the additional potential effluent release points for the Hermes 2 facility which were not a part of the Hermes 1 design. The staff's evaluation of the preliminary design information for the PGS is discussed in section 9.9 of this SE. Based on the above, the staff finds that the identification of potential gaseous effluent release points is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 radiation exposure control and dosimetry demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 11.1.5. This finding is based on the fact that the PSAR identifies applicable requirements for radiation exposure control and includes appropriate preliminary information on access controls, shielding, and design features to help ensure that uncontrolled radiation releases and unauthorized entry into high radiation areas will be prevented and radiation doses will be maintained ALARA and within regulatory limits.

11.1.3.5 Contamination Control

The staff reviewed section 11.1.6 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 11.1.6, "Contamination Control"). The staff found that section 11.1.6 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 approach to contamination control remains identical to that proposed for Hermes 1. Based on these consistencies, this section incorporates by reference section 11.1.3.5 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 approach to contamination control demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 11.1.6, to help ensure that the spread of contamination at Hermes 2 will be minimized.

11.1.3.6 Environmental Monitoring

The staff reviewed section 11.1.7 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 11.1.7, "Environmental Monitoring"). The staff found that section 11.1.7 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 approach to environmental monitoring control remains identical to that proposed for Hermes 1. Based on these consistencies, this section incorporates by reference section 11.1.3.6 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 approach to environmental monitoring demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 11.1.7, to help ensure any environmental impacts from Hermes 2 operation will be appropriately assessed.

11.1.4 Conclusion

Based on its findings above, the staff concludes the information in Hermes 2 PSAR section 11.1 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 radiation protection can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

11.2 Radioactive Waste Management

11.2.1 Introduction

Section 11.2, "Radioactive Waste Management," of the Hermes 2 PSAR describes at a high level the Hermes radioactive waste management program and preliminary facility design information for radioactive waste handling.

11.2.2 Regulatory Evaluation

The staff reviewed section 11.2.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarity of the Hermes 1 and Hermes 2 facilities and the consistency of the radioactive waste management approach between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 11.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 11.2.2 of the Hermes 1 SE.

11.2.3 Technical Evaluation

The staff reviewed section 11.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 11.2, "Radioactive Waste Management"). The staff found that section 11.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 radioactive waste management program, radioactive waste handling systems and controls, and release of radioactive waste design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 11.2.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding radioactive waste management for the Hermes 2 facility demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 11.2. The staff finds that the PSAR provides adequate preliminary information on the radioactive waste management program, radioactive waste handling systems and controls, and release of radioactive waste to help ensure radioactive waste from Hermes 2 will be dispositioned appropriately and in accordance with applicable regulations.

11.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes PSAR section 11.2 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of radioactive waste management for the Hermes 2 facility can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

11.3 Summary and Conclusions on Radiation Protection and Waste Management

The staff evaluated the information on radiation protection and waste management at Hermes 2, as described in PSAR chapter 11, and finds that the preliminary information and design criteria for the radiation protection and waste management programs and provisions, including the principal design criteria, design bases, and information relating to materials of construction, general arrangement, and approximate dimensions: (1) provide reasonable assurance that the final design will conform to the design bases, (2) meet all applicable regulatory requirements, and (3) meet the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed facility design for radiation protection and waste management, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis of radiation protection and waste management, and which can reasonably be left for later consideration, will be provided in the OL application.

- There is reasonable assurance: (i) that the construction of the Hermes 2 facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission’s regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

11.4 References

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

-----. “Transmittal of Responses to NRC Requests for Confirmation of Information for the Review of the Hermes Environmental Report,” dated April 22, 2022, ML22115A204.

-----. “Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1]),” Revision 3, dated May 31, 2023, ML23151A743.

-----. “Transmittal of Response to Hermes 2 General Audit Question 1.5-1,” dated October 27, 2023, ML23300A141.

-----. “Kairos Power Response to Hermes 2 General Audit Question 1.5-2,” dated October 27, 2023, ML23300A144.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC). NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. Regulatory Guide 4.21, “Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning,” Revision 0. NRC: Washington, D.C., dated June 2008, ML080500187.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report – General Audit,” dated June 2023, ML23160A287.

-----, “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

Tennessee Valley Authority. “Clinch River Nuclear Site Early Site Permit Application, Part 3, Environmental Report,” Revision 2, dated January 2019, ML19030A478.

12 CONDUCT OF OPERATIONS

The conduct of operations involves the administrative aspects of facility operation (i.e., the facility organizational structure, review and audit activities, facility procedures, required actions for technical specification violations, reporting requirements, and recordkeeping), emergency planning, quality assurance, security, operator training and requalification, and startup and material control and accounting (MC&A) plans.

This chapter of the Kairos Power LLC (Kairos) Hermes 2 construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the preliminary information provided in chapter 12, "Conduct of Operations," of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed Hermes 2 PSAR chapter 12 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary information on the Hermes 2 conduct of operations for the issuance of CPs in accordance with Title 10, *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." The staff's reviews and evaluations for areas relevant to PSAR chapter 12, including regulations and guidance used, a summary of the application information reviewed, and evaluation findings and conclusions, are discussed in the SE sections below for each specific area of review. A summary and overall conclusion on the staff's technical evaluation of the Hermes 2 conduct of operations are provided in SE section 12.14, "Summary and Conclusions on Conduct of Operations."

12.1 <u>Organization</u>

12.1.1 Introduction

Section 12.1, "Organization," of the Hermes 2 PSAR describes the organizational structure, functional responsibilities, levels of authority, and interfaces for establishing, executing, and verifying the organizational structure concerning facility operation. The organizational structure includes internal and external functions including interface responsibilities for multiple organizations. PSAR section 12.1 also discusses the organizational aspects of the radiation protection (RP) program, staffing, and selection and training of personnel.

12.1.2 Regulatory Evaluation

The staff reviewed section 12.1.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facilities designs and the consistency of the preliminary organization between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.1.2 of the Hermes 1 SE.

12.1.3 Technical Evaluation

The staff reviewed section 12.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.1 "Organization"). The staff found that section 12.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes, which are evaluated below. Based on the similarities between the Hermes 1 and Hermes 2 facility designs, the staff finds that the organizational structures, functional responsibilities, levels of authority, and interfaces for the Hermes 1 facility can be applied to the Hermes 2 facility. Based on these consistencies, this section incorporates by reference section 12.1.3 of the Hermes 1 SE.

12.1.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 12.1, as compared to the information in Hermes 1 PSAR section 12.1, include the following:

- Staffing may be shared to support each of the licensed reactors on the site.

In Hermes 2 PSAR section 12.1, Kairos states that its staff may be used to perform tasks that support the Hermes 1 and Hermes 2 facilities. Based on its review of the Hermes 2 PSAR, the staff found that the Hermes 2 facility is sufficiently similar to the Hermes 1 facility such that use of the same staff across both facilities would be appropriate for certain functions. The staff anticipates similar staff training and competencies to apply to Hermes 1; Hermes 2, Unit 1; and Hermes 2, Unit 2. Additionally, currently operating power reactor sites that contain multiple units, including those with different plant designs, have had staff that perform certain activities for all units for many decades, demonstrating the validity of this approach. Based on the above, the staff finds that shared staffing between Hermes 1 and Hermes 2 facilities is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 organization demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, “Standard Review Plan and Acceptance Criteria,” section 12.1, “Organization.”

12.1.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.1 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35, “Issuance of construction permits,” and 10 CFR 50.40, “Common standards.” Further information as may be required to complete the review of the Hermes 2 organization (e.g., detailed information on staffing, including control room staffing, and training) can reasonably be left for later consideration in the operating license (OL) application since this information is not necessary to be provided as part of a CP application.

12.2 Review and Audit Activities

12.2.1 Introduction

Section 12.2, “Review and Audit Activities,” of the Hermes 2 PSAR describes review and audit activities during facility operation at Hermes 2.

12.2.2 Regulatory Evaluation

The staff reviewed section 12.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information on review and audit activities between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.2.2 of the Hermes 1 SE.

12.2.3 Technical Evaluation

The staff reviewed section 12.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.2, “Review and Audit Activities”). The staff found that section 12.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. Based on the similarities between the Hermes 1 and Hermes 2 facilities, the staff found that an identical approach for review and audit activities will be appropriate for Hermes 1 and Hermes 2. Based on these consistencies, this section incorporates by reference section 12.2.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 review and audit activities demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 12.2, “Review and Audit Activities.”

12.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.2 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 review and audit activities (e.g., detailed information on review and audit committee composition, qualifications, charter and rules, and review and audit committee functions including review, approval, audit, and reporting functions) can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.3 <u>Procedures</u>

12.3.1 Introduction

Section 12.3, “Procedures,” of the Hermes 2 PSAR describes the use of operating procedures during Hermes 2 facility operation.

12.3.2 Regulatory Evaluation

The staff reviewed section 12.3.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information on the proposed approach for procedures between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.3.2 of the Hermes 1 SE.

12.3.3 Technical Evaluation

The staff reviewed section 12.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.3, “Procedures”). The staff found that section 12.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. Based on the similarities between Hermes 1 and Hermes 2, the staff found that an identical approach for procedures will be appropriate for Hermes 1 and Hermes 2. Based on these consistencies, this section incorporates by reference section 12.3.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 procedures demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 12.3.

12.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.3 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 procedures (e.g., detailed information on review, approval, and change processes for procedures) can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.4 Required Actions

12.4.1 Introduction

Section 12.4, “Required Actions,” of the Hermes 2 PSAR describes actions that will be taken when a safety limit is exceeded or a limiting condition for operation or surveillance requirement is not met.

12.4.2 Regulatory Evaluation

The staff reviewed section 12.4.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information regarding required actions between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.4.2 of the Hermes 1 SE.

12.4.3 Technical Evaluation

The staff reviewed section 12.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.4, “Required Actions”). The staff found that section 12.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. Based on the similarities between Hermes 1 and Hermes 2, the staff found that an identical approach to required actions will be appropriate for Hermes 1 and Hermes 2. Based on these consistencies, this section incorporates by reference section 12.4.3 of the Hermes 1 SE.

Based on its review, the staff determined that the level of detail provided regarding Hermes 2 required actions is adequate and meets the applicable acceptance criteria of NUREG-1537, Part 2, section 12.4, “Required Actions.”

12.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.4 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Kairos's required actions can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.5 Reports

12.5.1 Introduction

Section 12.5, "Reports," of the Hermes 2 PSAR describes required routine operating reports and reporting requirements for changes to the Hermes 2 facility or facility organization to be provided to the NRC.

12.5.2 Regulatory Evaluation

The staff reviewed section 12.5.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information regarding reports between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.5.2 of the Hermes 1 SE.

12.5.3 Technical Evaluation

The staff reviewed section 12.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.5, "Reports"). The staff found that section 12.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. Based on the similarities between Hermes 1 and Hermes 2, the staff also finds that an identical approach to reports will be appropriate for Hermes 1 and Hermes 2. Based on these consistencies, this section incorporates by reference section 12.5.3 of the Hermes 1 SE.

Based on its review, the staff determined that the level of detail provided regarding Hermes 2 reports is adequate and meets the applicable acceptance criteria of NUREG-1537, Part 2, section 12.5, "Reports."

12.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.5 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 reports can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.6 Records

12.6.1 Introduction

Section 12.6, "Records," of the Hermes 2 PSAR describes the process for managing test reactor facility records.

12.6.2 Regulatory Evaluation

The staff reviewed section 12.6.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information on records management between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.6.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.6.2 of the Hermes 1 SE.

12.6.3 Technical Evaluation

The staff reviewed section 12.6 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.6, "Records"). The staff found that section 12.6 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. Based on the similarities between Hermes 1 and Hermes 2 facilities, the staff finds that an identical approach to records management will be appropriate for Hermes 1 and Hermes 2. Based on these consistencies, this section incorporates by reference section 12.6.3 of the Hermes 1 SE.

Based on its review, the staff determined that the level of detail provided regarding Hermes 2 records is adequate and meets the applicable acceptance criteria of NUREG-1537, Part 2, section 12.6, "Records."

12.6.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.6 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 records can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.7 Emergency Planning

12.7.1 Introduction

Section 12.7, "Emergency Planning," of the Hermes 2 PSAR discusses emergency planning. Specifically, the Hermes 2 PSAR provides a description of the preliminary plans for addressing emergencies in PSAR chapter 12, appendix A, "Description of the Emergency Plan," (i.e., PSAR appendix 12A) which is referenced in PSAR section 12.7.

12.7.2 Regulatory Evaluation

The staff reviewed section 12.7.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and consistency of the preliminary information related to the emergency planning approach between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.7.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.7.2 of the Hermes 1 SE.

12.7.3 Technical Evaluation

The staff reviewed section 12.7 and appendix 12A of the Hermes 2 PSAR and compared it to the equivalent sections in the Hermes 1 PSAR (section 12.7, “Emergency Planning” and appendix A, “Description of the Emergency Plan”). The staff found that section 12.7 and appendix 12A of the Hermes 2 PSAR contain information consistent with that in the Hermes 1 PSAR, except for a minor change which is evaluated below. The staff also verified that the Hermes 2 preliminary plans for addressing emergencies remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 12.7.3 of the Hermes 1 SE.

12.7.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR, appendix 12A, section G, “Evacuation,” as compared to the information in Hermes 1 PSAR, appendix 12A, section G, “Evacuation,” includes the following:

- Language clarifying that Hermes 2 is a test reactor facility.

In Hermes 2 PSAR, appendix 12A, section G, Kairos states that the facility is licensed as a test reactor. While this text differs slightly from the equivalent section in the Hermes 1 PSAR, the intent remains the same (i.e., to reinforce that certain regulatory requirements do not apply to test facilities). This minor change has no impact on the Hermes 2 preliminary plans for addressing facility emergencies. Based on the above, the staff finds that the clarifying language is acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 preliminary plans for addressing emergencies satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 12.7, the applicable guidance in American Nuclear Standards Institute/American Nuclear Society-15.16-2015, “Emergency Planning for Research Reactors,” the applicable guidance evaluation items contained in NUREG-0849, “Standard Review Plan for the review and Evaluation of Emergency Plans for Research and Test Reactors,” and are also consistent with the guidance in Regulatory Guide 2.6, “Emergency Planning for Research and Test Reactors and Other Non-Power Production and Utilization Facilities,” Revision 2, as applicable.

12.7.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that Kairos’s preliminary plans for coping with emergencies are sufficient and comply with the applicable requirements of 10 CFR 50.34(a), including 10 CFR 50.34(a)(10), which requires that the PSAR include “[a] discussion of the applicant’s preliminary plans for coping with emergencies," 10 CFR 50.35, 10 CFR 50.40, and 10 CFR Part 50, appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," section I, "Introduction," and section II, "The Preliminary Safety Analysis Report." Further information as may be required to complete the review of Hermes 2 emergency planning can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.8 Security

12.8.1 Introduction

Section 12.8, "Security," of the Hermes 2 PSAR provides preliminary information regarding security planning for the Hermes 2 facility.

12.8.2 Regulatory Evaluation

The staff reviewed section 12.8.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and consistency of the preliminary information related to the security approach between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.8.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.8.2 of the Hermes 1 SE.

12.8.3 Technical Evaluation

The staff reviewed section 12.8 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.8, "Security"). The staff found that section 12.8 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 security planning approach remains identical to that proposed for Hermes 1. Based on these consistencies, this section incorporates by reference section 12.8.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided regarding security planning for the Hermes 2 facility is adequate and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 12.8, "Security Planning."

12.8.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.8 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 security planning can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.9 <u>Quality Assurance</u>

12.9.1 Introduction

Section 12.9, “Quality Assurance,” of the Hermes 2 PSAR describes quality assurance (QA) for the Hermes 2 facility, and states that the description of Kairos’s QA program for the design, construction, and operation of Hermes 2 is based on ANSI/ANS 15.8-1995 (R2005), “Quality Assurance Program Requirements for Research Reactors,” and the guidance in RG 2.5, “Quality Assurance Program Requirements for Research and Test Reactors,” Revision 1. Kairos provided its Quality Assurance Program Description (QAPD) as appendix B to PSAR section 12 (i.e., PSAR appendix 12B).

12.9.2 Regulatory Evaluation

The staff reviewed section 12.9.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the QA program between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.9.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.9.2 of the Hermes 1 SE.

12.9.3 Technical Evaluation

The staff reviewed section 12.9, “Quality Assurance” and appendix 12B, “Quality Assurance Program,” of the Hermes 2 PSAR and compared them to the equivalent sections in the Hermes 1 PSAR (section 12.9, “Quality Assurance” and appendix 12B, “Quality Assurance Program”). The staff found that section 12.9 and appendix 12B of the Hermes 2 PSAR contain information consistent with that in the Hermes 1 PSAR, except for a minor change which is evaluated below. The staff also verified that the approach to QA remains identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 12.9.3 of the Hermes 1 PSAR.

12.9.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 12.9, as compared to the information in Hermes 1 PSAR section 12.9, includes the following:

- An additional sentence noting that the QAPD provided in appendix 12B was written for Hermes 1 but is also applicable to Hermes 2.

The QAPD provided in the Hermes 2 PSAR, appendix 12B, is identical to the QAPD provided in the Hermes 1 PSAR, appendix 12B and is also titled the same. The information contained in the QAPD is independent of the facility differences between Hermes 1 and Hermes 2. Therefore, the same QAPD is applicable to both Hermes 1 and Hermes 2. Based on the above, the staff finds that use of the Hermes 1 QAPD for Hermes 2 is acceptable.

On the basis of its review, the staff finds that the QAPD discussed in PSAR section 12.9 and provided in PSAR appendix 12B demonstrates an adequate basis for a preliminary design and satisfies the guidance relevant to design, fabrication, construction, and testing in sections 1 and 2 of ANSI/ANS 15.8-1995, which the NRC endorsed in RG 2.5, Revision 1, and that the

QAPD is also consistent with the guidance contained within NUREG-1537, Part 2, section 12.9, “Quality Assurance.”

12.9.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the Hermes 2 QAPD is sufficient and complies with the requirements of 10 CFR 50.34(a)(7), which requires, in part, that an applicant for a CP provide a description of the QA program to be applied to the design, fabrication, construction, and testing of the SSCs of the facility. Accordingly, the staff concludes that the information in PSAR section 12.9 and PSAR appendix 12B is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40, and, as such, the Hermes 2 QAPD is acceptable for implementation during the design and construction of the Hermes 2 facility. Further information as may be required to complete the review of Kairos’s QA program for the conduct of operations and decommissioning can reasonably be left for later consideration in the OL application (or a proposed decommissioning plan, as appropriate) since this information is not necessary for the review of a CP application.

Paragraph 50.55(f) of 10 CFR requires, in part, that a nuclear power plant or fuel reprocessing plant CP holder implement the QA program described in its safety analysis report. Because the Hermes 2 facility is neither a nuclear power plant nor a fuel reprocessing plant, the requirements of 10 CFR 50.55(f) would not apply to Hermes 2. Therefore, the staff recommends that the CPs include the permit condition provided below to: (1) ensure consistency in expectations for Kairos’s implementation of its QA program developed pursuant to 10 CFR 50.34(a)(7); (2) establish criteria for changes to the QA program and for the notifications Kairos must make to the NRC regarding such changes; and (3) facilitate the correction of any identified deficiencies in the implementation of the QA program through the NRC’s enforcement process during construction inspection. The permit condition is as follows:

> Kairos shall implement the QA program described, pursuant to 10 CFR 50.34(a)(7), in Chapter 12, Appendix B, of Revision 1 of the Hermes 2 PSAR, including revisions to the QA program in accordance with the provisions below.
>
> Kairos may make changes to its previously accepted QA program description without prior Commission approval, provided the changes do not reduce the commitments in the QA program description as accepted by the Commission. Changes to the QA program description that do not reduce the commitments must be submitted to the Commission within 90 days.
>
> Changes to the QA program description that do reduce the commitments must be submitted to the Commission and receive Commission approval prior to implementation, as follows:
>
> - Changes must be submitted as specified in 10 CFR 50.4.
> - The submittal of changes to the QA program description must include all pages affected by the changes and must be accompanied by a forwarding letter identifying the changes, the reason for the changes, and the basis for concluding that the revised program incorporating the changes continues to satisfy the PSAR Revision 1 QA program description commitments previously accepted by

the NRC (the letter need not provide the basis for changes that correct spelling, punctuation, or editorial items).

- A copy of the forwarding letter identifying the changes must be maintained as a record by Kairos for three years.

- Changes to the QA program description shall be regarded as accepted by the Commission upon Kairos's receipt of a letter to this effect from the appropriate reviewing office of the Commission or 60 days after Kairos's submittal to the Commission, whichever occurs first.

12.10 Operator Training and Requalification

12.10.1 Introduction

Section 12.10, "Reactor Operating Training and Requalification," of the Hermes 2 PSAR provides preliminary information on Hermes 2 operator training and requalification.

12.10.2 Regulatory Evaluation

The staff reviewed section 12.10.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information related to the operator training and requalification approaches between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.10.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.10.2 of the Hermes 1 SE.

12.10.3 Technical Evaluation

The staff reviewed section 12.10 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.10, "Reactor Operator Training and Requalification"). The staff found that section 12.10 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 approaches to reactor operator training and requalification for the CP application remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 12.10.3 of the Hermes 1 SE.

Based on its review, the staff determined that the level of detail provided regarding Hermes 2 operator training and requalification is adequate and meets the applicable acceptance criteria of NUREG-1537, Part 2, section 12.10, "Operator Training and Requalification."

12.10.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.10 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of Hermes 2 operator training and requalification can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.11 Startup Plan

12.11.1 Introduction

Section 12.11, “Startup Plan,” of the Hermes 2 PSAR discusses the Hermes 2 startup plan.

12.11.2 Regulatory Evaluation

The staff reviewed section 12.11.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary information related to a startup plan between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 12.11.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 12.11.2 of the Hermes 1 SE.

12.11.3 Technical Evaluation

The staff reviewed section 12.11 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 12.11, “Startup Plan”). The staff found that section 12.11 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. Based on the similarities between Hermes 1 and Hermes 2, the staff found that a generally similar approach for the startup plan will be appropriate for Hermes 1 and Hermes 2 (i.e., that the startup plan for both facilities would be provided as part of an OL application). Based on these consistencies, this section incorporates by reference section 12.11.3 of the Hermes 1 SE.

Based on its review, the staff determined that the level of detail provided regarding a Hermes 2 startup plan is adequate and meets the applicable acceptance criteria of NUREG-1537, Part 2, section 12.11, “Startup Plan.”

12.11.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in Hermes 2 PSAR section 12.11 is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of a Hermes 2 startup plan can reasonably be left for later consideration in the OL application since this information is not necessary for the review of a CP application.

12.12 Environmental Report

Kairos did not provide, and the staff did not review, environmental information in the PSAR as described in section 12.12, “Environmental Reports,” of NUREG-1537, Parts 1, “Format and Content,” and 2. In lieu of providing environmental information in the PSAR, Kairos provided environmental information in an Environmental Report submitted as part of the CP application on July 14, 2023. The staff’s evaluation and conclusions of Kairos’s environmental information are proposed to be issued in August 2024.

12.13 Material Control and Accounting Plan

NUREG-1537, Parts 1 and 2, do not include guidance or acceptance criteria for MC&A plans. Furthermore, Kairos did not provide, and the staff did not review, a MC&A plan in the PSAR.

While MC&A is not discussed in the PSAR, PSAR section 9.6, "Possession and Use of Byproduct, Source, and Special Nuclear Material," 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 the future. The staff notes that licensees possessing SNM must comply with the applicable requirements of 10 CFR Part 74, "Material Control and Accounting of Special Nuclear Material."

During the Hermes 2 General Audit, Kairos confirmed via its answer to audit question 1.5-2 (ML23300A144) that it will take the same approach as for Hermes 1 and provide an MC&A plan with a Hermes 2 OL application or other licensing submittal (e.g., a CP amendment) requesting authorization to possess SNM, as appropriate.

Because the CP application does not request authorization to possess SNM, and because information on MC&A is not required for an applicant that does not request authorization to possess SNM, the staff finds that it is acceptable that the Hermes 2 PSAR does not include information on MC&A. Information on MC&A at the facility can reasonably be left for later consideration in a Hermes 2 OL application or other licensing submittal requesting authorization to possess SNM, as appropriate.

12.14 Summary and Conclusions on the Conduct of Operations

The staff evaluated the information on the Hermes 2 conduct of operations as described in PSAR chapter 12 and finds that the preliminary plans and information on the Hermes 2 conduct of operations: (1) meet all applicable regulatory requirements and (2) meet the applicable acceptance criteria in NUREG-1537, Part 2, allowing the staff to make findings that:

- Kairos's preliminary information and commitments to develop the Hermes 2 organization, review and audit programs, procedures, required actions, reporting and recordkeeping requirements, security plan, and operator training and requalification plans are sufficient and meet the applicable regulatory requirements and guidance for the issuance of CPs. Further information on these items can reasonably be left for later consideration in the OL application.

- Information on the Hermes 2 startup plan and MC&A plan can reasonably be left for later consideration in the OL application.

- The preliminary information on emergency planning is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs. Further information can reasonably be left for later consideration in the final safety analysis report (FSAR) and updated emergency plan submitted with an OL application.

- The Hermes 2 QAPD is sufficient and meets the applicable regulatory requirements and guidance for the issuance of CPs. Further information related to QA during operations and decommissioning can reasonably be left for later consideration during future reviews of a Hermes 2 OL application and proposed decommissioning plan, respectively.

Based on these findings and subject to the condition referenced above, the staff concludes the following regarding the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the FSAR.

- There is reasonable assurance: (i) that the construction of the Hermes 2 facility will not endanger the health and safety of the public, and (ii) that construction activities can be conducted in compliance with the Commission's regulations.

- Kairos is technically qualified to engage in the construction of its proposed Hermes 2 facility in accordance with the Commission's regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

12.15 References

American Nuclear Society, American National Standards Institute/American Nuclear Society (ANSI/ANS)-15.8-1995, "Quality Assurance Programs Requirements for Research Reactors," American Nuclear Society, La Grange Park, Illinois.

-----. ANSI/ANS-15.1-2007, "The Development of Technical Specifications for Research Reactors," American Nuclear Society, La Grange Park, Illinois.

-----. ANSI/ANS-15.16-2015, "Emergency Planning for Research Reactors," American Nuclear Society, La Grange Park, Illinois.

-----. ANSI/ANS-15.4-2016, "Selection and Training of Personnel for Research Reactors," American Nuclear Society, La Grange Park, Illinois.

Kairos Power LLC., "Submittal of the Environmental Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," dated October 31, 2021, ML21306A131.

-----. "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," Revision 3, dated May 31, 2023, ML23151A743.

-----. "Kairos Power Response to Hermes 2 General Audit Question 1.5-2," dated October 27, 2023, ML23300A144.

-----. "Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1," dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC). Regulatory Guide 5.59, “Standard Format and Content for a Licensee Physical Security Plan for the Protection of Special Nuclear Material,” Revision 1, NRC: Washington, D.C., dated February 1983, ML100341301.

-----. NUREG-0849, “Standard Review Plan for the Review and Evaluation of Emergency Plans for Research and Test Reactors,” NRC: Washington, D.C., dated October 1983, ML062190191.

-----. NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. Regulatory Guide 2.5, “Quality Assurance Program Requirements for Research and Test Reactors,” Revision 1, NRC: Washington, D.C., dated June 2010, ML093520099.

-----. Regulatory Guide 2.6, “Emergency Planning for Research and Test Reactors and Other Non-Power Production and Utilization Facilities,” Revision 2, NRC: Washington, D.C., 2017, ML17262A472.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report – General Audit,” dated June 2023, ML23160A287.

-----. “Environmental Impact Statement for Construction Permit for the Kairos Hermes [1] Testing Reactor,” NRC: Washington, D.C., dated August 17, 2023, ML23214A269.

-----. “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

13 ACCIDENT ANALYSES

This chapter of the Hermes 2 construction permit (CP) safety evaluation (SE) describes the technical review and evaluation by the U.S. Nuclear Regulatory Commission (NRC) staff (the staff) of the preliminary design of the Kairos Power LLC (Kairos) Hermes 2 facility as presented in chapter 13, “Accident Analysis,” of the Hermes 2 preliminary safety analysis report (PSAR), Revision 1. The staff reviewed Hermes 2 PSAR chapter 13 against applicable regulatory requirements using regulatory guidance and standards to assess the sufficiency of the preliminary design of the Hermes 2 facility.

Chapter 13 of the Hermes 2 PSAR provides information and analyses results for the potential radiological consequences of an accident at the Hermes 2 facility. Kairos uses the dose consequences of a maximum hypothetical accident (MHA) to bound the potential postulated events (anticipated operational occurrences and design-basis accidents). The evaluation of the safety of a test reactor requires analyses of the plant’s responses to postulated equipment failures or malfunctions. Such analyses help to determine the limiting conditions for operation (LCOs), limiting safety system settings, and design specifications for safety-related components and systems to protect public health and safety. Kairos’s analyses are also performed to demonstrate that the reactor site criteria required by Title 10 of the *Code of Federal Regulations* (10 CFR) Part 100, “Reactor Site Criteria” are met for each Hermes 2 unit individually. Kairos is not requesting Commission approval of the safety of any design feature or specification in the CP application, as permitted by 10 CFR 50.35(b).

Kairos uses the functional containment approach in which the tri-structural isotropic (TRISO) fuel and a molten salt coolant, a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF_2) that is referred to as Flibe, are the barriers credited to retain fission products. The use of the functional containment approach to protect public health and safety was approved by the Commission in the Staff Requirements Memorandum to SECY-18-0096, “Functional Containment Performance Criteria for Non-Light-Water-Reactors.” A more detailed discussion on the functional containment approach can be found in section 6.2, “Functional Containment,” of this SE.

In its review of PSAR chapter 13, the staff considered the information in technical report KP-TR-017, “KP-FHR Core Design and Analysis Methodology,” Revision 1, dated September 29, 2022, and technical report KP-TR-022, “Hermes 2 Postulated Event Methodology,” Revision 1, dated May 23, 2024, which are part of the Hermes 2 CP application and referenced in Revision 1 of the PSAR.

For a site with multiple reactor facilities such as Hermes 2, 10 CFR 100.11(b) requires that consideration be given to the degree of independence of the reactors in evaluating the site. If the reactors are independent to the extent that an accident in one reactor would not initiate an accident in another, the size of the exclusion area, low population zone, and population center distance shall be fulfilled with respect to each reactor individually. However, if the reactors are interconnected to the extent that an accident in one reactor could affect the safety of operation of any other, the size of the exclusion area, low population zone, and population center distance shall be based upon the assumption that all interconnected reactors emit their postulated fission product releases simultaneously.

PSAR section 1.4, “Shared Facilities and Equipment,” states that the only shared systems between Hermes 2 Unit 1 and Unit 2 are non-safety systems. In addition, PSAR section 1.4

states that the onsite infrastructure that is not credited to perform a safety function or needed for safe operation may be shared with other nearby or onsite facilities such as Hermes 1. PSAR chapter 7, “Instrumentation and Control Systems,” clarifies that only portions of the non-safety related instrument and controls systems that control shared systems are shared between the units. In PSAR section 13.1, “Initiating Events and Scenarios,” Kairos further indicates that certain initiating events may result in a transient in both units; however, Kairos asserts that the progression of events and the response of each unit remain independent. In the staff’s evaluation of the MHA and other postulated events presented in this chapter of the SE, the degree of independence between Hermes 2 Unit 1 and Unit 2 is considered to determine compliance with 10 CFR 100.11(b) requirements.

13.1 Initiating Events and Scenarios

Section 13.1 of the Hermes 2 PSAR describes the postulated events evaluated by Kairos for the Hermes 2 facility. Several design features in the Hermes 2 design are similar to those in the Hermes 1 design, such as the reactor vessel system, reactor core and nuclear design, thermal-hydraulic design of the reactor, and the primary heat transport system (PHTS). Furthermore, the use of functional containment to contain the radionuclides and the safety-related systems, such as the decay heat removal system (DHRS), reactor control and shutdown system (RCSS), and reactor protection system (RPS) are identical between Hermes 1 and Hermes 2. In section 13.1 of the Hermes 2 PSAR, Kairos states that the postulated event description and analysis methodology presented in chapter 13 of the PSAR and in technical report KP-TR-022 are derived from the Hermes 1 postulated event methodology in technical report KP-TR-018, “Hermes Postulated Event Methodology,” by identifying new postulated initiating events unique to Hermes 2.

The key differences in the Hermes 2 design as compared to the Hermes 1 design include:

- Intermediate heat transport system (IHTS) and its associated subsystems and components, such as the intermediate heat exchanger (IHX), intermediate salt vessels (ISV), superheater, intermediate salt pumps (ISPs), and rupture disks
- Power generation system (PGS) and its associated subsystems such as the turbine generator system, steam system, and the condensate and feedwater system
- Two-unit plant configuration with the shared PGS
- New safety features such as the safety-related rupture disks in the IHTS and an RPS trip of the ISPs
- Limits on the allowable amount of material at risk for release (MAR) in the IHTS and PGS
- Limits on the allowable amount of Flibe and water in the IHTS

In section 13.1 of the Hermes 2 PSAR, Kairos states that the new safety features and proposed operational limits ensure that the events initiating from failures in the Hermes 2 design-specific systems (e.g., IHTS and PGS) can either be prevented or be grouped under the existing Hermes 1 event categories. Furthermore, Kairos states that the new Hermes 2 events do not introduce new phenomena that require identification of additional figures of merit (FOMs) to ensure that consequences of postulated events remain bounded by the MHA.

The objectives of the postulated event analysis as listed in NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1, chapter 13, are:

- Ensure that enough events have been considered to include any accident with significant radiological consequences. Rejection of a potential event should be justified in the discussions.
- Categorize the initiating events and scenarios by type and likelihood of occurrence so that only the limiting cases in each group must be quantitatively analyzed.
- Develop and apply consistent, specific acceptance criteria for the consequences of each postulated event.

Therefore, the scope of technical evaluation presented in this SE is to ensure that:

- Hermes 2 design-specific postulated events are adequately identified and categorized,
- Hermes 2 design-specific postulated events are adequately described, and important mitigation features are identified,
- Adequate FOMs and associated acceptance criteria are identified to ensure that the consequences of the postulated events remain bounded by the MHA,
- MHA remains bounding for Hermes 2 events, and
- Progression of events and the response of each unit remain independent in compliance with 10 CFR 100.11(b) requirements.

In addition to the information in the Hermes 2 PSAR and KP-TR-022, the staff's evaluation was also supported by the general audit (Agencywide Documents Access and Management System (ADAMS) Accession No. ML24193A214) and the independent scoping calculations performed by the staff and its contractors using a MELCOR/SCALE computer model.

The event categories identified in PSAR section 13.1 are consistent with those listed in NUREG-1537, Part 1 section 13.1, "Accident-Initiating Events and Scenarios," except for the malfunction of an experiment. As discussed in chapter 10, "Experimental Facilities and Utilization," of this SE, Hermes 2 will not include special facilities dedicated to the conduct of reactor experiments or experimental programs, so the experiment malfunction event is not applicable. Events Kairos precluded by design are discussed in section 13.1.10, "Prevented Events," of this SE.

13.1.1 Maximum Hypothetical Accident

13.1.1.1 Introduction

Section 13.1.1, "Maximum Hypothetical Accident," of the Hermes 2 PSAR provides the MHA event description and assumptions. Section 13.2.1, "Maximum Hypothetical Accident," of the Hermes 2 PSAR provides a conservative evaluation of the MHA in order to bound the radionuclide release of all credible accidents. This analysis is done to demonstrate that the 10 CFR 100.11, "Determination of exclusion area, low population zone, and population center distance," dose reference values are met at the exclusion area boundary (EAB) and outer boundary of the low population zone (LPZ) in support of the safety analysis requirements in 10 CFR 50.34(a)(1)(i) and the test reactor siting evaluation factors in 10 CFR Part 100, Subpart A, "Evaluation Factors for Stationary Power Reactor Site Applications Before January 10, 1997 and for Testing Reactors," for all credible accidents.

An important component of the analysis of the MHA and its consequences is the identification of the radionuclide MAR due to the accident scenario, which includes the release from TRISO fuel, including fuel manufacturing defects, Flibe coolant inventory, gas space inventory, and radionuclides deposited in steel or graphite structures within the reactor and PHTS. The radionuclide retention and transport are determined by following the methodology provided in the mechanistic source term topical report KP-TR-012-NP-A, "KP-FHR Mechanistic Source Term Methodology Topical Report," Revision 3, dated March 28, 2022. Bounding values for Flibe circulating activity, retained tritium, and activated argon are assumed in KP-TR-012-NP-A. In PSAR section 14.1, "Introduction," Kairos provided regulatory controls based on the bounding values assumed in the MHA analysis. PSAR chapter 14, "Technical Specifications," table 14.1-1, "Proposed Variables and Conditions for Technical Specifications," includes proposed technical specification (TS) LCOs in section 3.3, "Coolant Systems," which will include an upper bounding radionuclide limit in the reactor coolant during normal operation to ensure postulated events do not exceed limits. The proposed LCO will also include an upper bounding limit on quantity of radioactive MAR in the cover gas, IHTS, and PGS to ensure a postulated event does not exceed limits. The specific values for the upper bounding limits will be based upon the finalized event analyses, including the MHA, and are to be provided by Kairos in the Hermes 2 operating license (OL) application.

Retention and transport of radionuclides is predominately a function of the associated fuel, Flibe, and vapor space temperatures, as well as the available surface area and volumes for depositing radionuclides. The MHA uses a bounding fuel, Flibe, and stainless steel 316 temperature versus time profile. These factors bound the conditions of the other evaluated events.

13.1.1.2 Regulatory Evaluation

The staff reviewed section 13.1.1.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the evaluated MHA between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.1.2 of the Hermes 1 SE.

13.1.1.3 Technical Evaluation

The staff reviewed section 13.1.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.1 "Maximum Hypothetical Accident"). The staff found that section 13.1.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes, which are evaluated below. The staff also verified that the MHA remains identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 13.1.1.3 of the Hermes 1 SE.

13.1.1.3.1 Minor Changes Compared to Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 13.1.1, as compared to the information in Hermes 1 PSAR section 13.1.1, include the following:

- The addition of the IHTS and PGS
- Use of KP-TR-022 instead of KP-TR-018

In Hermes 2 PSAR section 13.1.1, the MHA, in effect, considers the MAR in the two new systems of the Hermes 2 facility, the IHTS and PGS. The staff reviewed the Hermes 2 PSAR and KP-TR-022, including information supporting the PSAR reviewed during the general audit, and determined that the Hermes 2 conservative analysis assumptions in the MHA remain identical to those in Hermes 1. Specifically, the staff verified that no additional radionuclide generation occurs in the IHTS and PGS, the MAR in the IHTS and PGS originates in the PHTS, the Hermes 2 functional containment does not include the IHTS or PGS, and Hermes 2 PSAR table 13.1-1, "Acceptance Criteria for Figures of Merit," includes FOMs and acceptance criteria to ensure that the consequences of events that include releases from the IHTS and PGS are bounded by the consequences of the MHA. The staff observed that, in effect, the conservative radionuclide release modeling in the MHA analysis neglects any radionuclide retention in the IHTS and PGS. Based on the above, the staff finds that the addition of the IHTS and PGS to the MHA is acceptable.

Additionally, the staff finds the use of KP-TR-022 instead of KP-TR-018 to be acceptable because KP-TR-022 is an updated version of KP-TR-018 that contains additional information specific to Hermes 2.

On the basis of its review, the staff finds that the level of detail provided in the Hermes 2 MHA demonstrates an adequate basis for a preliminary design and satisfies the applicable guidance and acceptance criteria of NUREG-1537, Part 2, "Standard Review Plan and Acceptance Criteria," chapter 13, "Accident Analyses," allowing the staff to make the following relevant findings:

- Kairos developed and analyzed an MHA, which is an accident that would release fission products and would have consequences greater than any credible accident. The MHA scenario is not credible, and the combination of bounding conditions analyzed is beyond what is assumed for design-basis accidents. The MHA serves as a bounding accident analysis for the Hermes 2 facility.
- Because the assumptions of the scenario are bounding, the doses calculated for the MHA will likely not be exceeded by any accident considered credible.

13.1.1.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analysis of the MHA, as described in Hermes 2 PSAR section 13.1.1 is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35, "Issuance of construction permits," and 10 CFR 50.40, "Common standards." Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to the design basis during the evaluation of the final safety analysis report (FSAR) as part of the OL application review.

13.1.2 Insertion of Excess Reactivity

13.1.2.1 Introduction

Section 13.1.2, "Insertion of Excess Reactivity," of the Hermes 2 PSAR and KP-TR-022 discuss the insertion of excess reactivity postulated event. KP-TR-022 appendix A, section A.1, "Insertion of Excess Reactivity," provides an example analysis of the insertion of excess reactivity postulated event. The reactivity insertion transient involves a change in core reactivity that adds heat to the primary system. The narrative for the assumed limiting event is given in KP-TR-022 section 3.2.2.2, “Insertion of Excess Reactivity,” and in PSAR section 13.1.2. The PSAR states that this assumed limiting event bounds other insertion of reactivity events, including events listed in PSAR section 13.1.2. Kairos identified this event as one of the bounding fuel performance cases, as stated in KP-TR-022 section 4.5.2.2, “Transient Analysis Methods.” In KP-TR-022 section 3.2.2.3, “Increase in Heat Removal,” Kairos also states that the increase in heat removal events are bounded by the insertion of excess reactivity event. Therefore, the increase in heat removal events are grouped under the insertion of excess reactivity event category in section 13.1.2 of the PSAR.

PSAR section 13.1.10.7, “Insertion of Excess Reactivity Beyond Rate Assumed in Postulated Events,” describes why rapid reactivity insertions beyond that assumed in PSAR section 13.1.2 are not considered. The staff evaluated this in section 13.1.10.3, “Technical Evaluation,” of this SE.

13.1.2.2 Regulatory Evaluation

The staff reviewed section 13.1.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the postulated insertion of excess reactivity events between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.2.2 of the Hermes 1 SE.

13.1.2.3 Technical Evaluation

The staff reviewed section 13.1.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.2, “Insertion of Excess Reactivity”). The staff found that section 13.1.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few significant changes, which are evaluated below in section 13.1.2.3.1. The staff found that the following portions of section 13.1.2 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 13.1.2.1, “Initial Conditions Assumptions”
- Section 13.1.2.2, “Structures, Systems, and Components Mitigation Assumptions”
- Section 13.1.2.3, “Transient Assumptions”

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, section 13.1.2 of the Hermes 2 PSAR contains information consistent with section 13.1.2 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 13.1.2.3 of the Hermes 1 SE.

13.1.2.3.1 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in section 13.1.2 of the Hermes 2 PSAR, as compared to section 13.1.2 of the Hermes 1 PSAR, include information regarding the following:

- The following events were added to the increase in heat removal group of events in the insertion of excess reactivity postulated event category:
    - ISP overspeed

- spurious opening of a turbine bypass valve or steam safety valve
- superheater shell leak
- steam line break
- spurious actuation of PHTS normal decay heat removal rejection radiator

These changes are identified in section 13.1.2 of the Hermes 2 PSAR.

The staff evaluated the sufficiency of this additional preliminary information on the Hermes 2 preliminary analysis of the insertion of excess reactivity postulated event using the guidance and acceptance criteria from NUREG-1537, Parts 1 and 2, chapter 13.

The newly identified increase in heat removal events adequately account for the potential initiators from the newly added IHTS and PGS systems. Insertion of excess reactivity can be caused by overcooling due to the combination of decreasing PHTS temperature and negative coolant and void reactivity coefficients. Thus, the staff finds the that the Hermes 2 insertion of excess reactivity postulated events and increase in heat removal events are adequately identified and classified.

The Hermes 2 PSAR identifies a continuous withdrawal of a control element as the limiting insertion of excess reactivity event for the Hermes 2 design. The staff completed a scoping calculation for a main steam line break event to further inform the review of the newly identified insertion of excess reactivity postulated events for Hermes 2. The scoping calculation showed that this event does not surpass the identified limiting insertion of excess reactivity postulated event in terms of severity and that the MHA remains bounding. Furthermore, the scoping calculation also show that the large thermal inertia of the IHTS and PHTS salt result in an overall mild temperature response in the reactor core. As identified in appendix A of this SE, Kairos must confirm the limiting event, key conservative analysis assumptions, and initial conditions through sensitivity calculations or other appropriate analysis as part of the OL application.

Regarding event progression and mitigation, the Hermes 1 safety systems that mitigate postulated events are also present in the Hermes 2 design. Specifically, the Hermes 1 and Hermes 2 reactor trip signal for the insertion of excess reactivity postulated events is initiated by a high flux protection signal. The Hermes 2 RPS has new safety-related trip signals for the ISP to trip concurrently with the primary salt pump (PSP) to limit overcooling. The PSP and ISP trips effectively isolate the PHTS from the IHTS and PGS due to a significant reduction in heat transfer, leading to a subsequent event progression similar to those for Hermes 1 events.

The staff observed that some insertion of excess reactivity postulated events (e.g., opening of turbine bypass valve) may result in initiation of postulated events in both units; however, systems needed to mitigate these events (i.e., RPS, RCSS, DHRS, reactor vessel) are independent and not shared between units. Additionally, the large thermal inertia of the intermediate loops minimizes the possibility of transients in one unit affecting the other unit and maintains unit independence.

Kairos has not identified any new FOMs for the Hermes 2 insertion of excess reactivity postulated events. As discussed above in SE section 13.1.1.3, the Hermes 2 design and functionality remain identical to Hermes 1 with respect to the conservative analysis assumptions in the MHA, no additional radionuclide generation occurs in the Hermes 2 systems not included in the Hermes 1 (i.e., IHTS and PGS), the Hermes 2 functional containment does not include the IHTS and PGS, and Hermes 2 PSAR table 13.1-1 includes FOMs and acceptance criteria to ensure that the consequences of events that include releases from the IHTS and PGS are bounded by the consequences of the MHA. Therefore, the staff finds that the FOMs identified for the Hermes 2 insertion of excess reactivity postulated event are acceptable.

On the basis of its review, the staff finds that:

- The Hermes 2 PSAR adequately identifies and categorizes insertion of excess reactivity and increased heat removal events that are unique to the Hermes 2 design.
- The Hermes 2 PSAR provides adequate description of design-specific insertion of excess reactivity and increased heat removal events, including the event mitigation features.
- The Hermes 2 PSAR identifies adequate FOMs and associated acceptance criteria to ensure that the consequences of the insertion of excess reactivity and increased heat removal postulated events remain bounded by the MHA.
- The MHA remains bounding for the insertion of excess reactivity and increased heat removal events specific to Hermes 2.
- The Hermes 2 reactors are independent to the extent that postulated insertion of excess reactivity and increased heat removal events in one unit will not initiate an accident in the other unit, in compliance with 10 CFR 100.11(b) requirements.

13.1.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analysis of the insertion of excess reactivity postulated events, as described in PSAR section 13.1.2, is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information as may be required to complete the review of the Hermes 2 insertion of excess reactivity postulated event can reasonably be left for later consideration at the OL stage since this information is not necessary for the review of a CP application.

13.1.3 Salt Spills

13.1.3.1 Introduction

Section 13.1.3, “Salt Spills,” of the Hermes 2 PSAR describes the postulated limiting salt spill event. A salt spill is a loss of coolant event in which a pipe break or other leak causes Flibe and associated radionuclides to be released into the reactor building. The PSAR states that the loss of salt inventory is detected by the RPS based on low reactor coolant inventory, and the reactor is shut down by inserting the shutdown elements. The decay heat removal safety function is accomplished by parasitic losses or the operation of the DHRS and parasitic heat losses. Design features such as the safety-related trip function for the PSP and anti-siphon features limit the salt inventory loss. Radionuclides are mobilized by aerosol generation from the break, pool splash, evaporation from the Flibe free surface, and air ingress oxidizing the non-wetted graphite surfaces. Leaks from the IHTS are also included in the salt spill event category.

13.1.3.2 Regulatory Evaluation

The staff reviewed section 13.1.3.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the evaluation of postulated salt spill events between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.3.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.3.2 of the Hermes 1 SE.

13.1.3.3 Technical Evaluation

The staff reviewed section 13.1.3 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.3, "Salt Spills"). The staff found that section 13.1.3 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few minor and significant changes, which are evaluated below in sections 13.1.3.3.1 and 13.1.3.3.2, respectively. The staff found that the following portions of section 13.1.3 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- 13.1.3.1, "Initial Conditions Assumptions"
- 13.1.3.2, "Structures Systems and Components Mitigation Assumptions"
- 13.1.3.3, "Transient Assumptions"

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, section 13.1.3 of the Hermes 2 PSAR contains information consistent with section 13.1.3 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 13.1.3.3 of the Hermes 1 SE.

13.1.3.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 13.1.3, as compared to the information in Hermes 1 PSAR section 13.1.3, includes the following:

- Added text to clarify that the RPS trips the heat rejection blower to limit the amount of air ingress following a postulated heat rejection radiator (HRR) tube break during low power operations.

In Hermes 2 PSAR section 13.1.3, Kairos states that in the limiting salt spill postulated event scenario, the RPS trips the heat rejection blower to limit the amount of air ingress following postulated HRR tube breaks during low power operations. The added text "during low power operations" is not a substantive change from the Hermes 1 PSAR description of the scenario for the limiting salt spill postulated event. As described in Hermes 2 PSAR section 5.1.1.6, "Heat Rejection Subsystem," for the Hermes 2 reactor, the HRR is only in operation during low power operations when the PGS is not in operation. Therefore, the limiting salt spill postulated event scenario remains the same with respect to limiting air ingress following postulated HRR tube breaks. Based on the above, the staff finds that the clarification regarding the RPS trip of the heat rejection blower is acceptable.

13.1.3.3.2 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in section 13.1.3 of the Hermes 2 PSAR, as compared to section 13.1.3 of the Hermes 1 PSAR, include information regarding the following:

- Two new Hermes 2-specific events were added to the other salt spill group of events bounded by the limiting salt spill postulated event:
    - leaks from the intermediate heat transport system that contains a non-Flibe coolant, which may contain a non-zero amount of radionuclides
    - intermediate heat exchanger tube break or leak

These changes are identified in section 13.1.3 of the Hermes 2 PSAR.

The staff evaluated the sufficiency of this additional preliminary information on the Hermes 2 preliminary analysis of the limiting salt spill postulated event using the guidance and acceptance criteria from NUREG-1537, Parts 1 and 2, chapter 13.

The additional salt spill events specific to the Hermes 2 design adequately account for events that initiate in the newly added IHTS and include the additional radionuclide release pathways through and from the IHTS, as discussed in KP-TR-022 sections 3.2.2.1, "Salt Spills," 3.2.2.7, "Intermediate Heat Exchanger Tube Break," and 4.5.1, "Salt Spills." Thus, the staff finds the that the Hermes 2 salt spill postulated events are adequately identified and classified.

As described in Hermes 2 PSAR section 13.1.3, the assumed limiting event for this category is a hypothetical double-ended guillotine break in the PHTS piping. As identified in appendix A of this SE, Kairos must confirm the limiting event, as well as key conservative analysis assumptions and initial conditions, as part of the OL application through sensitivity calculations or other appropriate analysis.

The event progression and mitigation approach for the additional salt spill events specific to Hermes 2 are similar to those for the limiting salt spill postulated event described in the PSAR, while considering the potential additional transport and release pathways through the IHTS. Furthermore, important phenomena such as jet breakup and aerosolization for the BeNaF intermediate salt are similar to the phenomena for Flibe primary salt in the limiting salt spill postulated event and are modeled in the same way.

The same safety systems that play an accident mitigation role in the limiting salt spill postulated event for Hermes 1 are also available for Hermes 2. As described in Hermes 2 PSAR section 13.1.3.2, there is no change in the role of the RPS, DHRS, pebble handling and storage system (PHSS) trip, and RCSS in shutting down the reactor and removing decay heat during the limiting salt spill postulated event from that described in the Hermes 1 PSAR, even with consideration of the added IHTS and PGS in Hermes 2. In addition, as described in Hermes 2 PSAR section 13.1 and KP-TR-022 section 3.2.2.7, the Hermes 2 RPS will concurrently trip both the PSP and ISP to minimize heat transfer in the IHX, therefore limiting the PHTS cooldown due to events initiated in the IHTS. Consistent with the Hermes 1 PSAR, the Hermes 2 PSAR section 13.1.3 states that the anti-siphon design feature in the PHTS is credited to limit the amount of Flibe available to spill out of the break in the limiting salt spill postulated event. The staff observed that the same design feature will limit the amount of Flibe lost in the IHX tube break salt spill.

With respect to the salt spill event radionuclide transport and release phenomena, the aerosolization of salt from an IHX tube break or leak event would be limited as compared to aerosolization from the PHTS salt spill event due to the difference in thermal-hydraulic conditions in the downstream IHTS volume. Additional radionuclide generation does not occur in the Hermes 2 IHTS, and the primary source of MAR in the IHTS is operational leakage from the PHTS. Therefore, the limiting salt spill postulated event is bounding for other postulated salt spill events with respect to the MAR. Furthermore, as described Hermes 2 PSAR table 13.1-1 and table 14.1-1, Hermes 2 will have a limit on the quantities of MAR in the IHTS, which will significantly limit the releases and any dose consequences of a break from the IHTS and ensure that a postulated event does not exceed the MHA dose.

As described in Hermes 2 PSAR section 13.1.3 and table 13.1-1, no new FOMs and associated acceptance criteria to ensure that the MHA remains bounding for salt spill events are identified for the salt spill postulated events specific to Hermes 2. No additional radionuclide generation occurs in the Hermes 2 IHTS. In addition, the MHA preliminary analysis is not affected by the Hermes 2 design differences because the radionuclide release modeling in the MHA analysis assumes a release directly from the PHTS, which effectively neglects any radionuclide retention in the IHTS and PGS. Therefore, the currently identified FOMs for Hermes 1 are also acceptable for Hermes 2 events in this category.

On the basis of its review, as described above, the staff finds that:

- The Hermes 2 PSAR adequately identifies and categorizes the salt spill events that are unique to the Hermes 2 design.
- The Hermes 2 PSAR adequately describes Hermes 2 design-specific salt spill events, including the event mitigation features.
- The Hermes 2 PSAR identifies adequate FOMs and associated acceptance criteria to ensure that the consequences of the salt spill events remain bounded by the MHA.
- The MHA remains bounding for the Hermes 2-specific salt spill events.
- The Hermes 2 reactors are independent to the extent that a postulated salt spill event in one unit will not initiate and accident in the other unit, in compliance with 10 CFR 100.11(b) requirements.

13.1.3.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analysis of the postulated salt spill event, as described in PSAR chapter 13, is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to the design basis during the evaluation of the FSAR as part of the OL application review.

13.1.4 Loss of Forced Circulation

13.1.4.1 Introduction

Section 13.1.4, "Loss of Forced Circulation," of the Hermes 2 PSAR and KP-TR-022-NP sections 3.2.2.4 "Loss of Forced Circulation," and 4.5.3, "Loss of Forced Circulation," discuss the loss of forced circulation postulated event. KP-TR-022-NP section A.4, “Loss of Forced Circulation,” provides example analyses of the loss of forced circulation postulated event. Two bounding transient scenarios, overheating and overcooling, are analyzed for the loss of forced circulation postulated event. The postulated overheating event intends to bound the consequence of overheating due to a loss of forced circulation or loss of normal heat sink, and the postulated overcooling event intends to bound the consequence of freezing in the downcomer due to a loss of forced circulation. Kairos states in PSAR section 13.1.4 that the assumed limiting loss of forced circulation event bounds other loss of forced circulation events, including events listed in PSAR section 13.1.4.

13.1.4.2 Regulatory Evaluation

The staff reviewed section 13.1.4.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the postulated loss of forced circulation event between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.4.2 of the Hermes 1 SE.

13.1.4.3 Technical Evaluation

The staff reviewed section 13.1.4 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.4, “Loss of Forced Circulation”). The staff found that section 13.1.4 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few significant changes, which are evaluated below in SE section 13.1.4.3.1. The staff found that the following portions of section 13.1.4 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 13.1.4.1, “Initial Conditions Assumptions”
- Section 13.1.4.2, “Structures Systems and Components Mitigation Assumptions”
- Section 13.1.4.3, “Transient Assumptions”

Since the Hermes 2 system design and functionality largely remain identical to Hermes 1, apart from the differences evaluated below, section 13.1.4 of the Hermes 2 PSAR contains information consistent with section 13.1.4 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 13.1.4.3 of the Hermes 1 SE.

13.1.4.3.1 Significant Change Compared to the Hermes 1 PSAR

The significant change contained in section 13.1.4 of the Hermes 2 PSAR, as compared to section 13.1.4 of the Hermes 1 PSAR, includes information regarding the following:

- The following events were added to the loss of normal heat sink group of events in the loss of forced circulation postulated event category:
    - Turbine trip
    - ISP failure
    - Superheater tube rupture
- A paragraph was added to further discuss a postulated superheater tube rupture.

These changes are identified in section 13.1.4 of the Hermes 2 PSAR.

The staff evaluated the sufficiency of this additional preliminary information on the Hermes 2 preliminary analysis of the loss of forced circulation postulated event using the guidance and acceptance criteria from NUREG-1537, Parts 1 and 2, chapter 13.

The newly identified events adequately account for the potential loss of normal heat sink initiators in the newly added IHTS or PGS. Loss of forced circulation and loss of normal heat sink events result in a reduction in heat removal from the reactor. Compared to other loss of normal heat sink events in the Hermes 1 and Hermes 2 PSARs, a loss of heat sink due to initiating events in the IHTS or PGS would have a similar impact on the reactor thermal-hydraulic and neutronic response; however, they would likely evolve more slowly than an initiating event in the PHTS because of the separation of the PHTS and IHTS and the large thermal inertia of those systems. For these reasons, the staff finds that the Hermes 2 loss of forced circulation postulated events are adequately identified and classified.

The Hermes 2 PSAR identifies a PSP seizure as the limiting loss of forced circulation event for the Hermes 2 design. The staff performed scoping calculations for a loss of forced circulation event for Hermes 2. These scoping calculations showed that the MHA bounds a loss of forced circulation event. As identified in appendix A of this SE, Kairos must confirm the loss of forced circulation limiting event, as well as key conservative analysis assumptions and initial conditions, as part of the OL application through sensitivity calculations or other appropriate analysis.

The same safety systems that mitigate loss of forced circulation events for the Hermes 1 design are also available for Hermes 2. These include the RPS, which detects the off-normal condition and initiates a reactor trip and PSP trip; the DHRS, which is credited for decay heat removal when the normal heat removal pathway is unavailable; and the RCSS, which provides the negative reactivity to shut down the reactor when a trip is demanded.

For the Hermes 2 design, the RPS will also initiate an ISP trip. The PSP and ISP trips effectively isolate the PHTS from the IHTS and PGS due to a significant reduction in heat transfer, leading to a subsequent event progression similar to those for Hermes 1. In addition, Hermes 2 relies upon the design of the IHTS to mitigate a postulated superheater tube rupture event and prevent gross failure of the IHX, as further evaluated in section 13.1.10.3.2 of this SE.

The staff observed that events initiating in the PGS (e.g., turbine trip) may result in postulated events in both units. However, systems needed to mitigate the events are independent and not shared between units, so the event progression in one unit would not affect the progression in the other unit.

Kairos has not identified any new FOMs for the Hermes 2-specific loss of forced circulation events. As discussed in SE section 13.1.1.3, the Hermes 2 design and functionality remain identical to Hermes 1 with respect to the conservative analysis assumptions in the MHA; no additional radionuclide generation occurs in the Hermes 2 systems not included in Hermes 1 (i.e., IHTS and PGS); the Hermes 2 functional containment does not include the IHTS and PGS; and Hermes 2 PSAR table 13.1-1 includes FOMs and acceptance criteria to ensure that the consequences of events that include releases from the IHTS and PGS are bounded by the consequences of the MHA. Therefore, the staff finds that the FOMs identified for the Hermes 2 loss of forced circulation postulated events are acceptable.

On the basis of its review, the staff finds that the level of detail provided on the preliminary analyses of the loss of forced circulation postulated events satisfies the applicable acceptance criteria of NUREG-1537, Part 2, chapter 13 and that:

- The Hermes 2 PSAR adequately identifies and categorizes loss of forced circulation and loss of heat sink events that are unique to the Hermes 2 design.
- The Hermes 2 PSAR adequately describes Hermes 2 design-specific loss of forced circulation and loss of heat sink events, including the event mitigation features.
- The Hermes 2 PSAR identifies adequate FOMs and associated acceptance criteria to ensure that the consequences of the loss of forced circulation and loss of heat sink events remain bounded by the MHA.
- The MHA remains bounding for the Hermes 2-specific loss of forced circulation and loss of heat sink events.
- The Hermes 2 reactors are independent to the extent that a postulated loss of forced circulation or loss of heat sink event in one unit will not initiate an accident in the other unit, in compliance with 10 CFR 100.11(b) requirements.

13.1.4.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analyses of the loss of forced circulation postulated events, as described in PSAR section 13.1.4, are sufficient and meet the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to the design basis during the evaluation of the FSAR as part of the OL application review.

13.1.5 Mishandling or Malfunction of Pebble Handling and Storage System

13.1.5.1 Introduction

Section 13.1.5, “Mishandling or Malfunction of the Pebble Handling and Storage System,” of the Hermes 2 PSAR describes the preliminary evaluation of the category of postulated events involving a mishandling or malfunction of the PHSS. As assumed by Kairos, the limiting postulated event for this category of events is a break in a fuel transfer line during extraction, resulting in a spill of pebbles onto the floor of the room.

13.1.5.2 Regulatory Evaluation

The staff reviewed section 13.1.5.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the postulated events involving a mishandling or malfunction of the PHSS between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.5.2 of the Hermes 1 SE.

13.1.5.3 Technical Evaluation

The staff reviewed section 13.1.5 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.5, "Mishandling or Malfunction of Pebble Handling and Storage System"). The staff found that section 13.1.5 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR. The staff also verified that the Hermes 2 PHSS design and functionality remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 13.1.5.3 of the Hermes 1 SE.

On the basis of its review, the staff finds that the level of detail provided on the postulated PHSS event is consistent with the applicable guidance and acceptance criteria in NUREG-1537, Parts 1 and 2, chapter 13, "Accident Analysis," and demonstrates an adequate design basis for a preliminary design.

Additionally, as discussed in section 9.3.3.1, "Minor Changes Compared to the Hermes 1 PSAR," of this SE, each Hermes 2 unit has its own PHSS, and no components are shared between the units. Therefore, the staff finds that the Hermes 2 reactors are independent to the extent that a postulated PHSS mishandling or malfunction event in one unit will not initiate an accident in the other unit, in compliance with 10 CFR 100.11(b) requirements.

13.1.5.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analysis of the postulated PHSS event, as described in PSAR chapter 13, is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration during the OL application. The staff will confirm that the final design conforms to the design basis during the evaluation of the FSAR as part of the OL application review.

13.1.6 Radioactive Release from a Subsystem or Component

13.1.6.1 Introduction

Section 13.1.6, "Radioactive Release from a Subsystem or Component," of the Hermes 2 PSAR describes the preliminary evaluation of the category of postulated events with radioactive release from a subsystem or component due to the failure of a system or component that contains radioactive material. As assumed by Kairos, the limiting event for this category of events is a seismic event that results in the failure of all systems containing radioactive material that are not qualified to maintain structural integrity in a design-basis earthquake for a single unit (including shared systems).

13.1.6.2 Regulatory Evaluation

The staff reviewed section 13.1.6.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the preliminary evaluation of postulated radioactive release events from a subsystem or component between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.6.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.6.2 of the Hermes 1 SE.

13.1.6.3 Technical Evaluation

As shown in PSAR table 13.1-1, the only FOM to ensure that the radioactive release from a subsystem or component category of events is bounded by the MHA radiological consequence analysis is the amount of radioactive material contained in the subsystems and components. As stated in section 13.1.6 of the PSAR, Kairos is applying a design requirement on the amount of MAR in the systems expected to accumulate radionuclides during operation. Kairos identifies systems where the accumulation of radionuclides is expected to occur during the plant operating lifetime and could be released by a single initiating event such as a design-basis earthquake. The systems identified by Kairos in PSAR chapter 9, “Auxiliary Systems,” that contain radionuclides are the tritium management system, inert gas system, chemistry control system (including filters), inventory management system, IHTS, and PGS. The staff finds that subsystem or component MAR design limits can be set such that the MHA release remains bounding, but the combined release from all subsystems and components not designed to withstand the limiting external or internal event will need to be evaluated as part of the OL application when specific MAR values are available.

The staff finds that the level of detail provided on radioactive release from a subsystem or component is consistent with the applicable guidance and acceptance criteria in NUREG-1537, Parts 1 and 2, chapter 13. Specifically, NUREG-1537, Part 2, chapter 13, subheading “External Events,” states that:

> [f]or events that cause facility damage […], the damage is within the bounds discussed for other accidents in this chapter. Therefore, exposure to the workers and the public is within acceptable limits and external events do not pose an unacceptable risk to the health and safety of the public.

Limiting the stored MAR in subsystems or components below an amount that ensures the MHA remains bounding satisfies the NUREG-1537 guidance.

13.1.6.4 Conclusion

Based on the staff findings above, the staff concludes that the preliminary analyses of the radioactive releases from a subsystem or component are sufficient and meet the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. The combined release from all subsystems and components not designed to withstand the limiting external or internal event will need to be evaluated as part of the OL application when specific MAR subsystem or component values are available.

13.1.7 (not used)

13.1.8 General Challenges to Normal Operation

13.1.8.1 Introduction

Section 13.1.8, “General Challenges to Normal Operation,” of the Hermes 2 PSAR states that this category of events includes challenges to normal operation that require or cause an automatic or manual shutdown of the plant but are not covered by another event category. These events could be caused by control system anomalies, operator actions, or malfunctions of equipment or instrumentation.

13.1.8.2 Regulatory Evaluation

The staff reviewed section 13.1.7.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the postulated challenges to normal operation between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.7.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.7.2 of the Hermes 1 SE.

13.1.8.3 Technical Evaluation

The staff reviewed section 13.1.8 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.8, "General Challenges to Normal Operation"). The staff found that section 13.1.8 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a minor change, which is evaluated below. The staff also verified that the Hermes 2 general challenges to normal operations remain largely identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 13.1.7.3 of the Hermes 1 SE.

13.1.8.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 13.1.8, as compared to the information in Hermes 1 PSAR section 13.1.8, includes the following:

- "[H]eat rejection subsystem" was replaced with "intermediate heat transport system" in the list of plant systems that could challenge normal operations

The IHTS for Hermes 2 is the analog of the heat rejection subsystem for Hermes 1; the PHTS transfers heat to these respective systems during normal operation.

While the Hermes 2 design includes new systems compared to Hermes 1, the systems do not introduce new phenomena or FOMs. Therefore, the staff's conclusion that events in the challenges to normal operation event category are expected to be less limiting than the bounding events in other event categories (e.g., insertion of excess reactivity, loss of forced circulation) is unchanged. Based on the above, the staff finds that replacing the heat rejection subsystem with the intermediate heat transport system in PSAR section 13.1.8 to be acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 general challenges to normal operation demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Part 2, chapter 13.

13.1.8.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analyses of general challenges to normal operation are sufficient and meet the applicable regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Final determination that the consequences of chapter 13 postulated events bound those of general challenges to normal operation will be evaluated when a detailed design is provided as part of the OL application.

13.1.9 Internal and External Hazard Events

13.1.9.1 Introduction

Section 13.1.9, "Internal and External Hazard Events," of the Hermes 2 PSAR describes the types of internal and external hazard events considered in the Hermes 2 design bases and the design's ability to cope with these events.

13.1.9.2 Regulatory Evaluation

The staff reviewed section 13.1.8.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the evaluation of internal and external hazard events between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.8.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.8.2 of the Hermes 1 SE.

13.1.9.3 Technical Evaluation

The staff reviewed section 13.1.9 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.9, "Internal and External Hazard Events"). The staff found that section 13.1.9 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few significant changes, which are evaluated below in section 13.1.9.3.1. The staff found that the portions of section 13.1.9 in the Hermes 2 PSAR that discuss the following subjects contain information consistent with the Hermes 1 PSAR:

- The internal fire and internal water flood events listed as internal hazard events in the design basis
- The list of all external hazard events in the design basis
- The general discussion of protection of engineered safety features
- The discussion of seismic events

Since the Hermes 2 system design, functionality, and analyses largely remain identical, apart from the differences evaluated below, section 13.1.9 of the Hermes 2 PSAR contains information consistent with section 13.1.9 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 13.1.8.3 of the Hermes 1 SE.

13.1.9.3.1 Significant Change Compared to the Hermes 1 PSAR

A significant change contained in section 13.1.9 of the Hermes 2 PSAR, as compared to section 13.1.9 of the Hermes 1 PSAR, includes information regarding the following:

- Identification of two additional hazard events unique to Hermes 2: turbine missiles and high-energy breaks in the PGS

The staff's evaluation of a turbine missile generated due to a postulated failure of a turbine generator is presented in section 9.9.2, "Turbine Generator System," of this SE, and the staff's evaluation of the high-energy steam line break is presented in section 9.9.1, "Steam System," of this SE. As described in those SE sections, the staff finds that the preliminary design of the facility is consistent with PDC 4 for safety-related SSCs to be appropriately protected against the dynamic effects of turbine generator and steam system malfunctions and accidents. In addition, the staff finds that the preliminary design satisfies the applicable acceptance criteria of NUREG-1537, Part 2, section 9.7, "Other Auxiliary Systems," in that potential malfunctions should not result in reactor accidents, uncontrolled release of radioactivity, or interfere with or prevent safe shutdown of the reactor.

The other consequences of a turbine failure event are bounded by the loss of forced circulation event as evaluated in section 13.1.4.3 of this SE. The staff's evaluation of increased heat removal due to a steam line break is presented in section 13.1.2.3 of this SE.

The staff finds the inclusion of turbine missiles and high-energy breaks in the PGS as internal hazard events in PSAR section 13.1.9 acceptable because they account for design differences between Hermes 1 and Hermes 2, and Kairos has adequately addressed the events elsewhere in the PSAR.

13.1.9.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analyses of the internal and external hazard events are sufficient and meet the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration during the OL application.

13.1.10 Prevented Events

13.1.10.1 Introduction

PSAR section 13.1.10 describes events that were not analyzed in the PSAR as they are precluded by design.

13.1.10.2 Regulatory Evaluation

The staff reviewed section 13.1.9.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the evaluation of prevented events between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.1.9.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.1.9.2 of the Hermes 1 SE.

13.1.10.3 Technical Evaluation

The staff reviewed section 13.1.10 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.1.10, "Prevented Events"). The staff found that section 13.1.10 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few minor and significant changes, which are evaluated below in sections 13.1.10.3.1 and 13.1.10.3.2, respectively. The staff found that the following portions of section 13.1.10 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Section 13.1.10.1, “Recriticality or Reactor Shutdown System Failure”
- Section 13.1.10.2, “Degraded Heat Removal or Uncooled Events”
- Section 13.1.10.3, “Flibe Spill Beyond Maximum Volume Assumed in Postulated Salt Spills”
- Section 13.1.10.4, “In-Service TRISO Failure Rates and Burnups Above Assumptions in Postulated Events”
- Section 13.1.10.5, “Significant Air Ingress Into the PHTS”
- Section 13.1.10.6, “DHRS Reactor Cavity Flooding”
- Section 13.1.10.7, “Insertion of Excess Reactivity Beyond Rate Assumed in Postulated Events”
- Section 13.1.10.8, “Criticality Occurrence External to Reactor Core”
- Section 13.1.10.9, “Excessive Radionuclide Release from Flibe”

Since the Hermes 2 system design, functionality, and analyses largely remain identical, apart from the differences evaluated below, section 13.1.10 of the Hermes 2 PSAR contains information consistent with section 13.1.10 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 13.1.9 of the Hermes 1 SE.

13.1.10.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 13.1.10, as compared to the information in Hermes 1 PSAR section 13.1.10, include the following:

- Section 13.1.10.3 adds the ISP as a component tripped by the RPS.
- Section 13.1.10.7 adds the ISP as a component susceptible to pump overspeed that could increase core cooling.

Hermes 2 PSAR section 7.3, “Reactor Protection System,” adds a safety-related ISP trip resulting from RPS actuation. Because the change to section 13.1.10.3 is consistent with the change to the RPS functions described in PSAR section 7.3, the staff finds that the addition of the ISP as a component tripped by the RPS to section 13.1.10.3 to be acceptable.

The addition of the ISP to the Hermes 2 design introduces the possibility of an ISP overspeed condition leading to overcooling and insertion of excess reactivity. However, the ISP will operate within defined limits that ensure the consequences of an ISP overspeed are bounded by the insertion of excess reactivity events analyzed in section 13.1.2 of the Hermes 2 PSAR. Therefore, the staff finds that adding the ISP as a component susceptible to pump overspeed is acceptable. The staff will confirm that the consequences of an ISP overspeed are bounded as part of the OL application review.

13.1.10.3.2 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in section 13.1.10 of the Hermes 2 PSAR, as compared to section 13.1.10 of the Hermes 1 PSAR, include information regarding the following:

- New potential internal or external events involving the IHTS or PGS that could prevent safety-related SSCs from performing their safety function
- Gross failure of the IHX due to a PGS superheater tube rupture or leak

These changes are identified in Hermes 2 PSAR sections 13.1.10.10, "Internal or External Events Interfering with SSCs," and 13.1.10.11, "IHX Gross Failure Due to Superheater Tube Rupture or Leak," respectively.

The staff evaluated the sufficiency of this additional preliminary information on the Hermes 2 prevented events using the guidance and acceptance criteria from NUREG-1537, Parts 1 and 2, chapter 13.

Internal or External Events Interfering with SSCs

Hermes 2 PSAR section 13.1.10.10 states that components containing Flibe and BeNaF will be located in areas that use design features such as steel liners to prevent Flibe-concrete and BeNaF-concrete interactions that could adversely affect safety functions of SSCs. Hot Flibe or BeNaF could potentially degrade concrete and mix with the degradation products, which has a currently unknown impact on the chemical form and radionuclide retention properties of the salt. The use of steel liners in areas of potential salt spills would minimize or prevent this phenomenon. Therefore, the staff finds the commitments to be acceptable.

Hermes 2 PSAR section 13.1.10.10 also adds information about potential impacts of the PGS. It states that the turbine will be oriented such that turbine blade missiles would not prevent safety-related SSCs from fulfilling their safety functions. Furthermore, as discussed in Hermes 2 PSAR section 9.9.2, "Turbine Generator System," the turbine generator is located in the turbine building away from the safety-related SSCs and is designed with a control feature that monitors the turbine shaft speed for overspeed protection. These design features are expected to minimize the potential for turbine missile generation and its impact on the safety-related SSCs. In addition, as discussed in Hermes 2 PSAR section 9.9.1 and section 9.9.3, "Condensate and Feedwater System," PGS piping would be located to ensure that postulated failures of the piping would not prevent safety-related SSCs from fulfilling their safety functions. The staff finds these changes acceptable because they demonstrate Kairos's consideration of how the non-safety related PGS could potentially affect safety-related SSCs and preclusion of such impacts by design.

The staff will confirm the design features described in Hermes PSAR section 13.1.10.10 as part of its review of the OL application.

IHX Gross Failure Due to Superheater Tube Rupture or Leak

Hermes 2 PSAR section 13.1.10.11 states that a superheater tube rupture could over-pressurize the IHTS. A safety-related feature relieves the pressure to prevent significant Flibe-water interaction in the PHTS that could result from a gross failure of the IHX due to over-pressurization.

Hermes 2 PSAR figure 5.1-1, “Primary Heat Transport System and Intermediate Heat Transport System Process Flow Diagram,” shows how BeNaF from the IHTS flows through the tube side of the superheater and transfers heat to the steam in the shell side of the superheater. As shown in Hermes 2 PSAR table 9.9-1, “Key Design Power Generation System Parameters,” the superheater steam pressure is 14 MPa, whereas the IHTS design pressure is near ambient pressure, according to Hermes 2 PSAR table 5.2-1, “Key Design Parameters of the Intermediate Heat Transport System.”

Therefore, a breach of a superheater tube would result in a large driving force propelling steam from the PGS into the IHTS, causing an overpressure condition. Absent a means to mitigate the overpressure, the IHTS could fail, with failures potentially occurring in the IHX. In this situation, steam or water could mix with the intermediate coolant and a small allowable amount of primary coolant (Flibe) that may already be present in the IHTS (see Hermes 2 PSAR table 14.1-1, “Proposed Variables and Conditions for Technical Specifications,” for more information) or a greater amount of Flibe if the IHX has failed due to the overpressure. The impact of water/steam mixing with Flibe on the radionuclide retention of Flibe has not been experimentally investigated and no reliable analytical models exist to predict the behavior. Therefore, Kairos’s approach is to preclude the scenario by design.

Hermes 2 PSAR section 5.2.1.2, “Intermediate Inert Gas Subsystem,” describes the safety-related rupture disks that are designed to preclude a gross failure of the IHX resulting from a superheater tube break or rupture. Hermes 2 PSAR section 5.2.3, “System Evaluation,” states that the rupture disks are sized to ensure that pressures in the ISVs, the IHX, and connecting piping do not exceed allowable pressure limits and that the rupture disk and ISV design provide a relief path for steam to prevent it from reaching the IHX. Hermes 2 PSAR section 13.1.4, “Loss of Forced Circulation,” states that the orientation of the ISV inlet and outlet prevents the steam from the superheater tube rupture from entering the piping connecting the ISVs to the IHX. The thermal-hydraulic conditions in the IHTS (i.e., high temperature and low pressure relative to steam in PGS) will prevent steam or water from accumulating in the IHTS, further reducing the potential for steam or water to reach the IHX.

In the absence of any explicit modeling or experimental data, the staff finds that there is large uncertainty in the progression of events following a postulated superheater tube break or rupture. It appears that the IHX tubes are relied upon to prevent Flibe-water interaction during this event. However, as discussed in SE section 5.2, “Intermediate Heat Transport System,” the IHTS (including the IHX tubes) is considered non-safety related by Kairos except for one component, the rupture disks. Consequently, as discussed in section 3.6.3.2 of this SE, the staff was unable to confirm that the IHX complies with the Hermes 2 definition of “safety-related” structures, systems, and components (SSCs). In response to request for confirmation of information (RCI) number 1 (ML24103A241), Kairos confirmed that the final design for Hermes 2 will demonstrate that the IHX tubes will not need to be classified as a safety-related SSC, or, if the IHX tubes are relied upon to remain functional during and after a postulated event, Kairos will demonstrate that their failure is not credible considering all relevant factors.

Given the descriptions in the Hermes 2 PSAR, the staff considers it plausible for Kairos to produce a final IHTS design, including IHX and rupture disks, that meets its design bases. The staff will confirm the adequacy of the rupture disks and overall IHTS design to preclude significant Flibe-water interaction resulting from a superheater tube break or rupture as part of its review of the OL application.

On the basis of its review, the staff finds that the level of detail provided in PSAR section 13.1.10 is consistent with the applicable guidance and acceptance criteria in NUREG-1537, Parts 1 and 2, chapter 13, “Accident Analysis,” and demonstrates an adequate design basis for a preliminary design. Specifically, PSAR section 13.1.10 provides sufficient justification for why the prevented events are excluded from the design basis. However, the staff will confirm that these events should be excluded during review of the final design submitted as part of an OL application.

13.1.10.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the information in PSAR section 13.1.10 is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration during the OL application.

13.2 Accident Analysis and Determination of Consequences

Section 13.2 of the Hermes 2 PSAR provides Kairos’s analysis of the radiological consequences of accidents, focusing on the MHA.

13.2.1 Maximum Hypothetical Accident

13.2.1.1 Introduction

Section 13.2.1, “Maximum Hypothetical Accident,” of the Hermes 2 PSAR describes the evaluation of the radiological consequences of the MHA. The MHA analysis is intended to be bounding for the postulated events described in PSAR chapter 13 and is performed to demonstrate that the 10 CFR 100.11 dose reference values are met at the EAB and outer boundary of the LPZ in support of the safety analysis requirements in 10 CFR 50.34(a)(1)(i) and the siting evaluation factors in 10 CFR 100, Subpart A.

13.2.1.2 Regulatory Evaluation

The staff reviewed section 13.2.1.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the proposed MHA between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.2.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.2.1.2 of the Hermes 1 SE.

13.2.1.3 Technical Evaluation

The staff reviewed section 13.2.1 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.2.1, “Maximum Hypothetical Accident”). The staff found that section 13.2.1 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a minor change, which is evaluated below. The staff also verified that the Hermes 2 MHA remains identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 13.2.1.3 of the Hermes 1 SE.

13.2.1.3.1 Minor Change Compared to the Hermes 1 PSAR

The minor change in Hermes 2 PSAR section 13.2.1, as compared to the information in Hermes 1 PSAR section 13.2.1, includes the following:

- The MHA is applicable to each Hermes 2 unit separately.

In Hermes 2 PSAR section 13.2.1, Kairos did not identify changes to the MHA compared to Hermes 1 PSAR section 13.2.1; however, accidents for each unit need to be addressed. As discussed in the introduction to Hermes 2 PSAR chapter 13, the two units are independent to the extent that a postulated accident in one unit would not affect the safety of operation of the other unit. Therefore, in accordance with the requirements in 10 CFR 100.11(b), the MHA and postulated events are evaluated against the siting criteria for each unit separately. The staff reviewed the description of the Hermes 2 MHA analysis methods, inputs, and assumptions and determined they are same as in the Hermes 1 PSAR, and similarly finds that Kairos's MHA analysis assumptions and methods are consistent with the approved methodology in topical report KP-TR-012-NP-A.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 evaluation of the radiological consequences of the MHA demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria in NUREG-1537, Parts 1 and 2, chapter 13 to ensure that the radiation dose requirements of 10 CFR 100.11 are met.

13.2.1.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the preliminary analysis of the radiological consequences of the MHA, as described in PSAR chapter 13 and confirmed during the staff's audit of supporting documents, is sufficient and meets the applicable regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Additionally, the staff concludes that the discussion of design bases and preliminary design for control room radiological habitability, as described in Hermes 2 PSAR sections 3.1, "Introduction," and 7.4, "Main Control Room and Remote Onsite Shutdown Panel," is sufficient and meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to the design basis during the evaluation of the FSAR as part of the OL application review.

13.2.2 Postulated Event Methodology

13.2.2.1 Introduction

Section 13.2.2, "Postulated Event Methodology and Sample Results," of the Hermes 2 PSAR describes Kairos's use of KP-TR-022-NP to derive the FOMs and associated acceptance criteria that ensure the radiological consequences of the MHA bound those of the postulated events described in PSAR chapter 13. PSAR table 13.1-1, "Acceptance Criteria for Figures of Merit," provides the FOMs and acceptance criteria for each postulated event category. For each postulated event, the results of the transient analysis are to be compared to each relevant FOM and associated acceptance criterion derived from the MHA analysis.

The referenced technical report, KP-TR-022-NP, describes the postulated events; transient analysis methods, including evaluation models; and the methodology to be used to ensure that the final design features of the Hermes 2 facility are sufficient to mitigate the effects of the postulated events and keep the potential consequences of the events bounded by the MHA. The technical report summarizes the MHA only to provide context for the derivation of the FOMs for the postulated events.

13.2.2.2 Regulatory Evaluation

The staff reviewed section 13.2.2.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the postulated event methodology between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 13.2.2.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 13.2.2.2 of the Hermes 1 SE.

13.2.2.3 Technical Evaluation

The staff reviewed section 13.2.2 of the Hermes 2 PSAR and compared it to the equivalent section in the Hermes 1 PSAR (section 13.2.2, “Postulated Event Methodology and Sample Results”). The staff found that section 13.2.2 of the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for minor changes, which are evaluated below. The staff also verified that the Hermes 2 FOMs and the associated acceptance criteria remain identical to Hermes 1. Based on these consistencies, this section incorporates by reference section 13.2.2.3 of the Hermes 1 SE.

13.2.2.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR section 13.2.2, as compared to the information in Hermes 1 PSAR section 13.2.2, include the following:

- PSAR section 13.3, “References,” cites technical report KP-TR-022. Technical report KP-TR-018 was cited for Hermes 1.
- PSAR table 13.1-1 was modified to account for MAR for events that include releases from the IHTS and PGS.

In Hermes 2 PSAR section 13.3, Kairos cites technical report KP-TR-022 instead of technical report KP-TR-018 that was cited in section 13.3 of the Hermes 1 PSAR. KP-TR-022 updates the information previously provided in KP-TR-018 with additions to the postulated event methodology to account for the Hermes 2 design, including the added systems and the two units of the facility. To account for these design differences, KP-TR-022 includes an additional postulated event category for the IHX tube break and places other IHTS and PGS failure events within the categories that already existed in KP-TR-018. As provided in table 3-2, “Derived Figures of Merit and Acceptance Criteria for Postulated Events,” of KP-TR-022, the methodology did not identify new derived FOMs or acceptance criteria and included the new IHX tube break and releases from the IHTS and PGS as applicable events for relevant FOMs. The staff used KP-TR-022 in its review of PSAR chapter 13. Through comparison of the information in the Hermes 2 PSAR and KP-TR-022 section 1.1, as verified in the general audit (ML24193A214), the staff finds that the key design features of the Hermes 2 facility are consistent with those in KP-TR-022. Therefore, the postulated event methodology, including the transient analysis methods in KP-TR-022, is applicable to Hermes 2, and the citation of KP-TR-022 instead of KP-TR-018 is acceptable.

In addition, Hermes 2 PSAR table 13.1-1 was modified to account for MAR for events that include releases from the IHTS and PGS. This modification appropriately accounts for the additional locations of MAR and the pathways for their release in the Hermes 2 design compared to the Hermes 1 design. The changes to Hermes 2 PSAR table 13.1-1 are consistent with the changes to table 3-2 of KP-TR-022. Based on the above, the staff finds that the changes to Hermes 2 PSAR table 13.1-1 are acceptable.

On the basis of its review, the staff finds that the level of detail provided regarding the Hermes 2 postulated event evaluation methodology demonstrates an adequate basis for a preliminary design and satisfies the applicable acceptance criteria of NUREG-1537, Parts 1 and 2, chapter 13, to ensure that final design features are sufficient to mitigate the effects of the postulated events and keep the potential consequences of the events bounded by the MHA.

13.2.2.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes that the methodology used to show that the radiological consequences of the postulated events are bounded by the MHA analysis is sufficient and that the methodology meets the applicable regulatory requirements and guidance identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further technical or design information required to complete the safety analysis may reasonably be left for later consideration. The staff will confirm that the final design conforms to the design basis during the evaluation of the FSAR as part of the OL application review.

13.3 Summary and Conclusions on Accident Analyses

The staff evaluated the information regarding the Hermes 2 accident analysis described in PSAR chapter 13 and finds that the accident analysis of the preliminary design, including the PDC, design bases, information relative to materials of construction, general arrangement, and approximate dimensions, as well as the preliminary analysis and evaluation of the design and performance of SSCs of the facility: (1) provides reasonable assurance that the final design will conform to the design basis, (2) meets all applicable regulatory requirements, and (3) meets all applicable acceptance criteria discussed in NUREG-1537. Based on these findings, the staff concludes the following regarding the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos described the proposed design of the systems supporting the accident analysis, including, but not limited to, the principal architectural and engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the safety analysis, and which can reasonably be left for later consideration, will be supplied in the FSAR as part of the OL application.

- There is reasonable assurance that, taking into consideration the site criteria contained in 10 CFR Part 100, the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public.

- There is reasonable assurance that: (i) the construction of the facility will not endanger the health and safety of the public, and (ii) construction activities can be conducted in compliance with the Commission's regulations.

- The issuance of a permit for the construction of the facility would not be inimical to the common defense and security or to the health and safety of the public.

13.4 References

Argonne National Lab, "Development of a Reference Model for Molten-Salt-Cooled Pebble-Bed Reactor Using SAM," ANL/NSE-20/31, dated September 2020.

Electric Power Research Institute (EPRI), "Uranium Oxycarbide (UCO) Tristructural (TRISO)-Coated Particle Fuel Performance," Topical Report EPRI-AR-1(NP)-A, EPRI Report #3002019978, 2020, ML20336A052.

Fauske & Associates, Inc., Industry Degraded Core Rulemaking (IDCOR) Program Report, "Technical Report 11.7: FAI Aerosol Correlation," dated March 1985, ML20214T484.

Kairos Power LLC, KP-TR-012-NP-A, "KP-FHR Mechanistic Source Term Methodology Topical Report," Revision 3, dated March 2022. ML22136A291 (redacted version).

-----. KP-TR-011-NP-A, "Fuel Qualification Methodology for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor (KP-FHR)," Revision 2, dated June 2022, ML23089A398 (redacted version).

-----. "Response to NRC Request for Additional Information 348 and 339," dated August 31, 2022, ML22243A247.

-----. "Transmittal of Response to NRC Question on Salt Spill from Chapters 4 and 13 Audit on Preliminary Safety Analysis Report," dated August 31, 2022, ML22243A254.

-----. KP-TR-018, "Postulated Event Analysis Methodology," Revision 2, February 28, 2023, ML23055A676 (redacted version).

-----. "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," Revision 3, dated May 31, 2023, ML23151A743.

-----. "Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1," dated May 23, 2024, ML24144A090.

Ougouag, A., Ortensi, J., Hiruta, H., “Analysis of an Earthquake-Initiated-Transient in a PBR,” 2009 International Conference on Advances in Mathematics, Computation Methods, and Reactor Physics.

U.S. Nuclear Regulatory Commission (NRC), NUREG-1537, Part 1, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Format and Content,” dated February 1996, ML042430055.

-----. NUREG-1537, Part 2, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Standard Review Plan and Acceptance Criteria,” dated February 1996, ML042430048.

-----. Regulatory Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” dated July 2000, ML003716792.

-----. NUREG/CR-7220, “SNAP/RADTRAD 4.0: Description of Models and Methods,” dated June 2016, ML16160A019.

-----. SECY-18-0096, “Functional Containment Performance Criteria for Non-Light-Water-Reactors,” dated September 28, 2018, ML18114A546.

-----. “NRC Final RAI 348 on Shutdown Rod Reliability and Defense in Depth,” dated August 2, 2022, ML22227A180.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report Chapters 4 and 13 (Accident Analysis),” dated June 2023, ML23160A287.

-----. “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes 2 Construction Permit Preliminary Safety Analysis Report – General Audit,” dated July 11, 2024, ML24193A214.

X. Zhou, et. al., “Oxidation Behavior of Matrix Graphite and Its Effect on Compressive Strength,” Science and Technology of Nuclear Installations, dated August 2017.

14 TECHNICAL SPECIFICATIONS

The principal purpose of technical specifications (TSs) is to maintain system performance and ensure safe reactor operation. This is accomplished by including in the TSs limiting or enveloping conditions of design and operation, ensuring that emphasis is placed on the safety of the public, the facility staff, and the environment. TSs are typically derived from the facility descriptions and safety considerations contained in the facility safety analysis report.

This chapter of the Kairos Power LLC (Kairos) Hermes 2 construction permit (CP) safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) technical review and evaluation of the probable subjects of TSs for the Hermes 2 facility as presented in preliminary safety analysis report (PSAR), Revision 1, chapter 14, "Technical Specifications."

14.1 Introduction

Hermes 2 PSAR chapter 14 provides preliminary information on Hermes 2 facility TSs that will be applicable for various operating modes during Hermes 2 operation. In PSAR section 14.1, "Introduction," Kairos discusses the general format and content of the TSs as well as variables and conditions that are expected to be the subjects of TSs. Kairos also discusses some probable subjects of TSs in other PSAR chapters. Kairos does not provide actual TSs in the PSAR; PSAR section 14.1 states that the Hermes 2 TSs will be provided in an operating license (OL) application. In PSAR section 14.2, "Operating Modes," Kairos summarizes the five different Hermes 2 operating modes for the Hermes 2 TSs.

14.2 Regulatory Evaluation

The staff reviewed section 14.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facilities and the consistency of the proposed subjects of TSs between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 14.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 14.2 of the Hermes 1 SE.

14.3 Technical Evaluation

The staff reviewed chapter 14 of the Hermes 2 PSAR and compared it to the equivalent material in the Hermes 1 PSAR (chapter 14, "Technical Specifications"). The staff found that the Hermes 2 PSAR contains information consistent with that in the Hermes 1 PSAR, except for a few minor changes and a few significant changes, which are evaluated below in sections 14.3.1 and 14.3.2, respectively. The staff found that the following portions of chapter 14 in the Hermes 2 PSAR contain information consistent with the Hermes 1 PSAR (e.g., minor or editorial changes only):

- Sections 14.1, "Introduction," through 14.3, "References"
- Table 14.1-1, "Proposed Variables and Conditions for Technical Specifications," sections 2.0 through 3.2, and sections 3.4 through 6.0
- Table 14.2-1, "Operating MODES for Technical Specifications"

Since the Hermes 2 system design and functionality largely remain identical, apart from the differences evaluated below, chapter 14 of the Hermes 2 PSAR contains information consistent with chapter 14 of the Hermes 1 PSAR. Based on these consistencies, this section incorporates by reference section 14.3 of the Hermes 1 SE.

14.3.1 Minor Changes Compared to the Hermes 1 PSAR

The minor changes in Hermes 2 PSAR sections 14.1 and 14.2, "Operating Modes," as compared to the information in Hermes 1 PSAR sections 14.1 and 14.2, include the following:

- Clarification that the TS variables and conditions apply to both Hermes 2 units
- Clarification that the operating modes apply to both Hermes 2 units

In Hermes 2 PSAR section 14.1, Kairos clarifies that the proposed TS variables and conditions listed in Hermes 2 PSAR table 14.1-1 apply to both Unit 1 and Unit 2. In section 14.2 of the Hermes 2 PSAR, Kairos clarifies that the operating modes listed in table 14.2-1 are applicable to both Unit 1 and Unit 2. The staff finds that these clarifications are appropriate for the two-unit Hermes 2 facility because all reactors must have TSs and the two units are proposed to be identical.

Similar to the Hermes 1 PSAR, other Hermes 2 PSAR chapters discuss additional probable subjects of TSs including shutdown margin, moderator pebble to fuel pebble ratio, and fuel enrichment (Hermes 1 PSAR section 4.5.4.2, "Testing and Monitoring," and Hermes 2 PSAR section 4.5.4.2, "Testing and Monitoring"), and pebble burnup limits (Hermes 1 PSAR section 9.3.4, "Testing and Inspection," and Hermes 2 PSAR section 9.3.4, "Testing and Inspection"). The staff assumes that other proposed TSs discussed in the Hermes 2 PSAR would also apply to both Unit 1 and Unit 2 because the units are identical. Based on the above, the staff finds that the clarifications are acceptable.

14.3.2 Significant Changes Compared to the Hermes 1 PSAR

Significant changes contained in chapter 14 of the Hermes 2 PSAR, as compared to chapter 14 of the Hermes 1 PSAR, include information regarding additional proposed limiting conditions for operation (LCOs) for the following structures, systems, and components that are added in Hermes 2 and were not included in the design of Hermes 1:

- Intermediate heat transport system (IHTS), and
- Power generation system (PGS).

These changes are identified in section 3.3, "Coolant Systems," of Hermes 2 PSAR table 14.1-1. The additional proposed LCOs for the IHTS address a limit on the quantities of radioactive material at risk (MAR) in the IHTS, operability of IHTS rupture disks, and limits on the quantities of Flibe and water in the IHTS salt coolant. The additional proposed LCO for the PGS addresses a limit on the quantities of MAR in the PGS. During the General Audit, Kairos confirmed that all the MAR in the IHTS (i.e., in both the IHTS cover gas and coolant) and all the MAR in the PGS (i.e., in both steam and water) will be addressed by the proposed TSs.

The staff evaluated the sufficiency of this additional preliminary information in Hermes 2 PSAR chapter 14 on the Hermes 2 TS using the guidance and acceptance criteria from chapter 14, "Technical Specifications," of NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1, "Format and Content," and Part 2, "Standard Review Plan and Acceptance Criteria." In its evaluation, the staff also considered the preliminary safety analysis information in other Hermes 2 PSAR chapters. The staff finds Kairos's addition of the IHTS and PGS parameters discussed above as probable subjects of TS LCOs to be acceptable. This acceptance is based on the staff's conclusion that Kairos has adequately identified probable subjects of TSs that are consistent with important parameters determined as a result of the preliminary safety analyses in the PSAR. Additionally, the staff concluded that Kairos gave special attention to items (e.g., safety limits, limiting safety system settings, and LCOs) that may significantly influence the final design, and that the probable subjects of TSs are supported by appropriate bases. The staff expects that additional subjects of TSs will likely be needed but finds that other probable subjects of TSs beyond those specifically listed in PSAR chapter 14 are, in general, less likely to significantly influence the final design.

Therefore, based on the information in Hermes 2 PSAR chapter 14 and other PSAR chapters, the staff finds that Kairos's identification and justification of the probable subjects of TSs meets the applicable acceptance criteria in chapter 14 of NUREG-1537. The staff will perform a detailed evaluation of the complete and finalized TSs for Hermes 2, including safety limits, limiting safety system settings, LCOs, surveillance requirements, design features, and administrative controls, during its review of a Hermes 2 OL application.

14.4 Conclusion

Based on the staff findings above, and as incorporated by reference from the Hermes 1 SE, the staff concludes the information in chapter 14 of the Hermes 2 PSAR is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40. Further information, including a complete set of Hermes 2 TSs and associated bases, as may be required to complete the review of a Hermes 2 OL application can reasonably be left for later consideration in a final safety analysis report since this information is not necessary for the review of a CP application.

14.5 Summary and Conclusions on Technical Specifications

The staff evaluated the information on the Hermes 2 TSs as described in PSAR chapter 14 and finds that the preliminary TS methodology: (1) meets all applicable regulatory requirements, and (2) meets the applicable acceptance criteria in chapter 14 of NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusions regarding issuance of CPs in accordance with 10 CFR 50.35 and 10 CFR 50.40:

- Kairos has described the proposed design of the facility, including, but not limited to, the principal engineering criteria for the design, and has identified the major features or components incorporated therein for the protection of the health and safety of the public.

- Such further technical or design information as may be required to complete the SE of the Hermes 2 TSs, and which can reasonably be left for later consideration, will be provided in the final safety analysis report.

- There is reasonable assurance: (i) that the construction of the facility will not endanger the health and safety of the public, and (ii) that construction activities will be conducted in compliance with the Commission's regulations.

- The issuance of permits for the construction of the Hermes 2 facility would not be inimical to the common defense and security or to the health and safety of the public.

14.6 References

American National Standards Institute/American Nuclear Society (ANSI/ANS)-15.1-2007, “The Development of Technical Specifications for Research Reactors,” American Nuclear Society, La Grange Park, Illinois.

Kairos Power LLC, “Fuel Qualification Methodology for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor (KP-FHR),” KP-TR-011-NP-A, Revision 2, dated June 2022, ML23089A398 (redacted version).

-----. “Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1]),” Revision 3, dated May 31, 2023, ML23151A743.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

U. S. Nuclear Regulatory Commission (NRC). NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 1, “Format and Content,” and Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report – General Audit,” dated June 2023, ML23160A287.

------. “Safety Evaluation Related to the Kairo Power LLC Construction Permit Application for the Hermes [1] Test Reactor, Docket 50-7513,” dated June 13, 2023, ML23158A265.

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes 2 Construction Permit Preliminary Safety Analysis Report – General Audit,” dated July 11, 2024, ML24193A214.

15 FINANCIAL QUALIFICATIONS

Financial qualifications establish whether an applicant is financially qualified to own, construct, operate, and decommission a non-power production or utilization facility. Financial qualifications related to the issuance of a construction permit (CP) include estimates of construction costs, estimates of fuel cycle costs, and sources to cover costs.

This chapter of the Hermes 2 CP safety evaluation (SE) describes the U.S. Nuclear Regulatory Commission (NRC) staff's (the staff's) review and evaluation of Kairos's financial qualifications as presented in chapter 15, "Financial Qualifications," of the Hermes 2 Preliminary Safety Analysis Report (PSAR), Revision 1.

15.1 Financial Ability to Construct the Hermes 2 Facility

15.1.1 Introduction

Section 15.1, "Financial Ability to Construct the Hermes 2 Facility," of the Hermes 2 PSAR describes whether Kairos Power LLC (Kairos) is financially qualified to, among other things, construct the Hermes 2 facility. The application includes required financial information for CPs, as set forth by the NRC in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.33(f), which demonstrates that Kairos possesses or has reasonable assurance of obtaining the necessary funds to cover estimated construction costs and related fuel cycle costs. The application includes estimates of the total construction costs of the facility and related fuel cycle costs and indicates the sources of funds to cover these costs.

15.1.2 Regulatory Evaluation

The staff reviewed section 15.1.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facilities, the staff finds that the regulations and guidance listed in section 15.1.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 15.1.2 of the Hermes 1 SE.

15.1.3 Technical Evaluation

15.1.3.1 Construction Costs

Pursuant to 10 CFR 50.33(f)(1) and 10 CFR Part 50, appendix C, section II.A.1, "Estimate of construction costs," which references the requirements in appendix C, section I.A.1, "Estimate of construction costs," Kairos provided the projected costs for the construction of the proposed Hermes 2 test reactor facility in a proprietary enclosure to the CP application. The costs included estimates for coolant, fuel for the initial core, and overnight capital. The Kairos estimates are proprietary and are therefore not discussed in this public SE.

As part of the Hermes 1 General Audit (ML23160A287), the staff reviewed the Hermes 1 overnight capital cost (OCC) and fuel cost target model, including the basis for each element of the estimate and associated statistical analyses. According to Kairos, the estimate for OCC, excluding fuel, is based on a top-down cost model and validated through a bottoms-up cost model, which incorporates experience from manufacturing, procurement, contracting, and construction costs for Kairos's Engineering Test Unit. By letter dated October 27, 2023

(ML23300A144), Kairos confirmed that prior Hermes 1 audit responses were considered applicable to Hermes 2; therefore, the Hermes 1 OCC and fuel cost target model audit discussions are applicable to Hermes 2. The staff reviewed the detailed OCC model inputs, applying the same methodology, and found that the OCC target for the Hermes 2 facility is reasonable.

Based on a detailed review of the cost to construct the facility and the supporting bases and assumptions discussed above, the staff finds that Kairos's cost estimate for the Hermes 2 facility is reasonable.

15.1.3.2 Sources of Construction Funds

According to the Hermes 2 CP application, funding for the design and construction costs (including reactor coolant and initial fuel load) relies on raised equity funding. The amount of funding available covers the estimated cost to construct the facility and includes a contingency allowance. The application states that this contingency allowance by Kairos investors is available, if needed, for Hermes 2. The staff finds that the contingency allowance provides additional assurance that Kairos has, or can obtain, the required funding for the project.

The staff compared the total estimated cost to the total secured funding available to complete the project and found that the available funding covers the estimated cost and includes contingency funding, as needed. Therefore, based on the general financial plan described in the application and financial commitments currently in place, the staff finds that Kairos's financial plan is reasonable.

15.1.3.3 Technical Summary

Kairos has supplied financial information for construction and nuclear fuel inventory cost. The staff reviewed the financial ability of Kairos to construct the proposed facility and to cover fuel cycle costs. The staff finds that the financial information provided satisfies the applicable acceptance criteria of NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 2, "Standard Review Plan and Acceptance Criteria," section 15.1, "Financial Ability to Construct a Non-Power Reactor," and demonstrates adequate financial assurance for construction.

15.1.4 Conclusion

The staff concludes that there is reasonable assurance that funds will be made available to construct and cover fuel cycle costs for the Hermes 2 facility and that the financial status of Kairos regarding construction and fuel cycle costs is in accordance with the requirements of 10 CFR 50.33(f). Therefore, the staff concludes that Kairos's financial qualifications for construction of the Hermes 2 facility and associated fuel cycle costs are acceptable.

Based on the staff's findings above, the staff concludes that the information regarding Kairos's financial ability to construct the Hermes 2 facility is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.40, "Common standards."

15.2 Financial Ability to Operate the Hermes 2 Facility

Information related to Kairos's financial qualifications to operate the Hermes 2 facility will be reviewed as part of the operating license (OL) application review process.

15.3 Financial Ability to Decommission the Hermes 2 Facility

Information related to funds that be available to decommission the Hermes 2 facility will be reviewed as part of the OL application review process.

15.4 Foreign Ownership, Control, or Domination

15.4.1 Introduction

Section 104 of the Atomic Energy Act (AEA) of 1954, as amended, prohibits the Commission from issuing a license to an alien, a foreign corporation, or other entity if the Commission knows or has reason to believe it is owned, controlled, or dominated by an alien, a foreign corporation, or a foreign government. Section 15.4, "Foreign Ownership, Control, or Domination," of the Hermes 2 PSAR describes the ownership and control of Kairos.

15.4.2 Regulatory Evaluation

The staff reviewed section 15.4.2, "Regulatory Evaluation," of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the ownership and control structures between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 15.4.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 15.4.2 of the Hermes 1 SE.

15.4.3 Technical Evaluation

According to the application, Kairos is a limited liability company formed in the State of Delaware with a principal place of business in Alameda, California. Kairos is a privately held company with a limited number of investors, all of whom are U.S. citizens or entities owned or controlled by U.S. citizens. Additionally, the application states that all current investors and employees with the options to hold future shares totaling one percent or more of Kairos's stock or options are U.S. citizens or entities owned or controlled by U.S. citizens. Finally, Kairos Power LLC key management personnel, specifically the Chief Executive Officer, is a U.S. citizen and may be contacted through the Kairos Power LLC headquarters address. The staff conducted an independent analysis, including open-source research and verification of the information provided in the CP application, and found no evidence of foreign ownership, control, or domination (FOCD). Therefore, the staff does not know or have reason to believe that Kairos is owned, controlled, or dominated by a foreign interest.

15.4.4 Conclusion

Based on staff findings above, the staff concludes that the information on FOCD is sufficient and meets the applicable guidance and regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.40.

15.5 <u>Nuclear Insurance and Indemnity</u>

15.5.1 Introduction

The Price-Anderson Act, found in section 170 of the AEA, provides a system to pay funds for claims by members of the public for personal injury and property damage resulting from any nuclear incident. The Price-Anderson Act provides coverage in varying degrees. The Price-Anderson Act implementing regulations are found in 10 CFR Part 140, “Financial Protection Requirements and Indemnity Agreements.” Section 15.5, “Nuclear Insurance and Indemnity,” of the Hermes 2 PSAR describes Kairos’s intent to obtain insurance and financial protection in accordance with the Price-Anderson Act. The staff evaluated the sufficiency of Kairos’s nuclear insurance and indemnity considerations, as described in Hermes 2 PSAR section 15.5.

15.5.2 Regulatory Evaluation

The staff reviewed section 15.5.2, “Regulatory Evaluation,” of the Hermes 1 SE for applicability to the Hermes 2 SE. Based on the similarities between the Hermes 1 and Hermes 2 facility designs and the consistency of the nuclear insurance and indemnity considerations between Hermes 1 and Hermes 2, the staff finds that the regulations and guidance listed in section 15.5.2 of the Hermes 1 SE are applicable to Hermes 2. Therefore, this section incorporates by reference section 15.5.2 of the Hermes 1 SE.

15.5.3 Technical Evaluation

As stated in its application, Kairos intends to obtain insurance and financial protection consistent with the requirements of the Price-Anderson Act, pursuant to Section 170 of AEA and the requirements in 10 CFR Part 140. After receipt of the CPs and a 10 CFR Part 70, “Domestic Licensing of Special Nuclear Material,” license to possess fuel, Kairos will obtain financial protection of $1 million in insurance consistent with 10 CFR 140.13, “Amount of financial protection required of certain holders of construction permits and combined licenses under 10 CFR part 52.” Prior to operation, Kairos will obtain the full financial protection required by 10 CFR 140 using the formula provided in 10 CFR 140.12(b). The amounts of financial insurance required by 10 CFR 140.12(b) and documentation required by 10 CFR 140.15, “Proof of financial protection,” will be provided with the application for an OL.

The staff reviewed Kairos’s intent to obtain $1 million in financial protection in accordance with 10 CFR 140.13 prior to the possession of fuel. Because the CPs do not authorize the possession of fuel, this item can reasonably be left for later consideration and is identified in appendix A of this SE. Additionally, an OL application will need to identify the amounts needed for full financial protection. Proof of financial protection and execution of an indemnity agreement, as required by section 170 of the AEA, will be required before an OL is issued.

15.5.4 Conclusion

Based on staff findings above, the staff concludes that the information regarding nuclear insurance and indemnity is sufficient and meets the applicable regulatory requirements identified in this section for the issuance of CPs in accordance with 10 CFR 50.40.

15.6 <u>Summary and Conclusions on Financial Qualifications</u>

The staff evaluated the information regarding Kairos's financial qualifications, as described in PSAR chapter 15 and proprietary documents supporting the Hermes 2 CP application. Based on the information provided, the staff finds: (1) that Kairos's financial qualifications for construction of the Hermes 2 facility and associated fuel cycle costs are acceptable and meet the requirements of 10 CFR 50.33(f), and (2) the staff does not know or have reason to believe that Kairos is owned, controlled, or dominated by a foreign interest. Such further information as may be required to assess financial qualifications for operation and decommissioning, as well as proof of financial protection and execution of an indemnity agreement, which can reasonably be left for later consideration, will be supplied as part of the OL application.

Therefore, based on its review, the staff finds that the information on financial qualifications: (1) meets all applicable regulatory requirements, and (2) meets the applicable acceptance criteria in NUREG-1537, Part 2. Based on these findings, the staff makes the following conclusion regarding issuance of CPs in accordance with 10 CFR 50.40:

- Kairos is financially qualified to engage in the construction of its proposed facility in accordance with the Commission's regulations.

15.7 <u>References</u>

Kairos Power LLC. "Financial Information," dated July 14, 2023, ML23195A126 (proprietary information, not publicly available).

-----. "Submittal of the Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor (Hermes [1])," Revision 3, dated May 31, 2023, ML23151A743.

-----. "Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1," dated May 23, 2024, ML24144A090.

-----. "Kairos Power Response to Hermes 2 General Audit Question 1.5-2," dated October 27, 2023, ML23300A144.

-----. "Transmittal of Changes to Construction Permit Application – Financial Information Enclosure and PSAR Chapter 15," dated April 12, 2024, ML24103A245.

U. S. Nuclear Regulatory Commission (NRC). NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 1, "Format and Content," and Part 2, "Standard Review Plan and Acceptance Criteria," NRC: Washington, D.C., dated February 1996, ML042430055 and ML042430048.

-----. "Final Standard Review Plan on Foreign Ownership, Control, or Domination," Federal Register, September 28, 1999, (64 FR 52355).

-----. “Summary Report for the Regulatory Audit of Kairos Power LLC Hermes [1] Construction Permit Preliminary Safety Analysis Report – General Audit,” dated June 2023, ML23160A287.

-----. “Safety Evaluation Related to the Kairos Power LLC Construction Permit Application for the Hermes [1] Test Reactor,” dated June 16, 2023, ML23158A265.

16 OTHER LICENSE CONSIDERATIONS

The Kairos Power LLC (Kairos) Hermes 2 preliminary safety analysis report (PSAR), Revision 1, chapter 16, “Other License Considerations,” section 16.1, “Prior Use of Facility Components,” states that the Hermes 2 facility will be “constructed of new and appropriately qualified structures, systems, and components to conduct operations. Discussions regarding used systems and components are not applicable to the facility.” Additionally, in PSAR section 16.2, “Medical Use of Non-Power Reactors,” Kairos states that the Hermes 2 facility will “not contain equipment or facilities associated with direct medical administration of radioisotopes or other radiation-based therapies and [Kairos] has no plans at this time to support medical uses. Therefore, discussions involving medical use of the facility are not applicable.” PSAR chapter 16 does not identify any other special license considerations that are not discussed elsewhere in the PSAR.

The U.S. Nuclear Regulatory Commission (NRC) staff (the staff) evaluated the information on the Hermes 2 facility in the PSAR and finds that the preliminary design of the Hermes 2 facility does not include prior use components and that the Hermes 2 facility will not be used for direct medical therapy. Furthermore, the staff did not identify any other special license considerations relevant to Hermes 2 that are not addressed elsewhere in the PSAR and considered in other chapters of this safety evaluation (SE), as appropriate. The staff concludes that an evaluation using the guidelines of NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 2, “Standard Review Plan and Acceptance Criteria,” chapter 16, “Other License Considerations,” is not necessary because:

1. All equipment to be installed in the Hermes 2 facility will be new and purpose-built. No prior use components will be used in the construction of the reactor or support systems.
2. The Hermes 2 facility will not contain equipment or facilities associated with the direct medical administration of radioisotopes or other radiation-based therapies.
3. There are no identified license considerations relevant to Hermes 2 that are not considered elsewhere in this SE.

16.1 References

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

The U. S. Nuclear Regulatory Commission (NRC), NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430048.

17 DECOMMISSIONING AND POSSESSION-ONLY LICENSE AMENDMENTS

The Kairos Power LLC (Kairos) preliminary safety analysis report (PSAR), Revision 1, chapter 17, “Decommissioning and Possession Only License Amendments,” section 17.1, “Decommissioning,” states that a decommissioning report for the Hermes 2 facility will be provided with an operating license (OL) application, as required by Title 10 of the *Code of Federal Regulations* (10 CFR) section 50.33, “Contents of applications; general information,” paragraph (k). Furthermore, section 17.2, “Possession-Only License Amendments,” of the Hermes 2 PSAR states that possession-only licenses are not applicable to the construction and operation phases of the Hermes 2 facility. Kairos’s construction permit (CP) application did not include a decommissioning report or plan, or a possession-only license amendment request.

The U.S. Nuclear Regulatory Commission (NRC) staff (the staff) notes that 10 CFR 50.33(k) requires an applicant for an OL for a utilization facility to submit a decommissioning report but does not require an applicant for a CP for a utilization facility to submit a decommissioning report or plan. The guidance of NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 2, “Standard Review Plan and Acceptance Criteria,” chapter 17, “Decommissioning and Possession-Only License Amendments,” indicates that decommissioning plans and applications for possession-only licenses are submitted by nonpower reactor licensees who wish to terminate operations and decommission their facilities. The staff evaluated PSAR chapter 17 considering these requirements and guidance. Because Kairos’s application seeks CPs for a utilization facility, and because Kairos is not seeking a possession-only license, the staff concludes that no decommissioning information or possession-only license amendment request needs to be provided in the PSAR or evaluated by staff for the issuance of CPs for a utilization facility under 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities.”

17.1 References

The U. S. Nuclear Regulatory Commission (NRC), NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors,” Part 2, “Standard Review Plan and Acceptance Criteria,” NRC: Washington, D.C., dated February 1996, ML042430048.

-----. “Submittal of the Hermes 2 Preliminary Safety Analysis Report for the Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor, Revision 1, and the Postulated Event Analysis Methodology Technical Report [KP-TR-022], Revision 1,” dated May 23, 2024, ML24144A090.

18 HIGHLY ENRICHED TO LOW-ENRICHED URANIUM CONVERSION

The Kairos Power LLC (Kairos) preliminary safety analysis report (PSAR), Revision 1, chapter 18, "Highly Enriched to Low Enriched Uranium Conversion," states that the Hermes 2 reactor fuel will be high-temperature graphite-matrix coated tristructural isotropic (TRISO) particles using high-assay, and low-enriched uranium (LEU). The Hermes 2 facility will not utilize highly enriched uranium (HEU), i.e., uranium that is enriched to 20 percent or more in uranium-235.

The U.S. Nuclear Regulatory Commission (NRC) staff (the staff) evaluated the information on the Hermes 2 facility in the PSAR and finds that the preliminary design of the facility does not utilize HEU. Therefore, the staff concludes that an evaluation of HEU to LEU conversion using the guidelines of NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 2, "Standard Review Plan and Acceptance Criteria," chapter 18, "Highly Enriched to Low-Enriched Uranium Conversions," is not necessary.

18.1 References

Kairos Power LLC. "Submittal of the Construction Permit Application for the Hermes 2 Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor," Revision 1, dated May 23, 2024, ML24144A090.

The U. S. Nuclear Regulatory Commission (NRC), NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors," Part 2, "Standard Review Plan and Acceptance Criteria," NRC: Washington, D.C., dated February 1996, ML042430048.

APPENDIX A
POST CONSTRUCTION PERMIT ACTIVITIES - CONSTRUCTION PERMIT CONDITIONS AND ADDITIONAL ITEMS FOR THE OPERATING LICENSE APPLICATION

A.1 Construction Permit Conditions

The U.S. Nuclear Regulatory Commission (NRC) staff (the staff) has determined that the construction permits (CPs) need to be conditioned to require that Kairos will perform analysis of excavations for safety related structures at the site and implement its quality assurance program during construction. Therefore, the staff recommends that, should the permits be granted, the CPs include the conditions set forth below. Additional details on the basis for each of these conditions appears in chapter 2, "Site Characteristics," and chapter 12, "Conduct of Operations," of the Hermes 2 CP safety evaluation (SE).

Proposed Permit Condition	SE Section	Description
1	2.5, Geology, Seismology, and Geotechnical Engineering	In order to confirm that the exposed bedrock does not show signs of karstic dissolution when the excavations are complete and before the foundation is prepared, Kairos shall perform detailed geologic mapping of excavations for safety related engineered structures; examine and evaluate geologic features discovered in those excavations, such as karst; and notify the Director of the Office of Nuclear Reactor Regulation, or the Director's designee, as specified in Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.4, "Written communications," once excavations for safety-related structures are open for examination by the staff.
2	12.9, Quality Assurance	To ensure consistency in expectations for Kairos's implementation of its QA program developed pursuant to 10 CFR 50.34(a)(7); establish criteria for changes to the QA program and for the notifications Kairos must make to the NRC regarding such changes; and facilitate the correction of any identified deficiencies in the implementation of the QA program through the NRC's enforcement process during construction inspection, Kairos shall implement the QA program described, pursuant to 10 CFR 50.34(a)(7), in Chapter 12, Appendix B, of Revision 1 of the Hermes Preliminary Safety Analysis Report (PSAR), including revisions to the QA program in accordance with the provisions below. Kairos may make changes to its previously accepted QA program description without prior Commission approval, provided the changes do not reduce the commitments in the QA program description as accepted by the Commission. Changes to the QA program description that do not reduce the commitments must be submitted to the Commission within 90 days.

		Changes to the QA program description that do reduce the commitments must be submitted to the Commission and receive Commission approval prior to implementation, as follows: • Changes must be submitted as specified in 10 CFR 50.4. • The submittal of changes to the QA program description must include all pages affected by the changes and must be accompanied by a forwarding letter identifying the changes, the reason for the changes, and the basis for concluding that the revised program incorporating the changes continues to satisfy the PSAR Revision 1 QA program description commitments previously accepted by the NRC (the letter need not provide the basis for changes that correct spelling, punctuation, or editorial items). • A copy of the forwarding letter identifying the changes must be maintained as a record by Kairos for three years. • Changes to the QA program description shall be regarded as accepted by the Commission upon Kairos's receipt of a letter to this effect from the appropriate reviewing office of the Commission or 60 days after Kairos's submittal to the Commission, whichever occurs first.

A.2 Additional Items for an Operating License Application

The Hermes 2 CP application provided a preliminary design. In the PSAR and during audit meetings, Kairos identified elements of design, analysis, and administration that require additional development or resolution. The staff determined that resolution of these items is not necessary for the issuance of CPs, but that Kairos should ensure that these items are fully addressed in the Final Safety Analysis Report (FSAR) supporting an operating license (OL) application. The staff is tracking these items to ensure that significant issues are considered during the review of an OL application for the Hermes 2 facility.

These items constitute information needs but do not form the only acceptable set of information for the FSAR. In addition, these items do not relieve Kairos from any requirement in the regulations that governs the application. After issuance of an OL, these items are not controlled by NRC requirements unless such items are restated in the FSAR.

The staff reviewed the Hermes 1 SE and the Hermes 2 SE and found that most of the items listed in appendix A.2 of the Hermes 1 SE are applicable to Hermes 2 because large portions of the Hermes 1 PSAR are identical to the Hermes 2 PSAR. Kairos confirmed the applicability of these items to Hermes 2. Therefore, for clarity and completeness, the staff used italicized text in the table below to denote items in appendix A.2 of the Hermes 1 SE that are: (1) applicable to Hermes 2, with minor editorials or clarifications identified in brackets, and (2) the staff confirmed that these italicized items were described in the corresponding sections of the Hermes 1 SE that have been incorporated by reference into the Hermes 2 SE. The items that are new or had significant changes from the Hermes 1 SE appendix A.2 table are listed below with added text shown as underlined and deleted text shown with strikethrough. The items with plain text are discussed in the Hermes 2 SE (i.e., not incorporated by reference) and do not contain any changes from the Hermes 1 SE appendix A.2.

PSAR Section and/or Related Audit Question	Associated Documents	Description
Section 1.7, Compliance with the Nuclear Waste Policy Act of 1982		In PSAR section 1.7, Kairos stated that it will provide additional information in the OL application regarding the disposition of high-level waste and spent nuclear fuel.
Section 2.2.3, Analysis of Potential Accidents at Facilities		*In PSAR Section 2.2.3, Kairos stated that the locations and quantities of onsite chemical storage have not yet been determined, so the effects of potential hazards from onsite chemicals will be evaluated in the OL application.*
<u>Section 2.2.3, Analysis of Potential Accidents at Facilities</u>		<u>In PSAR section 2.2.3, Kairos stated that the locations and quantities of onsite chemical storage at the proposed Kairos Power Hermes 1 Facility, Kairos Power Atlas Fuel Fabrication Facility, TRISO-X Fuel Facility, Clinch River Nuclear Site, Coqui Pharmaceutical Facility, and</u>

PSAR Section and/or Related Audit Question	Associated Documents	Description
		regional airport (Oak Ridge airport) have not yet determined, so the effects of explosions, flammable vapor clouds, and toxic chemicals from onsite chemical storage at these nearby facilities and at the Ultra Safe Nuclear Corporation Pilot Fuel Manufacturing Facility will be reviewed in the OL application and accounted for in the final design.
Table 2.2-1		On PSAR table 2.2-1 Kairos stated the presence of a diesel fuel storage tank on Hermes 1 site has been analyzed and that other chemical hazards will be analyzed with the operating license application.
Section 2.2.3.4, Fires		*In PSAR Section 2.2.3.4, Kairos stated that effects of potential brush or forest fires will be evaluated in the OL application.*
Section 2.3.5, Long-Term Atmospheric Dispersion Estimates for Routine Releases		*In PSAR Section 2.3.5, Kairos stated that details regarding the long-term dispersion modeling, modeling inputs, and analysis will be provided in the OL application.*
Section 2.4, Hydrology		*In PSAR Section 2.4, Kairos stated that additional information relevant to stream blockage and diversion flows will be provided in the OL application.*
Section 2.4.2, Floods, and Section 2.4.3, Credible Hydrological Events and Design Basis		*PSAR Sections 2.4.2 and 2.4.3 stated that a probable maximum flood (PMF) study will be discussed with the application for an OL. The PMF evaluation should consider flood elevations induced by local intense precipitation and watershed wide probable maximum precipitation events.*
Section 2.4.4, Groundwater		*In PSAR Section 2.4.4, Kairos stated that seasonal changes to groundwater levels will be addressed in the OL application.*
Section 2.5.2.1, Karst, and Section 2.5.4.3, Karst; [Hermes 1] Site	*[Hermes 1 Site Characteristics Audit Report (ML23115A480)]*	*In PSAR Sections 2.5.2.1 and 2.5.4.3, Kairos stated that it will supplement the karst investigations with a set of tests and surveys in the OL application. These tests*

PSAR Section and/or Related Audit Question	Associated Documents	Description
Characteristics Audit Question 2.5-11		*and surveys include site reconnaissance, light detection and ranging imaging, and inventory of surface depressions in the site area. In addition, deeper boreholes will be drilled at the reactor location selected. Rock cores recovered will be analyzed in the laboratory to characterize the karst features. A site model of the karst features will be developed and presented with the OL application.*
Section 2.5.2.3, Soil Borings, [Hermes 1] Site Characteristics Audit Question 2.5-3	*[Hermes 1 Site Characteristics Audit Report (ML23115A480)]*	*In PSAR Section 2.5.2.3, Kairos presented results from preliminary laboratory testing of site soil layers limited to soil index properties. Kairos stated that a more comprehensive characterization of the geotechnical properties of both soil and rock layers present at the proposed site will be provided in the OL application. The network of rock fractures (e.g., rock joints, bedding planes, small faults, etc.) will be characterized and used to evaluate the bearing capacity and expected settlement of the reactor foundation.*
Section 2.5.3, Vibratory Ground Motion; NRC Preliminary Question 2.5-1	*KP-NRC-2202-002 (ML22040A336)* *[NRC Preliminary Questions (ML22024A492)]*	*PSAR Section 2.5.3 relies on the information of the Clinch River Early Site Permit application's earthquake catalog, which ends in 2013. In KP-NRC-2202-002[, with regards to the Hermes 1 CP application,] Kairos stated that an updated earthquake catalog will be provided in the OL application to demonstrate that the assumptions and conclusions in the Clinch River probabilistic seismic hazard analysis (PSHA) remain valid.*
Section 2.5.3.4, ~~Vibratory Ground Motion~~ Design Response Spectra		In PSAR Section 2.5.3.4, Kairos indicates that ~~stated~~ for the Hermes 2 OL application, the design response spectra will be supplemented with the results of a site response ~~spectra~~ analysies, which ~~that~~ will rely on pending in-situ shear wave velocity measurements ~~derived from the Clinch River PSHA and updated as appropriate in the OL application~~.

PSAR Section and/or Related Audit Question	Associated Documents	Description
Section 2.5.4.1, Surface Faulting		*In PSAR Section 2.5.4.1, Kairos stated that information on surface faulting will be provided in the OL application.*
Section 2.5.4.2, Liquefaction Potential; [Site Characteristics Audit Question 2.5-16]	*[Hermes 1 Site Characteristics Audit Report (ML23115A480)]*	*In PSAR Section 2.5.4.2, Kairos proposed to place the Hermes [2] non-safety related foundation mat over a fill. Kairos will address the effects of potential liquefaction on the foundations of the non-safety related structures surrounding the reactor in the OL application.*
Section 2.5.5.2.1, Bearing Capacity; [Site Characteristics Audit Question 2.5-5]	*[Hermes 1 Site Characteristics Audit Report (ML23115A480)]*	*In PSAR Section 2.5.5.2.1, Kairos proposed to provide additional details on the bearing capacity and expected settlement of the safety related reactor foundation and the non-safety related structures in the OL application. In addition, additional details will be provided on the lateral pressure on the reactor structure and non-safety related structures.*
Section 3.4.1.5, Structural Model, and Section 3.4.1.6, Response Analysis		*In PSAR Sections 3.4.1.5 and 3.4.1.6, Kairos stated that additional details on the models, including the structural model finite element results, assignment of the structural mass, and modeling methods and assumptions for the soil-structure interaction analysis and seismic response analysis, will be provided in the OL application.*
Section 3.5.3.2.1, External Flood Design Features		*In PSAR Section 3.5.3.2.1, Kairos stated that it will provide the description of the specific grading and drainage features in the OL application. The impacts of the site grading and drainage on the safety related structures, systems, and components (SSCs) should be addressed.*
Section 3.5.3.2.2, Internal Flood and Spray Design Features		*In PSAR Section 3.5.3.2.2, Kairos stated that it will specify automatic or a manual termination of flow for water sources external to the safety-related portion of*

PSAR Section and/or Related Audit Question	Associated Documents	Description
		the Reactor Building (e.g., fire water) in the OL application.
Section 3.5.3.2.2, Internal Flood and Spray Design Features		*In PSAR Section 3.5.3.2.2, Kairos stated further information on the analysis of the impacts of internal flooding and spraying will be provided in the OL application.*
PSAR Section 3.5.2, Design Bases, and 3.5.3, System Evaluation; Hermes 2 General Audit Question 3.5-1	Hermes 2 General Audit Report (ML24193A214)	In PSAR sections 3.5.2 and 3.5.3, Kairos stated that consistent with PDC 4, the safety-related portion of the Reactor Building is designed to be protected from and provide protection of other safety-related SSCs against environmental and dynamic effects associated with high-pressure steam system pipe leaks and breaks. Kairos stated during the audit that the OL application will provide specific details that demonstrates the design or design features of the safety-related reactor building portion and safety-related SSCs located inside meet PDC 4 for environmental conditions and dynamic effects of high-pressure steam line leaks and breaks, or other equipment failure.
Section 3.5.3.3.1, Seismic Design of the Safety-Related Portion of the Reactor Building; Hermes 2 General Audit Question 3.5-1	Hermes 2 General Audit Report (ML24193A214)	Kairos stated during the general audit that the OL application will provide specific details and justification for the selected limit state(s) (A, B, C, or D in American Society of Civil Engineers 43-19, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities") for the seismic design of the safety-related portion of the reactor building that contains and protects all Hermes 2 safety-related SSCs.
Section 3.5.3.3.2, Seismic Isolation System		*In PSAR Section 3.5.3.3.2, Kairos stated that it will provide further details of the base isolation system and associated structural analysis in the OL application.*
Section 3.5.3.4, Conformance with PDC 2 for Other Hazards		*In PSAR Section 3.5.3.4, Kairos stated additional detail about the structural design features for the safety-related portion of the Reactor Building, informed*

PSAR Section and/or Related Audit Question	Associated Documents	Description
		by the results of the hazards analysis, will be provided in the OL application.
Table 3.6-2, Design and Construction Codes and Standards for Fluid Systems		*In footnote 6 to PSAR Table 3.6-2, Kairos stated that departures from American Society of Mechanical Engineers (ASME) Code requirements, if needed, will be identified in the OL application.*
[Section 3.6, Systems and Components; Hermes 1] General Audit Question 3.6-1	*[Hermes 1 General Audit Report (ML22039A336)]* *KP-TR-013-NP, Revision 4 (ML22263A456)*	*Kairos stated during the [Hermes 1 general] audit that the OL application will document that safety related metallic components in the reactor vessel system are bounded by testing conditions in referenced topical report KP-TR-013-NP, "Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor," Revision 4.*
Section 4.2.1.2, Fuel Qualification	*EPRI-AR-1(NP)-A (ML20336A052)*	*In PSAR Section 4.2.1.2, Kairos stated that it will demonstrate that the fuel meets the conditions and limitations of the NRC SE for EPRI-AR-1(NP)-A, "Uranium Oxycarbide (UCO) Tristructural (TRISO-Coated Particle Fuel Performance" as part of the OL application.*
Section 4.2.1.6, Evaluation of Fuel Design Bases		*In PSAR Section 4.2.1.6, Kairos stated that the results of a laboratory testing program to confirm that the fuel's physical form is maintained during operation, the pebble remains buoyant, and there is no significant salt infiltration into the pebble will be provided in the OL application.*
Section 4.2.2.3, System Evaluation		*In PSAR Section 4.2.2.3, Kairos stated that the Reactivity Control and Shutdown System shutdown element insertion versus time will be provided in the OL application.*
Section 4.3, Reactor Vessel System; [Hermes 1] General Audit question 4.3-6	*[Hermes 1 General Audit Report (ML23160A287)]*	*PSAR Section 4.3 stated that coolant purity limits will be established with consideration given to chemical attack and fouling of the vessel. During the [Hermes 1 general] audit, Kairos indicated the OL application will provide relevant coolant purity limits and describe the*

PSAR Section and/or Related Audit Question	Associated Documents	Description
		bases for establishing the limits, required actions, and time to complete these actions.
Section 4.3, Reactor Vessel System; [Hermes 1] General Audit question 4.3-8	*[Hermes 1 General Audit Report (ML23160A287)]*	*PSAR Section 4.3 stated the graphite reflector will be qualified and designed to meet ASME Boiler and Pressure Vessel Code Section III Division 5 requirements. During the [Hermes 1 general] audit, Kairos indicated the OL application will describe how all applicable requirements of the ASME Boiler and Pressure Vessel Code Section III Division 5 are met.*
Section 4.3, Reactor Vessel System; [Hermes 1] General Audit question 4.3-11	*[Hermes 1 General Audit Report (ML23160A287)]*	*PSAR Sections 4.3.1.1 and 4.3.1.2 state that the vessel and vessel internals are designed to support on-line monitoring, inspection, and maintenance activities. Kairos stated during the [Hermes 1 general] audit that the OL application will provide additional details on how vessel integrity will be assured through monitoring and inspection programs and confirm the vessel is designed to allows for those programs.*
Section 4.3, Reactor Vessel System; Hermes 2 General Audit Question 4.3-3	Hermes 2 General Audit Report (ML24193A214)	Kairos stated during the Hermes 2 general audit that an assessment of thermal embrittlement of metallic materials on the mechanical performance of safety-related components for the 11-year proposed operational lifetime will be provided in the Hermes 2 OL application.
Section 4.3, Reactor Vessel System; Table 4.3-8, Qualification Requirements for Graphite Data		Table 4.3-8 states that the graphite is expected is expected to remain pre-turnaround. If final design data and turnaround analysis shows that graphite exceeds turnaround fluence, then irradiation creep data for ET-10 will be obtained and used.
Section 4.3.4, Testing and Inspection		*In PSAR Section 4.3.4, Kairos stated that an inservice inspection program that includes the reactor vessel and internals will be provided in the OL application.*

PSAR Section and/or Related Audit Question	Associated Documents	Description
Section 4.4.3, Biological Shield - Evaluation		*In PSAR Section 4.4.3, Kairos stated that an evaluation of the performance of the biological shield to meet 10 CFR Part 20, "Standards for Protection Against Radiation," will be provided in the OL application.*
Section 4.5.1.1, Overview of Core Nuclear Design		*In PSAR section 4.5.1.1, Kairos stated that initial startup and power ascension will be discussed in the OL application.*
Section 4.5, Nuclear Design; [Hermes 1] Accident Analysis Audit (ML22041B665) question 67	*[Hermes 1 Accident Analysis Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 accident analysis] audit that the OL application will provide specific details of the pebble burnup monitoring.*
Section 4.6.1.2, Coolant Flow Path		*In PSAR Section 4.6.1.2, Kairos stated that qualification or functional testing plans and results needed to validate performance assumed in the safety analysis will be provided in the OL application.*
Section 4.6.3, System Evaluation		*In PSAR Section 4.6.3, Kairos stated that the results of analyses supporting the inherent stability of the reactor will be provided in the OL application.*
Section 4.7.4, Testing and Inspection		*In PSAR Section 4.7.4, Kairos stated that an inservice inspection program that includes the reactor vessel support system will be provided in the OL application.*
Section 5.1.1.1, Reactor Coolant; Hermes 1 General Audit Question 5.1-13	*[Hermes 1 General Audit Report (ML23160A287)]* *KP-TR-005-NP-A, Revision 1 (ML20219A591)*	*PSAR Section 5.1.1.1 stated that the properties of the Flibe reactor coolant can be found in KP-TR-005-NP-A, Revision 1. Kairos stated during the [Hermes 1 general] audit that the OL application will describe how Flibe properties are confirmed.*
Section 5.1.3, [System Evaluation]		*In PSAR Section 5.1.3, Kairos stated that thermodynamic data to calculate transport of radionuclides through Flibe will be justified in the OL application.*
Section 5.1.3, System Evaluation		In PSAR section 5.1.3, Kairos stated that the compatibility of the primary to

PSAR Section and/or Related Audit Question	Associated Documents	Description
		intermediate coolant interaction will be demonstrated as part of the OL application.
Section 5.1.3, Primary Heat Transport System; [Hermes 1] General Audit question 5.1-4	*[Hermes 1 General Audit Report (ML23160A287)]*	*PSAR Section 5.1.3 describes a postulated air ingress event. Kairos stated during the [Hermes 1 general] audit that the OL application will provide results of material qualification testing related to postulated air ingress into the primary heat transport system (PHTS) and its effects on materials used in the reactor vessel system, including graphite components.*
Section 5.1.4, [Testing and Inspection]		*In PSAR Section 5.1.4, Kairos stated that descriptions of testing and inspection of PHTS will be provided with the OL application.*
Section 5.2; Intermediate Heat Transport System	Response to RCI 1 (ML24103A243)	For the OL application, analyses will be performed for the intermediate heat transport system (IHTS) to demonstrate that under all postulated events, including a superheater tube rupture event, the intermediate heat exchanger (IHX) tubes would not need to be classified as a safety-related SSC.
Section 5.2; Intermediate Heat Transport System	Response to RCI 2 (ML24103A243)	The OL application will demonstrate that the contamination of Flibe in the PHTS by a postulated BeNaF ingress from the IHTS (bounding all postulated events and normal operation) will remain within the purity specification for sodium impurities in topical report KP TR-005-P-A, "Reactor Coolant for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor," or Kairos will provide justification in the FSAR for exceeding the purity specification.
Section 5.2; Intermediate Heat Transport System	Response to RCI 3 (ML24135A382)	The OL application will include a final design for the IHTS and the safety-related rupture disks (including design features, potential qualification testing, or other justification) that justifies that the rupture disks will reliably perform their safety

PSAR Section and/or Related Audit Question	Associated Documents	Description
		function to provide overpressure protection preventing a gross failure of the intermediate heat exchanger.
Section 6.2, Functional Containment		*In PSAR Section 6.2, Kairos stated that the specified acceptable system radionuclide release design limits and technical specifications supporting the functional containment concept will be provided in the OL application.*
Section 6.3, Decay Heat Removal System (DHRS); [Hermes 1 DHRS] Audit Question 6.3-10	*[Hermes 1 DHRS Audit Report (ML23115A480)]*	*Kairos stated during the [Hermes 1 DHRS] audit that the OL application will evaluate the magnitude and effects of thermal gradient asymmetry in the event of loss of inventory in one DHRS train.*
Section 6.3.4, [Testing and Inspection]		*In PSAR Section 6.3.4, Kairos stated that descriptions of testing and inspection of DHRS will be provided with the OL application.*
Section 7.2.3, System Evaluation		In PSAR section 7.2.3, Kairos stated that further analysis of the timeliness of Plant Control System (PCS) signals will be provided in the OL application.
Section 7.2.3, System Evaluation		In PSAR section 7.2.3, Kairos stated that specific design features and the SSCs to which they are applied will be provided in the OL application.
Section 7.2.3, System Evaluation		In PSAR section 7.2.3, Kairos stated that additional information on the PCS that is dependent on the final design of reactor SSCs and the power generation system (PGS), such as hardware and software specifics, software flow diagrams, a description of how the operation and support requirements will be met, and the basis for PCS system reliability and reliability targets, will be provided in the OL application.
Section 7.3.[1, Description]		*In PSAR Section 7.3[.1], Kairos stated that the final design for the neutron flux monitoring will be provided in the OL application.*

PSAR Section and/or Related Audit Question	**Associated Documents**	**Description**
Section 7.3.[3, System Evaluation]		*In PSAR Section 7.3[.3], Kairos stated that the Reactor Protection System (RPS) alarm signals to the main control room and information on the minimum redundancy in the RPS to permit period testing without compromising RPS function will be provided in the OL application.*
Section 7.3.[3, System Evaluation]		*In PSAR Section 7.3[.3], Kairos stated that a description of how the RPS operational and support requirements will be met, including the enclosure housing the RPS cabinets, will be provided in the OL application.*
Section 7.4.3.1, Main Control Room		*In PSAR Section 7.4.3.1, Kairos stated that a description of the analysis of operator dose will be provided in the OL application.*
Section 7.4.3.2, Remote Onside Shutdown Panel		*In PSAR Section 7.4.3.2, Kairos stated that procedures for safe shutdown of the reactor through the remote onsite shutdown panel will be provided in the OL application.*
Section 7.5.3, [System Evaluation]		*In PSAR Section 7.5.3, Kairos stated that the number and type of RPS sensors needed to be consistent with the safety analysis and their suitability for their operating environment will be provided in the OL application.*
Table 7.5-1, Parameter Range for Safety-Related Sensors		*In PSAR Table 7.5-1, Kairos stated that the parameter ranges for vessel level, area radiation, source range neutronics, and power range neutronics will be provided in the OL application.*
Table 7.5-2, Parameter Range for Non-Safety Related Sensors		*In PSAR Table 7.5-2, Kairos stated that the parameter ranges for vessel level, area radiation, pressure, and flow rate in the reactor vessel will be provided in the OL application.*
Section 8.3.1.1, Backup Generators		In PSAR section 8.3.1.1, Kairos stated that a list of the specific essential loads

PSAR Section and/or Related Audit Question	Associated Documents	Description
		that receive backup power will be provided in the OL application.
Section 9.1.1, Chemistry Control System		In PSAR section 9.1.1, Kairos stated a description of the offline sample analysis equipment will be provided in the OL application ~~that a list of the specific essential loads that receive backup power will be provided in the OL application~~.
Section 9.1.1, Chemistry Control System; [Hermes 1] General Audit question 9.1-3	*[Hermes 1 General Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide all coolant purity specifications, required actions, time to complete these actions if specifications are not met, and how the specifications are consistent with results of material compatibility testing (e.g., metallic material corrosion testing, fuel qualification testing, etc.).*
Section 9.1.1, Chemistry Control System; [Hermes 1] General Audit question 9.1-2	*[Hermes 1 General Audit Report (ML23160A287)]* *KP-NRC-2208-007 (ML22231B228)*	*In KP-NRC-2208-007, Kairos stated that the OL application will demonstrate that the Chemistry Control System can measure a well-mixed representative sample of the reactor coolant.*
Section 9.1.4.1.1, RV Coolant Level Management Tank		*In PSAR Section 9.1.4.1.1, Kairos stated that additional details on the inventory management system vessel level monitoring will be provided in the OL application.*
Section 9.3.3, ~~Pebble Handing and Storage System~~ System Evaluation		In PSAR section ~~9.3.1.5~~ 9.3.3, Kairos stated that a summary of the criticality analyses confirming the Pebble Handling and Storage System (PHSS) design maintains a safe geometrical configuration will be provided in the OL application.
Section 9.3, Pebble Handling and Storage System; [Hermes 1] General Audit Question 9.3-2	*[Hermes 1 General Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide the detailed spent fuel storage canister design, including how hydrofluoric acid effects will be managed.*
Section 9.3.1.5, Pebble Inspection		*In PSAR Section 9.3.1.5, Kairos stated that further details related to inspections*

PSAR Section and/or Related Audit Question	Associated Documents	Description
		for wear and damage of moderator and fuel pebbles will be provided in the OL application.
Section 9.4, Fire Protection Systems and Programs		*In PSAR Section 9.4, Kairos stated that a description of the fire protection program and a fire hazards analysis will be provided in the OL application.*
Section 9.6, Possession and Use of Byproduct, Source, and Special Nuclear Material		*In PSAR Section 9.6, Kairos stated that a description of the administrative procedures related to use of byproduct, source, and special nuclear material will be provided in the OL application.*
Section 9.7, Plant Water Systems; [Hermes 1] General Audit question 9.7-2	*[Hermes 1 General Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 general] audit that the OL application will identify all auxiliary water systems which connect to a system containing radioactive material and will be designed to meet the requirements of 10 CFR 20.1406.*
~~Section 9.7.3, Component Cooling Water System~~		~~In PSAR Section 9.7.3, Kairos stated that, for the Component Cooling Water System, specific design features and the SSCs to which they are applied will be provided in the OL application.~~
Section 9.8.1, Remote Maintenance and Inspection System		*In PSAR Section 9.8.1, Kairos stated that, for the Remote Maintenance and Inspection System, specific design features and the SSCs to which they are applied will be provided in the OL application.*
Section 9.8.4.[3, System Evaluation]		*In PSAR Section 9.8.4.3, Kairos stated that further information about the design of the superstructure in the event of a fire will be provided in the OL application.*
Section 11.1, Radiation Protection		*In PSAR Section 11.1, Kairos stated that additional details of the radiation protection (RP) programs will be provided in the OL application.*
Section 11.1.1, Radiation Sources		*In PSAR Section 11.1.1, Kairos stated that additional details of radiation sources, including activity and external radiation*

PSAR Section and/or Related Audit Question	Associated Documents	Description
		fields in the facility, will be provided in the OL application.
Section 11.1.2, Radiation Protection Program, and section 11.1.3, ALARA Program		*In PSAR Section 11.1.2 and 11.1.3, Kairos stated that additional details for both the RP program and the as low as reasonably achievable (ALARA) program will be provided in the OL application.*
Section 11.1.4, Radiation Monitoring and Surveying		*In PSAR Section 11.1.4, Kairos stated that additional details of radiation monitoring and surveying, including a description of the equipment, methods, and procedures, will be provided in the OL application.*
Section 11.1.5, Radiation Exposure Control and Dosimetry		*In PSAR Section 11.1.5, Kairos stated that additional details on dosimetry, radiation exposure control and assess control, including locations of radiological control areas, access controls, shielding, remote handling equipment, and expected annual radiation exposures, will be provided in the OL application.*
Section 11.1.5, Radiation Exposure Control and Dosimetry		*In PSAR Section 11.1.5, Kairos stated that an effluent analysis corresponding to the final detailed design will be provided in the OL application.*
Section 11.1.6, Contamination Control		*In PSAR Section 11.1.6, Kairos stated that a description of design features for the control of radioactive contamination at the Hermes facility will be provided in the OL application.*
Section 11.1.7, Environmental Monitoring		*In PSAR Section 11.1.7, Kairos stated that a description of the radiological environmental monitoring program will be provided in the OL application.*
Section 11.2.1, Radioactive Waste Management Program		*In PSAR Section 11.2.1, Kairos stated that a detailed description of the radioactive waste management program will be provided with the OL application.*
Section 11.2.2.[3 System Evaluation]		*In PSAR Section 11.2.2[.3], Kairos stated that a description of radioactive waste handling systems design and controls will be provided in the OL application.*

PSAR Section and/or Related Audit Question	Associated Documents	Description
Section 11.2.3, Release of Radioactive Waste		*In PSAR Section 11.2.3, Kairos stated that a description of the radioactive effluents from the facility, including points of effluent release and effluent monitoring equipment, will be provided in the OL application.*
Section 12.1.3, Staffing		*In PSAR Section 12.1.3, Kairos stated that specific staffing considerations, minimum staffing levels, allocation of control functions, overtime restrictions, shift turnover, procedures, training, and availability of Senior Operators during routine operations will be provided in the OL application.*
Section 12.1.4, Selection and Training of Personnel		*In PSAR Section 12.1.4, Kairos stated that a description of the training program and the required minimum qualifications for facility staff will be provided in the OL application.*
Section 12.1.5, Radiation Safety		*In PSAR Section 12.1.5, Kairos stated that details related to the authority of the RP program staff with respect to facility operations will be provided in the OL application.*
Section 12.2, Review and Audit Activities		*In PSAR Section 12.2, Kairos stated that details of review and audit activities and who holds the approval authority and how it communicates and interacts with facility and corporate management will be provided in the OL application.*
Section 12.3, Procedures		*In PSAR Section 12.3, Kairos stated that a description of the facility procedures, including the review, approval, and changes processes, will be provided in the OL application.*
Sections 12.4, Required Actions, 12.5, Reports, and 12.6, Records		*In PSAR Sections 12.4, 12.5 and 12.6, Kairos stated that technical specifications will be provided in the OL application.*
Appendix 12A, Section A.2, Authorities and Responsibilities of		*In PSAR Appendix 12A, Section A.2, Kairos stated that additional roles and responsibilities for emergency response*

PSAR Section and/or Related Audit Question	Associated Documents	Description
Facility Emergency Personnel		*personnel emergency classification levels and the associated protective actions will be provided in the OL application.*
Appendix 12A, Section B, Authorities and Responsibilities of Governmental Agencies		*In PSAR Appendix 12A, Section B, Kairos stated that the arrangements with the City of Oak Ridge and Oak Ridge Central Fire Station, Oak Ridge Police Department, Oak Ridge Methodist Medical Center, and the State of Tennessee, will be obtained and documented in the OL application.*
Appendix 12A, Section F, Training		*In PSAR Appendix 12A, Section F, Kairos stated that the details of the training program for emergency response personnel will be provided in the OL application.*
Appendix 12A, Section H.2, Assessment Facilities and Equipment		*In PSAR Appendix 12A, Section H.2, Kairos stated that a listing of the current locations for emergency equipment cabinets and other emergency equipment storage areas, plus representative equipment inventories for these storage locations, will be provided in the OL application.*
Appendix 12A, Section H.5, Instrumentation for Specific Radionuclide Identification and Analysis		*In PSAR Appendix 12A, Section H.5, Kairos stated that the actual equipment in the Hermes facility for specific radionuclide identification and analysis will be provided in the OL application.*
[Hermes 1] General Audit question 12.2.7-1	*[Hermes 1 General Audit Report (ML23160A287)]* *NUREG-0849, Standard Review Plan for the Review and Evaluation of Emergency Plans for Research and Test Reactors, (ML062190191)*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide additional details and features on the Hermes 1 reactor facility access routes following the guidance in NUREG-0849.*

PSAR Section and/or Related Audit Question	Associated Documents	Description
[Hermes 1] General Audit question 12.2.7-2a	*[Hermes 1 General Audit Report (ML23160A287)]* *10 CFR 50, Appendix E, Section II.A and NUREG-0849*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide additional details on the emergency organization and the relationship with other support organizations consistent with NUREG-0849.*
[Hermes 1] General Audit question 12.2.7-2c	*[Hermes 1 General Audit Report (ML23160A287)]* *10 CFR 50, Appendix E, Section II.A and NUREG-0849*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide additional descriptions of organizational responsibilities, including the 24-hour on-shift staff positions and lines of succession consistent with NUREG-0849.*
[Hermes 1] General Audit question 12.2.7-3	*[Hermes 1 General Audit Report (ML23160A287)]* *NUREG-0849*	*Kairos stated during the [Hermes 1 general] audit that the OL application will describe agreements or arrangements with local emergency response agencies that would augment and extend the capability of the Hermes 1 facility's emergency organization and also identify any procedures developed for emergency response coordination consistent with NUREG-0849.*
[Hermes 1] General Audit question 12.2.7-4	*[Hermes 1 General Audit Report (ML23160A287)]* *NUREG-0849*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide Hermes emergency classification descriptions as described in NUREG-0849, Section 4.0.*
Section 13.1, Initiating Events and Scenarios, and section 13.2, Accident Analysis and Determination of Consequences; [Hermes 1] Accident Analysis Audit question 13	[Hermes 1 Accident Analysis Audit Report (ML23160A287)]	Kairos stated during the [Hermes 1 accident analysis] audit that the OL application will provide dose analyses for events bounded by the maximum hypothetical accident (MHA) release, such as salt spill, PHSS break, and seismic, along with a comparison to the acceptance criteria for the figures of merit in PSAR table 13.1-1.
Section 13.1.2, Insertion of Excess Reactivity; section 13.1.3, Salt Spills;	Hermes 2 General Audit Report (ML24193A214)	Kairos stated during the general audit that they will confirm the limiting event, key conservative analysis assumptions, and initial conditions through sensitivity

PSAR Section and/or Related Audit Question	Associated Documents	Description
<u>section 13.1.4, Loss of Forced Circulation</u>		<u>calculations or other appropriate analysis as part of the OL application.</u>
Section 13.1.2, Insertion of Excess Reactivity; [Hermes 1] Accident Analysis Audit question 48	[*Hermes 1 Accident Analysis Audit Report (ML23160A287)]* *KP-TR-018-NP, Revision 2 (ML20219A591)*	*In KP-TR-018-NP Section 4.5.2.2 and during the Hermes 1 accident analysis audit, Kairos stated that the OL application will provide analyses for a range of insertion rates for insertion of excess reactivity scenarios.*
Section 13.1.2, Insertion of Excess Reactivity; [Hermes 1] Accident Analysis Audit question 55	*[Hermes 1 Accident Analysis Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 accident analysis] 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.*
Section 13.1.2, Insertion of Excess Reactivity; [Hermes 1] Accident Analysis Audit question 56	*[Hermes 1 Accident Analysis Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 accident analysis] audit that deviations of component temperatures above the MHA will be addressed and justified case by case in the OL application.*
Section 13.1.2, Insertion of Excess Reactivity; [Hermes 1] Accident Analysis Audit question 57	*[Hermes 1 Accident Analysis Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 accident analysis] audit that the OL application will provide the underlying assumptions for mapping between nuclear design, fuel performance, and safety analysis assumptions.*
[Hermes 1] Accident Analysis Audit question 53-8	*[Hermes 1 Accident Analysis Audit Report (ML23160A287)]* *KP-TR-018-NP [(ML20219A591)]*	*Kairos stated during the [Hermes 1 accident analysis] audit that the methodology in KP-TR-018-NP will be updated as part of the OL application (or in a separate topical report).*
Section 13.1.4, Loss of Forced Circulation	*[KP-TR-018-NP, Revision 2 (ML20219A591)]*	*In KP-TR-018-NP, Section 3.2.2.4, Kairos stated that the OL application will provide analyses with a spectrum of reactor decay heat levels and operating power levels for long-term overcooling scenarios.*
[Hermes 1] General Audit question 14-3	*[Hermes 1 General Audit Report (ML23160A287)]*	*Kairos stated during the [Hermes 1 general] audit that the OL application will provide analyses demonstrating that vessel temperature is not needed as a*

PSAR Section and/or Related Audit Question	Associated Documents	Description
		Limiting Safety System Setting (LSSS) because the other LSSSs will ensure that unacceptable vessel temperatures will not be reached.
Section 14.1, Technical Specifications Introduction		*In PSAR Section 14.1, Kairos stated that the technical specifications and parameter limits will be provided in the OL application.*
Table 14.1-1, Proposed Variables and Conditions for Technical Specifications		*In PSAR Table 14.1-1, Kairos stated that design features and administrative controls will be provided in the OL application.*
Section 15.2, Financial Ability to Operate the Kairos Power Facility		In PSAR section 15.2, Kairos stated that estimates of the total annual operating costs for each of the first five years of operation of the facility will be provided in the OL application.
Section 15.3, Financial Ability to Decommission the Kairos Power Facility		In PSAR section 15.3, Kairos stated that information regarding funds to decommission the facility and a site-specific decommissioning plan will be provided in the OL application.
Section 15.5, Nuclear Insurance and Indemnity		*In PSAR Section 15.5, Kairos stated that it will obtain $1 million in financial protection in accordance with 10 CFR 140.13 prior to being licensed to possess fuel. Kairos also stated that the amounts of financial insurance required by 10 CFR 140.12(b) and documentation required by 10 CFR 140.15 will be provided in the OL application.*
Section 17.1, Decommissioning		In PSAR section 17.1, Kairos stated that a decommissioning report for the facility will be provided in the OL application.
KP-TR-017-NP, KP-FHR Core Design and Analysis Methodology, Section 7.1	*[KP-TR-017-NP (ML22272A598)]*	*In KP-TR-017-NP Section 7.1, Kairos stated that the completion of verification and validation of the core design and analysis codes and methodology, including uncertainties, will be provided in the OL application.*

A.3 Research and Development Items

The provisions of 10 CFR 50.34(a)(8) require that the PSAR identify those structures, systems, or components of the facility that require additional 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. Kairos stated it will complete the following research and development activities before the latest date of completion of construction activities in December 2027.

PSAR Section	Associated Documents	Description
Section 4.2.1, Reactor Fuel	KP-TR-011-NP-A, Fuel Qualification Methodology for the Kairos Power Fluoride Salt-Cooled High Temperature Reactor (KP-FHR), Revision 2 (ML23089A398)	Perform a laboratory testing program to confirm fuel pebble behavior.
Section 4.3, Reactor Vessel System	KP-TR-013-NP-A, Metallic Materials Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor, Revision 4 (ML23102A179)	Perform testing of high temperature material to qualify Alloy 316H and ER16-8-2.
Section 4.3, Reactor Vessel System	KP-TR-014-NP-A, Graphite Material Qualification for the Kairos Power Fluoride Salt-Cooled High-Temperature Reactor, Revision 4 (ML23108A317)	Perform analysis related to potential oxidation in certain postulated events for the qualification of the graphite used in the reflector structure.
Section 4.3.4, Reactor Vessel System Testing and Inspection		Develop a high temperature material surveillance sampling program for the reactor vessel and internals.
Section 4.5, Nuclear Design		Development and validation of computer codes for core design and analysis methodology.
Section 4.6, Thermal-Hydraulic Design		Develop and perform qualification testing for a fluidic diode device.
Section 5.1.3, Primary Heat Transport System – System Evaluation		Justification of thermodynamic data and associated vapor pressure correlations of representative species.

PSAR Section	Associated Documents	Description
Section 5.1.3, Primary Heat Transport System – System Evaluation		Complete compatibility evaluations of the intermediate coolant and reactor coolant chemical interaction
Section 7.5.3, Sensors - System Evaluation		Develop process sensor technology for key reactor process variables.
Section 9.1.1, Chemistry Control System		Develop the reactor coolant chemical monitoring instrumentation.

APPENDIX B
PRINCIPAL CONTRIBUTORS

Name	Chapter	Area of Expertise
Adams, Ben	4, 6, 9, 13	Criticality Safety, Nuclear Engineering
Ani, Suzanne	12	Material Control and Accounting
Ashcraft, Joseph	7, 9	Instrumentation and Controls
Ayegbusi, Odunayo	12	Quality Assurance
Bettes, Brian		Project Management
Bielen, Andrew	4	Criticality Safety, Nuclear Engineering
Campbell, Shawn	13	Nuclear Engineering
Chereskin, Alexander	4, 5, 9	Chemical Engineering, Materials Engineering
Cheung, Calvin	7, 9	Instrumentation and Controls
Cuadrado de Jesus, Samuel		Project Management
Ghosh, Amitava	2, 3	Geography, Geotechnical Engineering
Goel, Vijay	8	Electrical Engineering
Gordon, Matthew	3, 5	Materials Engineering
Hart, Michelle	4, 11, 13	Health Physics, Waste Management
Harwell, Shawn	15	Financial Qualifications
Helvenston, Edward	9, 10, 11, 12, 14, 16, 17, 18	Project Management, Radiation Protection
Hiser, Matthew	3, 5	Project Management, Materials Engineering
Jones, Steve	3, 4, 9	Systems Engineering
Koch, Patrick	9	Civil Engineering, Structural
Mott, Kenneth	12	Emergency Preparedness
Orenak, Michael		Project Management
Ray, Sheila	8	Electrical Engineering
Robinson, Jay	9	Fire Protection
Sawant, Pravin	3, 4, 5, 13, 14	Lead Reviewer, Nuclear Engineering
Schaperow, Jason	9	Nuclear Engineering
See, Kenneth	2, 3	Hydrology
Seymour, Jesse	7, 12	Human Factors Engineering
Siwy, Alex	6, 9, 13	Mechanical Engineering
Song, Clair	3, 4, 5	Mechanical Engineering
Tabatabai, Sarah	2, 3	Geophysics

Thomas, George	3, 4	Civil Engineering, Structural
Thompson, Jenise	2	Geology, Seismic
Waugh, Andrew	12	Reactor Security
White, Jason	2, 3	Meteorology

APPENDIX C

REPORT BY THE ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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

July 17, 2024

Honorable Christopher T. Hanson
Chair
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: SAFETY EVALUATION OF THE KAIROS NON-POWER REACTOR HERMES 2 CONSTRUCTION PERMIT APPLICATION

Dear Chair Hanson:

During the 717th meeting of the Advisory Committee on Reactor Safeguards, July 10 through 12, 2024, we completed our review of the Kairos Non-Power Reactor Hermes 2 construction permit application and the associated safety evaluation (SE). Appendix I provides the dates that our Kairos Subcommittee reviewed this matter. Appendix II provides the list of memos with our detailed reviews of the application and associated SE in cases where technical issues were identified. During these meetings, we had the benefit of discussions with NRC staff and representatives from Kairos Power LLC (Kairos). We also had the benefit of the referenced documents. This report fulfills the requirements of Section 182b of the Atomic Energy Act, as amended, and Title 10 of the *Code of Federal Regulations* (10 CFR) 50.58(a).

CONCLUSIONS AND RECOMMENDATIONS

1. Because the design of Hermes 2 builds extensively on the design of Hermes 1, the staff performed a “delta” review of Hermes 2 by (a) comparing the applicant’s preliminary safety analysis report (PSAR) with the corresponding PSAR for Hermes 1, and (b) using the guidance provided in NUREG-1537 for non-power reactors as the basis for their evaluation. We note that this was an efficient and effective approach to conducting the Hermes 2 safety evaluation.

2. We agree with the staff that there is confidence the facility can be constructed in accordance with relevant regulations and the design bases outlined in the PSAR. Detailed design, analysis, and technology qualification will be completed prior to the operating license (OL) review.

3. Our review indicated that the design changes in Hermes 2 have no adverse influence on the safety functions or their implementation. The Hermes 1 Maximum Hypothetical Accident (MHA) was still found to be bounding for Hermes 2, and the effects of two Hermes 2 reactors with a greater lifetime were appropriately accounted for in the source term estimates. The planned metallic materials and graphite testing will address potential corrosion and radiation damage concerns to accommodate the longer planned lifetime for Hermes 2.

4. A number of issues noted in this letter should be considered by the staff prior to the issuance of the OL. These issues are related to the consequences of a postulated superheater tube rupture into the atmospheric-pressure intermediate salt loop; REDOX[1] control in the Flibe (a molten salt coolant which is a eutectic mixture of LiF and BeF_2); and corrosion and tritium control in BeNaF (a mixture of BeF_2 and NaF), the salt used in the intermediate loop.

5. The construction permit application for Hermes 2 should be approved.

BACKGROUND

The Hermes 2 facility consists of two 35-MWth test reactors that share a common power conversion system. The design builds upon the Hermes 1 test reactor design and contains the following three major design changes: (1) each test reactor has an intermediate salt loop to transfer heat from the reactor, (2) each intermediate salt loop has a steam superheater that feeds a common turbine in the shared power conversion system, and (3) the lifetime of the facility is 11 years instead of the four year lifetime of Hermes 1. The facility will be licensed under 10 CFR Part 50.21 (a Class 104c license).

Hermes 2 shares many of the same safety characteristics of Hermes 1. They both use TRISO-fueled pebbles in Flibe, resulting in a high-temperature low-pressure system with the following robust inherent or passive safety characteristics: functional containment provided by TRISO fuel and Flibe; primary heat transport system that operates near atmospheric pressure; negative reactivity coefficients (fuel, moderator, and coolant temperature); and reactor vessel and other safety-related components located within a seismically-isolated structure.

DISCUSSION

The staff performed a "delta" review of Hermes 2 by (a) comparing the applicant's PSAR with the corresponding PSAR for Hermes 1, and (b) using the guidance provided in NUREG-1537 for non-power reactors as the basis for their evaluation. The considerable commonality between the Hermes 2 and Hermes 1 designs provided for a more efficient review compared to past multi-phased safety reviews. Our approach built upon our review of Hermes 1 to determine the safety significance of design changes. For our review, a cognizant member of the Committee reviewed a given chapter of the PSAR and the associated staff SE chapter. A memo was written by the cognizant member if technical issues were identified for further discussion. If no issues were identified in a specific chapter, no memo was written. This approach was efficient and allowed us to concentrate on the key technical issues. We also note that Kairos' identification of Hermes 2 PSAR text that had been changed from Hermes 1 helped focus and improve the efficiency of our review.

Safety Review Questions

Our review included the following questions when evaluating the safety aspects of the Hermes 2 design:

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[1] REDOX is nomenclature (REDuction OXidation) to describe the chemical potential of the system.

- Do the design changes affect the safety functions identified in the design (functional containment, decay heat removal, and reactivity control)? Do they change the structures, systems, and components that implement those safety functions?
- Do the design changes introduce new accident sequences that change the MHA? Do the changes impact normal and accident source terms for the design?
- Do the changes affect the list of items that need to be confirmed prior to issuance of an OL (the staff's Appendix A of the Hermes 1 SE)?
- Are the co-location effects of Hermes 1 and Hermes 2 accounted for?
- Do the design changes influence waste streams?

Our review indicated that the design changes in Hermes 2 had no adverse influence on the safety functions or their implementation. The Hermes 1 MHA was still found to be bounding for Hermes 2 and the effects of two Hermes 2 reactors with a greater lifetime were appropriately accounted for in the source term estimates. The planned metallic material and graphite testing will address potential corrosion and radiation damage concerns to accommodate the longer planned lifetime for Hermes 2. The effects of co-location and changes in waste streams are noted and details will be addressed in the OL application.

We find that Kairos' systematic examination of postulated events in Hermes 1 and Hermes 2 with their associated figures of merit (e.g., time-at-temperature and material at risk) and subsequent comparison against the bounding MHA to be an elegant, simple, and transparent approach to the overall safety analysis. Such an approach should be considered for potential microreactor applications.

The staff's use of Appendix A in their SE is an effective approach to track the large number of technology development issues for Hermes 1 and Hermes 2 that need to be resolved through testing prior to the OL issuance. Communicating the results of the testing to the staff as far in advance of the final safety analysis report (FSAR) application as possible will facilitate the review and approval process for the OL.

Technical Issues for Further Consideration

Based on our review, we have identified a number of technical issues that remain to be resolved prior to staff approval of an OL application.

<u>Superheater Tube Rupture Event</u>

A superheater tube rupture in the power generation system will quickly pressurize the intermediate heat transport system that is designed for near atmospheric pressure, potentially challenging the integrity of the tubes in the intermediate heat exchanger (IHX). Safety-related rupture disks are proposed by Kairos to prevent the pressure from reaching the point where the tubes in the IHX fail.

The staff identified the following information as necessary to assure that the IHX tubes are protected during this postulated event: design features; qualification testing results; piping geometry and location of rupture disks to adequately relieve pressure and provide a relief path for the steam from the break; the operating environment of the rupture disks including temperature and chemistry (e.g., hydrogen fluoride exposure); the potential for adverse impact on rupture disk function from material aging or degradation due to environment effects; potential for salt vapor deposition to impede rupture disk function; and design considerations such as redundancy and diversity that would provide adequate reliability. This event will be reassessed by the staff at the OL stage.

There is large uncertainty in the progression of events following a postulated superheater tube rupture, and little data exists on the chemical interactions between steam/water and Flibe. Limited data on water/salt interactions in the event of a spill were developed during the Aircraft Reactor Test (ART) and Molten Salt Reactor Experiment (MSRE) projects. The testing indicated pressurization of the test cell where the spill occurred due to the production of steam upon contact of the water and molten salt but no degradation of the salt. However, it is important to note that the mode of interaction in the Hermes 2 design is quite different than a spill geometry. High pressure steam or water, depending on the location of the break, would vigorously enter the atmospheric pressure intermediate salt loop. According to the safety analysis documentation for the MSRE, "in an accident involving contact between salt and water, fairly rapid generation of hydrofluoric acid is expected."

The design of the passive rupture disks in the intermediate coolant loop and the time needed for disks to actuate (relative to the event-generated pressure wave and the speed of sound in the salt) will be critical in mitigating the progression of this event and limiting overall damage. In light of the uncertainties associated with the progression of this postulated event, we believe strong preventive measures are preferred over mitigative ones. Were Kairos to be unsuccessful in designing the rupture disks to protect the IHX tubes, the safety classification of the IHX, the intermediate loop, or both may have to be reconsidered. Alternatively, the bounding nature of the MHA may have to be re-evaluated.

This type of event is a broader safety issue related to any design where the reactor primary or intermediate loop at atmospheric pressure interfaces with a high-pressure steam power conversion system, particularly where the coolants involved are chemically reactive. Designing to address steam generator tube rupture can be a challenge. Other designs in the past have addressed this issue by designing the intermediate loop for high pressure. The staff should anticipate this situation for other advanced reactor system safety applications going forward.

<u>Material Properties of BeNaF</u>

The salt used in the intermediate coolant system, BeNaF, is different than Flibe. Upon a heat exchanger tube break, BeNaF and Flibe will mix. The resulting salt, FLiNaBe, has been studied in a limited manner and has a melting point of 305°C, lower than either Flibe or BeNaF making solidification upon mixing unlikely. Kairos has committed to performing compatibility tests between the two salts. They also will evaluate the potential for structural material corrosion with the BeNaF salt and with a mixture of the Flibe and BeNaF salts.

There is no discussion in the safety documentation of key material properties including density, heat capacity, melting point, eutectic formation, viscosity, and tritium transport properties of the BeNaF salt. A search of open literature (and documented in the Chapter 4, "Reactor Description," memo) indicates that the properties of this salt are similar to Flibe. These open literature properties imply that no major surprises are expected when Kairos completes the compatibility tests described above.

REDOX Control in Flibe

In preparing for the Hermes 2 review, the Committee has come across some literature on REDOX control in fluoride high temperature reactors that suggests the approach proposed by the applicant could be unacceptable to control corrosion and may have deleterious side effects.[2] Numerous open literature references have pointed out that in a system with graphite, use of a sacrificial Be metal electrode would produce excessively reducing conditions in the reactor coolant resulting in the formation of metal carbides. The formation of metal carbides could degrade the graphite components in the core (e.g., fueled pebbles or reflector). Simple static corrosion tests of stainless steel and graphite in purified but non-REDOX controlled Flibe have identified the presence of a chromium carbide (Cr_7C_3) in grain boundaries of the steel. The net corrosion rate of the steel was 1.8 times greater in the presence of graphite.

Therefore, active REDOX control for prevention of material corrosion should be taken into account for both Hermes 1 and Hermes 2. Some of the planned material corrosion testing by Kairos will inform the control strategy. Because of the complexity of REDOX control at the system level given the temporal temperature gradients and complex flows in the reactor, this issue may only be resolved during operation of these reactor systems. Additional technical specifications may be necessary to monitor and assess the influence of REDOX control on the potential degradation of graphite components. In this regard, operation of Hermes 1 may inform the Hermes 2 operational approach to address this issue.

Tritium Control in the Intermediate Loop

The tritium cleanup system for the intermediate loop will use hydrofluorination to convert tritium to tritium fluoride by injecting about 100 ppm hydrogen fluoride (HF) into BeNaF, the intermediate coolant salt. As noted by the staff and from the open literature, HF is corrosive under these high temperature conditions. Hydrofluorination is an oxidative process that generally runs counter to maintaining reducing conditions in the salt to minimize corrosion. How these two competing chemical processes (corrosion versus tritium control) will be successfully implemented requires more design detail. At this stage of the design, Kairos has committed to maintaining the intermediate coolant salt within proposed impurity limits as a potential means to limit corrosion.

SUMMARY

Because the design of Hermes 2 builds extensively on the design of Hermes 1, the staff performed a "delta" review of Hermes 2 by (a) comparing the applicant's PSAR with the corresponding PSAR for Hermes 1, and (b) using the guidance provided in NUREG-1537 for non-power reactors as the basis for their evaluation. We note that this was an efficient and effective approach to conducting the Hermes 2 safety evaluation. We agree with the staff that there is confidence the facility can be constructed in accordance with relevant regulations and

[2] Structural material corrosion by molten salt is a key concern. Neutron absorption in the Li-6 in the Flibe will produce tritium fluoride and can make the salt redox condition more oxidizing, resulting in the enhanced corrosion of transition metals such as Ni, Fe, and Cr in the structural components. The corrosion leads to both the degradation of the materials of construction and perturbation of the properties of the salt. The neutron absorption creates an increasingly oxidizing environment that requires REDOX control to avoid corrosion of metallic components.

the design bases outlined in the PSAR. Detailed design, analysis, and technology qualification will be completed prior to the OL review.

Our review indicated that the design changes in Hermes 2 have no adverse influence on the safety functions or their implementation. The Hermes 1 MHA was still found to be bounding for Hermes 2, and the effects of two Hermes 2 reactors with a greater lifetime were appropriately accounted for in the source term estimates. The planned metallic materials and graphite testing will address potential corrosion and radiation damage concerns to accommodate the longer planned lifetime for Hermes 2.

A number of issues noted in this letter should be considered by the staff prior to the issuance of the OL. These issues are related to the consequences of a postulated superheater tube rupture into the atmospheric-pressure intermediate salt loop; REDOX control in the Flibe; and corrosion and tritium control in BeNaF, the salt used in the intermediate loop.

The staff's use of Appendix A in their SE is an effective approach to track the large number of technology development issues for Hermes 1 and Hermes 2 that need to be resolved through testing prior to the OL issuance. Communicating the results of this testing to the staff as far in advance of the FSAR application as possible will facilitate the review and approval process for the OL.

The construction permit application for Hermes 2 should be approved.

Sincerely,

Signed by Kirchner, Walter on 07/17/24

Walter L. Kirchner
Chair

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Appendix I

ACRS Review of Construction Permit Application for Kairos Power Fluoride Salt-Cooled, High Temperature Non-Power Reactor – Hermes 2

Subcommittee (SC) Meetings	Date	Subject	Transcript Accession No.
SC	5/16/2024	Hermes 2 Non-Power Reactor Preliminary Safety Analysis	ML24177A224
SC	6/4/2024	Hermes 2 Non-Power Reactor Preliminary Safety Analysis	ML24189A000
SC	6/26/2024	Hermes 2 Non-Power Reactor Preliminary Safety Analysis	ML24198A003

Appendix II

Lead Member Memoranda on Preliminary SE Chapters on Kairos Power Hermes 2 Non-Power Reactor Preliminary Safety Analysis Report

Subject	Date	ADAMS Accession No. ***(Package No. is*** ML24185A042***)***
Input for ACRS Review of Kairos Non-Power Reactor Hermes 2 Construction Permit Application - Safety Evaluation for Chapter 4, "REACTOR DESCRIPTION"	7/5/2024	ML24185A048
Input for ACRS Review of Kairos Non-Power Reactor Hermes 2 Construction Permit Application - Safety Evaluation for Chapter 5, "HEAT TRANSPORT SYSTEM"	7/5/2024	ML24185A050
Input for ACRS Review of Kairos Non-Power Reactor Hermes 2 Construction Permit Application –Safety Evaluation for Chapter 7, "INSTRUMENTATION AND CONTROL SYSTEMS" and Chapter 8, "ELECTRIC POWER SYSTEMS"	7/5/2024	ML24185A044
Input for ACRS Review of Kairos Non-Power Reactor Hermes 2 Construction Permit Application - Safety Evaluation for Chapter 13, "ACCIDENT ANALYSIS"	7/5/2024	ML24185A046

July 17, 2024

SUBJECT: SAFETY EVALUATION OF THE KAIROS NON-POWER REACTOR HERMES 2 CONSTRUCTION PERMIT APPLICATION

Accession No: ML24197A152 **Publicly Available (Y/N):** Y **Sensitive (Y/N):** N
If Sensitive, which category?
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