Status Report - KP-FHR (United States of America)

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1. Overview

- ☐ **In Operation**
- ☐ **Under Construction**
- ☐ **Described in**

Link to PRIS	--

- ☑ **New Concept**

Number of Units	--
Year	--

Reference Plant

Name of Site	--
Link to PRIS	--
Net Power Output (MWe)	140
Gross Power Output (MWe)	--

1.1 Introduction

The Kairos Power fluoride salt-cooled high-temperature reactor (KP-FHR) is a novel advanced reactor technology that leverages TRISO fuel in pebble form combined with a low-pressure fluoride salt coolant. The technology uses an efficient and flexible steam cycle to convert heat from fission into electricity.

This advanced reactor technology is designed for high availability and performance with low maintenance and lifecycle costs, providing dispatchable power that improves grid resiliency and security. In combination with variable renewables, this technology can create a path to a truly clean energy system. The KP-FHR aims to be cost competitive with natural gas.

1.2 Development Milestones

2018	Pre-Conceptual Design completed

2018	Commissioned R-Lab
2018	Initiation of Pre-Application Review with NRC
2020	Acquisition of KP-Southwest Facility in Albuquerque, NM
2020	Commissioned S-Lab
2020	Formed strategic partnership with Materion Corporation to produce Flibe
2020	Awarded $629M cost-shared Advanced Reactor Demonstration Program Risk Reduction Award from the U.S. DOE
2021	Cooperative Development Agreement with Tennessee Valley Authority to deploy Hermes low-power demonstration reactor
2021	Testing Facility construction completed in Albuquerque, NM
2021	Hermes Construction Permit Application accepted for review by U.S. Nuclear Regulatory Commission
2021	Construction begins on the first Engineering Test Unit (ETU 1.0)
2022	Kairos Power establishes the KP-OMADA Advanced Nuclear Alliance with leading North American utilities and generation companies
2022	Kairos Power commissions Molten Salt Purification Plant to produce Flibe coolant for the ETU series
2022	30,000th pebble manufactured for ETU 1.0
2023	Kairos Power loads 12 metric tons of Flibe into ETU 1.0 and commences molten salt operations
2023	NRC issues Construction Permit for Hermes test reactor
2024	ETU 1.0 completes 2,400 hours of pumped salt operations and enters decommissioning
2024	Construction begins on the second Engineering Test Unit (ETU 2.0)
2024	Construction begins on the Hermes demonstration reactor in Oak Ridge, Tennessee

1.3 Design organization or vendor company

1.4 Links to designer/vendor website

1.5 Design Description

The fundamental design concept is the combination of Tri-structural Isotropic (TRISO) particle fuel coupled with molten fluoride salt coolant (2LiF:BeF2, Flibe). This combination results in a high temperature, low-pressure reactor with robust, passive safety systems. In addition to robust, inherent safety, the design also reduces reliance on high-cost, nuclear grade components and structures and leverages conventional technologies to lower capital costs.

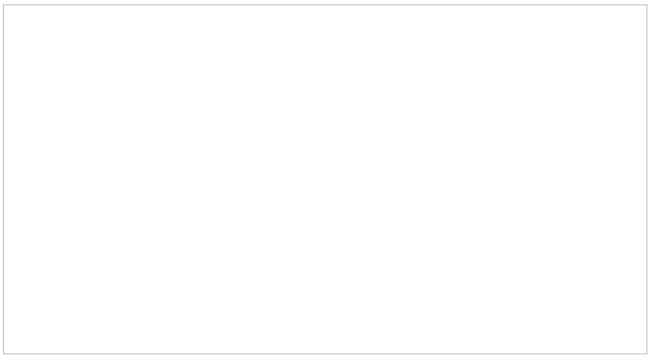


Figure 1. KP-FHR Power conversion system diagram.

1.6 Licensing Application Support Documents

Kairos Power received its construction permit (CP) for the Hermes low-power demonstration reactor from the U.S. Nuclear Regulatory Commission (NRC) in December 2023. Scheduled to enter operation in 2026, Hermes is a reduced scale (35MWth) demonstration reactor that will prove Kairos Power's capability to deliver low-cost nuclear heat.

1.7 Reactor Unit in PRIS

2. Category Fields

Table 1: ARIS Category Fields

ARIS Category	Value	Units of Examples
Current/Intended Purpose	Demonstration	e.g. Commercial – Electric/Non-electric, Prototype/FOAK, Demonstration, Experimental
Main Intended Application (once commercial)	Dispatchable	e.g. Baseload, Dispatchable, Off-grid/Remote, Mobile/Propulsion, Non-electric (specify)

Reference Location	Inland	e.g. On Coast, Inland, Below-Ground, Floating-Fixed, Marine-Mobile, Submerged-Fixed (Other-specify)
Reference Site Design (reactor units per site)	Single Unit	e.g. Single Unit, Dual Unit, Multiple Unit (# units)
Core Coolant	Molten Salts	H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Reactor Core Size (1 core)	30 MWth <= Thermal power < 1000 MWth	e.g. Thermal Power < 30 MWth, 30 MWth ≤ Thermal power < 1000 MWth, 1000 MWth ≤ Thermal power ≤ 3000 MWth, Thermal power > 3000 MWth
Reactor Type	MSR	e.g. PWR, BWR, HWR, SCWR, GCR, GFR, SFR, LFR, MSR, ADS
Reactor Size	SMR	e.g. PWR, SMR
Neutron Moderator	Graphite	e.g. H2O, D2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
NSSS Layout		e.g. Loop-type (# loops), Direct-cycle, Semi-integral, Integral, Pool-type
Primary Circulation	Forced	e.g. Forced (# pumps), Natural
Thermodynamic Cycle	Rankine	e.g. Rankine, Brayton, Combined-Cycle (direct/indirect)
Secondary Side Fluid		e.g. H2O, He, CO2, Na, Pb, PbBi, Molten Salts, (Other-specify)
Fuel Form	Coated Sphere	e.g. Fuel Assembly/Bundle, Coated Sphere, Plate, Prismatic, Contained Liquid, Liquid Fuel/Coolant
Fuel Lattice Shape		e.g. Square, Hexagonal, Triangular, Cylindrical, Spherical, Other, n/a
Rods/Pins per Fuel Assembly/Bundle		e.g. #, n/a
Fuel Material Type		e.g. Oxide, Nitride, Carbide, Metal, Molten Salt, (Other-specify)

Design Status	Conceptual Design	e.g. Conceptual, Detailed, Final (with secure suppliers)
Licensing Status		e.g. DCR, GDR, PSAR, FSAR, Design Licensed (in Country), Under Construction (# units), In Operation (# units)
Neutron Spectrum	Thermal	e.g. Fast, Thermal

3. Parameter Fields

Table 2: ARIS Parameter Fields

ARIS Parameter	Value	Units of Examples
Plant Infrastructure		
Design Life	80	Years
Lifetime Capacity Factor		%, defined as Lifetime MWe-yrs delivered / (MWe capacity * Design Life), incl. outages
Major Planned Outages		# days every # months (specify purpose, including refuelling)
Operation / Maintenance Human Resources		# Staff in Operation / Maintenance Crew during Normal Operation
Reference Site Design		n Units/Modules
Capacity to Electric Grid		MWe (net to grid)
Non-electric Capacity		e.g. MW(th) heat at x °C, m3/day desalinated water, kg/day hydrogen, etc.
In-House Plant Consumption		MWe
Plant Footprint		m2 (rectangular building envelope)
Site Footprint		m2 (fenced area)
Emergency Planning Zone		km (radius)
Releases during Normal Operation		TBq/yr (Noble Gases / Tritium Gas / Liquids)
Load Following Range and Speed		x – 100%, % per minute
Seismic Design (SSE)		g (Safe-Shutdown Earthquake)

NSSS Operating Pressure (primary side)		MPa(abs), i.e. MPa(g)+0.1, at core outlet
NSSS Operating Pressure (secondary side)		MPa(abs), i.e. MPa(g)+0.1, at secondary side outlet
Primary Coolant Inventory (incl. pressurizer)		kg
Nominal Coolant Flow Rate (primary)		kg/s
Nominal Coolant Flow Rate (secondary)		kg/s
Core Inlet Coolant Temperature	550	ºC
Core Outlet Coolant Temperature	650	ºC
Available Tempeature as Process Heat Source		ºC
NSSS Largest Component		e.g. RPV (empty), SG, Core Module (empty/fuelled), etc.
- NSSS Largest Component Length		mm
- NSSS Largest Component Diameter		mm
- NSSS Largest Component Thickness		mm
- NSSS Largest Component Weight		tonne
Reactor Vessel Material		e.g. SS304, SS316, SA508, 800H, Hastelloy N
Steam Generator Design		e.g. Vertical/Horizontal, U-Tube/ Straight/Helical, cross/counter flow
Secondary Coolant Inventory		kg
Pressurizer Design		e.g. separate vessel, integral, steam or gas pressurised, etc.
Pressurizer Volume		m3 / m3 (total / liquid)
Containment Type		Dry (single/double), Dry/Wet Well, Inerted, etc.
Containment Volume		m3

Spent Fuel Pool Capacity and Total Volume		Years of full-power operation / m3
Non Electric Application		-
Core Delta Temperature		ºC
Fuel/Core		
Single Core Thermal Power	320	MW(th)
Refuelling Cycle	continuous	months or “continuous”
Fuel Material	TRISO particles in graphite pebble matrix / pebble bed	e.g. UO2, MOX, UF4, UCO
Enrichment (avg./max.)	19.75	%
Average Neutron Energy		eV
Fuel Cladding Material		e.g. Zr-4, SS, TRISO, E-110, none
Number of Fuel “Units”		Specify as Assembly, Bundle, Plate, Sphere, or n/a
Weight of one Fuel Unit		kg
Total Fissile Loading (initial)		kg fissile material (specify isotopic and chemical composition)
% of fuel outside core during normal operation		Applicable to online refuelling and molten salt reactors
Fraction of fresh-fuel fissile material used up at discharge		%
Core Discharge Burnup		MWd/kgHM (heavy metal, eg U, Pu, Th)
Pin Burnup (max.)		MWd/kgHM
Breeding/Conversion Ratio		Fraction of fissile material bred in-situ over one fuel cycle or at equilibrium core
Reprocessing		e.g. None, Batch, Continuous (FP polishing/actinide removal), etc.
Main Reactivity Control		e.g. Rods, Boron Solution, Fuel Load, Temperature, Flow Rate, Reflectors
Solid Burnable Absorber		e.g. Gd2O3

Core Volume (active)		m3 (used to calculate power density)
Fast Neutron Flux at Core Pressure Boundary		n/(cm²*s)
Max. Fast Neutron Flux		n/(cm²*s)
Core Control Rod Absorber		-
Core Soluble Neutron Absorber		-
Safety Systems		
Number of Safety Trains	Active / Passive	% capacity of each train to fulfil safety function
- reactor shutdown	Active/Passive	- / - / -
- core injection	Active/Passive	- / - / -
- decay heat removal	Active/Passive	- /- / -
- containment isolation and cooling	Active/Passive	- / - / -
- emergency AC supply (e.g. diesels)	Active/Passive	- / - / -
DC Power Capacity (e.g. batteries)		Hours
Events in which Immediate Operator Action is required		e.g. any internal/external initiating events, none
Limiting (shortest) Subsequent Operator Action Time		Hours (that are assumed when following EOPs)
Severe Accident Core Provisions		e.g. no core melt, IVMR, Core Catcher, Core Dump Tank, MCCI
Core Damage Frequency (CDF)		x/reactor-year (based on reference site and location)
Severe Accident Containment Provisions		e.g., H2 ignitors, PARs, filtered venting etc.
Large Release Frequency (LRF)		x/reactor-year (based on reference site and location)
Overall Build Project Costs Estimate or Range (excluding Licensing, based on the Reference Design Site and Location)		
Construction Time (nth of a kind)		Months from first concrete to criticality

Design, Project Mgmt. and Procurement Effort		Person-years (PY) [DP&P]
Construction and Commissioning Effort		PY [C&C]
Material and Equipment Overnight Capital Cost		Million US$(2015) [M&E], if built in USA
Cost Breakdown	%[C&C]/%[M&E]	
- Site Development before first concrete		(e.g. 25/10) (30/40) (20/25) (20/10) (5/15) (----------) (to add up to 100/100)
- Nuclear Island (NSSS)		
- Conventional Island (Turbine and Cooling)		
- Balance of Plant (BOP)		
- Commissioning and First Fuel Loading		
Factory / On-Site split in [C&C] effort		%/% of total [C&C] effort in PY (e.g., 60/40)
Nuclear System		
System Steam Flow Rate		kg/s
System Steam Pressure		MPa
System Steam Temperature		ºC
System Feedwater Flow Rate		kg/s
System Feedwater Temperature		ºC
Reactor Core		
Active Core Height		m
Equivalent Core Diameter		m
Average Linear Heat Rate		kW/m
Average Fuel Power Density		kW/kgU
Average Core Power Density		MW/m3
Outer Diameter Of Fuel Rods		mm

4. Plant Layout, Site Environment and Grid Integration

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4.1 Site Requirements during Construction
4.2 Site Considerations during Operation
4.3 Grid Integration

5. Technical NSSS/Power Conversion System Designn

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Main Design Features

Power Conversion

The power conversion system will leverage prior technology demonstration of solar nitrate salt steam generators and conventional power conversion technologies for the balance of plant.

Reactor Core

4.0-cm diameter spherical fuel and moderator pebbles forming the active region of the core. The core design utilizes a cylindrical geometry with a graphite side-reflector and bottom and top graphite structures. The core internal structures enable reactivity control and shutdown elements.

Reactivity Control

Reactivity control for reactor maneuvering and non-accident events is provided by control elements that insert into the graphite reflector surrounding the pebble bed core. Reactivity control during accident events is provided by shutdown elements that insert directly into the pebble bed. The shutdown elements are gravity driven and are released by the reactor protection system. Both the shutdown and control elements consist of a composite structure of neutron absorber material made of natural B4C in an inert gas with SS316H cladding. The shutdown and control elements fail safe (insert) on a loss of power. The number and the location of the shutdown elements are selected to provide sufficient shutdown margin at zero-power conditions. The shutdown system is designed with sufficient reactivity worth to shut down the core from hot full power assuming the failure of the highest worth control element. The reactivity control elements can be inserted for shutdown at a rate sufficient to assure that the design limits for the fission product barriers are not exceeded.

Reactor Vessel and Internals

The KP-FHR reactor vessel operates at low pressure, so has thin-walled construction using 316H stainless steel that complies with ASME Section III, Division 5 requirements. The reactor internals include a core barrel and reflector support structure that position and retain the graphite reflector structure which maintains alignment of the structure to form the major flow paths and reactor core volume. As the pebbles are positively buoyant in the coolant, defueling occurs from the top of the core and online fuel addition from the bottom. The reactivity control and other components interface through

the top head.

Instrumentation and Control System

The Kairos Power Instrumentation and Control Systems takes advantage of the inherent safety features of the KP-FHR technology to simplify the reactor protection system configuration and automated actions. The system is sufficiently simplified to allow for deterministic analysis of all design basis events. The plant control system operates within the protection system established operating envelope as an industrial control system, maximizing automation and continuous health monitoring of the plant. The I&C Reactor Protection System (RPS) provides protection during steady state and transient power operation and includes the capability to manually or automatically trip the reactor and activate RVACS. The RPS is fully independent of the Plant Control System, which provides overall control during normal operation, startup or shutdown.

5.1 Primary Circuit
5.2 Reactor Core and Fuel
5.3 Fuel Handling
5.4 Reactor Protection
5.5 Secondary Side
5.6 Containment/Confinement
5.7 Electrical, I&C and Human Interface

5.8 Unique Technical Design Features (if any)

6. Technology Readiness

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Testing Conducted for Design Verification and Validation

Kairos Power is committed to a culture that embraces iterative development and facilitates an integrated design philosophy, testing program, and licensing approach to mitigate technical, licensing, manufacturing, and construction risk while establishing cost certainty through iterative hardware demonstrations.

By mirroring SpaceX and its successful rapid spiral development, Kairos Power accelerates test cycles for innovation and optimization. Our rapid iterative approach leverages multiple design-build-test cycles with both nuclear and non-nuclear systems prior to the first commercial reactor. Major hardware iterations include:

- **Engineering Test Units (ETUs)** – non-nuclear systems that test mechanical designs, scale up Flibe production, establish manufacturing infrastructure, and build a sustainable supply chain for raw materials and off-the-shelf components. ETU 1.0 completed 2,400 hours of pumped salt

operations in February 2024 and entered decommissioning. ETU 2.0 will begin operation in 2025.

- **Hermes** – a 35 MWth non-power reactor that will demonstrate Kairos Power's ability to produce affordable nuclear heat. Currently in the design phase, Hermes is scheduled to be operational in 2026.
- **U-Facility** – a non-nuclear demonstration intended to test the manufacturing and construction of primary reactor systems, serve as a training center, and reduce O&M cost uncertainty
- **KP-X** – a first-of-a-kind 140 MWe commercial KP-FHR operating at grid-scale

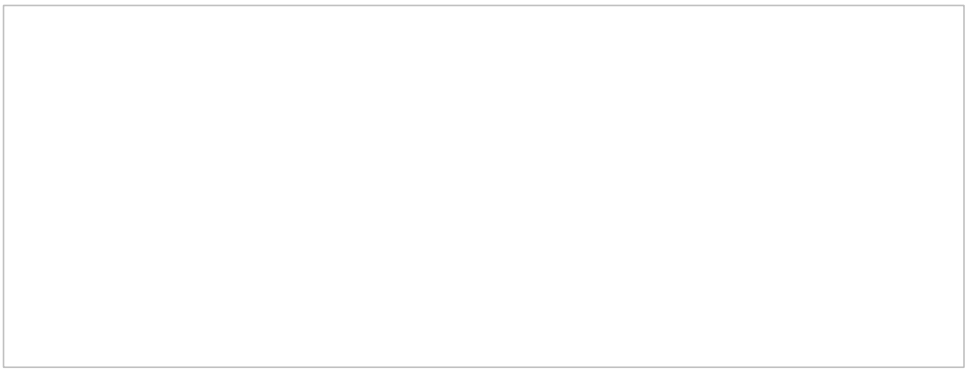


Figure 2. Kairos Power's Rapid iterative approach to hardware development.

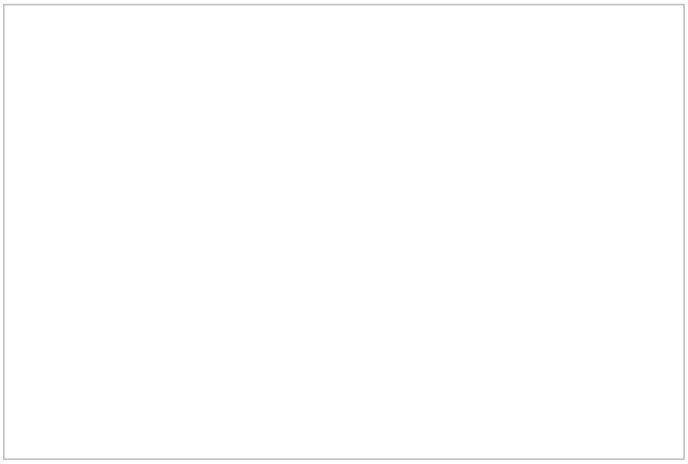


Figure 3. Engineering Test Unit 1.0.

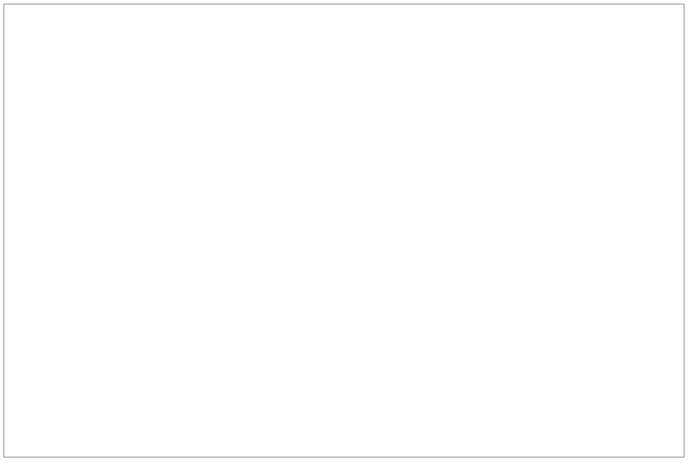


Figure 4. Salt Lab located in Alameda, CA.

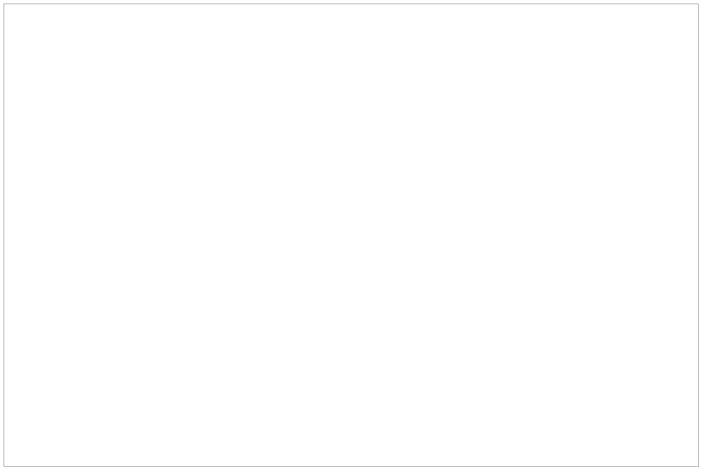


Figure 5. RAPID Lab located in Alameda, CA.

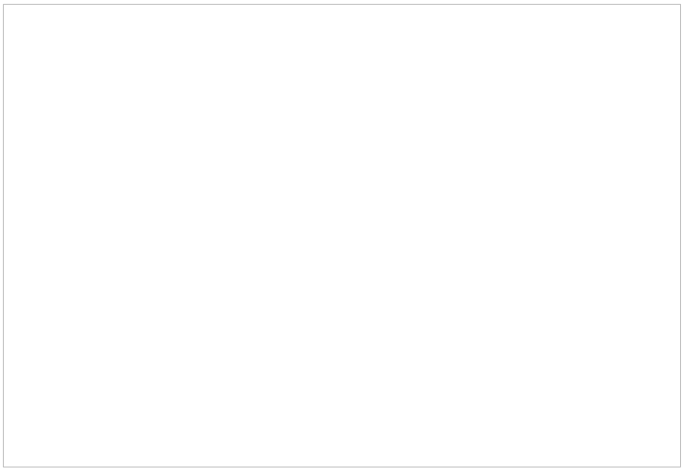


Figure 6. In-house manufacturing shop located in KP-Southwest.

6.1 Deployed Reactors
6.2 Reactors under Licensing Review
6.3 Reactors in the Design Stage

7. Safety Concepts

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Engineered Safety System Approach and Configuration

The reactor system includes a pebble bed core, surrounded by a graphite reflector, contained within a cylindrical 316H stainless steel reactor vessel.

Decay Heat Removal System

Decay heat removal during normal operations and non-accident events is provided by a normal

shutdown cooling system that connects directly to the primary heat transport system. Decay heat removal during accident events is provided by a passive reactor vessel auxiliary cooling system (RVACS) located external to the reactor vessel. No coolant injection is required for inventory makeup nor decay heat removal functions under accident conditions. The RVACS relies on decay heat through thermal radiation and natural convective heat transfer utilizing a thermosyphon concept. The system evaporates water to provide heat removal and does not require inventory makeup for a minimum of 72 hours. System valves are fail-safe and do not rely on safety related electrical power or operator action.

Emergency Core Cooling System

Kairos Power reactors have uniquely large safety margins based on the selected combination of fuel and coolant, which allows emergency cooling to be driven by fundamental physics rather than engineered systems.

Containment System

Functional containment in the KP-FHR is provided by the robust intrinsic safety characteristics of the TRISO fuel and Flibe coolant to ensure that the health and safety of the public and workers are protected. Multiple additional barriers in the KP-FHR provide defense-in-depth.

Chemical Control System

A Chemistry Control System (CCS) monitors the salt coolant to detect impurities, ensuring it stays within an established operating window.

Spent Fuel Cooling Safety Approach / System

The zirconium cladding used in light-water reactor fuel contains substantial stored energy, which affects the safety significance of spent fuel cooling systems. KP-FHR fuel is fully ceramic, which simplifies cooling requirements for fuel in the pebble handling system and also in canister storage.

Plant Safety and Operational Performances

The KP-FHR leverages intrinsic safety characteristics of the fuel and coolant to achieve uniquely large safety margins while lowering capital costs and improving operating economics. The fuel in the KP-FHR is the TRISO particle fuel, which can withstand fuel particle temperatures up to 1600°C. The Flibe is chemically stable and is at low-pressure, with a boiling point of 1430°C, notably lower than 1600°C and yet functionally very high. The combination of extremely high-temperature-tolerant fuel and low-pressure, single-phase, chemically stable reactor coolant removes entire classes of potential fuel-damage scenarios, greatly simplifying the design and reducing the number of safety systems. The intrinsic low pressure of the reactor and associated piping, along with the functional containment provided by the TRISO fuel, enhances safety and eliminates the need for high-pressure containment structures.

7.1 Safety Philosophy and Implementation
7.2 Transient/Accident Behaviour

8. Fuel and Fuel Cycle

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Fuel Characteristics

Kairos Power's reactor uses fully ceramic fuel, which maintains structural integrity even at extremely high temperatures and will be undamaged to well above melting temperatures of conventional metallic reactor fuels.

Fission Product Management

The fundamental safety strategy for the KP-FHR is rooted in the retention of fission products within the TRISO layers of the fuel particle design with additional retention in the flibe salt coolant. The TRISO layers are credited for providing a 'functional containment' for meeting design basis accident dose limits. The silicon carbide (SiC) coating on the TRISO particles is the primary fission product barrier, while the pyrolytic carbon layers and matrix act as secondary barriers for trapping or impeding the transport of fission products and protecting the integrity of the SiC layer.

Fuel Cycle Approach

The KP-FHR operates on a continuous refueling cycle. Fuel pebbles are extracted from the core in the reactor vessel and inspected for burnup and integrity in a pebble handling system. Pebbles are either inserted back into the active core or directed to spent fuel storage. Fuel pebbles pass through the core six times on average before reaching full burnup.

Waste Management and Disposal Plan

The used TRISO pebble fuel and a small inventory of 'greater than Class C' waste is packaged in multi-purpose canisters for dry interim storage and subsequent off-site transportation for direct geologic disposal or recycling depending upon national policies. All remaining waste streams from operation and decommissioning qualify for low-level waste disposal.

8.1 Fuel Cycle Options
8.2 Resource Use Optimization
8.3 Unique Fuel/Fuel Cycle Design Features

9. Safeguard & Physical Security

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9.1 Safeguards
9.2 Security
9.3 Unique Safeguards and/or Security Features

10. Project Delivery & Economics

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10.1 Project Preparation and Negotiation
10.2 Construction and Commissioning
10.3 Operation and Maintenance