Enclosure 2
Response to NRC Question on Fluidic Diode Testing and PSAR Chapter 4 Changes
(Non-Proprietary)

As part of the NRC general audit of the PSAR, the NRC staff asked questions regarding the development program of the fluidic diode.

As described in PSAR Section 4.3, the fluidic diode supports a safety-related heat removal function by supporting an adequate amount of natural circulation flow in the reactor vessel. To provide this function, the fluidic device's design is undergoing an ongoing testing and development program as stated in PSAR Section 1.3.9. PSAR Section 4.6 has been updated to state that the development program will include qualification or functional testing as required by design verification.

The PSAR includes commitments to test safety-related structures, systems, and components to ensure the successful performance of safety functions. As described in PSAR Chapter 4, the fluidic diode will meet PDC 4 and PDC 35. PDC 4 requires that the diode can perform its safety function under the environmental conditions associated with normal plant operation as well as during postulated events. PDC 35 requires that the diode performs its safety function by supporting sufficient removal of residual core decay heat following postulated accident scenarios. As described in PSAR Chapter 12, Appendix B, Section 2.3.3, the adequacy of the design will be verified using methods including the performance of qualification tests. Qualification testing for the fluidic diode will be defined in a test plan that includes appropriate acceptance criteria and demonstrates the component reliability and adequacy of performance under conditions that simulate the most adverse design basis conditions.

As discussed above, qualification testing may be used as part of the design verification process. The design verification will characterize the baseline flow and evaluate potential phenomena that may affect the ability to remove residual core decay heat through natural circulation flow, including:

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]] The testing plans are based on the preliminary design, and final testing needs will be determined through preliminary tests, detailed design development, and analysis.

The testing and development program will provide justification that the diodes will be able to maintain an adequate flow rate required to remove decay heat from the core during a postulated event. The program needed to validate the diode performance in normal and postulated event conditions will be available with the application for an operating license. The results of this program needed to qualify the component through startup qualification testing will be available during the operation phase.

In addition, the PSAR includes commitments to ensure the continued operability of the fluidic diode through inspection and monitoring, which ensures that degradation mechanisms will not prevent the fluidic diode from performing its safety function. Section 4.3.3 commits the diode to PDC 36 and PDC 37, which require that the functionality of the diode can be confirmed through monitoring and inspection. As described in RAI 339, the monitoring and inspection strategy for the diode will ensure that the diode performs its safety function in a postulated event.

1.3.9 Research and Development

The requirements in 10 CFR 50.34(a) 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. Such additional development activities are described below:

- Perform a laboratory testing program to confirm fuel pebble behavior (Section 4.2.1)
- Develop a high temperature material surveillance sampling program for the reactor vessel and internals (Section 4.3.4)
- Perform testing of high temperature material to qualify Alloy 316H and ER16-8-2 (Section 4.3)
- Perform analysis related to potential oxidation in certain postulated events for the qualification of the graphite used in the reflector structure (Section 4.3)
- Development and validation of computer codes for core design and analysis methodology (Section 4.5)
- Develop and perform qualification testing for a fluidic diode device (Section 4.6)
- Justification of thermodynamic data and associated vapor pressure correlations of representative species. (Section 5.1.3)
- Complete evaluations of the intermediate and reactor coolant chemical interaction (Section 5.1.3)
- Develop process sensor technology for key reactor process variables (Section 7.5.3)
- Develop the reactor coolant chemical monitoring instrumentation (Section 9.1.1)

1.3.10 References

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

4.6 THERMAL-HYDRAULIC DESIGN

4.6.1 Description

The thermal hydraulic design of the reactor is a combination of design features that enable effective heat transport from the fuel pebble to the reactor coolant and eventually to the heat rejection system of the reactor, considering the effects of bypass flow and flow non-uniformity. The design features that play a key role in the thermal-hydraulic design of the reactor system include the fuel pebble (see Section 4.2.1), reactor coolant (see Section 5.1), reactor vessel and reactor vessel internal structures (see Section 4.3), the primary heat transport system (PHTS) (see Section 5.1), and the primary heat rejection system (PHRS) (see Section 5.2).

4.6.1.1 Core Geometry

The core geometry is maintained in part by the reactor vessel internals including the reflector blocks which keep the pebbles in a general cylindrical core shape. Coolant inlet channels in the graphite reflector blocks are employed to limit the core pressure drop. The use of pebbles in a packed bed configuration also creates local velocity fields that enhance pebble-to-coolant heat transfer. The reactor thermal hydraulic design uses the following heat transfer mechanisms to extract the fission heat.

- Pebble-to-coolant convective heat transfer
- Pebble radiative heat transfer
- Pebble-to-pebble heat transfer by pebble contact conduction
- Pebble-to-pebble heat transfer by conduction through the reactor coolant
- Heat transfer to the graphite reflector by modes of conduction, convection, and radiation.

4.6.1.2 Coolant Flow Path

During normal operation, reactor coolant at approximately 550°C enters the reactor vessel from two PHTS cold leg nozzles and flows through a downcomer formed between the metallic core barrel and the reactor vessel shell as shown in Figure 4.6-1. The coolant is distributed along the vessel bottom head through the reflector support structure, up through coolant inlet channels in the reflector blocks and the fueling chute and into the core with a portion of the coolant bypassing the core via gaps between the reflector blocks. The coolant transfers heat from fuel pebbles which are buoyant in the coolant and provides cooling to the reflector blocks and the control elements via engineered bypass flow. Coolant travels out of the active core through the upper plenum via the coolant outlet channels and exits the reactor vessel via the PHTS outlet. The maximum vessel exit temperature is 620°C and dependent on the amount of corresponding bypass flow through the reflector blocks.

During postulated events where the normal heat removal path through the PHTS is no longer available, including when the PHTS is drained, a fluidic diode (see Section 4.3), is used to create an alternate flow path. During such events, forced flow from the primary salt pump (PSP) is also not available. The fluidic diode then directs flow from the hot well to the downcomer as shown in Figure 4.6-1. This opens the path for continuous flow via natural circulation. During normal operation, while the PSP is in operation, the fluidic diode minimizes reverse flow. Qualification or functional testing plans for the fluidic diode as well as any test results needed to validate performance assumed in the safety analysis will be available with the application for an operating license.