**Enclosure 1**

**Response to NRC Questions 10 and 13 on PSAR Section 4.2**

**(Non-Proprietary)**

## Question Number: 2-3-22 Q10

Related to the discussion of PDC 4 in PSAR Section 4.2.2.3, what would be the effect on the neutron absorbing material in the control elements if it came in contact with the coolant? LWR operation experience has demonstrated that stainless steel clad, $B_4C$ control rods have failed, and absorber material unexpectedly dissolved in the coolant. Is there a plan for testing the potential interaction of $B_4C$ and Flibe? If not, what is the basis for not testing?

## Kairos Power Response:

Kairos Power is aware of LWR operating experience related to absorber material unexpectedly dissolving in the coolant. If Flibe were to come into direct contact with $B_4C$, there is expected to be some dissolution of the $B_4C$ absorber material. Kairos Power plans to perform testing to understand the rate of $B_4C$ dissolution in Flibe at temperature as part of control and shutdown element development and qualification testing.

The design of the control and shutdown element stainless clad accounts for the expected wear over the lifetime of the element, as described in the response to Question 2-3-22 Q13. As a result, failure of the cladding and dissolution of the absorber material is not expected. As described in PSAR Section 4.2.2.4, Kairos Power will periodically sample for the presence of boron in the Flibe during plant operations as an indicator of dissolution. In addition, as described in Section 4.2.2.4, the control and shutdown elements will be periodically inspected during operation to ensure that there is no unacceptable wear or other damage to the cladding that encapsulates the $B_4C$ absorber material.

## References:

None

## Impact on Licensing Document:

No changes are made to the Kairos Power Preliminary Safety Analysis Report as a result of this response.

## Question Number: 2-3-22 Q13

The discussion of PDC 4 in PSAR Section 4.2.2.3 states control and shutdown elements are tested to ensure that wear during element movement is acceptable. Will this test program be performed out-of-pile before initial reactor operation? What are the wear acceptance criteria (e.g., two-thirds of cladding thickness)?

## Kairos Power Response:

The control and shutdown element testing described in PSAR Section 4.2.2.3 will be performed out-of-pile prior to operation. This would be as part of development and qualification testing and will be conducted by moving the control and shutdown elements for a length of time such that the accumulated length of travel of the elements is greater than the design length of travel during the element lifetime. As part of this development testing, wear acceptance criteria will be established for use in design. The stress analysis on the control and shutdown element cladding will also consider the effects of irradiation and cladding wear during the element lifetime.

## References:

None

## Impact on Licensing Document:

Section 4.2.2.3 of the Kairos Power Preliminary Safety Analysis Report will be revised to reflect the response above. A markup is provided with this response.

Consistent with PDC 28, the RCSS has appropriate limits on the potential amount and rate of reactivity increase to ensure the effects of postulated reactivity events can neither damage the safety significant elements of the reactor coolant boundary or disturb the core and internals such the ability to cool the core is impaired. The system allows only one element to move at a given time.

Consistent with PDC 29, the RCSS, in conjunction with reactor protection systems, assures an extremely high probability of accomplishing its safety-related functions.

4.2.2.3 System Evaluation

The RCSS meets the design bases as described below:

PDC 2

As noted in Section 4.2.2.1, the control elements are inserted into guide structures in the reflector. The RCSS components, guide structures, and reflector blocks ensure the ability of the control and shutdown elements to insert under conditions of reflector block misalignment that could potentially occur in a design basis earthquake. The design basis earthquake is described in Section 3.4. This seismic analysis determines the maximum deflection of the insertion path. Insertion capability will be assessed in a one-time test prior to initial operation that deflects the control element guide structures consistent with the expected misalignment caused by such an event. The control element insertion time is measured and compared to the control element insertion time testing performed with no deflection of the reflector guide structures. The testing is performed to confirm that the control element insertion time is within the insertion time assumed in the postulated event analysis in Chapter 13 under the condition of maximum expected misalignment from a design basis earthquake. Additionally, the reflector blocks maintain the element insertion pathway as described in Section 4.3. The shutdown elements, which insert into the pebble bed, are not affected by the maximum misalignment of the graphite blocks. These control and shutdown element design features provide conformance to PDC 2.

PDC 4

The RCSS is compatible with the environmental conditions that the RCSS will be subjected to during normal operation, maintenance, testing, and postulated events.

The RCSS elements are made with stainless steel cladding. Wear rates due to flow induced vibration are expected to be low in comparison to those of typical operating reactors with stainless steel cladding given the lower core flow rates (<0.13 meter/second) in the design. The neutron absorbing material is enclosed in two stainless steel barriers to mitigate the loss of neutron absorbing material in the shutdown elements. The control elements have a single thicker stainless steel barrier to ensure the absorbing material does not come in contact with the coolant. The control and shutdown elements are qualification tested out of pile prior to operation and a conservative wear limit is established to ensure that wear during control and shutdown element movement is acceptable. The control elements and shutdown elements can be removed for inspection or replaced if necessary. In addition, the control and shutdown elements are not adversely affected by neutron and gamma heating.

Analysis is performed on the control and shutdown elements to determine the internal gas release and swelling of the $B_4C$ during normal operation over their design lifetime. The resulting increase in gas pressure is analyzed to ensure that stresses on the control element tubes are within allowable stress limits for SS 316H. In addition, the effects of irradiation on SS 316H and clad wear are accounted for in the ~~design~~stress analysis.

A finite element model is developed to calculate the forces on the control and shutdown elements during normal operation and postulated events. This analysis includes thermal stresses from internal heat generation, is performed under maximum heat generation conditions, and demonstrates that control and shutdown element cladding stresses are within limits and are not subject to bowing or binding due to differential thermal expansion.

There is extensive experience (References 5, 6, and 7) with $B_4C$ under irradiation. In addition, the $B_4C$ melting temperature is more than 1000˚C above the Hermes operating temperatures.

The control and shutdown elements and drive mechanisms are also analyzed to meet ASME Section III, Division V loads due to operational stepping, reactor trip, stuck element, fatigue, and shipping and handling. All stresses in the components of the reactivity elements are within limits.

Materials utilized in the RCSS elements are qualified for their operating environment. Materials are chosen to ensure reactor coolant induced diffusion bonding does not occur at interfaces where movement or separation is necessary.

~~The control and shutdown elements are tested to ensure that wear during control and shutdown element movement is acceptable.~~

These evaluations demonstrate conformance with PDC 4.

PDC 23

The safety-related reactor trip function of the RCSS is initiated by the reactor protection system through the reactor trip system (RTS) and is based on redundant trip determination signals to automatically open the reactor trip breakers. Removal of power from the electromagnetic clutch in the RCSS allows the control and shutdown elements to fall into the core by gravity. Normally open relays are utilized for this system such that during operation they are energized allowing the system to operate. When the RTS actuates, the energy holding the relays closed is removed and this loss of supply power initiates a reactor trip. The RCSS accomplishes safe shutdown (i.e., reactor trip) via gravity insertion of the control and shutdown elements on a reactor trip signal; or on a loss of normal electrical power after a short time delay to mitigate spurious trips. The electrical system design is described in Chapter 8. The reactor control and reactor protection system architecture are described in Chapter 7. These features, in conjunction with Chapter 7, demonstrate conformance to PDC 23.

PDC 26

The control and shutdown elements meet the requirements of PDC 26. The compliance with the requirements in PDC 26 is discussed in Section 4.5.

PDC 28

The control elements traverse their full range of movement in 100 seconds. This maximum design speed is analyzed in Chapter 13 to ensure that the rate of reactivity addition does not impact the safety significant portions of the reactor coolant boundary and also does not disturb the core and internals and impair cooling of the core.

PDC 29

The RCSS supports a high probability of accomplishing its design function, because the trip function is safety-related and the elements are inserted via gravity. There are two means of inserting negative reactivity and these two means contain sufficient negative reactivity such that the highest worth reactivity element can fail to insert, and the safety-related function can still be achieved. The first means of inserting reactivity would be to use the motor to lower the element into the core region. The second means is upon a reactor trip which releases the elements, allowing them to drop into the core by gravity.