Enclosure 1

Changes to Hermes PSAR Chapters 3, 4, 6, and 14

(Non-Proprietary)

6. Components will be designed and fabricated using the technical guidance in ASME Code, Section III, Division 5, with departures. Specifically, Hermes will implement an ANSI/ANS 15.8 Quality Assurance Program, as described in Section 12.9 rather than the NQA-1 standard specified in the ASME code. Therefore, the components will not meet ASME Code, Section III, Division 5 requirements that are dependent on or tied specifically to an NQA-1 program. Appropriate departures will be taken to the quality assurance related guidance of the ASME Code requirements for Hermes components, including stamping and certification requirements in the Code that are dependent on implementation of an NQA-1 program. Departures from other ASME Code requirements, if any, ~~are also anticipated and~~ will be identified and justified with the Operating License Application. ~~Such departures will still meet the intent of the code technical guidance and provide reasonable assurance of component performance.~~

4.3 REACTOR VESSEL SYSTEM

4.3.1 Description

This section provides an overview of the reactor vessel system (see Figure 4.3-1) which includes the reactor vessel and the reactor vessel internals. The reactor vessel forms a major element of the reactor coolant boundary and the inert gas boundary. The reactor vessel and vessel internals define the flow path for reactor coolant and fuel into the core. The reactor vessel system contains the reactor core and provides for circulation of reactor coolant and pebbles as well as insertion of the reactivity control and shutdown elements through the reactor core.

The reactor vessel system provides a flow path for reactor coolant to transfer heat from the reactor core to the primary heat transport system (PHTS) during normal operations. The reactor coolant enters the reactor vessel through two side inlet nozzles and flows downward through a downcomer annulus formed between the metallic core barrel and the reactor vessel shell. Coolant flow moves through the vessel bottom plenum formed by the reflector support structure and is distributed into the core by the design of the reflector blocks. Upon exiting the core, the coolant leaves the reactor vessel via the primary salt pump (PSP) (see Section 5.1.1) which draws suction directly from a pool of reactor coolant above the core and inside the vessel. Design features are provided in fluid systems connected to the reactor vessel to limit loss of coolant inventory in the event of a break in those systems as described in Sections 5.1, 9.1.4, and 9.3.

The reactor vessel system also provides a flow path for pebbles to allow online refueling and defueling of the reactor core by the pebble handling and storage system (PHSS) (Section 9.3) during normal operation. The PHSS inserts pebbles into the reactor vessel and delivers them to the fueling chute below the reactor core by the pebble insertion line (Section 9.3.1). The buoyant pebbles float upward, and pebbles inserted via the insertion line will join the packed pebble-bed in the reactor core. Upon circulating through the core, the pebbles accumulate in the de-fueling chute at the top of the reactor core. The pebble extraction machine (PEM) (Section 9.3.1) at the top of the reactor core removes pebbles from the reactor vessel (see Figure 4.3-2.)

During postulated events when the PHTS is not available, the reactor vessel provides an alternative flow path as discussed in Section 4.6.1 to allow natural circulation of the reactor coolant to remove heat from the reactor core. The reactor coolant leaving the core flows into the hot well, fluidic diode pathway, fluidic diode, through a core barrel penetration, and back into the downcomer annulus as shown in Figure 4.3-1. The heat from the core is transferred to the reactor vessel shell which transfers the heat to the decay heat removal system (DHRS) (Section 6.3).

The reactor vessel system interfaces with fuel (Section 4.2.1), primary heat transport system (PHTS) (Section 5.1), reactivity control and shutdown system (RCSS) (Section 4.2.2), reactor vessel support system (RVSS) (Section 4.7), decay heat removal system (DHRS) (Section 6.3), pebble handling and storage system (PHSS) (Section 9.3), reactor thermal management system (RTMS) (Section 9.1.5), inert gas system (IGS) (Section 9.1.2), inventory management system (IMS) (Section 9.1.4), and instrumentation and controls (Chapter 7).

4.3.1.1 Reactor Vessel

The reactor vessel is a vertical cylinder design with flat top and bottom heads. The vessel houses the reactor vessel internals. The reactor vessel shell and bottom head provide a major element of the reactor coolant boundary. The vessel is constructed of 316H stainless steel (SS) with ER16-8-2 weld metal and is designed and fabricated using the technical guidance in ASME BPVC Section III, Division 5 (Reference 1) ~~with departures~~ as shown in Table 3.6-2. It contains the inventory of reactor coolant such that the reactor core is covered by the coolant during normal operation and postulated event. There are no penetrations or attachments to the vessel below the coolant level. The design of the reactor vessel allows for online monitoring, in-service inspection, and maintenance.

4.3.1.1.1 Vessel Top Head

The reactor vessel top head (see Figure 4.3-2) is a flat 316H SS disc bolted and flanged to the vessel shell. This interface is designed for leak-tightness but is not credited as being leak tight in safety analyses. The vessel top head controls the radial and circumferential positions of the reflector blocks to ensure a stable core configuration for all conditions (e.g., reactor trip and core motion). The top head contains penetrations, as shown in Figure 4.3-2 and Table 4.3-1, into and out of the vessel and provides for the attachment of supporting equipment and components (e.g., reactivity control elements, reactivity shutdown elements, pebble handling and storage system components, material sampling port, thermocouples, etc.). The top head supports the vessel material surveillance system (MSS) which provides a remote means to insert and remove material test specimens into and from the reactor to support testing. A hold-down structure sub-assembly is welded underneath the vessel top head. This structure contacts with the top surface of the graphite reflector and provides structural support against upward loads during normal operation and most postulated events. A secondary hold-down structure is installed through the upper graphite layers, extending from the reflector top into submerged graphite layers to transfer upward loads from submerged graphite to the vessel top head during postulated air ingress events. The secondary hold down structure extends to below the minimum reactor vessel coolant level that could result from postulated salt spill events.

4.3.1.1.2 Vessel Shell

The reactor vessel is a 316H SS cylindrical shell that, along with the vessel bottom head, serves to form the safety-related reactor coolant boundary within the reactor vessel. It contains and maintains the inventory of reactor coolant inside the vessel. The shell provides the geometry for coolant inlet and vessel surface for the DHRS which transfers heat from the reactor vessel during postulated events. The inside of the shell uses 316H SS tabs to maintain the core barrel in a cylindrical geometry and has a welded connection at the top of the core barrel.

4.3.1.1.3 Vessel Bottom Head

The reactor vessel bottom head is a flat 316H SS disc that is welded to the vessel shell. It contains and maintains the inventory of the reactor coolant inside the vessel, supports the vessel internals, maintains the reactor coolant boundary and provides flow geometry for low pressure reactor coolant inlet to the core. Hydrostatic, seismic and gravity loads on the vessel and vessel internals are transferred to the bottom head and are transferred to the RVSS.

4.3.1.2 Reactor Vessel Internals

The reactor vessel internal structures include the graphite reflector blocks, core barrel and reflector support structure. The vessel internal structures define the flow paths of the fuel and reactor coolant, provide a heat sink, a pathway for instrumentation insertion, control and shutdown element insertion, as well as provide neutron shielding and moderation surrounding the core. The reactor vessel internal structures are designed and fabricated using the technical guidance in ASME BPVC Section III, Division 5 (Reference 1) ~~with departures~~ as shown in Table 3.6-2. The design of the structures support inspection and maintenance activities as well as monitoring of the reactor vessel system.

4.3.3 System Evaluation

The 316H SS structures of the reactor vessel system are fabricated and tested to meet the intent of Reference 1 standards ~~with departures~~ as shown in Table 3.6-2. The 316H SS vessel internals also satisfy the chemistry restrictions of the ASME Section III code in Division 5, Article HGB-2000. Per the ASME standard, ER16-8-2 weld metal will be used in fabrication of the 316H structures. Commensurate with the safety-related function of the reflector block in ensuring acceptable design limits and maintaining the reactor coolant flow path, quality related controls will be placed on the ET-10 graphite. The graphite reflector will be designed to meet the intent of Reference 1 standards ~~with departures~~ shown in Table 3.6-2. KP-FHR specifications and procurement documents incorporate and reference the applicable guidance and ASME standards. The quality assurance program is described in Section 12.9. These controls demonstrate conformance with PDC 1.

The reactor vessel system makes up a portion of the reactor coolant boundary. The reactor vessel and graphite reflector blocks are therefore designed to maintain geometry during a safe shutdown earthquake to ensure the vessel integrity, insertion of negative reactivity via the RCSS, and to maintain the flow path. The reactor vessel and vessel internals will have dynamic behaviors during a design basis earthquake. These include fluid-structure interaction within the vessel, oscillatory response of components mounted to the reactor top head, i.e., head-mounted oscillators, and relative movement of graphite reflector blocks with respect to one another within the coolant. These dynamic behaviors are accounted for in the design of the reactor and its internals, to ensure continued functionality during and after a design basis earthquake. Models are used to understand fluid migration tendencies considering the pebble bed, reflector blocks, core barrel, and other reactor vessel internal features. The insights gained from the analysis of these models are used to design the reactor to prevent damage to the vessel during a design basis earthquake. The reactor vessel, vessel internals, and vessel attachments such as the RCSS are classified as SDC-3 per ASCE 43-19 “Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities” (Reference 2). The reactor vessel will also be protected from the failure of nearby non-safety related SSCs during a design basis earthquake by seismically mounting, physically separating, or using a barrier to preclude adverse interaction, and from failure of attached non-safety related SSCs, such as attached piping (e.g., by design for preferential failure of the non-safety component is a way that does not impact the vessel). These features demonstrate compliance with PDC 2.

The reactor vessel can accommodate internal and external static and dynamic loads. The thermal expansion of the reactor vessel shell and bottom head is supported by the reactor vessel support system (RVSS) (see Section 4.7) during reactor startup, normal operation, and postulated events. Mechanical loadings from static weight, seismic load, and forces from the pebble bed, coolant, and core components are transferred to the vessel shell, to the bottom head, and then to the RVSS. The lateral load path of the vessel support is designed to preclude damage to the decay heat removal system and ensure the vessel maintains its integrity and remains in an upright position. The design of the vessel shell resists hoop stresses from the pressure in the downcomer and supports the transfer of static and dynamic loads between the vessel top head and the vessel bottom head to the RVSS. There are also no pressurized piping systems in or around the reactor vessel, thus precluding pipe whip hazards. Heavy load considerations are addressed in Section 9.8.4, Cranes and Rigging. These features demonstrate compliance with PDC 4.

Core cooling is maintained through the design of the reactor vessel and the reactor vessel internals. As described in Section 4.3.1.2, the vessel and vessel internals define the coolant flow path. To preclude degradation to the vessel due to corrosion of the stainless steel, the reflector blocks and the vessel are “baked” (i.e., heated uniformly) to remove residual moisture prior to coming into contact with coolant.

Table 6.3-4: Applicable Design Codes and Standards for the DHRS

Code	Title	Applicability
ASME Sec. III Div. 5 Class B (Reference 1)	ASME Boiler and Pressure Vessel Code – High Temperature Reactors	The DHRS metallic pressure boundary and supports will be designed and fabricated using the technical guidance in ASME, Section III, Division 5, ~~with departures~~ as shown in Table 3.6-2.
ASCE 43-19 (Reference 2)	Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities	Provides design criteria for seismic analysis of reactor components (including DHRS).
ASCE 4-16 (Reference 3)	Seismic Analysis of Safety-Related Nuclear Structures	Provides additional design criteria for safety-related systems (including DHRS) that expand upon ASCE 43-19.
ACI 349-13 (Reference 4)	Code Requirements for Nuclear Safety-Related Concrete Structures and Commentary	Applicable to cavity support structures for DHRS panels and potentially the condenser pool construction.

Section	Section Name	LCO or Condition	Basis
2.2	LSSS	The high-power flux trip function shall not exceed an upper bound limit as specified in the safety analysis.	Limiting the upper bound limit will ensure that the reactor will trip prior to challenging a safety limit assumed in the safety analysis.
3.0	Limiting Conditions for Operation (LCOs) LCOs are derived from the safety analysis and are implemented administratively or by control and monitoring systems to ensure safe operation of the facility. The LCOs are the lowest functional capability or performance level required for safe operation of the facility. The proposed subjects of LCOs are provided below.		
3.1	Reactor Core Parameters	Pebble wear is within acceptable limits to support pebble reinsertion.	The objective is to ensure that pebble wear is controlled within limits assumed by or associated with safety analyses, to prevent reinsertion if wear exceeds those limits.
		Reactor power shall not exceed the licensed reactor power level.	The objective is to limit the maximum operating power to ensure that the safety limits will not be exceeded.
3.2	Reactor Control and Safety Systems	Reactivity coefficients are within limits over the allowable range of operation.	The objective is to infer or calculate reactivity coefficients during normal plant operation to limit the severity of a reactivity transient.
		Reactor protection system operability	The objective is to specify the requirement to have an operable reactor protection system to ensure that the safety limits will not be exceeded.
3.3	Coolant Systems	Reactor coolant chemical composition is maintained within allowable limits.	The objective is to ensure that the thermophysical properties and chemical composition of the reactor coolant are maintained within limits assumed by or associated with safety analyses.