The continuous operation of the DHRS does not require a control actuation to transition from normal operation to passive heat removal. However, event monitoring and the capability for active actuation are provided. The primary interfacing systems through which these occur are described in Chapter 7.

The DHRS is located in the reactor building, which is described in Section 3.5 and contains the reactor cavity and the reactor cell. The DHRS thimbles and steam separators are located within the reactor cavity, but do not have direct contact with the reactor vessel shell. Energy is transferred from the vessel to the DHRS through thermal radiation and convection. The reactor auxiliary heating system (RAHS) is located in the free space between the reactor vessel and the reactor cavity insulation (see Section 9.1.5), but the overall performance of the RAHS does not adversely affect the DHRS removal efficiency because it is deactivated while the DHRS is actively removing heat. The water storage tanks are located outside of the reactor cavity, within the reactor cell. The primary biological shield is a concrete structure which separates the reactor cavity from the reactor cell. This provides direct structural support for the DHRS thimble units and separation and shielding of the water storage tanks from the reactor cavity environments. It also provides through-ports for the steam return and thimble feedwater lines. The primary biological shield is described in Section 4.4. The DHRS primary mode of heat removal is venting steam produced in the thimbles to the atmosphere through the water storage tanks.

The primary components of the DHRS are described in the following subsections.

6.3.1.1 Water Storage Tanks

The DHRS contains four water storage tanks which supply cooling inventory to the DHRS thimbles. These tanks are located outside of the reactor cavity, within the reactor cell, at a higher elevation than other DHRS components. This location enables gravity-driven flow to the thimbles and steam separators. Each water storage tank is coupled to a set of six thimbles through a feedwater line and steam return line which pass through the primary biological shield. These lines are distributed to individual thimbles through the steam separator located in the upper reactor cavity.

At least three storage tanks must be available for the DHRS to adequately perform its function during postulated event conditions. Each tank holds sufficient inventory such that the thimbles connected to it may be operated continuously for at least 72 hours following a loss of the water storage tank feedwater supply during a postulated event. In addition, tank water level is monitored to ensure DHRS operability. Each storage tank is located in an independent location such that damage at one location does not preclude operation of the entire DHRS when required for decay heat removal. This location also provides additional assurance that failures of the water storage tank do not result in leaking into the reactor cell, and that vented or leaked water and steam do not mix with Flibe.

The key water storage tank parameters are provided in Table 6.3-1.

6.3.1.2 Steam Separators

The steam separators provide an interface between the water storage tanks and the individual thimbles that the tanks supply. The steam separator achieves this function by controlling the water level inside its volume through the use of a passive float valve located on the thimble feedwater line. The controlled free surface in the separator is located above the thimble feedwater port and below the steam vent port. The throughput of water is therefore a function of the boil-off rate in the thimbles. Figure 6.3-2 provides a notional diagram of the DHRS separator and float valve.

The float valve consists of a free hollow float which blocks the feedwater line when water level exceeds a threshold value and allows for continuous flow at all other float positions. There are no independent moving mechanical parts beyond the float itself. The valve is designed with sufficient reliability to support the safety case and provide a passively controlled flow of feedwater to the thimbles. The valve

is fail-open by design with sufficient redundancy to ensure reliable operation upon demand. Fail-open performance floods the separator volume upon failure and does not affect the net heat removal performance of the thimbles.

The separators are contained within the leak barrier (described in Section 6.3.1.4); therefore, failures of the separator pressure boundary do not preclude the heat removal function of the DHRS. The water ejected from the separator due to a failure of the pressure boundary is captured in the monitored leak barrier. This initiates shutdown of the reactor if it has not already occurred. The leak barrier is a pressure boundary, which ensures that water does not leak directly into the reactor cavity or cell.

The key steam separator parameters are provided in Table 6.3-2.

6.3.1.3 Thimbles

The DHRS thimbles are annular thermosyphons located circumferentially around the outside of the reactor vessel. The thimbles remove heat from the reactor vessel through continuous boil-off of the thimble feedwater supply. A thimble consists of a centrally located guide tube contained within an evaporator tube. The entire unit is fully enclosed within an outer thimble casing, which is part of the leak barrier (see Figure 6.3-3). Heat from the reactor vessel is incident upon the leak barrier, which re-irradiates to the evaporator tube. Fluid is fed from the steam separator to the guide tube and back up the evaporator tube through buoyancy-driven flow. The density differential associated with this flow is developed in the evaporator region, where heat is absorbed in the fluid via convective heat transfer, causing nucleation and flow boiling. The two-phase mixture is ejected into the steam separator, which returns liquid to the static level and allows steam to flow freely out the steam return line. The fluid re-circulation and steam production rate in the thimble is a function of the reactor vessel surface temperature, resulting in a variable flow rate that accommodates the reactor vessel conditions.

The thimbles are supported by the weld joint to the steam separators and are seismically restrained. The thimbles are located in the free gas space between the vessel shell surface and the insulation lining the primary biological shield. The distribution of thimbles is such that failure of all six thimbles from a single train does not cause the reactor vessel to exceed its temperature limits.

The thimbles include an outer casing, which functions as part of the leak barrier system as described in Section 6.3.1.4. Individual thimbles may be either plugged or replaced during maintenance periods. Each train of DHRS includes one redundant thimble, such that the loss of a single thimble will not inhibit operation of the train.

The key thimble parameters are provided in Table 6.3-3.

6.3.1.4 Leak Barrier

Components in the reactor cavity are designed to prevent water leaks and flooding. For this reason, DHRS components located inside the reactor cavity are dual-walled. This includes the thimbles, separators, and thimble feedwater and steam-return piping. The outer casing of the thimbles serves as a dual-wall. The continuous and connected dual-wall may be pressurized for periodic leak checking of the gas region during normal operation. This confirms integrity of the water pressure boundary and the leak barrier. In addition, continuous leak detection of the internal water pressure boundary is possible by monitoring for a relative rise in humidity in the gas space and a drop in the external surface temperature, which would indicate the formation of a leak. Therefore, this system provides a reliable mechanism for prevention of flooding into the reactor cavity. This secondary barrier also provides protection for the DHRS from external hazards associated with Flibe coolant leaking from the PHTS in the event of a failure.

Figure 6.3-2: Notional Diagram of the DHRS Separator and Float Valve

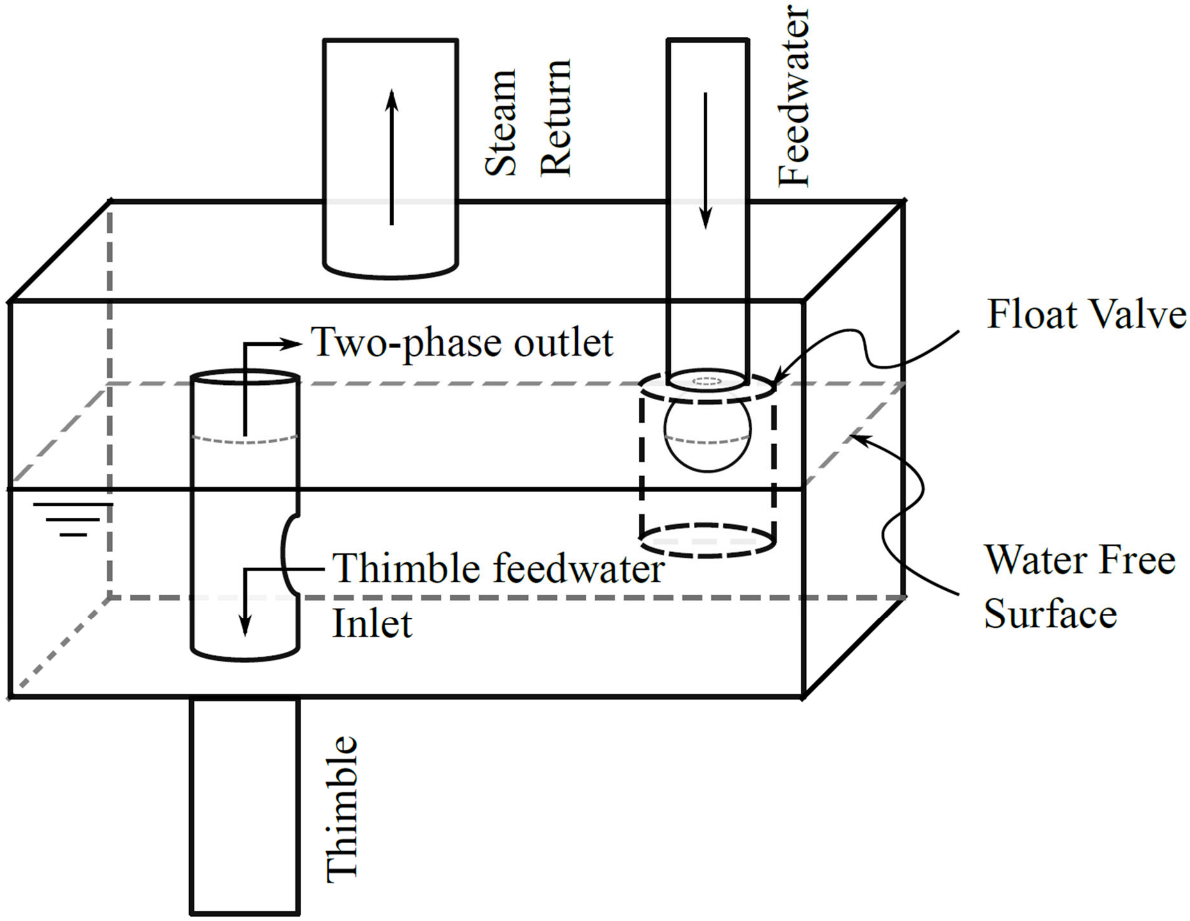

Figure 6.3-3: Annular Thimble Geometry