## 6.3 DECAY HEAT REMOVAL SYSTEM

### 6.3.1 Description

The decay heat removal system (DHRS) removes residual decay heat from the reactor core during normal and off-normal conditions. The DHRS is credited in Chapter 13 for decay heat removal during postulated events that assume the primary heat transport system and primary heat rejection system are unavailable, including the maximum hypothetical accident. The portions of the DHRS that must function to perform the decay heat removal credited in Chapter 13 are designated as safety-related and are all passive. There are no active safety-related portions of the DHRS, and the DHRS does not require electrical power to perform safety functions during postulated events. The DHRS is an ex-vessel system that continuously operates when the reactor is operating above a threshold power by removing energy from the vessel wall via thermal radiation and convective heat transfer to water-based thermosyphons. Inventory in the thermosyphons is boiled off and vents directly to the atmosphere outside of the reactor building.

The DHRS consists of annular thermosyphon thimbles in the reactor cavity, steam separators, and water storage tanks. These components are arranged into four independent cooling trains with inventory sufficient to sustain passive operation of the DHRS for ~~at least 72 hours~~up to 7 days ~~following~~ as needed to mitigate a postulated event where normal cooling systems are unavailable. Each train is composed of one water storage tank, one steam separator, and six thimbles. The general arrangement of the DHRS is illustrated in Figure 6.3-1.

The operation of the DHRS is governed by two operational modes. When reactor power is less than a specified threshold power, parasitic losses from the reactor vessel due to convective losses from air ingress and parasitic thermal-radiation and conduction losses through solid structures are sufficient to maintain vessel temperatures below the design limit during a postulated event when the PHTS is unavailable. When the reactor power is above the threshold power, supplemental cooling by the DHRS is required. This threshold power depends on the reactor power history due to the accumulation of fission products in the core as a function of power. The threshold power is nominally 10 MW for a fresh core. As such, the DHRS operating modes are defined as:

- Low Decay Power Operation (Reactor power < threshold power)
  Thermosyphon thimbles in the reactor cavity are dry and isolated from the rest of the system. Water is held in four separate water storage tanks (one for each DHRS train) located above the thimbles and outside of the reactor cavity. Decay heat removal is achieved through parasitic cavity losses.
- High Decay Power Operation (Reactor power > threshold power)
  The thimbles are filled with water and the connected steam separator contains a free surface below the thimble outlet and above the thimble inlet. The separator is continuously and passively replenished from the water storage tank as water in the thimbles is boiled off and vented to atmosphere outside the reactor building, thereby removing heat from the reactor vessel.

These operating states require a transition period. The transition period occurs at the threshold power, where decay heat loads exceed the removal rate by natural parasitic losses. The isolation valves on the thimble feedwater lines open, which allows water to flow from the water storage tank to the thimbles, as indicated by a positive flow rate. The peak flow rate is limited by frictional losses due to the line sizes and gravitational head associated with the water storage tank locations. The temperature of the evaporator tubes contained in the thimbles decreases from standby temperature (550 °C) during low decay power operation to the nominal boil-off operating temperature (100 °C) as the evaporator is

wetted. The transient quenching process time is dependent on the thimble feedwater flow rate. Steady-state conditions occur upon completion of the fill with a pseudo-stable liquid level in the separators.

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~~up to 7 days as needed to mitigate postulated events resulting in ~~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.

tornadoes, floods, and wind-induced missile events. The DHRS design requirements for seismic and other natural hazards demonstrate conformance with the requirements in PDC 2.

The DHRS is designed and located to minimize the probability and effect of fires and explosions by the use of low combustible materials and physical separation. These design features, in conjunction with the fire protection plan described in Section 9.4, provide assurance that the DHRS demonstrate conformance with the requirements in PDC 3.

The DHRS is designed with materials that will withstand the radiation environment of the reactor cavity and environmental temperatures up to 800 °C to ensure the DHRS is capable of performing its safety function under conditions associated with normal operation, maintenance, testing, and postulated events. The DHRS is designed against equipment failures that could result from Flibe spills. Pipe whip and other similar dynamic failures are avoided by the low-pressure design of the DHRS and the use of restraints. Each component of the DHRS is designed such that failure of one component does not cascade and cause failures of nearby safety systems, including other DHRS components. These design considerations demonstrate conformance with the requirements in PDC 4.

Natural circulation in the reactor core transfers decay heat from the fuel to the reactor vessel shell when normal cooling is not available, as described in Section 4.6.3. Thermal-hydraulic calculations demonstrate that the DHRS is capable of passively removing a sufficient amount of decay heat from the reactor vessel without reliance on electric power for ~~at least 72 hours~~up to 7 days ~~following~~ as needed to mitigate postulated events, such that the reactor vessel temperature remains below its design limit of 816 °C and is decreasing~~ by the end of the 72-hour period~~. In addition, fuel temperatures remain below their design limits. The DHRS is designed with sufficient redundancy, leak detection capability, and isolation to ensure the safety function can be performed assuming a single failure. The system includes four independent loops and maintains the ability to perform its function with the loss of a single loop. Isolation of the four water storage tanks from one another ensures that damage at one tank location does not result in a total loss of DHRS inventory. The thimbles, separators, and thimble feedwater and steam-return piping are all contained within the leak barrier. The leak barrier provides leak detection capability and ensures that a failure of the primary DHRS pressure boundary does not prevent the system from performing its heat removal function. These DHRS design features, along with the natural circulation characteristics of the reactor core, demonstrate conformance with the requirements in PDC 34 and PDC 35.

The DHRS design includes the capability for online monitoring of leaks to monitor for system integrity and to ensure that DHRS inventory remains sufficient to perform the safety-related heat removal function. The water level in the storage tanks is also capable of being monitored to ensure that sufficient inventory is present at the onset of a postulated event to provide sufficient cooling capacity. The DHRS is also sufficiently accessible to perform inspections for system integrity. These features satisfy PDC 36.

When the reactor is above threshold power, the DHRS is an "always on" operating condition which provides an ongoing demonstration of system availability. The transition from normal to postulated event operation can also be functionally tested. These features demonstrate conformance with the requirements in PDC 37.

### 6.3.4 Testing and Inspection

The details of the inspection and testing program for DHRS to satisfy the applicable portions of ASME Section XI, Division 1 and 2, "Rules for Inservice Inspection of Nuclear Power Plant Components" (Reference 2) will be described in the application for an Operating License.

**Table 6.3-1: Water Storage Tank Parameters**

| Parameter | Value |
|---|---|
| Material | Stainless Steel |
| Design Pressure [psig] | 30 |
| Design Temperature [°F] | 274 |
| Minimum Volume per tank [gal] | ~~1738~~2900 |
| Number per reactor | 4 |

# CHAPTER 8 ELECTRIC POWER SYSTEMS

## 8.1 SUMMARY DESCRIPTION

The purpose of the electrical system is to provide power to plant equipment for operation. The electrical system consists of the non-Class 1E normal power system (discussed in Section 8.2) and the backup power system (discussed in Section 8.3). During normal operations, the local utility supplies AC electrical power to the normal power system. If the normal power source fails, the backup power system supplies plant power. The backup power system utilizes backup generators and uninterruptible power supplies (UPS) to achieve this function.

Owing to the passive design of Hermes, safety-related structures, systems, and components (SSCs) do not require electric power to perform safety-related functions ~~for a minimum of 72 hours~~ following a ~~design basis~~postulated event. Therefore, AC power from off-site or backup power sources is not required to mitigate a ~~design basis~~postulated event. A simplified diagram of the major electrical system components is provided in Figure 8.1-1.

## 8.2 NORMAL POWER SYSTEM

### 8.2.1 Description

The normal power system is supplied by an offsite power source from the local utility. The local utility provides a medium voltage feeder. From the point of connection, an appropriate step-down transformer reduces the voltage to the nominal bus voltage of 480 V, which is distributed to plant loads as depicted in Figure 8.1-1. A loss of voltage or degraded voltage condition on the normal power system does not adversely affect the performance of safety-related functions.

#### 8.2.1.1 AC Electrical Power

AC power is distributed to the plant electrical loads during startup and shutdown, normal operation, and off-normal conditions. The AC electrical power components include the following:

- A single incoming feeder from the utility to the normal power system with nominal feeder voltage of 4.16 kV,
- A 4.16 kV/480 V step down transformer, and
- The low voltage AC electrical power distribution with nominal bus voltages of 480 V and 120 V.

Selected loads are supplied with continual AC electrical power via uninterruptible power supplies (UPS). Each UPS provides a highly reliable power supply during normal operations and is automatically configured to provide backup power during a loss of normal electrical power event. The backup function of the UPS is described in Section 8.3.1.2.

#### 8.2.1.2 DC Electrical Power

DC electrical power supply is limited to instrumentation and control functions that require 24 VDC electrical power for operation. The cabinets associated with these functions are equipped with 120 VAC to 24 VDC power supplies, as shown in Figure 8.1-1. AC electrical power is supplied to these cabinets via UPS to ensure continuous, failure-tolerant DC power during normal operation and for a specified ~~minimum~~ maximum duty cycle following a total loss of AC electrical power.

### 8.2.2 Design Bases

The normal power system does not perform any safety-related functions and is not credited for the mitigation of postulated events. The system is also not credited with performing safe shutdown functions.

### 8.2.3 System Evaluation

The normal power system is provided to permit functioning of plant SSCs that require electrical power. The passive design features, based on fundamental physics principles, do not rely on electrical power for safety-related SSCs to perform their safety functions during postulated events. These features demonstrate conformance with the requirement in PDC 17.

As discussed above, the normal power system is not relied on for safety-related SSCs to perform their safety functions ~~for a minimum of 72 hours~~ following postulated events. Therefore, there are no safety-related portions of the normal power system, and no tests or inspections are required to demonstrate conformance with the requirement in PDC 18.

The design of the normal power system is such that malfunction of the system will not cause reactor damage or prevent safe reactor shutdown. The normal power system ensures that adequate independence is maintained between the non-safety related equipment and circuits of the normal power system and Class 1E instrumentation and control (I&C) equipment and circuits (see Section 8.3.3).

## 8.3 BACKUP POWER SYSTEM

### 8.3.1 Description

The purpose of the backup power system (BPS) is to provide AC electrical power to the essential facility loads when the normal AC power supply is not available. The system includes backup generators and uninterruptible power supplies (UPS), as well as electrical equipment and circuits used to interconnect the backup generators to the low voltage AC electrical power distribution. In addition, the facility is equipped with a plug-in connection for use with a portable 480 VAC generator to provide power to essential loads in the event the backup generators are unavailable.

#### 8.3.1.1 Backup Generators

The backup generators automatically start in the event of a loss of offsite power and provide backup electrical power to the essential facility loads. There will be at least one redundant generator by design (n-1 contingency), which ensures that sufficient backup power will be supplied in the event of a single generator failure. The backup generators are located on an enclosed skid installation outside the reactor building and include conventional components such as:

- Engine starter
- Combustion air intake and engine exhaust
- Engine cooling
- Engine lubricating oil
- Engine fuel (including fuel storage and transfer)
- Generator excitation, protective relaying, and associated instrumentation and controls

The backup generators are provided with controls to facilitate manual startup and shutdown, either locally or from a transfer switch in the main control room (MCR) (see Section 7.4), and to provide for monitoring and control during backup generator operation.

The backup generator switchgear is connected to a distribution switchgear which provides power to 480 V motor control centers (MCCs) and distribution panels. On a loss of normal power, the backup generators start up and the automatic transfer switch (ATS) transfers power supply from the normal utility feed to the backup generator feed. A load shedding scheme is employed to ensure that only essential loads are supplied with backup power. A list of the specific essential loads that receive backup power will be provided in the application for an Operating License.

#### 8.3.1.2 Uninterruptible Power Supplies

Selected loads are supplied with continuous AC electrical power via uninterruptible power supplies (UPS), as depicted in Figure 8.1-1. Each UPS provides a highly reliable power supply during normal operations and is automatically configured to provide backup power during a loss of normal electrical power event. The UPS are sized to provide sufficient power to those selected loads to maintain functionality during backup generator startup, and for their respective specified ~~minimum~~ maximum duties as described in Section 8.3.3.

### 8.3.2 Design Bases

The BPS does not perform any safety-related functions and is not credited for the mitigation of postulated events. The system is also not credited with performing safe shutdown functions.

### 8.3.3 System Evaluation

The normal and backup power systems are designed to prevent interference with safety-related functions. If the backup generators fail during a loss of normal power event, the UPS supplying the

reactor protection system (RPS) block loads (as shown in Figure 8.1-1) will fail by design to ensure proper fail-safe functions. This UPS is sized to provide short-term backup power to the RPS block loads, and to lose power on failure of the backup generators. The fail-safe functions are described in further detail in the following paragraphs and in Section 7.3.

To ensure fail-to-safety in the event of a complete loss of AC electrical power, the reactivity control and shutdown system (RCSS) is equipped with a safety-related clutch that requires 24 VDC to remain closed. On a loss of power, the relay opens, and the control elements drop into the reactor by gravity.

To ensure fail-to-safety in the event of a complete loss of AC electrical power, the primary salt pump (PSP) and intermediate salt pump (ISP) power supplies are equipped with relays requiring 24 VDC to remain closed. On a loss of power, the relays open to prevent inadvertent pump restart on power restoration. A manual reset is required to restart the pumps.

On activation of the decay heat removal system (DHRS), the reactor protection system will remove 24 VDC from the activation circuit relay to prevent inadvertent shut down of the DHRS by operator error.

Equipment for monitoring reactor status will be supplied by UPS until the normal power supply or backup generators are restored.

The BPS is provided to permit functioning of SSCs following a loss of normal power. The passive design features of the Hermes reactor, based on fundamental physics principles, do not rely on AC or DC electrical power for safety-related SSCs to perform their safety functions during postulated events. Safe shutdown of the reactor does not rely on AC electrical power from the BPS. These features demonstrate conformance with the requirements in PDC 17.

As discussed above, the BPS is not relied on for safety-related SSCs to perform their safety functions ~~for a minimum of 72 hours~~ following postulated events. Therefore, there are no safety-related portions of the BPS, and no tests or inspections are required to demonstrate conformance with the requirement in PDC 18.

The backup power system is not safety-related, but portions of the system may cross the isolation moat discussed in Section 3.5. SSCs that cross a base-isolation moat may experience differential displacements as a result of seismic events. The backup power system is designed so that postulated failures of SSCs in the system from differential displacements do not preclude a safety-related SSC from performing its safety function. Design features addressing differential displacement are discussed in Section 3.5. These features demonstrate conformance with the requirement in PDC 2.

The backup power system is designed in accordance with NFPA 70, “National Electrical Code” (Reference 8.3-1).

### 8.3.4 Testing and Inspection

The BPS does not perform any safety functions. Periodic inspection and testing are performed on the BPS for operational purposes.

### 8.3.5 References

1. National Fire Protection Association, NFPA 70, “National Electrical Code.” 2020.