# Enclosure 3

## MFN 14-052, Revision 1

## GEH Revised Response to RAI 06.02.01.01.C-1

## ABWR DCD DRAFT Revision 6 Markups

### 5.4.7.2 Systems Design

#### 5.4.7.2.1 System Diagrams

All of the RHR System components are shown in the P&ID (Figure ). A description of the controls and instrumentation is presented in Subsection 7.3.1.1.1.

Figure  is the RHR process diagram and data. All of the sizing modes of the system are shown in the process data. The interlock block diagram (IBD) for the RHR System is provided in Section 7.3.

Interlocks are provided to prevent (1) drawing vessel water to the suppression pool, (2) opening vessel suction valves above the suction lines or the discharge line design pressure, (3) inadvertent opening of drywell spray valves during RHR operation where the injection valve to the reactor is open and when drywell pressure is not high enough to require the drywell spray for pressure reduction, and (4) pump start when suction valve(s) are not open. A description of the RHR System logic (i.e., interlocks, permissives) is presented in Table 5.4-3.

#### 5.4.7.2.2 Equipment and Component Description

(1) System Main pumps

The main pumps must satisfy the following system performance requirements. The pump equipment performance requirements include additional margins so that the system performance requirements can be achieved. These margins are standard GEH equipment specification practice and are included in procurement specifications for flow and pressure measuring accuracy and for power source frequency variation.

| | |
|---|---|
| Number of pumps | 3 |
| Pump type | Centrifugal |
| Drive unit type | Constant Speed Induction Motor |
| Design flow rate | 954 $m^3/h$ |
| Total discharge head at design flow rate | 125m |
| Maximum bypass flow | 147.6 $m^3/h$ |
| Minimum total discharge head at maximum bypass flow rate | 220m Max<br>195m Min |
| Maximum runout flow | 1130 $m^3/h$ |

| | |
|---|---|
| Maximum pump brake horsepower | 550 kW |
| Net positive suction head (NPSH) at 1m above the pump floor setting | 2.4m |
| Process fluid temperature range | 10 to 182°C |

(2) Heat Exchangers

The RHR heat exchangers have three major functional requirements imposed upon them, as follows:

(a) **Post-LOCA Containment Cooling—**The RHR System limits the peak bulk suppression pool temperature to less than 97°C by direct pool cooling with two out of the three divisions.

(b) **Reactor Shutdown—**The RHR System removes enough residual heat (decay and sensible) from the reactor vessel water to cool it to 60°C within 24 hours after the control rods are inserted. This mode shall be manually activated after a blowdown to the main condenser reduces the reactor pressure to below 0.93 MPaG with all three divisions in operation.

(c) **Safe Shutdown—**The RHR System brings the reactor to a cold shutdown condition of less than 100°C within 36 hours of control rod insertion with two out of the three divisions in operation. The RHR System is manually activated into the shutdown cooling mode below a nominal vessel pressure of 0.93 MPaG.

The RHR heat exchanger capacity is required to be sufficient to meet each of these functional requirements. The limiting function for the RHR heat exchanger capacity is post-LOCA containment cooling. The heat exchanger capacity, K, is ~~370.5kJ/°C-s~~$4.27 \times 10^5$ W/°C per ~~heat exchanger.~~RHR heat transfer loop. This K value characterizes the combined performance of the equipment outline in Appendix 5B.3-(d).

The performance characteristics of the heat exchangers are shown in Table 5.4-4.

(3) Valves

All of the directional valves in the RHR System are conventional gate, globe, and check valves designed for nuclear service. The injection valves are high speed valves, as operation for RHR injection requires. Valve pressure ratings are to provide the

### 5B.2.2 Preliminary

Determine the elevation distance between the suppression pool (S/P) water level and the reactor pressure vessel's (RPV) normal water level. Call this the static head, Hs. See Figure 5B-1 for illustration.

By analysis, determine the expected pressure difference between the drywell and the wetwell airspace resulting from the highest expected flow rate through the vents from the drywell into the S/P when RHR injection flow is needed. Call this the vent head, Hv.

Prepare the plant equipment related to each RHR loop for a flow test from the S/P into the RPV. The RPV head could be on or off for these tests. The following described test-analysis plan is applicable to the three RHR loops.

Perform a flow test from the suppression pool into the RPV; this is the LPFL line. Measure the flow rate, Q1, with the RHR flow element and the pressure head across the pump, H1, as the difference between the RHR pump suction to pump outlet. Q1 will be greater than 954 $m^3$/h.

### 5B.2.3 Beginning Injection Flow

**Analysis** — Determine the hydraulic head loss, Hmin, for the LPFL line for the minimum flow mode flowrate, QMin, from the head to flow-squared relationship as follows:

PMin = HMin + Hs + Hv + ~~11.55~~1.55 MPa+ margin

**Test** — Using the minimum flow mode, measure the pressure head across the pump, Pmin, (outlet-suction) at the minimum flow rate, Qmin. The pump outlet pressure during the minimum flow mode is the highest pressure from the RHR System that is available for initiating injection into the RPV as the RPV depressurizes. Therefore, the minimum flow condition is equivalent to the pressure where "the LPFL injection flow for each loop begins" as stated by the design commitment.

**Confirmation** — (Convert all terms to consistent units)

$$PMin = HMin + Hs + Hv + 1.55\ MPa + margin$$

### 5B.2.4 Rated Injection Flow

**Analysis** — Determine the hydraulic head loss for the LPFL line at 954 $m^3$/h, H954, from the head to flow-acquired relationship as follows:

H954 ~~+~~= $(H1 - Hs)(954/Q1)^2$

**Test** — Using the full test loop (same as the S/P cooling mode) and its throttle valve, measure the pressure head across the pump, P954, (outlet - suction) at a flow rate greater than, but approximately equal to 954 $m^3$/h.

**Confirmation** — (Convert all terms to consistent units)

P954 ~~+~~= H954 + Hs + Hv + 0.27 MPa+ margin

## 5B.3 Outline For Heat Exchanger Confirmation

**Analysis**

(a) Sizing of the RHR heat exchanger was based on the ~~S/P cooling needed during a feedwater line break LOCA to maintain the S/P temperature below 97°C with any two of~~requirements for shutdown cooling heat removal requirements to support a 17 day refueling outage with three RHR loops operating. The result was each loop having the same identical heat exchanger, each characterized within an overall heat removal capacity of ~~370.5 kJ/s°C~~$4.27 \times 10^5$ W/°C for each loop.

(b) The heat removal capacity is specified as ~~370.5 kJ/sec °C~~$4.27 \times 10^5$ W/°C, which is a constant in the following equation.

Q~~, kJ/s~~ = (~~370.5~~$4.27 \times 10^5$)(Ti - Tu)

where Ti = Temperature from the ~~S/P~~reactor or into the RHR heat exchanger

Tu = Ultimate heat sink temperature

(c) For the system design sizing analysis, the heat exchanger capacity was assumed constant over the range of analysis, which covered the ~~S/P~~reactor temperature range of ~~43.3°C to 97°C~~28.3°C to 49°C. Water from the ~~S/P~~reactor is the input to the RHR heat exchanger, or Ti. The heat exchanger flow rate (~~S/P~~reactor side, tube side) was assumed constant at 954 $m^3$/h.

(d) The ~~370.5 kJ/s °C~~$4.27 \times 10^5$ W/°C constant characterizes the combined performance of the following equipment, flow conditions, and peripheral heat loads.

- RHR heat exchanger thermal design,
- RHR pump at constant flow rate,
- RCW partial flow through the RHR heat exchanger (shell side),
- RCW (Reactor Building Cooling Water System) heat exchangers thermal design (3 per division),
- RCW pumps at constant flow (2 per division),
- RCW heat loads other than RHR applicable during the design basis event,

- RSW (Reactor Service Water System) pumps at constant flow rate (2 per division)

(e) A detailed analytical heat exchanger and pump design that incorporates the features of ~~4~~(d) above in an overall integrated solution will be available by the applicant. This detailed analytical model will produce heat removal capacity values equal to or greater than ~~370.5 kJ/s°C~~ $4.27 \times 10^5$ W/°C over the same temperature operating range used for the system analysis ~~(43.3°C to 97°C)~~(28.3°C to 49°C). This may be a combination of the applicants own analysis plus the analysis of equipment vendors.

(f) The detailed analytical design of the heat exchangers will develop geometric and material features that are used in the manufacture of the heat exchangers. These geometric and material features are available in the procurement documents for the equipment.

(g) A document must be prepared that extracts features from the detailed RHR and RCW heat exchanger analyses, which identifies the heat transfer dependent geometric and material design features of the heat exchangers. This document will identify the heat transfer features developed by the analyst that the fabrication documents must incorporate.

**Confirmation**

Confirmation will be satisfied by the acceptable inspections of the following documentation.

- The overall integrated detailed analysis of the features in paragraphs (d) and (e) above must incorporate the correct input characteristic parameters from all interfacing systems.
- The heat transfer dependent geometric and material design features of paragraph (g) above are fully extracted from the overall integrated detailed analysis of paragraphs (d) and(e) above.
- The fabrication documents for the plant installed RHR and RCW heat exchangers incorporate the heat transfer dependent geometric and material design features of paragraph (g) above.
- The RCW performance is satisfied.
- The RSW performance is satisfied.

## Table 6.2-2a Engineered Safety Systems Information for Containment Response Analyses

| | Full Capacity | Containment Analysis Value |
|---|---|---|
| **A. Containment Spray** | | |
| 1. Number of RHR Pumps | 2* | 1* |
| 2. Number of Lines | 2* | 1* |
| 3. Number of Heat Exchangers | 2† | 1† |
| 4. Drywell Flow Rate (kg/h) | $0.84 \times 10^6$ | $0.84 \times 10^6$ |
| 5. Wetwell Flow Rate (kg/h) | $1.14 \times 10^5$ | $1.14 \times 10^5$ |
| **B. Containment Cooling System** | | |
| 1. Number of RHR Pumps | 3 | 2 |
| 2. Pump Capacity ($m^3$/h/pump) | 954 | 954 |
| 3. RHR Heat Exchangers | | |
| a. Type–U-tube, | | |
| b. Number | 3 | 2 |
| c. Heat Transfer Area ($m^2$/unit) | ~~5~~‡ | ~~5~~‡ |
| d. Overall Heat Transfer Coefficent ~~(Btu/h — $m^2$ °C/unit)~~(W/°C) | ~~5~~‡ | ~~5~~‡ |
| e. Reactor Cooling Water Flowrate ($m^3$/h) | 1200 | 1200 |
| f. Maximum Cooling Water Inlet Temperature (°C) | 35 | 35 |

* Two redundant loops available with one pump each.

† One header each for drywell and wetwell.

‡ The RHR heat exchanger characteristic has been defined by an overall K coeficient based on a temperature difference and the heat rate. The defining equation is:

$$Q = (K)(\Delta T)$$

The K value is $4.27 \times 10^5$ W/°C.
The applicable temperature difference occurs form the RHR heat exchanger's reactor side inlet to the ultimate heat sink temperature. Thus, K is a characteristic of the combined RHR and reactor cooling water system's heat exchangers.