5B RHR Injection Flow And Heat Capacity Analysis Outlines

5B.1 Introduction

This appendix provides procedure outlines of suggested methods to perform the inspections, tests, analyses and confirmations of the Residual Heat Removal System. These outlines use test data, plant geometry, and analyses to confirm requirements when the reactor is pressurized. They also use inspection of vendor information and analyses to confirm heat transfer conditions before there is a source of heat for actual tests.

5B.2 Outline For Injection Flow Confirmation

The RHR injection flow has two features. The first is for beginning injection flow, and the second is for rated injection flow (954 m^3/h).

5B.2.1 Input Data

RHR System functional tests shall be performed on the RHR LPFL mode. Analysis shall be performed to convert the test results to the conditions of the design commitment based upon the following criteria.

5B.2.1.1 Beginning Injection Flow

- loop flow and pump discharge and suction pressure data from the flooder mode with the reactor at atmospheric pressure
- pump discharge and suction pressure data in the minimum flow mode
- plant as-built dimensional data from suppression pool surface level to RPV normal water level
- calculation of vent pressure drop from drywell to wetwell
- supplier provided pump performance data.

5B.2.1.2 Rated Injection Flow

- loop flow and pump discharge and suction pressure data from the flooder mode with the reactor at atmospheric pressure
- pump discharge and suction pressure data in the test loop mode
- plant as-built dimensional data from suppression pool surface level to RPV normal water level
- calculation of vent pressure drop from drywell to wetwell
- supplier provided pump performance data.

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:

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

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 shutdown cooling needed during a cooldown to a normal 17-day refueling outage. The result was each loop having the identical heat exchanger, each characterized within an overall heat removal capacity of 4.27×10^5 W/°C for each loop.

(b) The heat removal capacity is specified as 4.27×10^5 W/°C, which is a constant in the following equation.

$$Q,W = (4.27 \times 10^5 \text{ W/°C}) (Ti - Tu)$$

where Ti = Temperature from the Reactor or into the RHR heat exchanger, °C

Tu = Ultimate heat sink temperature, °C

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

(d) The 4.27×10^5 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 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 4.27 x 10^5 W/°C over the same temperature operating range used for the system analysis (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.

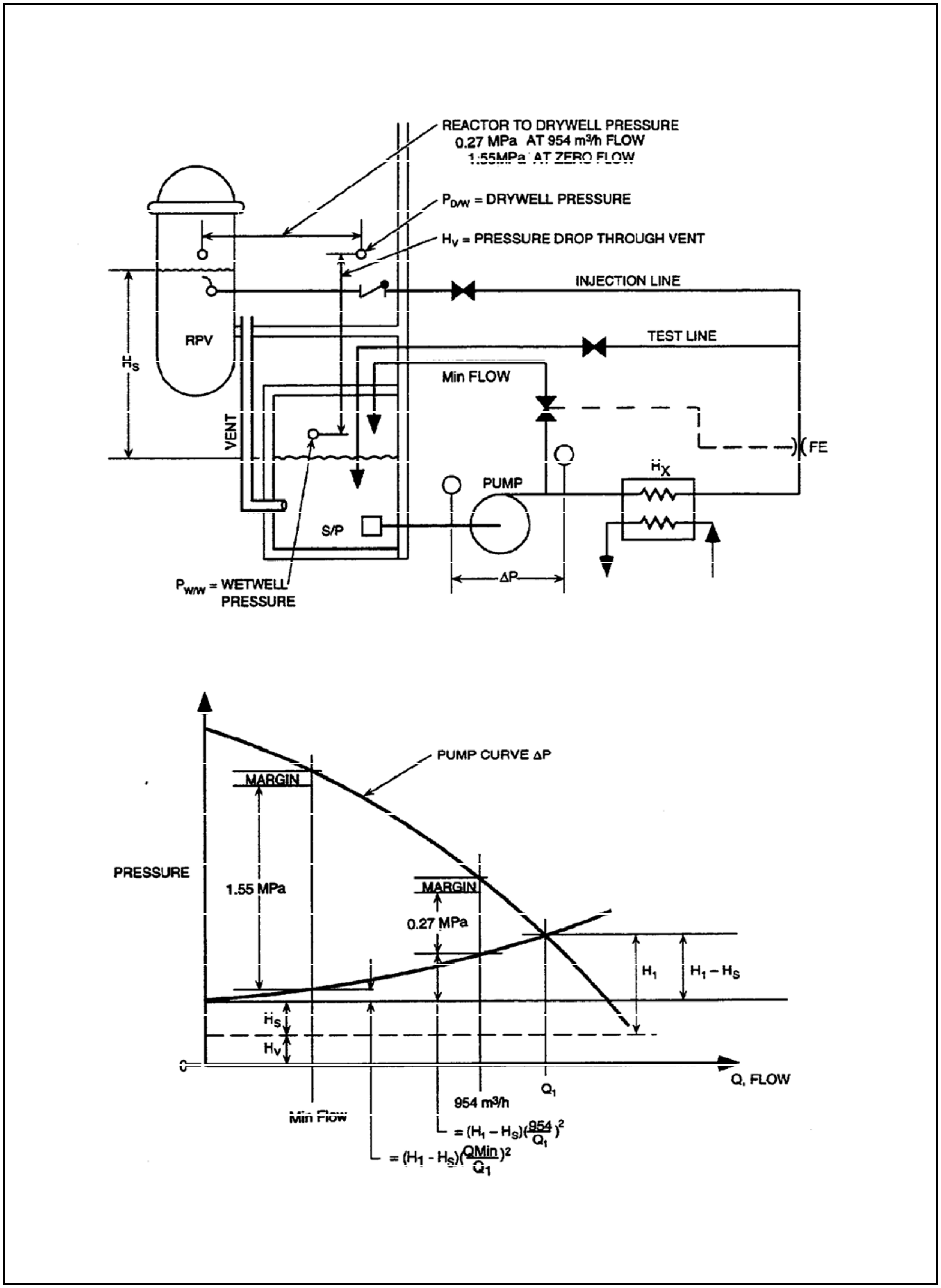

Figure 5B-1 Injection Flow