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 (RHR). 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

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 functional tests shall be performed on the RHR low pressure flooder (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 LPFL 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 water level to Reactor Pressure Vessel (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 LPFL 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 water level to RPV normal water level

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* Estimated values. The final values to be provided in the FSAR.

- 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 m3/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:

$$\text{PMin} = \text{HMin} + \text{Hs} + \text{Hv} + 1.55\ \text{MPa} + \text{margin}$$

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 RHR 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)

$$\text{PMin} = \text{HMin} + \text{Hs} + \text{Hv} + 1.55\ \text{MPa} + \text{margin}$$

5B.2.4 Rated Injection Flow

Analysis — Determine the hydraulic head loss for the LPFL line at 954 m3/h, H954, from the head to flow-squared relationship as follows:

$$\text{H954} = (\text{H1} - \text{Hs})(954/\text{Q1})2$$

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)

$$P954 = H954 + Hs + Hv + 0.27\ \text{MPa} + \text{margin}$$

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 loss of coolant accident (LOCA) to maintain the S/P temperature below 97°C with any two of 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* for each loop.

(b) The heat removal capacity is specified as 370.5 kJ/s °C*, which is a constant in the following equation.

Q, kJ/s = (370.5)(Ti - Tu)

where Ti = Temperature from the S/P 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 temperature range of 43.3°C to 97°C. Water from the S/P is the input to the RHR heat exchanger, or Ti. The heat exchanger flow rate (S/P side, tube side) was assumed constant at 954 m^3/h*.

(d) The 370.5 kJ/s°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,
- Reactor Building Cooling Water System (RBCW) partial flow through the RHR heat exchanger (shell side),
- RBCW heat exchangers thermal design (3 per division),

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* To be verified and final values to be provided in FSAR.

- RBCW pumps at constant flow (2 per division),
- RBCW heat loads other than RHR applicable during the design basis event,
- Reactor Service Water System (RSW) pumps at constant flow rate (2 per division)

(e) A detailed analytical heat exchanger and pump design that incorporates the above features in an overall integrated solution will be available. This detailed analytical model will produce heat removal capacity values equal to or greater than 370.5 kJ/s°C[*] over the same temperature operating range used for the system analysis (43.3°C to 97°C). This may include 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 RBCW 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 RBCW heat exchangers incorporate the heat transfer dependent geometric and material design features of paragraph (g) above.
- The RBCW performance is satisfied.
- The RSW performance is satisfied.

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[*] Estimated values. The final values to be provided in the FSAR.

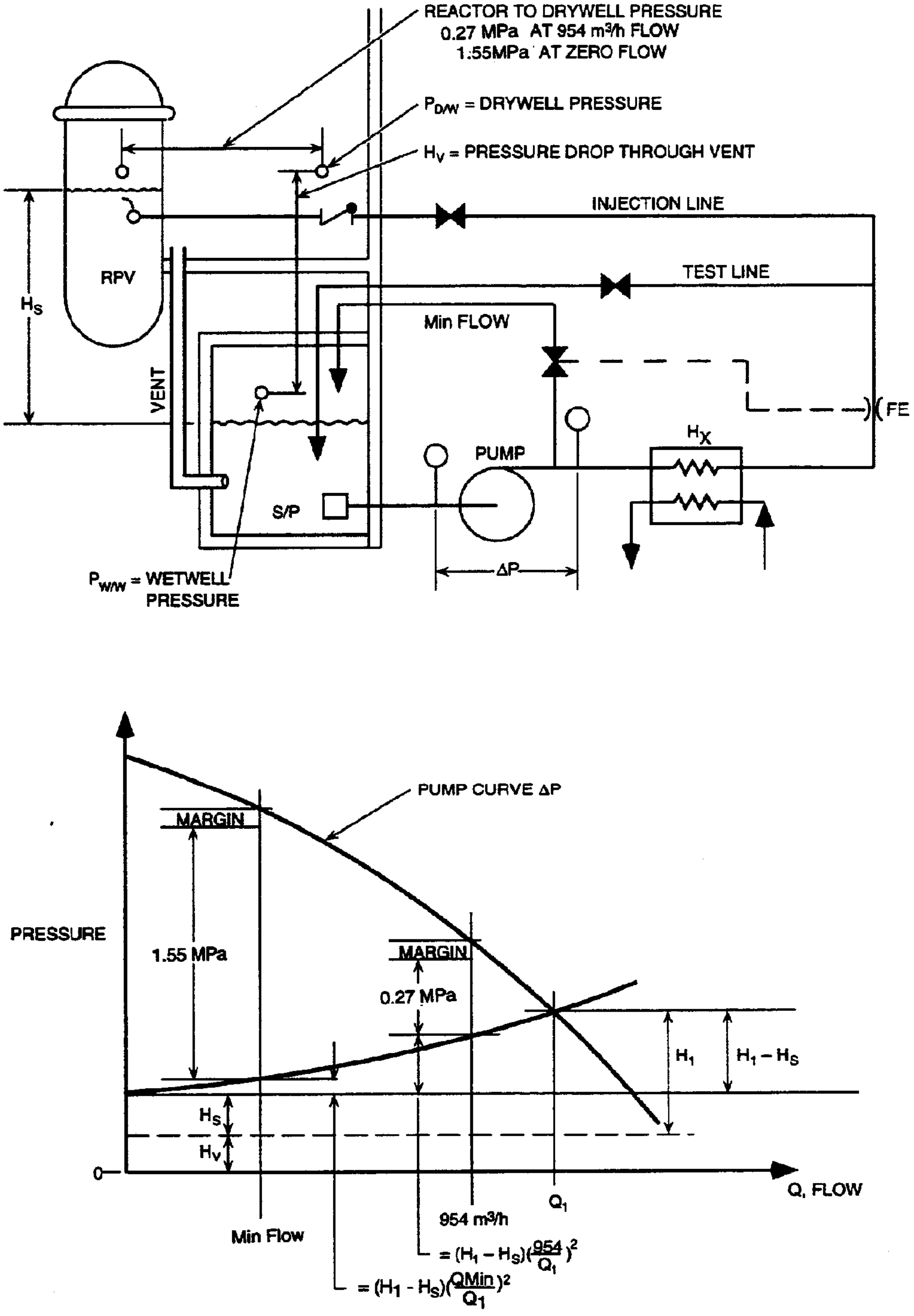

Figure 5B-1 Injection Flow