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DYNAMIC ANALYSIS OF THE M/S HEATER DRAIN SYSTEM

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AFT – Auxiliary Flash Tank
BWR – Boiling Water Reactor
LWR – light water reactors
MDT – Main Drain Tank
MFT – Main Flash Tank

ABSTRACT

The objective of this paper is to provide a RELAP5 model of the heater drain system of a BWR. Most water driven turbine power plants have comparable systems. The purpose of the RELAP5 model is to simulate and evaluate operational transients in the heater drain system so evaluations of the system can be performed. Other possible uses of this model are for reactor simulator support, for support to operations in determining what if scenarios during operation and for supporting plant engineering in changing and modifying the system for optimum operation.

INTRODUCTION

During the life of a power plant, the heater drain system is always a challenge to be maintained and operated properly. The objective of this analysis is to provide a RELAP5 model of the heater drain system. The purpose of the RELAP5 model is to simulate the operation of the heater drain system.

The moisture separator/reheater drain system serves the dual purpose of recovering demineralizer water at saturation temperature from exhaust steam, and of improving the plant heat balance by reclaiming the energy of this water through feed water heating. There are two parallel paths that are almost symmetric, which run from the turbine elements to the high-pressure heaters and the condenser.

The moisture separator/reheater drain system for this plant includes twelve 6 inch double-ported flow control valves. Flow through the valves is controlled by the position of the top and bottom guided throttle plug with linear characteristics. Water level sensors in the main drain tanks control these valves.

There are six main drain tanks. Four main drain tanks identified as 1-1, 1-4, 1-2 and 1-5 that collect exhausted heating steam as water at the saturated temperature from the tube side of the first and second stage reheaters, respectively. Two additional main drain tanks identified as main drain tanks 1-3 and 1-6 collect water from the moisture separators and vent steam back to moisture separators 1-1 and 1-3, respectively. If the main drain tank level rises, the flow control valves to the main flash tanks respond by opening further. If the level continues to rise in the main flash tanks when the control valves are fully open, a second level controller causes the normally closed control valves in the lines to the auxiliary flash tank 1-3 to open. Low quality steam supplied to auxiliary flash tank 1-3 is either vented as steam to condenser A or pumped as a liquid to the condenser A.

The base RELAP5 model developed provides a good representation of this BWR heater drain system. Comparisons with data for the 100% power case and for the 60% power case were good.

USE OF RELAP5/MOD3.3 FOR THE SIMULATION

The heater drain system was modeled using RELAP5/Mod3.3 (See Ref. 1). RELAP5/M3.3 is a "best estimate" system code suitable for the analysis of all transients and postulated accidents in Light Water Reactor (LWR) systems, including both large- and small-break loss-of-coolant accidents (LOCAs) as well as the full range of operational transients. The one dimensional RELAP5/M3.3 code is based on a non-

homogeneous and non-equilibrium model for the two-phase system that is solved by a fast, partially implicit numerical scheme to permit economical calculation of system transients.

In addition, RELAP5 can be used to solve many plant thermal-hydraulic problems (See Refs. 2 & 3). Modeling of single and two-phase systems can be accomplished using many types of valves, heat exchangers and pumps. The code includes many generic models allowing simulation of general thermo hydraulic systems. The models include pumps, valves, pipes, heat releasing or absorbing structures, electric heaters, jet pumps, turbines, separators, accumulators, and control system logic elements. RELAP5 represents the aggregate accumulation of experience in modeling reactor core behavior during accidents, two-phase flow processes, and LWR systems. The code development has benefited from extensive application and validation comparisons with many experimental programs. Validation of RELAP5 for simulating piping systems is provided in Reference 4.

DISCUSSION

A RELAP5/M3.3 model was constructed to simulate the single and two-fluid in a BWR heater drain system. The heater drain system increases the efficiency of the power plant by draining condensed water from the turbine and using it to heat the feedwater coming into the power station. Because of the two-phase and subcooled liquid flow interaction and the complexity of the system, pressure oscillations are encountered in the system that could cause long-term damage to the piping, valves and restraints for the system. To understand the behavior of the system a RELAP5 model was constructed. .

The moisture separator/reheater drain system includes twelve 6-inch Fisher double-ported flow control valves. Flow through the valves is controlled by the position of the top and bottom guided throttle plug with linear characteristics. Water level sensors in the main drain tanks control these valves. A sketch of the moisture separator/reheater drain system is shown in Figure 1.

There are six main drain tanks. Four main drain tanks identified as 1-1, 1-4, 1-2 and 1-5 that collect exhausted heating steam as water at the saturated temperature from the tube side of the first and second stage reheaters, respectively. Main drain tanks 1-1 and 1-4 operate at 422 psia at 100% power. Main drain tanks 1-2 and 1-5 operate at 950 psia at 100 % power. Uncondensed steam from these four drain tanks is vented back to the reheater tube side. Two additional main drain tanks identified as main drain tanks 1-3 and 1-6 collect water from the moisture separators and vent steam back to moisture separators 1-1 and 1-3, respectively. Main drain tanks 1-3 and 1-6 operate at 171 psia at 100 % power.

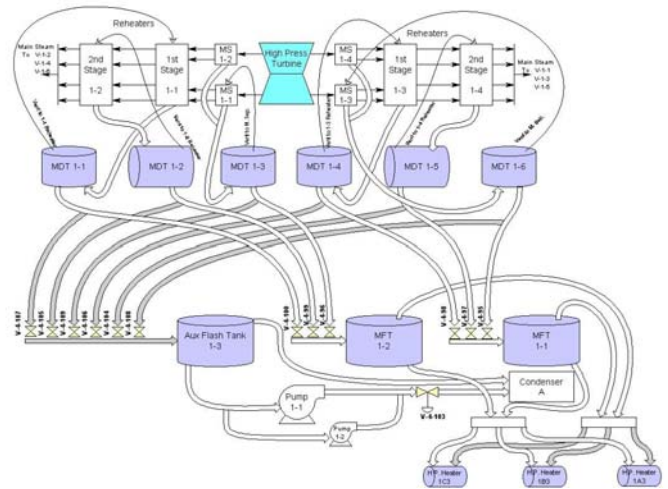


Figure 1 Sketch of Heater Drain System

RELAP5 MODEL DEVELOPMENT

The RELAP5 M3.3 model was developed based on design drawings, field data and set point data. Most the data was taken directly from information presented in design drawings. In some cases, the data was scaled from the design drawings.

1. Loss Coefficients

The piping and valve loss coefficients were based on information presented in References 5, 6 and 7.

2. Valves and Water Level in Tanks

The moisture separator/reheater drain system includes twelve 6" Fisher Type control valves. Flow through the valve is controlled by the position of the top and bottom guided throttle plug with linear characteristics. As the water rises in the drain tank, the control valves open to allow water into the flash tanks or at higher water levels in the drain tanks, the control valves regulating the flow to the auxiliary flash tank open.

3. RELAP5 Models

The RELAP5 Heater Drain model consists of 7 sub-models. The Main Drain Tank models are show in Figures 2 through 7. The Auxiliary Flash Tank (AFT) sub-model is shown in Figure 8 and the Main Flash Tanks 1-1 and 1-2 sub-models are shown in Figures 9 & 10. The Auxiliary Flash Tank sub-model represents the Auxiliary Flash Tank, the two pumps that take water from the Auxiliary Flash Tank to the condenser and the steam line from the top of the Auxiliary Flash Tank to the condenser.

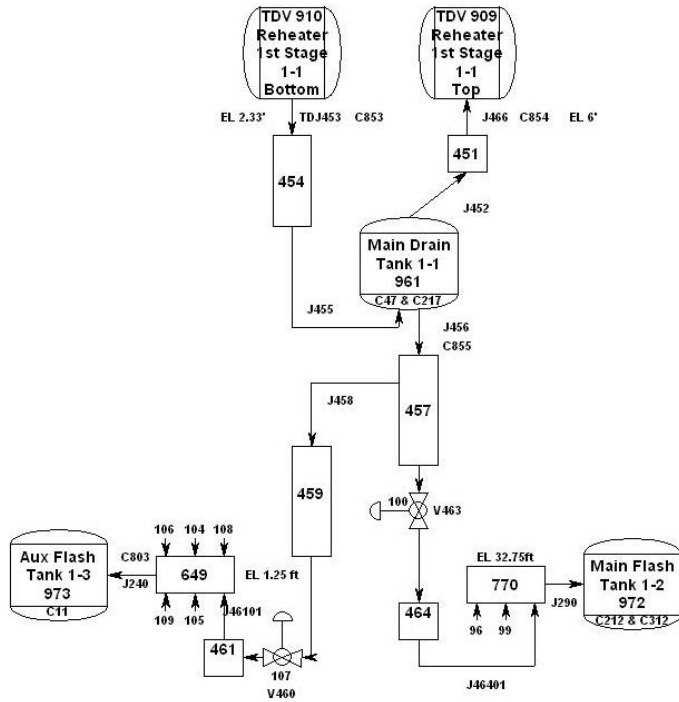


Figure 2 RELAP5 Nodal Diagram for Discharge Piping From Main Drain Tank 1-1

The Main Flash Tanks (MFTs) are the primary receivers of water from the MDTs. MDTs 1-1, 1-2 and 1-3 drain to MFT 1-2 and MDTs 1-4, 1-5 and 1-6 drain to MFT 1-1. The water is drained (See Figure 10) or vented (See Figure 9) from the MFTs to the feedwater heaters.

The Auxiliary Flash Tank acts as a back up to the 2 Main Flash Tanks (MFTs). When the MDTs achieved a high water level setting, valves are opened that allow water to go to the AFT. The water from the AFT is vented, drained or pumped to the condenser.

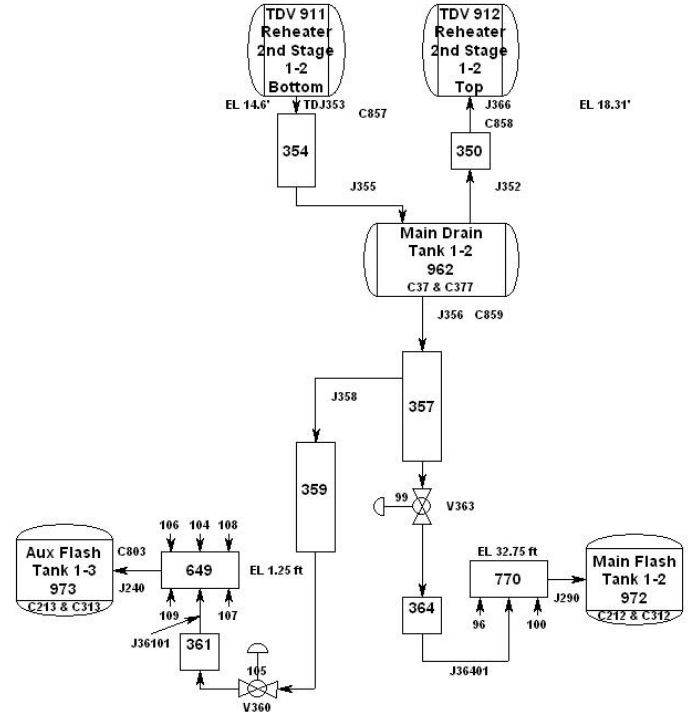


Figure 3 RELAP5 Nodal Diagram for Discharge Piping From Main Drain Tank 1-2

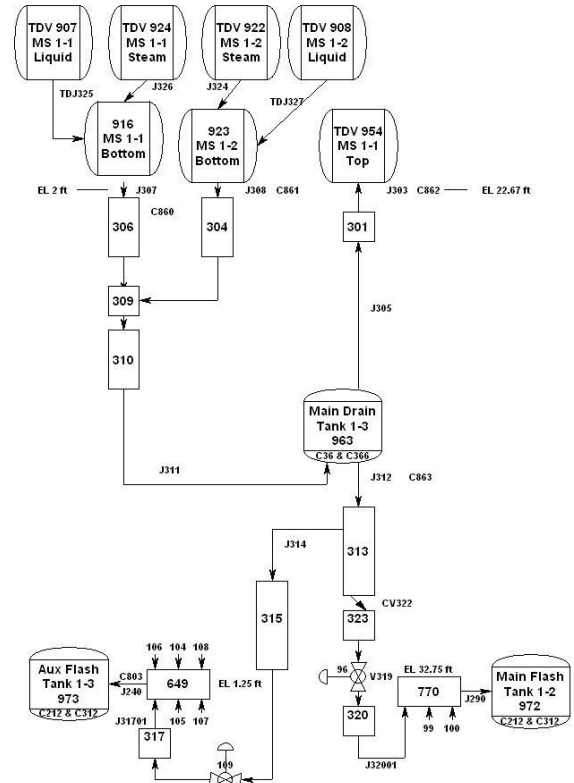


Figure 4 RELAP5 Nodal Diagram for Discharge Piping From Main Drain Tank 1-3

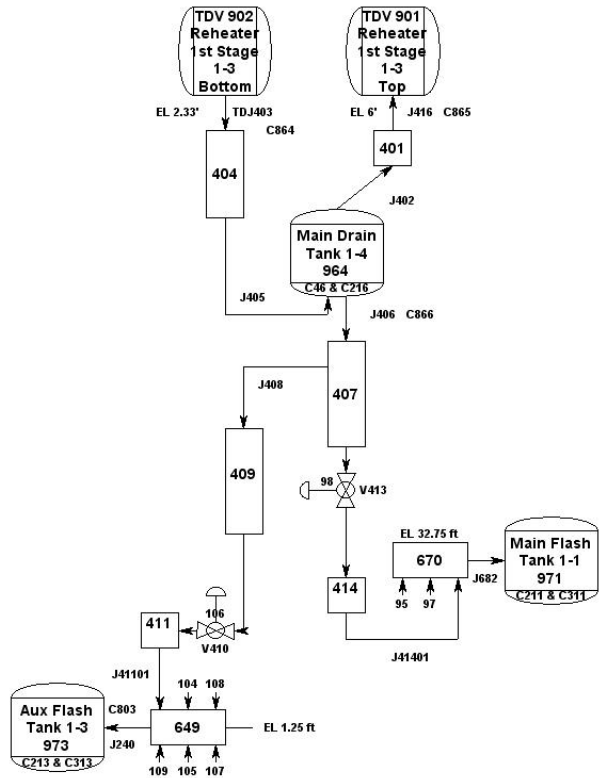


Figure 5 RELAP5 Nodal Diagram for Discharge Piping From Main Drain Tank 1-4

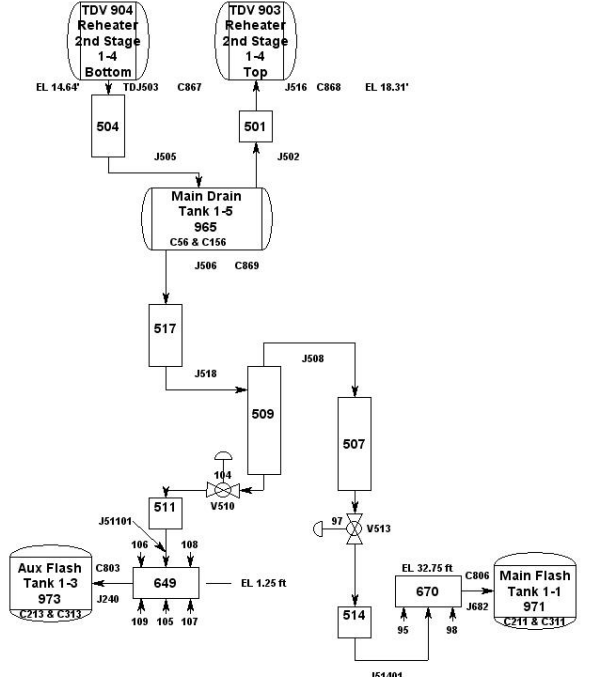
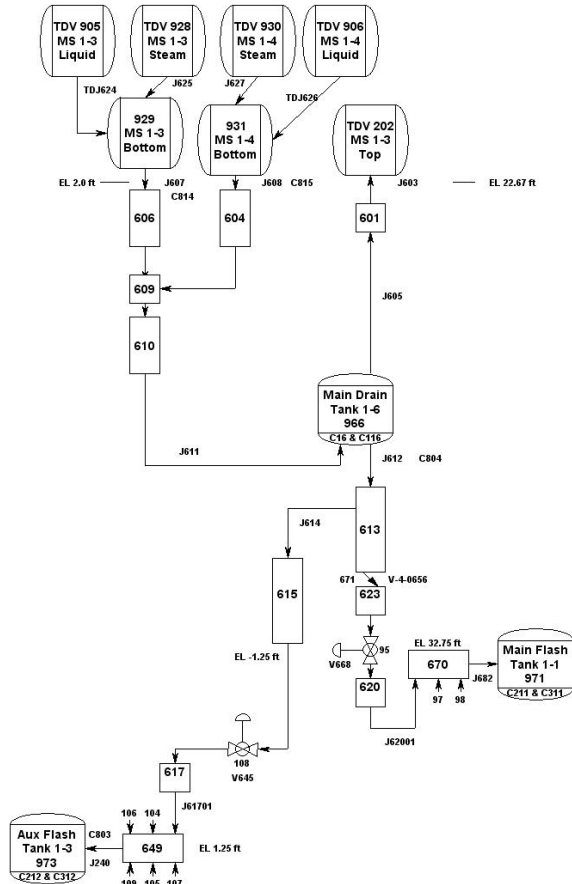


Figure 6 RELAP5 Nodal Diagram for Discharge Piping From Main Drain Tank 1-5



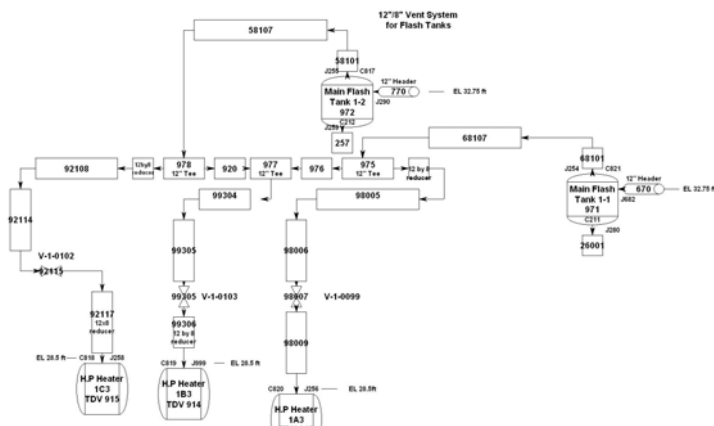


Figure 9 RELAP5 Nodal Diagram for Vent Piping From Main Flash Tanks 1-1 and 1-2

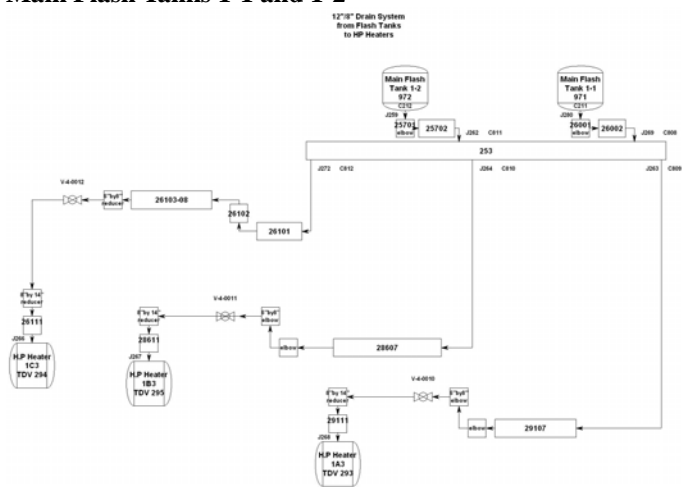


Figure 10 RELAP5 Nodal Diagram for Drain Piping From Main Flash Tanks 1-1 and 1-2

RESULTS

Table 1 presents the RELAP5 calculated results for the 100% and 60% power base cases of a number of parameters that have data taken from the plant computer. A comparison was performed between the plant data and the RELAP5 calculated values and presented in Table 1. Good agreement for most parameters is shown throughout.

During the low-pressure drain of the moisture separators into MDT 1-3 and MDT 1-6, a froth mixture forms in each tank causing the control valves V-4-096 and V-4-095 to oscillate. These oscillations result in all piping systems associated with MDT 1-3 and MDT 1-6 to move due to the forces that are caused by the fluid oscillations. Control valve V-4-096 regulates water level in MDT 1-3 and control valve V-4-095 regulates water level in MDT 1-6.

Sensitivity studies were performed to determine what actions or modifications that could be performed to reduce oscillations in the MDT 1-3 and 1-6 piping. The sensitivity studies include adjusting the valve response time by applying a delay of two seconds, four seconds, six seconds and eight seconds. The results of these studies are shown in Figure 11 for the 100% power case.

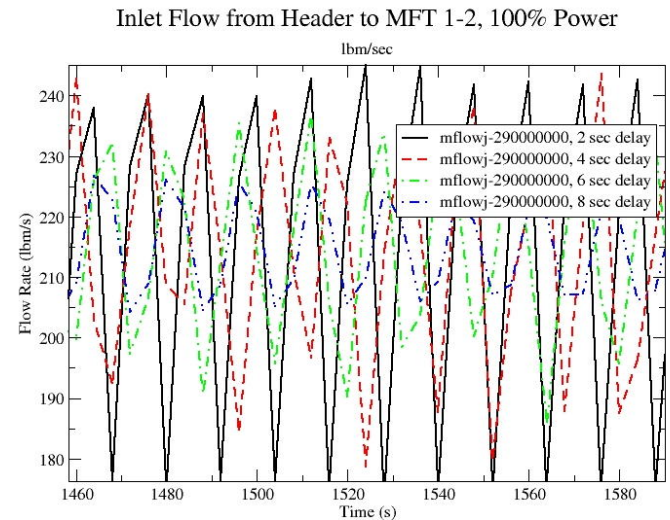


Figure 11 Flows from MDT 1-3 to MFT 1-2 with Time Delays in Control Valve 96 Actuations

In reviewing the results presented on Figure 11, one can see that the flow oscillations are reduced significantly by the time delays in the control valve's actuation. Similar results are seen with the flows associated with Control Valve 95 that regulates flow between MDT 1-6 and MFT 1-2.

CONCLUSIONS

During the lower-pressure drain of the moisture separators into MDT 1-3 and MDT 1-6, a froth mixture forms in each tank causing the control valves V-4-096 and V-4-095 to oscillate and thereby causing flows leaving the valves to oscillate. Control valve V-4-096 regulates water level in MDT 1-3 and control valve V-4-095 regulates water level in MDT 1-6.

As one can see in Figure 11, the 8-second delay reduces the oscillations in control valves V-4-095 and V-4-096 significantly. It is recommended that 8-second delays or equivalent instrumentation adjustments be placed on the control valves V-4-096 and V-4-095 water level sensing instrumentation.

Table 1 Comparison of Plant Data to RELAP5 Calculated Values for the 60% and 100% Power Cases

Parameter	RELAP5 Comp	Data 60% Power	Data 100% Power	RELAP5 60% Power	RELAP5 100% Power
RH 1-1 Pressure	910	244.3 psia	421.8 psia	244.3 psia	421.8 psia
RH 1-1 Flow	TDJ453	27.1 lb/s	47.0 lb/s	27.1 lb/s	47.0 lb/s
RH 1-2 Pressure	911	968.7 psia	950 psia	968.7 psia	950 psia
RH 1-2 Flow	TDJ353	50.98 lb/s	57.46 lb/s	50.98 lb/s	57.46 lb/s
RH 1-3 Pressure	902	244.5 psia	422.5 psia	244.5 psia	422.5 psia
RH 1-3 Flow	TDJ403	26.70 lb/s	45.7 lb/s	26.70 lb/s	45.7 lb/s
RH 1-4 Pressure	904	968.7 psia	950 psia	968.7 psia	950 psia
RH 1-4 Flow	TDJ503	52.35 lb/s	62.3 lb/s	52.35 lb/s	62.3 lb/s
MS 1-1 Pressure	924	104.6 psia	171 psia	104.6 psia	171 psia
MS 1-1 Flow	J307	31.155 lb/s	54.7 lb/s	29.0 os lb/s	55.3 os lb/s
MS 1-2 Pressure	922	104.6 psia	171.2 psia	104.6 psia	171.2 psia
MS 1-2 Flow	J308	31.155 lb/s	54.7 lb/s	29.0 os lb/s	55.2 os lb/s
MS 1-3 Pressure	928	104.5 psia	171.6 psia	104.5 psia	171.6 psia
MS 1-3 Flow	J607	31.2 lb/s	54.8 lb/s	29.7 os lb/s	55.4 os lb/s
MS 1-4 Pressure	930	104.5 psia	171.6 psia	104.5 psia	171.6 psia
MS 1-4 Flow	J608	31.2 lb/s	54.8 lb/s	29.3 os lb/s	55.1 os lb/s
HPH 1A3 D Tem	293	≤ 347.6 F	≤ 328 F	250 F	291 F
HPH 1B3 D Tem	295	≤ 347.6 F	≤ 328 F	250 F	291 F
HPH 1C3 D	294	≤ 347.5 F	≤ 328.1 F	250 F	291 F
HPH 1A3 D Flo	J268	120 lb/s	124.9 lb/s	116.1 os lb/s	123.2 os lb/s
HPH 1B3 D Flo	J267	0 lb/s	124.9 lb/s	5.9 os lb/s	124 os lb/s
Parameter	RELAP5 Comp	Data 60% Power	Data 100% Power	RELAP5 60% Power	RELAP5 100% Power
HPH 1C3 D Flo	J266	120 lb/s	124.9 lb/s	104.6 os lb/s	117 os lb/s
HPH 1A3 V Pres	913	≤ 43.5 psia	≤ 89.3 psia	30 psia	59.6 psia
HPH 1B3 V Pres	914	≤ 42.5 psia	≤ 88.9 psia	42.5 psia	59.6 psia
HPH 1C3 V Pres	915	≤ 44.0 psia	≤ 89.9 psia	30 psia	59.6 psia
HPH 1A3 V Flo	J256	29.8 lb/s	49.5 lb/s	20.6 os lb/s	23.1 os lb/s
Cond A	917	29.2" Hg Vacuum (.36 psia)	28.05" Hg Vacuum (.92 psia)	.36 psia	.92 psia
AFT, Pressure	973	16" Hg (6.9 psia)	12" Hg (8.8 psia)	2.7 os psia	2.7 psia
MFT 1-1	971	54.7 psia	94.7 psia	54.7 os psia	79 os psia
MFT 1-2	972	54.7 psia	94.7 psia	54.7 os psia	80 os psia
MDT 1-1 Press	96101	244.3 psia	421.8 psia	244.9 psia	422.5 psia
MDT 1-2 Press	96201	968.7 psia	950 psia	969.3 psia	949.8 psia
MDT 1-3 Press	96301	104.6 psia	171 psia	104.9 os psia	172.3 os psia
MDT 1-4 Press	96401	244.5 psia	422.5 psia	245.2 psia	423.2 psia
MDT 1-5 Press	96501	968.7 psia	950 psia	969.4 psia	950.7 psia
MDT 1-6 Press	96601	104.5 psia	171.6 psia	108.1 psia	75 os psia
MDT 1-1 Level Collapsed	C47	20"	20-22"	23"	23"
MDT 1-1 Actual Density	Rho96 101	NA	NA	52.8 os lb/ft**3	51.1 lb/ft**3
MDT 1-1 Actual WL	Rho96 1	NA	NA	20"	22"
MDT 1-2 Level Collapsed	C37	25"	26"	23"	23"
MDT 1-2 Actual Density	Rho96 201	NA	NA	46.5 os lb/ft**3	46.7 lb/ft**3

Note: os implies that the fluid is oscillating

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