

RAI 5:

Please provide a plant sample break spectrum analysis with all of the EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, changes included. This could be accomplished by comparing the results of a sample plant SBLCOA spectrum with and without the EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, changes. This should include the severance of the safety injection line, as well.

Response to RAI 5:

Break spectrums for three sample plants were performed using EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0 methodology. The three sample plants include:

- Westinghouse 3-Loop
- Westinghouse 4-Loop
- Combustion Engineering 2x4

In addition to the spectrum of break sizes, this response also includes the analysis of breaks in attached piping (double-ended guillotine break of the safety injection line). Some of the important input parameters used in the sample problems are included in Table 5-1.

Westinghouse 3-Loop

A full spectrum of break sizes for a Westinghouse 3-Loop sample plant was performed. []

In addition to the break spectrum, an analysis of a double-ended guillotine break in the attached piping (safety injection line) has been included.

The limiting break for a cold leg pump discharge (CLPD) break, an accumulator line break, and a pumped SI line break are presented in Table 5-2, Table 5-3, and Table 5-4, respectively. The results from the break spectrum analysis are presented in Table 5-5. The limiting PCT is 1735°F for a 7.6 inch equivalent pipe diameter break size. A listing of the sequence of events for each break size in the spectrum is shown in Table 5-6a through Table 5-6c. Plots of some of the more important parameters for the limiting break of 7.6 inches are presented in Figure 5-1 through Figure 5-16.

Table 5-6b shows the expected trend for loop seal clearing:

- Only one loop seal clears for break sizes less than 3.396 inches.¹
- For break sizes of 3.396 inches and above, multiple loop seals are cleared.

¹ Although the 2.8-inch break size clears multiple loop seals, the effect is negligible because the additional loop seals clear after the time of PCT.

A double ended break in the accumulator piping or in the pumped SI piping connecting to the RCS does not produce a limiting case. An acceptable amount of emergency core cooling flow is delivered to the intact loops in both cases.

Westinghouse 4-Loop

A full spectrum of break sizes for a Westinghouse 4-Loop sample plant was performed. [

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In addition to the break spectrum, an analysis of a double-ended guillotine break in a safety injection line (more specifically an accumulator line) has been included.

The limiting break for a CLPD break and an accumulator line break are presented in Table 5-7 and Table 5-8, respectively. The results from the break spectrum analysis are presented in Table 5-9. The limiting PCT is 1429°F for a 8.10 inch equivalent pipe diameter break size. A listing of the sequence of events for each break size in the spectrum is shown in Table 5-10a through Table 5-10d. Plots of some of the more important parameters for the limiting break of 8.10 inches are presented in Figure 5-17 through Figure 5-34.

Table 5-10c shows the expected trend for loop seal clearing:

- Only one loop seal clears for break sizes less than 3.92 inches.
- For break sizes of 3.92 inches and above, multiple loop seals are cleared.²

A double ended break in the accumulator piping connecting to the RCS does not produce a limiting case. An acceptable amount of emergency core cooling flow is delivered to the intact loops.

Combustion Engineering 2x4

A full spectrum of break sizes for a Combustion Engineering 2x4 Loop sample plant was performed. [

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In addition to the break spectrum, an analysis of a double-ended guillotine break in a safety injection tank (SIT) line has been included.

The limiting break for a CLPD break and an SIT line break are presented in Table 5-11 and Table 5-12, respectively. The results from the break spectrum analysis are presented in Table 5-13. The limiting PCT is 1831°F for a 3.50 inch equivalent pipe diameter break size. A listing of the sequence of events for each break size in the spectrum is shown in Table 5-14a through Table 5-14d. Plots of some of the more important parameters for the limiting break of 3.50 inches are presented in Figure 5-35 through Figure 5-50.

² One loop seal clears for the 4.00-inch break, which results in a more conservative PCT.

Table 5-14c shows the expected trend for loop seal clearing:

- Only one loop seal clears for break sizes less than 3.79 inches³.
- For break sizes of 3.79 inches and above, multiple loop seals are cleared.

A double ended break in the SIT piping connecting to the RCS does not produce a limiting case. An acceptable amount of emergency core cooling flow is delivered to the intact loops.

The high pressure safety injection (HPSI) pump performance was for the CE 2x4 sample problem was requested in discussions with the NRC. The HPSI pump performance curve used in the CE 2x4 sample problem is presented in Figure 5-51.

References:

1. EMF-2328(P)(A), "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based," March 2001.
2. EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based," March 2012.

³ For the 3.60-inch and 3.70-inch breaks, it is apparent that the pressure drop required to vent core steam through one suction leg is large enough that the system would clear one or more additional legs.

Table 5-1: Sample Problem Design Inputs

Parameter	W3 Loop	W4 Loop	CE 2x4
Analyzed Reactor Power (MWt)	2958	3479	3029
Hot Assembly Type	17x17	17x17	14x14
F_q	2.52	2.65	2.11
$F_{\Delta H}$	1.73	1.71	1.75
RCS Flow (lbm/s)	30,415	39,789	39,101
Tavg (or Tcold) (°F)	588.8	578.2	551.0
Pressurizer Pressure (psia)	2250	2250	2250
Pressurizer Level (%)	60	60	65.6
SG Tube Plugging (%)	10	15	10
ECCS Injection Temperature (°F)	125	110	104
HPSI Delay (s)	29	37	30
LPSI Delay (s)	37	37	30
Accumulator pressure (psia)	599.7	614.7	244.7
Accumulator liquid volume (ft ³)	1012	1050	1130

Table 5-2: Cold Leg Pump Discharge Break Results – W 3-Loop

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
7.6	1735	199.14	44	10.875	0.0114	0.871

Table 5-3: Accumulator Line Break Results – W 3-Loop

Break size (ft ²)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
0.6013	1476	122.36	42	10.38	0.0024	0.12

Table 5-4: Pumped SI Line Break Results – W 3-Loop

Break size (ft ²)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
0.1469	1075	202.03	42	10.38	0.0002	0.0082

Table 5-5: Break Spectrum Results – W 3-Loop

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)	Rupture Time (s)	Rupture Node	Rupture Elevation (ft)
	692.4	1.35	42	10.38	0.0003	0.0004	N/A	N/A	N/A
	692.4	1.35	42	10.38	0.0002	0.0002	N/A	N/A	N/A
	692.4	1.35	42	10.38	0.0002	0.0002	N/A	N/A	N/A
	972.5	4349.2	45	11.13	0.0004	0.0199	N/A	N/A	N/A
	1134.1	3429.0	43	10.63	0.0011	0.0771	N/A	N/A	N/A
	1194.7	3398.5	44	10.88	0.0028	0.140	N/A	N/A	N/A
	1224.0	3112.5	44	10.88	0.0025	0.131	N/A	N/A	N/A
	1255.6	2707.3	44	10.88	0.0027	0.144	N/A	N/A	N/A
	1304.4	2365.8	44	10.88	0.0036	0.186	N/A	N/A	N/A
	1578.1	1728.6	45	11.13	0.0200	0.511	N/A	N/A	N/A
	1298.0	1798.9	44	10.88	0.0032	0.174	N/A	N/A	N/A
	1275.2	1682.0	44	10.88	0.0021	0.117	N/A	N/A	N/A
	1070.7	1165.0	43	10.63	0.0003	0.0134	N/A	N/A	N/A
	991.9	281.82	42	10.38	0.0002	0.0042	N/A	N/A	N/A
	1050.1	198.85	42	10.38	0.0002	0.0069	N/A	N/A	N/A
	1123.1	209.86	42	10.38	0.0004	0.0254	N/A	N/A	N/A
	1519.3	209.58	44	10.88	0.0071	0.309	N/A	N/A	N/A
	1617.5	205.21	44	10.88	0.0082	0.494	200.07	43	10.63
	1734.1	199.14	44	10.88	0.0114	0.871	185.61	43	10.63

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)	Rupture Time (s)	Rupture Node	Rupture Elevation (ft)
	1699.5	195.59	44	10.88	0.0090	0.721	184.26	43	10.63
	1610.3	186.44	44	10.88	0.0061	0.468	181.18	43	10.63
	1579.7	180.00	43	10.63	0.0051	0.342	178.76	43	10.63
	1593.0	177.15	43	10.63	0.0075	0.401	173.93	42	10.38
	1608.0	158.25	43	10.63	0.0054	0.412	153.43	42	10.38
	1611.6	142.34	42	10.38	0.0053	0.401	137.67	42	10.38
	1546.6	126.89	42	10.38	0.0036	0.219	125.33	41	10.13
	1532.9	117.67	42	10.38	0.0030	0.186	116.15	41	10.13

Table 5-6a: Break Spectrum Sequence of Events – W 3-Loop

Break size (in)	PCT (°F)	LL PZR Trip (s)	SIAS Initiated (s)	Reactor Trip (s)	LHSI Loop 1 (s)	LHSI Loop 2 (s)	LHSI Loop 3 (s)
	692.4	138.54	282.9	140.54	N/A	N/A	N/A
	692.4	31.93	48.65	33.94	N/A	N/A	N/A
	692.4	28.89	44.01	30.89	N/A	N/A	N/A
	972.5	26.25	40.14	28.25	N/A	N/A	N/A
	1134.1	23.96	36.90	25.96	N/A	N/A	N/A
	1194.7	21.95	34.13	23.95	N/A	N/A	N/A
	1224.0	20.18	31.72	22.18	N/A	N/A	N/A
	1255.6	18.61	29.61	20.61	N/A	N/A	N/A
	1304.4	17.22	27.75	19.22	N/A	N/A	N/A
	1578.1	15.98	26.10	17.98	N/A	N/A	N/A
	1298.0	14.85	24.62	16.85	N/A	N/A	N/A
	1275.2	13.84	23.29	15.84	N/A	N/A	N/A
	1070.7	10.03	18.67	12.04	N/A	N/A	N/A
	991.9	7.67	15.73	9.68	N/A	N/A	N/A
	1050.1	5.21	11.95	7.21	N/A	N/A	N/A
	1123.1	4.14	9.26	6.14	N/A	N/A	N/A
	1519.3	3.67	7.78	5.68	N/A	N/A	N/A
	1617.5	3.55	7.36	5.55	1014.41	1014.45	1013.88
	1734.1	3.53	7.29	5.54	950.62	950.65	950.05
	1699.5	3.51	7.22	5.51	196.68	196.74	196.66

Break size (in)	PCT (°F)	LL PZR Trip (s)	SIAS Initiated (s)	Reactor Trip (s)	LHSI Loop 1 (s)	LHSI Loop 2 (s)	LHSI Loop 3 (s)
	1610.3	3.49	7.15	5.49	190.69	859.67	858.54
	1579.7	3.47	7.08	5.48	710.66	710.65	709.91
	1593.0	3.46	7.02	5.46	179.96	180.59	180.35
	1608.0	3.37	6.75	5.37	157.73	157.70	157.83
	1611.6	3.29	6.52	5.30	140.43	140.86	140.89
	1546.6	3.23	6.33	5.23	124.90	124.50	124.81
	1532.9	3.17	6.17	5.17	113.49	113.45	113.52

Table 5-6b: Break Spectrum Sequence of Events – W 3-Loop

Break size (in)	PCT (°F)	Loop Seal 1 Clear (s)	Loop Seal 2 Clear (s)	Loop Seal 3 Clear (s)	Break Uncovery (s)	Core Uncovery (s)	Non-Condensables at Break (s)
	692.4	N/A	N/A	N/A	N/A	N/A	N/A
	692.4	N/A	N/A	1009.23	1023.09	N/A	N/A
	692.4	N/A	N/A	914.92	927.51	805.00	N/A
	972.5	N/A	N/A	833.12	845.47	823.00	N/A
	1134.1	N/A	N/A	765.32	777.02	546.00	N/A
	1194.7	N/A	N/A	704.67	715.47	680.00	N/A
	1224.0	N/A	N/A	646.25	656.97	643.00	N/A
	1255.6	N/A	N/A	599.40	609.86	408.00	N/A
	1304.4	N/A	N/A	561.73	571.25	354.00	N/A
	1578.1	1744.88	1744.78	523.68	533.06	334.00	N/A
	1298.0	N/A	N/A	489.14	497.82	323.00	N/A
	1275.2	N/A	N/A	459.33	467.71	284.00	N/A
	1070.7	352.34	351.96	352.72	368.95	210.00	1310
	991.9	277.64	277.92	277.24	295.15	167.00	902
	1050.1	193.71	192.33	192.13	203.86	111.00	514
	1123.1	139.23	140.07	138.94	148.14	81.00	338
	1519.3	99.27	101.36	99.25	108.77	59.00	240
	1617.5	83.60	84.99	82.47	105.03	56.00	208
	1734.1	82.19	81.81	80.54	101.86	53.00	202

Break size (in)	PCT (°F)	Loop Seal 1 Clear (s)	Loop Seal 2 Clear (s)	Loop Seal 3 Clear (s)	Break Uncovery (s)	Core Uncovery (s)	Non-Condensables at Break (s)
	1699.5	80.38	80.15	77.96	99.60	52.00	196
	1610.3	77.95	78.54	75.36	96.35	52.00	190
	1579.7	75.84	76.03	73.07	94.42	50.00	184
	1593.0	75.39	75.61	72.46	94.67	50.00	180
	1608.0	66.20	66.16	62.91	83.25	44.00	158
	1611.6	60.66	62.79	59.28	76.49	42.00	142
	1546.6	48.92	55.59	48.72	69.14	38.00	126
	1532.9	44.15	44.16	45.39	62.75	38.00	116

Table 5-6c: Break Spectrum Sequence of Events – W 3-Loop

Break size (in)	PCT (°F)	Accumulator Flow Loop 1 (s)	Accumulator Flow Loop 2 (s)	Accumulator Flow Loop 3 (s)
	692.4	N/A	N/A	N/A
	692.4	N/A	N/A	N/A
	692.4	N/A	N/A	N/A
	972.5	N/A	N/A	N/A
	1134.1	N/A	N/A	N/A
	1194.7	3391.32	3389.70	3390.19
	1224.0	3051.18	3050.14	3050.39
	1255.6	2660.34	2659.40	2659.66
	1304.4	2315.33	2314.63	2314.81
	1578.1	1713.23	1711.72	1713.91
	1298.0	1750.88	1750.33	1750.59
	1275.2	1636.61	1636.05	1633.74
	1070.7	1133.96	1133.56	1133.62
	991.9	801.95	801.59	801.64
	1050.1	459.32	459.12	459.13
	1123.1	300.18	300.09	299.96
	1519.3	211.36	211.29	211.29
	1617.5	180.33	180.25	180.00
	1734.1	174.49	174.43	174.42

Break size (in)	PCT (°F)	Accumulator Flow Loop 1 (s)	Accumulator Flow Loop 2 (s)	Accumulator Flow Loop 3 (s)
	1699.5	169.50	169.45	169.37
	1610.3	163.37	163.33	163.28
	1579.7	158.12	158.07	158.06
	1593.0	155.39	155.34	155.32
	1608.0	132.47	132.41	132.40
	1611.6	120.03	119.98	119.96
	1546.6	105.22	105.19	105.16
	1532.9	95.19	95.17	95.19

Table 5-7: Cold Leg Pump Discharge Break Results – W 4-Loop

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
8.1	1428.2	176.29	42	10.38	0.0014	0.156

Table 5-8: Accumulator Line Break Results – W 4-Loop

Break size (ft²)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
0.4176	1297.3	174.76	42	10.38	0.0007	0.0845

Table 5-9: Break Spectrum Results – W 4-Loop

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)	Rupture Time (s)	Rupture Node	Rupture Elevation (ft)
	690.5	1.24	42	10.38	2.41E-04	3.95E-04	N/A	N/A	N/A
	690.5	1.24	42	10.38	2.07E-04	2.85E-04	N/A	N/A	N/A
	1004.6	1696.30	42	10.38	3.00E-04	4.90E-03	N/A	N/A	N/A
	690.5	1.24	42	10.38	1.23E-04	1.67E-04	N/A	N/A	N/A
	690.5	1.24	42	10.38	9.61E-05	1.33E-04	N/A	N/A	N/A
	836.7	1275.60	46	11.38	8.10E-05	9.84E-04	N/A	N/A	N/A
	1026.6	865.49	44	10.88	1.91E-04	1.05E-02	N/A	N/A	N/A
	822.6	285.08	42	10.38	6.42E-05	6.18E-04	N/A	N/A	N/A
	905.3	239.33	42	10.38	7.65E-05	1.74E-03	N/A	N/A	N/A
	962.8	196.74	43	10.63	8.75E-05	3.57E-03	N/A	N/A	N/A
	985.8	174.28	42	10.38	8.41E-05	3.86E-03	N/A	N/A	N/A
	984.1	162.46	42	10.38	8.19E-05	3.35E-03	N/A	N/A	N/A
	1188.7	205.73	42	10.38	5.56E-04	4.69E-02	N/A	N/A	N/A
	1409.5	208.08	43	10.63	1.73E-03	1.76E-01	N/A	N/A	N/A
	1291.8	187.20	42	10.38	7.16E-04	8.08E-02	N/A	N/A	N/A
	1338.8	181.79	42	10.38	8.17E-04	1.05E-01	N/A	N/A	N/A
	1419.2	188.52	42	10.38	1.41E-03	1.61E-01	N/A	N/A	N/A
	1428.2	176.29	42	10.38	1.40E-03	1.56E-01	N/A	N/A	N/A
	1339.1	176.81	42	10.38	1.12E-03	8.72E-02	N/A	N/A	N/A

[illegible]

Table 5-10a: Break Spectrum Sequence of Events – W 4-Loop

Break size (in)	PCT (°F)	LL PZR Trip (s)	SIAS Initiated (s)	Reactor Trip (s)	RHR Loop 1 (s)	RHR Loop 2 (s)	RHR Loop 3 (s)	RHR Loop 4 (s)
	690.5	225.0	239.1	227.5	N/A	N/A	N/A	N/A
	690.5	87.32	101.01	89.82	N/A	N/A	N/A	N/A
	1004.6	43.33	56.34	45.83	N/A	N/A	N/A	N/A
	690.5	23.53	36.00	26.03	N/A	N/A	N/A	N/A
	690.5	13.29	25.13	15.79	N/A	N/A	N/A	N/A
	836.7	7.68	18.83	10.18	N/A	N/A	N/A	N/A
	1026.6	4.93	15.24	7.43	N/A	N/A	N/A	N/A
	822.6	0.76	12.11	3.26	N/A	N/A	N/A	N/A
	905.3	0.68	10.92	3.18	N/A	N/A	N/A	N/A
	962.8	0.63	9.94	3.13	N/A	N/A	N/A	N/A
	985.8	0.58	9.28	3.08	N/A	N/A	N/A	450.89
	984.1	0.55	8.77	3.05	N/A	N/A	N/A	N/A
	1188.7	0.52	8.36	3.02	340.16	340.16	340.16	332.96
	1409.5	0.49	8.03	2.99	294.37	294.37	294.37	290.28
	1291.8	0.48	7.87	2.98	265.57	265.57	265.57	263.15
	1338.8	0.48	7.82	2.98	254.55	254.55	254.55	251.39
	1419.2	0.47	7.77	2.98	252.77	252.77	252.77	248.54
	1428.2	0.47	7.73	2.97	240.10	240.10	240.10	237.37
	1339.1	0.47	7.69	2.97	239.04	239.04	239.04	236.21

Break size (in)	PCT (°F)	LL PZR Trip (s)	SIAS Initiated (s)	Reactor Trip (s)	RHR Loop 1 (s)	RHR Loop 2 (s)	RHR Loop 3 (s)	RHR Loop 4 (s)
	1398.6	0.46	7.64	2.97	227.63	227.63	227.63	225.76
	1352.2	0.46	7.56	2.96	219.51	219.51	219.51	217.51
	1350.2	0.44	7.39	2.94	182.06	182.06	182.06	181.96
	1398.3	0.43	7.23	2.93	160.24	160.24	160.24	157.31
	1392.5	0.42	7.15	2.92	141.14	141.14	141.14	139.95

Table 5-10b: Break Spectrum Sequence of Events – W 4-Loop

Break size (in)	PCT (°F)	SI Loop 1 (s)	SI Loop 2 (s)	SI Loop 3 (s)	SI Loop 4 (s)	CC All Loops (s)	SG-1 AFW (s)	SG-2 AFW (s)	SG-3 AFW (s)	SG-4 AFW (s)
	690.5	754.74	754.74	754.74	754.72	276.1	N/A	291.12	N/A	291.12
	690.5	294.98	294.98	294.98	294.22	138.01	N/A	153.45	N/A	153.45
	1004.6	181.44	181.44	181.44	180.62	93.34	N/A	109.46	N/A	109.46
	690.5	127.63	127.63	127.63	126.89	73.00	N/A	89.64	N/A	89.64
	690.5	62.14	62.14	62.14	92.81	62.13	N/A	79.36	N/A	79.36
	836.7	55.83	55.83	55.83	55.83	55.83	N/A	73.77	N/A	73.77
	1026.6	52.24	52.24	52.24	52.24	52.24	N/A	70.95	N/A	70.95
	822.6	49.12	49.12	49.12	49.12	49.11	N/A	66.83	N/A	66.83
	905.3	47.93	47.93	47.93	47.93	47.92	N/A	66.74	N/A	66.74
	962.8	46.95	46.95	46.95	46.95	46.95	N/A	66.67	N/A	66.67
	985.8	46.28	46.28	46.28	46.28	46.28	N/A	66.63	N/A	66.63
	984.1	45.77	45.77	45.77	45.77	45.77	N/A	66.60	N/A	66.60
	1188.7	45.36	45.36	45.36	45.36	45.36	N/A	66.59	N/A	66.59
	1409.5	45.04	45.04	45.04	45.04	45.04	N/A	66.59	N/A	66.59
	1291.8	44.87	44.87	44.87	44.87	44.87	N/A	66.58	N/A	66.58
	1338.8	44.82	44.82	44.82	44.82	44.82	N/A	66.58	N/A	66.58
	1419.2	44.77	44.77	44.77	44.77	44.77	N/A	66.58	N/A	66.58
	1428.2	44.73	44.73	44.73	44.73	44.73	N/A	66.57	N/A	66.57
	1339.1	44.69	44.69	44.69	44.69	44.69	N/A	66.58	N/A	66.58

Break size (in)	PCT (°F)	SI Loop 1 (s)	SI Loop 2 (s)	SI Loop 3 (s)	SI Loop 4 (s)	CC All Loops (s)	SG-1 AFW (s)	SG-2 AFW (s)	SG-3 AFW (s)	SG-4 AFW (s)
	1398.6	44.65	44.65	44.65	44.65	44.65	N/A	66.58	N/A	66.58
	1352.2	44.57	44.57	44.57	44.57	44.57	N/A	66.57	N/A	66.57
	1350.2	44.39	44.39	44.39	44.39	44.39	N/A	66.55	N/A	66.55
	1398.3	44.23	44.23	44.23	44.23	44.23	N/A	66.53	N/A	66.53
	1392.5	44.16	44.16	44.16	44.16	44.15	N/A	66.52	N/A	66.52

Table 5-10c: Break Spectrum Sequence of Events – W 4-Loop

Break size (in)	PCT (°F)	LS-1 Clear (s)	LS-2 Clear (s)	LS-3 Clear (s)	LS-4 Clear (s)	Break Uncovery (s)	Core Uncovery (s)	Non-Condensables at Break (s)
	690.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	690.5	N/A	N/A	N/A	N/A	2614.16	2084.00	N/A
	1004.6	N/A	N/A	N/A	1692.87	1371.34	968.00	N/A
	690.5	N/A	N/A	N/A	945.08	862.96	560.00	N/A
	690.5	N/A	N/A	N/A	574.34	582.55	510.00	N/A
	836.7	N/A	N/A	N/A	449.13	456.42	282.00	N/A
	1026.6	N/A	N/A	N/A	352.88	345.06	186.00	N/A
	822.6	285.19	284.21	282.17	286.46	292.13	140.00	N/A
	905.3	233.41	235.34	236.68	235.71	242.70	118.00	N/A
	962.8	192.42	192.41	191.61	194.61	202.17	88.00	N/A
	985.8	168.98	169.47	171.87	170.31	176.32	78.00	N/A
	984.1	147.16	149.11	151.68	151.67	157.30	66.00	N/A
	1188.7	131.43	132.02	132.55	132.84	137.75	60.00	N/A
	1409.5	113.24	114.23	114.78	114.06	121.63	54.00	N/A
	1291.8	104.69	104.96	104.92	104.77	112.18	50.00	1012.00
	1338.8	105.86	106.91	106.97	115.76	115.09	50.00	N/A
	1419.2	103.55	103.37	103.63	105.73	111.51	48.00	N/A
	1428.2	101.91	103.20	103.97	115.66	111.34	48.00	N/A
	1339.1	96.81	97.74	98.10	99.41	105.47	46.00	N/A

Break size (in)	PCT (°F)	LS-1 Clear (s)	LS-2 Clear (s)	LS-3 Clear (s)	LS-4 Clear (s)	Break Uncovery (s)	Core Uncovery (s)	Non-Condensables at Break (s)
	1398.6	98.44	99.63	99.76	111.22	106.71	46.00	N/A
	1352.2	84.11	84.72	84.59	84.35	95.04	44.00	N/A
	1350.2	87.01	87.60	88.41	92.07	94.84	42.00	272.00
	1398.3	78.43	78.45	78.49	79.67	84.69	38.00	240.00
	1392.5	76.96	76.63	76.57	86.40	82.50	36.00	226.00

Table 5-10d: Break Spectrum Sequence of Events – W 4-Loop

Break size (in)	PCT (°F)	Accumulator Flow Loop 1 (s)	Accumulator Flow Loop 2 (s)	Accumulator Flow Loop 3 (s)	Accumulator Flow Loop 4 (s)
	690.5	N/A	N/A	N/A	N/A
	690.5	N/A	N/A	N/A	N/A
	1004.6	N/A	N/A	N/A	N/A
	690.5	N/A	N/A	N/A	N/A
	690.5	N/A	N/A	N/A	N/A
	836.7	1269.34	1269.35	1269.36	1269.18
	1026.6	803.59	803.58	803.62	803.36
	822.6	639.17	639.17	639.17	639.11
	905.3	487.01	487.02	487.04	486.99
	962.8	393.96	393.96	393.96	393.90
	985.8	332.29	332.29	332.29	332.22
	984.1	286.00	286.00	286.00	285.92
	1188.7	249.68	249.68	249.69	249.69
	1409.5	209.22	209.22	209.21	209.08
	1291.8	190.11	190.12	190.12	190.07
	1338.8	179.85	179.85	179.85	179.76
	1419.2	177.64	177.64	177.64	177.53
	1428.2	166.36	166.36	166.36	166.26
	1339.1	167.04	167.04	167.05	166.93

Break size (in)	PCT (°F)	Accumulator Flow Loop 1 (s)	Accumulator Flow Loop 2 (s)	Accumulator Flow Loop 3 (s)	Accumulator Flow Loop 4 (s)
	1398.6	155.55	155.55	155.55	155.44
	1352.2	156.39	156.40	156.40	156.25
	1350.2	130.43	130.43	130.44	130.37
	1398.3	113.64	113.64	113.64	113.55
	1392.5	106.79	106.79	106.79	106.76

Table 5-11: Cold Leg Pump Discharge Break Results – CE 2X4

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
3.50	1831.0	1646.30	45	11.125	0.0777	4.59

Table 5-12: SIT Line Break Results – CE 2X4

Break size (ft²)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)
0.5592	1423.0	199.21	41	10.125	0.0018	0.0898

Table 5-13: Break Spectrum Results – CE 2X4

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)	Rupture Time (s)	Rupture Node	Rupture Elevation (ft)
	683.7	0.64	40	9.88	0.0002	0.0003	N/A	N/A	N/A
	683.7	0.64	40	9.88	0.0001	0.0002	N/A	N/A	N/A
	1117.4	2831.1	42	10.38	0.0015	0.0586	N/A	N/A	N/A
	1341.6	2144.1	43	10.63	0.0076	0.276	N/A	N/A	N/A
	1583.4	1810.2	45	11.13	0.0338	1.62	1756.8	44	10.88
	1669.4	1784.6	45	11.13	0.0458	2.68	1535.0	44	10.88
	1831.0	1646.3	45	11.13	0.0777	4.59	1344.8	43	10.63
	1525.9	2030.4	44	10.88	0.0167	0.728	N/A	N/A	N/A
	1568.3	1715.7	45	11.13	0.0226	1.45	1666.6	44	10.88
	1718.6	1612.9	45	11.13	0.0383	2.92	1375.7	44	10.88
	1744.4	1547.1	45	11.13	0.0349	2.62	1313.2	44	10.88
	1770.9	1422.4	45	11.13	0.0324	2.26	1236.0	43	10.63
	1777.6	1216.1	44	10.88	0.0283	2.04	1082.8	43	10.63
	1821.2	1115.4	44	10.88	0.0290	2.23	990.59	43	10.63
	1784.2	1046.5	44	10.88	0.0243	1.83	947.01	43	10.63
	1781.1	978.77	43	10.63	0.0227	1.73	890.75	43	10.63
	1772.2	919.32	43	10.63	0.0213	1.61	841.62	43	10.63
	1751.6	867.70	43	10.63	0.0191	1.42	801.86	43	10.63
	1743.2	821.91	43	10.63	0.0179	1.28	762.72	42	10.38

Break size (in)	PCT (°F)	PCT Time (s)	PCT Node	PCT Elevation (ft)	Total Oxidation (percent)	Maximum Oxidation (percent)	Rupture Time (s)	Rupture Node	Rupture Elevation (ft)
	1695.6	737.16	43	10.63	0.0142	0.984	694.76	42	10.38
	1574.9	477.45	43	10.63	0.0087	0.469	469.82	43	10.63
	1740.8	327.52	43	10.63	0.0199	1.15	286.28	42	10.38
	1596.5	247.23	43	10.63	0.0086	0.513	237.48	42	10.38
	1515.5	192.48	42	10.38	0.0043	0.184	N/A	N/A	N/A
	1559.6	166.20	41	10.13	0.0059	0.232	N/A	N/A	N/A

Table 5-14a: Break Spectrum Sequence of Events – CE 2X4

Break size (in)	PCT (°F)	LL PZR Trip (s)	SIAS Initiated (s)	Reactor Trip (s)	LPSI Loop 1A (s)	LPSI Loop 1B (s)	LPSI Loop 2A (s)	LPSI Loop 2B (s)
	683.7	220.85	377.88	221.75	N/A	N/A	N/A	N/A
	683.7	51.7	81.26	52.6	N/A	N/A	N/A	N/A
	1117.4	33.01	53.69	33.91	N/A	N/A	N/A	N/A
	1341.6	23.05	38.68	23.95	N/A	N/A	N/A	N/A
	1583.4	19.23	32.95	20.13	N/A	N/A	N/A	N/A
	1669.4	18.18	31.46	19.08	N/A	N/A	N/A	N/A
	1831.0	17.22	30.14	18.12	N/A	N/A	N/A	N/A
	1525.9	16.35	28.94	17.25	N/A	N/A	N/A	N/A
	1568.3	15.56	27.86	16.46	N/A	N/A	N/A	N/A
	1718.6	14.90	26.96	15.81	N/A	N/A	N/A	N/A
	1744.4	14.18	25.96	15.08	N/A	N/A	N/A	N/A
	1770.9	13.57	25.13	14.48	N/A	N/A	N/A	N/A
	1777.6	12.51	23.68	13.42	N/A	N/A	N/A	N/A
	1821.2	12.06	23.05	12.96	N/A	N/A	N/A	N/A
	1784.2	11.64	22.48	12.54	N/A	N/A	N/A	N/A
	1781.1	11.25	21.95	12.16	N/A	N/A	N/A	N/A
	1772.2	10.91	21.46	11.81	N/A	N/A	N/A	N/A
	1751.6	10.59	21.01	11.49	N/A	N/A	N/A	N/A
	1743.2	10.30	20.60	11.21	N/A	N/A	N/A	N/A

Break size (in)	PCT (°F)	LL PZR Trip (s)	SIAS Initiated (s)	Reactor Trip (s)	LPSI Loop 1A (s)	LPSI Loop 1B (s)	LPSI Loop 2A (s)	LPSI Loop 2B (s)
	1695.6	9.81	19.85	10.72	N/A	N/A	N/A	N/A
	1574.9	8.45	17.24	9.35	N/A	N/A	544.5	544.51
	1740.8	7.92	15.56	8.82	N/A	N/A	340.97	341.11
	1596.5	7.63	14.39	8.54	N/A	N/A	257.8	257.86
	1515.5	7.43	13.47	8.33	N/A	N/A	203.1	203.13
	1559.6	7.35	13.11	8.25	N/A	N/A	174.14	174.11

Table 5-14b: Break Spectrum Sequence of Events – CE 2X4

Break size (in)	PCT (°F)	HPSI Loop 1A (s)	HPSI Loop 1B (s)	HPSI Loop 2A (s)	HPSI Loop 2B (s)	CC Loop 1A (s)	CC Loop 2B (s)	SG-1 AFW (s)	SG-2 AFW (s)
	683.70	895.23	895.22	895.22	892.89	527.88	527.88	843.95	843.95
	683.70	253.50	253.50	253.50	252.78	231.26	231.26	531.79	531.79
	1117.40	178.01	178.01	178.02	177.50	203.69	203.69	486.11	486.11
	1341.60	135.82	135.82	135.83	135.40	188.68	188.68	457.60	457.60
	1583.4	116.06	116.06	116.06	115.59	182.94	182.94	443.72	443.72
	1669.4	109.71	109.71	109.74	109.27	181.46	181.46	439.15	439.15
	1831.0	103.80	103.80	103.80	103.33	180.14	180.14	435.54	435.54
	1525.9	98.18	98.18	98.18	97.68	178.94	178.94	432.40	432.40
	1568.3	92.84	92.83	92.83	92.30	177.85	177.85	429.93	429.93
	1718.6	88.28	88.28	88.28	87.72	176.96	176.96	427.96	427.96
	1744.4	83.00	82.99	82.99	82.45	175.96	175.96	579.55	579.55
	1770.9	78.55	78.54	78.53	78.02	175.13	175.13	579.52	579.52
	1777.6	70.70	70.70	70.69	70.19	173.68	173.68	581.28	581.28
	1821.2	67.38	67.38	67.37	66.88	173.05	173.05	580.51	580.51
	1784.2	64.40	64.39	64.39	63.89	172.48	172.48	578.36	578.36
	1781.1	61.64	61.64	61.63	61.13	171.95	171.95	578.02	578.02
	1772.2	59.07	59.07	59.07	58.54	171.47	171.47	579.94	579.94
	1751.6	56.69	56.68	56.69	56.15	171.01	171.01	590.35	590.35
	1743.2	54.51	54.51	54.49	53.97	170.60	170.60	643.65	643.65

Break size (in)	PCT (°F)	HPSI Loop 1A (s)	HPSI Loop 1B (s)	HPSI Loop 2A (s)	HPSI Loop 2B (s)	CC Loop 1A (s)	CC Loop 2B (s)	SG-1 AFW (s)	SG-2 AFW (s)
	1695.6	50.55	50.55	50.56	50.08	169.85	169.85	660.67	660.67
	1574.9	47.24	47.24	47.24	47.24	167.24	167.24	600.41	600.41
	1740.8	45.56	45.56	45.56	45.56	165.56	165.56	593.83	593.83
	1596.5	44.39	44.39	44.39	44.39	164.39	164.39	644.67	644.67
	1515.5	43.47	43.47	43.47	43.47	163.47	163.47	N/A	N/A
	1559.6	43.11	43.11	43.11	43.11	163.11	163.11	1095.57	1095.57

Table 5-14c: Break Spectrum Sequence of Events – CE 2X4

Break size (in)	PCT (°F)	LS-1A Clear (s)	LS-1B Clear (s)	LS-2A Clear (s)	LS-2B Clear (s)	Break Uncovery (s)	Core Uncovery (s)	Non-Condensables at Break (s)
	683.70	N/A	N/A	N/A	4943.10	4952.66	N/A	N/A
	683.70	N/A	N/A	N/A	1018.09	1084.93	N/A	N/A
	1117.40	N/A	N/A	N/A	654.00	677.11	1906.00	N/A
	1341.60	N/A	N/A	N/A	493.93	508.47	308.00	N/A
	1583.4	N/A	N/A	N/A	420.82	435.04	246.00	N/A
	1669.4	N/A	N/A	N/A	399.76	413.87	234.00	N/A
	1831.0	N/A	N/A	N/A	379.53	393.54	224.00	N/A
	1525.9	397.94	397.47	N/A	361.03	374.95	210.00	N/A
	1568.3	379.17	379.91	N/A	343.54	357.43	200.00	N/A
	1718.6	332.62	339.97	332.91	332.63	353.41	194.00	N/A
	1744.4	315.72	317.12	317.18	315.79	337.94	184.00	N/A
	1770.9	303.03	303.91	302.06	301.38	326.28	176.00	N/A
	1777.6	277.10	278.44	277.30	276.93	299.70	154.00	N/A
	1821.2	265.43	265.82	265.28	264.58	284.35	150.00	N/A
	1784.2	255.26	255.30	254.83	253.97	275.82	144.00	N/A
	1781.1	245.62	245.52	245.55	244.51	266.84	138.00	N/A
	1772.2	237.19	236.93	236.48	235.51	257.77	136.00	N/A
	1751.6	228.76	229.48	228.24	227.23	245.67	132.00	N/A
	1743.2	222.82	221.49	220.46	219.44	236.23	128.00	N/A

Break size (in)	PCT (°F)	LS-1A Clear (s)	LS-1B Clear (s)	LS-2A Clear (s)	LS-2B Clear (s)	Break Uncovery (s)	Core Uncovery (s)	Non-Condensables at Break (s)
	1695.6	207.18	206.34	205.71	204.36	222.23	120.00	N/A
	1574.9	152.60	152.46	152.69	150.70	163.56	86.00	N/A
	1740.8	110.30	110.78	111.56	108.73	131.73	62.00	N/A
	1596.5	83.23	84.95	251.12	80.83	101.93	50.00	N/A
	1515.5	63.47	69.21	63.96	61.25	82.28	42.00	254.00
	1559.6	56.35	57.88	55.58	56.94	73.48	40.00	242.00

Notes:

1. For the 3.50-inch break, Loop Seal 1B clears 40 seconds after the first temperature excursion has been terminated by the clearing of Loop Seal 2B.

Table 5-14d: Break Spectrum Sequence of Events – CE 2X4

Break size (in)	PCT (°F)	SIT Flow Loop 1A (s)	SIT Flow Loop 1B (s)	SIT Flow Loop 2A (s)	SIT Flow Loop 2B (s)
	683.70	N/A	N/A	N/A	N/A
	683.70	N/A	N/A	N/A	N/A
	1117.40	N/A	N/A	N/A	N/A
	1341.60	N/A	N/A	N/A	N/A
	1583.4	N/A	N/A	N/A	N/A
	1669.4	N/A	N/A	N/A	N/A
	1831.0	N/A	N/A	N/A	N/A
	1525.9	2279.04	2279.02	2279.11	2314.30
	1568.3	N/A	N/A	N/A	N/A
	1718.6	1691.29	1691.40	1691.37	1699.88
	1744.4	1540.27	1540.41	1540.40	1546.82
	1770.9	1413.79	1413.91	1413.88	1418.20
	1777.6	1208.87	1208.97	1208.96	1212.18
	1821.2	1108.45	1108.55	1108.52	1111.63
	1784.2	1039.27	1039.35	1039.29	1041.73
	1781.1	972.01	971.78	971.99	974.15
	1772.2	912.93	912.94	912.95	914.81
	1751.6	861.07	860.89	861.13	862.86
	1743.2	814.55	814.48	814.74	816.27
	1695.6	730.11	729.86	730.12	731.47

Break size (in)	PCT (°F)	SIT Flow Loop 1A (s)	SIT Flow Loop 1B (s)	SIT Flow Loop 2A (s)	SIT Flow Loop 2B (s)
	1574.9	472.45	472.47	472.47	473.25
	1740.8	322.56	322.56	322.58	323.05
	1596.5	241.96	241.97	241.98	242.32
	1515.5	188.53	188.56	188.17	188.47
	1559.6	160.31	160.30	160.31	160.53

Figure 5-1: Break Mass Flow Rate – W 3-Loop

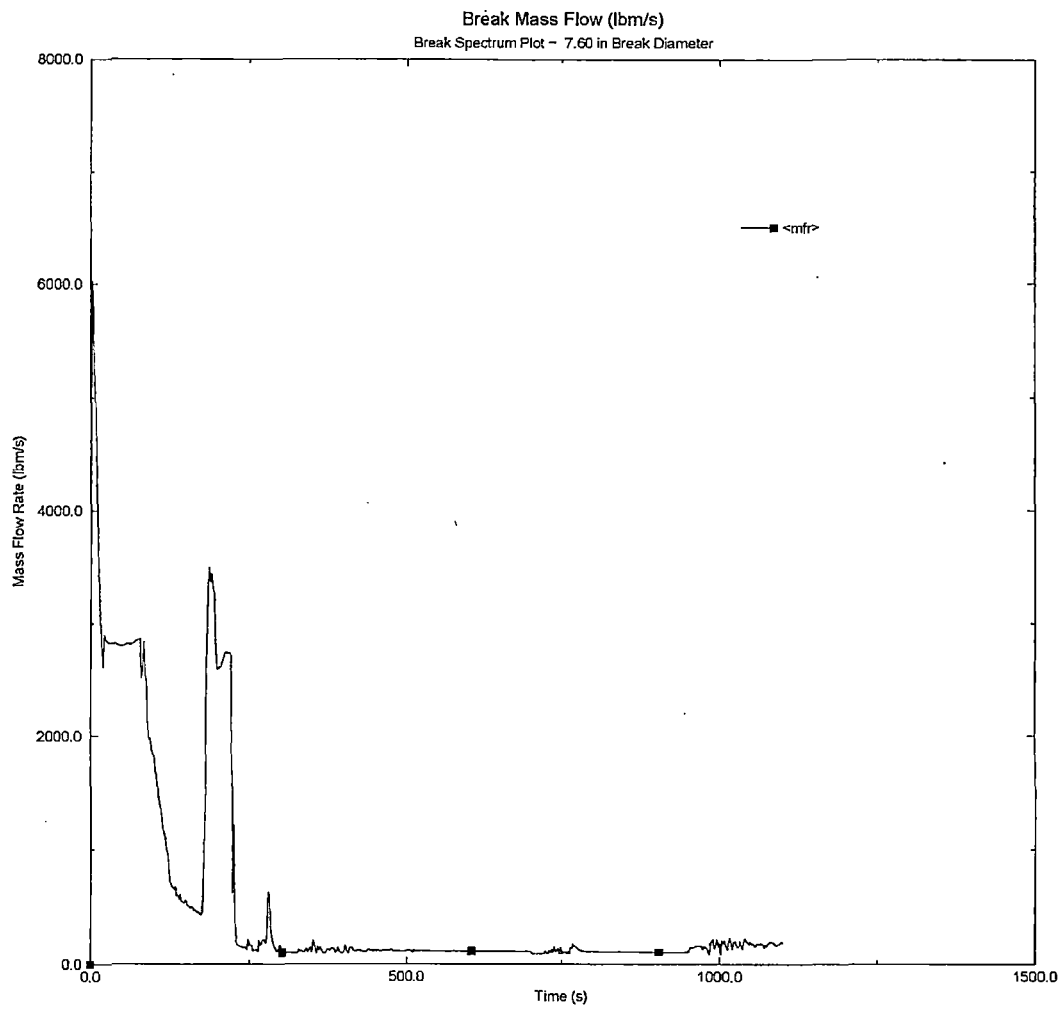


Figure 5-2: Hot Assembly Levels – W 3-Loop

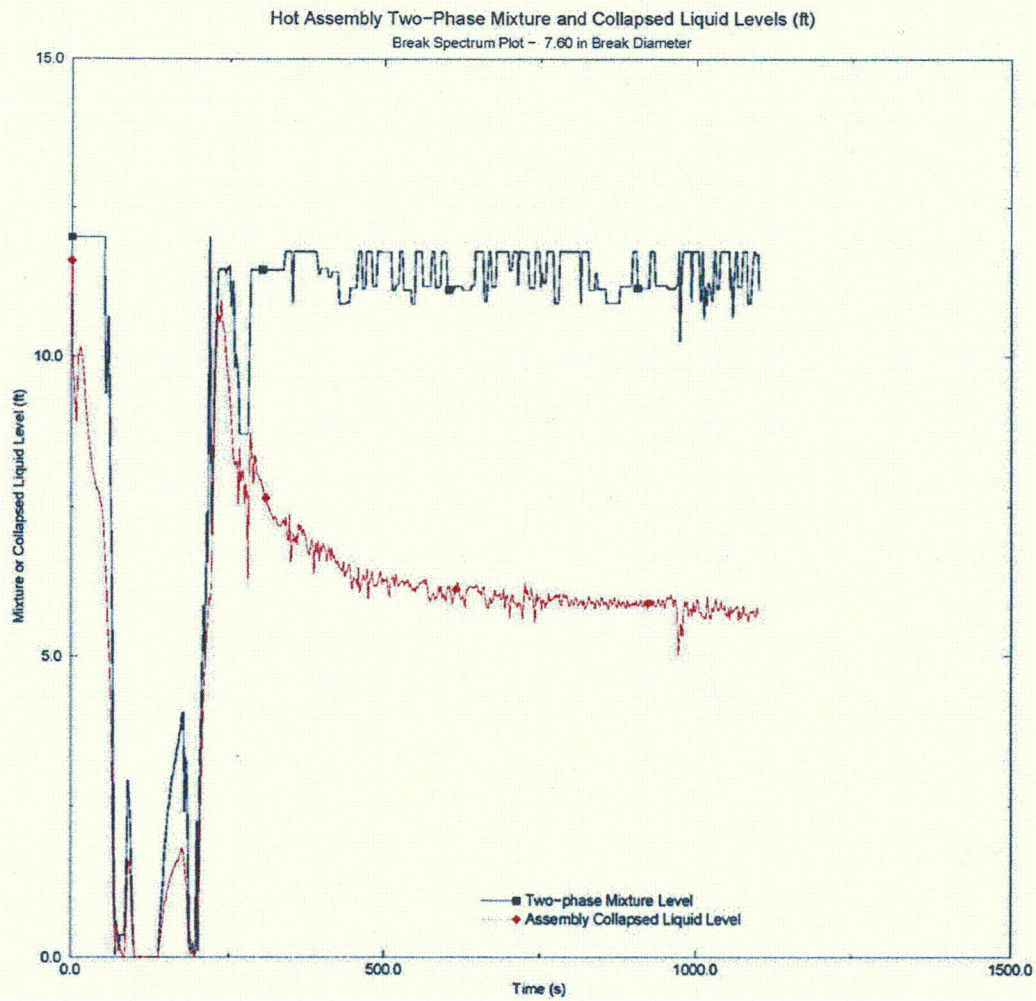


Figure 5-3: RCS and RV Mass Inventories – W 3-Loop

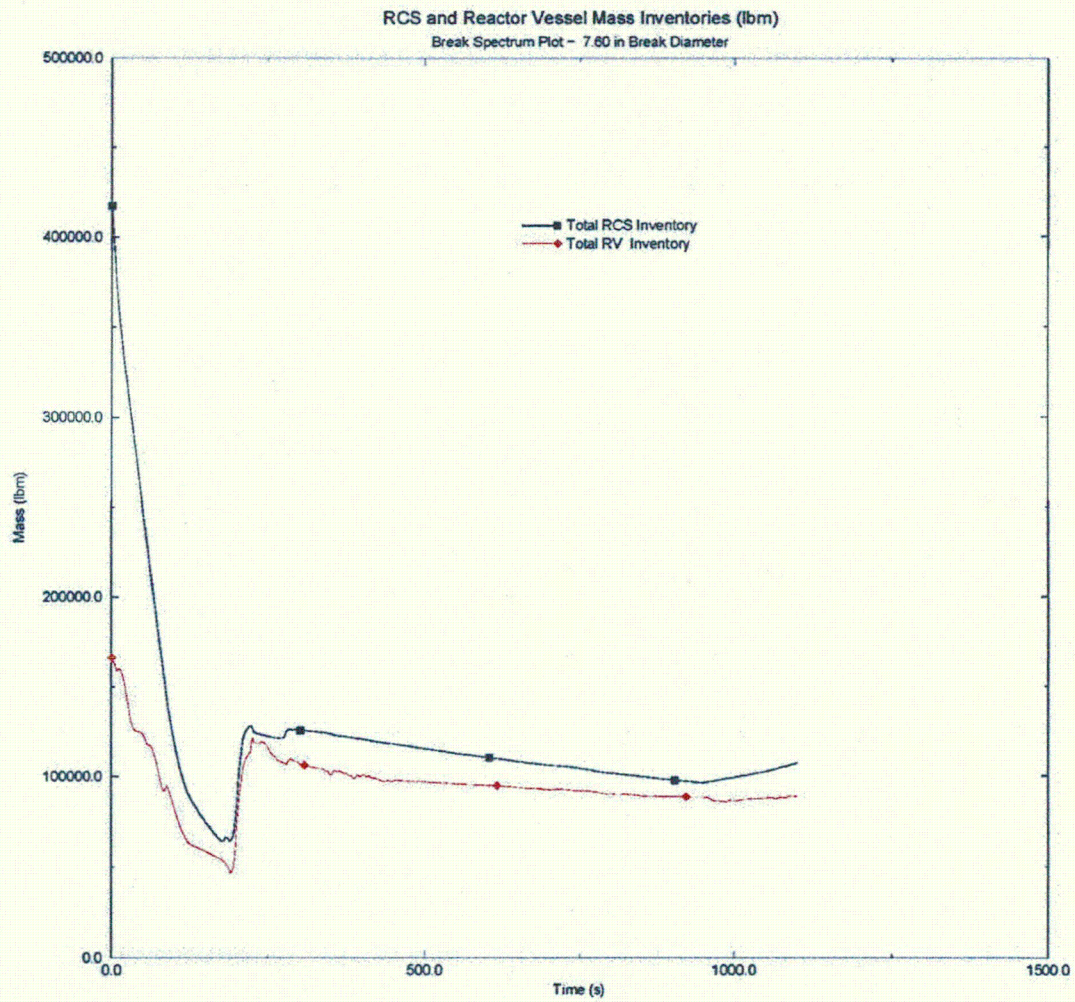


Figure 5-4: Core Power – W 3-Loop

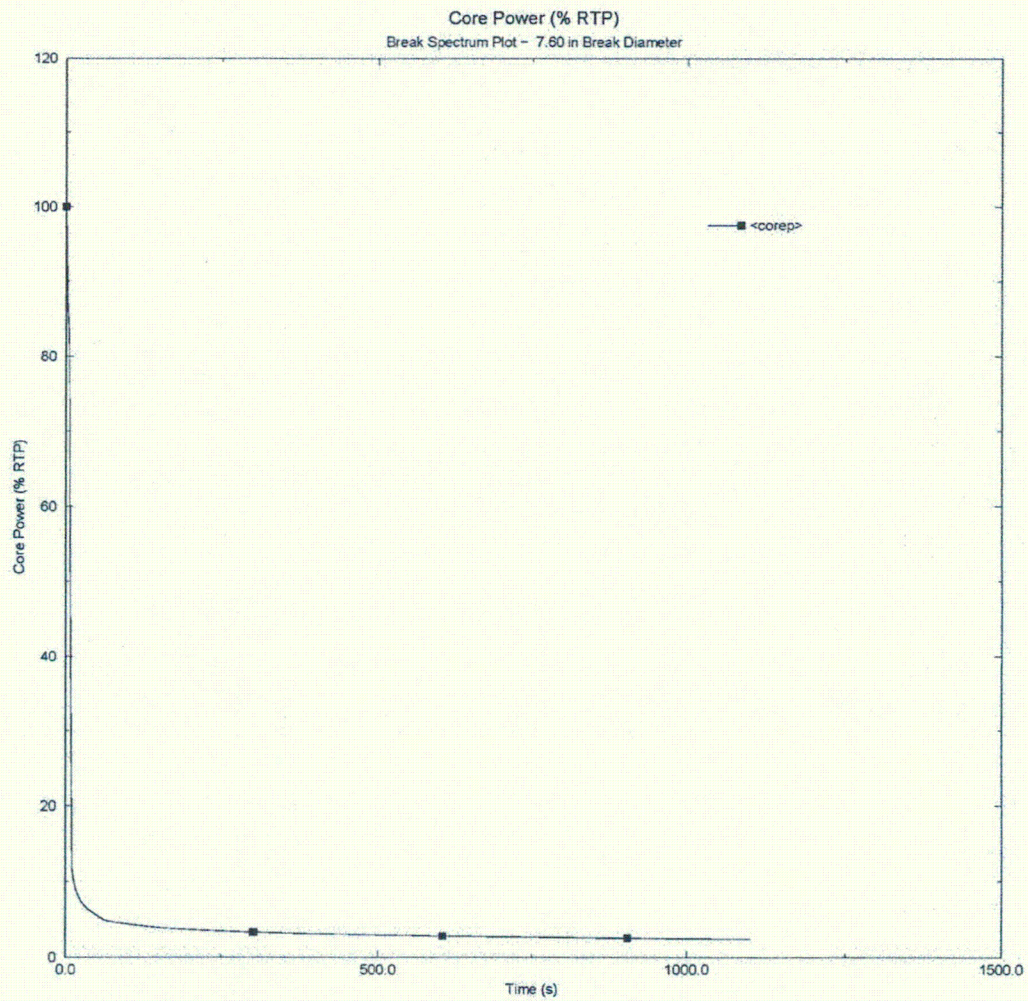


Figure 5-5: Break Void Fraction – W 3-Loop

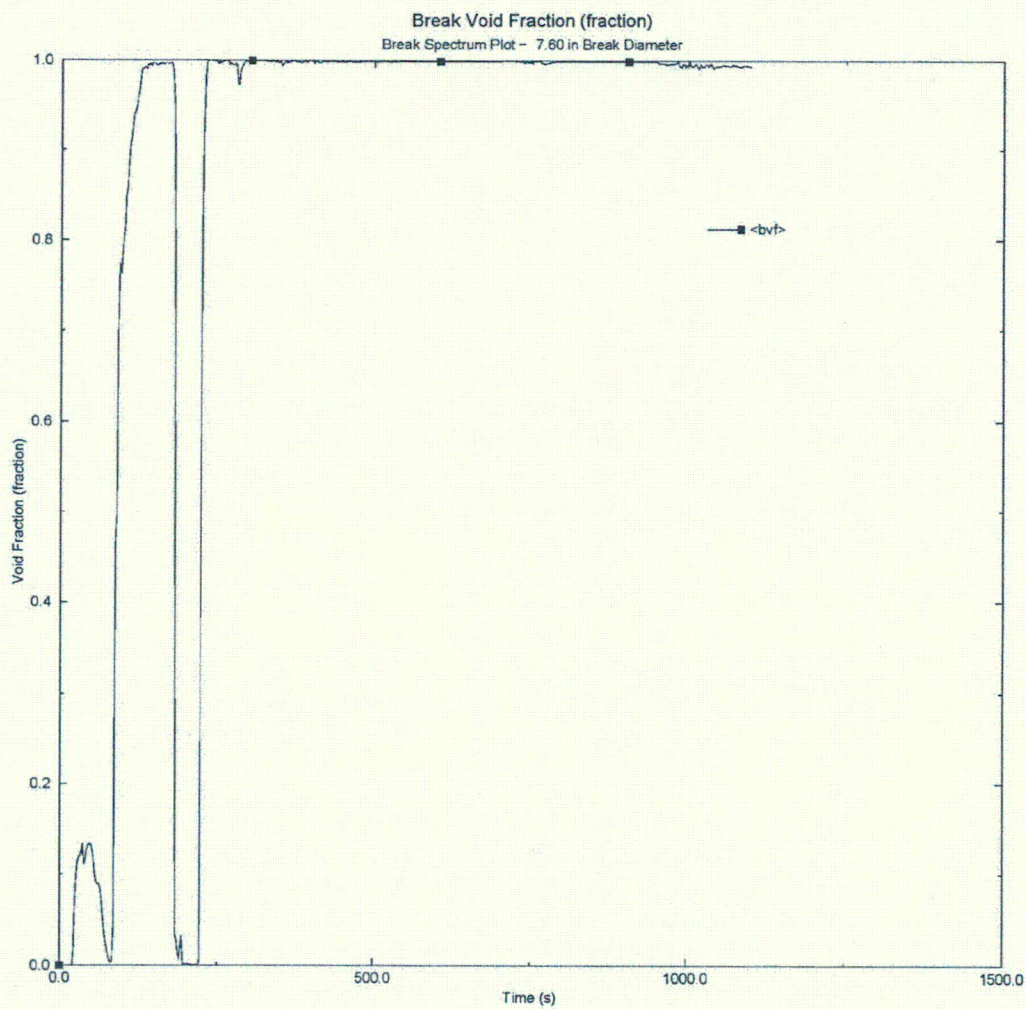


Figure 5-6: High Head Safety Injection (HHSI) Mass Flow Rates – W 3-Loop

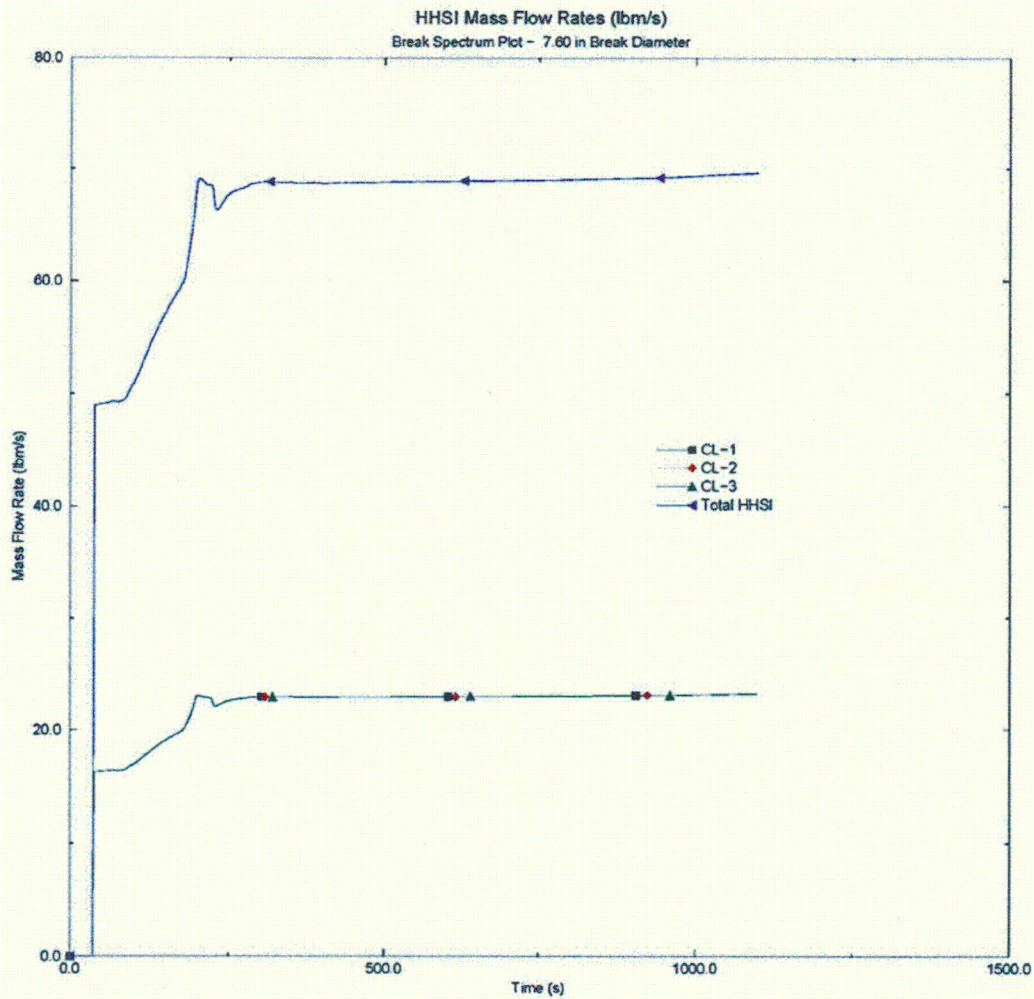


Figure 5-7: Accumulator Mass Flow Rates – W 3-Loop

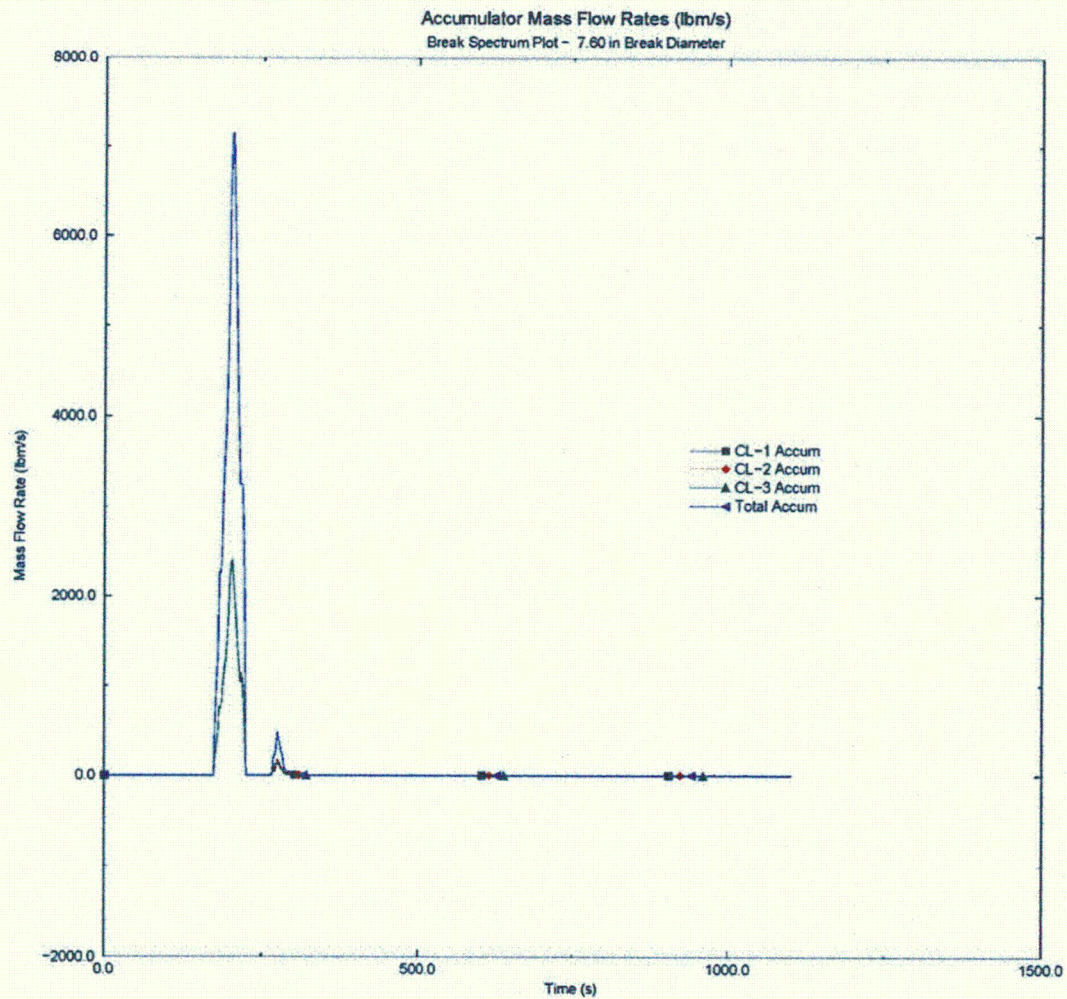


Figure 5-8: Loop Seal Void Fraction – W 3-Loop

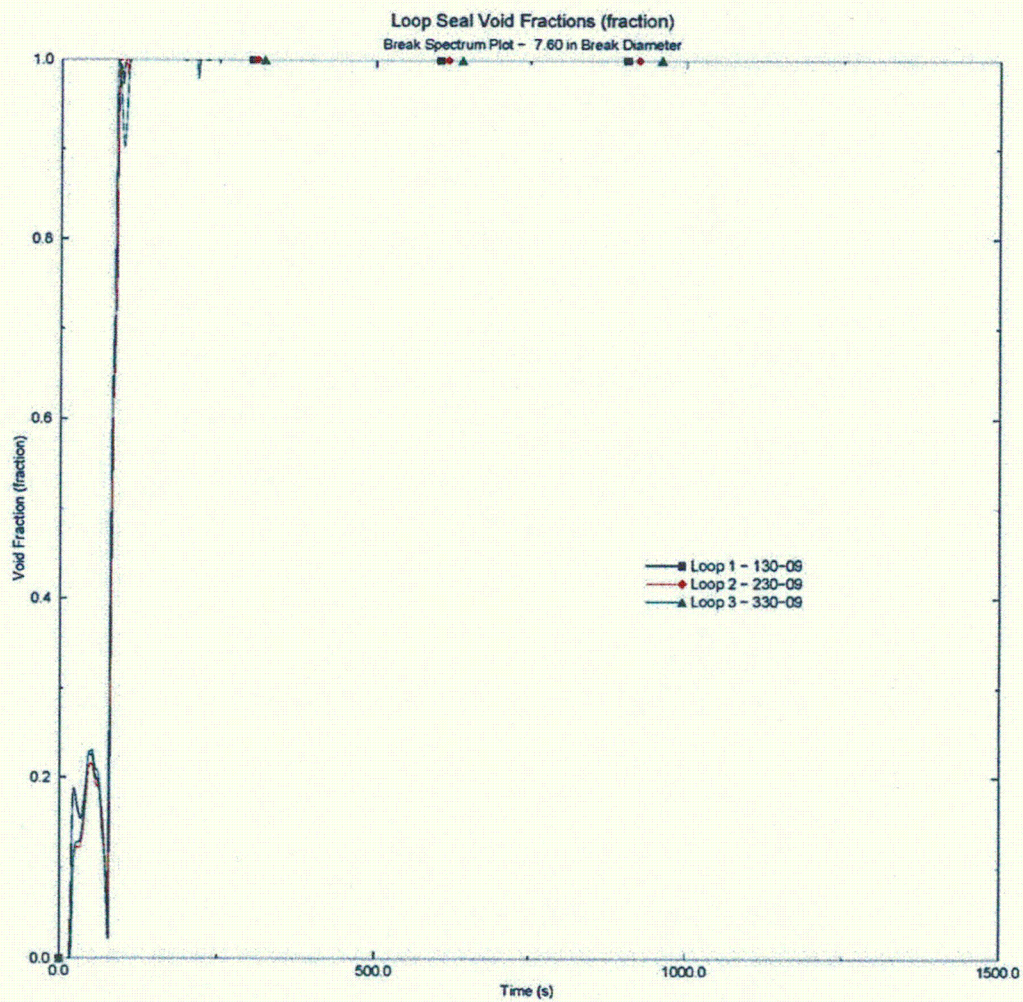


Figure 5-9: SG Mass Inventories – W 3-Loop

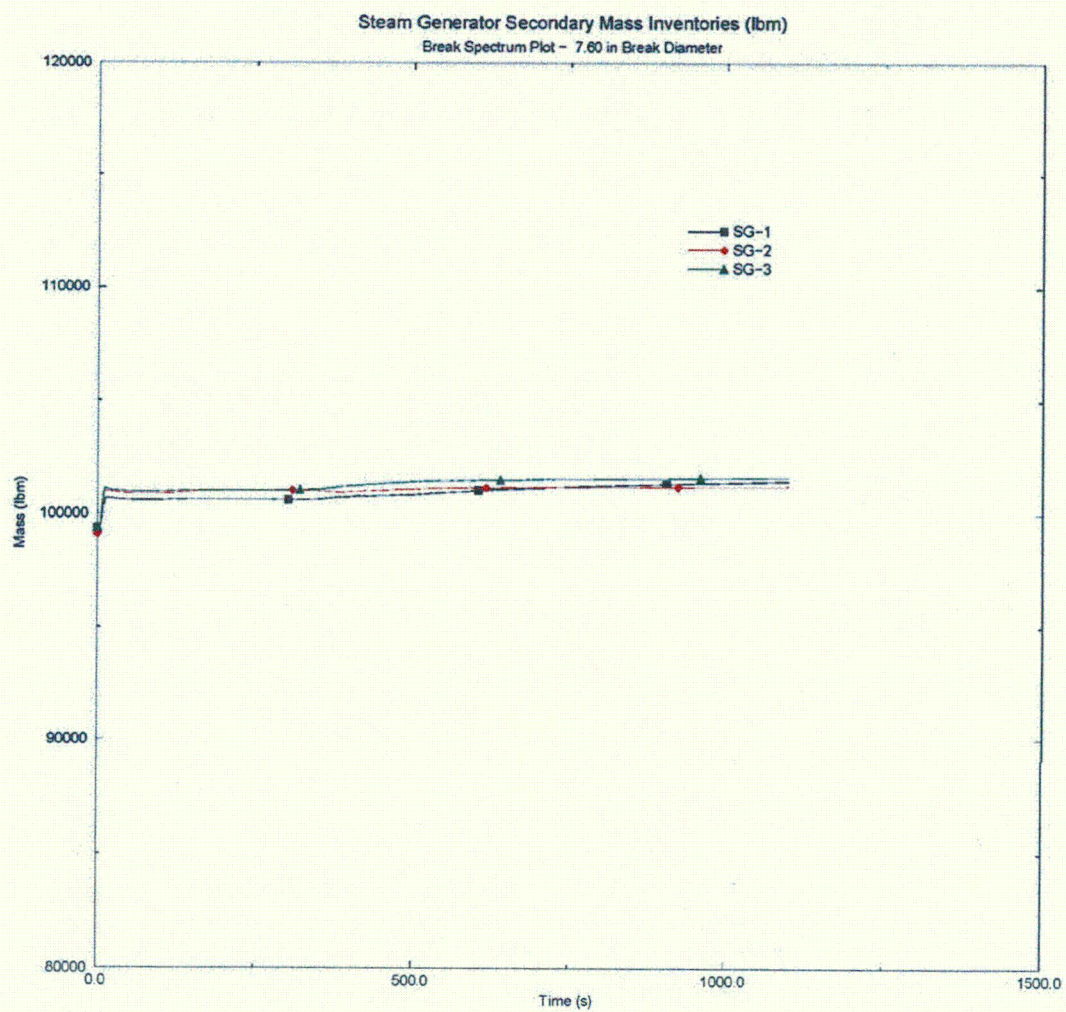


Figure 5-10: AFW Mass Flow Rate – W 3-Loop

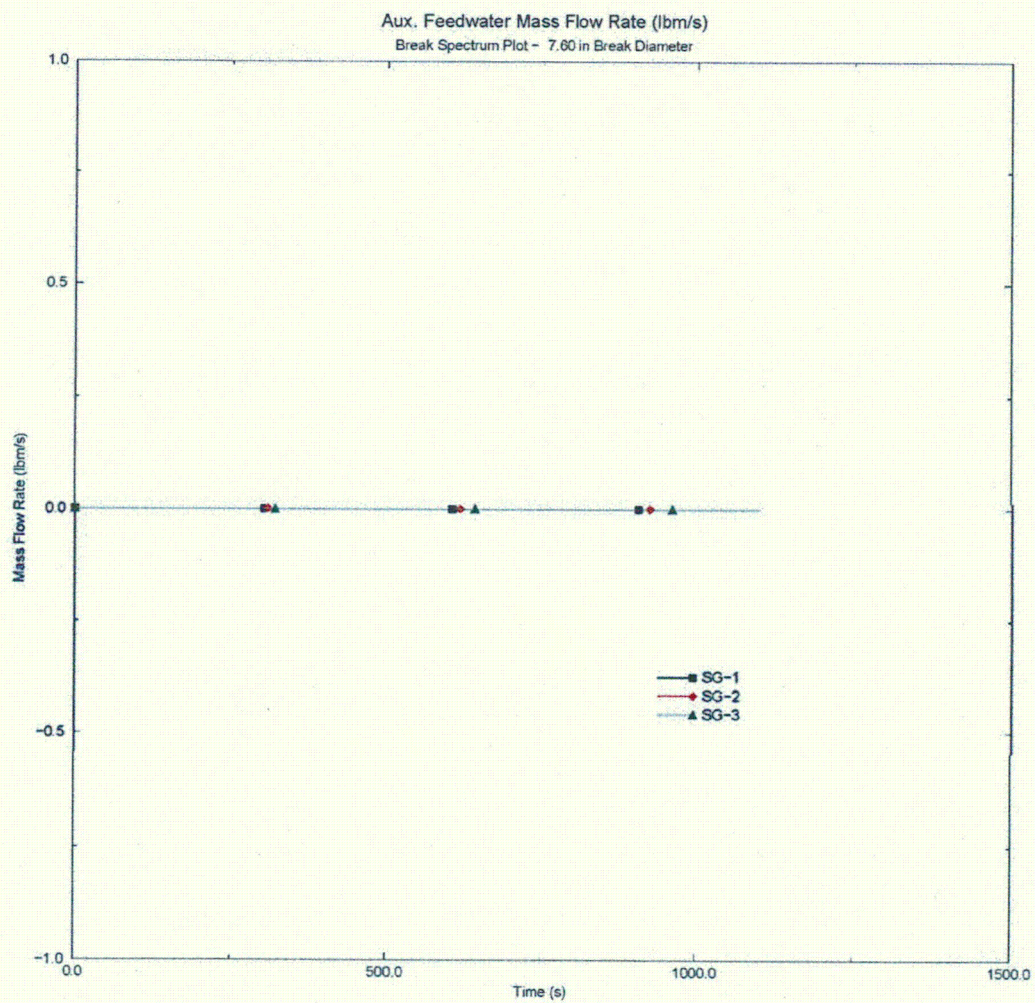


Figure 5-11: Cold Leg Mass Flow Rates – W 3-Loop

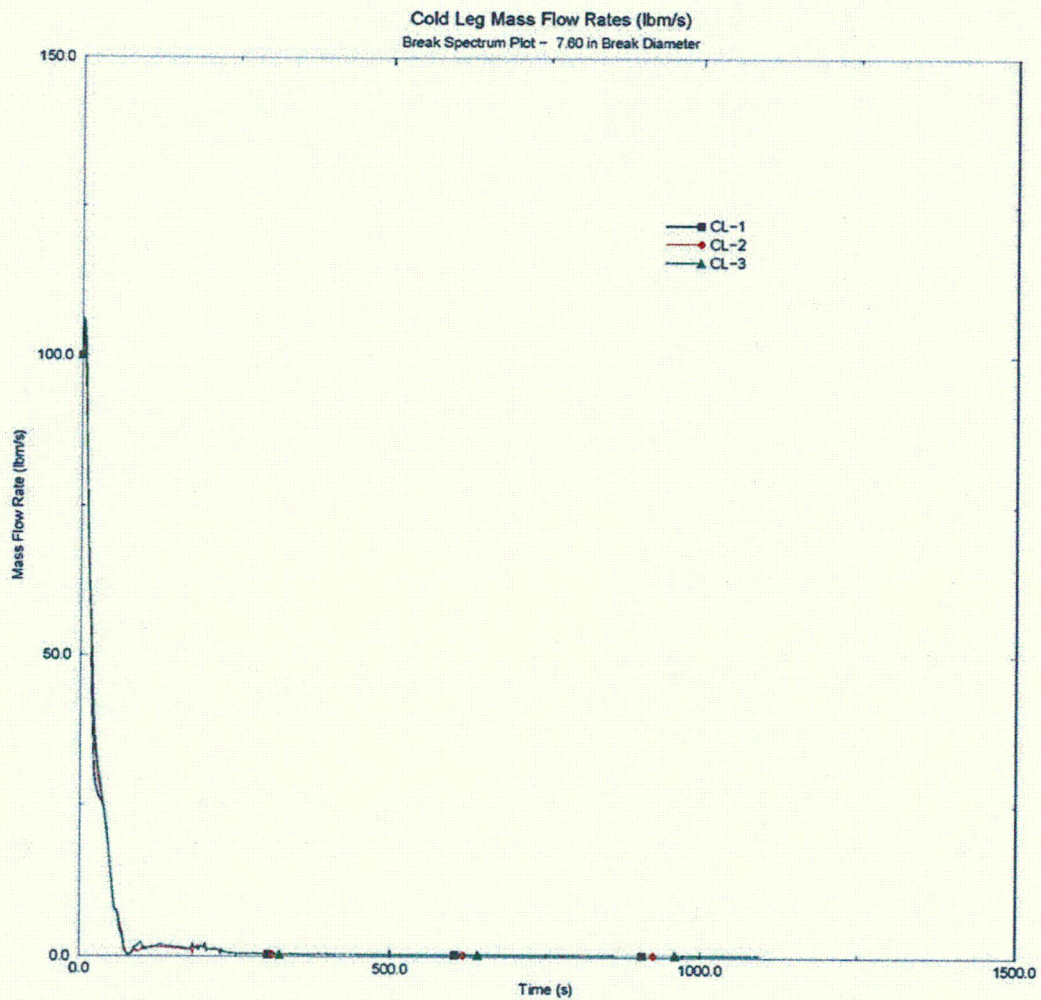


Figure 5-12: Pressurizer and Secondary Pressures – W 3-Loop

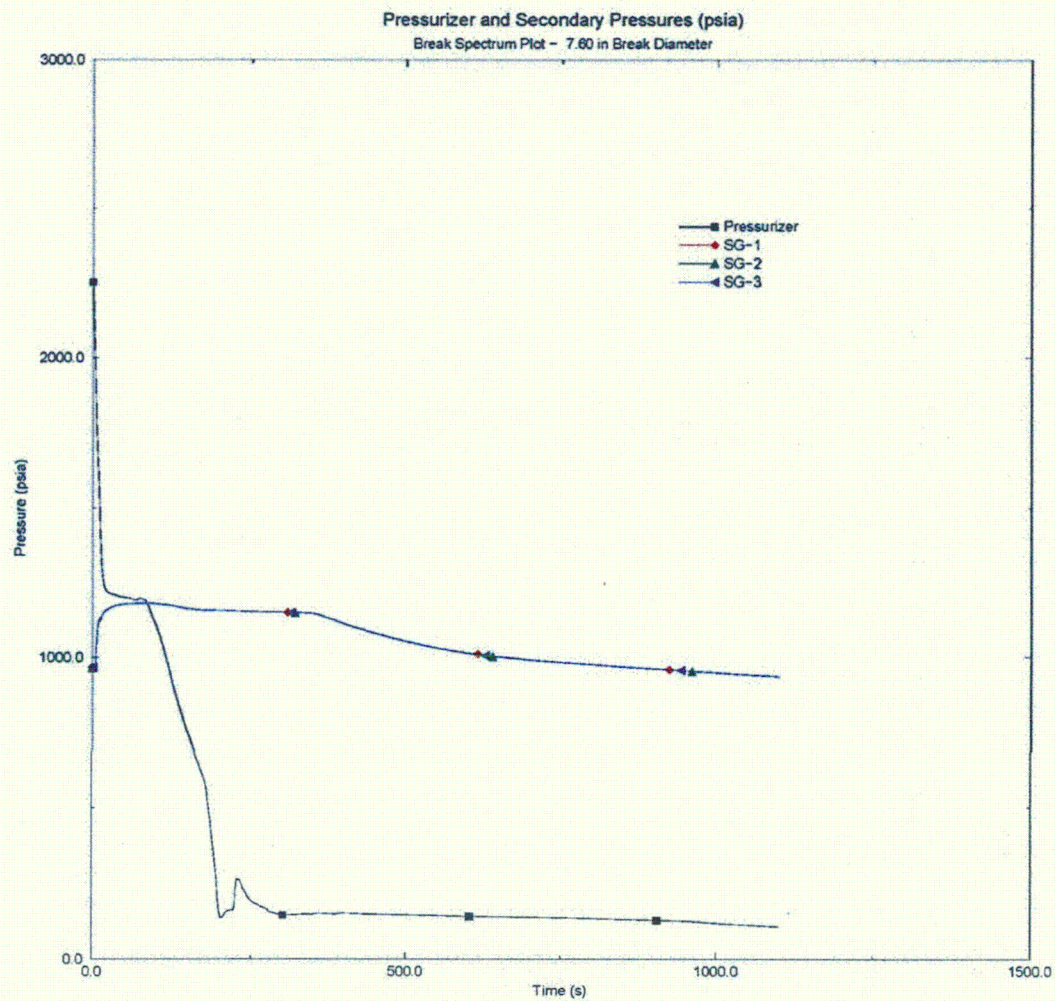


Figure 5-13: MFW Mass Flow Rates – W 3-Loop

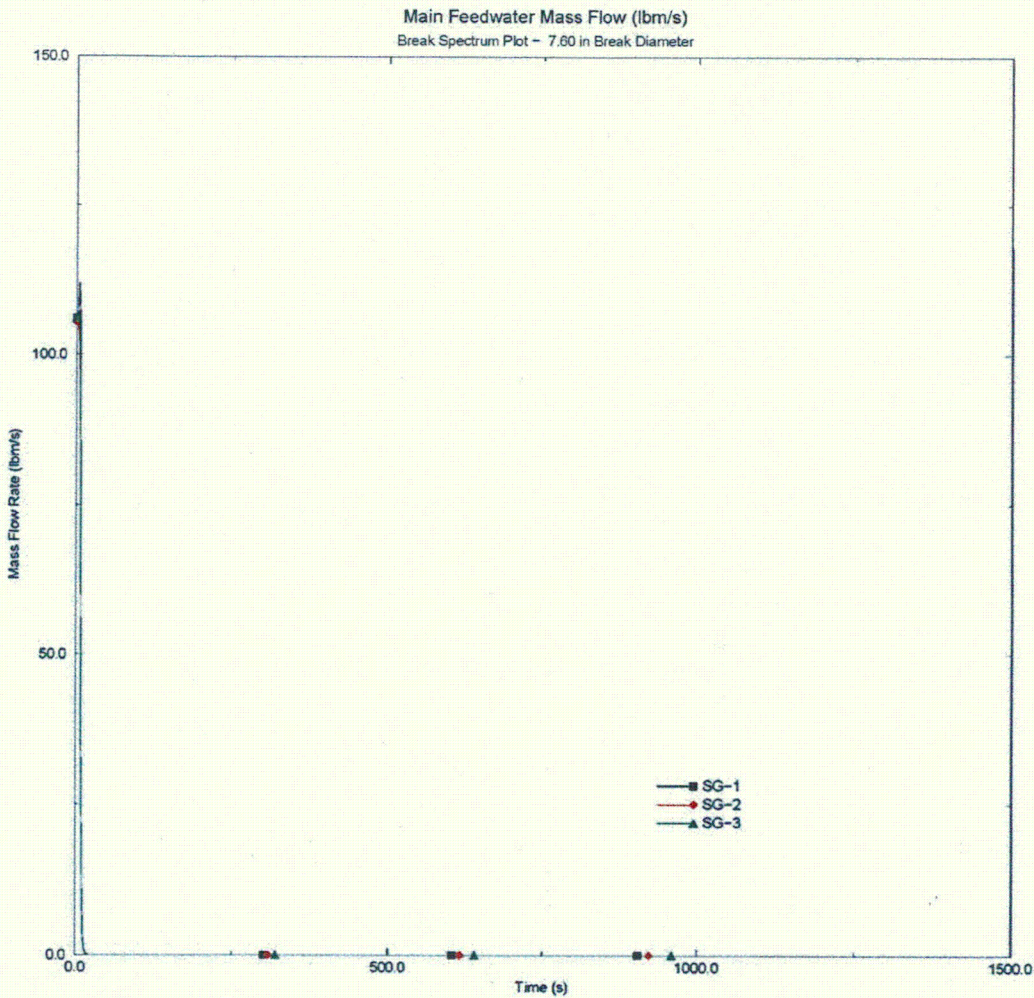


Figure 5-14: Non-Condensable Quality at the Break – W 3-Loop

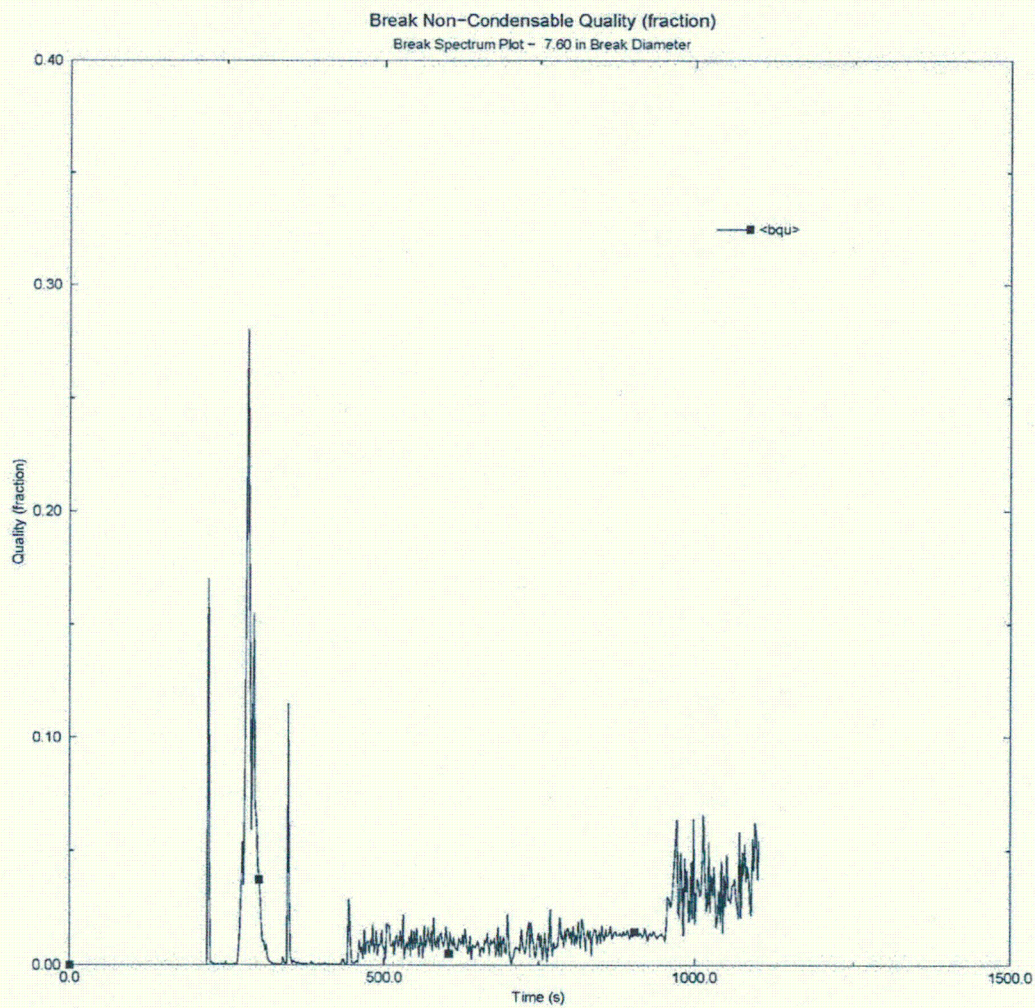


Figure 5-15: PCT and ECCS Flow Rates – W 3-Loop

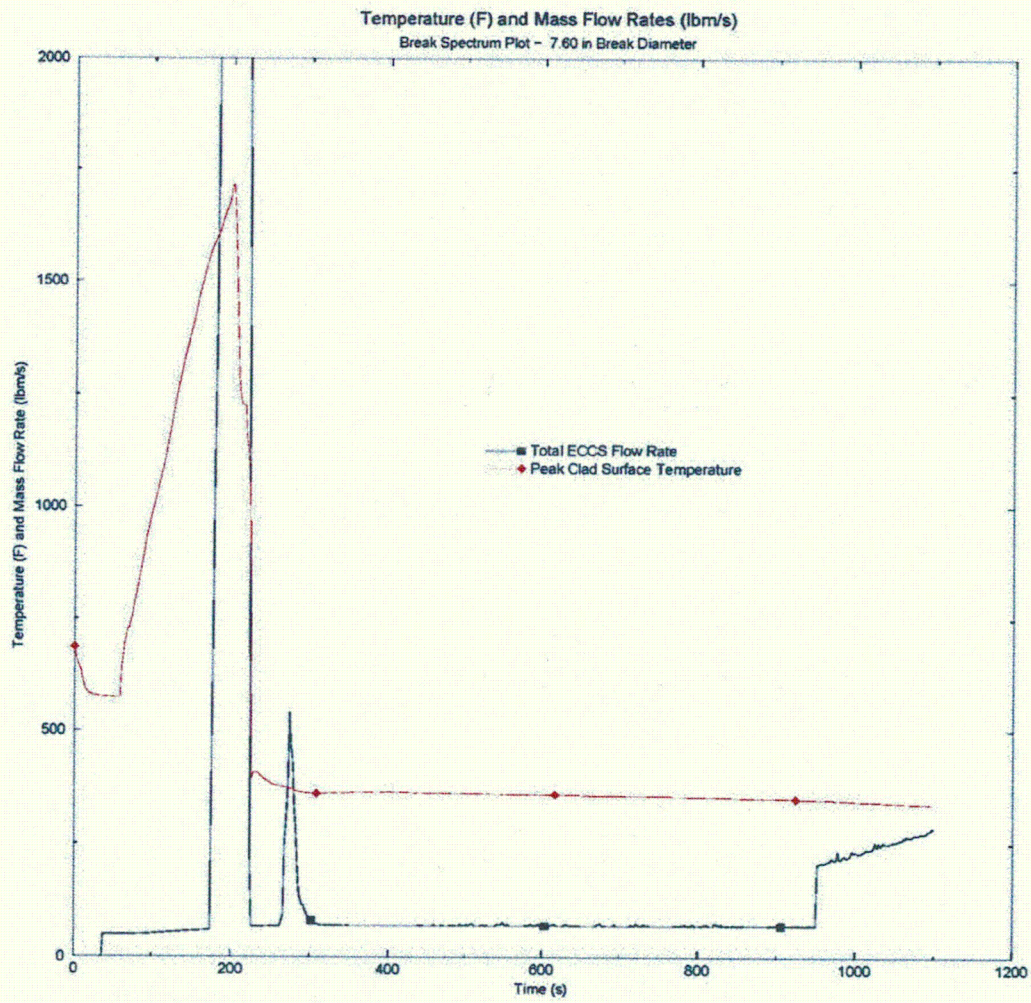


Figure 5-16: Reactor Power – W 3-Loop

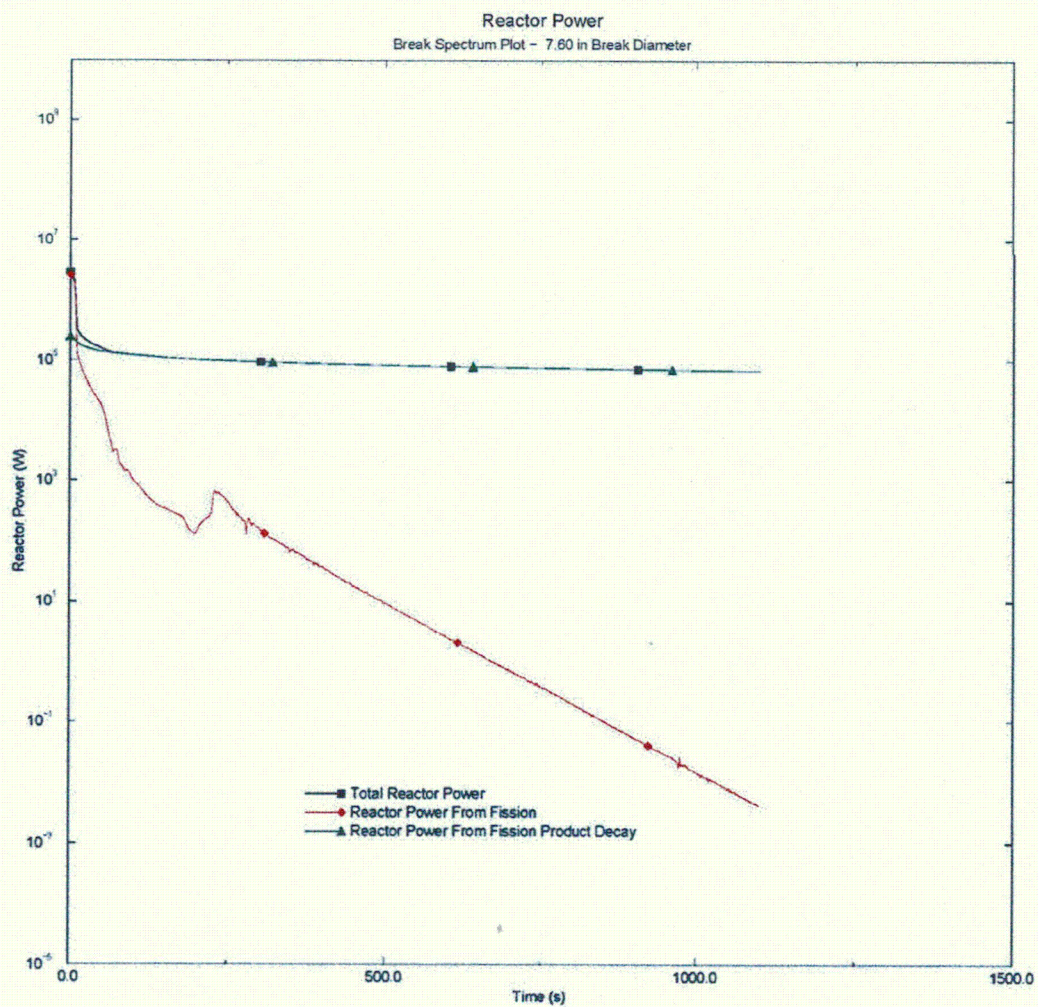


Figure 5-17: Break Mass Flow Rate – W 4-Loop

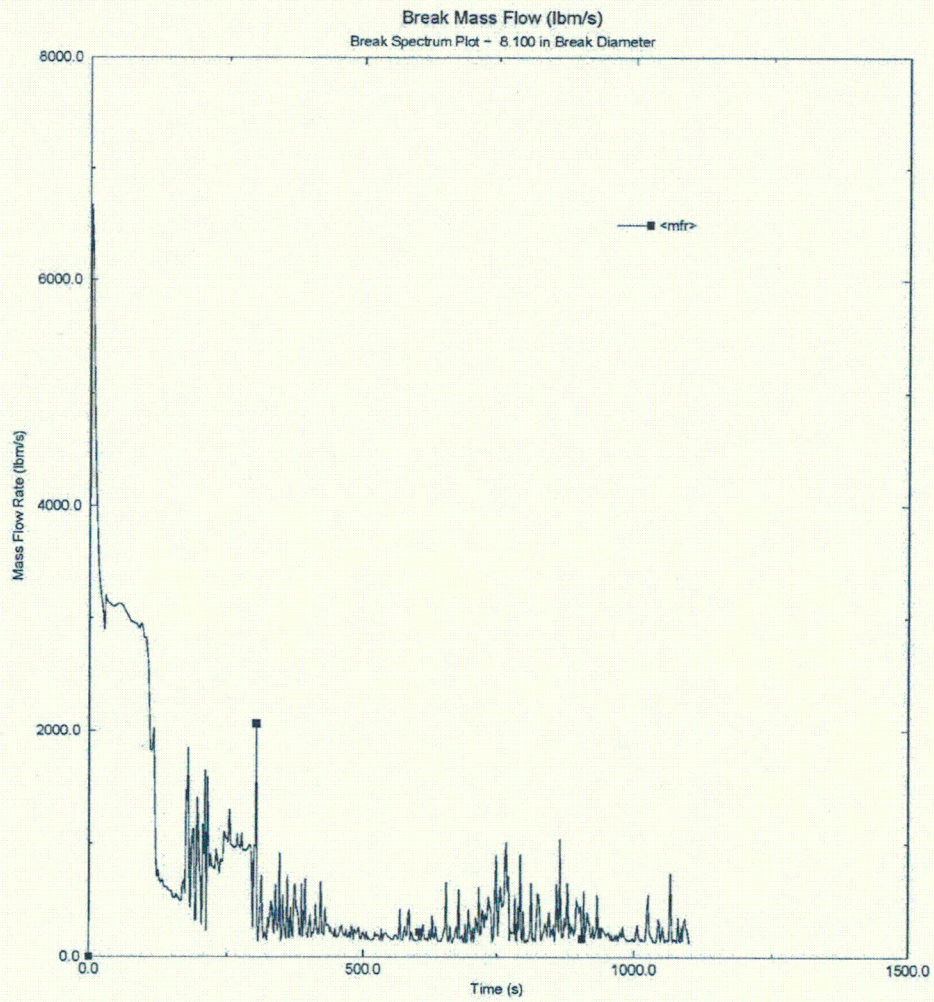


Figure 5-18: Hot Assembly Levels – W 4-Loop

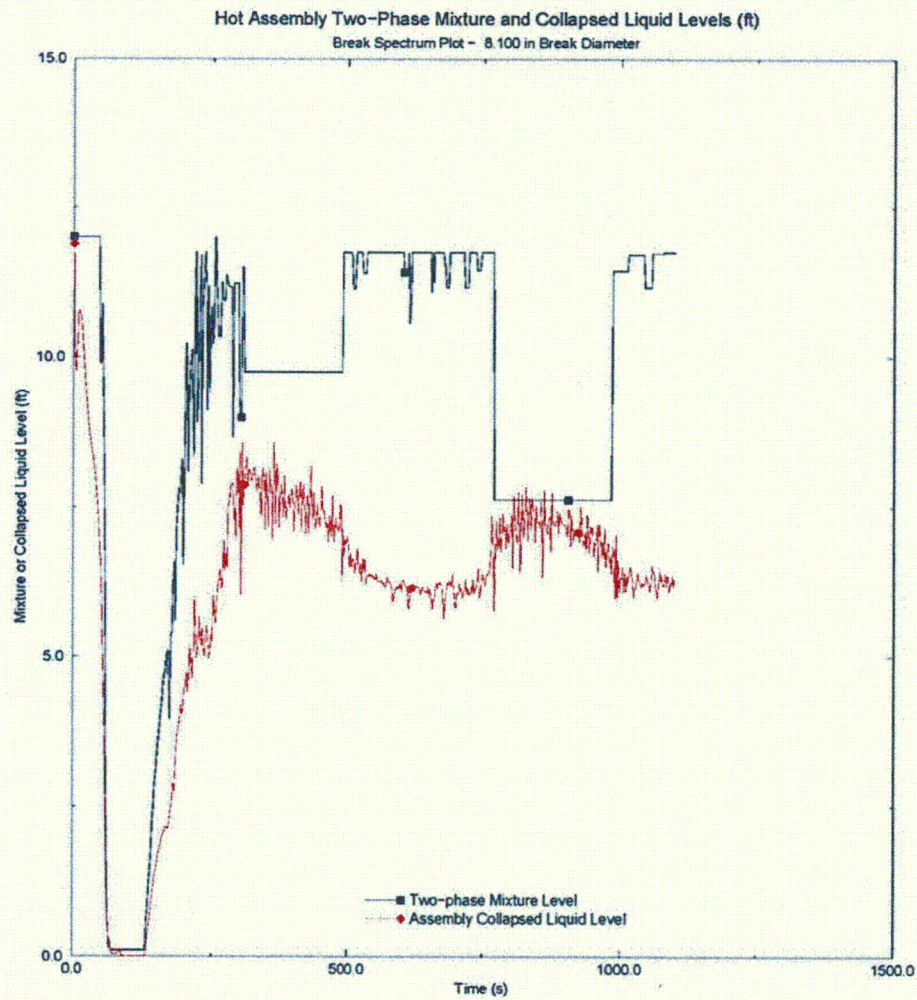


Figure 5-19: RCS and RV Mass Inventories – W 4-Loop

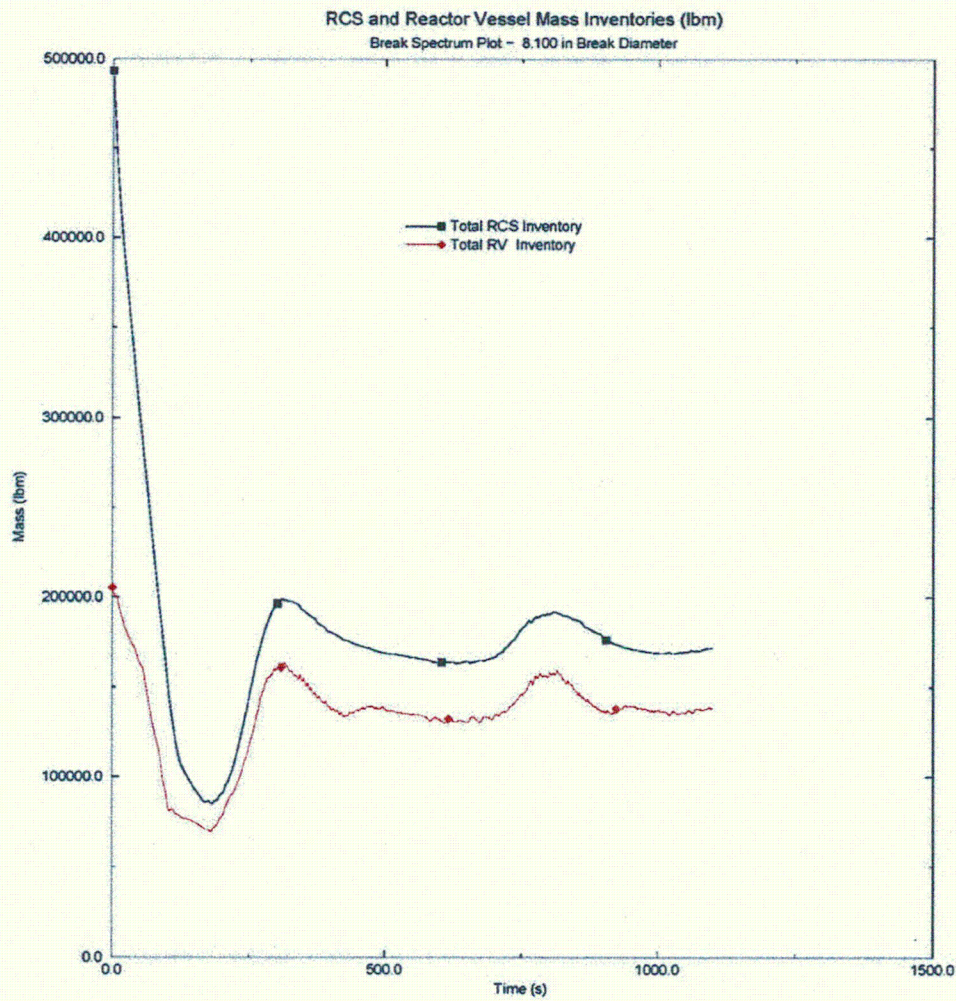


Figure 5-20: Core Power – W 4-Loop

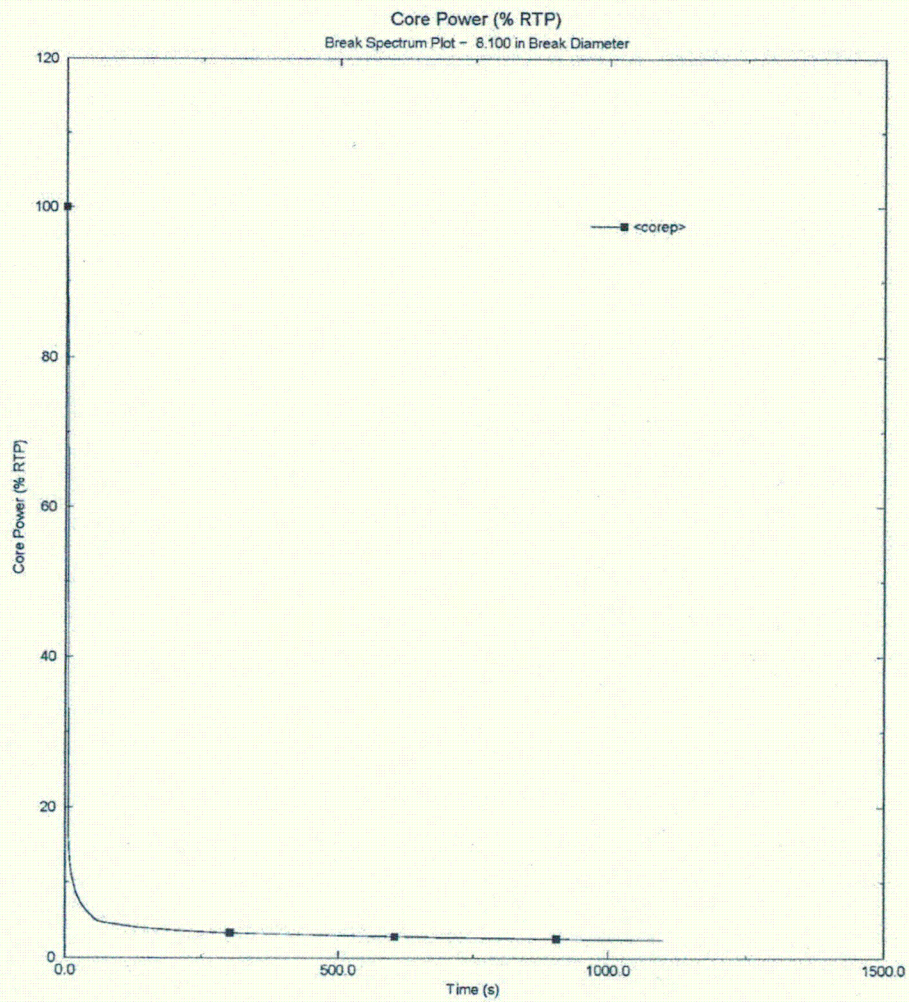


Figure 5-21: Break Void Fraction – W 4-Loop

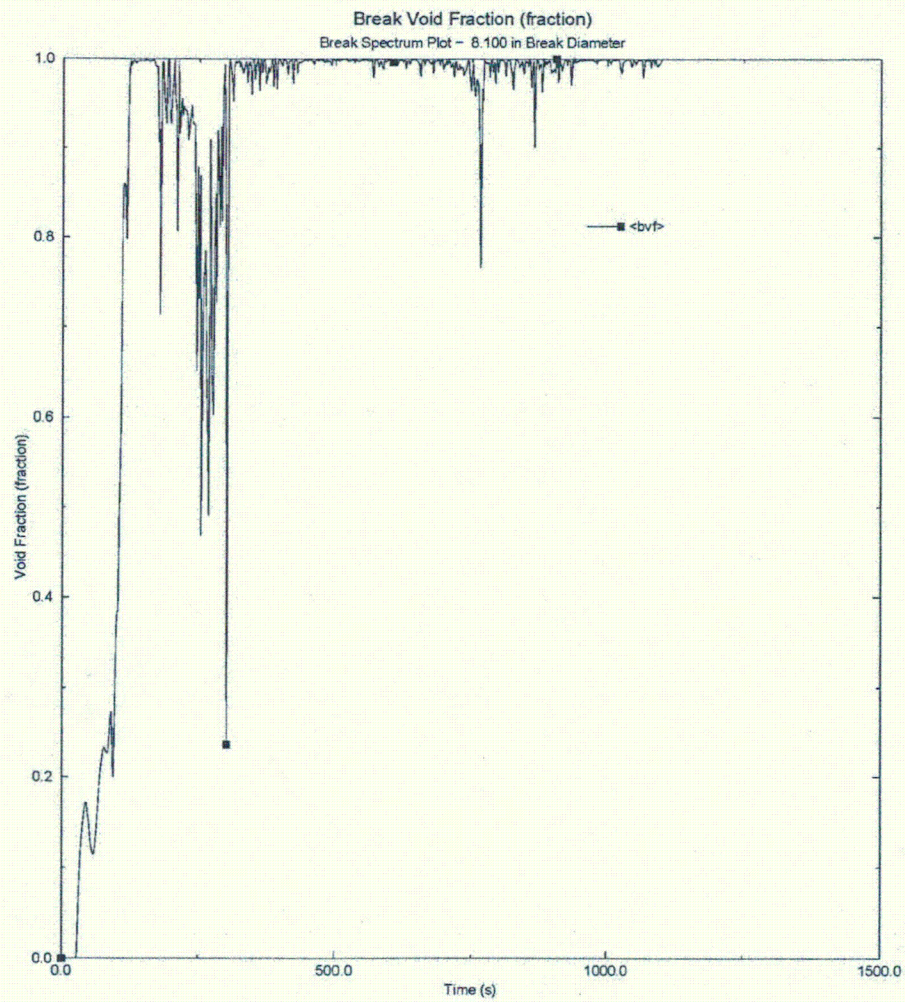


Figure 5-22: SI Mass Flow Rates – W 4-Loop

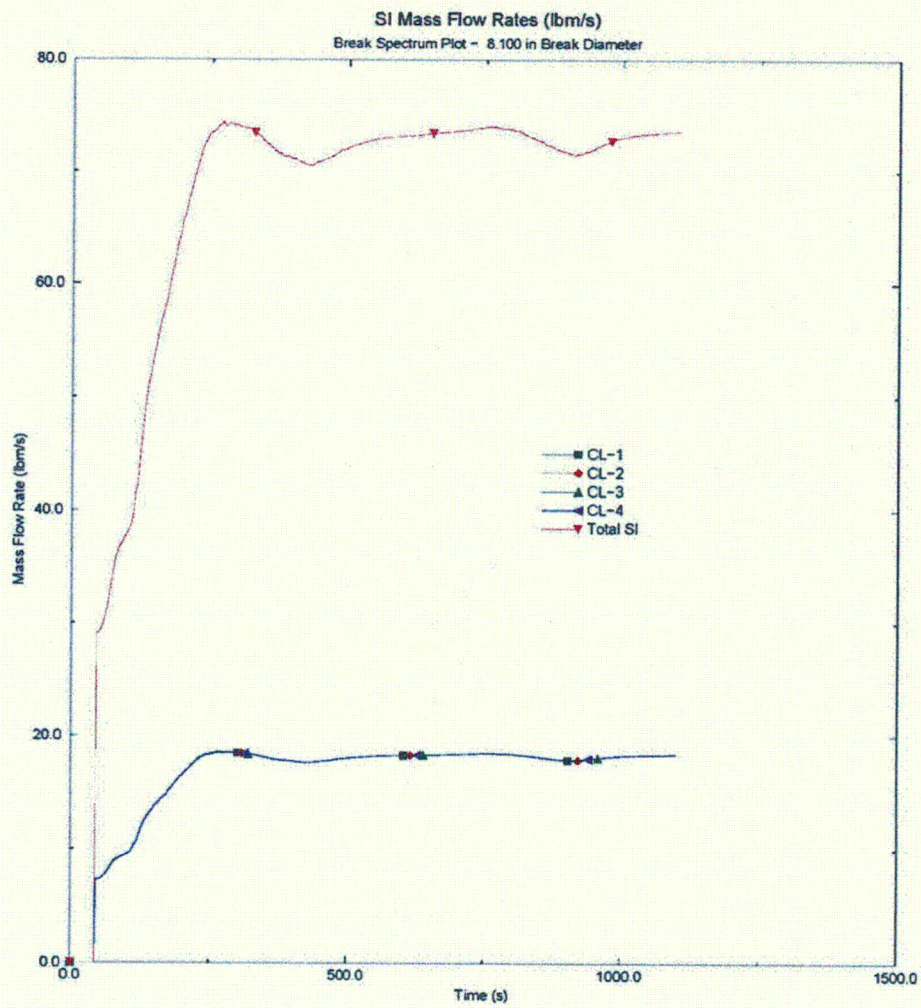


Figure 5-23: RHR Mass Flow Rates – W 4-Loop

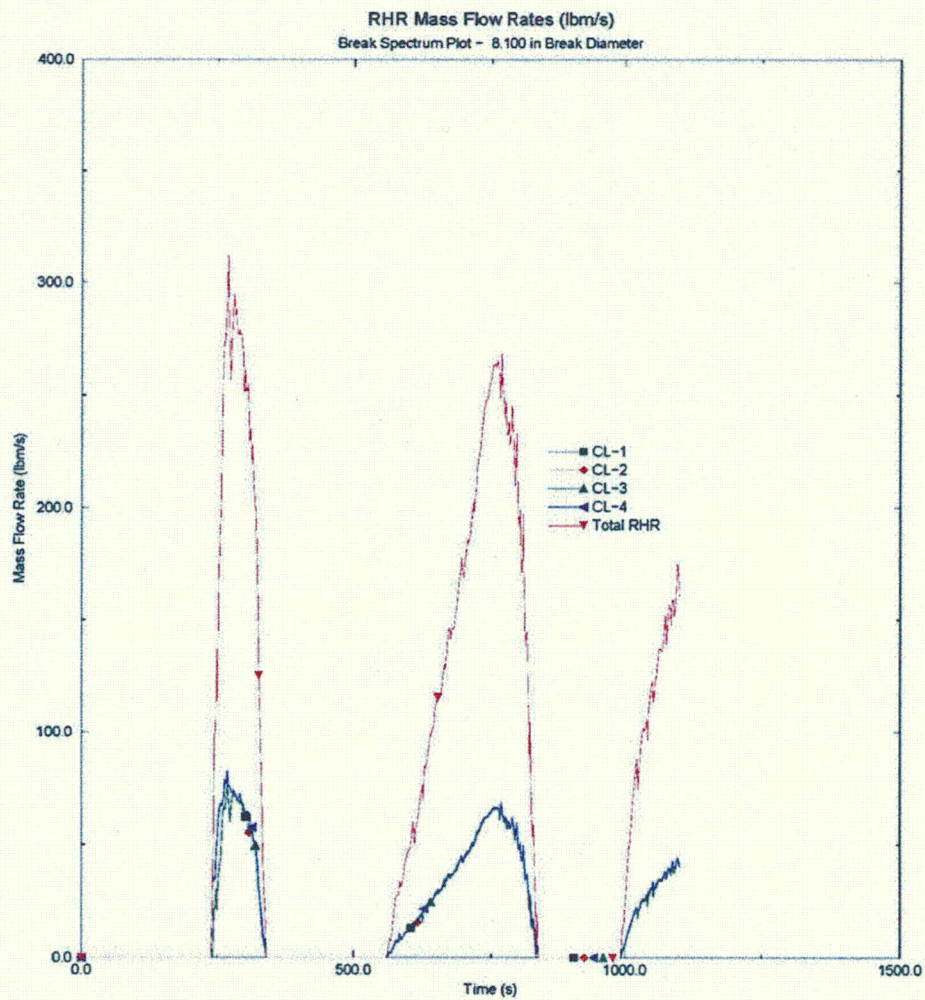


Figure 5-24: Centrifugal Charging Mass Flow Rates – W 4-Loop

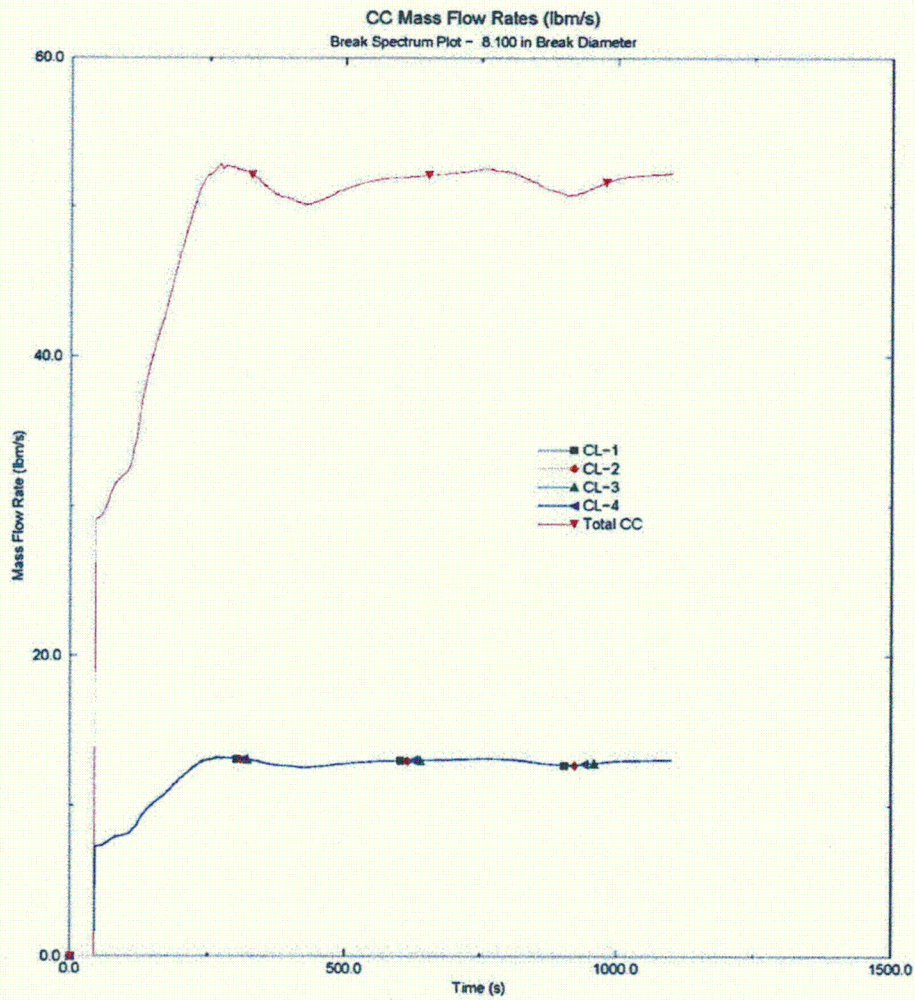


Figure 5-25: Accumulator Mass Flow Rates – W 4-Loop

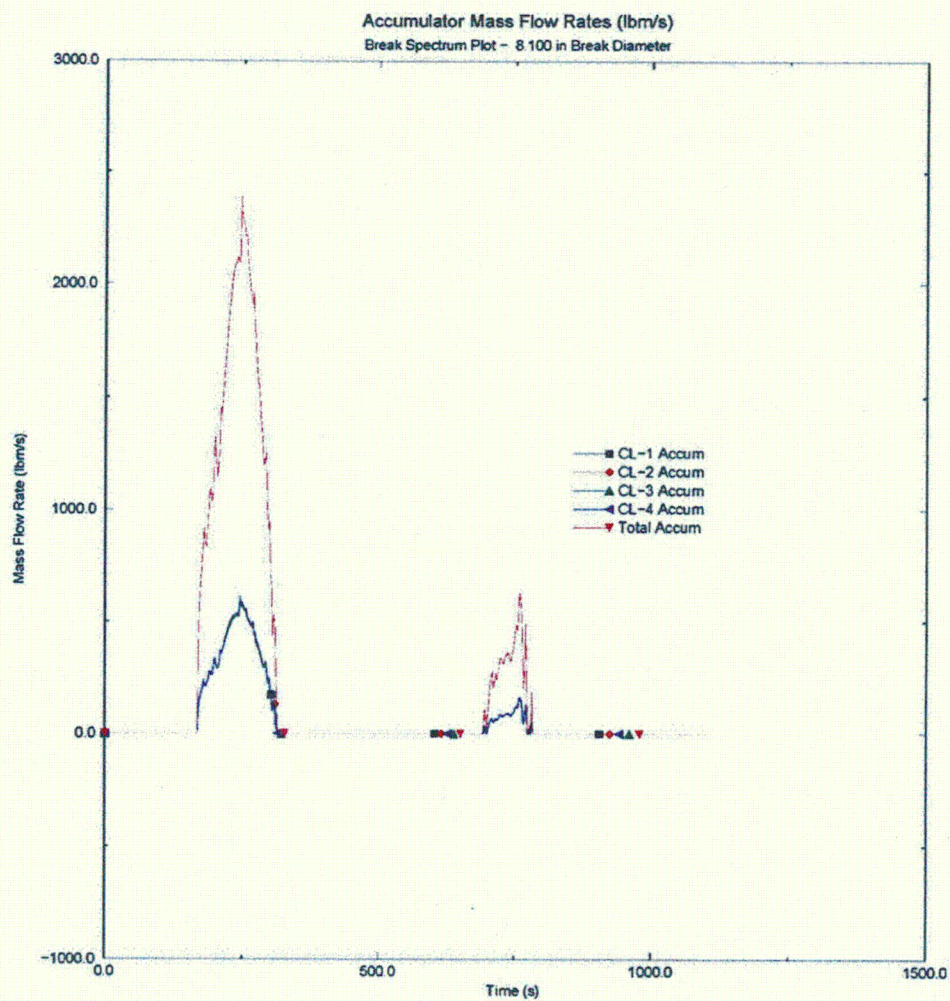


Figure 5-26: Loop Seal Void Fraction – W 4-Loop

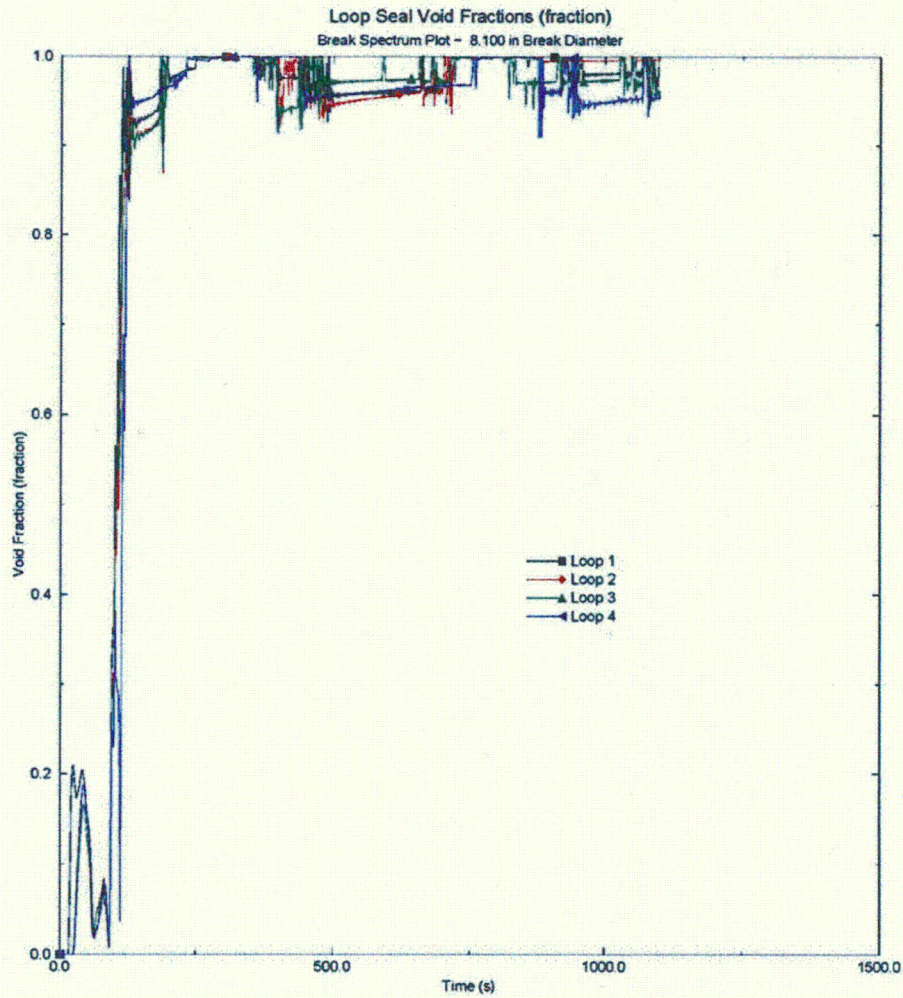


Figure 5-27: SG Mass Inventories – W 4-Loop

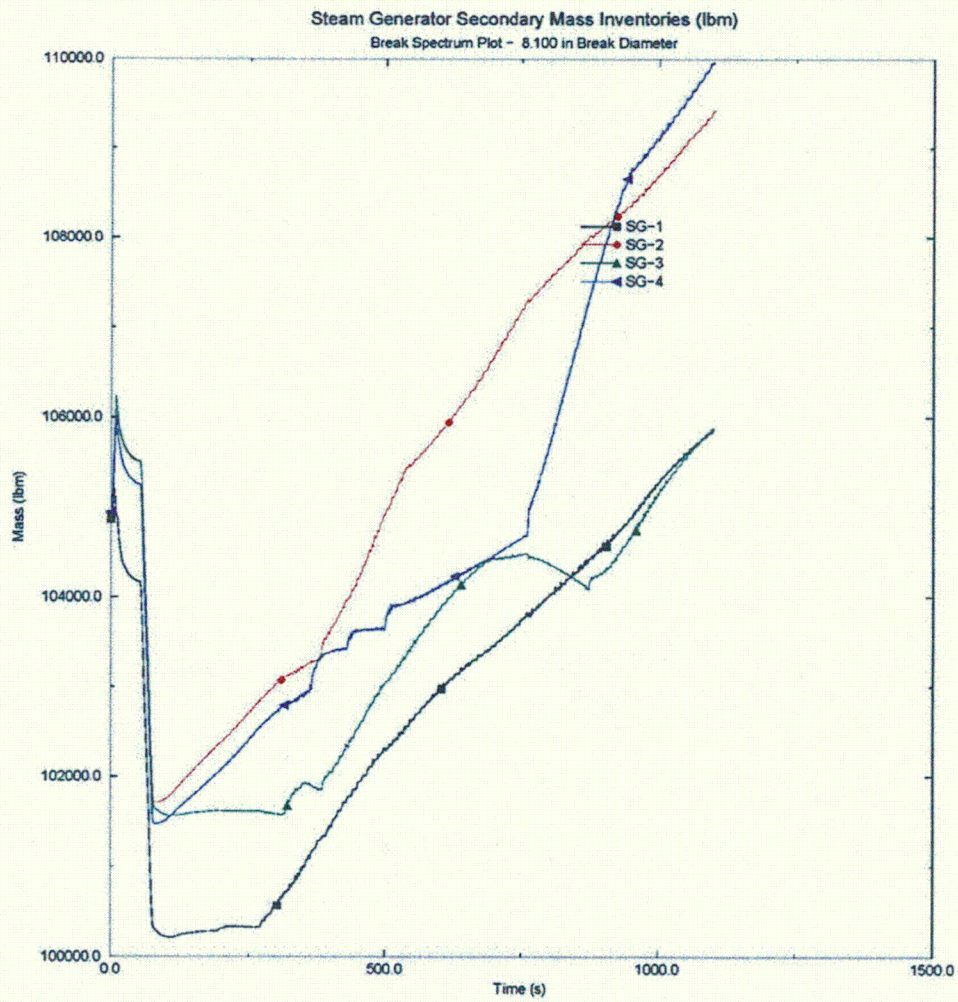


Figure 5-28: AFW Mass Flow Rate – W 4-Loop

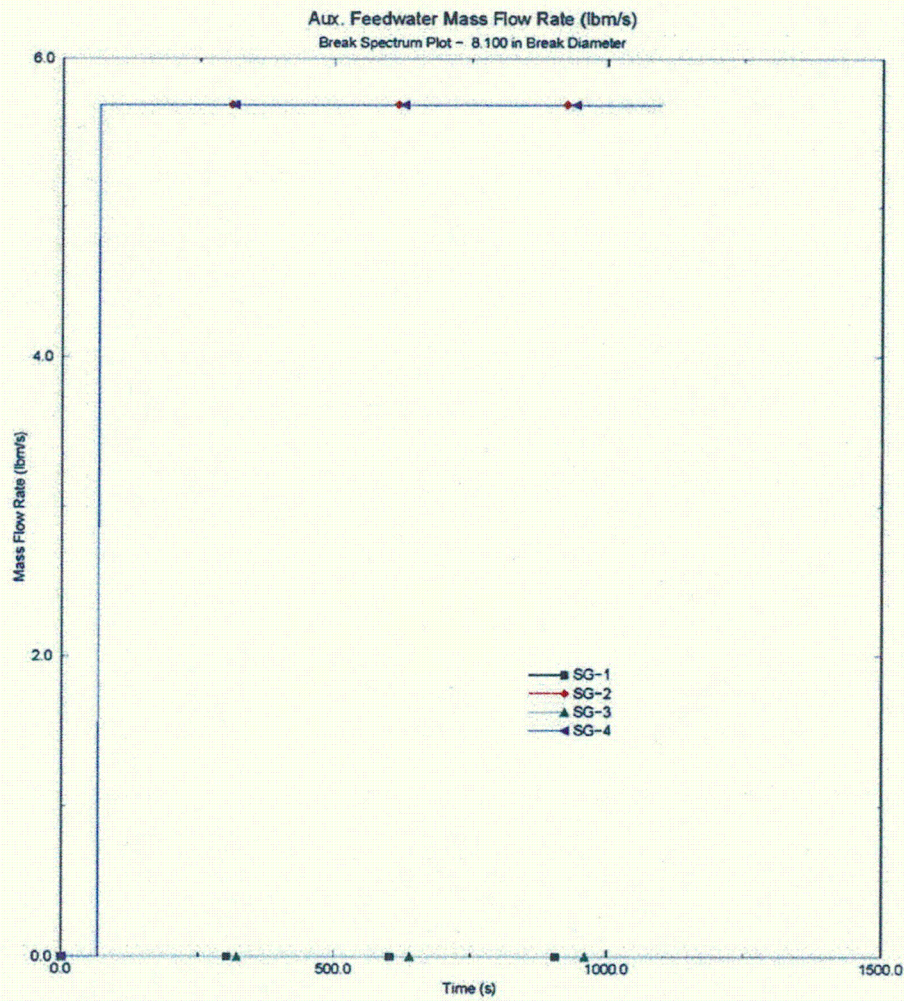


Figure 5-29: Cold Leg Mass Flow Rates – W 4-Loop

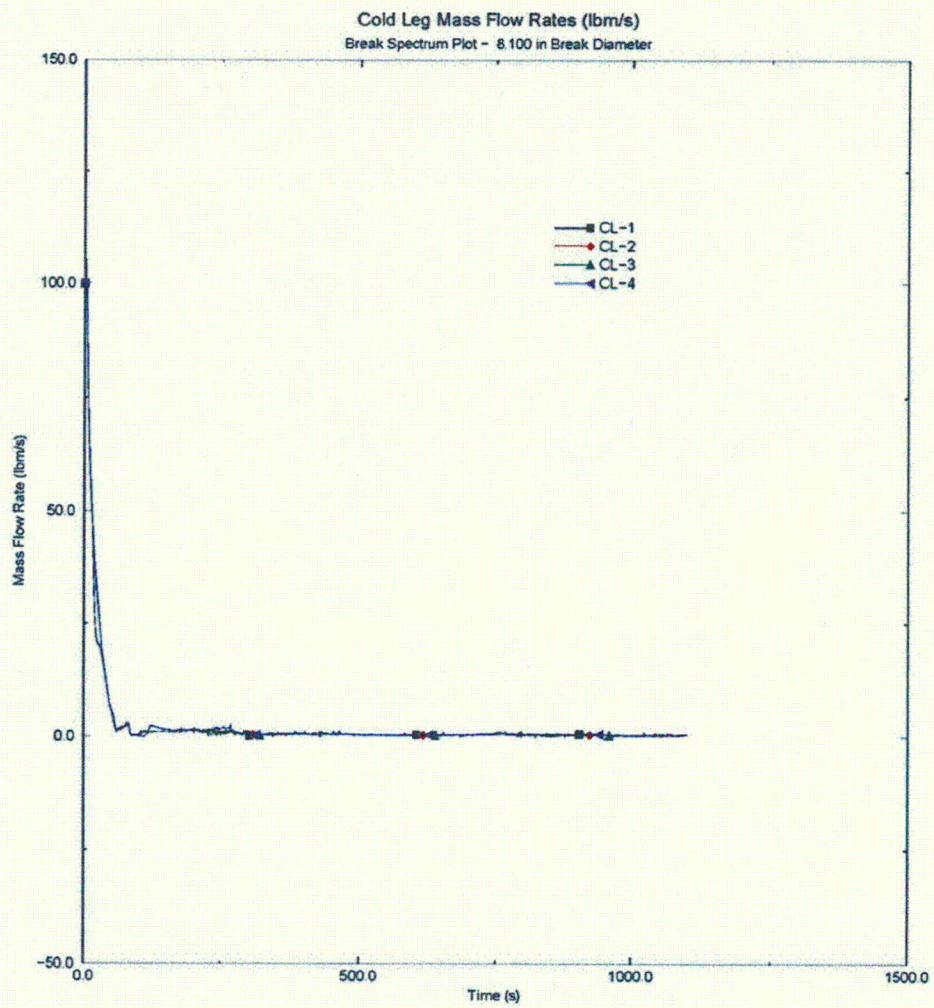


Figure 5-30: Pressurizer and Secondary Pressures – W 4-Loop

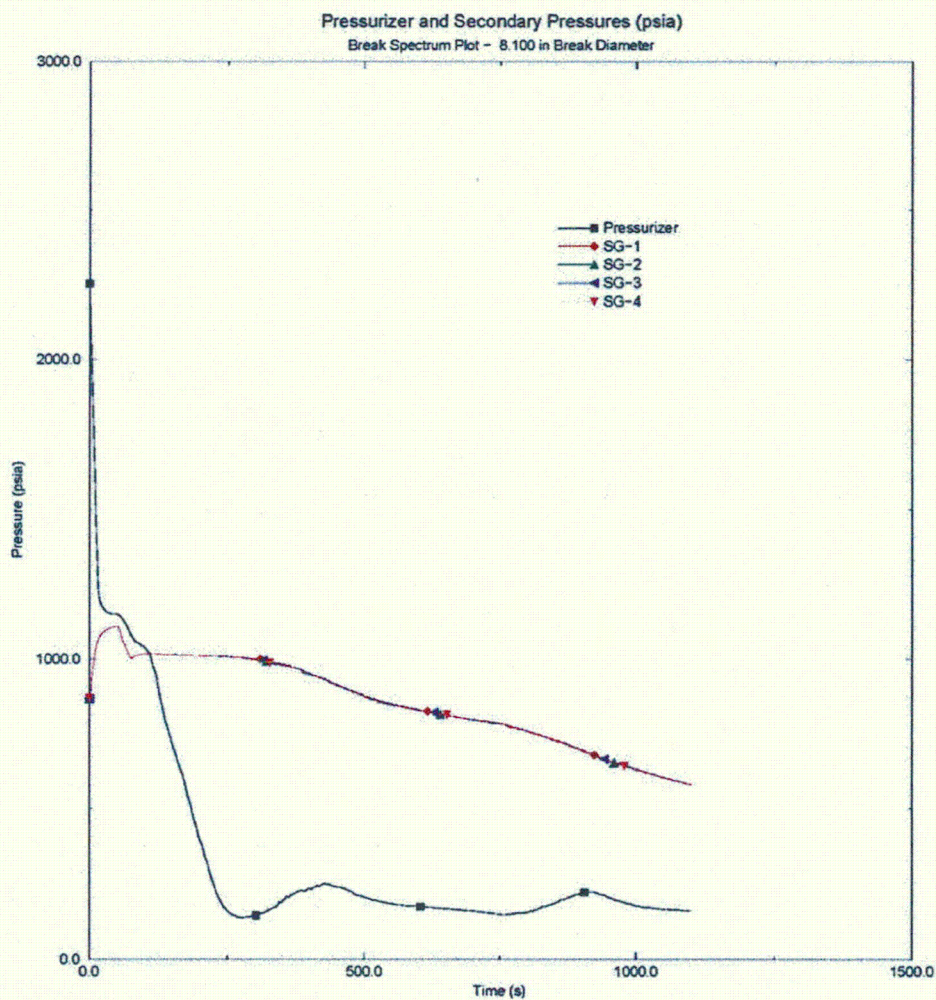


Figure 5-31: MFW Mass Flow Rates – W 4-Loop

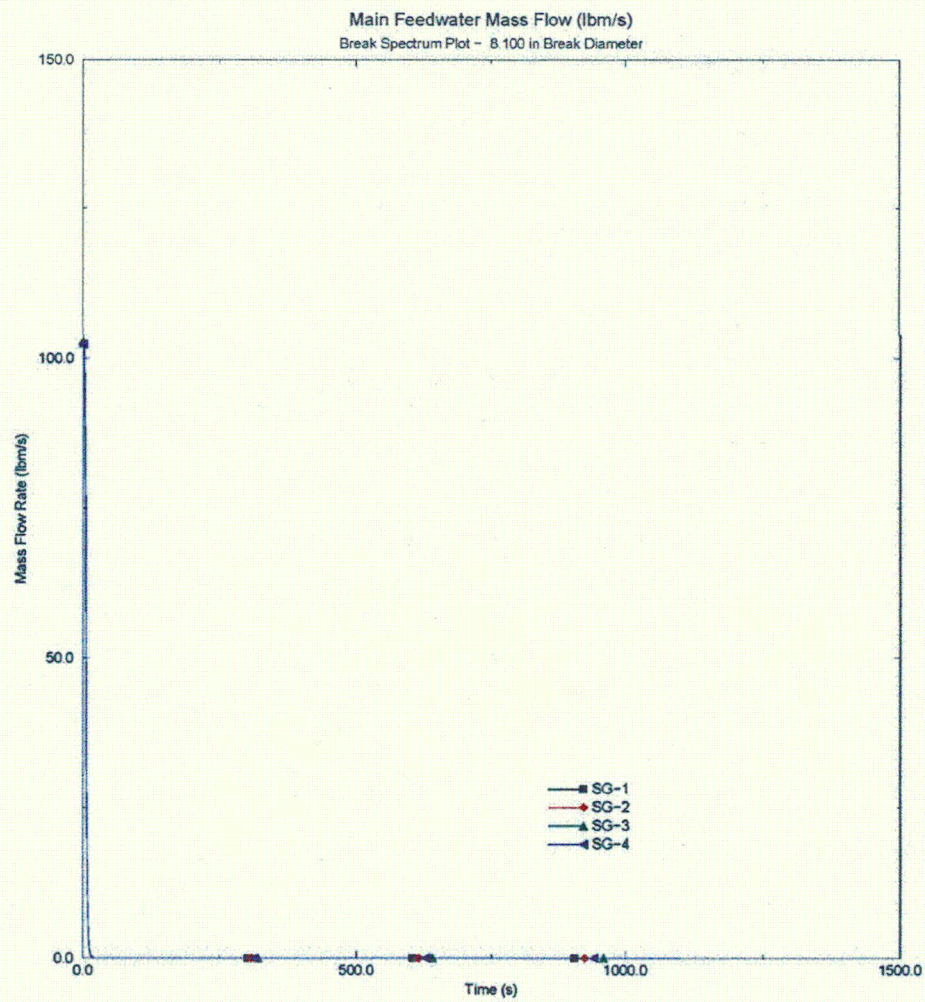


Figure 5-32: Non-Condensable Quality at the Break – W 4-Loop

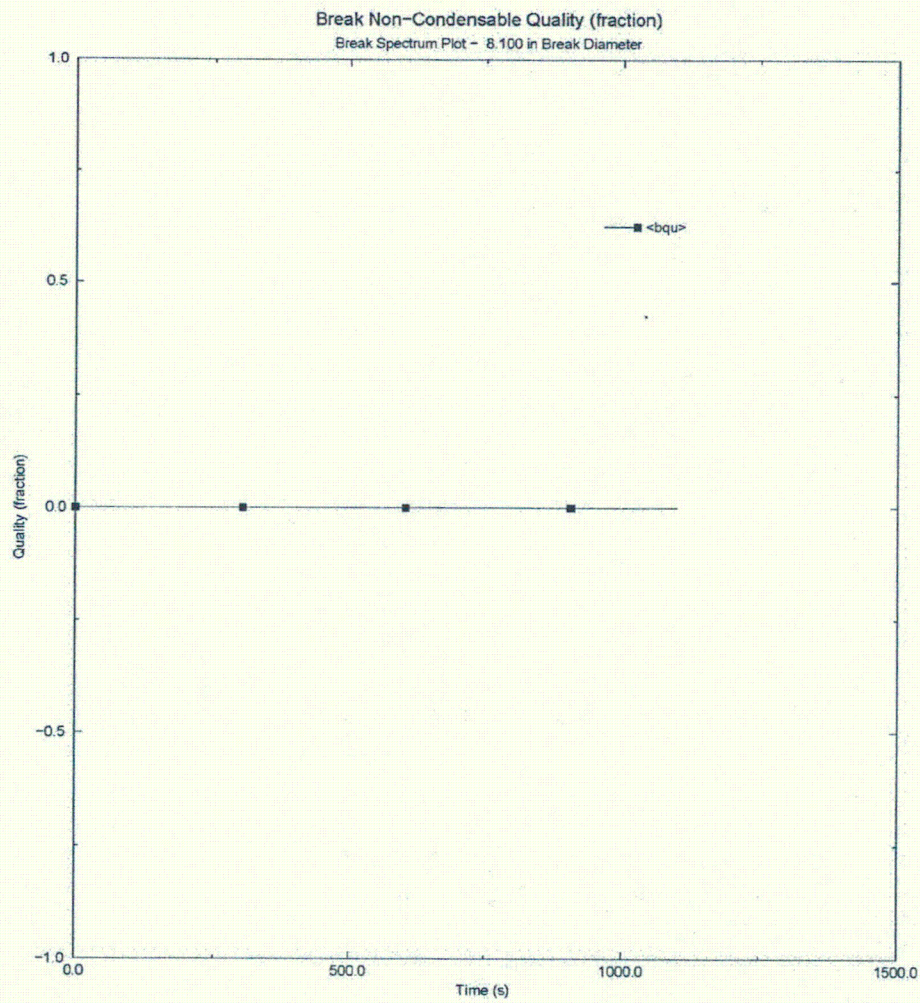


Figure 5-33: PCT and ECCS Flow Rates – W 4-Loop

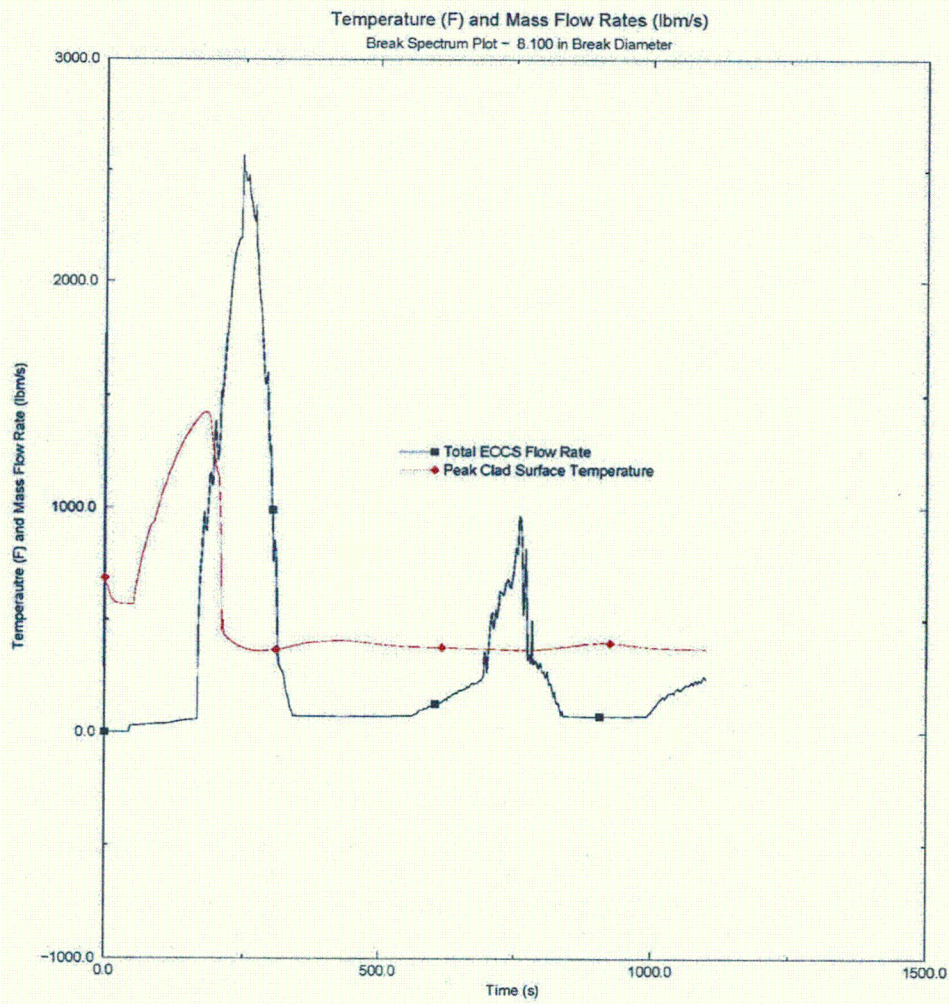


Figure 5-34: Reactor Power – W 4-Loop

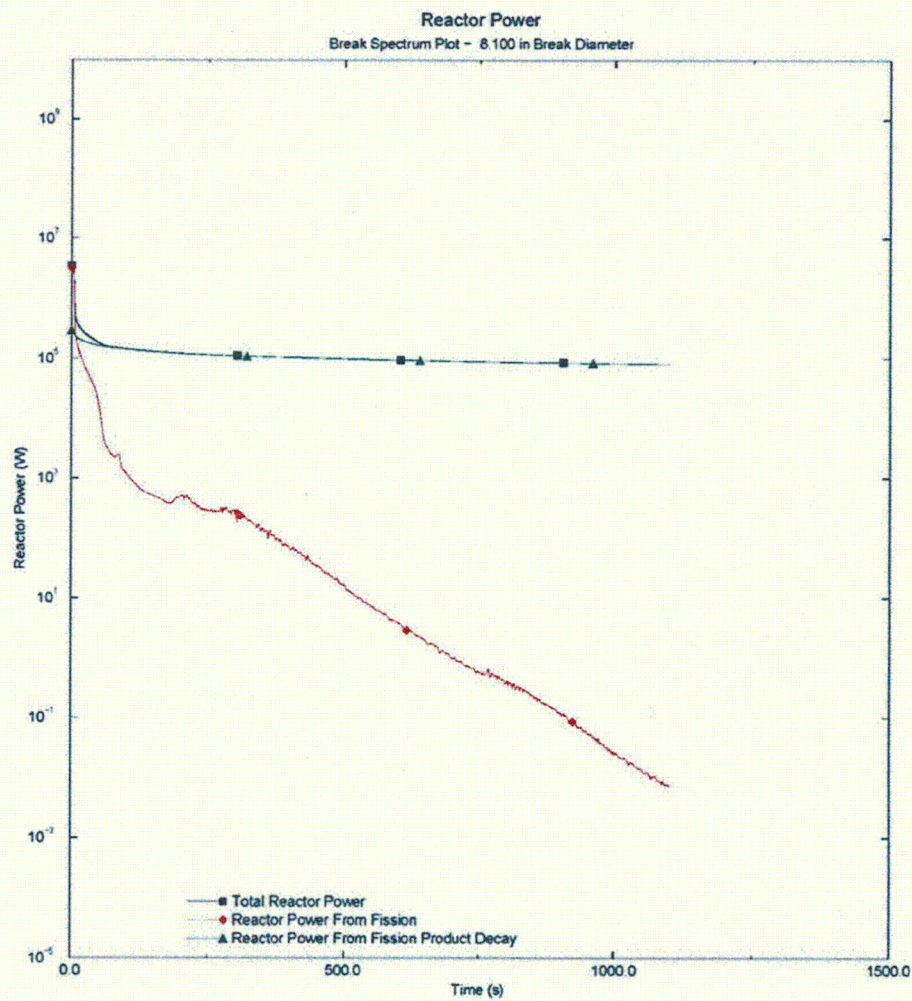


Figure 5-35: Break Mass Flow Rate – CE 2x4

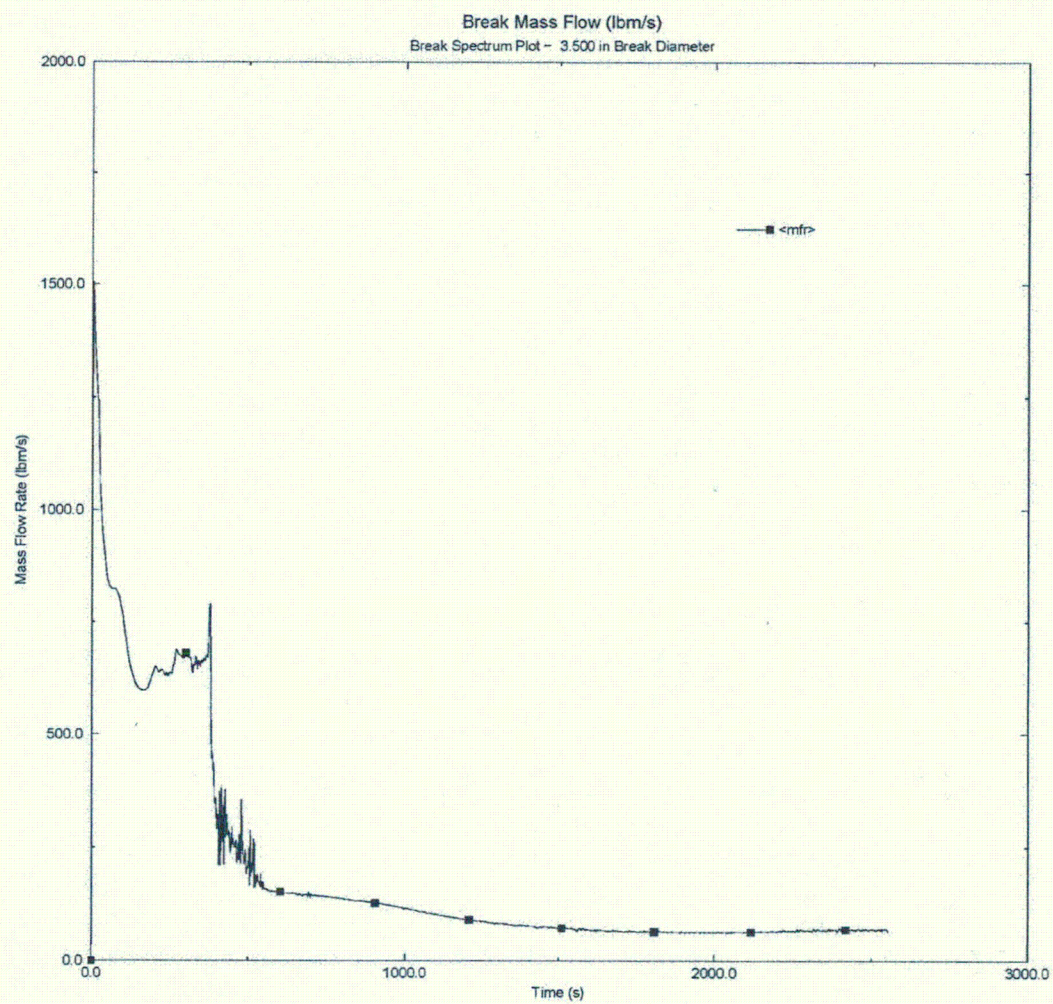


Figure 5-36: Hot Assembly Levels – CE 2x4

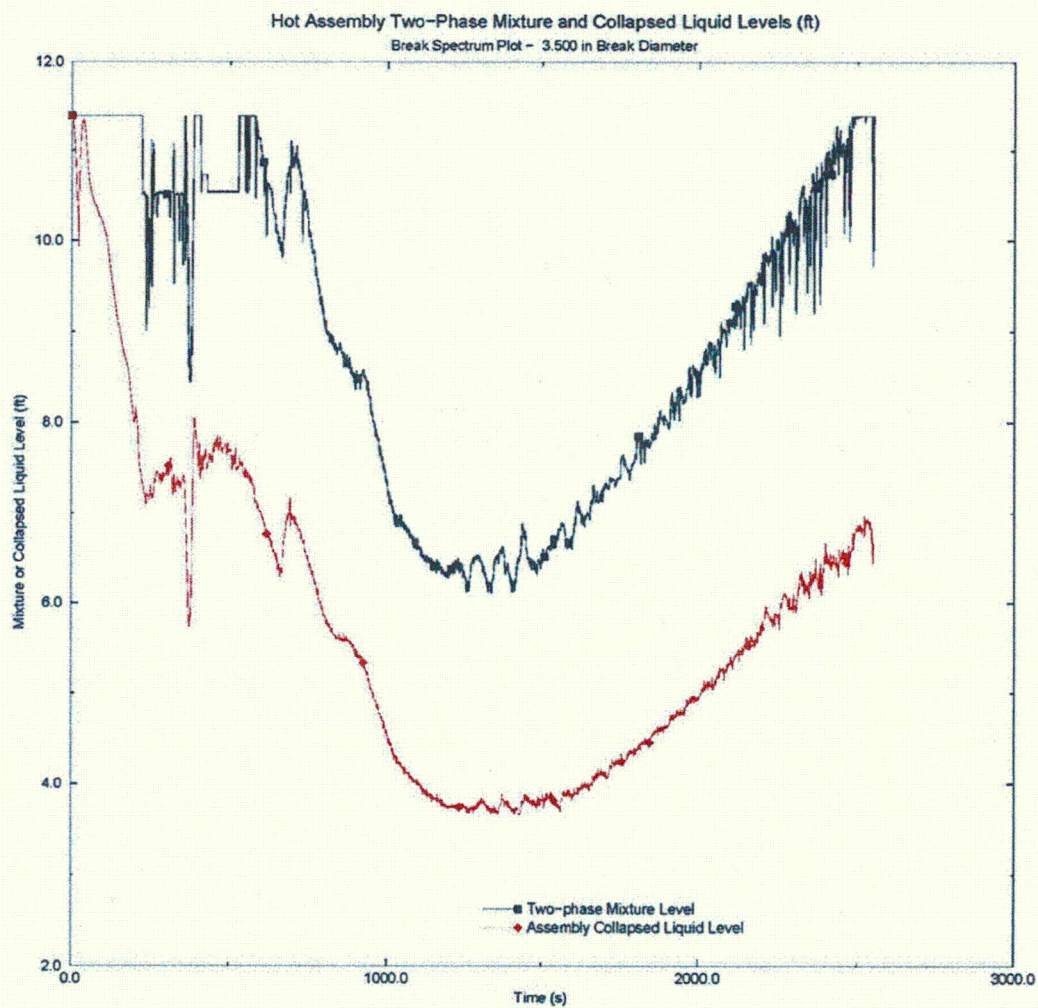


Figure 5-37: RCS and RV Mass Inventories – CE 2x4

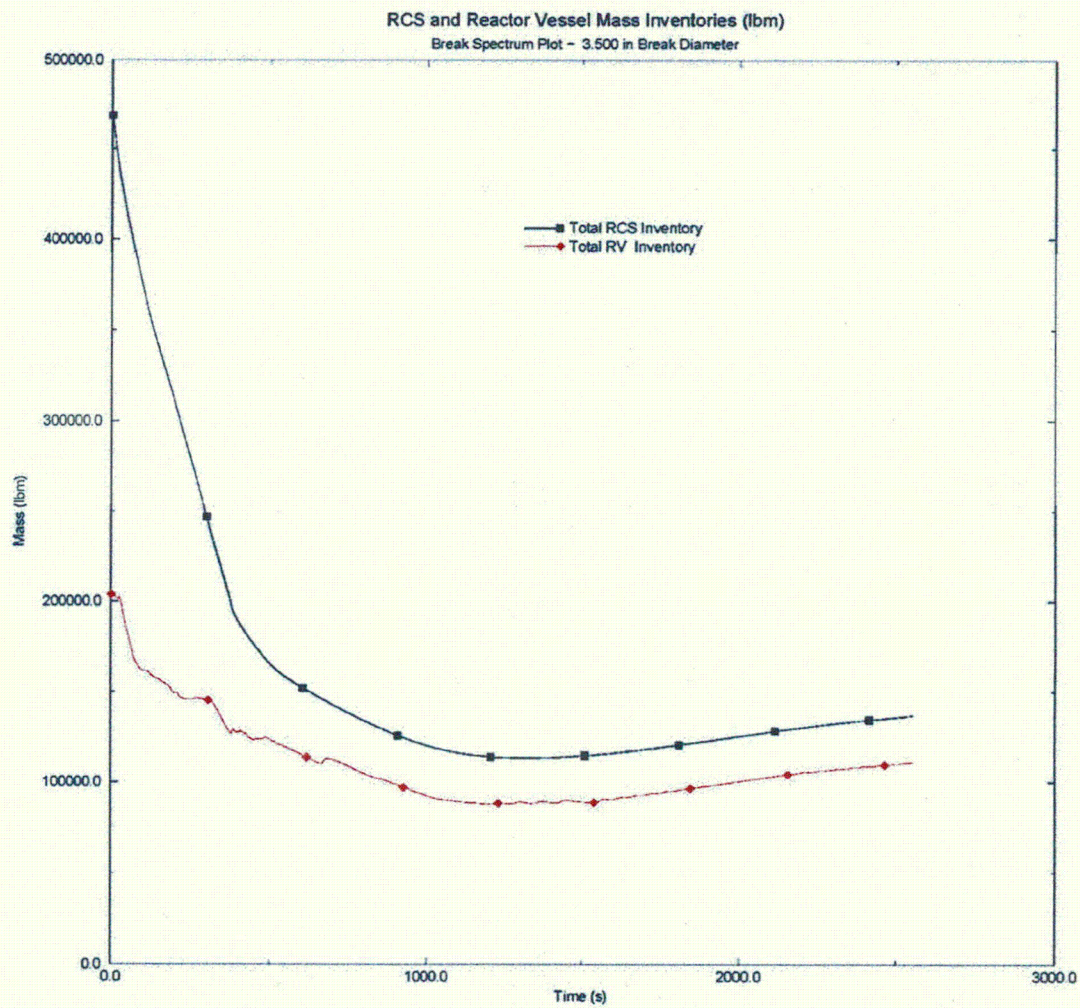


Figure 5-38: Core Power – CE 2x4

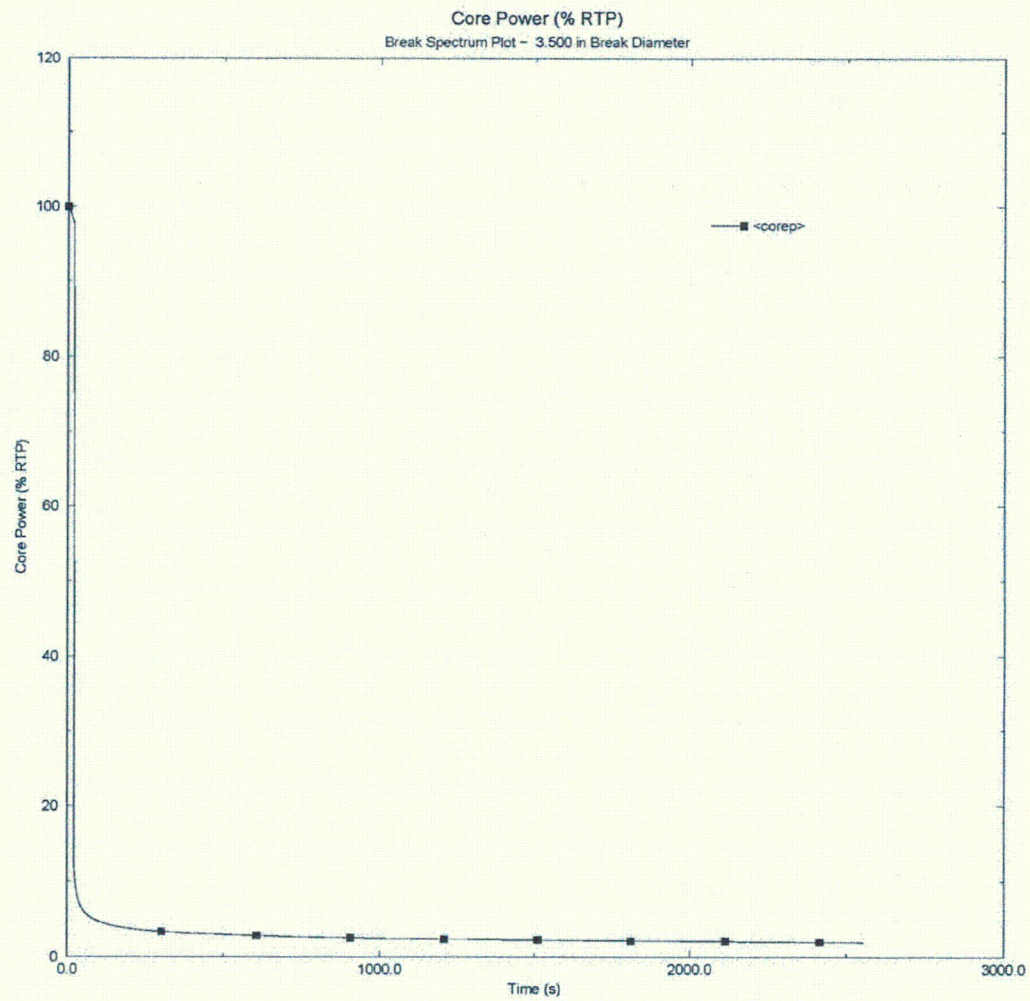


Figure 5-39: Break Void Fraction – CE 2x4

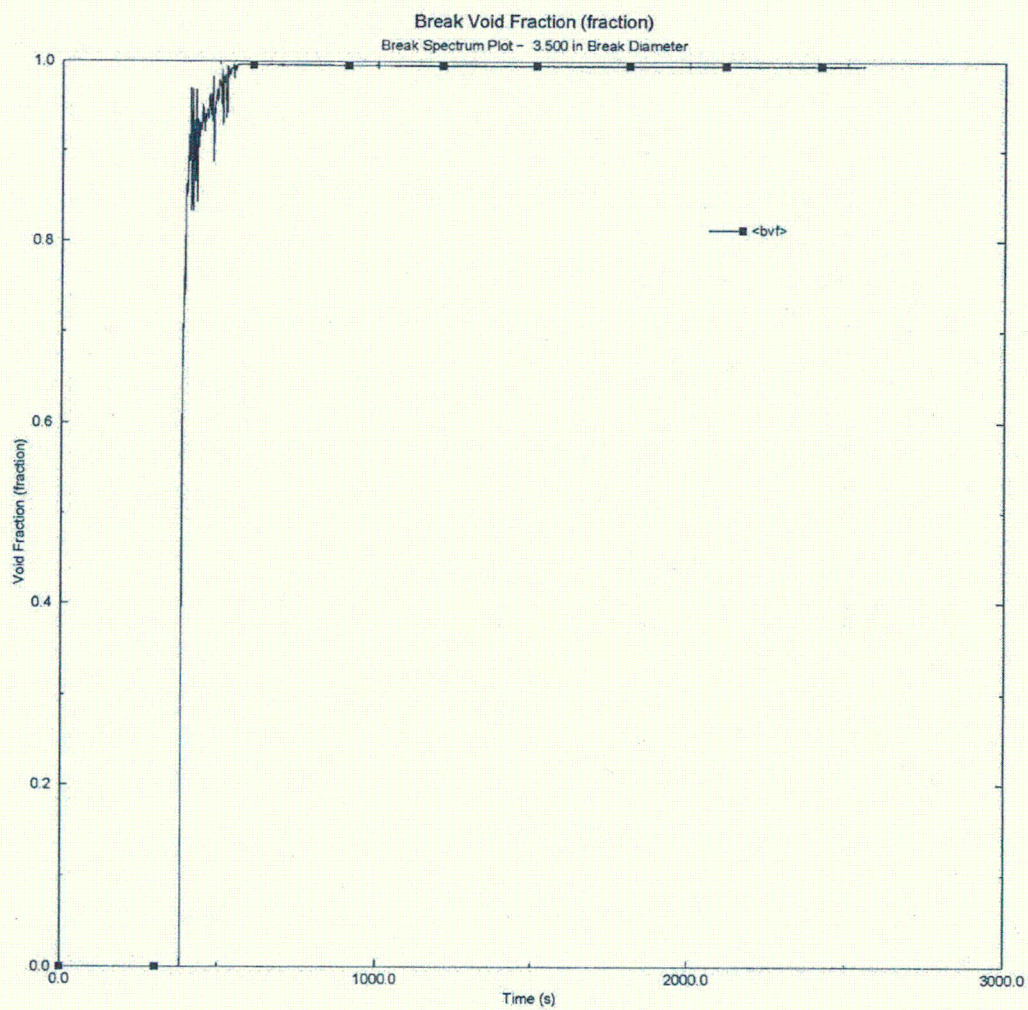


Figure 5-40: HPSI Mass Flow Rates – CE 2x4

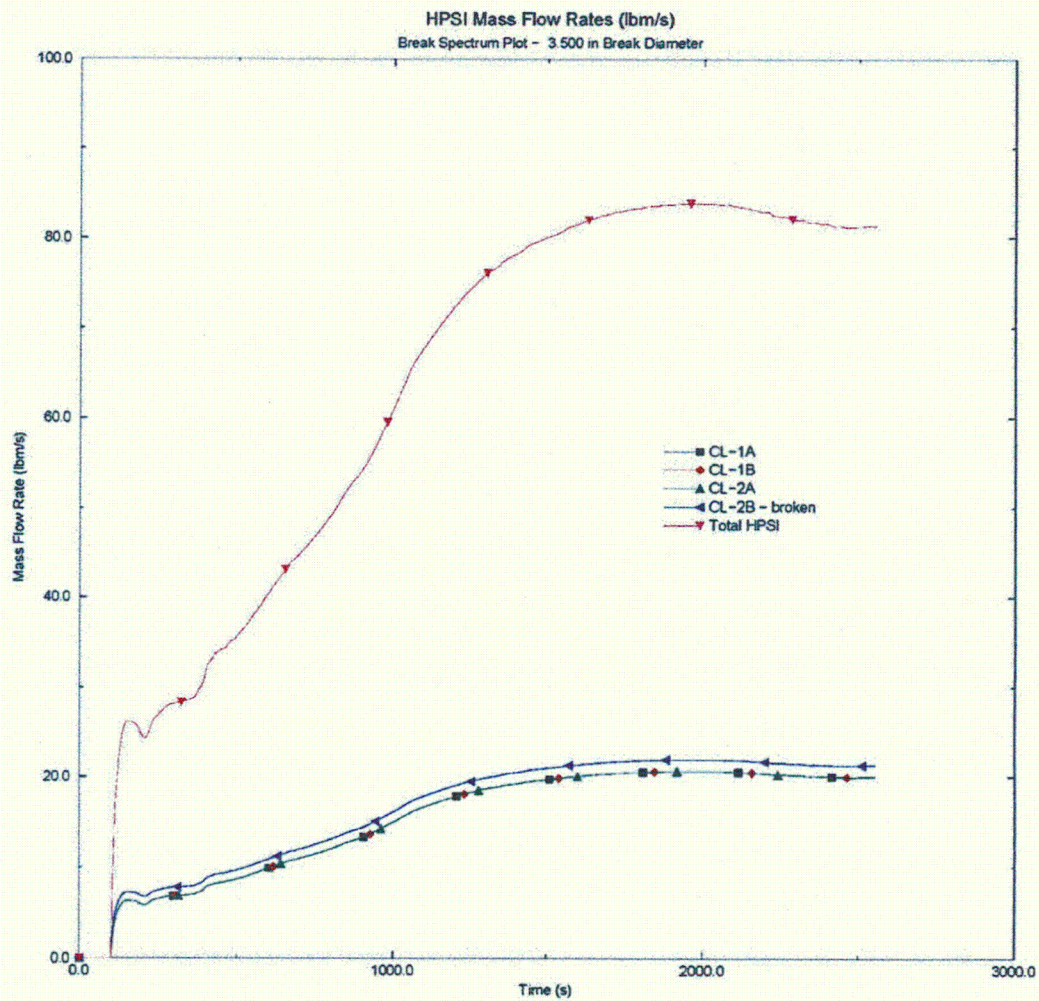


Figure 5-41: SIT Mass Flow Rates – CE 2x4

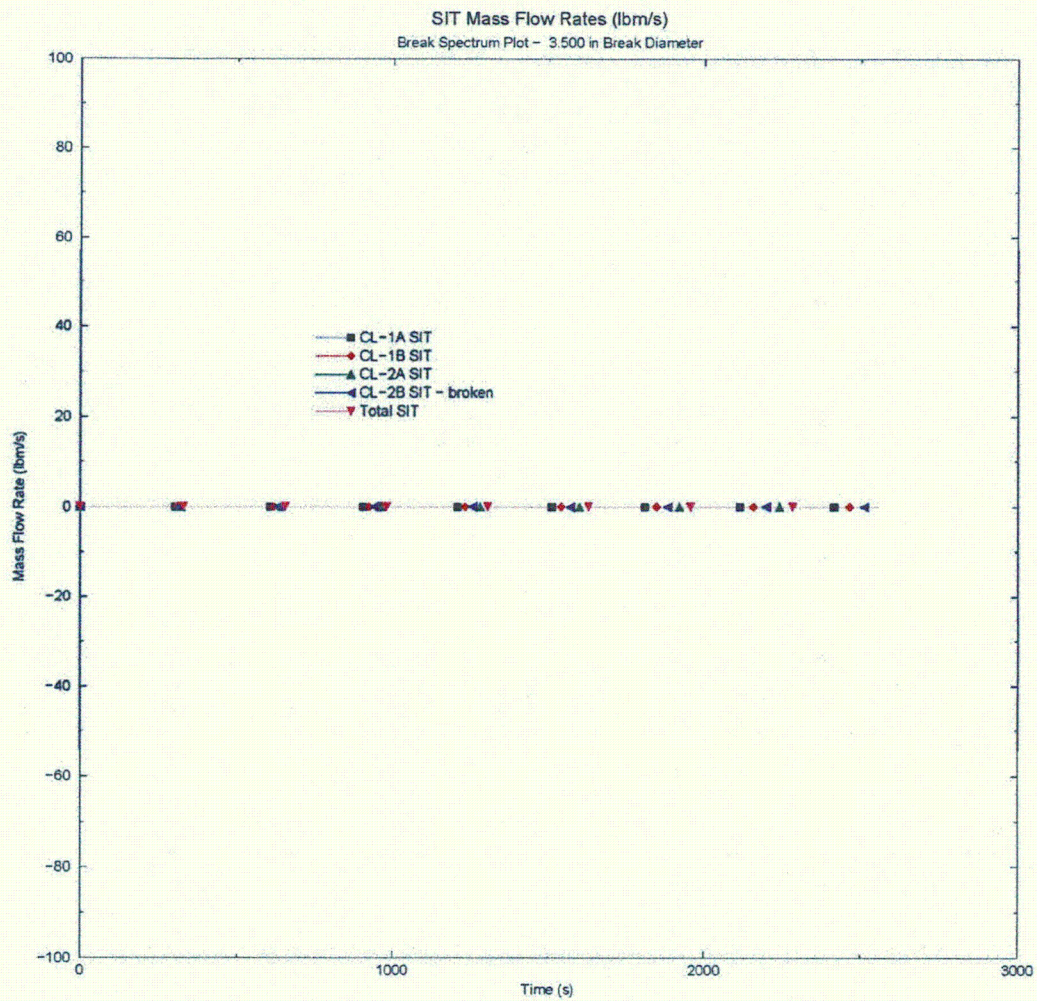


Figure 5-42: Loop Seal Void Fractions – CE 2x4

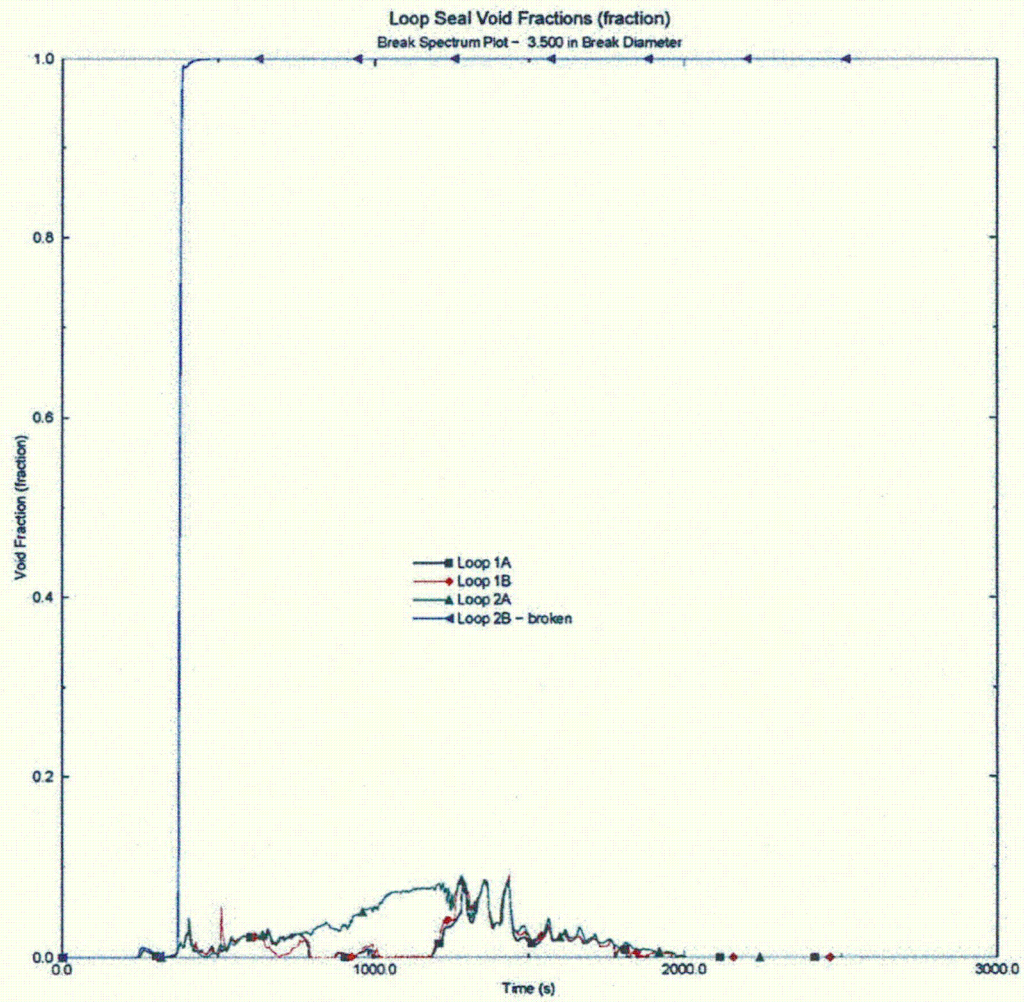


Figure 5-43: SG Mass Inventories – CE 2x4

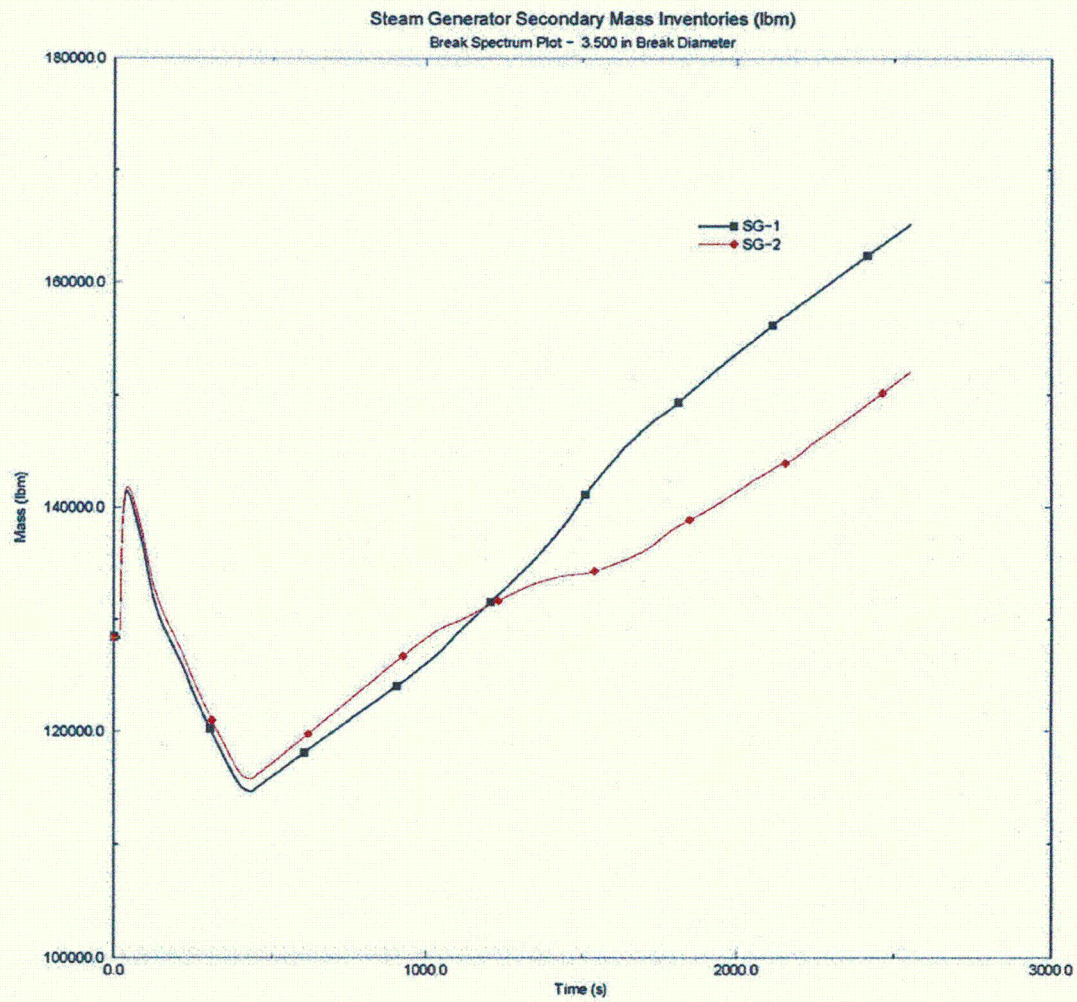


Figure 5-44: AFW Mass Flow Rate – CE 2x4

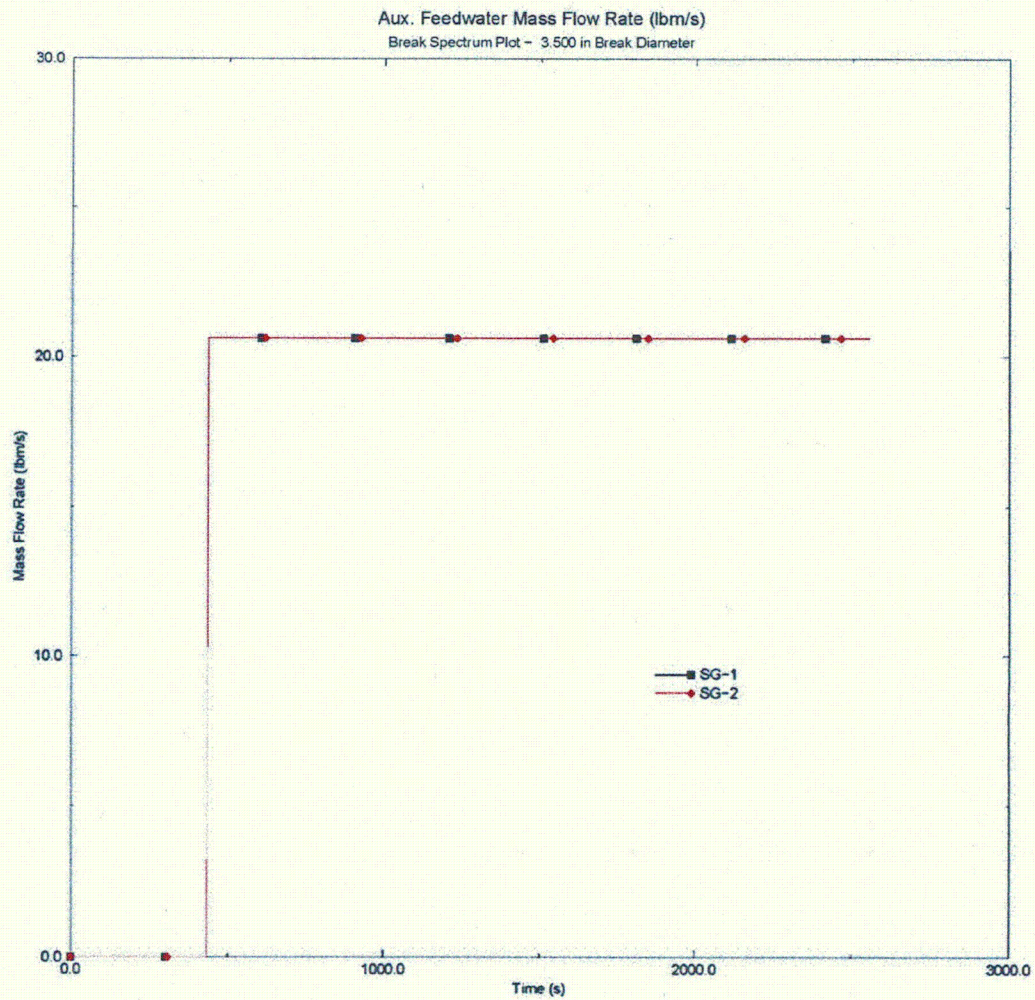


Figure 5-45: Cold Leg Mass Flow Rates – CE 2x4

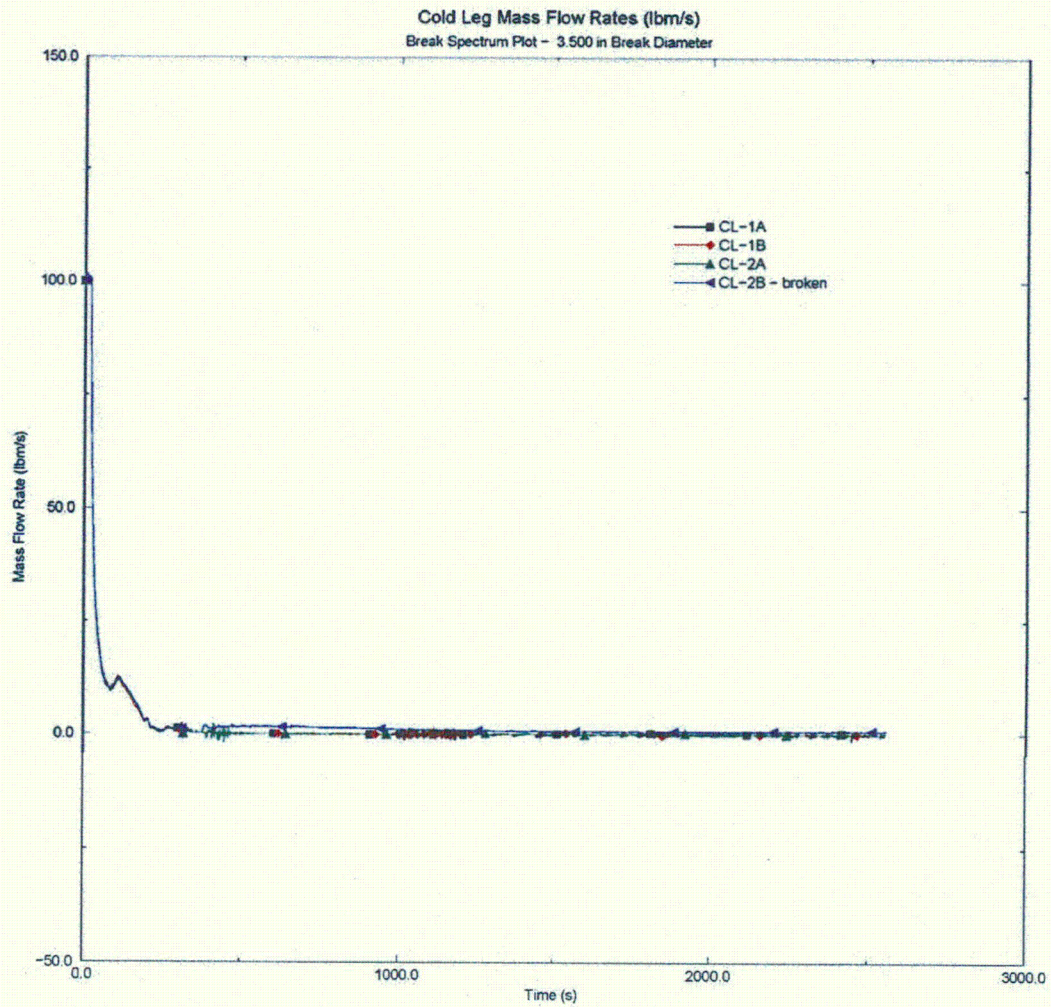


Figure 5-46: Pressurizer and Secondary Pressures – CE 2x4

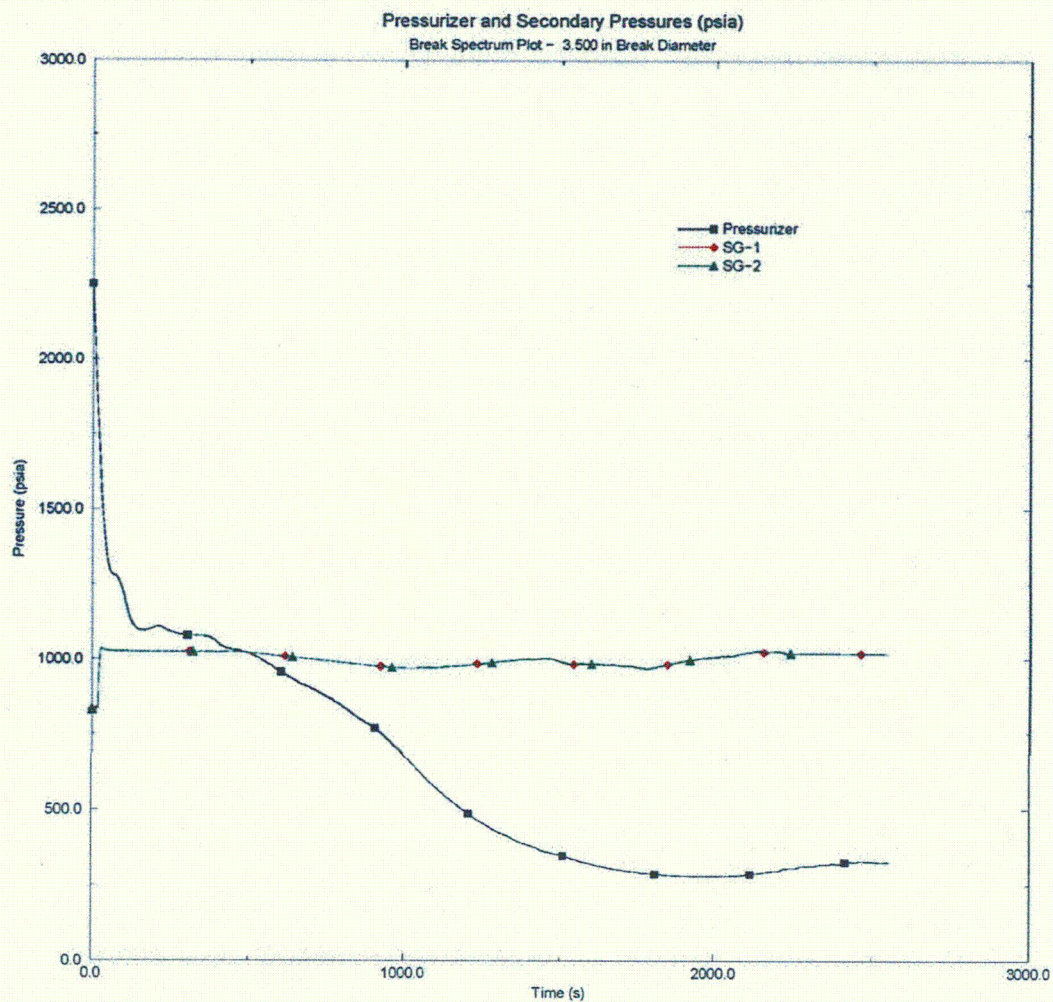


Figure 5-47: MFW Mass Flow Rates – CE 2x4

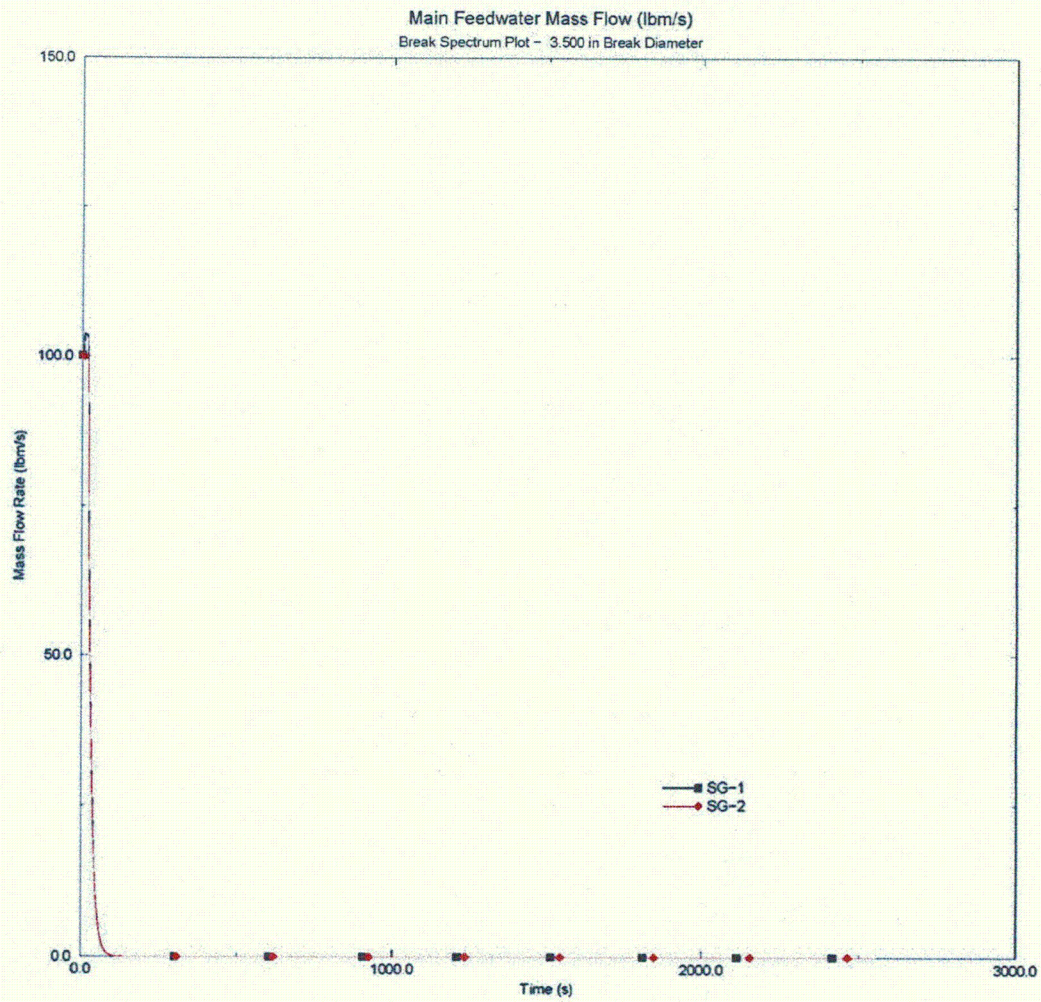


Figure 5-48: Non-Condensable Quality at the Break – CE 2x4

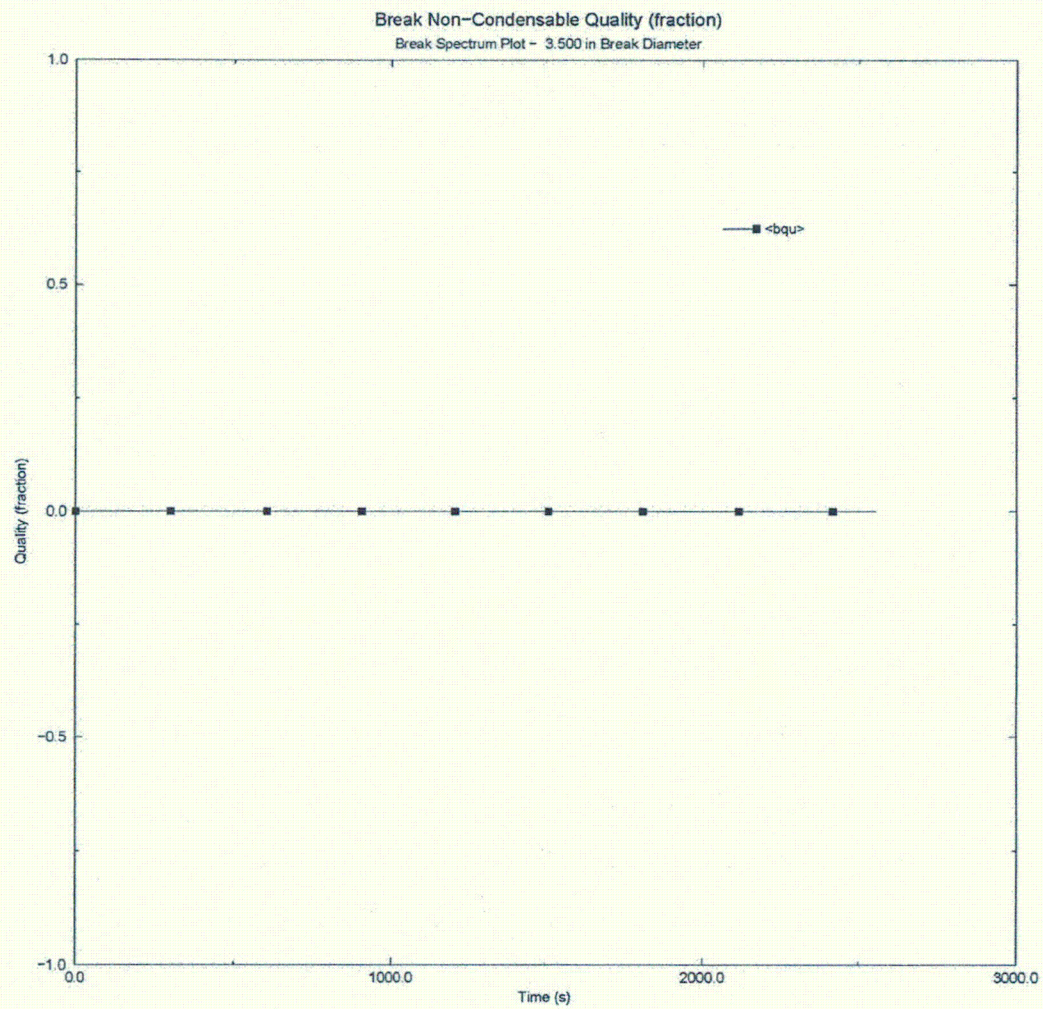


Figure 5-49: PCT and ECCS Flow Rates – CE 2x4

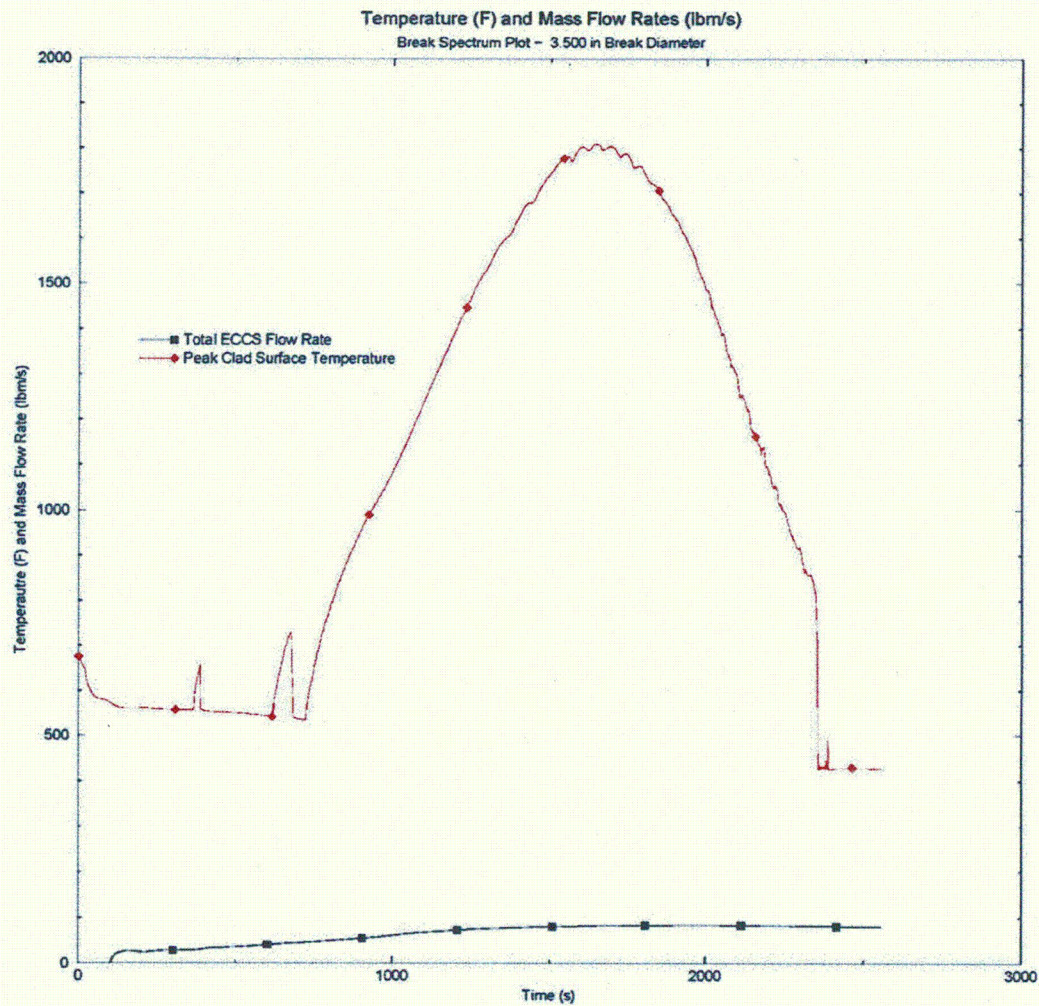


Figure 5-50: Reactor Power – CE 2x4

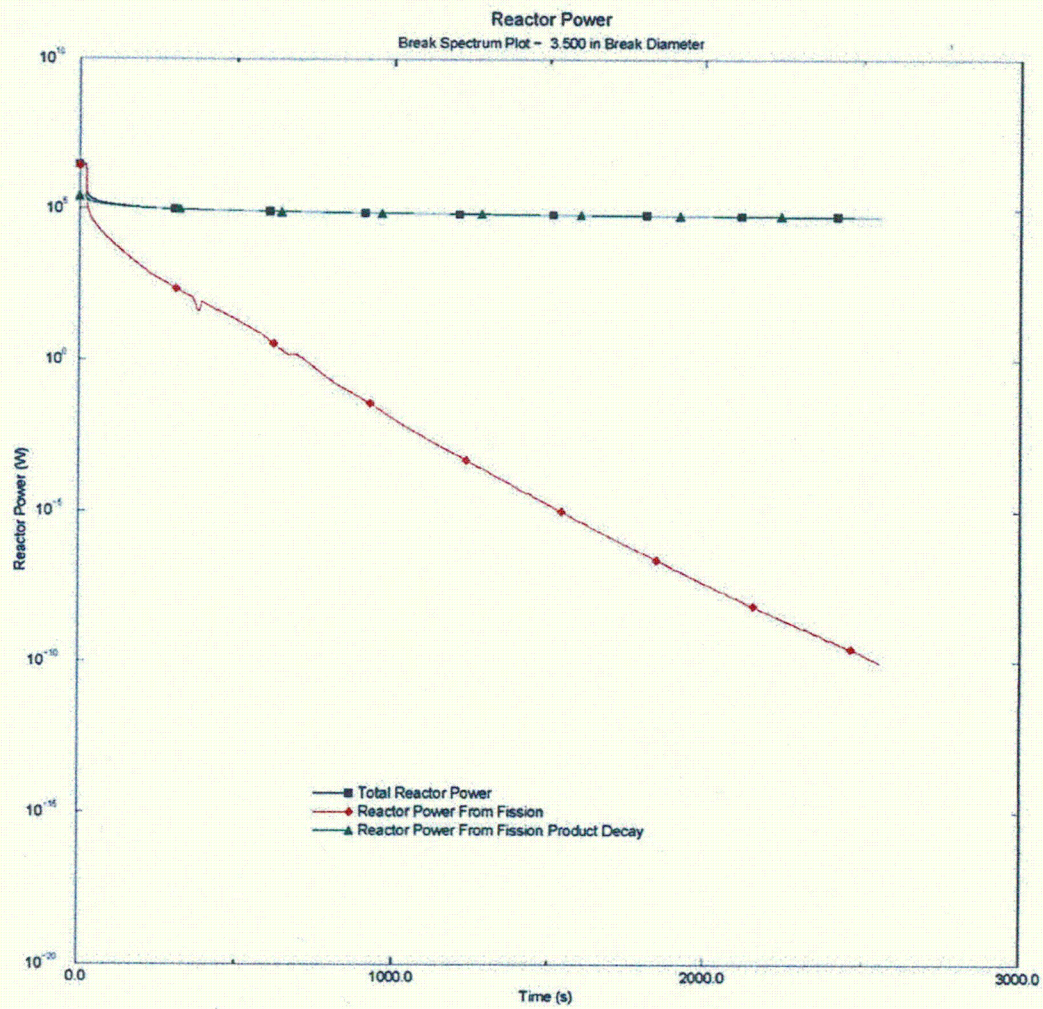
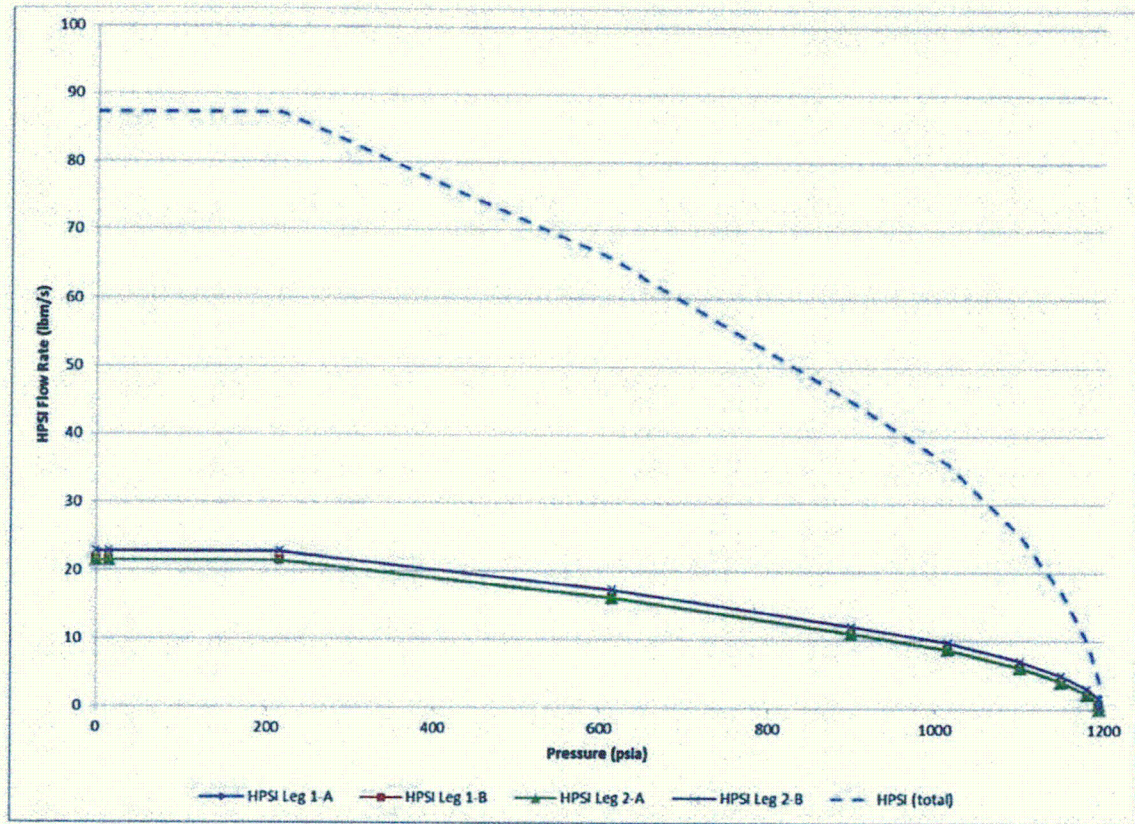


Figure 5-51: High Pressure Safety Injection Curve for CE 2x4 Sample Problem



RAI 6:

NUREG/IA-0116 documented S-RELAP5 code failures for the UPTF Test 11 for runs 36-45, please verify that the coding error has been corrected in the AREVA version and that these tests were properly simulated.

Response to RAI 6:

The RELAP5 code failures reported in NUREG/IA-0116 for UPTF Test 11 for runs 36 to 45 are unrelated to the AREVA version of the RELAP5 code, S-RELAP5. S-RELAP5 has been benchmarked to UPTF Test 11 and the results are presented in Reference 1. The code failures reported in NUREG/IA-0116 are for a different version of the RELAP5 code and do not occur in the S-RELAP5 calculations for this test. The test was properly simulated as shown in Reference 1.

References:

1. EMF-2103(P)(A), Revision 0, "Realistic large Break LOCA Methodology for Pressurized Water Reactors," April 2003.



May 11, 2015
NRC:15:021

U.S. Nuclear Regulatory Commission
Document Control Desk
11555 Rockville Pike
Rockville, MD 20852

Response to Request for Comment on Draft Safety Evaluation for AREVA Inc. Topical Report EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based" (TAC No. ME8227)

In Reference 1, the NRC issued a draft safety evaluation (SE) on EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based" requesting that AREVA Inc. (AREVA) review the document for proprietary material and for factual errors.

AREVA reviewed the draft SE and determined that the draft SE contains information that was identified in the topical report (Reference 2) and RAI responses (Reference 3 and Reference 4) as being proprietary information. A number of technical corrections were also identified. Attachment 1 to this letter provides a marked-up copy of the draft SE showing the proprietary information and identifying technical corrections. Attachment 2 provides a list of the suggested changes to the SE.

In addition, a replacement for Figure 3.2 on page 3-4 of the submitted supplement (Reference 2) is needed. It was determined through the draft SE review that Figure 3.2 as submitted, although correct for the expected use as a part of this topical report, was not consistent with the intent of the text, which was to explain how the topical was used prior to the approval of this supplement. Figure 3.2 will be replaced to be consistent with the text of the "Approved" version of EMF-2328(P)(A) Revision 0, Supplement 1, Revision 0, when submitted to the NRC.

AREVA considers some of the information contained in the enclosed Attachments to be proprietary. As required by 10 CFR 2.390(b), an affidavit is enclosed (Attachment 3) to support withholding the information from public disclosure.

If you have any questions related to this letter please contact Mr. Morris E. Byram, Product Licensing Manager, by telephone at 434-832-4665 or by e-mail at Morris.Byram@areva.com.

Sincerely,

A handwritten signature in dark ink, appearing to read 'Philip A. Opasul'.

for Pedro Salas, Director
Licensing & Regulatory Affairs
AREVA Inc.

AREVA INC.

3315 Old Forest Road, Lynchburg, VA 24501
Tel.: 434 832 3000 - www.areva.com

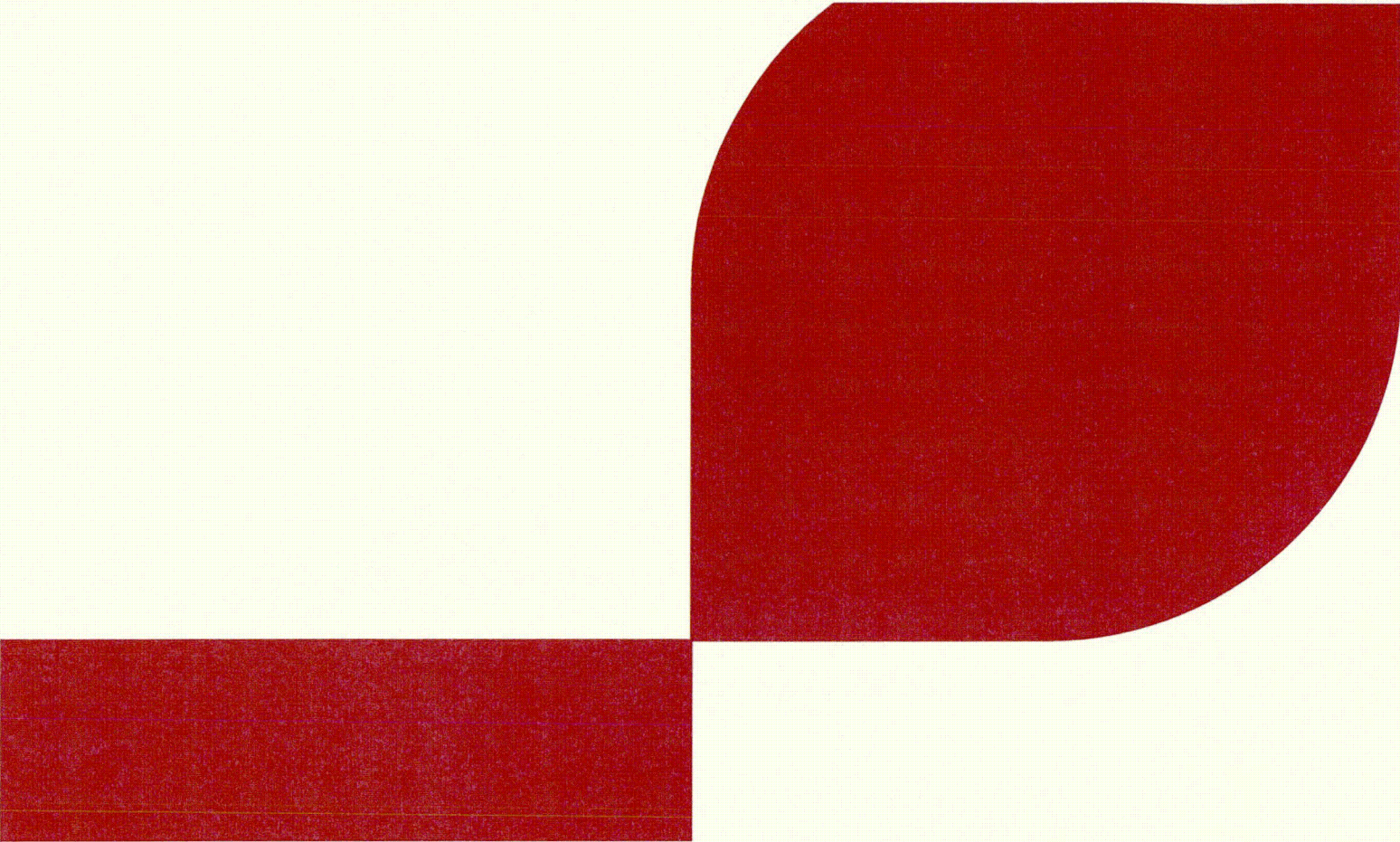
cc: J. G. Rowley
Project 728

References:

- Ref. 1: Letter, Anthony J. Mendiola (NRC) to Pedro Salas (AREVA Inc.), "Draft Safety Evaluation for AREVA NP Inc. Topical Report EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, 'PWR [Pressurized Water Reactor] Small Break LOCA [Loss-of-Coolant Accident] Evaluation Model, S-RELAP5 Based' (TAC NO. ME8227)," April 22, 2015.
- Ref. 2: Letter, Pedro Salas (AREVA NP Inc.) to Document Control Desk (NRC), "Request for Review and Approval of EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, 'PWR Small Break LOCA Evaluation Model, S-RELAP5 Based'," NRC:12:012, March 2, 2012.
- Ref. 3: Letter, Pedro Salas (AREVA Inc.) to Document Control Desk (NRC), "Response to Request for Additional Information Regarding EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, 'PWR Small Break LOCA Evaluation Model, S-RELAP5 Based'," NRC:14:032, June 6, 2014.
- Ref. 4: Letter, Pedro Salas (AREVA Inc.) to Document Control Desk (NRC), "Revised Response to Request for Additional Information Regarding EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, 'PWR Small Break LOCA Evaluation Model, S-RELAP5 Based'," NRC:14:055, October 3, 2014.

Attachments:

1. Mark-up of Draft Safety Evaluation for EMF-2328(P)(A), Revision 0, Supplement 1, Revision 0, "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based"
2. Summary Table of Proprietary Information and Technical Corrections
3. Notarized Affidavit



EMF-2328(NP)(A)
Revision 0
Supplement 1
Revision 0

PWR Small Break LOCA Evaluation Model,
S-RELAP5 Based

March 2012

AREVA NP Inc.



PROPRIETARY

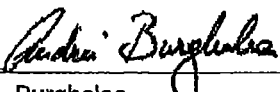
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DATE: 3-5-12

AREVA NP Inc.

EMF-2328(NP)(A)
Revision 0
Supplement 1
Revision 0

**PWR Small Break LOCA Evaluation Model,
S-RELAP5 Based**

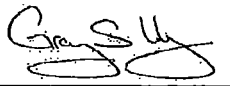
Prepared:  02/28/2012
A. E. Burghlea
CE & W LOCA Analysis
Date

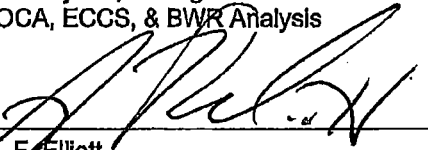
Contributors (In alphabetical order):
K.E. Carlson, L.M. Gerken, R.C. Gorman, R.C. Gottula, L.H. Nielsen,
C.K. Nithianandan

Reviewed:  2/29/2012
B. M. Dunn
CE & W LOCA Analysis
Date

Approved:  2/29/2012
E. J. Moore, Supervisor
CE & W LOCA Analysis
Date

Approved:  2/29/2012
R. L. Baxter, Supervisor
CE & W LOCA Analysis
Date

Approved: 
G. S. Uyeda, Manager
LOCA, ECCS, & BWR Analysis
Date

Approved:  3/2/12
G. F. Elliott
Regulatory Affairs
Date

Digitally signed by UYEDA Graydon
DN: cn=UYEDA Graydon, sn=UYEDA,
givenName=Graydon, l=Lynchburg, ou=AREVA
AMERICAS, o=AREVA, c=US,
email=Graydon.Uyeda@areva.com
Date: 2012.03.01 08:00:48 -05'00'

AREVA NP Inc.

Nature of Changes

Item	Page	Description and Justification
1.	All	This is a new document. Information provided herein complements and replaces some of the information contained in Revision 0 of the present document.

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Nomenclature

Acronym	Definition
BOC	Beginning of Cycle
CCFL	Counter Current Flow Limitation
CE	Combustion Engineering
CFR	Code of Federal Regulations
COLR	Core Operating Limits Report
ECCS	Emergency Core Cooling System
EM	Evaluation Model
EOC	End of Cycle
HHSI	High Head Safety Injection
HPSI	High Pressure Safety Injection
LHSI	Low Head Safety Injection
LOCA	Loss-of-Coolant Accident
LPSI	Low Pressure Safety Injection
MSSV	Main Steam Safety Valve
MTC	Moderator Temperature (reactivity) Coefficient
NSSS	Nuclear Steam Supply System
NRC	United States Nuclear Regulatory Commission
PCT	Peak Cladding Temperature
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
SBLOCA	Small Break Loss-of-Coolant Accident
SG	Steam Generator
SI	Safety Injection
SIT	Safety Injection Tank

1.0 Introduction

Reference 1 was originally submitted for NRC review in January 2000. Relative to the earlier Small Break Loss-of-Coolant Accident (SBLOCA) methodology, EMF-2328(P) replaced the set of three computer codes in References 2 and 3 (ANF-RELAP, RODEX2, and TOODEE2) with just two (S-RELAP5 and RODEX2A). Because of common aspects, EMF-2328(P) was regarded as an extension of the earlier methodology presented in References 2 and 3. NRC approval was granted March 2001 with the basis as presented in Reference 4. Modifications have been incorporated in accordance with annual 10 CFR 50.46 reports by AREVA NP Inc. (AREVA).

A collection of Errata was released in January 2008 to incorporate corrections to the BETHSY assessment in Section 5.0 (see Reference 5).

This supplement to EMF-2328(P), Revision 0 (Reference 1) provides additional modeling information on how the SBLOCA evaluation model (EM) will treat eight areas:

- Spectrum of break sizes,
- Core bypass flow paths in the reactor vessel,
- Reactivity feedback,
- Delayed reactor coolant pump (RCP) trip,
- Maximum accumulator / Safety Injection Tank (SIT) temperature,
- Loop seal clearing,
- Break in attached piping,
- Core nodalization.

Each issue is explained as to its treatment within the EM and the basis for that treatment, followed by a direct reference to any specific alteration of the treatment described in the main body of the Revision 0 topical. These changes are intended to improve the rigor and completeness of the original methodology.

2.0 Spectrum of Break Sizes

2.1 Summary

The break spectrum will include a wide enough range of break sizes to establish a clear trend in the peak cladding temperature (PCT) and to identify the limiting break size, from the smallest break that exceeds the capacity of the makeup system up to, and including, 10% of the cold leg area break, at which point the break spectrum will be covered by the Large Break LOCA EM (Reference 11). The break spectrum will be refined to identify both the break size where the evolution of the mitigating systems (pumped or passive injection) would determine where the transient is being turned over and the break size corresponding to the most limiting PCT. Criteria for spectrum density are provided below.

2.2 Include LHSI/LPSI

Because the spectrum includes larger breaks, the EM will include Low Head Safety Injection (LHSI) / Low Pressure Safety Injection (LPSI) boundary conditions for all SBLOCA analyses performed after the publication of this supplement.

2.3 Hot Leg Bend Angle

2.3.1 Physical Phenomena

2.3.2 Implementation

Figure 2.1 presents an example noding diagram showing the revised noding.

2.4 CCFL



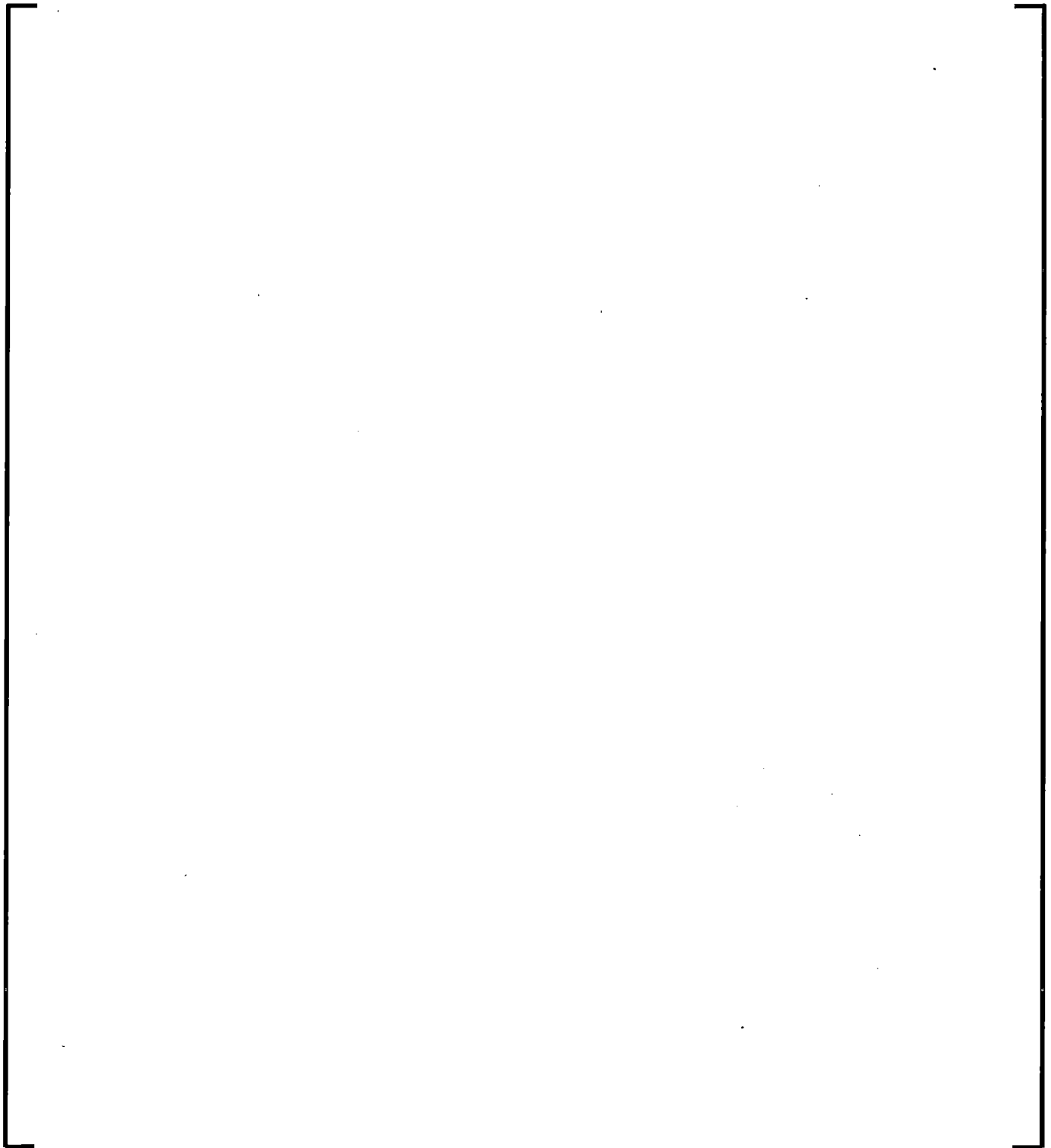


Figure 2.1 Example of Revised Primary System Nodalization

3.0 Core Bypass Flow Paths in the Reactor Vessel

3.1 Summary

A drawing of a representative recirculating steam generator PWR reactor vessel is provided in Figure 3.1. [

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3.2 Physical Processes

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3.3 Implementation

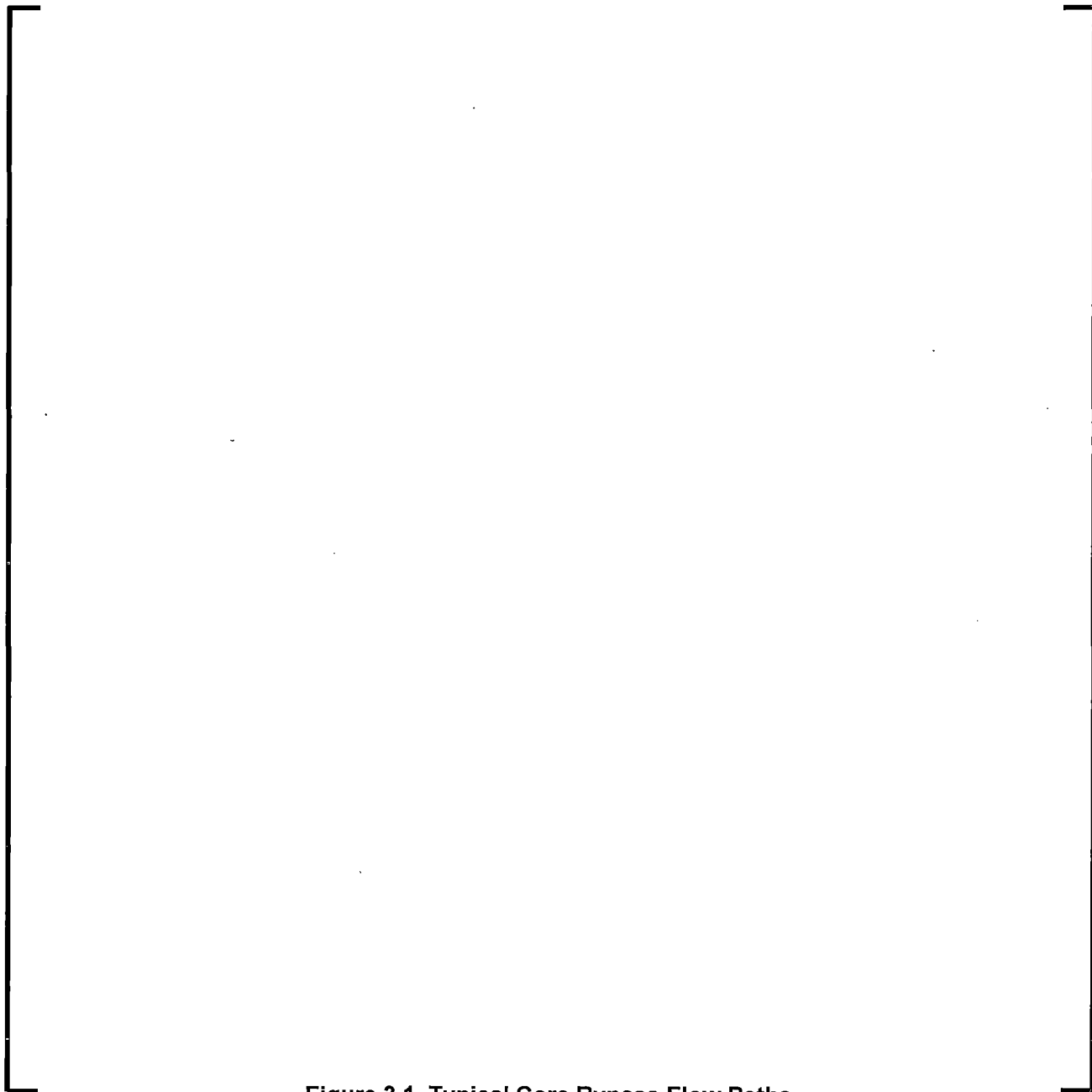


Figure 3.1 Typical Core Bypass Flow Paths

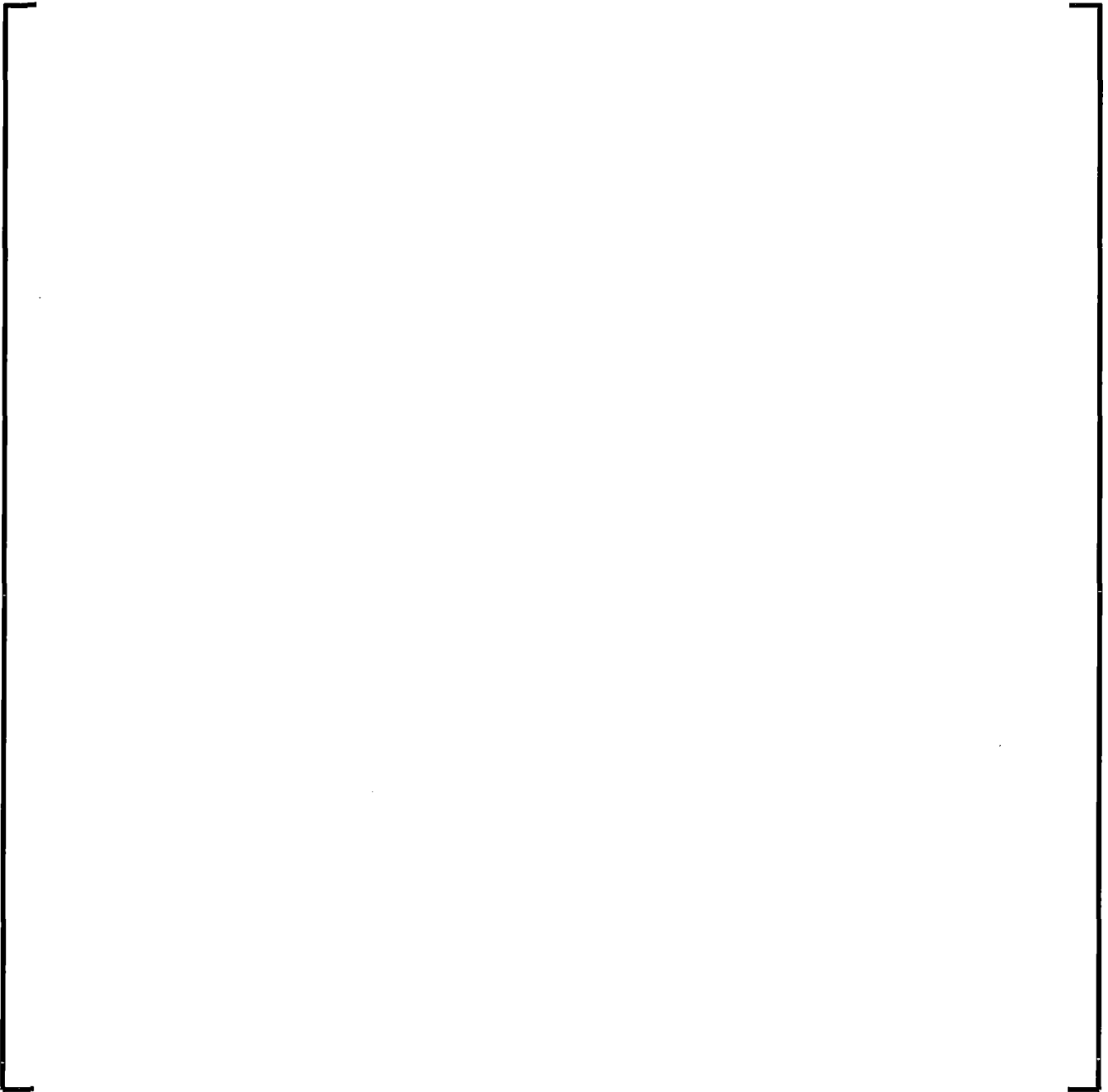


Figure 3.2 Example of Reactor Vessel Noding Diagram [
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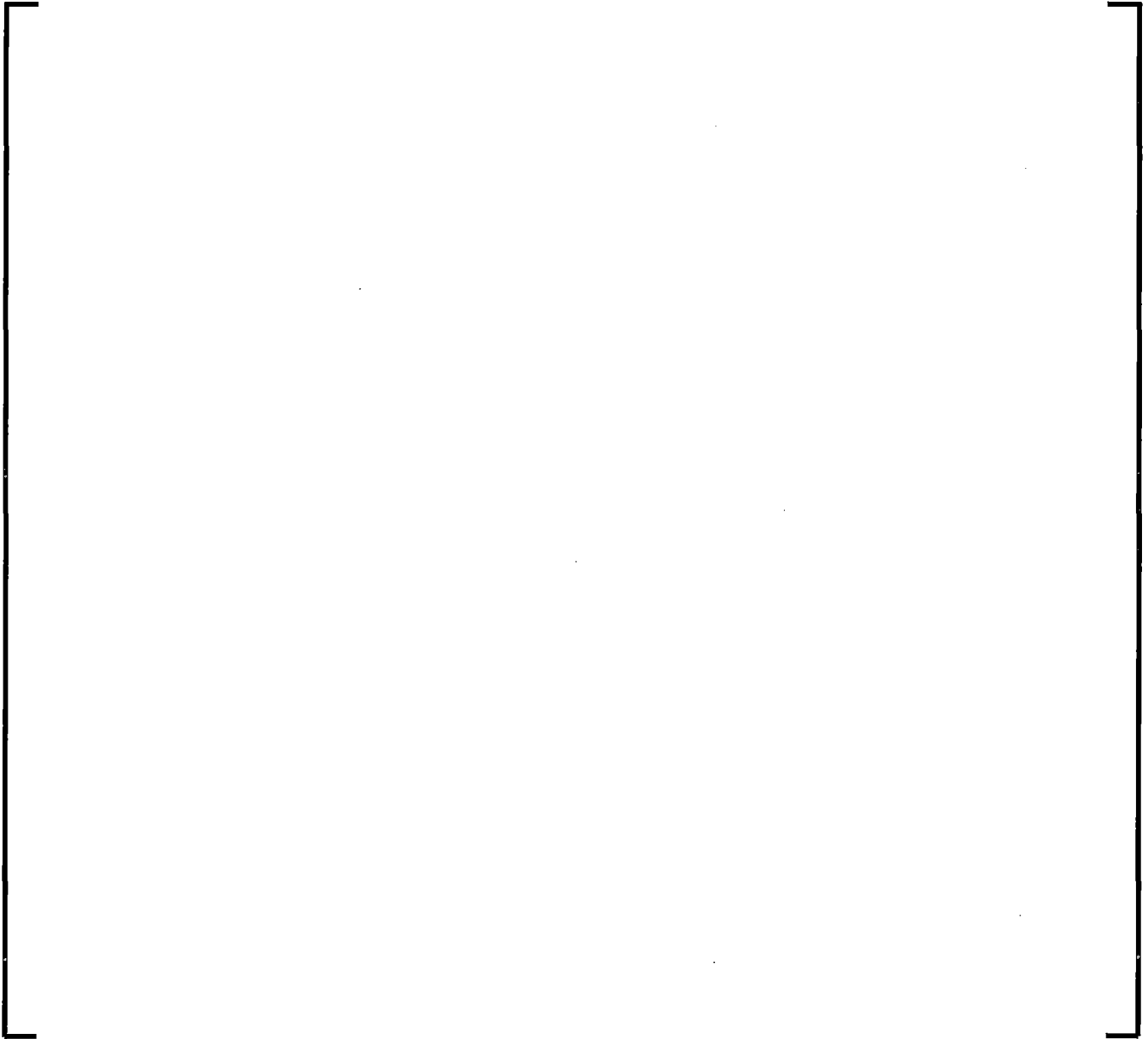


Figure 3.3 Example of Upper Head Spray Nozzle

4.0 Reactivity Feedback

4.1 Summary

The SBLOCA model will incorporate reactivity feedback including both moderator and Doppler. The modeling of moderator reactivity feedback will include the entire spectrum of core conditions, from no voiding (all liquid water) to complete voiding (all steam). Reactivity representing the control rods will be introduced with an appropriate time delay at the time of reactor trip. If necessary, a reactor trip on high power may be added to the model.

4.2 Change from Previous Treatment

In EMF-2328 Revision 0, the only reactivity modeled represents control rod insertion upon reactor trip. This is a conservative simplification whenever the moderator reactivity insertion is negative. The MTC is "most" negative at the End of Cycle (EOC) and the bounding conditions used as a basis for the analysis (i.e., the most adverse top skewed axial power shapes) are associated with EOC conditions. However, it is possible for the high boron concentrations associated with 24-month cycle lengths to produce a Beginning of Cycle (BOC) MTC that is slightly positive at full power. The BOC condition will be used as a basis for moderator reactivity feedback. This represents a conservatively bounding (although inconsistent) combination of boundary conditions.

4.3 Physical Processes

Because water is not perfectly incompressible, a substantial decrease in pressure results in some expansion of the primary coolant, decreasing moderator density. Because commercial light water reactor cores are under-moderated, a decrease in fluid density results in negative reactivity and a power decrease. However, at BOC conditions with high boron concentrations, the boron concentration change may be high enough to overwhelm this effect. If the boron concentration is high enough, the decrease in the concentration of soluble poison will be the dominant effect and possibly introduce positive reactivity.

Increases in fuel temperatures prior to reactor trip produce negative Doppler reactivity and reductions in reactor power.

4.4 Implementation

In addition to other neutronics parameters supporting the analysis of a SBLOCA, AREVA will use tables of

- K_{eff} as a function of moderator density, and
- K_{eff} as a function of fuel temperature.

While it is only applicable to negative reactivity, in accordance with Section I.A.2 of Appendix K, shutdown reactivities resulting from temperatures and voids shall be given their minimum plausible values, including allowance for uncertainty.

When Technical Specifications (or the COLR) allow a positive MTC at full power, the maximum plausible value will be incorporated in order to allow an increase in core power prior to reactor scram.

5.0 Delayed RCP Trip

5.1 Summary

The Revision 0 EM assumes that RCP trip occurs only at the time of reactor scram, coincident with the loss of offsite power. (See the third paragraph in Section 3.2 on page 3-3 of Reference 1, as well as the fourth and fifth paragraphs in Section 6.1 on page 6-1 and the second row in Table 6.2 on page 6-9 of Reference 1.) As an additional set of cases in which offsite power continues to be available, delayed RCP trip will also be analyzed. This includes:

- review of current plant licensing basis, including the details of Emergency Operating Procedures , and
- separate analysis of Hot and Cold Leg break locations, considering different break sizes for each.

5.2 History/Background

Section II.K.3.5 of NUREG-0737 calls for the analysis of a delayed RCP trip for SBLOCA analyses. This was followed with specific recommendations for manual RCP trip in References 7 and 8 as NRC Generic Letters applicable to Westinghouse and CE plants. The US fleet responded to these requirements with a variety of analyses assumptions regarding timely RCP trip. For the analyses performed under this evaluation model, the justification for the pump trip action will mirror the existing basis with the exception that the EMF-2328 EM, including this supplement, will be used for any calculations and that hot leg breaks will be included.

5.3 Physical Processes

Under continued operation of the RCPs, the heat transfer in the core and primary side of the SGs is by forced convection. While this provides increased core cooling and heat removal, it can also contribute to increased depletion of the amount of liquid in the RCS. With RCP trip on scram, the RCS transitions to relatively stagnant conditions with a steam bubble forming in the top of the reactor vessel. The size of the steam bubble increases and gradually extends into the upper plenum, the hot legs and the SGs. When the break uncovers, the break flow changes from mostly liquid to predominantly steam, trapping a significant amount of liquid in the lower

regions of the RCS. In contrast, keeping the RCPs running forces a mixture of steam and liquid to flow throughout the RCS throughout the transient. There is no extreme separation of the liquid and steam phases and no break uncover time. The fraction of the break flow that is liquid is lower at first, improving system liquid inventory, but higher after the time the break would have uncovered if the pumps were not running. If the RCPs continue to operate, the RCS liquid inventory is gradually depleted far below that resulting when the RCPs are tripped early. So long as the RCPs continue to operate, the core will be effectively cooled. However, if the RCPs lose power or are tripped following the extra depletion of liquid inventory, there may not be enough liquid within the RCS to provide effective core cooling while the Emergency Core Cooling System (ECCS) is refilling the system. The key aspect is that after continued operation, if the RCPs trip, the sudden drop in fluid velocity in the core will produce a rapid separation of the liquid and steam phases in the core region.

As explained in the first paragraph of Section 3.1.1 of Revision 0, a break located in the cold leg will be limiting for the assumption of RCP trip at scram. However, for delayed RCP trip, other aspects (such as the distribution of liquid throughout the RCS) may become important enough that a break located in the hot leg piping becomes limiting.

With loss of offsite power at the time of reactor scram, the worst single-failure in Revision 0 is the loss of an emergency diesel generator (Reference 1, page 3-2 and page 6-1.) Since the continued availability of offsite power is necessary to supply power to the RCPs, for delayed RCP trip this changes slightly to (just) failure of an emergency electrical bus. The net effect is the same in terms of mitigating equipment assumed to be operable.

5.4 Implementation

Based on indications/conditions consistent with the plant licensing basis and Emergency Operating Procedures, if applicable, a spectrum of hot and cold leg breaks will be analyzed to support the RCP trip procedure. This spectrum may include a sensitivity on RCP trip time if such is required to support the trip procedure.

6.0 Maximum Accumulator/SIT and Refueling Water Storage Tank Temperature

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7.0 Loop Seal Biasing

7.1 Summary

In order to bound the possibilities discussed below, and to ensure a conservative evaluation, the S-RELAP5 based SBLOCA EM [

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7.2 Physical Processes

During a cold leg SBLOCA accident in PWRs with U-tube SGs, liquid can accumulate and form liquid plugs in the low elevation points of the loops such as the pump suction. An illustration of the typical loop seal configuration is provided in Figure 7.1. The water trapped in the primary loops between the SG and the RCP prevents the steam that is generated by core decay heat from escaping to the break. As a result, the steam pushes against the liquid interface in the vessel and the cross-over leg piping and keeps the break in the cold leg covered with liquid, thus (1) maximizing break flow and (2) depressing core liquid level. As steam continues to be produced and liquid is being lost out of the break, the space occupied by the steam expands and depresses the liquid level in the core and the downflow section of the cross-over piping.

The differential pressure in the loop will increase and reach a maximum as the core liquid level is depressed to its temporary minimum value corresponding to the spill-under elevation of the horizontal section of the loop seal piping.

The core liquid level depression may be aggravated by the amount of liquid holdup that can occur in the SG U-tubes, SG inlet plena, or the riser section of the hot leg piping.

occur in the SG U-tubes, SG inlet plenum, or the riser section of the hot leg piping.

Several interdependent hydraulic paths can be identified in a PWR with U-tube SGs. One of the hydraulic paths starts at the core and continues through the control rod guide tubes (and other open structures connecting the upper plenum to the upper head), to the upper head and through the downcomer to the upper head bypass flow path, if present and open at operating conditions (i.e., if designed as a distinct bypass path), and then to the downcomer and back to the core. The other hydraulic paths start at the core and follow the normal flow path through the hot legs, SG tubes, cold leg cross-over piping, pumps and back to the downcomer and the core. The situation is further complicated by the inability of any simulation to account for all the plant conditions that contribute to loop seal clearing phenomena. In a system without asymmetries the broken loop would tend to clear before the intact loops, due to the proximity to the break. This effect is small and may be overshadowed by the as-built plant differences. Density effects due to loop-to-loop temperature differences as little as 3 - 4 °F, can induce the preferential clearing of a given loop. Similarly, the actuation of the SG Main Steam Safety Valves (MSSVs) may drive the loop seal clearing in one or two loops over the other.

Through the examination of experimental data and analytical expectations for loop seal clearing, a trend can be established such that fewer loops will be clearing with decreasing break size. An evaluation of dominant causes considered that the strongest influence was likely the SG pressure (and MSSV operation) and its relationship to the primary side pressures and coolant temperatures. The second most dominant phenomenon is the break effect on local RCS pressure.

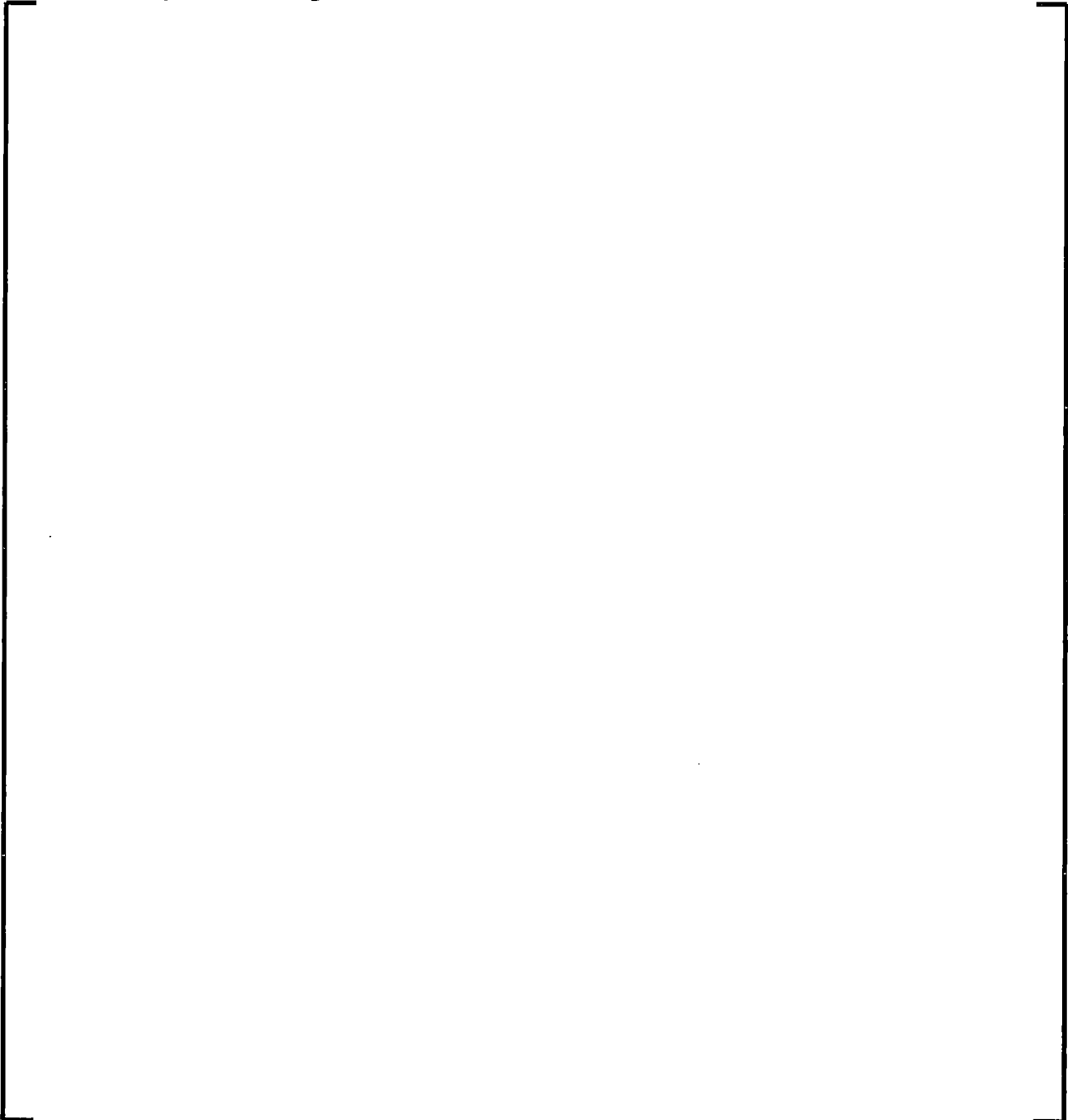
After the loop seal clearing, the core mixture level recovers as pressure imbalances throughout the RCS are relieved. At this point the break flow transitions from mostly liquid, prior to loop seal clearing, to mostly steam and some of the energy accumulated in the system can be evacuated through the break.

The corresponding momentary core level depression that occurs during the loop seal clearing period may generate a cladding temperature excursion. Because the excursion is naturally self-limiting, it does not, of itself, pose a serious concern to the plant, with the notable exception of the larger small breaks, where the timing of the momentary level depression may overlap with

period due to flow resistance to the break and residual liquid left in the loops.

7.3 Implementation

7.3.1 Loop Seal Biasing



7.3.2 Loop Seal Nodalization Changes



**Figure 7.1 Typical Loop Seal Configuration for Westinghouse
Plants**



Figure 7.2 Loop Seal Clearing vs. Break Size in Test Data

8.0 Break in Attached Piping

8.1 Summary

The ECCS must cope with ruptures of the main RCS piping and breaks in attached piping. To accomplish this, an evaluation is made of the ruptures in attached piping that also induce a compromise of the ability to inject emergency coolant into the RCS. Frequently, the limiting case for these breaks is a rupture of the SIT or accumulator line because one SIT or accumulator and one LHSI system and perhaps part of the High Pressure Safety Injection (HPSI) system will be lost directly to the containment. When combined with a single failure, the ECCS capability is significantly compromised. In order to assure acceptable ECCS performance, the scope of analysis will include accidents of this type.

8.2 Background

The RCS (Class 1) primary coolant pressure boundary does extend from the cold leg piping (itself) to the closest check valve in the piping. Attached piping, branching in from the Accumulators or the SITs and pumped SI (both HHSI/HPSI and LHSI/LPSI), may inject through common lines or through separate injection lines depending of the plant design. Regardless of length, the full RCS pressure is applicable to these runs of piping and breaks should be postulated within these pipes.

Section 6 "Conclusions" of the NRC Safety Evaluation of EMF-2328 (enclosed with Reference 4) calls for additional assessments for analysis of break sizes larger than 10 percent of the cold leg flow area. While a full double-ended break in Accumulator or SIT piping may slightly exceed this limit, this break size is a special exception for this particular application.

8.3 Physical Processes

Breaks located in piping attached to the cold leg are special cases in that (in addition to the loss of RCS inventory) delivery of ECCS is adversely affected.

For a full double-ended break in Accumulator or SIT piping, one less (or "N" – 1) of these tanks will deliver flow to the RCS. The affected tank will "spill" directly to Containment instead.

For a break in pumped SI piping, a disproportionate fraction of flow generated by the system will spill out of the break to Containment pressure, significantly reducing delivery to the intact cold legs. The extent of the flow asymmetry depends on system design and is very plant-specific. For example, orifices and globe valves may have been incorporated in the piping system for the purpose of flow balancing.

8.4 Implementation

At least one node or volume will be modeled between the cold leg and the break location (typically) at a check valve.

As a conservative simplification, containment pressure may be assumed constant at atmospheric pressure. The change in containment conditions is not expected to be significant.

Instead of a spectrum of break sizes, a double-ended break in attached piping is assumed as the worst case for the loss of RCS inventory and the ECCS flow split, i.e., the fraction spilling to Containment pressure versus delivery to the RCS.

For breaks in pumped SI piping, if calculations based on bounding assumptions do not show acceptable results, supporting detailed piping flow resistance network calculations may be required.

9.0 Core Nodalization

9.1 Summary

Analyses performed using the this supplement [

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9.2 Revised Core Nodalization

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9.3 Treatment of Hot Assembly Exit

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10.0 Conclusions

Supplement 1 presents a reconsideration of the treatment of the models and methodologies governing:

- Spectrum of break sizes,
- Core bypass flow paths in the reactor vessel,
- Reactivity feedback,
- Delayed Reactor Coolant Pump (RCP) trip,
- Maximum accumulator/SIT temperature,
- Loop seal clearing,
- Break in attached piping,
- Core nodalization.

[

All results of the supplement are considered to be part of the SBLOCA methodology of EMF-2328. For clarity, such analyses will be referred to as being conducted with the evaluation model documented in the EMF-2328, Revision 0 topical plus Supplement 1 to EMF-2328.

]

11.0 References

1. EMF-2328(P)(A) Revision 0 "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based," March 2001.
2. XN-NF-82-49(P)(A), Revision 1 "Exxon Nuclear Company Evaluation Model – EXEM PWR Small Break Model," July 1988.
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10. EMF-2100(P), Revision 16, "S-RELAP5 Models and Correlations Code Manual," December 2011.
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Record of Changes

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2	Page iii	Replaced
3	Page v	Replaced
4	Page 2-3	Replaced
5	Page 3-4	Replaced
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8	Page 7-4	Replaced
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Nomenclature

Acronym	Definition
BOC	Beginning of Cycle
CE	Combustion Engineering
CFR	Code of Federal Regulations
COLR	Core Operating Limits Report
ECCS	Emergency Core Cooling System
EM	Evaluation Model
EOC	End of Cycle
HHSI	High Head Safety Injection
HPSI	High Pressure Safety Injection
LHSI	Low Head Safety Injection
LOCA	Loss-of-Coolant Accident
LPSI	Low Pressure Safety Injection
MSSV	Main Steam Safety Valve
MTC	Moderator Temperature (reactivity) Coefficient
NSSS	Nuclear Steam Supply System
NRC	United States Nuclear Regulatory Commission
PCT	Peak Cladding Temperature
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
SBLOCA	Small Break Loss-of-Coolant Accident
SG	Steam Generator
SI	Safety Injection
SIT	Safety Injection Tank

Figure 2.1 presents an example noding diagram showing the revised noding.

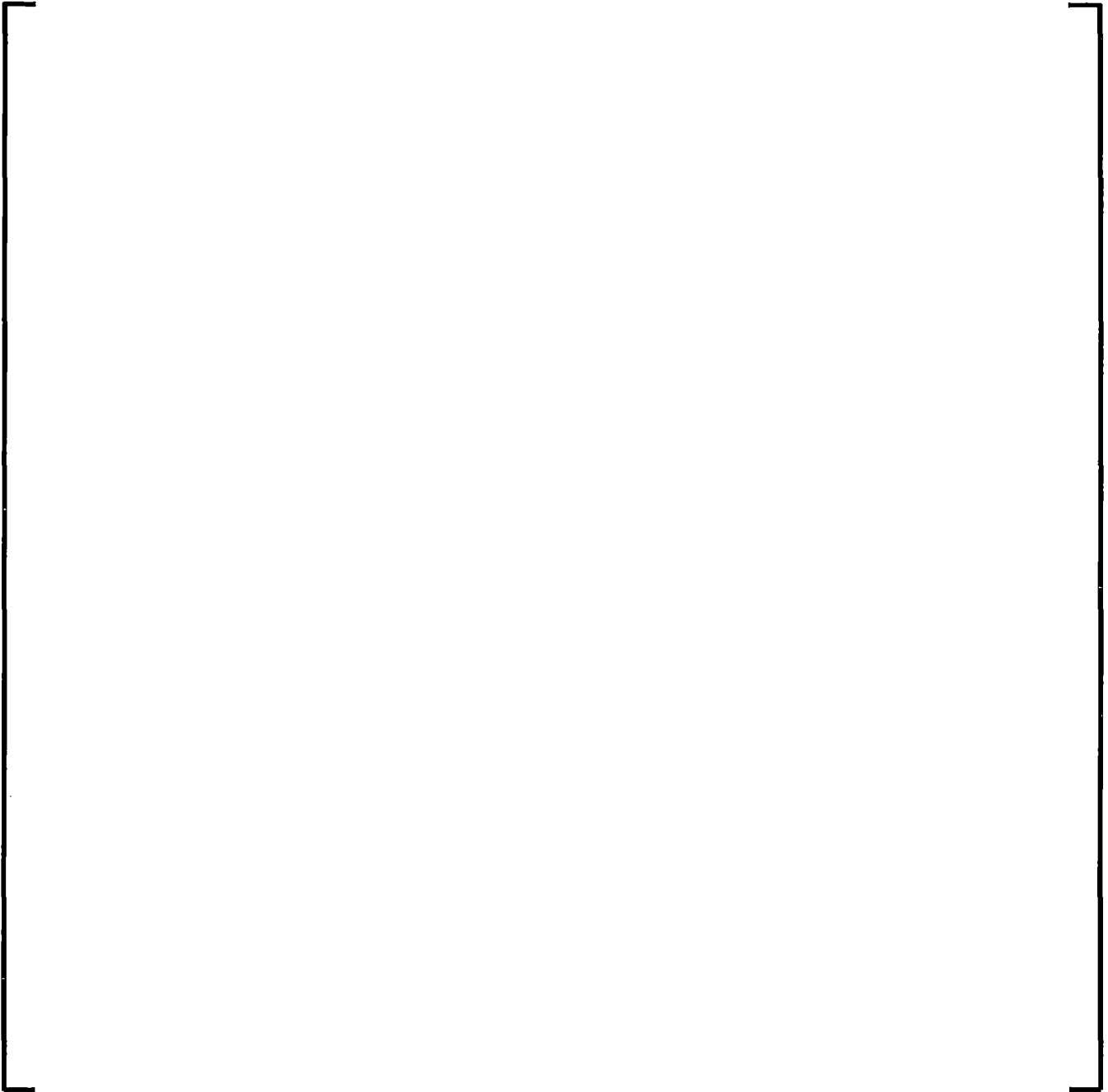


Figure 3.2 Example of Reactor Vessel Noding Diagram [

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7.0 Loop Seal Biasing

7.1 Summary

In order to bound the possibilities discussed below, and to ensure a conservative evaluation, the S-RELAP5 based SBLOCA EM [

]

7.2 Physical Processes

During a cold leg SBLOCA accident in PWRs with U-tube SGs, liquid can accumulate and form liquid plugs in the low elevation points of the loops such as the pump suction. An illustration of the typical loop seal configuration is provided in Figure 7.1. The water trapped in the primary loops between the SG and the RCP prevents the steam that is generated by core decay heat from escaping to the break. As a result, the steam pushes against the liquid interface in the vessel and the cross-over leg piping and keeps the break in the cold leg covered with liquid, thus (1) maximizing break flow and (2) depressing core liquid level. As steam continues to be produced and liquid is being lost out of the break, the space occupied by the steam expands and depresses the liquid level in the core and the downflow section of the cross-over piping.

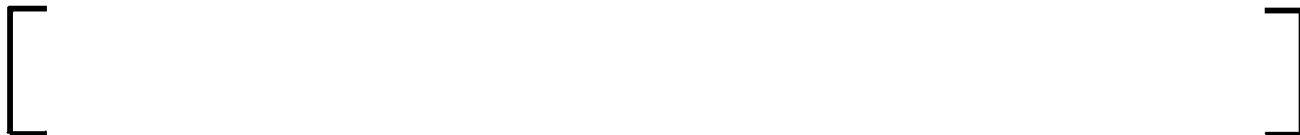
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The core liquid level depression may be aggravated by the amount of liquid holdup that can

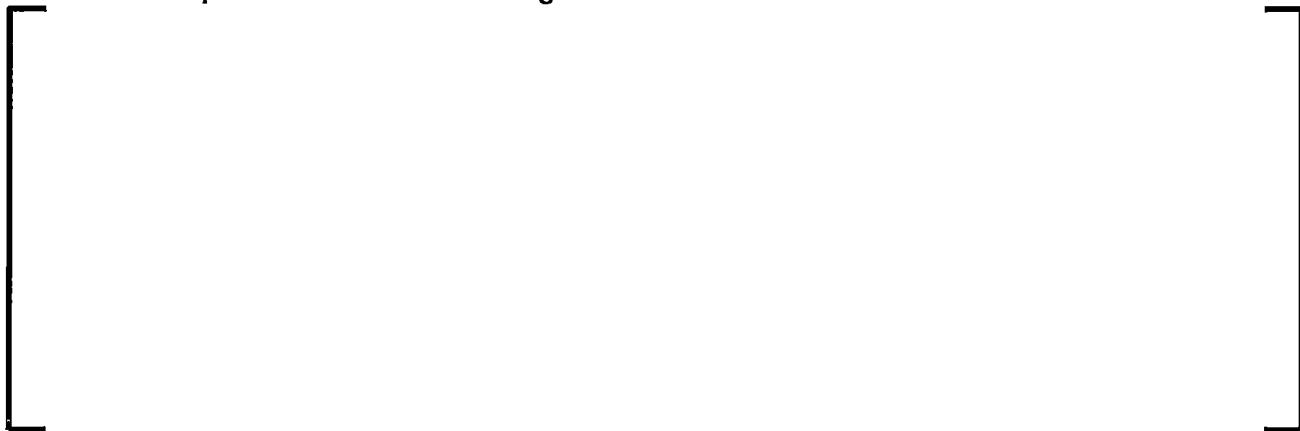
the onset of the second temperature excursion due to reduced core inventory. Nevertheless, the number of loops that clear, can have significant consequences during the core boildown period due to flow resistance to the break and residual liquid left in the loops.

7.3 Implementation

7.3.1 Loop Seal Biasing



7.3.2 Loop Seal Nodalization Changes



11.0 References

1. EMF-2328(P)(A) Revision 0 "PWR Small Break LOCA Evaluation Model, S-RELAP5 Based," March 2001.
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