BASH-EM Parametric Study Results

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Review of Previous W Decay Heat/Cathcart-Pawel Investigation

- In 1984, W studied the implications of relaxing Appendix K through the implementation of ANS 1979 Decay heat and the Cathcart-Pawel metal-water reaction correlation[1].
  - Relaxation of Decay Heat resulted in ~460°F PCT reduction.
  - Cathcart-Pawel correlation resulted in ~65°F PCT reduction.

- Westinghouse ECCS Evaluation Model, 1981 Version[2] produced results consistent with those obtained through the BASH-EM[3].

Code Structure

- SATAN
  - Calculates Thermal-Hydraulic (T/H) Response during Blowdown
  - Transfers core fluid conditions and normalized power to LOCBART to be used in Cladding heat-up calculations
- BASH
  - Calculates T/H Response during Refill and Reflood
  - Transfers Core inlet flooding rate and enthalpy to LOCBART
- LOCBART
  - Uses input from SATAN and BASH to calculate cladding heat-up throughout transient

Assumptions

- Decay heat modeled was modified at t~10s
  - Approximately the gamma switch time, where the heat added to the system is dominated by decay heat
- ANS 1979 Decay heat + 2σ ~
  (0.8) x ANS 1971 Decay Heat + 20%
- Inlet Flooding Rate was not adjusted for decay heat calculations
- HLNG calculated at 75s after BOC, from plant specific temperatures and modeled throughout reflood, consistent with latest RAI response

ANS 1979 Decay Heat Calculation

- 3-loop Westinghouse Plant, Early Reflood PCT
  - Approximation of Decay Heat led to ~260°F PCT Reduction
- 4-loop Westinghouse Plant, Late Reflood PCT
  - Approximation of Decay Heat led to ~450°F PCT Reduction
  - No clad rupture calculated to occur
- Comparison to Best Estimate Calculations will be addressed by Mitch

Peak Cladding Temperature Summary 4-loop plant, Late Reflood PCT

	BASH-EM	BASH-EM w/ ANS '79 Decay Heat Approximation
Peak Cladding Temperature (°F)	2077.9	1628.4
PCT Time (s)	232.2	184.7
PCT Elevation (ft.)	7.25	7.25
Hot Rod Burst Time (s)	127.10	--
Hot Rod Burst Elevation (ft.)	7.25	--
Maximum ZrO_2 (%)	11.97%	0.91%
Max ZrO_2 Elevation (ft.)	7.25	7.25
Assembly Blockage (%)	58.31%	--

Peak Cladding Temperature Summary 3-loop plant, Early Reflood PCT

	BASH-EM	BASH-EM w/ ANS '79 Decay Heat Approximation
Peak Cladding Temperature (°F)	2004.9	1746.2
PCT Time (s)	53.3	54.5
PCT Elevation (ft.)	5.50	5.50
Hot Rod Burst Time (s)	37.97	43.95
Hot Rod Burst Elevation (ft.)	5.50	5.50
Maximum ZrO_2 (%)	4.46%	1.80%
Max ZrO_2 Elevation (ft.)	5.50	5.50
Assembly Blockage (%)	31.41%	32.24%

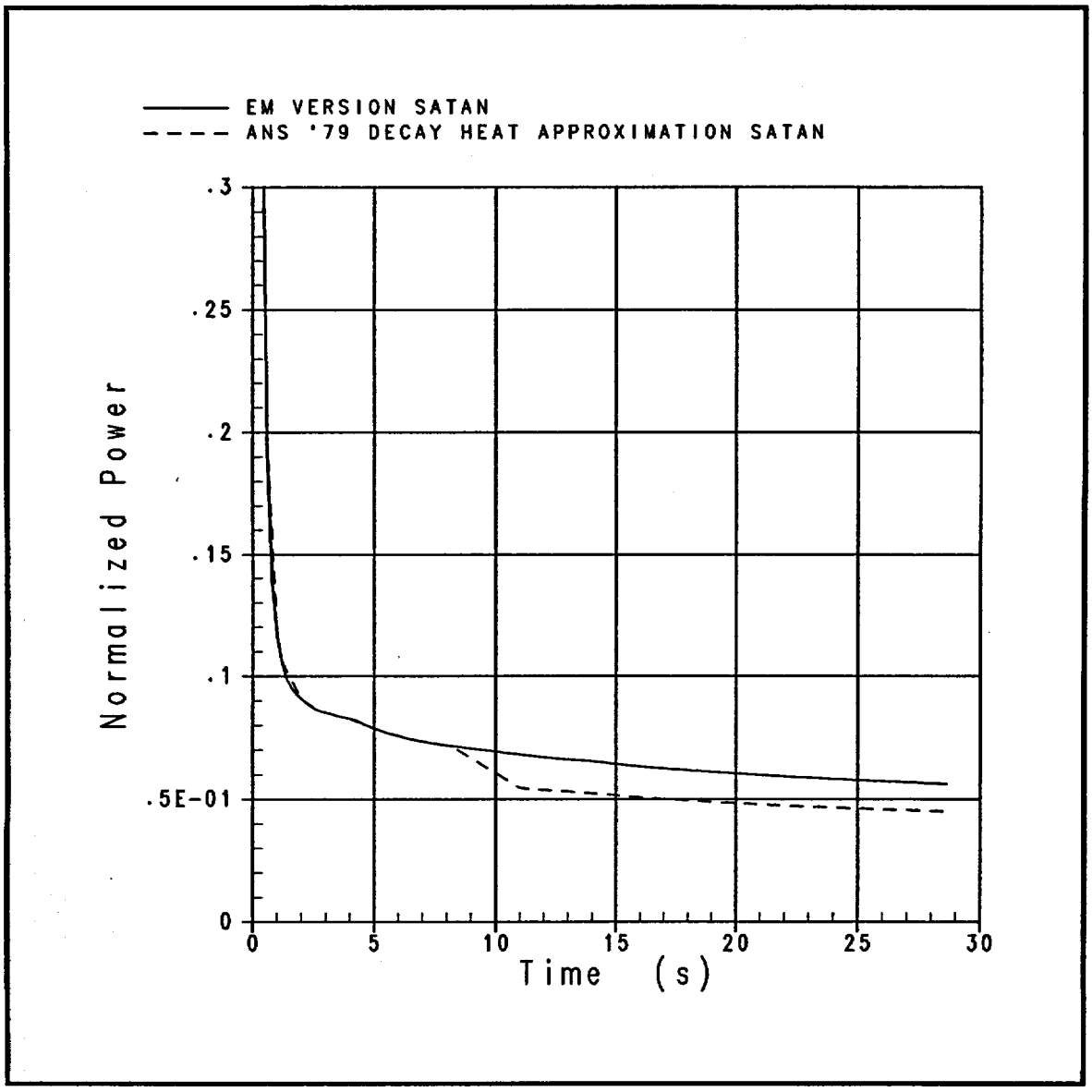

Figure 1
4-loop, Late Reflood PCT
Normalized Power During Blowdown
EM vs. ANS 1979 Decay Heat Approximation

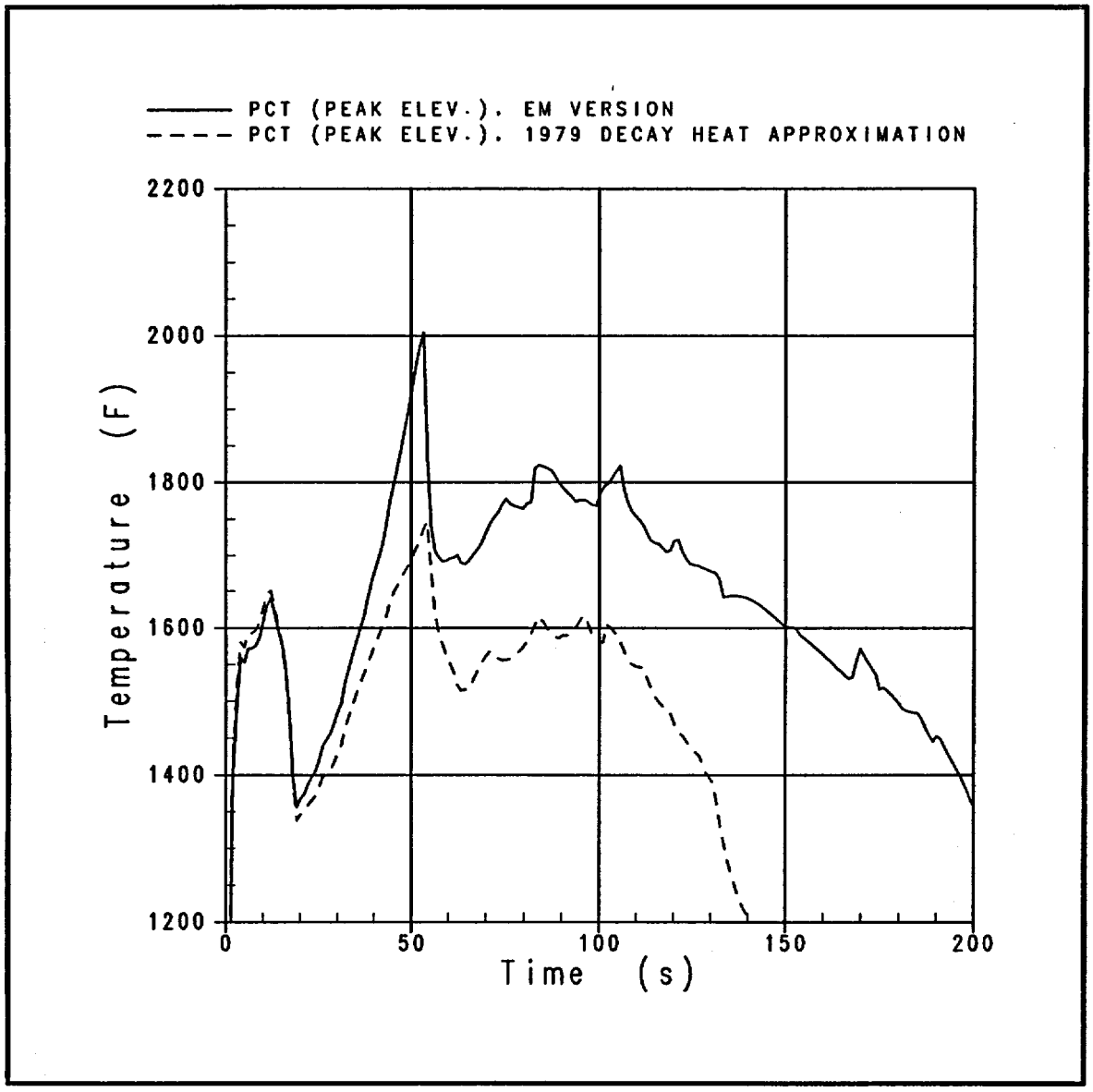

Figure 2
3-loop, Early Reflood PCT
Peak Cladding Temperature (°F)
EM vs. ANS 1979 Decay Heat Approximation

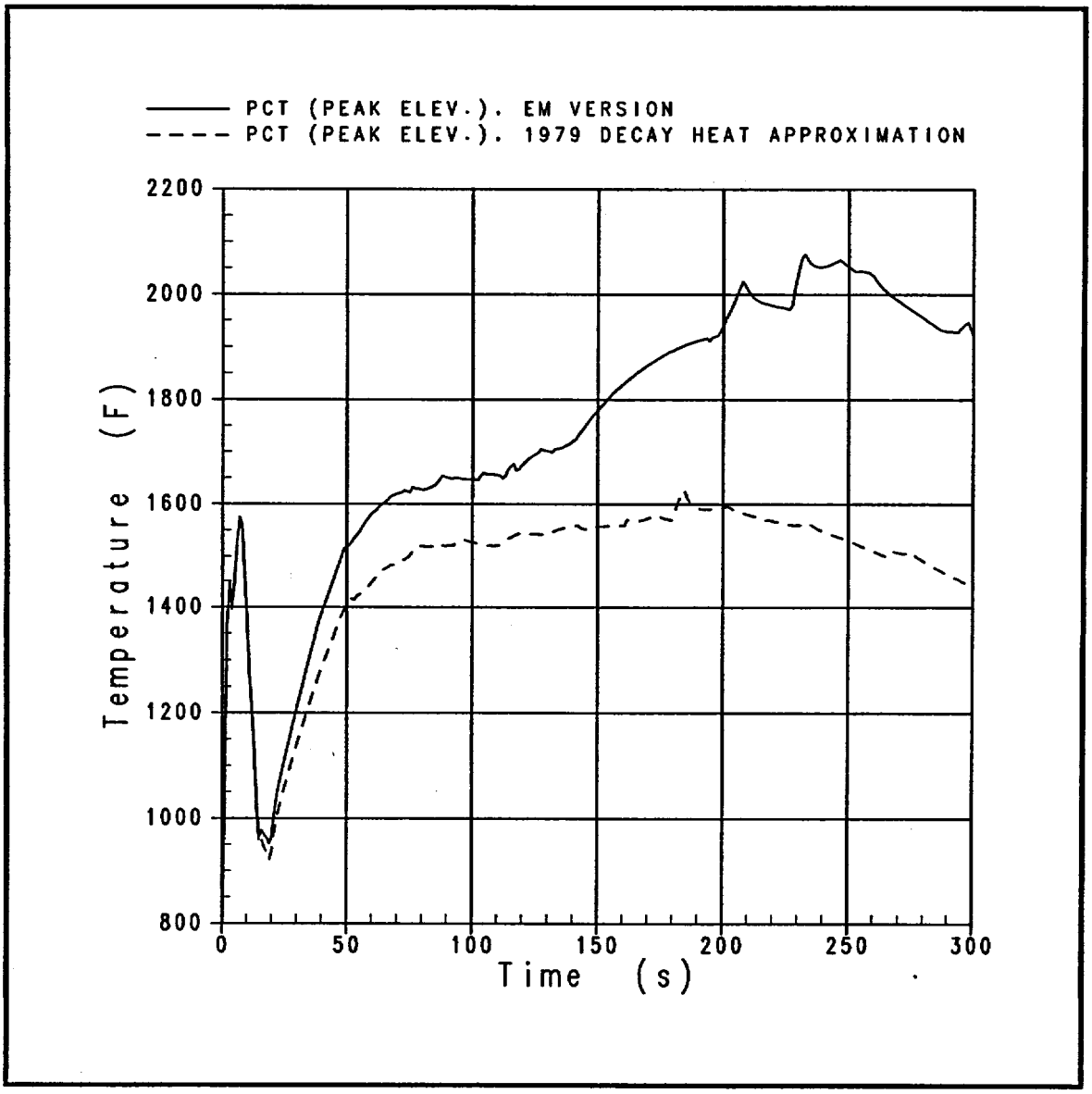

Figure 3
4-loop, Late Reflood PCT
Peak Cladding Temperature (°F)
EM vs. ANS 1979 Decay Heat Approximation

Cathcart-Pawel Metal Water Reaction Correlation Calculation

- 3-loop and 4-loop Westinghouse Plant
- Early and Late Reflood PCTs studied
- Cathcart-Pawel modeling resulted in ~45-55°F PCT Reduction

Peak Cladding Temperature Summary 4-loop plant, Late Reflood PCT

	BASH-EM	BASH-EM w/ ANS '79 Decay Heat Approximation	BASH-EM w/ Cathcart-Pawel Zirc-Oxide Reaction Correlation
Peak Cladding Temperature (°F)	2077.9	1628.4	2033.0
PCT Time (s)	232.2	184.7	232.2
PCT Elevation (ft.)	7.25	7.25	7.25
Hot Rod Burst Time (s)	127.10	--	127.21
Hot Rod Burst Elevation (ft.)	7.25	--	7.25
Maximum ZrO_2 (%)	11.97%	0.91%	9.38%
Max ZrO_2 Elevation (ft.)	7.25	7.25	7.25
Assembly Blockage (%)	58.31%	--	58.40%

'79 Decay Heat and Cathcart-Pawel not modeled together since decay heat case PCT too low to distinguish Cathcart-Pawel benefit

Peak Cladding Temperature Summary 3-loop plant, Early Reflood PCT

	BASH-EM	BASH-EM w/ ANS '79 Decay Heat Approximation	BASH-EM w/ Cathcart-Pawel Zirc-Oxide Reaction Correlation
Peak Cladding Temperature (°F)	2004.9	1746.2	1950.3
PCT Time (s)	53.3	54.5	53.3
PCT Elevation (ft.)	5.50	5.50	5.50
Hot Rod Burst Time (s)	37.97	43.95	37.94
Hot Rod Burst Elevation (ft.)	5.50	5.50	5.50
Maximum ZrO_2 (%)	4.46%	1.80%	4.00%
Max ZrO_2 Elevation (ft.)	5.50	5.50	5.50
Assembly Blockage (%)	31.41%	32.24%	31.43%

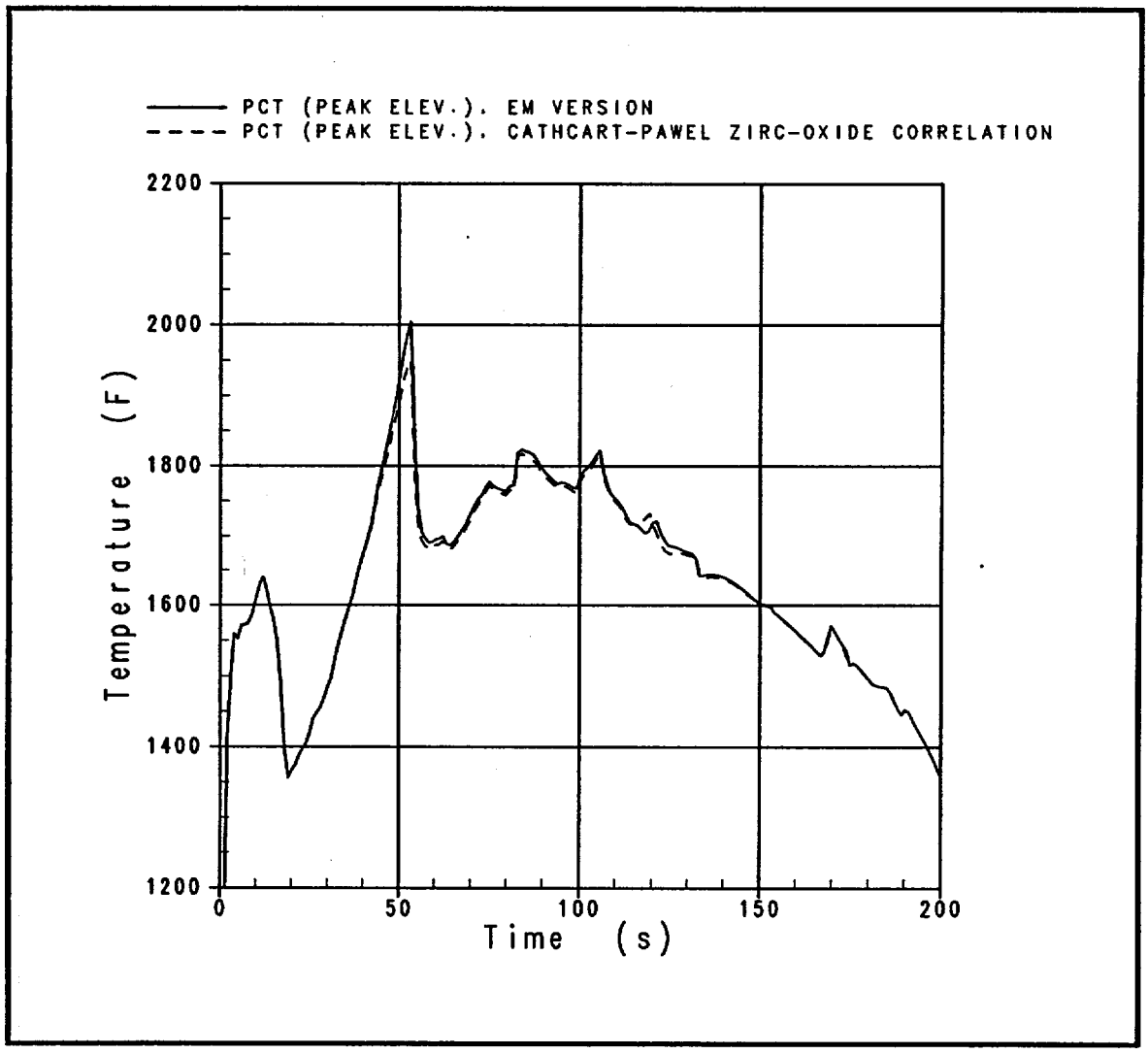

Figure 4
3-loop, Early Reflood PCT
Peak Cladding Temperature (°F)
Baker-Just vs. Cathcart-Pawel

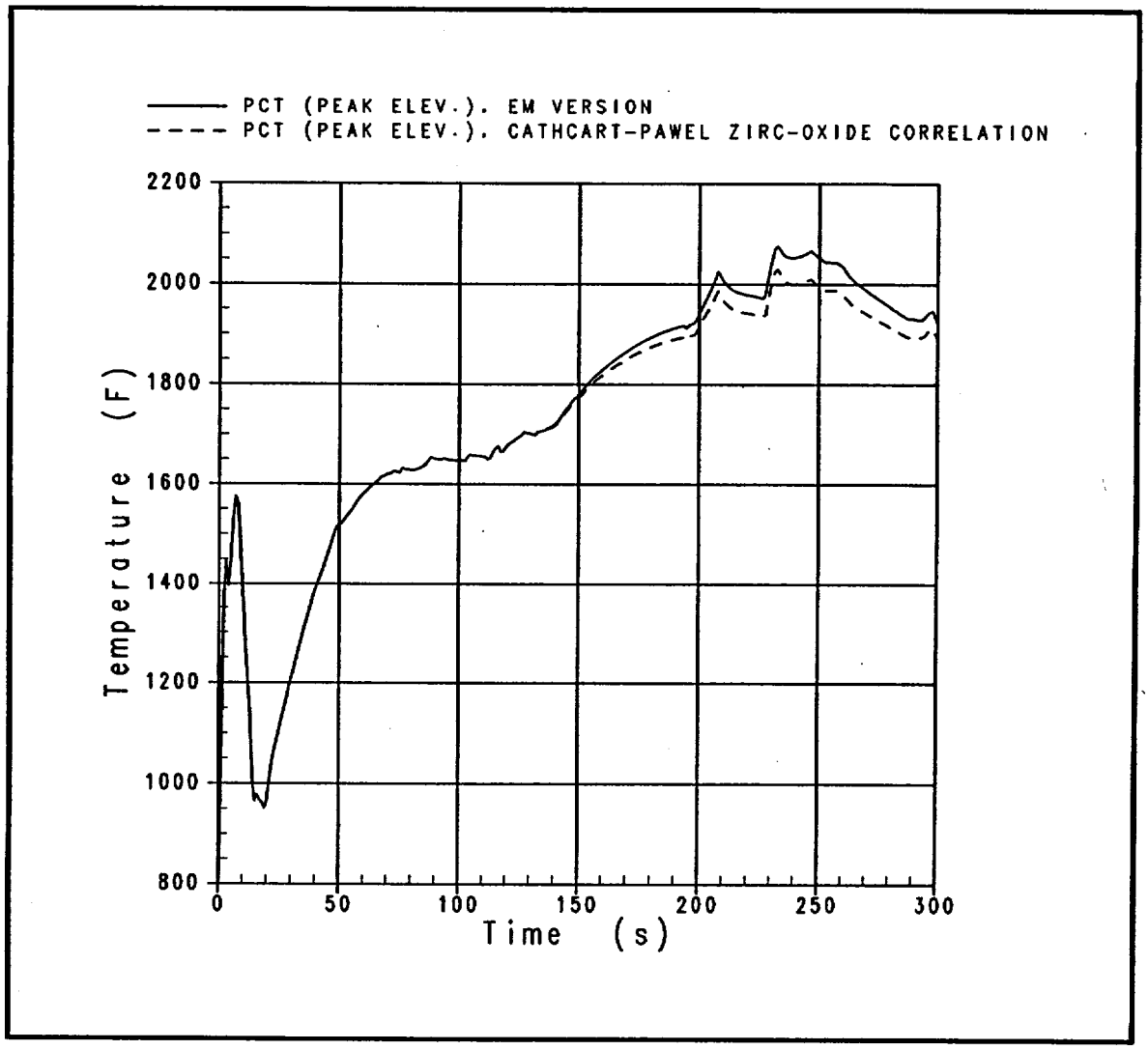

Figure 5
4-loop, Late Reflood PCT
Peak Cladding Temperature (°F)
Baker-Just vs. Cathcart-Pawel

Hot Leg Nozzle Gap Calculation

- 4-loop Westinghouse Plant, Late Reflood PCTs studied
  - Early Reflood PCTs not considered since inlet flooding rate is only mildly affected early in transient
- Gap calculated from plant-specific barrel and vessel temperatures at 75s after BOC and assumed constant throughout reflood
- Hot Leg Nozzle Gap modeling resulted in ~50-125°F PCT Reduction

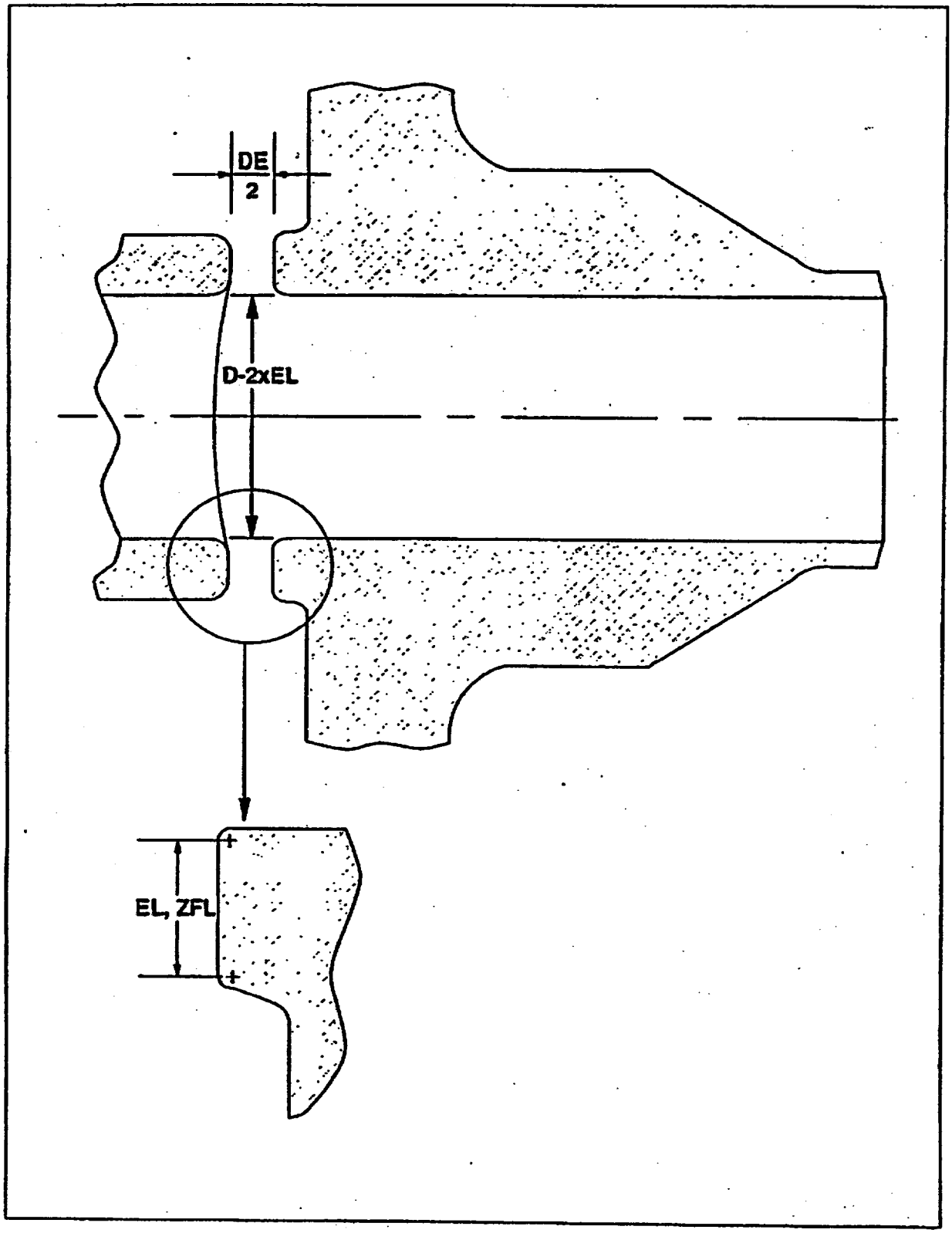

Figure 6
Hot Leg Nozzle Gap Illustration

Peak Cladding Temperature Summary 4-loop plant, Late Reflood PCT

	BASH-EM	BASH-EM w/ ANS '79 Decay Heat Approximation	BASH-EM w/ Cathcart-Pawel Zirc-Oxide Reaction Correlation	BASH-EM w/ Hot Leg Nozzle Gap – (gap calculated at 75 s)
Peak Cladding Temperature (°F)	2077.9	1628.4	2033.0	1952.3
PCT Time (s)	232.2	184.7	232.2	217.7
PCT Elevation (ft.)	7.25	7.25	7.25	7.25
Hot Rod Burst Time (s)	127.10	--	127.21	137.55
Hot Rod Burst Elevation (ft.)	7.25	--	7.25	7.25
Maximum ZrO_2 (%)	11.97%	0.91%	9.38%	7.31%
Max ZrO_2 Elevation (ft.)	7.25	7.25	7.25	7.25
Assembly Blockage (%)	58.31%	--	58.40%	58.42%

'79 Decay Heat and Cathcart-Pawel not modeled together since decay heat case PCT too low to distinguish Cathcart-Pawel benefit

Peak Cladding Temperature Summary 4-loop plant, Late Reflood PCT

(Results Transmitted in Response to RAI, February, 2000)

	BASH-EM	BASH-EM w/ Hot Leg Nozzle Gap – (gap calculated at 75 s)*
Peak Cladding Temperature (°F)	2103.2	2057.2
PCT Time (s)	188.7	183.8
PCT Elevation (ft.)	9.00	9.00
Hot Rod Burst Time (s)	47.10	47.10
Hot Rod Burst Elevation (ft.)	8.00	8.00
Maximum ZrO_2 (%)	5.59%	4.77%
Max ZrO_2 Elevation (ft.)	9.00	9.00
Assembly Blockage (%)	47.50%	47.50%

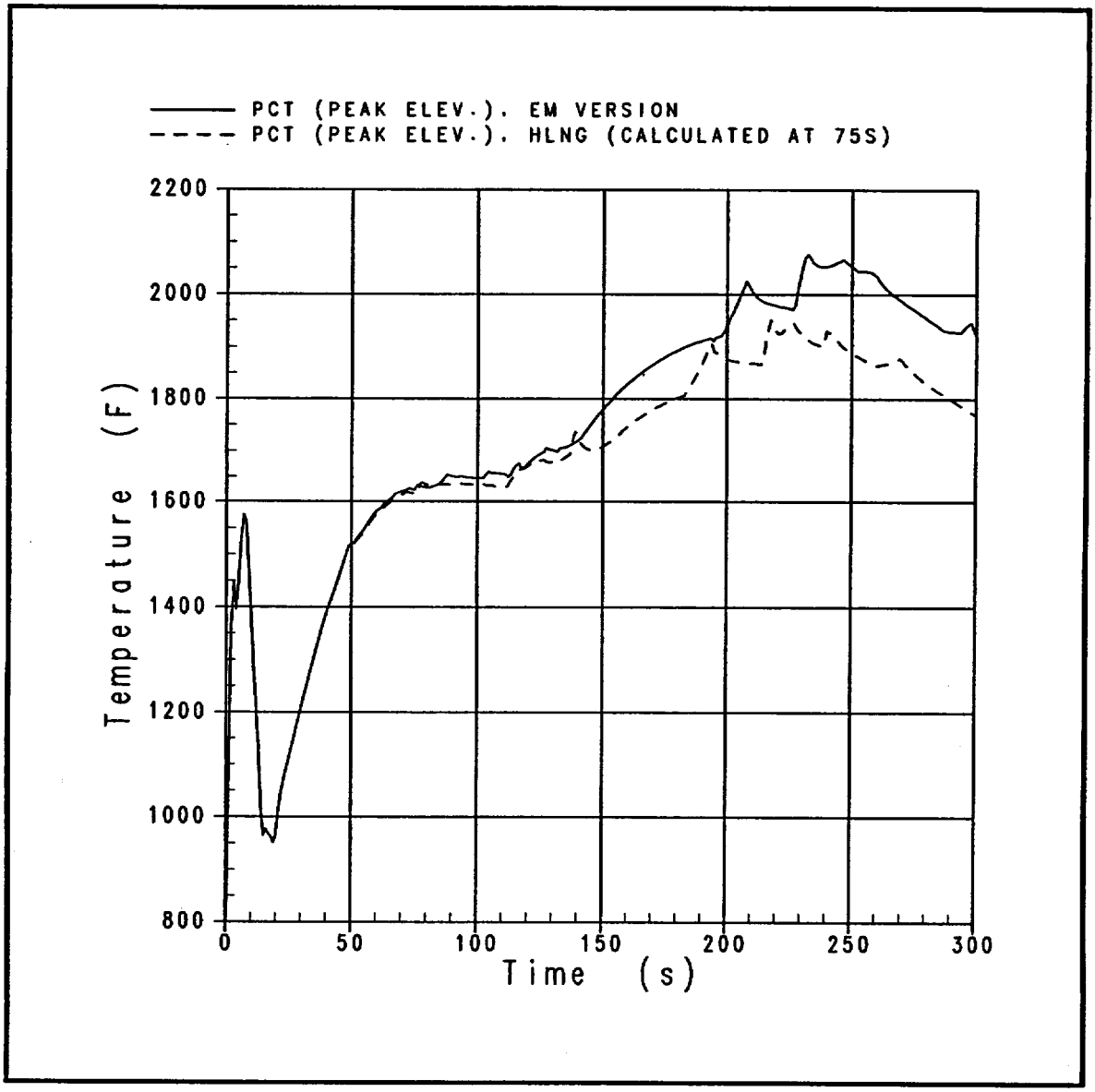

Figure 7
4-loop, Late Reflood PCT
Peak Cladding Temperature (°F)
Hot Leg Nozzle Gap (Calculated from 75s Gap)

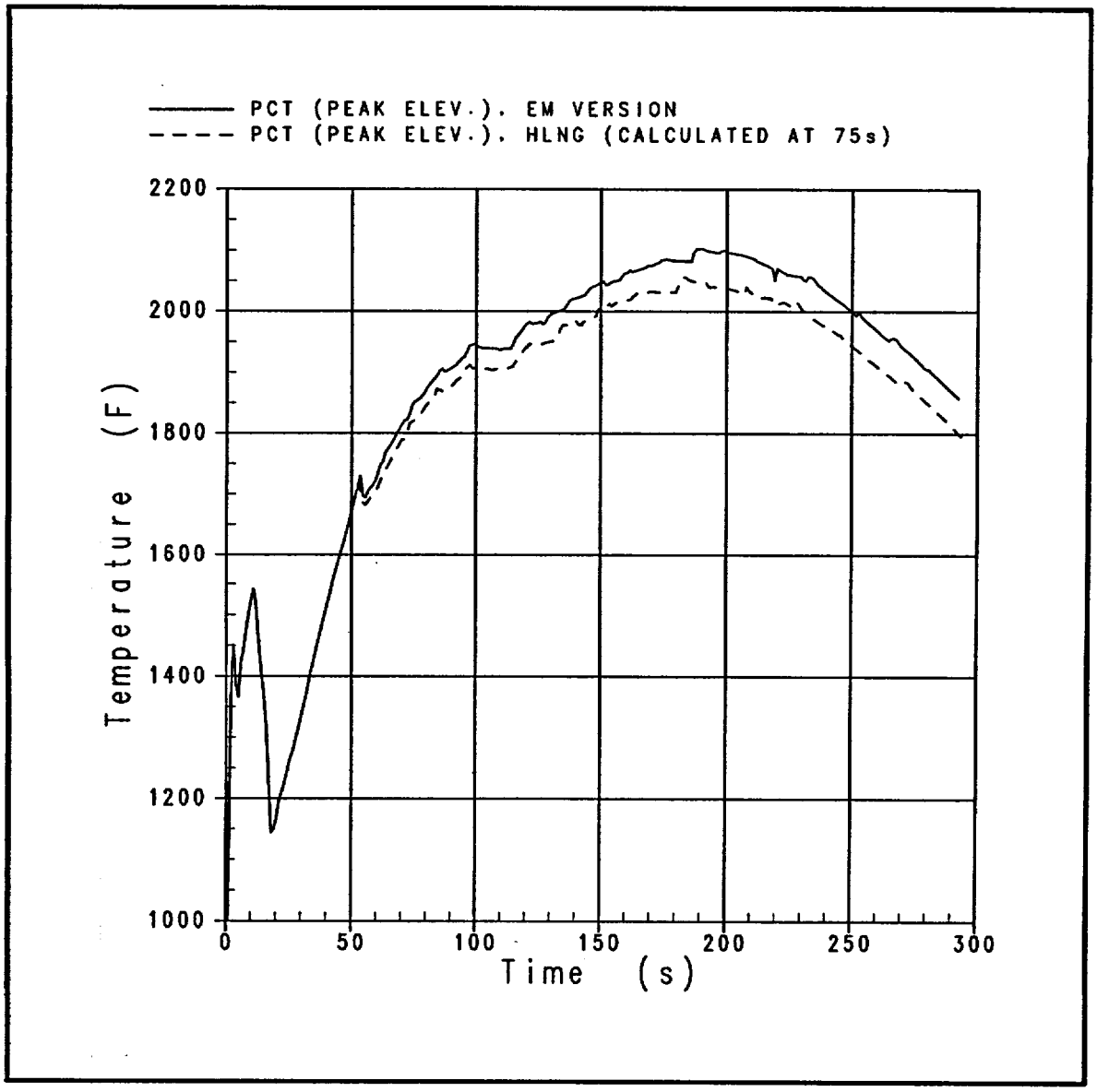

Figure 8
4-loop, Late Reflood PCT
(From RAI Response, February 2000)
Peak Cladding Temperature (°F)
Hot Leg Nozzle Gap (Calculated from 75s Gap)

References

1 F.F. Cadek, J.A. Gresham, L.E. Hochreiter, B.A. McIntyre, "Potential Thermal Margin Available From Changes in the Appendix K Rule", *Proceedings of the International Nuclear Power Plant Topical Meeting, Taipei, Taiwan, 1984.*

2 "Westinghouse ECCS Evaluation Model, 1981 Version", WCAP-9220-P-A, Revision 1 (Proprietary), February 1982.

3 "The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code", WCAP-10266-P-A, Revision 2 (Proprietary), March 1987.