Summary of FCS Containment Analysis without Containment Spray

AREVA NP, Inc.

Document 77-9051353NP-001

July 2007

Non-Proprietary

Summary of FCS Containment Analysis Without Containment Spray

Omaha Public Power District
Ft. Calhoun Nuclear Station

AREVA NP Inc.
Document 77-9051353NP-001
July 2007

Containment Analysis without Containment Spray Summary Report

For

Omaha Public Power District

Ft. Calhoun Station

Prepared by	J. M. Link	07/18/2007 Date
Reviewed by Safety Analysis	K. E. Higar	7/18/07 Date
Approved by Project Manager	D. A. Napior	7/18/07 Date

Table of Contents

List of Tables

List of Figures

List of Acronyms

AOR	Analysis of Record
CAC	Containment Air Cooler
CACF	Containment Air Cooling & Filtering Unit
CCW	Component Cooling Water
CS	Containment Spray
CTM	Containment
DEG	Double Ended Guillotine
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
EQ	Environmental Qualification
FCS	Ft. Calhoun Station
HL	Hot Leg
HPSI	High Pressure Safety Injection
LOCA	Loss-of-Coolant Accident
LOOP	Loss-of-Offsite Power
LPSI	Low Pressure Safety Injection
MER	Mass & Energy Release
MFW	Main Feedwater
MSLB	Main Steam Line Break
NPSH	Net Positive Suction Head
NRC	Nuclear Regulatory Commission
OPPD	Omaha Public Power District
PD	Pump Discharge
PS	Pump Suction
RAS	Recirculation Actuation Signal
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RW	Raw Water
SDC	Shutdown Cooling
SG	Steam Generator
SGTP	Steam Generator Tube Plugging
SI	Safety Injection
SIRWT	SI and Refueling Water Tank
SIT	Safety Injection Tank

1. Purpose

Omaha Public Power District (OPPD) plans to eliminate the automatic Containment Spray (CS) actuation for a Loss-of-Coolant Accident (LOCA) at the Ft. Calhoun Station (FCS). This plant change affects the containment pressure and temperature response following a LOCA. Analyses are required to demonstrate that the plant change does not cause adverse containment conditions and that safety system parameters remain within specifications. This document summarizes the results of the analyses performed by AREVA NP in support of eliminating the automatic CS actuation following a LOCA for FCS.

The LOCA containment vapor temperature response without containment spray, using the existing FCS GOTHIC model, is overly conservative using the existing containment analysis methodology defined in Reference 1. To generate a smoother code-to-code transition that remains conservative, methodology changes were required. Those changes, used in many of the analyses that support operation without containment spray for FCS, are described herein along with the results of an assessment on the methodology changes on both hot and cold leg break analyses with and without containment spray.

GOTHIC Version 7.2a was used to perform the calculations contained in this report. The methodology changes, however, are not restricted to a specific GOTHIC computer code version but rather to the modeling approach described in this report. Therefore, AREVA NP will use the modeling approach described in Reference 1 with the addition of the methodology changes described herein with the current and future GOTHIC computer code versions.

2. Background

As part of the containment analyses performed in accordance with the containment analysis methodology in Reference 1 there is a code-to-code transition for mass and energy release (MER) data generated by RELAP5/MOD2-B&W (RELAP5) to MER calculated in GOTHIC, herein called Transition. When modeling the Transition using the existing methodology and modeling CS, there is a small increase in containment vapor temperature after Transition, which has little affect on follow-on evaluations. However, when CS is not modeled, there is almost a step change in containment vapor temperature shortly after Transition. [

] The stored energy dissipation [
], mist removal and vapor condensation by the air coolers act to dryout the containment vapor space, which allows the vapor temperature to increase dramatically. The no CS post-transition phenomenon, although very conservative, is an artifact of the conservative code-to-code transition process and would not be an anticipated outcome.

Several phenomena important in the calculation of MER from the Reactor Coolant System (RCS) were evaluated. The application of decay heat [ ] is reasonably straight forward and calculated similarly between the computer codes. Typical RELAP5 MER analyses are run for 500-1000 seconds. However, containment analyses could be performed for as long as 30 days. Straight application of decay heat to meet the LOCA Evaluation Model requirements would apply a 1.2 multiplier on ANS 1971 decay heat standard plus heavy actinides. However, the containment analysis methodology in Reference 1, Section 5.1.2.3.2.4 specifically allows a reduction in the

decay heat multiplier to 1.1 after 1000 seconds per Branch Technical Position ASB 9-2 (Reference 2). Extended RELAP5 analyses performed beyond 1000 seconds could be analyzed using this same approach.

In the existing methodology, the stored energy in the RCS metal, including the loop piping, reactor vessel and internals, core, and pressurizer are dissipated [

]. Use of an alternate method of calculating the rate at which the stored energy is dissipated [ ] was evaluated and is summarized in Section 3.3.3.

In the existing methodology, the Transition is modeled at the end of the RELAP5 MER analysis, which occurs after core quench and typically between 500-1000 seconds. Extending the time of Transition by running the RELAP5 MER analysis to as late as recirculation actuation signal (RAS) was evaluated and is summarized Section 3.3.1.

3. Containment Analyses

Various containment analyses were performed to assess the effect of eliminating the automatic containment spray actuation following a LOCA at FCS. Those analyses were performed using GOTHIC 7.2a to evaluate short and long-term containment analysis without CS. The containment air coolers were included in the model as the only active containment energy removal mechanism. Short-term containment analyses, summarized in Section 3.1, were performed to evaluate peak pressure and vapor temperature and to select the limiting hot and cold leg break cases for evaluation of the long-term phenomena. Given the limiting breaks from the short-term analysis, long-term RELAP5 MER cases were performed to generate data beyond the time of RAS, which is summarized in Section 3.2. The revised MER data was used in various containment analyses that implement the containment analysis methodology changes described herein.

An evaluation of the containment analysis methodology changes was performed for both a hot leg and cold leg pump suction break and summarized in Section 3.3. Cases analyzed with and without containment spray demonstrated acceptable containment vapor temperature response with Transition at RAS and using either the existing or alternate method of calculating the stored energy dissipation. Based on these results, the long-term containment analyses were analyzed with Transition at RAS and either the existing or alternate method of calculating the stored energy dissipation as discussed Sections 3.3.2 and 3.3.3, respectively.

Long-term containment analyses were performed for evaluation of the containment vapor temperature and sump temperature. The containment vapor temperature analysis, summarized in Section 3.4, was used in the evaluation of equipment Environmental Qualification (EQ) and the containment sump temperature profile, summarized in Section 3.5, was used in the evaluation of post-RAS net positive suction head (NPSH).

Finally, a Raw Water System / Component Cooling Water System (RW/CCW) analysis was performed to evaluate the effect of no containment spray on the peak CCW system temperature during a LOCA, which is summarized in Section 3.6.

3.1 Short-Term Containment Analysis

Containment analyses were performed without containment spray to assess the short-term impact of the LOCA blowdown and performance of containment cooling systems. The criterion for this analysis is the containment design pressure of 60 psig. Limiting cases were identified for evaluation of long-term issues. For a given mass and energy release, the containment peak pressure can change if the containment cooling capability changes, which may shift the peak time from the blowdown phase to the reflood phase. It was anticipated that these changes in peak containment pressure would not be large; however, the effect was evaluated.

A series of short-term containment analysis with containment spray were performed that demonstrated the peak containment pressure was acceptable. The results of that short-term analysis established the limiting hot and cold leg break configurations for subsequent long-term analyses with containment spray. Because the peak pressure might increase when crediting only containment air coolers, a series of short-term containment analysis cases without containment spray and with containment air coolers was analyzed. Both sets of short-term analyses, with and without containment spray, used the same RELAP5 generated mass and energy release (MER) data assuming both low and high constant containment back-pressures. The short-term containment analysis without containment spray demonstrated acceptable containment peak pressure response as shown in Table 1. Major inputs used in the short-term containment analyses are shown in Table 3.

The limiting peak containment pressure is 68.67 psia at a time of 13.22 seconds from a double-ended hot leg break with a discharge coefficient of 0.6, loss-of-offsite power (LOOP), single failure of EDG 1, minimum emergency core cooling system (ECCS), and a constant low containment backpressure during the mass and energy release analysis. The limiting peak containment vapor temperature is 277.44°F at a time of 13.04 seconds, from the same hot leg break case. A limiting peak containment pressure for cold leg breaks of 67.63 psia at a time of 165.88 seconds occurred for a double-ended cold leg pump suction break with a discharge coefficient of 0.8, LOOP, single failure of EDG 1, minimum ECCS, and a constant low containment backpressure during the mass and energy release analysis. The corresponding peak containment vapor temperature of 275.80°F at a time of 20.08 seconds was observed for the same cold leg break case. A complete set of results for the short-term LOCA containment analysis is shown in Table 1.

Using the site-specific atmospheric pressure of 14.2 psia, the peak containment pressure of 54.47 psig was obtained. The short-term analysis demonstrates that the peak containment pressure following a LOCA without containment spray meets the acceptance criterion of 60 psig. A majority of the peak pressures and temperatures occur prior to initiation of containment cooling. Thus, the spectrum analysis confirmed, as anticipated, that the hierarchy of limiting hot and cold leg breaks remained unchanged regardless of whether containment spray was modeled or not.

An additional purpose for analyzing the complete set of short-term cases without containment spray was to confirm that the sequence of evaluating the sensitivity studies (i.e., break size and location, availability of offsite power, single failure) remains valid in defining the limiting configuration. This verification was required because evaluation of the containment analysis methodology change discussed in Section 3.3 required running the limiting hot and cold leg RELAP5 MER analysis to at least the time of recirculation actuation signal (RAS). The evaluation

demonstrated that the sequence of performing the sensitivity studies remains valid, requiring no additional short-term cases be analyzed.

Therefore, the results of the short-term analysis confirmed that the selection of limiting cases remains valid for long-term analysis without containment spray. Containment pressure and vapor temperature for the limiting short-term cases are included as Figure 1 and Figure 2, respectively.

3.2 Mass and Energy Release Analysis

No additional short-term MER cases had to be analyzed based on the results of the short-term containment analyses performed without containment spray as discussed in Section 3.1. However, because of the methodology changes discussed in Section 3.3 the limiting hot and cold leg break MER analyses were run to RAS.

The existing short-term MER cases analyzed with RELAP5 support various short-term and long-term analyses with containment spray. The same MER datasets were used to evaluate the short-term containment response without containment spray summarized in Section 3.1. The RELAP5 cases associated with the limiting short-term containment analysis without containment spray discussed in Section 3.1 were run for 10,000 seconds to exceed the time of the RAS. Additional control variables were added to the model to support the alternate method of calculating the stored energy dissipation rates as discussed in Section 3.3.3.

The only other change made to the models for the long transient runs was to modify the implementation of core decay heat as discussed in Section 3.3.1. Major inputs used in the mass and energy release analyses are shown in Table 3.

The MER datasets from the long-term cases were extracted for use in various long-term containment analyses. Additional datasets were generated to define the average RCS conditions and heat structure and fluid stored energy values at the required transition times for subsequent analyses with and without containment spray. [

] The output of the added control variables were summarized at the same transient times as the stored energy datasets.

3.3 Containment Analysis Methodology Changes

The approved containment analysis methodology implements a code-to-code transition for MER from RELAP5 to GOTHIC after core quench in Reference 1, Section 5.1.2.3.2. A significant quantity of energy is stored in the primary and secondary heat structures and secondary fluid that dissipates over time to the RCS liquid and vapor and ultimately to the containment through the break as liquid and/or vapor. The containment analysis methodology in Reference 1 stipulates that the stored energy is transferred [ ] at rates calculated as discussed in Section 3.3.2.

Preliminary analyses without containment spray demonstrated that containment vapor temperature increased dramatically after Transition [

]. This behavior, although conservative, is unrealistic for many long-term containment analyses. Therefore,

methods were pursued that would give a conservative, yet more reasonable containment vapor temperature response. Two method changes were evaluated separately and in combination in the area of mass and energy release and stored energy dissipation.

The first approach is to delay transition to the time of RAS to produce a continuous containment vapor temperature response during a portion of the LOCA long-term transient when there are no changes in equipment operation that would upset the quiescent state of the RCS and containment. The RELAP5 simulation would be extended to a time beyond RAS. The mass and energy release rates from this system analysis (i.e., RELAP5) would be used in the containment analysis up to RAS. After Transition at RAS, the GOTHIC code would perform the MER rates.

[

] Further discussions of the existing and alternate methods of performing these calculations are included in Sections 3.3.2 and 3.3.3, respectively.

Each of these methodology changes was evaluated with and without containment spray as discussed in Section 3.3.4.

3.3.1 Extended RELAP5 Simulation

Extension of the Transition time to RAS requires continuation of the short-term MER analysis to the time of RAS. Only two substantive changes are required to extend the RELAP5 to RAS. The first change is to modify the implementation of core decay heat. The core heat input to the fuel from the existing kinetics model is retained through 1000 seconds. After 1000 seconds the model is modified to transition from the output of the kinetics model to decay heat values calculated based on ASB 9-2 (Reference 2). Ultimately, this method transitions the decay heat multiplier from 1.2 to 1.1 at 1000 seconds. The second change is to add control variables to the model to support the alternate method of calculating the stored energy dissipation rates as discussed in Section 3.3.3. [

]

The analysis is run for a duration that bounds the time of RAS for the cases to be evaluated accounting for the combination and mode of equipment operation that defines the latest SIRWT depletion time.

3.3.2 Existing Calculation Method

The currently approved method of calculating the rates at which the primary metal stored energy is dissipated [ ] is defined in Reference 1, Section 5.1.2.3.2.2. [

]

The existing method of calculating the rates at which the secondary stored energy, metal plus fluid, is dissipated [ ] is defined in Reference 1, Section 5.1.2.3.2.3. [ ]

3.3.3 Alternate Calculation Method

[ ] An alternate dissipation rate method was developed [ ]. The total stored energy to be dissipated is calculated the same as the existing method.]

3.3.4 Calculation Method Assessment

As discussed above, two changes to the containment analysis methodology were evaluated. Those analyses were performed with and without containment spray, for limiting hot leg and cold leg breaks, and separately and together. Plots of containment pressure, vapor temperature and liquid temperature are included in Figure 3 through Figure 14. Discussions of those analyses, based on a review of the containment vapor temperature responses, are included in Section 3.3.4.1 for cases with containment spray and Section 3.3.4.2 for cases without containment spray. The conclusion of the assessment was that each method is acceptable at generating a conservative containment response following transition. The methods can be applied separately or together and are applicable to hot and cold leg breaks with and without containment spray.

For the purposes of this assessment, stored energy dissipation was forced to be completely dissipated by 24 hours (86,400 seconds) by increasing the energy dissipation rates, as necessary. This approach is conservative for analyses such as those required to evaluate the reduction in containment pressure to half of the peak pressure in 24 hours. This technique is not required by the containment analysis methodology defined in Reference 1. However, it provides a common point of reference for the assessment of the methodology changes.

3.3.4.1 Containment Response with Containment Spray

Cases were analyzed with containment spray in operation to evaluate the effect of the changes in methodology in that configuration. Those cases were analyzed without containment air coolers in

operation and with shutdown coolers in operation consistent with the existing FCS GOTHIC LOCA long-term containment analysis model. The following observations apply to the containment vapor temperature response as shown in Figure 4 and Figure 7: For the purposes of this evaluation, early Transition corresponds to 1000 seconds, extended Transition corresponds to the time of RAS (~4280 seconds), existing energy method corresponds to the currently approved method of calculating the energy dissipation rates, and alternate energy method corresponds to the alternate method of calculating the energy dissipation rates.

- Early Transition with the existing energy method generates a small peak immediately after Transition[ ].
- Early Transition with the existing energy method generates large post-RAS peak caused by the spray temperature increase at RAS when suction is switched from the safety injection and refueling water tank (SIRWT) to the containment sump. Additionally, there is a reduction in safety injection (SI) flow due to the manual isolation of low pressure safety injection (LPSI) and increase in SI temperature caused by the shift in suction from the SIRWT to the containment sump.
- Use of the alternate energy method with early Transition reduced the containment vapor temperature in comparison to the early Transition with existing energy dissipation method from the time of Transition to the time of RAS. The code-to-code transition produced a relatively smooth and continuous vapor temperature response, as would be expected during this phase of the event.
- Use of the alternate energy method with early Transition generated a lower post-RAS peak compared to early Transition with the existing energy method.
- Early Transition with the existing and alternate energy methods evolve to approximately the same end state, which is expected because the stored energy dissipation has terminated by the end of the analysis.
- Extended Transition with the existing and alternate energy methods generated a smooth response out to RAS because a continuous set of data was used for the cases. The vapor temperature remained relatively close to that of the case with early Transition and the alternate energy method.
- Extended Transition with the existing and alternate energy methods generated similar responses post-RAS with the post-RAS peaks below that of the early Transition cases, which is caused by lower stored energy dissipation rates.
- Extended Transition with the existing and alternate energy methods evolve to approximately the same end state.
- Ultimately, all cases will evolve to the same end state defined by the decay heat and energy removal capabilities.

The conclusion of the evaluation of the containment analysis methodology changes for cases with containment spray is that extended Transition generates a smooth transient response out to RAS because of the continuity of the MER data. Early Transition with the alternate calculation of the stored energy dissipation rates generates a relatively smooth response out to RAS because of the redistribution of the stored energy dissipation; however, post-RAS response is decreased only

slightly. Significant reductions in the post-RAS containment response occur as a result of the late Transition with either the existing or alternate calculation of the stored energy dissipation rates, which generate approximately the same response. These observations apply to both the hot leg and cold leg break containment analyses.

3.3.4.2 Containment Response without Containment Spray

Cases were analyzed without containment spray to evaluate the effect of the changes in methodology in that configuration. Those cases were analyzed with containment air coolers in operation and without shutdown cooler operation consistent with the FCS GOTHIC LOCA long-term containment analysis model. The following observations apply to the containment vapor temperature response as shown in Figure 10 and Figure 13, For the purposes of this evaluation early Transition corresponds to 1000 seconds, extended Transition corresponds to the time of RAS (~8780 seconds), existing energy method corresponds to the currently approved method of calculating the energy dissipation rates, and alternate energy method corresponds to the alternate method of calculating the energy dissipation rates.

- Early Transition with the existing energy method generates a large peak immediately after Transition[ ].
- Early Transition with the existing energy method generates large post-RAS peak caused by the reduction in SI flow due to the manual isolation of LPSI and increase in SI temperature caused by the shift in suction from the SIRWT to the containment sump.
- Use of the alternate energy method with early Transition reduced the containment vapor temperature in comparison to the early Transition with existing energy dissipation method from the time of Transition to the time of RAS. The code-to-code transition produced a relatively smooth and continuous vapor temperature response, as would be expected during this phase of the event.
- Use of the alternate energy method with early Transition generated a lower post-RAS peak compared to early Transition with the existing energy method.
- Early Transition with the existing and alternate energy methods evolve to approximately the same end state, which is expected because the stored energy dissipation has terminated by the end of the analysis.
- Extended Transition with the existing and alternate energy methods generated a smooth response out to RAS because a continuous set of data was used for the cases. The vapor temperature remained relatively close to that of the case with early Transition and the alternate energy method.
- Extended Transition with the existing and alternate energy methods generated similar responses post-RAS with the post-RAS peaks below that of the early Transition cases, which is caused by lower stored energy dissipation rates.
- Extended Transition with the existing and alternate energy methods evolve to approximately the same end state.

- Ultimately, all cases will evolve to the same end state defined by the decay heat and energy removal capabilities.

The conclusion of the evaluation of the containment analysis methodology changes for cases with containment spray is that extended Transition generates a smooth transient response out to RAS because of the continuity of the MER data. Early Transition with the alternate calculation of the stored energy dissipation rates generates a relatively smooth response out to RAS because of the redistribution of the stored energy dissipation; however, post-RAS response is decreased only slightly. Significant reductions in the post-RAS containment response occur as a result of the late Transition with either the existing or alternate calculation of the stored energy dissipation rates, which generate approximately the same response. These observations apply to both the hot leg and cold leg break containment analyses.

3.4 Long-Term Containment Pressure and Vapor Temperature Analysis

A LOCA containment analysis was performed to evaluate long-term pressure and vapor temperature response. Specifically, the results of the analysis were evaluated to ensure that the containment pressure decreases to less than half the peak pressure within 24 hours. The limiting hot leg and cold leg break long-term cases with containment spray were analyzed without containment spray. The analysis was performed with the time of transition at RAS and the stored energy dissipation rates calculated using both the approved and alternate methods discussed in Section 3.3. A single train of Containment Air Coolers (CACs) was modeled with one Component Cooling Water (CCW) Pump in operation. Credit was taken for operator action at 30 minutes to power a second CCW pump, which increased the CCW flow on the secondary side of the CACs. The increased CCW flow increased the heat transfer capability of the CACs. However, a conservatively low heat removal capacity of the single train of containment air coolers was maintained.

As shown in Figure 17, containment pressures at 24 hours of 24.81 psia and 23.93 psia were obtained for the hot leg and cold leg breaks, respectively. Containment peak pressures of 68.67 psia and 67.63 psia were reported in Section 3.1 for the hot leg and cold leg breaks, respectively. These results demonstrate that containment pressure was reduced to less than ½ the peak within 24 hours without containment spray.

Plots of containment vapor temperature without containment spray are included in Figure 18 that shows the results for both the hot leg and cold leg break cases with the code-to-code transition at RAS and the alternate energy dissipation methodology. Containment vapor temperatures for the analyses without containment spray remain well below vapor temperatures from the analyses of record (AOR) for a majority of the transient as shown in Figure 15 and Figure 16 for the hot leg and cold leg breaks, respectively. Prior to RAS, there are periods where the vapor temperatures for the AOR are slightly below the new analysis values. However, the temperature differences are small and of very short duration, which are clearly compensated by the significant long-term differences. Therefore, elimination of the automatic containment spray actuation following a LOCA satisfies the equipment qualification requirements.

3.5 Long-Term Containment Sump Temperature Analysis

In general, the NPSH requirements for ECCS equipment taking suction from the containment sump are less without containment spray than with containment spray. Without containment spray, high pressure safety injection (HPSI) is the only system taking suction from the containment sump. Regardless, a LOCA containment analysis was performed to evaluate long-term sump temperature, specifically for use in providing input to NPSH calculations for equipment taking suction from the containment sump. The limiting hot leg and cold leg break long-term cases with containment spray were analyzed without containment spray. The analysis was performed with the time of transition at RAS and the stored energy dissipation rates calculated using the existing method discussed in Section 3.3. The resulting sump temperature, subcooling head, over-pressure head, and total available head as a function of time after RAS from the long-term containment sump temperature analysis are included in Table 2 for the limiting hot leg and cold leg breaks.

The cold leg pump suction break case analyzed generated the highest sump temperature at RAS (8780 sec) of 196.1°F with a corresponding containment pressure and vapor temperature of 21.9 psia and 181°F. A peak sump temperature following RAS of 196.6°F was observed approximately 2.9 hours after RAS. The sump temperatures without containment spray are less than the 209.6°F at RAS from the AOR with containment spray. The AOR calculated a subcooling head exceeding 8.99 ft within 2 hours after RAS. For the case without containment spray, the subcooling head exceeds 8.99 ft within 7.2 hours after RAS. Given the lower suction flowrate from the containment sump without containment spray and the lower sump temperatures, the NPSH requirements are clearly met.

3.6 CCW/RW Peak Temperature Analysis

The peak temperature of the component cooling water (CCW) system and limit on the raw water (RW) system maximum temperature are a function of the containment vapor temperature and humidity for the containment air coolers throughout the transient and sump temperature for the shutdown cooling (SDC) system after RAS. The post-LOCA transient behavior generates two peaks in heat load on the CCW and RW systems with the first occurring after containment peak vapor temperature and the second occurring after RAS. The pre-RAS peak CCW temperature with containment spray is more limiting for FCS than the post-RAS peak.

A change in containment response occurs because of the proposed change to eliminate actuation of containment spray following a LOCA and the unavailability of SDC after RAS without containment spray. Therefore, an evaluation was required of the pre-RAS impact on the CCW system following LOCA with containment air coolers as the only active means of containment energy removal. The post-RAS peak in containment vapor temperature is lower than the pre-RAS peak regardless of spray operation. Therefore, the containment air cooler heat load is lower post-RAS. Additionally, the post-RAS heat load is reduced by the lack of heat removal from SDC. Based on the aforementioned system response, the pre-RAS CCW temperature peak will be limiting regardless of CS operation.

Based on the results of the methodology change evaluation discussed in Section 3.3.4, the post-transition containment vapor temperature response, which is the major contributor to containment air cooler heat load, decreases smoothly to RAS with either a code-to-code transition at RAS or the

alternate method of calculating the stored energy dissipation rates with early or extended transition times. Therefore, only the pre-transition response need be evaluated for CCW heat load.

The limiting hot leg and cold leg break cases from the RW/CCW analysis with containment spray were run without containment spray. The hot leg and cold leg pump suction CCW temperatures at the containment air cooler secondary inlet are depicted in Figure 19. The peak CCW temperatures at the containment air cooler secondary inlet were 152.6°F and 156.4°F for the limiting hot leg and cold leg pump suction breaks, respectively. These temperatures are only slightly above the same cases with containment spray and remain less than the maximum allowed temperature of 160°F. The RW system inlet temperature remained at 90°F. The main steam line break (MSLB) transient results – which would continue to have an automatic containment spray actuation - remain bounding.

Therefore, operation without containment spray is acceptable with respect to RW/CCW operation.

4. Summary and Conclusions

As a result of eliminating the automatic actuation of containment spray following a LOCA at FCS, the containment vapor temperature response was found to be overly conservative. Therefore, changes to the existing containment analysis methodology defined in Reference 1 were investigated to alleviate the overly conservative response. Two methods changes were evaluated, later code-to-code transition from RELAP5/MOD2-B&W to GOTHIC for MER calculations and an alternate method of calculating stored energy dissipation rates. Both methodology changes (i.e., alternate energy dissipation calculation and Transition as late as RAS) were found to be acceptable at generating reasonable and conservative results separately and together for hot and cold leg breaks with and without containment spray. The overly conservative vapor temperature response was not as significant or prevalent when CS is modeled. Therefore, the existing methodology remains acceptable for containment analyses with containment spray in operation.

Analyses were performed to evaluate various aspects of the post-LOCA containment response for issues such as containment peak pressure, containment pressure reduced to half the peak in 24 hours, RW/CCW peak temperature and RW maximum temperature limit, which were found to be acceptable. Analyses were performed to generate conservative long-term containment vapor and sump liquid temperature responses that generate acceptable results in regard to equipment qualification and NPSH conditions in containment.

Both proposed changes to the AREVA NP containment analysis methodology, extending the code-to-code transition to RAS and alternate stored energy dissipation, were used in these analyses. Therefore, Nuclear Regulatory Commission (NRC) approval of these methodology changes is required prior to implementation of the results of these analyses.

5. References

1. AREVA Document 43-10252PA-00, "Analysis of Containment Response to Postulated Pipe Ruptures Using GOTHIC."
2. NUREG-0800, Section 9.2.5, Revision 2, Branch Technical Position ASB 9-2, "Residual Decay Energy for Light Water Reactors for Long-term Cooling."

Table 1: Short-Term Containment Analysis Results - No Containment Spray

	Peak Pressure		Peak Temperature		Break			ECCS	CTM	Offsite	MER Single
Case	(psia)	(sec)	(°F)	(sec)	Location	Configuration	C_d	Flow	Pressure	Power	Failure
HL1A-BTQC_NS	68.03	10.00	276.67	9.96	HL	DEG	1.0	Max	High	Avail	Note 1
HL1ALP-BYWR_NS	68.30	10.38	277.02	10.24	HL	DEG	1.0	Max	Low	Avail	Note 1
HL1BLP-CTLI_NS	68.28	10.38	277.00	10.27	HL	DEG	1.0	Max	Low	LOOP	Note 1
HL2ALP-BAEC_NS	*68.28*	*10.38*	*277.00*	*10.27*	*HL*	*DEG*	*1.0*	*Min*	*Low*	*LOOP*	*EDG 1*
HL2BLP-BEKS_NS	68.28	10.38	277.00	10.27	HL	DEG	1.0	Min	Low	LOOP	EDG 2
HL3A-BWER_NS	68.50	11.27	277.26	10.99	HL	DEG	0.8	Min	Low	LOOP	EDG 1
HL3A1-CMND_NS	**68.67**	**13.22**	**277.44**	**13.04**	HL	DEG	0.6	Min	Low	LOOP	EDG 1
HL3A2-BWVF_NS	68.25	16.00	276.86	15.85	HL	DEG	0.4	Min	Low	LOOP	EDG 1
HL3BBRKR-CRDR_NS	68.63	13.21	277.38	13.05	HL	Split	2A	Min	Low	LOOP	EDG 1
PD1E-BXJA_NS	66.92	16.83	275.11	16.69	PD	DEG	1.0	Max	High	Avail	Note 1
PD1ELP-BPCO_NS	67.05	17.12	275.27	16.93	PD	DEG	1.0	Max	Low	Avail	Note 1
PD1FLP-BIPH_NS	67.21	17.29	275.46	17.08	PD	DEG	1.0	Max	Low	LOOP	Note 1
PD2ELP-CGFA_NS	67.21	17.29	275.46	17.08	PD	DEG	1.0	Min	Low	LOOP	EDG 1
PS1C-CASJ_NS	67.47	18.91	275.77	18.80	PS	DEG	1.0	Max	High	Avail	Note 1
PS1CLPR-CJMH_NS	67.60	19.10	275.93	18.95	PS	DEG	1.0	Max	Low	Avail	Note 1
PS1D-CYVA_NS	67.28	18.59	275.53	18.45	PS	DEG	1.0	Max	High	LOOP	Note 1
PS1DLPR-BPYI_NS	67.36	18.74	275.64	18.61	PS	DEG	1.0	Max	Low	LOOP	Note 1
PS2CLP-CBWR_NS	67.57	173.57	275.64	18.61	PS	DEG	1.0	Min	Low	LOOP	EDG 1
PS2DLP-BYLG_NS	67.40	189.49	275.64	18.61	PS	DEG	1.0	Min	Low	LOOP	EDG 2
PS3C-CFSP_NS	**67.63**	**165.88**	**275.80**	**20.08**	PS	DEG	0.8	Min	Low	LOOP	EDG 1
PS3DAR1-BRGD_NS	67.41	21.29	275.66	21.13	PS	DEG	0.6	Min	Low	LOOP	EDG 1
PS3EBR1-BNIG_NS	67.24	19.65	275.46	19.59	PS	Split	2A	Min	Low	LOOP	EDG 1
PS3FAR-BYXC_NS	67.44	24.30	275.64	24.14	PS	Split	1A	Min	Low	LOOP	EDG 1
Maximum	68.67		277.44								

Notes:

1. The single failure is taken in the containment analysis.

Table 2: Long-Term Sump Temperature Analysis Results - No Containment Spray

Time since RAS	Hot Leg Break				Cold Leg Break			
	Sump Temperature (°F)	Subcooling Head (ft)	Overpressure Head (ft)	Total Available Head (ft)	Sump Temperature (°F)	Subcooling Head (ft)	Overpressure Head (ft)	Total Available Head (ft)
RAS	191.1	10.71	17.04	27.74	196.1	8.24	17.84	26.08
1 hour	190.5	10.98	22.57	33.56	195.9	8.35	23.97	32.32
2 hours	191.9	10.32	22.67	32.98	196.5	8.05	23.67	31.72
3 hours	192.8	9.90	22.46	32.36	196.6	7.96	23.23	31.19
4 hours	193.2	9.67	22.21	31.88	196.5	8.05	22.78	30.84
5 hours	193.3	9.62	21.88	31.50	196.1	8.26	22.30	30.56
10 hours	191.2	10.66	19.99	30.65	192.5	10.04	19.92	29.96
24 hours	182.4	14.49	14.68	29.18	179.5	15.60	13.29	28.89
7 days	162.1	21.28	7.49	28.77	162.0	21.30	6.92	28.22
30 days(1)	154.4	23.22	5.08	28.29	154.2	23.24	4.52	27.76

Notes:

1. The 30 day value is the data from the end of the computer run, which is roughly 800 seconds short of RAS plus 30 days.
2. The Subcooling Head and Overpressure Head were calculated with a FCS specific atmospheric pressure of 14.2 psia.
3. The Subcooling Head and Overpressure Head were calculated relative to STP (i.e., density of 62.4 lbm/ft^3). Therefore, Total Available Head also is relative to STP.

Table 3: LOCA Containment Analysis Inputs – No Containment Spray	
Parameter	Value
Containment	
Free Volume	1,044,469.86 ft^2
Initial Temperature	120°F
Initial Pressure	17.2 psia
Initial Relative Humidity	30%
Spray Flowrate	0 gpm
Spray Delay Time	N/A
Fan Cooler Heat Removal Rate(1) w/vapor at 288°F and CCW at 120°F	100e6 BTU/hr (<1800 sec) 150e6 BTU/hr (≥1800 sec)
Fan Cooler Air Flowrate (CACF/CAC)	77,400 cfm / 46,800 cfm
Fan Cooler Start Delay Time (CACF / CAC)	39.5 sec / 70.0 sec
Liquid/Vapor Interface Area	Short-term: 0 ft^2, Long-term: DEFAULT
SIRWT Temperature	115°F (only used for spray)
SIT Nitrogen Mass Flowrate	53.35 lbm/sec for 50 seconds
SIT Nitrogen Temperature	417.84°F
Revaporization Fraction	DEFAULT
RCS Conditions	
Core Power	1530 MWt
Decay Heat	1.2 * ANS71 + B&W Actinides (≤ 1000 sec)
	1.1 * ANS71 + B&W Actinides (> 1000 sec)
RCP Power	1.4 MWt / pump
Core Inlet Temperature	545.1°F
Core Outlet Temperature	594.8°F
Pressurizer	
Pressure	2123.2 psia
Initial Liquid Volume	700 ft^3
MFW & SGTP	
Temperature	447.5°F
Flow	951 gpm / SG (target)
Tube Plugging	0%
Pumped ECCS	
Actuation Pressure	Coincident with break
Delay Time	12.9 sec w/Offsite Power
	30.0 w/out Offsite Power
SIRWT Liquid Temperature	120°F
SIT	
Liquid Volume	815.4 – 909.0 ft^3
Minimum Gas Pressure	240 ± 12.4 psig
Maximum Gas Pressure	275 ± 12.4 psig
Liquid Temperature	120°F
Surge Line Lengths	85.115 ft, 70.92 ft, 98.506 ft, 70.176 ft
Elevation Change	8.625 ft
Liquid Volume from Check Valve to RCS	72.9 ft^3
Line K-factor	6.98 based on A=0.5592 ft^2

Notes:

1. Operator action is credited at 30 minutes to start a second CCW pump.

Figure 1: Short-Term Containment Pressure Response without Containment Spray

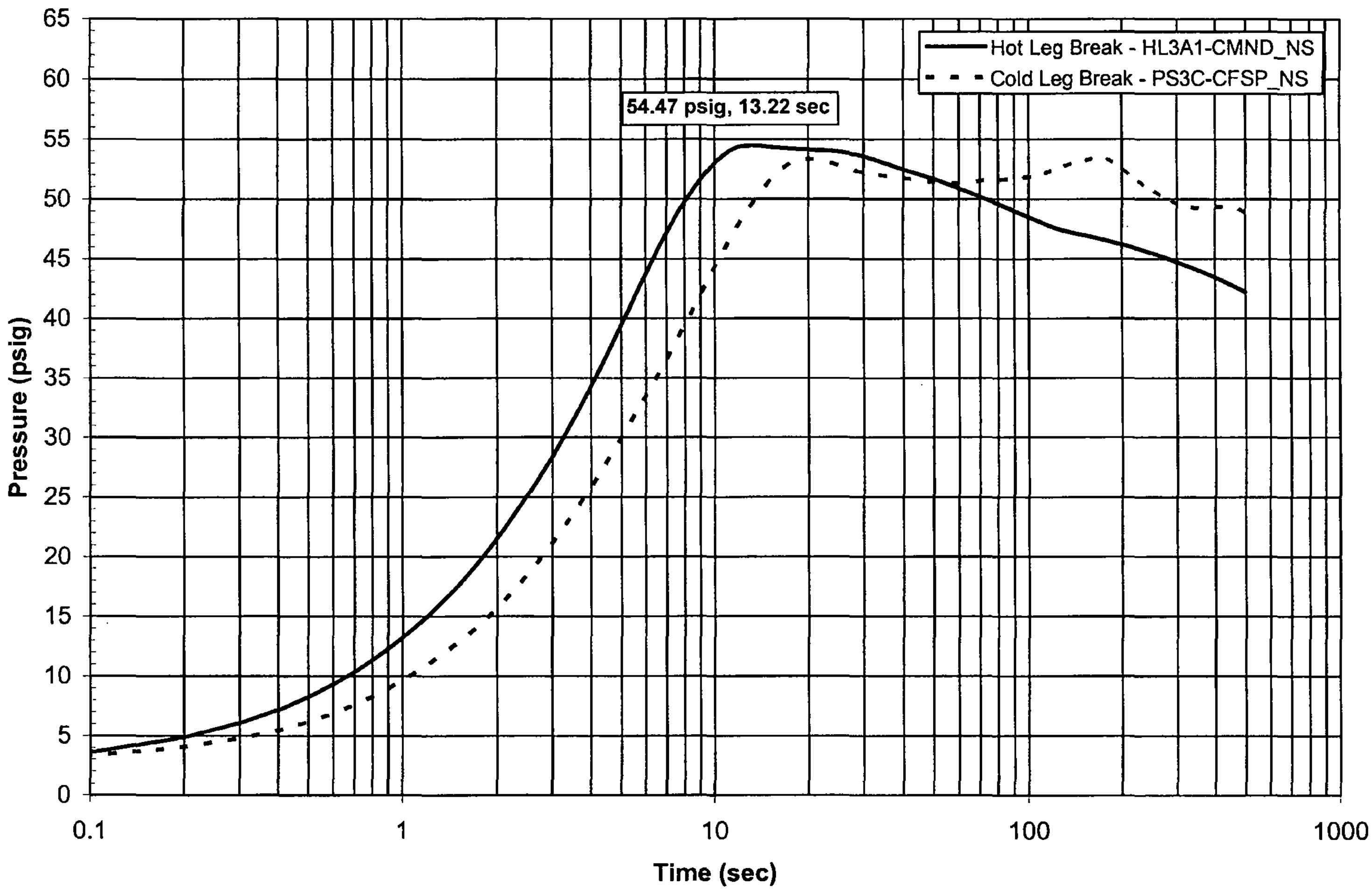

Figure 2: Short-Term Containment Vapor Temperature Response without Containment Spray

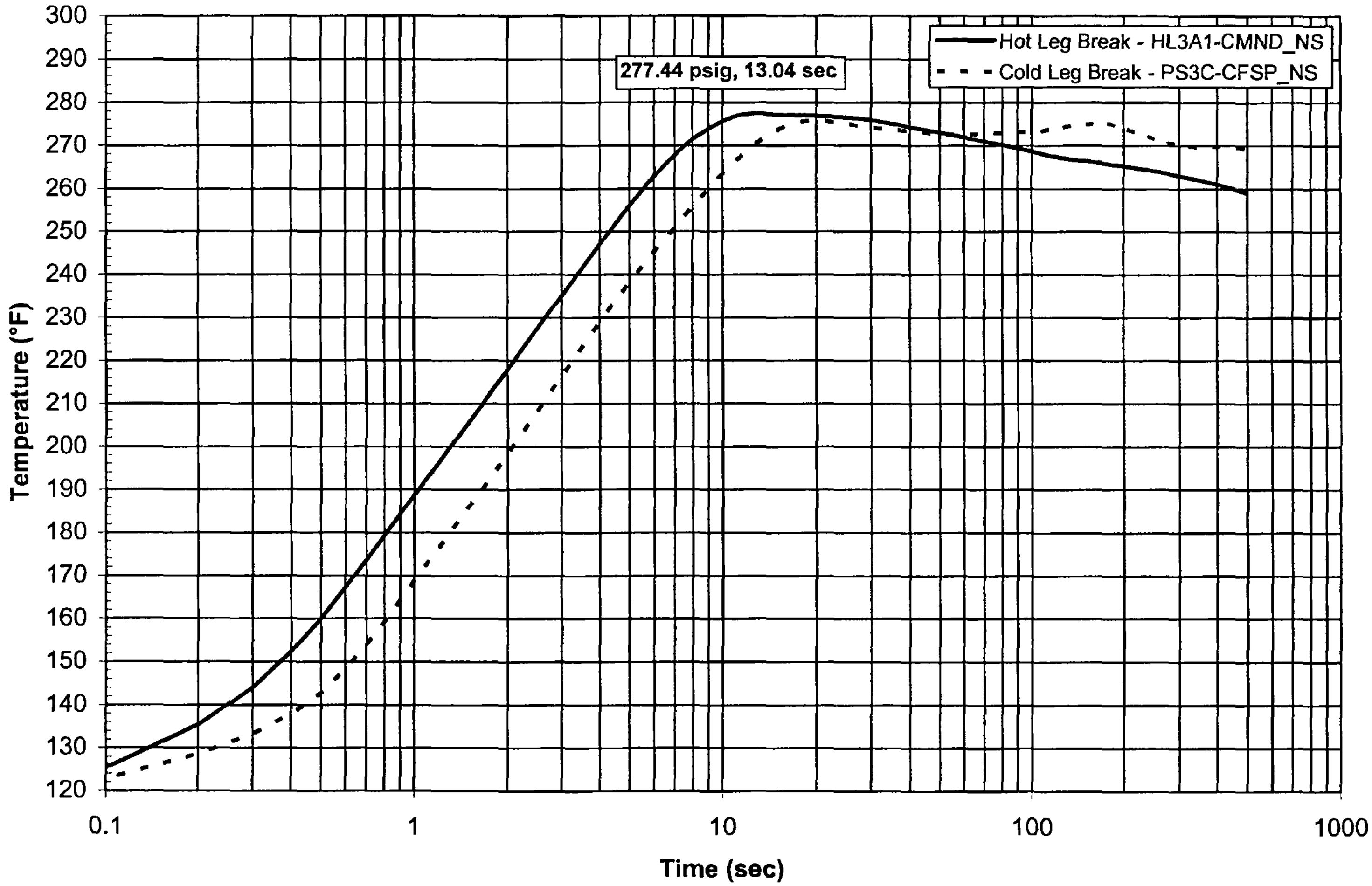

Figure 3: Hot Leg Break Containment Pressure with Containment Spray

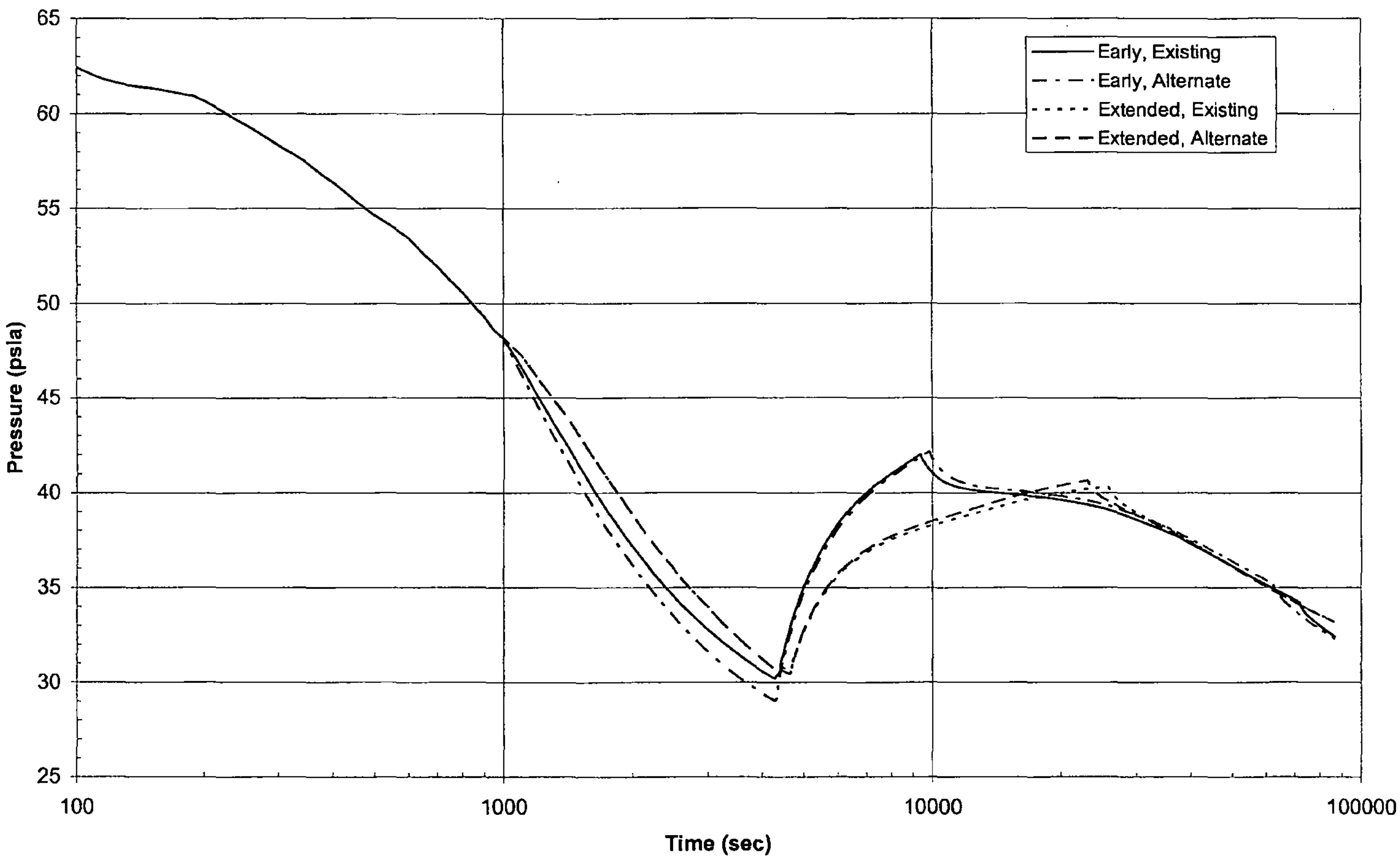

Figure 4: Hot Leg Break Containment Vapor Temperature with Containment Spray

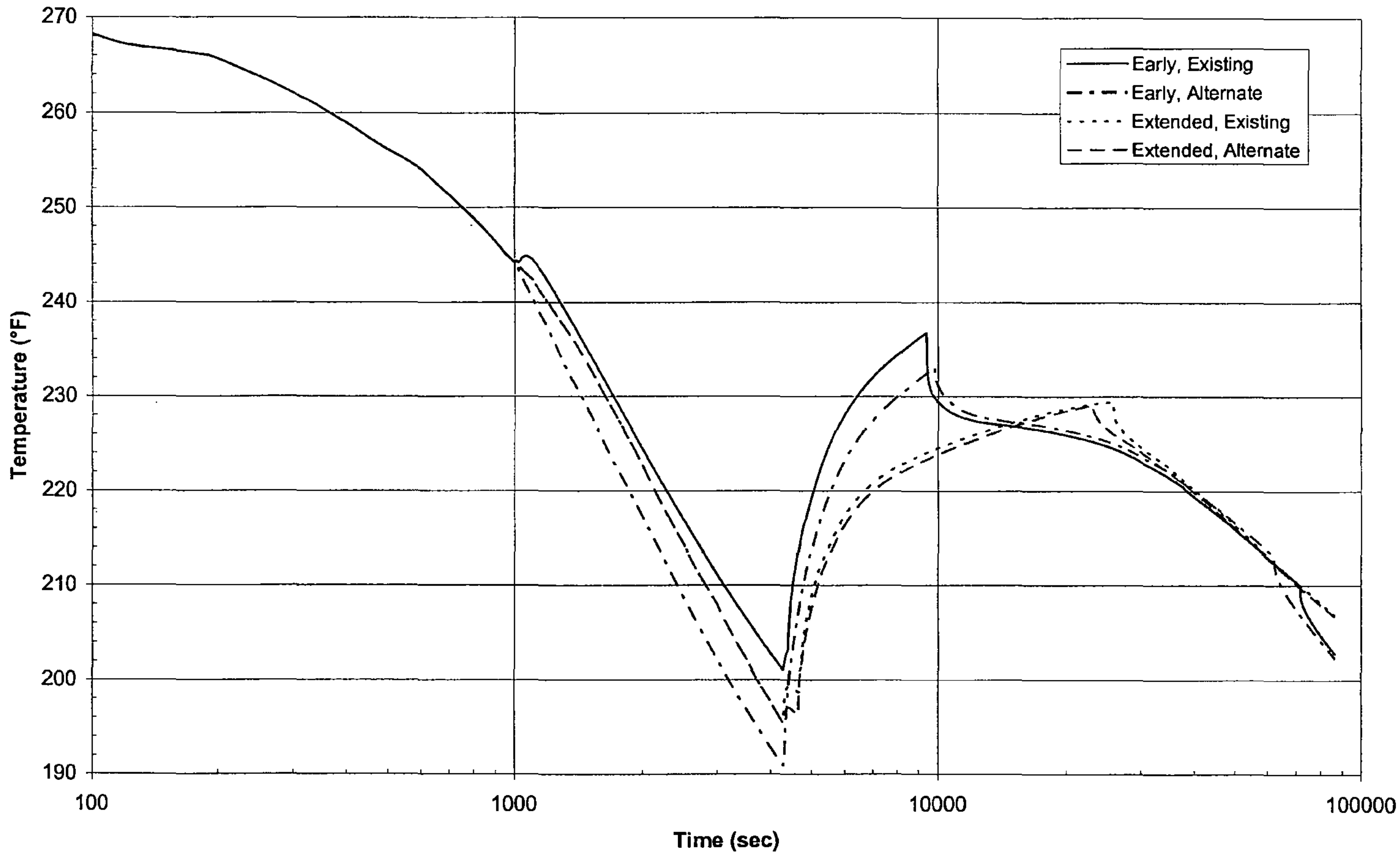

Figure 5: Hot Leg Break Containment Liquid Temperature with Containment Spray

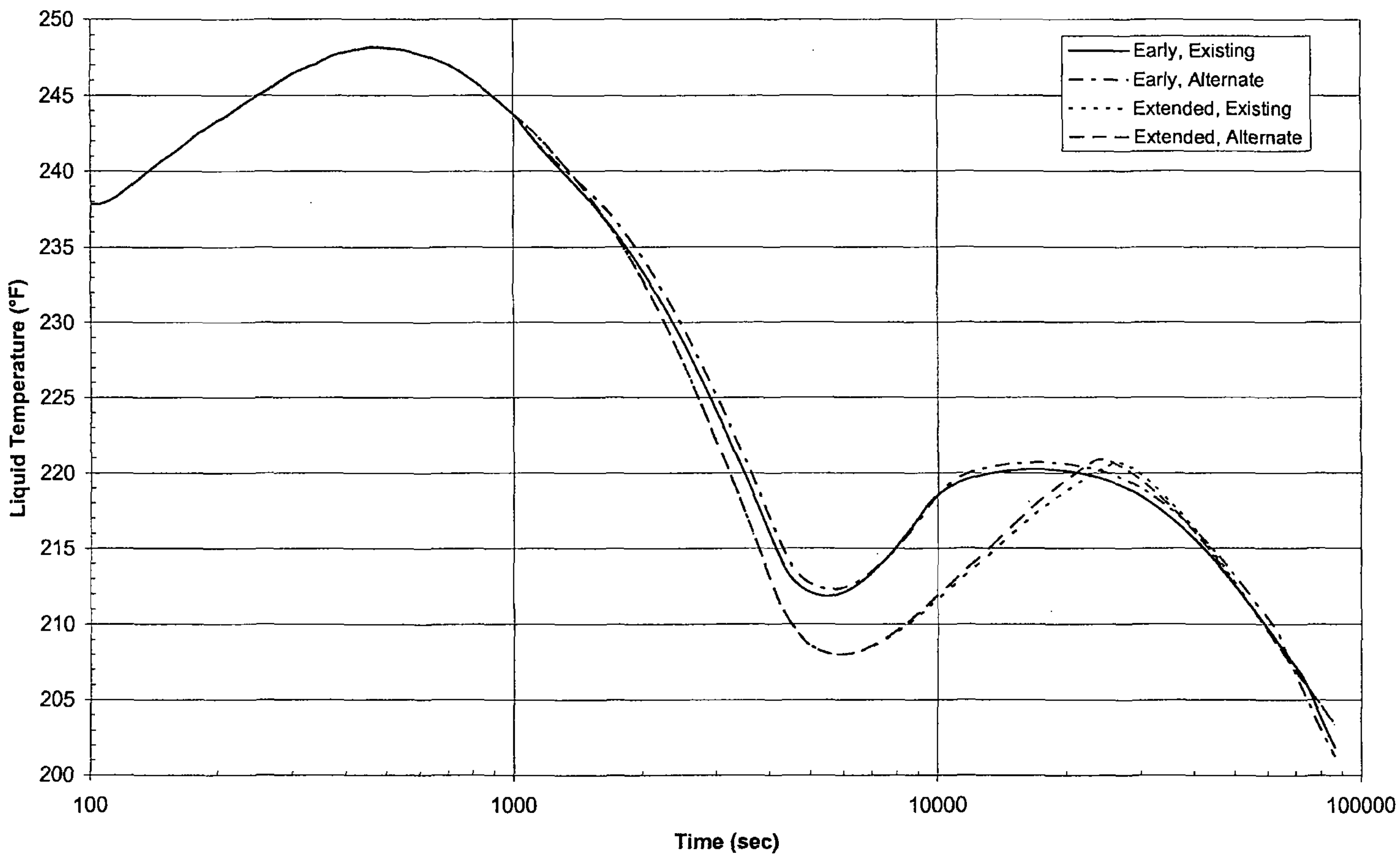

Figure 6: Cold Leg Break Containment Pressure with Containment Spray

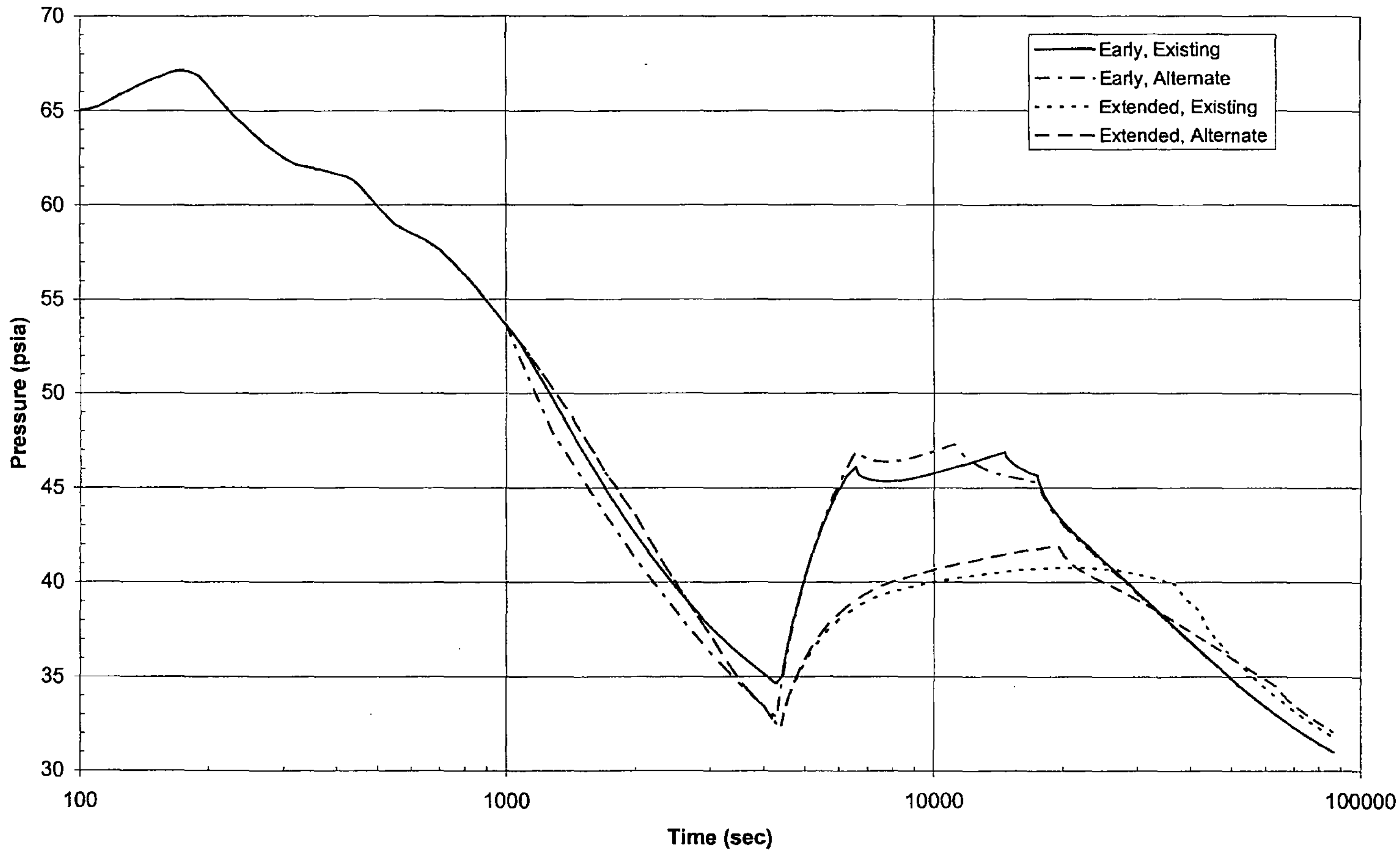

Figure 7: Cold Leg Break Containment Vapor Temperature with Containment Spray

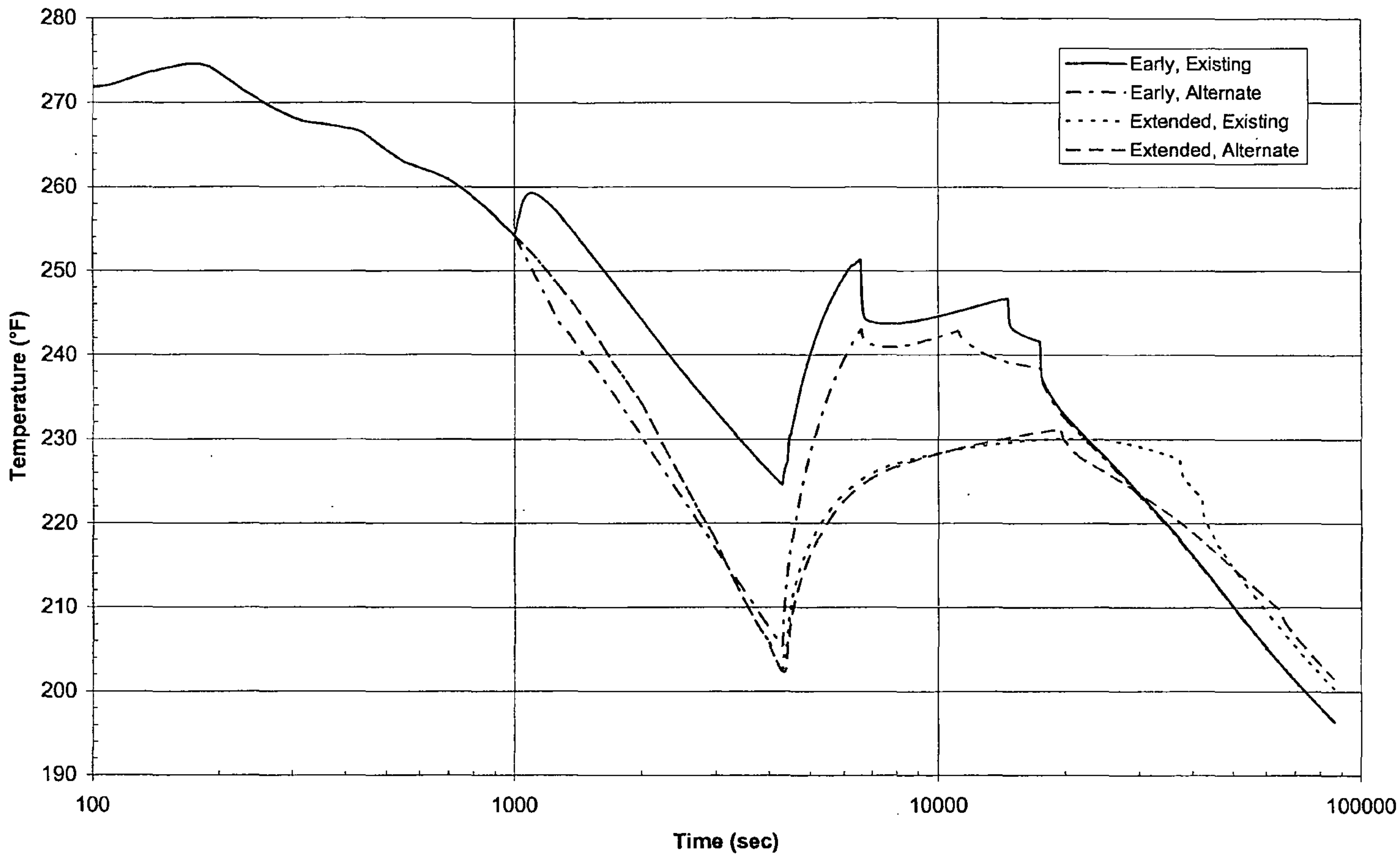

Figure 8: Cold Leg Break Containment Liquid Temperature with Containment Spray

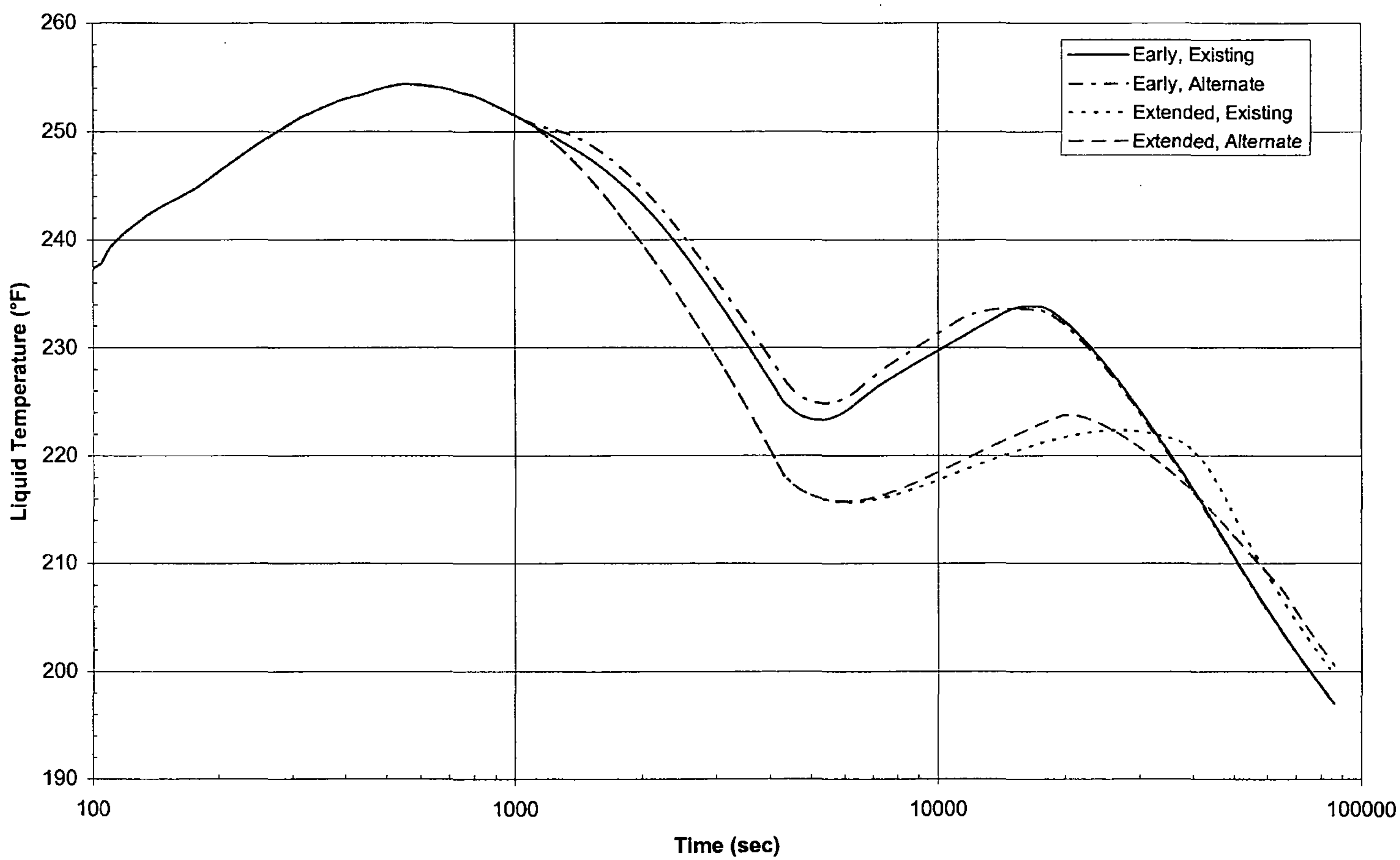

Figure 9: Hot Leg Break Containment Pressure without Containment Spray

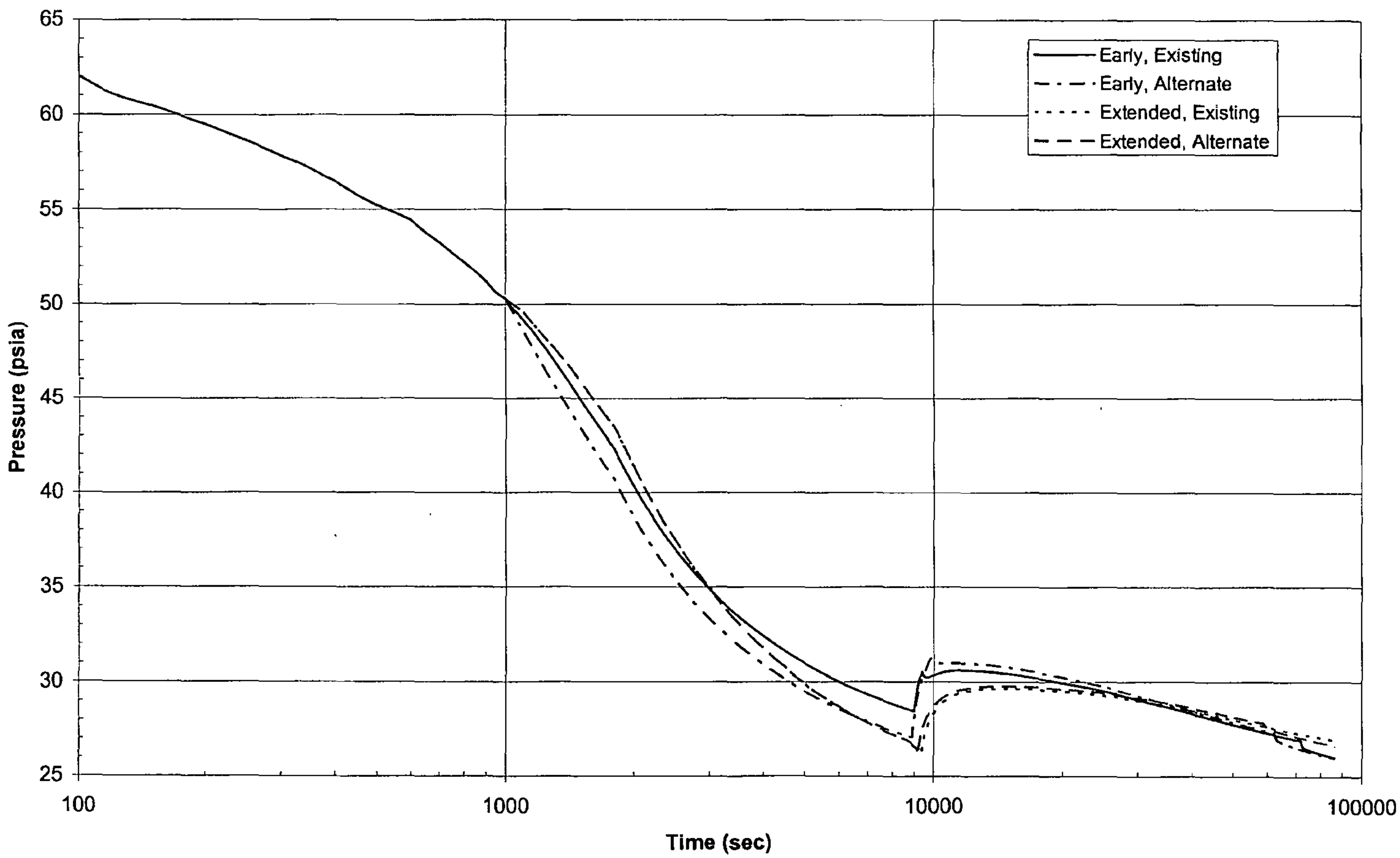

Figure 10: Hot Leg Break Containment Vapor Temperature without Containment Spray

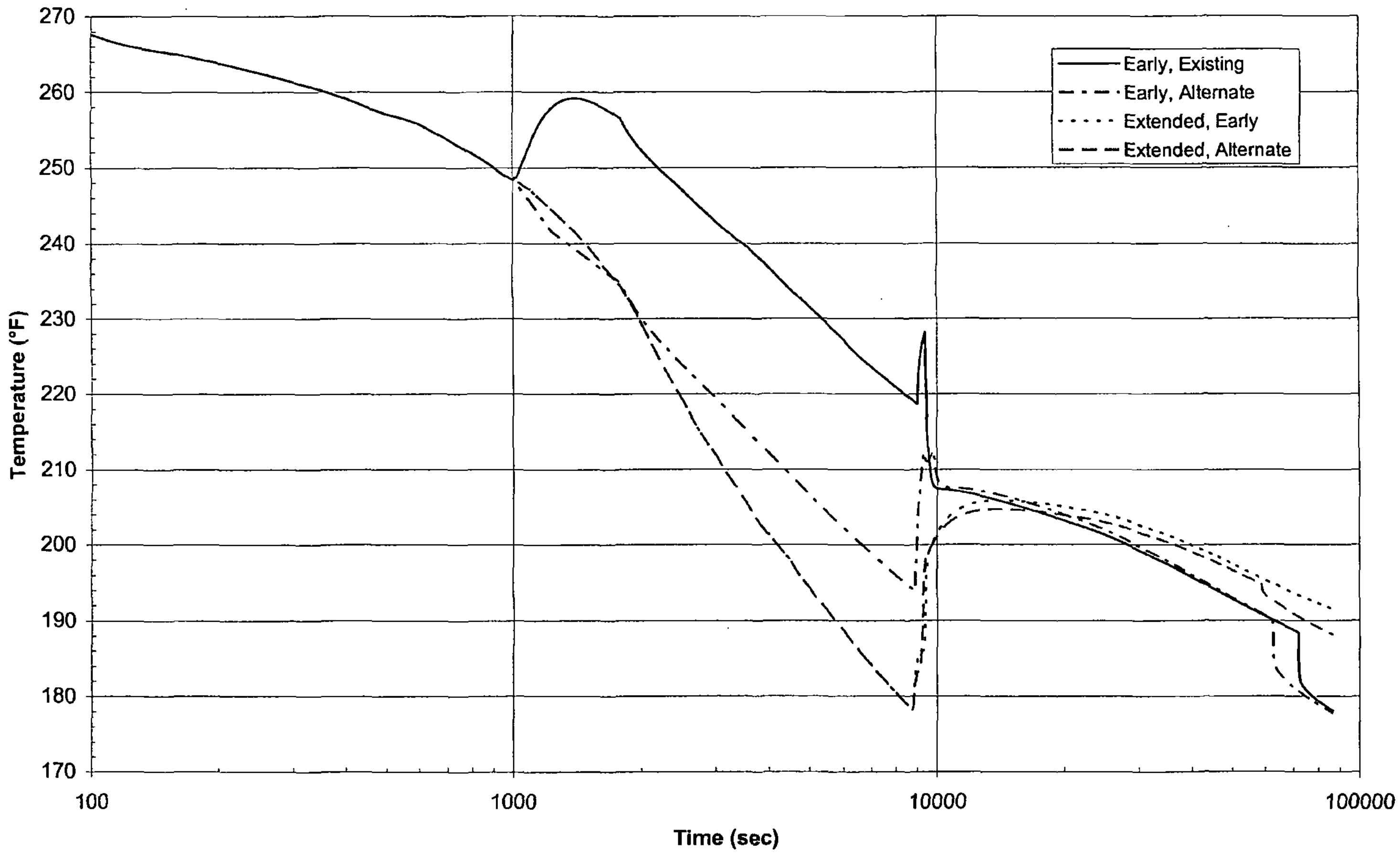

Figure 11: Hot Leg Break Containment Liquid Temperature without Containment Spray

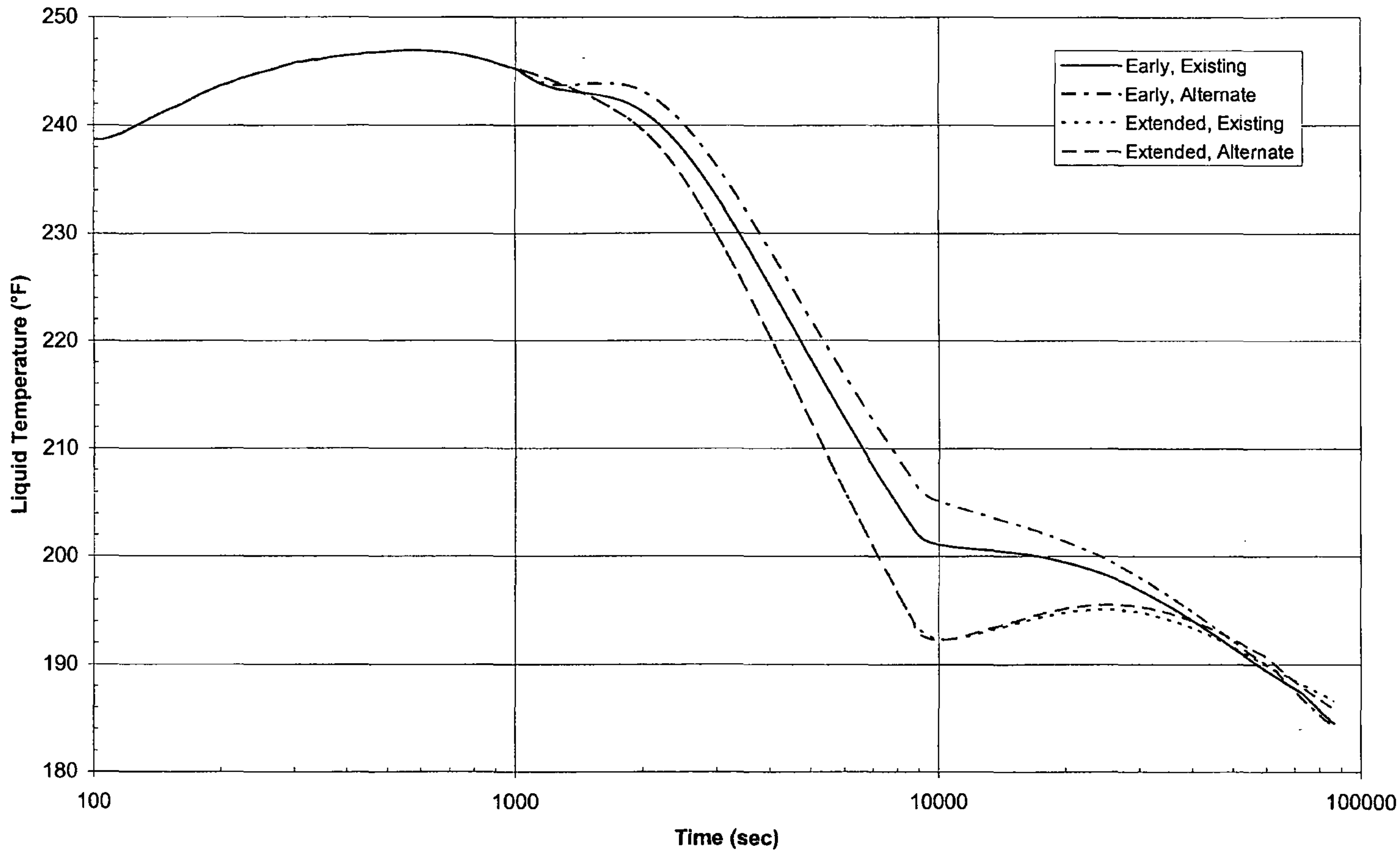

Figure 12: Cold Leg Break Containment Pressure without Containment Spray

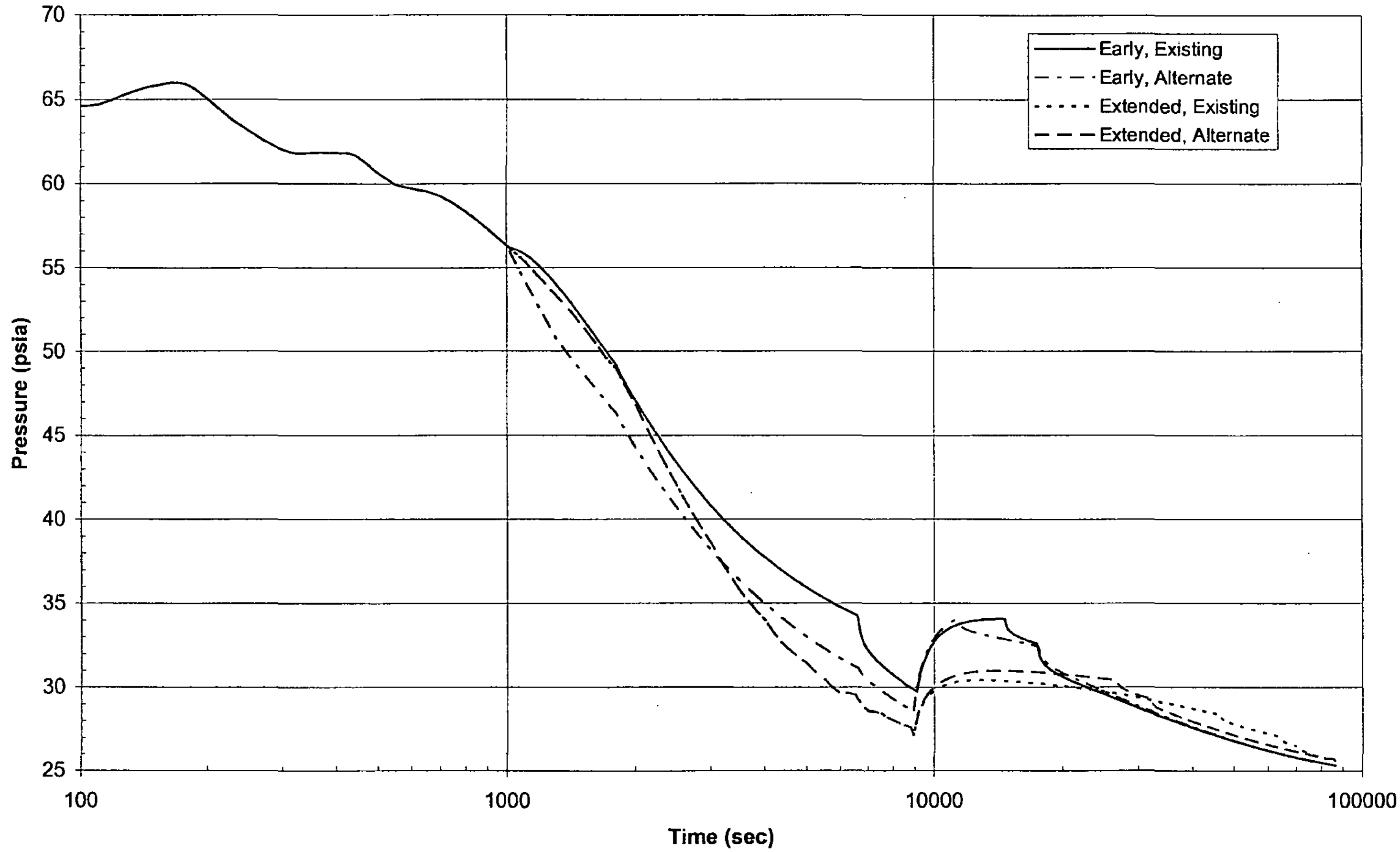

Figure 13: Cold Leg Break Containment Vapor Temperature without Containment Spray

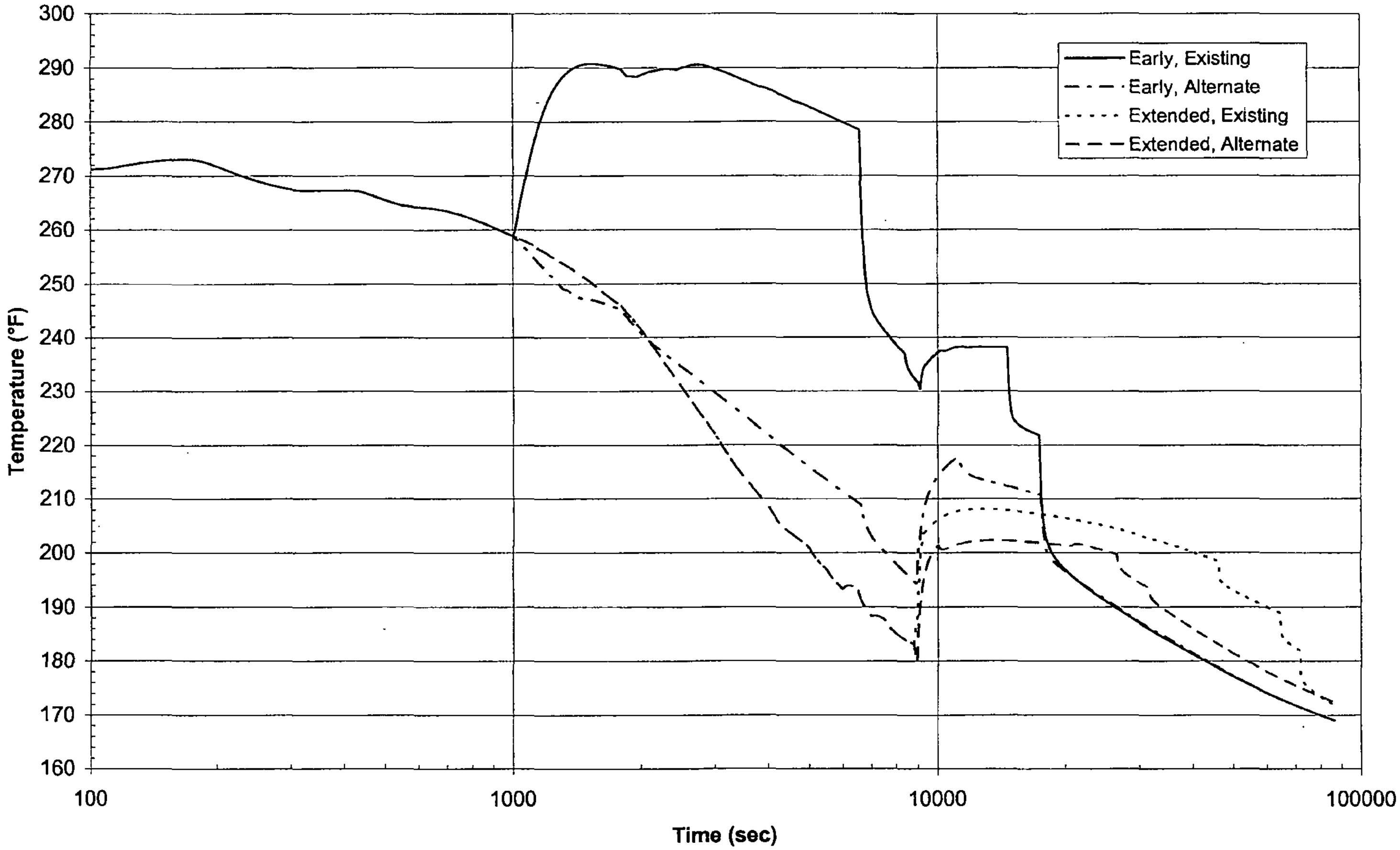

Figure 14: Cold Leg Break Containment Liquid Temperature without Containment Spray

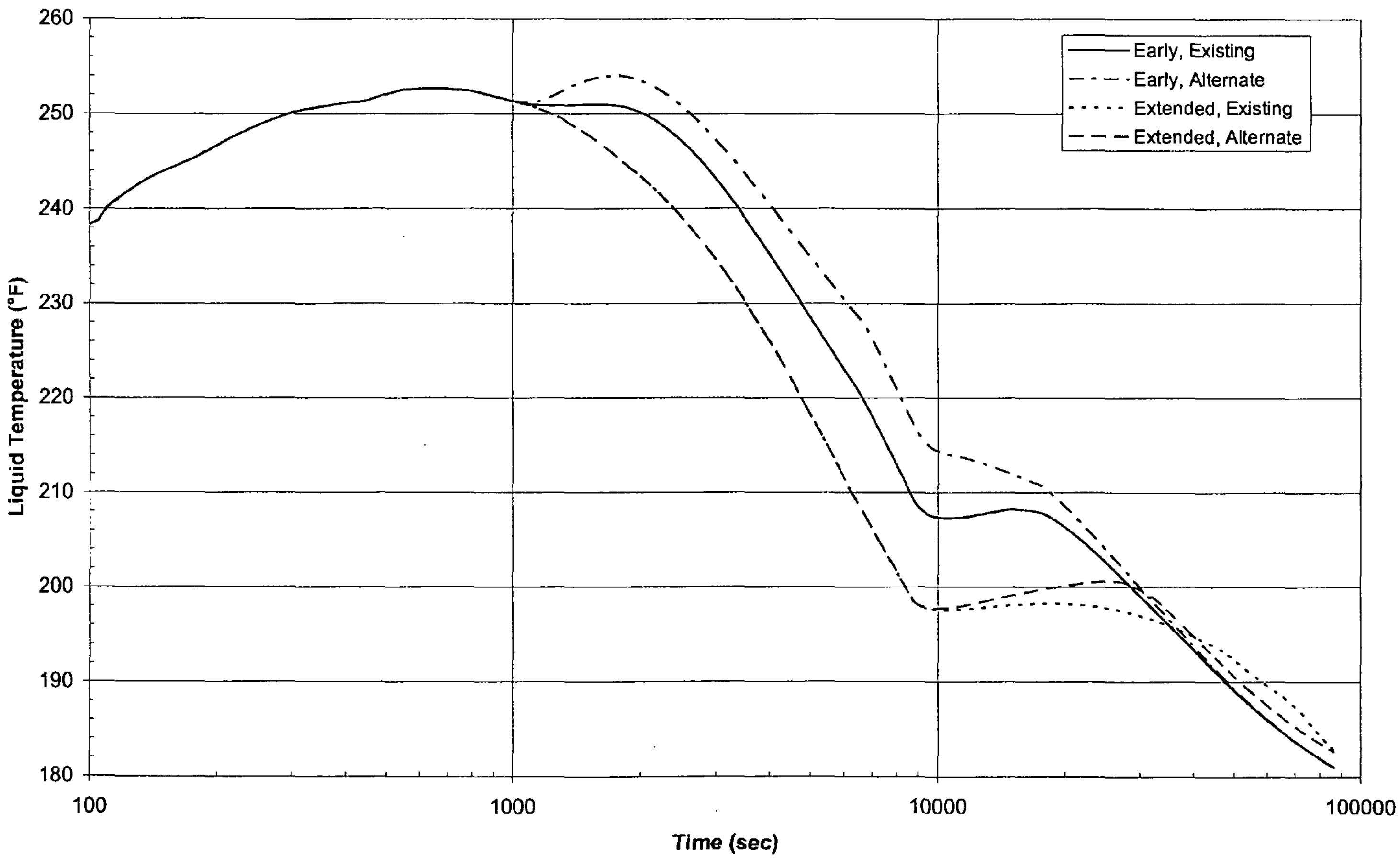

Figure 15: Long-Term Containment Vapor Temperature – Hot Leg

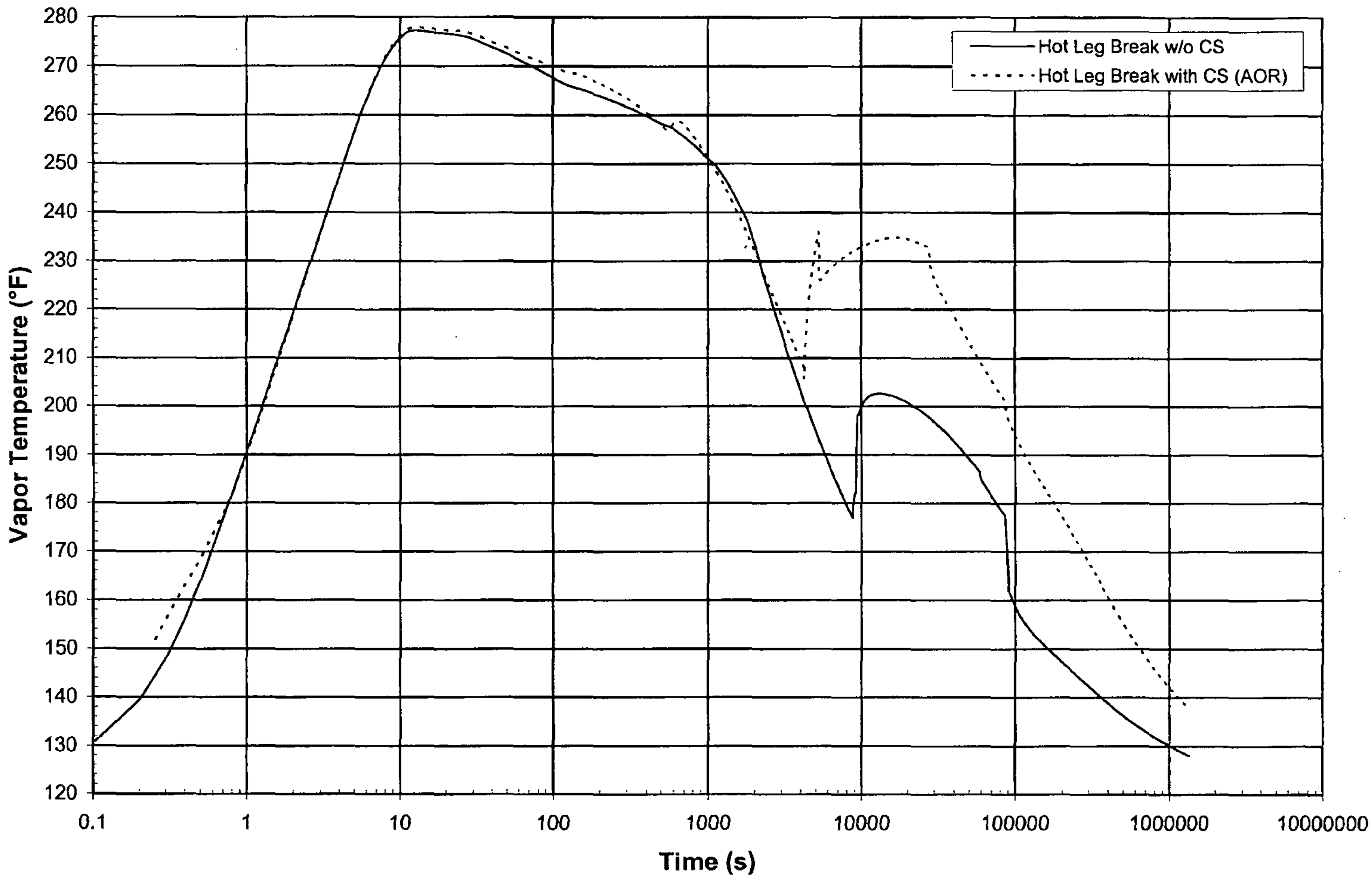

Figure 16: Long-Term Containment Vapor Temperature – Cold Leg

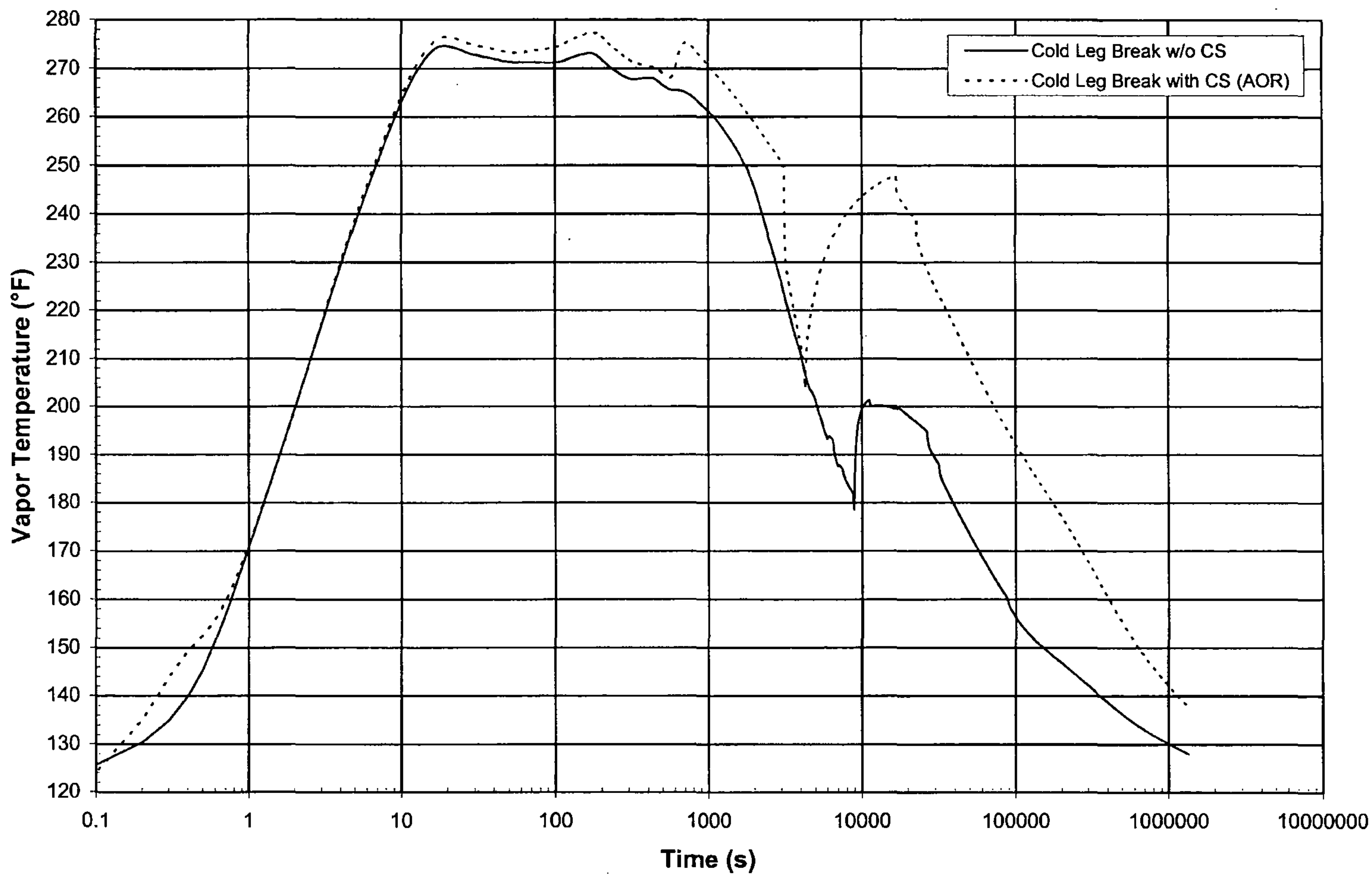

Figure 17: Long-Term Containment Pressure Response without Containment Spray

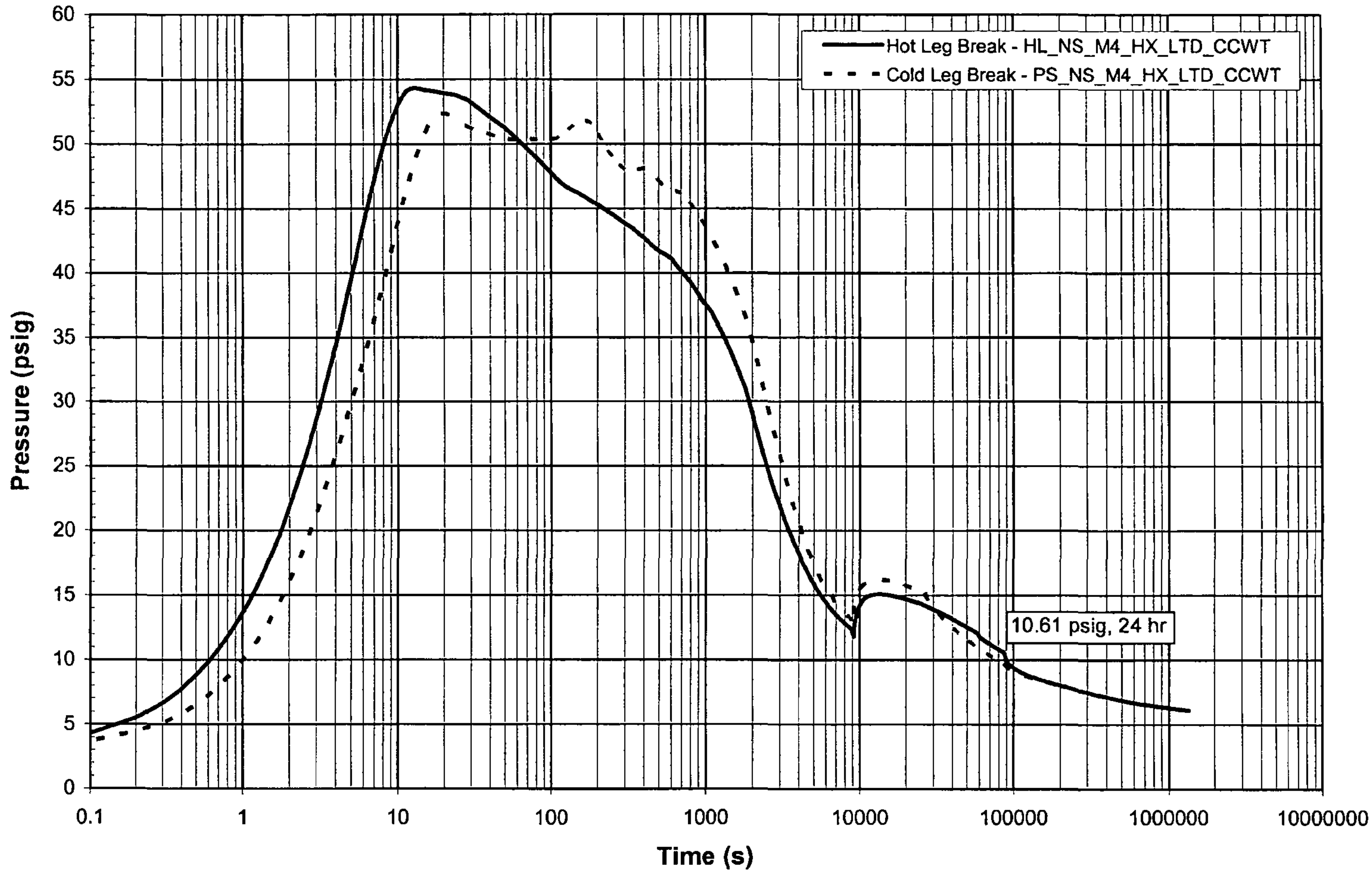

Figure 18: Long-Term Containment Vapor Temperature Response without Containment Spray

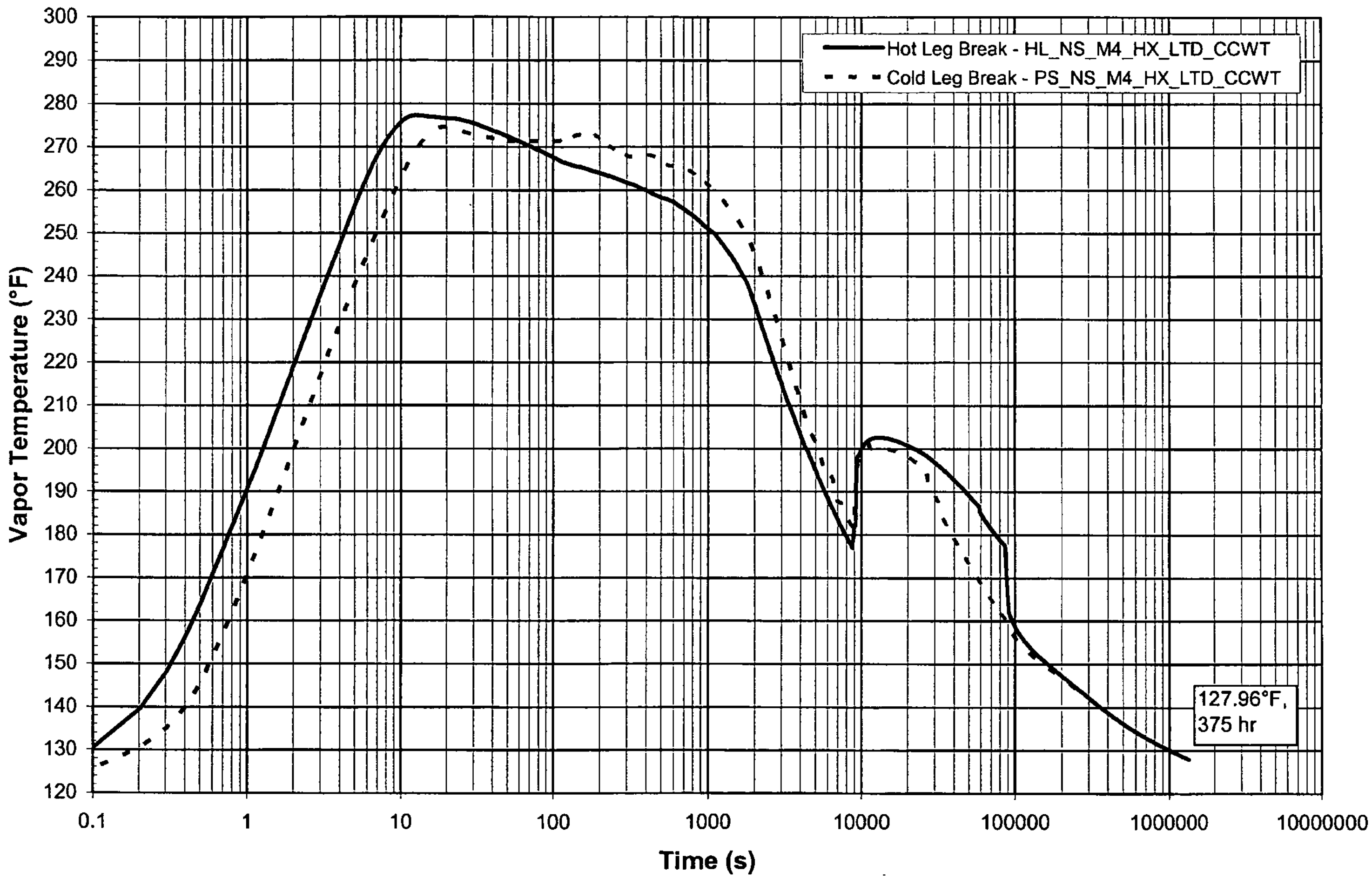

Figure 19: CCW Temperature without Containment Spray