ISL-NSAD-NRC-01-001

TECHNICAL EVALUATION REPORT

Duane Arnold Energy Center
Extended Power Uprate Containment Analysis
Audit Calculation

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ABSTRACT

An audit calculation has been performed for the Duane Arnold Energy Center (DAEC) long-term response of the Duane Arnold containment to a double-ended guillotine break of a recirculation line. These calculations used mass and energy input values and plant specific parameters furnished by the licensee and obtained from the Duane Arnold Energy Center Updated Safety Analysis Report. Although CONTAIN is a best-estimate code, these audit calculations used conservative assumptions. The results of these calculations for both the short term (peak pressure and drywell temperature) calculations and the long term (peak suppression pool temperature) calculations agree well with the licensee's results for the trend and timing of important parameters. The numerical values of the two calculations agree fairly well. The long-term CONTAIN calculation results in suppression pool conditions that are approximately 0.01 MPa (1.2 psia) and 2 ºK (4 ºF) higher than the GE results. Sensitivity studies have shown that these small differences can be explained by small changes in any one of several input values.

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Glossary

BWR	Boiling Water Reactor
CS	Containment Spray
DBA	Design Basis Analysis
DAEC	Duane Arnold Energy Center
ECCS	Emergency Core Cooling System
EPU	Extended Power Uprate
GE	General Electric Company
LOCA	Loss-of-Coolant Accident
MSLB	Main Steam Line Break
NMC	Nuclear Management Company, LLC
NPSH	Net Positive Suction Head
SRP	Standard Review Plan
SP	Suppression Pool
TS	Technical Specifications
UFSAR	Updated Final Safety Analysis Report

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1.0 INTRODUCTION

The Duane Arnold Energy Center (DAEC) is a General Electric (GE) designed Boiling Water Reactor (BWR). On November 16, 2000 Nuclear Management Company, LLC (NMC) requested a technical specification change to raise the rated thermal power of DAEC to 1912 MWt from its current limit of 1658 MWt (a 15.3% increase). This change is referred to as an Extended Power Uprate (EPU), since the rated power for DAEC had been uprated once before. Combined, these two power uprates raise the rated thermal power 120% from the original licensed value of 1593 MWt. In support of this technical specification change, NMC submitted containment analyses performed by GE at the EPU condition. The GE calculations showed a large margin to the containment design criteria related to drywell and wetwell peak pressures and temperatures. However, credit for containment pressure was required to ensure that the available Net Positive Suction Head (NPSH) for the ECCS pumps remains within limits. Because the requested power increase was much larger than those previously approved by the NRC, and because the GE codes have not been explicitly reviewed for this type of containment response application, audit calculations were performed.

These calculations used mass and energy input values provided by the licensee and plant specific parameters furnished by the licensee and obtained from the Duane Arnold Energy Center Updated Safety Analysis Report. Although CONTAIN is a best estimate code, these audit calculations used conservative assumptions similar to those used by the licensee.

The DAEC EPU does not change the reactor liquid mass inventory or operating pressure. However, other operating conditions will be changed which may significantly affect the containment response. The increased steam and feedwater flow at the higher power level will increase the core inlet subcooling about 7%. This greater subcooling increases the mass and energy release during the blowdown phase of LOCA events, increasing the short-term peak pressure and temperature. Because GE conservatively assumes that the initial reactor coolant is completed saturated for the long-term analysis, the EPU impacts the long-term containment response (suppression pool temperature and pressure) mainly due to the increase in decay heat following a LOCA or MSLB. These are also the dominant parameters for the available NPSH margin calculations. Therefore, the key results examined by the audit calculations were the drywell/wetwell pressure and temperature response for the short term analysis, and the suppression pool temperature for the long term calculation.

2.0 BACKGROUND

GE uses two different calculation procedures to predict containment response:

- Short- term pressure-temperature response to a DBA-LOCA is evaluated with the GE M3CPT code.
- Long-term analysis of the suppression pool temperature and available NPSH is performed by GE using the SHEX code.

GE uses different sets of non-mechanistic assumptions to conservatively model each case. For example, GE selects initial conditions which maximize the short-term blowdown mass and energy release for the case used to predict the peak containment pressure. However, GE maximizes the total energy release to containment for the long-term case by assuming the vessel inventory is saturated at the start of the LOCA event, even though this results in less mass released during the blowdown. Heat storage in structures is also conservatively neglected. (GE does include heat structures when performing NPSH calculations, as well as other assumptions that artificially minimize the pressure).

3.0 CONTAIN MODEL

The audit calculation was performed using the CONTAIN2.0 code [Ref. 1]. A previous Sandia study [Ref. 2] recommended a modeling procedure for CONTAIN code audit calculations. This procedure was followed where possible. As stated above, it was decided to make assumptions similar to the licensee's for these audit calculations. Therefore, actual GE break flow mass and energy release rates, and GE RHR and LPCI flows and energies were used as boundary conditions, instead of approximating mass and energy data from UFSAR information.

Most of the data needed to construct the CONTAIN model (mass and energy release rates, dimensions, loss coefficients, initial conditions, and modeling assumptions) were provided by GE in response to staff requests [Refs. 3-7]. As some of this information is considered GE proprietary, the construction of the CONTAIN input file was documented in a separate (proprietary) report [Ref. 8]. Geometric data not affected by the EPU (elevations and flow path lengths) were obtained from data and drawings provided in the DAEC UFSAR Section 6.2 [Ref. 9].

4.0 CONTAIN RESULTS

Figures 1-4 show CONTAIN results for a DBA LOCA double-ended guillotine break of a recirculation line. Figures 1 and 2 shows the long-term CONTAIN model results compared to GE's SHEX code. SHEX predicts slightly higher pressures and temperatures during the initial period, however, excellent agreement for suppression pool temperature and pressure were obtained after 40 minutes. The long-term CONTAIN calculation results in suppression pool conditions that are approximately 0.01 MPa (1.2 Psia) and 2 °K (4 °F) higher than the GE results. One exception was an apparently non-physical rise of 4-5 °K (8 °F) in the wetwell atmosphere temperature from 28800 seconds (8 hours) until 42000 seconds (11.7 hours) in the SHEX results. When questioned by the staff, GE responded that the anomalous behavior was this result of an inappropriate convergence parameter in the SHEX code. GE further stated that the improper setting of this convergence parameter did not impact the suppression pool temperature, which was the critical result for this calculation.

Sensitivity studies have also shown that the initial discrepancy in pressures and temperatures for the long-term case can mainly be ascribed to differences in modeling of mist/droplet retention in the drywell atmosphere. A portion of the small disagreement in long-term suppression pool pressures and temperatures can also be attributed to interpolation inaccuracies resulting from input of mass and energy data in CONTAIN as a linear multi-segment table.

CONTAIN has a mechanistic aerosol model that calculates droplet condensation and atmospheric liquid retention. Most containment codes (including SHEX) use simpler nonmechanistic models for condensation of atmospheric liquid. The action of containment sprays, which quickly condense atmospheric droplets, may mask this issue. As these cases conservatively assumed the sprays were unavailable, the CONTAIN mechanistic model relies on overflow out the break to act as a catalyst for droplet condensation. However, the magnitude and size distribution of the droplets resulting from post-reflood overflow out the break has considerable modeling uncertainty. The results shown in Figures 1 and 2 use the CONTAIN "dropout" option which removes atmospheric water by dropping out liquid every time step. Sensitivity studies of droplet related parameters have shown that the CONTAIN results for the initial 2400 second (40 minute) period can vary over a range which spans the GE results.

Figures 3 and 4 show short-term (0-30 seconds) results calculated with the CONTAIN short-term model compared to GE's M3CPT code. The short-term containment model differed from the long-term model in three ways:

- Different mass and energy release data were used.
- The initial vent submergence was changed to reflect the highest allowable suppression pool level (the long term model assumes that the suppression pool is at the lowest allowable level).
- Droplet parameters were changed to retain atmospheric liquid indefinitely (effectively the opposite of the “dropout” option).

The remaining model parameters were unchanged.

5.0 CONCLUSIONS

The short term (peak pressure and drywell temperature) calculations and the long term (peak suppression pool temperature) calculations agree well with the licensee’s results for the trend and timing of important parameters. Tables 1 and 2 compare the results obtained for the key parameters. Even though the CONTAIN and GE methodologies had some differences, generally very good agreement was obtained.

6.0 REFERENCES

1) K. K. Murata, et. al., "Code Manual for CONTAIN2.0: A Computer Code for Nuclear Reactor Containment Analysis," NUREG/CR-6533, SAND97-1735, Sandia National Laboratory, December 1997.

2) K. K. Murata, et. al., "CONTAIN Code Qualification Report/User Guide for Auditing Design Basis BWR calculations," Draft Final Report, Sandia National Laboratory, October 1999.

3) E. D. Schrull, "Safety Analysis Report for Duane Arnold Energy Center Extended Power Uprate", NEDC-32980P (Proprietary), General Electric Co., November 2000.

4) G. Van Middlesworth, DAEC Site Vice-President, Attachment I of Letter to NRR, "Response to Request for Additional Information (RAI) to Technical Specification Change Request TSCR-042 – Extended Power Uprate. (TAC # MB0543)", Control Number NG-01-0660, (Proprietary) Duane Arnold Energy Center, May 11, 2001.

5) G. Van Middlesworth, DAEC Site Vice-President, Attachment I of Letter to NRR, "Response to Request for Additional Information (RAI) to Technical Specification Change Request TSCR-042 – Extended Power Uprate. (TAC # MB0543)", Control Number NG-01-0721, (Proprietary) Duane Arnold Energy Center, May 29, 2001.

6) G. Van Middlesworth, DAEC Site Vice-President, Attachment I of Letter to NRR, "Response to Request for Additional Information (RAI) to Technical Specification Change Request TSCR-042 – Extended Power Uprate. (TAC # MB0543)", Control Number NG-01-0738, (Proprietary) Duane Arnold Energy Center, June 5, 2001.

7) G. Van Middlesworth, DAEC Site Vice-President, Attachment I of Letter to NRR, "Response to Request for Additional Information (RAI) to Technical Specification Change Request TSCR-042 – Extended Power Uprate. (TAC # MB0543)", Control Number NG-01-0805, (Proprietary) Duane Arnold Energy Center, June 28, 2001.

8) B. J. Gitnick,CONTAIN2.0 Model for Duane Arnold Uprate Audit Calculations, ISL Calculation File 5411-009-01 (Proprietary), Information Systems Laboratory, June 29, 2001.

9) Updated FSAR for Duane Arnold Energy Center, Docket #50-331.

Table 1. Short-Term Case
Comparison of Key Parameters

Parameter	M3CPT	CONTAIN
Peak Drywell Pressure	0.412 MPa [59.7 psia]	0.417 MPa [60.5 psia]
Peak Drywell Temperature	414.3 ºK [286.1 ºF]	415.7 ºK [288.6 ºF]
Time of Peak	4.31 seconds	4.30 seconds

Table 2. Long-Term Case
Comparison of Key Parameters

Parameter	SHEX	CONTAIN
Long Term Peak Suppression Pool Pressure	0.243 MPa [35.2 psia]	0.251 MPa [36.4 psia]
Long Term Peak Suppression Pool Temperature	375.0 ºK [215.3 ºF]	377.0 ºK [218.9 ºF]
Time of Peak	29555 seconds [8.2 hours]	32100 seconds [8.9 hours]

Figure 1. DAEC Uprate Long Term Case
Compartment Pressures vs Time

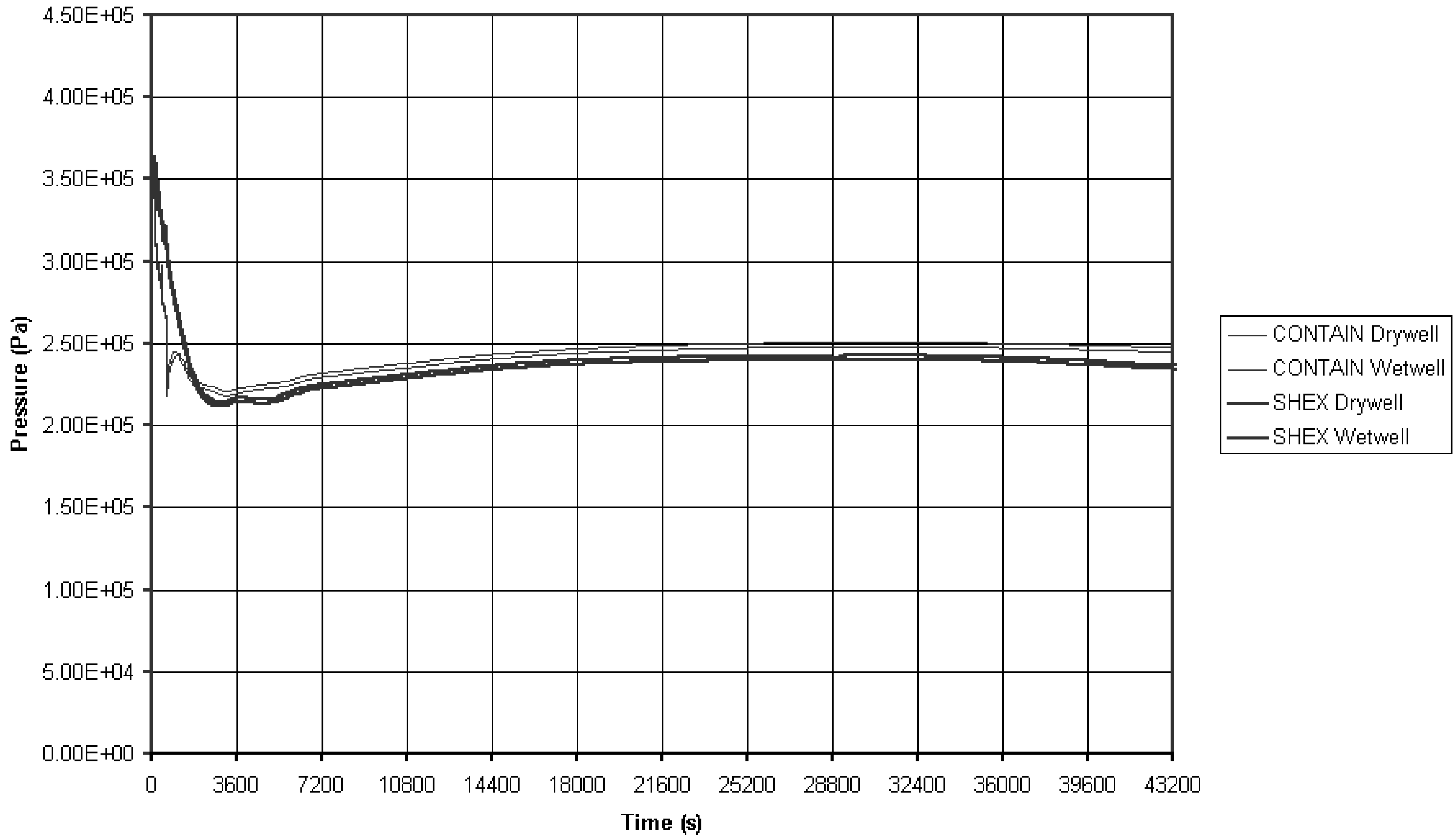

Figure 2. DAEC Uprate Long-Term Case
Temperatures vs Time

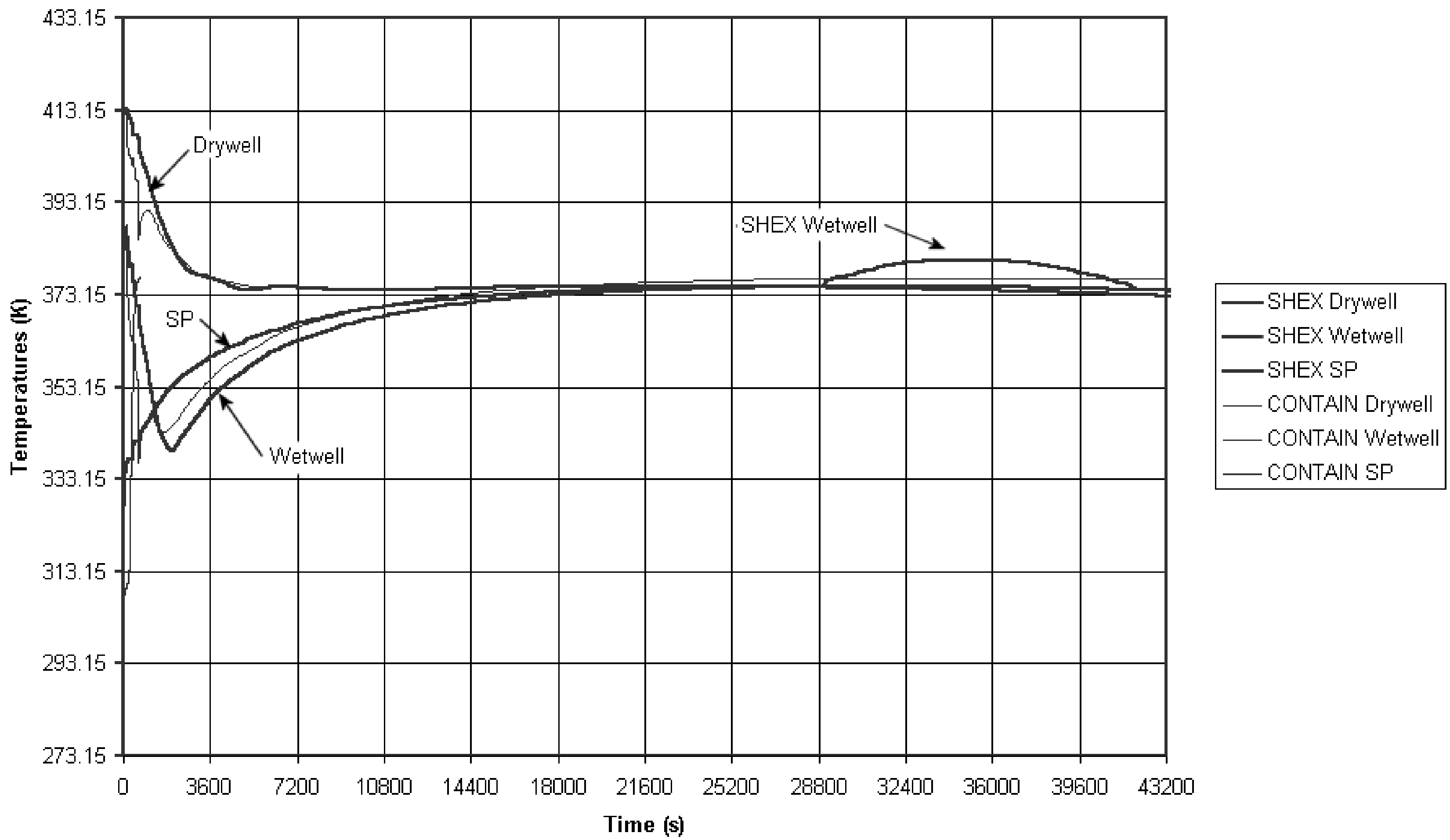

**Figure 3. DAEC Uprate Short Term Results
Compartment Pressures vs Time**

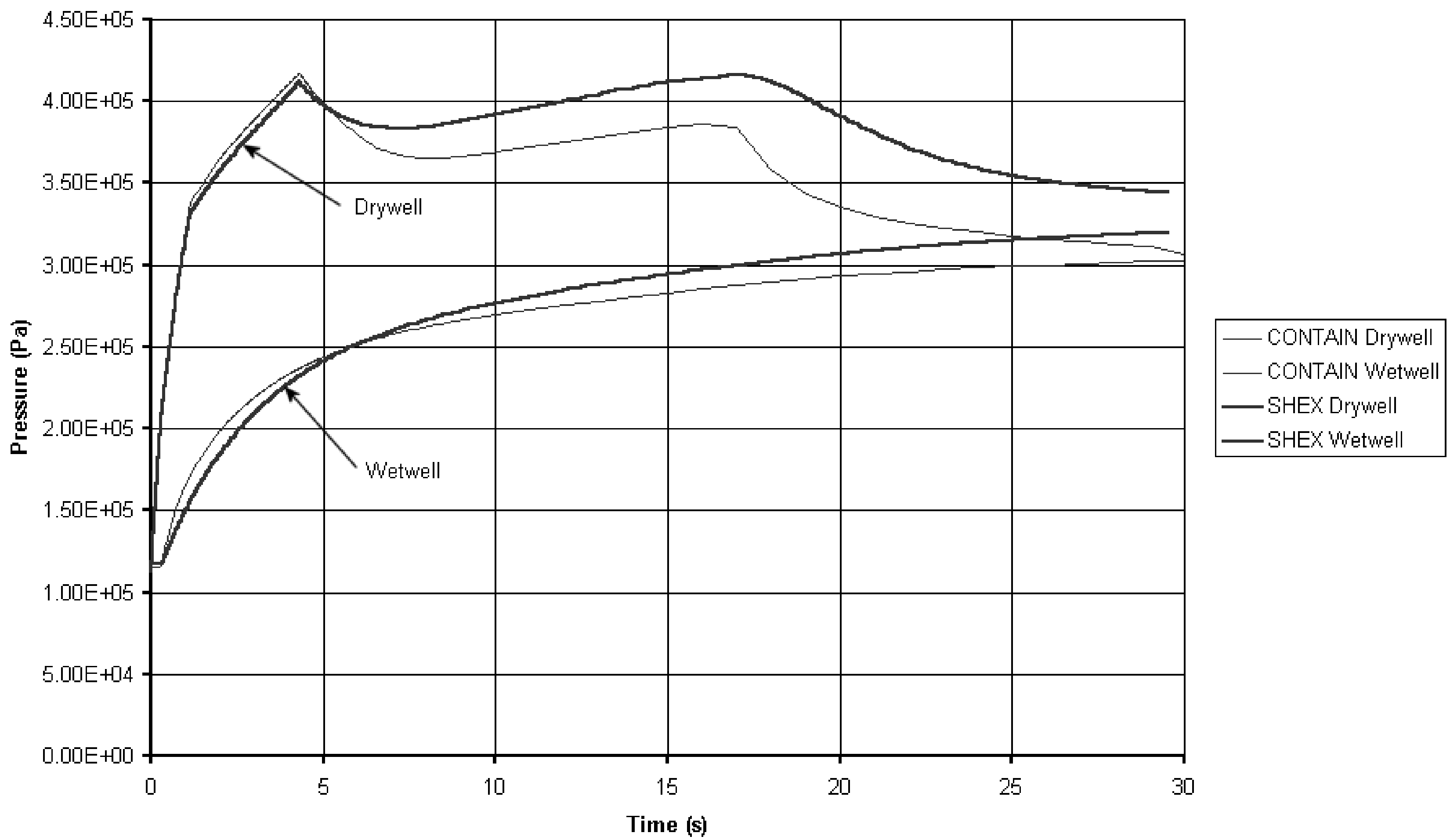

Figure 4. DAEC Uprate Short Term Results
Temperatures vs Time