ATTACHMENT 4

Browns Ferry Nuclear Plant (BFN)
Unit 1

Response to NRC Request for Supplemental Information Regarding Technical Specification Change TS-467 - Utilization of AREVA Fuel and Associated Analysis Methodologies

Browns Ferry Nuclear Plant Units 1, 2 and 3 SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis
(Non-Proprietary)

Attached is the non-proprietary version of the Browns Ferry Nuclear Plant Units 1, 2 and 3 SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis, Revision 7, dated January 2010.

HITACHI

GE Hitachi Nuclear Energy

NEDO-32484
Revision 7
DRF 0000-0011-1715
Class I
January 2010

NON-PROPRIETARY INFORMATION

BROWNS FERRY NUCLEAR PLANT UNITS 1, 2 AND 3

SAFER/GESTR-LOCA LOSS-OF-COOLANT ACCIDENT ANALYSIS

NON-PROPRIETARY NOTICE

This is a non-proprietary version of the document NEDC-32484P, Revision 7, from which the proprietary information has been removed. Portions of the document that have been removed are identified by white space within double square brackets, as shown here [[ ]].

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The only undertakings of the GE Hitachi Nuclear Energy (GEH) respecting information in this document are contained in the contract between TVA and GEH, and nothing contained in this document shall be construed as changing the contract. The use of this information by anyone other than TVA or for any purpose other than that for which it is intended is not authorized; and with respect to any unauthorized use, GEH makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document, or that its use may not infringe privately owned rights.

SCOPE OF CHANGES FROM REVISION 6

The purpose of this document revision is to identify GEH proprietary information within NEDC-32484P Revision 6 and create a non-proprietary version. No technical changes have been made in Revision 7 of this document.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

SUMMARY

A design requirement for nuclear power plants is the capability to withstand Design Basis Accidents. One of the postulated accidents is a guillotine break in the largest size pipe connected to the reactor vessel. Historically, the analysis of the large break loss-of-coolant accident (LOCA) has been performed on a very conservative basis with margin added at every step of the calculation. This was done partly as a result of the restrictions imposed by the requirements of 10CFR50.46 and Appendix K, and partly to compensate for uncertainties inherent in the simplified models. However, after years of research with large-scale experiments and the development of the best-estimate codes, improved and more realistic boiling water reactor (BWR) licensing models (i.e., SAFER/GESTR-LOCA) have been approved by the U.S. Nuclear Regulatory Commission (NRC). These new models calculate more realistic (yet conservative) peak cladding temperature (PCT) to relieve unnecessary plant operating and licensing restrictions. More realistic analyses also predict actual plant response during postulated accidents and can be used as a basis for more appropriate operator actions. The LOCA analysis for Browns Ferry Nuclear Plant (BFNP) Units 1, 2 and 3 uses these models and this licensing methodology.

The SAFER and GESTR-LOCA models are coupled mechanistic, reactor system thermal hydraulic, and fuel rod thermal-mechanical evaluation models. These models are based on realistic correlations and inputs. The SAFER/GESTR-LOCA methodology approved by the NRC allows the plant-specific break spectrum to be defined using nominal input assumptions. However, the calculation of the limiting PCT to demonstrate conformance with the requirements of 10CFR50.46 must include specific inputs documented in Appendix K. The SAFER/GESTR-LOCA Application Methodology requires:

(1) The Licensing Basis PCT must be less than 2200°F. This Licensing Basis PCT is derived by adding appropriate margin for specific conservatism required by Appendix K of 10CFR50 to the limiting PCT value calculated using nominal values.

(2) The Upper Bound PCT is required to be less than the Licensing Basis PCT.

The NRC placed a restriction of 1600°F on the Upper Bound PCT in the Safety Evaluation Report (SER) approving the SAFER/GESTR-LOCA application methodology. This restriction was based on the range of test data and analyses used to generically qualify the SAFER code and

application methodology. In a supplemental Licensing Topical Report, Reference 13, the NRC removed the Upper Bound PCT limit of 1600 °F. It was noted that GENE has performed the plant specific Upper Bound PCT calculations for its entire product line and unless there are significant changes to the plant's configuration, plant specific evaluation of the Upper Bound PCT is not required. Since this ECCS evaluation includes plant configuration changes, 10CFR50.46 error corrections, process updates and Extended Power Uprate (EPU), confirmation of the validity of existing Upper Bound PCT is required. Confirmation that the Licensing Basis PCT will continue to bound the Upper Bound PCT at current licensed thermal power (3458 MWt) is contained in Reference 16. Confirmation that the Licensing Basis PCT will continue to bound the Upper Bound PCT at EPU power (3952 MWt) is contained in Reference 20.

The SAFER/GESTR-LOCA analysis for the BFNP was performed in accordance with NRC requirements and demonstrates conformance with the Emergency Core Cooling System (ECCS) acceptance criteria of 10CFR50.46 Appendix K. A sufficient number of plant-specific break sizes were evaluated at EPU conditions (3952 MWt) to establish the behavior of both the nominal and Appendix K PCT as a function of break size. Different single failures were also investigated at EPU conditions in order to clearly identify the worst cases. The limiting large break from the EPU analysis and a limited spectrum of small break nominal and Appendix K cases were run at current licensed thermal power (CLTP) conditions (3458 MWt). [[

]] This analysis is applicable to core thermal power up to 3952 MWt (120% Original Licensed Thermal Power) and to the following operating conditions: Maximum Extended Load Line Limit Analysis (MELLLA), Maximum Extended Load Line Limit Analysis Plus (MELLLA+), Feedwater Temperature Reduction (FWTR), Increased Core Flow (ICF) and Single Loop Operation (SLO). The analysis results demonstrate that the five acceptance criteria for ECCS performance analysis outlined in 10CFR50.46 are satisfied for GE13 and GE14 fuel at both CLTP and EPU conditions. The Licensing Basis PCTs for BFNP have been calculated at both 3952 MWt (120% Original Licensed Thermal Power) and 3458 MWt (105% Original Licensed Thermal Power). The Licensing Basis PCTs at 3952 MWt are 1780°F for GE13 and 1830°F for GE14. The Licensing Basis PCTs at 3458 MWt are 1810°F for GE13 and 1760°F for GE14. These Licensing Basis PCTs are all well below the 2200°F limit. Therefore, BFNP Units

1, 2 and 3 meet the NRC SAFER/GESTR-LOCA licensing analysis requirements at both CLTP and EPU conditions.

1.0 INTRODUCTION

This document provides the results of the loss-of-coolant accident (LOCA) analysis performed by GE Nuclear Energy (GE-NE) for Browns Ferry Nuclear Plant (BFNP) Units 1, 2 and 3. The analysis was performed using the SAFER/GESTR-LOCA application methodology approved by the Nuclear Regulatory Commission (NRC) [Reference 1]. This analysis was performed at a thermal power level of 3952 MWt, which is the Extended Power Uprate (EPU) rated thermal power level for Units 1, 2 and 3. This power level is referred to as 100% rated power throughout this report. The Licensing Basis PCTs were also calculated at a thermal power level of 3458 MWt, which is the current licensed thermal power (CLTP) for Units 2 and 3. Unit 1 has a current licensed thermal power of 3293 MWt. The results for the analysis at 3458 MWt, 105% of the Unit 1 rated power, conservatively bounds Unit 1 operation at 3293 MWt. The analysis addressed a core flow range from 85% to 105% of rated flow at rated (EPU) power. The 85% core flow corresponds to the EPU point on the MELLLA+ rod line. Other off-rated analyzed cases were performed at CLTP power on the MELLLA+ rod line (68% core flow) and on the MELLLA rod line (81% core flow). In addition, some of the Emergency Core Cooling System (ECCS) and related equipment performance parameters were conservatively assumed, relative to actual ECCS performance. This report provides LOCA analyses for GE13 and GE14 fuel types. A detailed description of process changes, 10CFR50.46 error corrections, and plant configuration changes incorporated in this ECCS-LOCA analysis are described in Appendix C.

This LOCA analysis is performed in accordance with NRC requirements to demonstrate conformance with the ECCS acceptance criteria of 10CFR50.46. A key objective of the LOCA analysis is to provide assurance that the most limiting break size, break location, and single failure combination has been considered for the BFNP. Reference 2 documents the requirements and the approved methodology to satisfy these requirements.

The SAFER/GESTR-LOCA application methodology is based on the generic studies presented in Reference 2. The approved application methodology consists of three essential parts. First, potentially limiting LOCA cases are determined by applying realistic (nominal) analytical models across the entire break spectrum. Second, limiting LOCA cases are analyzed with an Appendix K model (inputs and assumptions) which incorporates all the required features of

10CFR50 Appendix K. For the most limiting cases, a Licensing Basis Peak Cladding Temperature (PCT) is calculated based on the nominal PCT with an adder to account statistically for the differences between the nominal and Appendix K assumptions. Finally, a statistically derived Upper Bound PCT is calculated to demonstrate the conservatism of the Licensing Basis PCT. The resulting Licensing Basis PCT conforms to all the requirements of 10CFR50.46 and Appendix K.

As discussed in Section 3.2, further plant specific evaluation of Upper Bound PCT is no longer required to meet the SAFER/GESTR-LOCA application methodology requirements, unless there are significant changes in the plant configuration.

2.0 DESCRIPTION OF MODELS

Four GE-NE computer models determine the LOCA response for the BFNP LOCA analysis: LAMB, TASC, SAFER and GESTR-LOCA. Together, these models evaluate the short-term and long-term reactor vessel blowdown response to a pipe rupture, the subsequent core flooding by ECCS, and the final rod heatup. Figure 2-1 is a flow diagram of these computer models, including the major code functions and the transfer of major parameters. The purpose of each model is described in the following subsections.

2.1 LAMB

This model (Reference 3) analyzes the short-term blowdown phenomena for postulated large pipe breaks in which nucleate boiling is lost before the water level drops sufficiently to uncover the active fuel. The LAMB output (most importantly, core flow as a function of time) is used in the TASC model for calculating blowdown heat transfer and fuel dryout time.

2.2 TASC

This model (Reference 7) completes the transient short-term thermal-hydraulic calculation for large recirculation line breaks. The time and location of boiling transition is predicted during the period of recirculation pump coastdown. When the core inlet flow is low, TASC also predicts the resulting bundle dryout time and location. The calculated fuel dryout time is an input to the long-term thermal-hydraulic transient model, SAFER. TASC explicitly models the axially varying flow areas and heat transfer surface resulting from part length fuel rods. TASC is also used to calculate the hot channel behavior during anticipated operational occurrences (Reference 6).

2.3 SAFER

This model (References 5 and 8) calculates the long-term system response of the reactor over a complete spectrum of hypothetical break sizes and locations. SAFER is compatible with the GESTR-LOCA fuel rod model for gap conductance and fission gas release. SAFER calculates the core and vessel water levels, system pressure response, ECCS performance, and other primary thermal-hydraulic phenomena occurring in the reactor as a function of time. SAFER realistically models all regimes of heat transfer which occur inside the core, and provides the PCT and the heat transfer coefficients (which determine the severity of the temperature change) as a function of time. For GE13 and GE14 fuel analysis with the SAFER code, the part length fuel rods are treated as full-length rods, which conservatively overestimates the hot bundle power.

2.4 GESTR-LOCA

This model (Reference 4) provides the parameters to initialize the fuel stored energy and fuel rod fission gas inventory at the onset of a postulated LOCA for input to SAFER. GESTR-LOCA also establishes the transient pellet-cladding gap conductance for input to both SAFER and TASC.

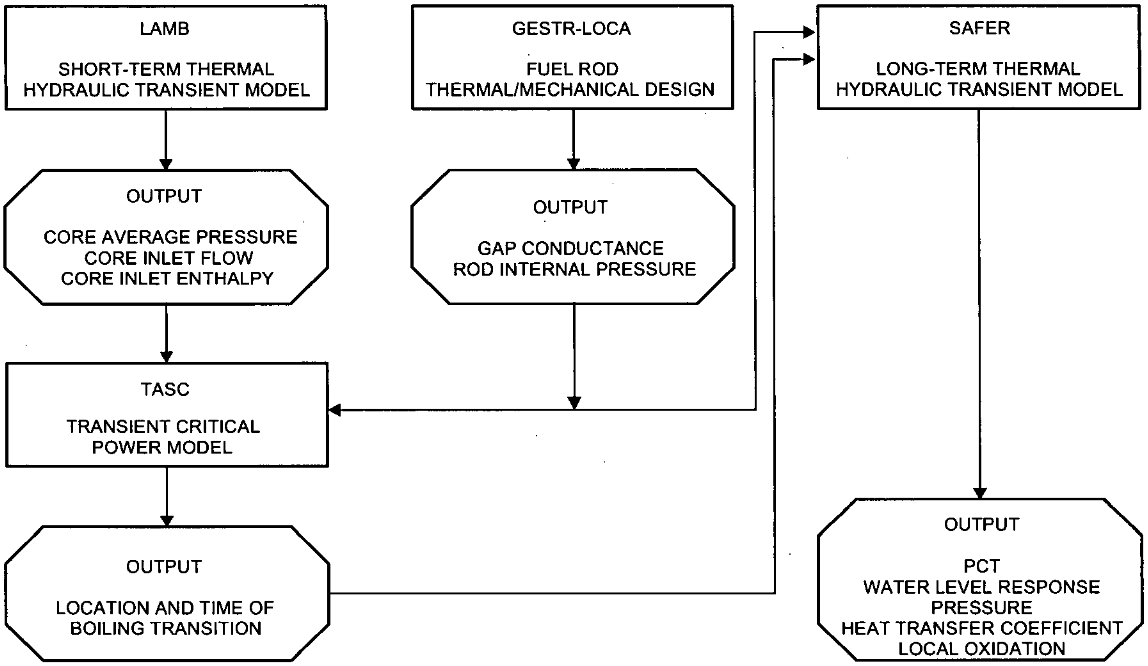


Figure 2-1 Flow Diagram of LOCA Analysis Using SAFER/GESTR

3.0 ANALYSIS PROCEDURE

3.1 LICENSING CRITERIA

The Code of Federal Regulations (10CFR50.46) outlines the acceptance criteria for ECCS analysis. The acceptance criteria are summarized below:

Criterion 1 - Peak Cladding Temperature - The calculated maximum fuel element cladding temperature shall not exceed 2200°F.

Criterion 2 - Maximum Cladding Oxidation - The calculated total local oxidation shall not exceed 0.17 times the total cladding thickness before oxidation.

Criterion 3 - Maximum Hydrogen Generation - The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all the metal in the cladding cylinder surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.

Criterion 4 - Coolable Geometry - Calculated changes in core geometry shall be such that the core remains amenable to cooling.

Criterion 5 - Long-Term Cooling - After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value, and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.

Conformance with Criteria 1 through 3 for BFNP Units 1, 2 and 3 is presented in this report. As discussed in Reference 3, conformance with Criterion 4 is demonstrated by conformance to Criteria 1 and 2. The bases and demonstration of compliance with Criterion 5 are documented in Reference 3 and remain unchanged by application of SAFER/GESTR-LOCA.

The licensing methodology utilizing SAFER/GESTR-LOCA is discussed in Section 3.2.

3.2 SAFER/GESTR-LOCA LICENSING METHODOLOGY

The SAFER/GESTR-LOCA licensing methodology approved by the NRC in Reference 1 allows the plant-specific break spectrum to be defined using nominal input assumptions. However, the calculation of the limiting PCT to demonstrate conformance with the requirements of 10CFR50.46 must include specific inputs and models documented in Appendix K.

The Licensing Basis PCT is based on the most limiting LOCA (highest PCT) and is defined as:

$$PCT_{Licensing} = PCT_{Nominal} + ADDER$$

The value of ADDER is calculated as follows:

$$ADDER^2 = [PCT_{App.\,K} - PCT_{Nominal}]^2 + \sum(\delta PCT_i)^2$$

where:

$PCT_{App.\,K}$ = Peak cladding temperature from calculation using Appendix K specified models and inputs.

$PCT_{Nominal}$ = Peak cladding temperature from nominal case.

$\sum(\delta PCT_i)^2$ = Plant variable uncertainty term.

The plant variable uncertainty term accounts statistically for the uncertainty in parameters which are not specifically addressed by 10CFR50 Appendix K.

To conform with 10CFR50.46 and the SAFER/GESTR-LOCA licensing methodology, the Licensing Basis PCT must be less than 2200°F.

Demonstration that the Licensing Basis PCT calculated above is sufficiently conservative is also required through the use of a statistical Upper Bound PCT as defined in Reference 2. The Upper Bound PCT is a function of the limiting break Nominal PCT, modeling bias, and plant variable uncertainty. The Upper Bound PCT is defined as:

$$PCT_{Upper\ Bound} = PCT_{Nominal} + \Delta 4\text{-}max_{generic} + (\Delta 3 + 2s_{\Delta 3})$$

where:

$\Delta 4\text{-}max_{generic}$ = Modeling bias. This term accounts for errors in modeling processes for which experimental data is available for comparison. These are primarily the LOCA thermal-hydraulic processes.

$(\Delta 3 + 2s_{\Delta 3})$= Plant variable uncertainties. This term accounts for the uncertainties due to inputs to the model. These are typical plant parameters with associated uncertainties in their measured values.

The Upper Bound PCT is required to be less than the Licensing Basis PCT. This ensures that the Licensing Basis PCT bounds the expected PCT for at least 95% of all postulated limiting break LOCAs which occur from limiting initial conditions. As part of the development of SAFER/GESTR-LOCA licensing methodology, GE-NE demonstrated that this criterion was satisfied for the BWR/3 and BWR/4 class of plants. The application methodology was also accepted on a generic basis for Upper Bound PCT up to 1600°F. For BFNP Units 1, 2 and 3, fuel and plant-specific evaluations were performed in Reference 14 to demonstrate conformance to these licensing criteria. In Reference 2, the application methodology was accepted on a generic basis for an Upper Bound PCT up to 1600°F. This 1600°F restriction was removed by Reference 13, as approved by Reference 17. References 16 (for CLTP conditions) and 20 (for EPU conditions) demonstrate that the Licensing Basis PCTs for the fuels and conditions analyzed bound the estimated Upper Bound PCTs based on a plant-specific Upper Bound PCT calculation previously performed.

3.3 BWR-3/4 GENERIC ANALYSIS

BFNP Units 1, 2 and 3 are BWR/4 product line plants. For the BWR-3/4 product lines, GE-NE performed a generic conformance calculation for the limiting hypothetical LOCA [Reference 2]. The limiting LOCA was determined from the nominal break spectrum as the break size and single ECCS component failure combination that yielded the highest nominal PCT. The Appendix K calculation was then performed for this limiting LOCA event to establish the basis for the licensing evaluation.

[[

]] As a result, this case was used to perform the Appendix K calculation. The Licensing Basis PCT for BWR-3/4 was then calculated by combining the nominal PCT with the adder described earlier. This generic evaluation demonstrated that a PCT margin greater than 150°F existed between the Upper Bound PCT and the Licensing Basis PCT [Reference 2].

3.4 BFNP UNITS 1, 2 AND 3 PLANT-SPECIFIC ANALYSIS

As discussed in the SER (Reference 2) the determination of the limiting case LOCA is based on:

1. The generic Appendix K PCT versus break size curve exhibits the same trends as the generic Nominal PCT versus break size curve for a given class of plants;

2. The limiting LOCA determined from Nominal calculations is the same as that determined from Appendix K calculations for a given class of plants; and

3. Both generic and Nominal PCT versus break size curve and Appendix K PCT versus break size curve for a given class of plants are shown to be applicable on a plant specific basis. Necessary conditions for demonstrating applicability include:

    a. Calculation of a sufficient number of plant specific PCT points to verify the shape of the curve
    b. Confirmation that plant specific Appendix K PCT calculations match the trend of the generic curve for that plant class
    c. Confirmation that plant specific operating parameters have been conservatively bounded by the models and inputs used in the generic calculations
    d. Confirmation that the plant specific ECCS is consistent with the referenced plant class ECCS configuration

Conformance to conditions 1 and 2 has been generically demonstrated in Reference 2. In order to show that conditions 3a and 3b have been satisfied, plant-specific analyses for break sizes ranging from [[ ]] for nominal assumptions and [[ ]] for Appendix K assumptions to the maximum DBA recirculation suction line break were performed at EPU conditions. The shape of the PCT versus break area curve is primarily dependent upon the plant ECCS configuration. Since the effect of power level on the break spectrum curve is secondary, the determination of the limiting break size, location, and single failure from the EPU break spectrum evaluation is also applicable to the CLTP condition. The full set of break spectrum cases that was run at EPU conditions is not required at CLTP conditions. The GE13 and GE14 CLTP small break evaluations included a limited spectrum of break sizes to determine the most limiting break size.

Since the effect of fuel type on the break spectrum curve is secondary, the determination of the limiting break size, location, and single failure from the GE13 break spectrum evaluation is also applicable to GE14 fuel. Compliance with conditions 3c and 3d was demonstrated with a plant-specific Upper Bound PCT calculation in Reference 14. Since this ECCS evaluation includes plant configuration changes, 10CFR50.46 error corrections, process updates and Extended Power Uprate (EPU), confirmation of the validity of existing Upper Bound PCT is required. Confirmation that the Licensing Basis PCT will continue to bound the Upper Bound PCT at current licensed thermal power (3458 MWt) is contained in Reference 16. Confirmation that the Licensing Basis PCT will continue to bound the Upper Bound PCT at EPU power (3952 MWt) is contained in Reference 20.

Different single failures were also investigated at EPU conditions to identify the worst cases. The limiting single failure at EPU conditions (battery failure) was assumed to also be the limiting single failure at CLTP conditions. This is a reasonable assumption because 1) battery failure is the expected limiting single failure for BWR3/4 plants, 2) the limiting large break with battery failure case at EPU conditions resulted in nominal and Appendix K PCTs that were more than 80°F higher than the second most severe failure (LPCI Injection Valve failure) and 3) the effect on PCT of a core power change would be similar for both of these failures. The break spectrum was first evaluated using nominal analysis assumptions (Table 3-1). The potentially limiting cases were then analyzed again with the analysis assumptions specified for the Appendix K calculations (Table 3-2). The normalized decay heat fractions used are shown in Figure 3-1. The BFNP nominal and Appendix K results were compared to assure that the PCT trends as a function of the break size were consistent with one another and with those of the generic BWR/4 break spectrum curve documented in Reference 2.

[[

]]

Table 3-1

ANALYSIS ASSUMPTIONS FOR NOMINAL CALCULATIONS
[Reference 2]

1.	Decay Heat	1979 American Nuclear Society (ANS) (Figure 3-1)
2.	Transition Boiling Temperature	Iloeje correlation
3.	Break Flow	1.25 HEM(1) (subcooled) 1.0 HEM(1) (saturated)
4.	Metal-Water Reaction	EPRI coefficients
5.	Core Power	100% of rated power(2)
6.	Peak Linear Heat Generation Rate	See Table 4-2
7.	Bypass Leakage Coefficients	Nominal values
8.	Initial Operating Minimum Critical Power Ratio (MCPR)	See Table 4-2
9.	ECCS Water Enthalpy (Temperature)	88 Btu/lbm (120°F)
10.	ECCS Initiation Signals	(See Table 4-3)
11.	ECCS Flow Initiation	Analysis assumes no ECCS flow until the injection/spray valve is fully open
12.	Automatic Depressurization System	120-second delay time (Table 4-3)
13.	ECCS Available	Systems remaining after worst case single failure
14.	Stored Energy	Best Estimate GESTR-LOCA
15.	Fuel Rod Internal Pressure	Best Estimate GESTR-LOCA
16.	Fuel Exposure	Limiting fuel exposure which maximizes PCT

(1) HEM: Homogeneous Equilibrium Model
(2) Rated power is 3458 MWt for CLTP and 3952 MWt for EPU

Table 3-2

ANALYSIS ASSUMPTIONS FOR APPENDIX K CALCULATIONS
[Reference 2]

1.	Decay Heat	1971 ANS + 20% Decay Heat (Figure 3-1)
2.	Transition Boiling Temperature	Transition boiling allowed during blowdown only until cladding superheat exceeds 300°F.
3.	Break Flow	Moody Slip Flow Model with discharge coefficients of 1.0, 0.8, and 0.6.
4.	Metal-Water Reaction	Baker–Just
5.	Core Power	102% of rated power[(1)]
6.	Peak Linear Heat Generation Rate	See Table 4-2.
7.	Bypass Leakage Coefficients	Same as Table 3–1.
8.	Initial Operating Minimum Critical Power Ratio (MCPR)	See Table 4-2.
9.	ECCS Water Enthalpy (Temperature)	Same as Table 3–1.
10.	ECCS Initiation Signals	Same as Table 3–1.
11.	ECCS Flow Initiation	Same as Table 3–1.
12.	Automatic Depressurization System	Same as Table 3–1.
13.	ECCS Available	Same as Table 3–1
14.	Stored Energy	Same as Table 3–1.
15.	Fuel Rod Internal Pressure	Same as Table 3–1.
16.	Fuel Exposure	Same as Table 3–1.

(1) Rated power is 3458 MWt for CLTP and 3952 MWt for EPU

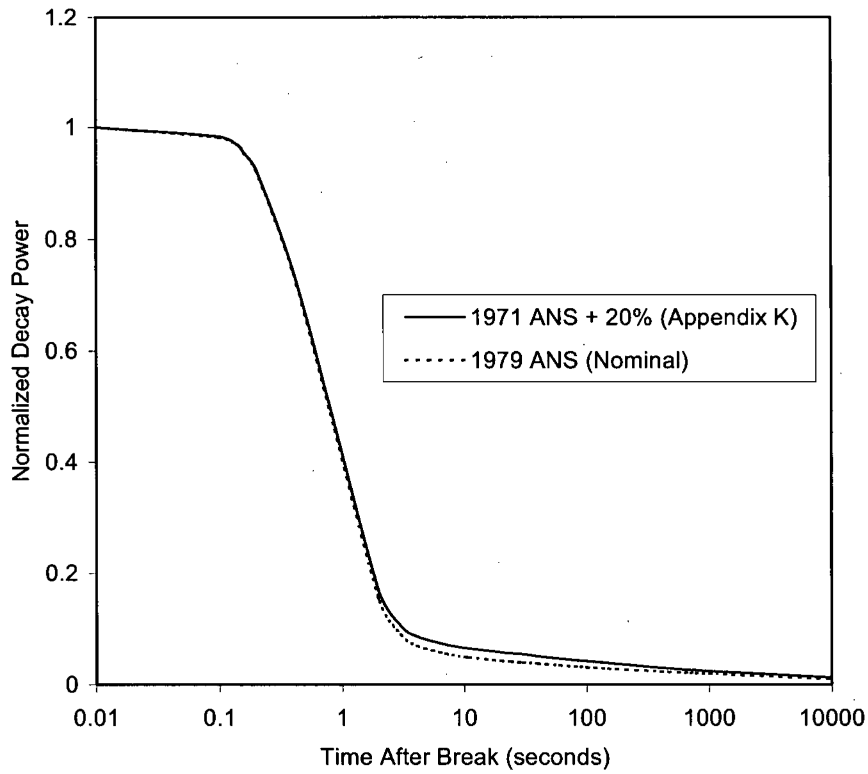


Figure 3-1. Decay Heat Used for Nominal and Appendix K Calculations

4.0 INPUT TO ANALYSIS

4.1 PLANT INPUTS

The significant plant input parameters for the BFNP LOCA analysis are presented in Tables 4-1, 4-2 and 4-3. Table 4-1 shows the plant operating conditions, Table 4-2 shows the fuel parameters, and Table 4-3 identifies the key ECCS parameters used in the analysis. Table 4-4 identifies the combinations of break locations, single failures and available systems specifically analyzed for the BFNP ECCS configuration, which is illustrated in Figure 4-1.

4.2 FUEL PARAMETERS

All SAFER/GESTR-LOCA analyses were performed with a bounding Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) at the most limiting combination of fuel rod power and pellet exposure (Table 4-2). The most limiting power/exposure combination was determined by performing generic sensitivity studies for each fuel type along the peak power/exposure envelope used for fuel thermal/mechanical design. The limiting exposures for each fuel type were found to be at the "knee" of each PLHGR curve. The axial power shape was varied for each analyzed power / flow condition to place the hot bundle on the PLHGR limit while the bundle power is on the MCPR limit.

4.3 ECCS PARAMETERS

The BFNP SAFER/GESTR-LOCA analysis incorporates values for some ECCS performance parameters that are more conservative, relative to either the basis for the current Technical Specifications or expected equipment performance. The intent is to perform the analysis in a very conservative manner to allow for future potential relaxation of ECCS equipment performance requirements. Table 4-3 shows the key performance input parameters used in the analysis (Reference 18).

Table 4-1

PLANT PARAMETERS USED IN
BFNP SAFER/GESTR-LOCA ANALYSIS

	CLTP		**EPU**	
Plant Parameters	**Nominal**	**Appendix K**	**Nominal**	**Appendix K**
Core Thermal Power (MWt)	3458	3527	3952	4031
Corresponding Power (% rated)	100	102	100	102
Vessel Steam Output (lbm/hr)	14.2×10^6	14.5×10^6	16.44×10^6	16.82×10^6
Rated Core Flow(1) (lbm/hr)	102.5×10^6	102.5×10^6	102.5×10^6	102.5×10^6
Vessel Steam Dome Pressure (psia)	1050	1053	1050	1054
Maximum Recirculation Suction Line(2) Break Area (ft^2)	4.24	4.24	4.24	4.24
Maximum Recirculation Discharge Line(3) Break Area (ft^2)	1.96	1.96	1.96	1.96

(1) [[

]]

(2) Suction line break area components include the minimum value of the recirculation suction line nozzle area or safe-end area (3.67 ft^2), one bank of jet pump nozzle areas (0.55 ft^2) and the bottom head drain area (0.02 ft^2).

(3) Discharge line break area components include the recirculation pump minimum eye area (1.39 ft^2), one bank of jet pump nozzle areas (0.55 ft^2) and the bottom head drain area (0.02 ft^2).

Table 4-2

FUEL PARAMETERS USED IN BFNP
SAFER/GESTR-LOCA ANALYSIS (1)

Fuel Parameter	Analysis Value	
	GE13	GE14
[[		
		]]
Number of Fuel Rods per Bundle (3)	74	92

(1) All parameters in this table apply to both EPU and CLTP conditions.

[[

]]

(3) GE13 (9x9) and GE14 (10x10) have 2 water rods occupying a 7-rod space and 8-rod space, respectively.

Table 4-3

ECCS PARAMETERS USED IN BFNP SAFER/GESTR-LOCA ANALYSIS

1. Low Pressure Coolant Injection (LPCI) System

	Variable	Units	Analysis Value
a.	Maximum vessel pressure at which pumps can inject flow	psig	319.5
b.	Minimum rated flow		
	Vessel to drywell differential pressure at which below listed flow rates are quoted	psid (vessel to torus)	20
	• 2 LPCI pumps injecting into one recirc loop	gpm	17300[(1)]
	• 2 LPCI pumps injecting into two recirc loops	gpm	18800[(1)]
	• 4 LPCI pumps injecting into two recirc loops	gpm	34600[(1)]
c.	Minimum flow at 0 psid		
	• 1 LPCI pump injecting into one recirc loop	gpm	9700[(1)]
	• 2 LPCI pumps injecting into one recirc loop	gpm	18000[(1)]
d.	Initiating Signals		
	Low-low-low water level (L1)	in. above vessel zero	372.5
	or		
	High drywell pressure	psig	2.6
	and		
	Low vessel pressure permissive	psig	335
e.	Maximum allowable time from initiation signal to pump at rated speed and capable of rated flow(including diesel-generator start and load time)	sec	44

[(1)] The minimum flow rate that the LPCI system is capable of providing to the vessel is identified in Items 1.b and 1.c. The LPCI leakage identified in Item 5.a is conservatively assumed to reduce the LPCI flow injected inside the shroud. For the LOCA analysis, the minimum LPCI flow rate (Items 1.b, 1.c) is reduced by the LPCI leakage in the analysis. The magnitude of the leakage is a function of the pressure difference between the vessel and the drywell. A quadratic shape is assumed for the LPCI flow vs. ΔP pump curve.

Table 4-3

ECCS PARAMETERS USED IN BFNP SAFER/GESTR-LOCA ANALYSIS
(Continued)

1. Low Pressure Coolant Injection (LPCI) System (Continued)

Variable		Units	Analysis Value
f.	Maximum allowable time from initiation signal to initiation of LPCI injection valve or recirc. discharge valve assuming that event-dependent conditions are not limiting	sec	33
g.	Pressure permissive at which LPCI injection valve may open	psig	335
h.	LPCI injection valve (IV) stroke time	sec	40
i.	Pressure permissive at which recirc. discharge valve may close	psig	200
j.	Recirc discharge valve stroke time	sec	36

Table 4-3

ECCS PARAMETERS USED IN BFNP SAFER/GESTR-LOCA ANALYSIS
(Continued)

2. Low Pressure Core Spray (LPCS) System

	Variable	Units	Analysis Value
a.	Maximum vessel pressure at which pumps can inject flow	psig	289
b.	Minimum rated flow for one LPCS loop (2 CS pumps) at vessel to torus pressure differential	gpm psid	5600(2) 105
c.	Minimum flow at 0 psid (vessel to torus) for one loop (2 core spray pumps)	gpm	7100(2)
d.	Initiating Signals		
	Low-low-low water level (L1) or High drywell pressure and Low vessel pressure permissive	in. AVZ psig psig	372.5 2.6 335
e.	Maximum allowable time from initiation signal to pumps at speed and capable of rated flow (including diesel-generator start and load time)	sec	43
f.	Maximum allowable time from initiation signal to initiation of LPCS injection valve assuming that event-dependent conditions are not limiting	sec	33
g.	Pressure permissive at which LPCS injection valve may open	psig	335
h.	LPCS injection valve (IV) stroke time	sec	33

(2) The minimum flow rate that the LPCS system is capable of providing to the vessel is identified in Items 2.b and 2.c. The core spray leakage identified in Items 5.b and 5.c is conservatively assumed to reduce the core spray flow injected inside the shroud. For the LOCA analysis, the minimum LPCS flow rate delivered to the vessel (Items 2.b, 2.c) is reduced by the LPCS leakage (sum of Items 5.b and 5.c) in the analysis. The magnitude of the leakage is a function of the pressure difference between the vessel and the drywell. A quadratic shape is assumed for the LPCS flow vs. ΔP pump curve.

Table 4-3

ECCS PARAMETERS USED IN BFNP SAFER/GESTR-LOCA ANALYSIS
(Continued)

3. High Pressure Coolant Injection (HPCI) System

Variable		Units	Analysis Value
a.	Operating pressure range		
	Maximum	psid (vessel to torus)	1120
	Minimum	psid (vessel to torus)	150
b.	Minimum flow over the above pressure range	gpm	4500
c.	Initiating Signals		
	Low-low water level (L2) or	in. AVZ	448
	High drywell pressure	psig	2.6
d.	Allowable time delay from initiating signal to rated flow available and injection valve wide open	sec	50[(3)]

[(3)] Does not include signal processing delay time of 2 seconds. (Analysis uses 52 seconds).

Table 4-3

ECCS PARAMETERS USED IN BFNP SAFER/GESTR-LOCA ANALYSIS
(Continued)

4. Automatic Depressurization System (ADS)

	Variable	Units	Analysis Value
a.	Total number of valves available	-	6
b.	Total number of valves assumed available in analysis[(4)]	-	6
c.	Minimum flow capacity per valve at vessel pressure	lbm/hr psig	800000 1125
d.	Initiating signal to start ADS blowdown timer		
	ECCS ready permissive (at least 1 LPCI or 2 core spray pumps are running)[(5)] and		
	Low-low-low water level (L1) and	in. AVZ	372.5
	Low water level (L3) and either	in. AVZ	518
	High drywell pressure or	psig	2.6
	High drywell pressure bypass timer elapsed[(6)]	sec	360
e.	Automatic timer delay time from initiating signal completed to initiation of valve opening.	sec	120

(4) A separate evaluation has been performed with one ADS valve out-of-service.
(5) For small recirculation line breaks, the ECCS ready permissive occurs 21 seconds after L1 is reached. This time delay includes a 2 sec. signal processing delay.
(6) Bypass timer starts on low-low-low water level (L1) signal.

Table 4-3

ECCS PARAMETERS USED IN BFNP SAFER/GESTR-LOCA ANALYSIS
(Continued)

5. In-Vessel Leakage Rates

Variable	Units	Analysis Value
a. LPCI leakage (principally around jet pump joints)		
- Leakage flow	gpm	600
- Pressure at which leakage flow is defined	psid	20
b. LPCS leakage[7]		
- Leakage flow	gpm	40
- Pressure at which leakage flow is defined	psid	105
c. Leakage allowance for LPCS repairs		
- Leakage flow	gpm	125
- Pressure at which leakage flow is defined	psid	105
d. Leakage allowance for access hole cover repairs		
- Leakage flow	gpm	160[8]
- Core flow at which leakage flow is defined	% of rated	105

(7) This leakage is from as-built openings, core spray thermal sleeve-safe end connection and quarter inch high point vent hole in core spray T-box.

(8) Access Hole Cover (AHC) leakage (Item 5.d) is modeled as an additional break path rather than as a reduction to the LPCI and/or LPCS flow rates inside the shroud. The AHC leakage flow includes both manhole covers and is based on the post-LOCA condition with no lost AHC bolts.

Table 4-4

BFNP SINGLE FAILURE EVALUATION

Assumed Failure[(1)]	Recirculation Suction Break Systems Remaining[(2)]	Recirculation Discharge Break Systems Remaining
Battery[(3)]	ADS[(3)], 1LPCS[(4)], 2LPCI (2 pumps into 1 loop)[(5)]	ADS[(3)], 1LPCS
Opposite Unit False LOCA Signal (Units 1 & 2 only)[(6)]	ADS, HPCI, 1LPCS, 2LPCI (2 pumps into 1 loop)[(5)]	ADS, HPCI, 1LPCS
LPCI Injection Valve	ADS, HPCI, 2LPCS, 2LPCI (2 pumps into 1 loop)[(5)]	ADS, HPCI, 2LPCS
Diesel Generator	ADS, 1LPCS, HPCI, 2LPCI (2 pumps into 1 loop)[(5)]	ADS, HPCI, 1LPCS
HPCI	ADS, 2LPCS, 4LPCI (2 per loop) [(5)]	ADS, 2LPCS, 2LPCI (2 pumps into 1 loop) [(5)]

(1) Other postulated failures are not specifically considered because they all result in at least as much ECCS capacity as one of the above assumed failures.

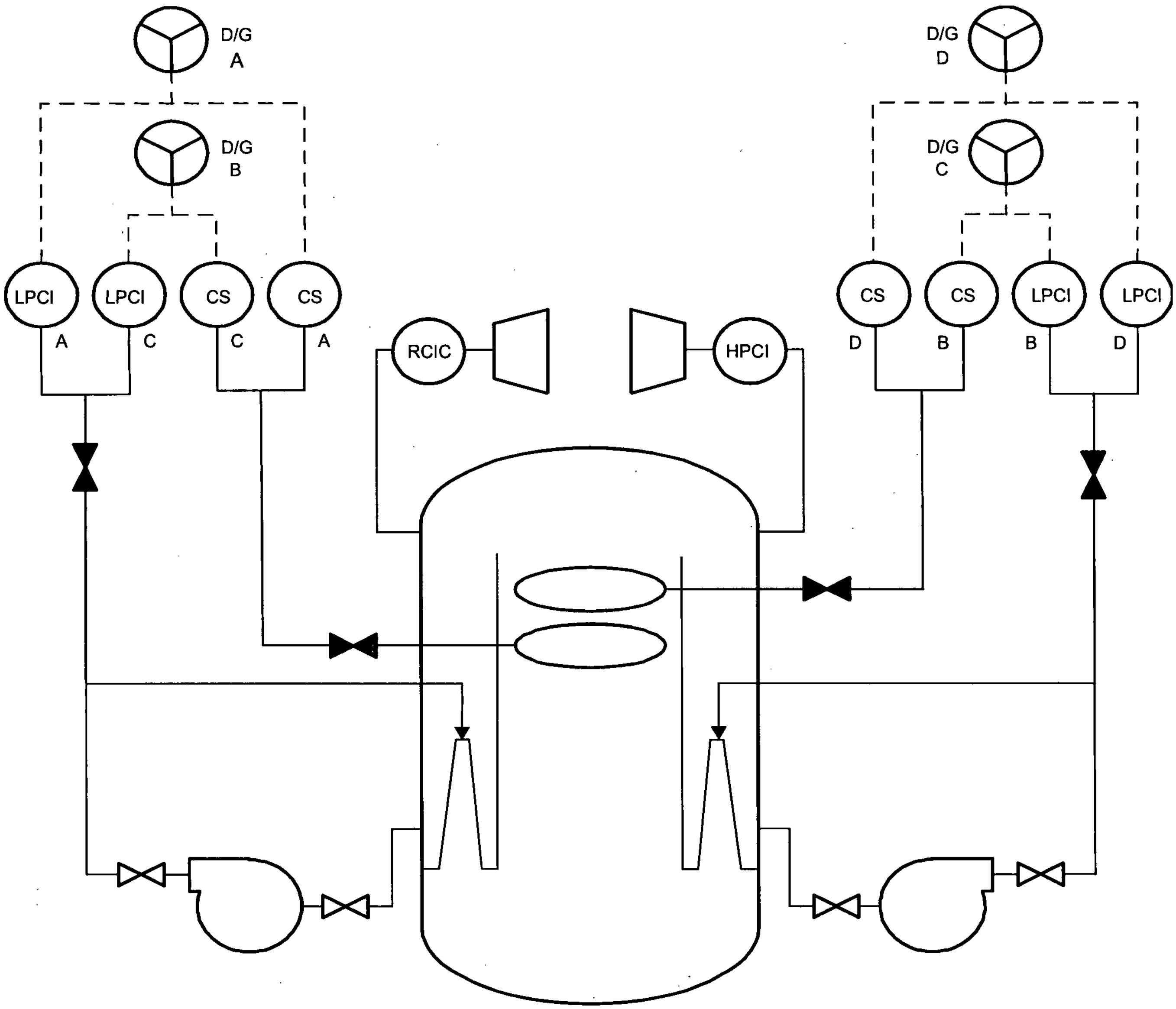
(2) Systems remaining, as identified in this table for recirculation suction line breaks, are applicable to other non-ECCS line breaks. For a LOCA from an ECCS line break, the systems remaining are those listed for recirculation suction breaks, less the ECCS in which the break is assumed.

(3) Six ADS valves are available in the BFNP. The analysis assumes all six ADS valves are available with HPCI inoperable with a supplemental analysis to support one ADS valve out of service.

(4) Each LPCS means operation of two core spray pumps in a system. It is assumed that both pumps in a system must operate to take credit for core spray cooling or inventory makeup.

(5) 2LPCI (2 pumps in 1 loop) means one LPCI loop with two RHR pumps operating. 2LPCI (2 pumps in 2 loops) means one RHR pump in each loop operating. 4LPCI (2 pumps in 2 loops) means two RHR pumps in each of the two loops operating.

(6) An Opposite Unit False LOCA signal only affects the number of available systems for combinations of real and spurious accident signals between Units 1 and 2. Combinations of real and spurious accident signals between Units 1 and 3, or between Units 2 and 3 will not impact the number of available systems in either unit.



* NOTE: BOTH CORE SPRAY PUMPS IN A SYSTEM MUST OPERATE TO ASSURE ADEQUATE SPRAY DISTRIBUTION

Figure 4-1 BFNP ECCS Configuration

5.0 RESULTS

5.1 BREAK SPECTRUM CALCULATIONS

5.1.1 Recirculation Line Breaks

5.1.1.1 Calculations at EPU Conditions

The recirculation line break spectrum was analyzed for the GE13 fuel type at EPU conditions using the nominal and Appendix K assumptions and the inputs discussed in Section 4.0. The limiting large break and a limited small break spectrum were also analyzed for GE14 using the nominal and Appendix K assumptions and the inputs discussed in Section 4.0. The results are listed in Table 5-1 and it can be seen that battery failure is the limiting single failure for both large and small breaks. A sufficient number of breaks were analyzed to establish the shape of the PCT versus break area curve (break spectrum shown in Figure 5-1). This ensures that the limiting combination of the break size, location, and single failure has been identified and is similar to that determined in the generic evaluation. The GE14 small break evaluation included a limited spectrum of break sizes to determine the most limiting break size.

Nominal EPU Results

The maximum recirculation suction line break with the limiting single failure of a DC power source (battery) was analyzed for GE13 and GE14 fuel types, using nominal assumptions and the inputs discussed in Section 4.0. From this analysis, the limiting fuel type for the maximum recirculation suction line break was found to be GE13 (Table 5-1). For this limiting fuel type, a sufficient number of breaks were analyzed and the shape of the PCT versus break area curve (break spectrum) was established. Figure 5-1 shows the nominal break spectrum results for the limiting fuel type. In addition, other potentially limiting combinations of single failure and break location were analyzed with the maximum break size. The most limiting single failure was found to be the battery failure.

The results of nominal calculations at EPU conditions show that the nominal PCT decreases with decreasing break size in the DBA to [[ ]] range, which is consistent with the trend observed in the generic break spectrum [Reference 2]. [[

]] The system response time histories for selected nominal cases are plotted in Appendix A.

In the large break range, the cladding temperature histories show two peaks during the heatup period. The first peak is due to early transition to film boiling (dryout) and is not sensitive to differences in break sizes. The second peak temperature is caused by core uncovery and is strongly dependent on ECCS performance. As shown in Table 5-1, all GE13 large break PCTs are 2nd peak limited, except for the 60% DBA and [[ ]] cases. These cases are first peak limited due to the conservative assumption that the depth of early boiling transition is the same for non-DBA large break cases as it is for the 100% DBA case.

For small breaks [[ ]], ECCS injection depends on reactor depressurization due to initiation of the Automatic Depressurization System (ADS). The highest calculated PCT in the small break range occurs near [[ ]]. The calculated PCT decreases as the break size increases above the limiting small break and decreases as the break size decreases below the limiting small break size. For small breaks that do not experience early film boiling, the cladding heatup occurs due to core uncovery. [[

]]

Appendix K EPU Results

Using the Appendix K assumptions, analyses of three break sizes (60%, 80% and 100% DBA) were performed for GE13 fuel with a battery failure, the limiting single failure determined from the nominal break spectrum analysis. This is intended to examine the sensitivity of Appendix K PCT to break size and to assure that the limiting break is consistent with the generic Appendix K results. The analysis of these three cases satisfies the Appendix K requirement for using the Moody Slip Flow model with three discharge coefficients of 0.6, 0.8 and 1.0 (Table 3-2). [[

]]

The PCT results for Appendix-K cases are summarized in Table 5-1 and the plots of system responses are presented in Appendix B.

Small Break Sensitivity Analysis Results

In addition to the small break evaluation discussed above that assumed 6 ADS valves available, a separate small break evaluation was performed at EPU conditions assuming five ADS valves available using both nominal and Appendix K assumptions with both GE13 and GE14 fuel. Results are shown in Table 5-1. Although there is a significant PCT increase that ranges from 185°F for the GE14 Appendix K case to 298°F for the GE14 nominal case, there is still adequate margin to the Licensing Basis PCT maximum limit of 2200°F. [[

]]

5.1.1.2 Calculations at CLTP Conditions

The limiting large break from the EPU analysis and a limited spectrum of small break nominal and Appendix K cases were run at CLTP conditions for both GE13 and GE14 fuel, using the input parameters discussed in Section 4.0. The results are shown in Table 5-1.

Nominal CLTP Results

The maximum recirculation suction line break with the limiting single failure of a DC power source (battery) was analyzed for GE13 and GE14 fuel types, using nominal assumptions and the inputs discussed in Section 4.0. [[

]]

Appendix K CLTP Results

[[

]]

The PCT results for Appendix-K cases are summarized in Table 5-1 and the plots of system responses are presented in Appendix B.

5.1.1.3 Effect of EPU on Nominal and Appendix K PCT

The effect of the EPU increase in core thermal power on the limiting large break nominal and Appendix K PCTs was small. The PCT changes ranged from +2 °F to –54 °F. The hot bundle power was analyzed on thermal limits (PLHGR and MCPR) while the average bundle power increased. This caused a minor change in flow distribution between the hot and average bundles, which resulted in slightly lower nominal and Appendix K PCTs.

The effect of the EPU power increase on the limiting small break nominal and Appendix K PCTs was significant, ranging from +71 °F to +230 °F. The increased decay heat associated with EPU resulted in higher heat flux, more steam generation, and a longer ADS blowdown time. This resulted in a later ECCS system injection and a higher PCT for the small break LOCA. As a result, the limiting LOCA case that defines the Browns Ferry Licensing Basis PCT at EPU for GE14 fuel is a small recirculation discharge line break with battery failure. A detailed comparison of modeling process updates of the previous ECCS-LOCA analysis (Reference 14) and the current analysis is contained in Appendix C.

5.1.2 Non-Recirculation Line Breaks

Non-recirculation line breaks were analyzed for GE14 fuel at EPU conditions using nominal assumptions. The results (Table 5-2) show that these postulated breaks are significantly less limiting than the postulated recirculation line breaks (Table 5-1). [[

]] The PCT response for non-recirculation breaks is primarily dependent upon break size and break location. The effects of core power level and fuel type are secondary. Thus, it is not necessary to evaluate the non-recirculation line breaks for either GE13 fuel or CLTP conditions.

5.2 COMPLIANCE EVALUATIONS

5.2.1 Licensing Basis PCT Evaluation

EPU Licensing Basis PCT Evaluation

The Licensing Basis PCTs for BFNP were calculated at EPU conditions for GE13 and GE14 fuel types based on the most limiting Appendix K PCTs at EPU power and rated flow, using the methodology described in Section 3.2. Plant-specific variable uncertainties, including backflow leakage, ECCS signal, stored energy, gap pressure, and ADS time delay, were evaluated for both fuel types to determine plant-specific adders. [[

]] For both fuel types, the Appendix K calculations demonstrate that the battery failure is the limiting single failure. The Licensing Basis PCTs at EPU conditions were calculated to be 1780°F for GE13 and 1830°F for GE14. The GE13 Licensing Basis PCT at EPU conditions is also applicable to GE11 fuel. (Since the ECCS-LOCA analyses are performed with equilibrium cores, the additional spacer in GE13 fuel has no impact on the bundle-to-bundle pressure drops.)

CLTP Licensing Basis PCT Evaluation

In order to assess the impact of EPU on the ECCS-LOCA analysis, the Licensing Basis PCTs were also calculated at CLTP conditions for both fuel types. The Licensing Basis PCTs for BFNP were calculated at CLTP conditions for GE13 and GE14 fuel types based on the most limiting Appendix K PCTs at CLTP and rated flow, using the methodology described in Section 3.2. As shown in Table 5-1, the limiting Appendix K PCTs for both fuel types occur at the maximum (DBA) recirculation suction line break. For both fuel types, the Appendix K calculations demonstrate that the battery failure is the limiting single failure. The Licensing Basis PCTs at CLTP conditions were calculated to be 1810°F for GE13 and 1760°F for GE14. The GE13 Licensing Basis PCT at CLTP conditions is also applicable to GE11 fuel.

Effect of EPU on Licensing Basis PCT

The effect of EPU on the Licensing Basis PCT is a 30°F decrease for GE13 and a 70°F increase for GE14. These effects are consistent with the EPU effects on Appendix K large and small break cases described in Section 5.1.1.

5.3 EXPANDED OPERATING DOMAIN AND ALTERNATE OPERATING MODES

The ECCS-LOCA evaluations of expanded operating domains and alternate operating modes are presented as sensitivity studies to the break spectrum analyses performed at rated conditions. The limiting break/failure combination is usually not affected by changes in the power / flow conditions. The largest PCT effect in the expanded operating domain occurs at reduced core, which can cause earlier dryout times. Small breaks are not affected by reduced core flow because nucleate boiling is maintained until core uncovery. Thus, only the limiting DBA recirculation line break/failure combination is analyzed, using nominal and Appendix K assumptions.

5.3.1 Increased Core Flow (ICF)

[[

]]

5.3.2 Reduced Core Flow Regions (MELLLA / MELLLA+)

Although the plant is currently operating in the Maximum Extended Load Line Limit Analysis (MELLLA) region, it is expected to transition to the Maximum Extended Load Line Limit Analysis Plus (MELLLA+) region. [[

]] If EBT occurs for the higher power node as a result of the reduced initial core flow, the resulting PCT can exceed the corresponding results for the rated core flow.

Low core flow effects on the ECCS analyses were generically addressed in Reference 9, which was approved by the NRC in Reference 10. These studies demonstrated that no MAPLHGR multiplier was required for low core flow operation for the BWR/4 plant class similar to the BFNP. The Reference 9 analysis (prior to consideration of MELLLA operation and ARTS) was performed consistent with the original setdown requirement. With ARTS for BFNP [Reference 11], the setdown factor on the flow-referenced APRM rod block system is removed and replaced with MAPLHGR and MCPR adjustment factors as functions of power and flow. The SAFER/GESTR-LOCA analysis for low core flow conditions in the MELLLA region was evaluated for BFNP, using the same ECCS inputs as used for the rated core flow conditions. In the SAFER/GESTR-LOCA analysis of the MELLLA+ region, credit was taken for the off-rated flow and power MAPLHGR and MCPR multipliers (MCPR(f), K(p), MAPFAC(f) and MAPFAC(p) of References 11 and 12).

[[

]] The analysis was performed with both nominal and Appendix K assumptions. The results are shown in Table 5-3, with EPU power / rated core flow results presented for comparison.

[[

]]

In the MELLLA and MELLLA+ regions, the PCT increase in comparison to the EPU power / rated flow cases is small relative to the available PCT margin to the 2200°F limit. As such, the ECCS-LOCA analysis does not impose any additional restrictions on the existing power and flow dependent MCPR and MAPLHGR multipliers in References 11 and 12.

5.3.3 Final Feedwater Temperature Reduction

The impact on LOCA results due to final feedwater temperature reduction (FFWTR) up to 55°F was evaluated for a core thermal power level of 3952 MWt at rated flow, using the same ECCS parameters as used for normal feedwater temperature. At EPU power, feedwater temperature reduction was evaluated at the 100% core flow condition because MELLLA flow at 99% of rated core flow has a negligible impact on PCT. The limiting LOCA event, a DBA recirculation suction line break with battery failure, was analyzed for this FFWTR case, using nominal and Appendix-K assumptions for GE13 fuel. [[

]]
This decrease in PCT at FFWTR conditions at EPU power is consistent with the decreasing PCT trend in the previous GE14 CLTP FFWTR results (Reference 19).

5.3.4 Single-Loop Operation (SLO)

[[

]]

5.4 MAPLHGR LIMITS

The SAFER/GESTR-LOCA analysis was performed with a bounding Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) at the most limiting combination of power and exposure for each analyzed fuel type (GE13 and GE14). The ECCS-based exposure dependent MAPLHGR limits are determined on a fuel type basis. The thermal limits applied to the GE13 and GE14 fuel types in the ECCS-LOCA evaluation are summarized in Table 6-3.

Application of the ARTS-based fuel thermal-mechanical design analysis limits [LHGRFAC(p) / LHGRFAC(f) or MAPFAC(p) / MAPFAC(f)] are required since the SAFER/GESTR-LOCA analysis of the MELLLA+ region takes credit for the off-rated flow and power PLHGR / MAPLHGR multipliers and also to ensure that two-loop off-rated conditions not specifically analyzed will not be limiting.

In Single Loop Operation, specific multipliers on PLHGR and MAPLHGR are required. The SLO multiplier is independent of the two-loop limits. The SLO multiplier is applicable to all fuel rod exposures. The SLO multiplier on PLHGR is not required if the MAPLHGR limits are based upon a bounding composite of ECCS and Thermal/Mechanical MAPLHGR limits.

Table 5-1

SUMMARY OF BFNP SAFER/GESTR-LOCA RESULTS
FOR RECIRCULATION LINE BREAKS[1]

Break Size	Break Location	Single Failure	Core Power	GE13 PCT (°F)	GE14 PCT (°F)
[[					
					]]

Table 5-1 (continued)
SUMMARY OF BFNP SAFER/GESTR-LOCA RESULTS
FOR RECIRCULATION LINE BREAKS[1]

Break Size	Break Location	Single Failure	Core Power	GE13 PCT (°F)	GE14 PCT (°F)
[[					
					]]

[[

]]

Table 5-2

SUMMARY OF BFNP SAFER/GESTR-LOCA RESULTS
FOR NON-RECIRCULATION LINE BREAKS[1,2]
(Nominal Analysis Basis)

Break Location	Break Size (ft^2)	Single Failure	GE14 PCT (°F)
[[			
			]]

[[

]]

Table 5-3

REDUCED CORE FLOW (MELLLA/MELLLA+)
RESULTS COMPARISON FOR BFNP[1,2]

Region	Core Power	Core Flow (% rated)	Analysis Basis	GE13 PCT (°F)	GE14 PCT (°F)
[[					
					]]

[[

]]

Table 5-4

SINGLE LOOP OPERATION RESULTS
COMPARISON FOR BFNP
DBA Recirculation Line Suction Break

		CLTP		EPU	
Analysis Basis	**Parameter**	**GE13**	**GE14**	**GE13**	**GE14**
[[					
					]]

[[

]]

Figure 5-1 Nominal and Appendix K LOCA Break Spectrum Results for GE13 Fuel at EPU Conditions

6.0 CONCLUSIONS

LOCA analyses have been performed for Browns Ferry Nuclear Plant Units 1, 2 and 3 using the GE SAFER/GESTR-LOCA application methodology approved by the NRC. These analyses were performed to demonstrate conformance with 10CFR50.46 and Appendix K, and to support a revised licensing basis for BFNP with the GE SAFER/GESTR-LOCA methodology.

As the BFNP SAFER/GESTR-LOCA results presented in Section 5 indicate, a sufficient number of plant-specific PCT points have been evaluated to establish the shape of both the nominal and Appendix-K PCT versus break size curves. The analyses demonstrate that the limiting GE13 Licensing Basis PCT at EPU conditions occurs for the recirculation suction line break DBA with battery failure. The analyses demonstrate that the limiting GE14 Licensing Basis PCT at EPU conditions occurs for the recirculation discharge line small break with battery failure at a break area of 0.06 ft^2.

The Licensing Basis PCTs were also calculated at the thermal power level of 3458 MWt, which is the current licensed thermal power (CLTP) for Units 2 and 3. The results for the analysis at 3458 MWt, 105% of the Unit 1 rated power, conservatively bounds Unit 1 operation at 3293 MWt. The analyses demonstrate that the limiting GE13 and GE14 Licensing Basis PCTs at CLTP conditions occurs for the recirculation suction line break DBA with battery failure.

Table 6-1 summarizes the key SAFER/GESTR licensing results for BFNP at EPU conditions. Table 6-2 summarizes the key SAFER/GESTR licensing results for BFNP at CLTP conditions. The thermal limits applied to the GE13 and GE14 fuel types in the ECCS-LOCA evaluation are summarized in Table 6-3. The analyses presented are performed in accordance with NRC requirements and demonstrate conformance with the ECCS acceptance criteria of 10CFR50.46. Therefore, the results documented in this report may be used to provide a new LOCA Licensing Basis for BFNP.

Table 6-1

SAFER/GESTR-LOCA LICENSING RESULTS
FOR BFNP UNITS 1, 2 AND 3 AT EPU (3952 MWt)

	Parameter	SAFER/GESTR-LOCA Results		Licensing Acceptance Criteria
1.	Fuel Type	GE13	GE14	
2.	Limiting Break Location	Recirculation Suction Line	Recirculation Discharge Line	
3.	Limiting Break Size	DBA	0.06 ft^2	
4.	Limiting ECCS Failure	Battery	Battery	
5.	Peak Cladding Temperature (Licensing Basis)	1780	1830	< 2200°F
6.	Maximum Local Oxidation	<2%	<3%	< 17%
7.	Core-Wide Metal-Water Reaction	<0.1%	<0.1%	< 1%
8.	Coolable Geometry	Items 5 & 6		PCT < 2200°F and Local Oxidation < 17%
9.	Long-Term Cooling	Core reflooded above Top of Active Fuel (TAF) or Core reflooded to the top of the jet pump suction and one Core Spray system in operation		Core temperature acceptably low and long-term decay heat removed; met by core reflooded above Top of Active Fuel (TAF) or Core reflooded to the top of the jet pump suction and one Core Spray system in operation

Table 6-2

SAFER/GESTR-LOCA LICENSING RESULTS
FOR BFNP UNITS 1, 2 AND 3 AT CLTP (3458 MWt)

	Parameter	**SAFER/GESTR-LOCA Results**		**Licensing Acceptance Criteria**
1.	Fuel Type	GE13	GE14	
2.	Limiting Break Location	Recirculation Suction Line	Recirculation Discharge Line	
3.	Limiting Break Size	DBA	DBA	
4.	Limiting ECCS Failure	Battery	Battery	
5.	Peak Cladding Temperature (Licensing Basis)	1810	1760	< 2200°F
6.	Maximum Local Oxidation	<2%	<2%	< 17%
7.	Core-Wide Metal-Water Reaction	<0.1%	<0.1%	< 1%
8.	Coolable Geometry	Items 5 & 6		PCT < 2200°F and Local Oxidation < 17%
9.	Long-Term Cooling	Core reflooded above Top of Active Fuel (TAF) or Core reflooded to the top of the jet pump suction and one Core Spray system in operation		Core temperature acceptably low and long-term decay heat removed; met by core reflooded above Top of Active Fuel (TAF) or Core reflooded to the top of the jet pump suction and one Core Spray system in operation

Table 6-3

THERMAL LIMITS USED IN THE BFNP ECCS-LOCA ANALYSIS

Parameter	Analysis Limit			
	GE13		GE14	
PLHGR – Exposure Limit Curve[1]	GWD/MT	kW/ft	GWD/MT	kW/ft
	0.0	14.4	0.0	13.4
	14.60	14.4	16.00	13.4
	30.00	12.29	63.50	8.0
	70.00	8.90	70.00	5.0
MAPLHGR – Exposure Limit Curve[1]	GWD/MT	kW/ft	GWD/MT	kW/ft
	0	13.42	0	12.82
	21.74	13.42	21.09	12.82
	30.00	12.29	63.50	8.0
	70.00	8.90	70.00	5.0
Initial Operating MCPR[1]	1.25		1.30	
Minimum R-Factor[1]	0.962		0.954	
SLO Multiplier on PLHGR & MAPLHGR (CLTP)[2]	0.87		0.93	
SLO Multiplier on PLHGR & MAPLHGR (EPU)[2]	0.87		0.90	
PLHGR limit used in the MELLLA+ region at CLTP / 68% flow (kW/ft)	13.23		12.31	
Initial Operating MCPR in the MELLLA+ region at CLTP / 68% flow	1.31		1.36	

(1) Applies to both CLTP and EPU conditions.
(2) The SLO multiplier on PLHGR is not required if the MAPLHGR limits are based upon a bounding composite of ECCS and Thermal/Mechanical MAPLHGR limits.

7.0 REFERENCES

1) Letter, C.O. Thomas (NRC) to J.F. Quirk (GE), "Acceptance for Referencing of Licensing Topical Report NEDE-23785, Revision 1, Volume III (P), The GESTR-LOCA and SAFER Models for the Evaluation of the Loss-of-Coolant Accident," June 1, 1984.

2) "The GESTR-LOCA and SAFER Models for the Evaluation of the Loss-of-Coolant Accident, Volume III, SAFER/GESTR Application Methodology," NEDE-23785-1-PA, General Electric Company, Revision 1, October 1984.

3) "General Electric Company Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50 Appendix K," NEDO-20566A, General Electric Company, September 1986.

4) "The GESTR-LOCA and SAFER Models for the Evaluation of the Loss-of-Coolant Accident; Volume I, GESTR-LOCA - A Model for the Prediction of Fuel Rod Thermal Performance," NEDC-23785-2-P, General Electric Company, May 1984.

5) "Compilation of Improvements to GENE's SAFER ECCS-LOCA Evaluation Model," NEDC-32950P, General Electric Company, January 2000.

6) "GE11 Compliance with Amendment 22 of NEDE-20411-P-A (GESTAR-II)," NEDE-31917P, General Electric Company, April 1991.

7) "TASC-03A, A Computer Program for Transient Analysis of a Single Fuel Channel," NEDC-32084P-A, Revision 2, General Electric Company, July 2002.

8) "SAFER Model for Evaluation of Loss-of-Coolant Accidents for Jet Pump and Non-Jet Pump Plants," NEDE-30996P-A, General Electric Company, October 1987.

9) Letter, R.L. Gridley (GE) to D.G. Eisenhut (NRC), "Review of Low-Core Flow Effects on LOCA Analysis for Operating BWRs - Revision 2," May 8, 1978.

10) Letter, D.G. Eisenhut (NRC) to R.L. Gridley (GE), "Safety Evaluation Report on Revision of Previously Imposed MAPLHGR (ECCS-LOCA) Restriction for BWRs at Less Than Rated Core Flow," May 19, 1978.

11) "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses at Browns Ferry Nuclear Plant Unit 1, 2 and 3," NEDC-32433P, General Electric Company, April 1995.

12) "GE14 Fuel Design Cycle-Independent Analyses for Browns Ferry Units 2 and 3," GE-

NE-L12-00889-00-01P, January 2002.

13) "GESTR-LOCA and SAFER Models for Evaluation of Loss-of Coolant Accident, Volume III, Supplement 1 – Additional Information for Upper Bound PCT Calculation," NEDE-23785P-A, Supplement 1, Revision 1, March 2002.

14) "Browns Ferry Nuclear Plant Units 1, 2 and 3 SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis," NEDC-32484P Revision 5, January 2002.

15) "Generic Guidelines for General Electric Boiling Water Reactor Extended Power Uprate," NEDC-32424P-A, Class III, February 1999 (ELTR-1).

16) "Elimination of the 1600°F Upper Bound PCT Limit on Browns Ferry Units 1-3," GE-NE-0000-0025-9481-R0, transmitted by GE letter, GE-ER3JXC9P-002, E.G. Thacker (GE) to John Elmerick (TVA), 4/29/2004.

17) Stuart A. Richards (NRC) to James F. Klapproth (GENE), Review of NEDE-23785P, Vol. III, Supplement 1, Revision 1, "GESTR-LOCA and SAFER Models for Evaluation of Loss-of-Coolant Accident Volume III, Supplement 1, Additional Information for Upper Bound PCT Calculation," (TAC No. MB2774), February 1, 2002.

18) "Browns Ferry Nuclear Plant (BFN) - Extended Power Uprate - Unit 1, 2, and 3 Asset Enhancement Program – FTR T0407 – Transmittal of Comments and Design Input Request T0407 Revision 1 for LOCA Reanalysis," Letter R05 031208 001 from J. Valente (TVA) to L. King (GE), December 8, 2003.

19) "Browns Ferry Nuclear Plant Units 1, 2 and 3 SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis," NEDC-32484P Revision 5, January 2002.

20) "Tennessee Valley Authority Browns Ferry Units 1, 2, 3 Asset Enhancement Program EPU and MELLLA+ Task T0407: ECCS-LOCA SAFER/GESTR," GE-NE-0000-0011-1721 Revision 0, March 2004.

APPENDIX A

SYSTEM RESPONSE CURVES FOR NOMINAL RECIRCULATION LINE BREAKS

Included in this appendix are the system response curves for the BFNP. Table A-1 shows the figure numbering sequence for the nominal recirculation breaks.

Table A-1

NOMINAL RECIRCULATION LINE BREAK FIGURE SUMMARY

Notes: All plots are for GE13 fuel, except when noted.

Break Size Break Location Single Failure Core Power Core Flow	DBA Suction Battery EPU Rated	80% DBA Suction Battery EPU Rated	60% DBA Suction Battery EPU Rated	1.0 ft^2 Suction Battery EPU Rated	[[ ]]	DBA Suction Battery CLTP Rated	[[ ]]
Water Level in Hot & Average Channels	A-1a	A-2a	A-3a	A-4a	A-5a	A-6a	A-7a
Reactor Vessel Pressure	A-1b	A-2b	A-3b	A-4b	A-5b	A-6b	A-7b
Peak Cladding Temperature	A-1c,f*	A-2c	A-3c	A-4c	A-5c,f*	A-6c,f*	A-7c,f*
Heat Transfer Coefficient	A-1d,g*	A-2d	A-3d	A-4d	A-5d,g*	A-6d,g*	A-7d,g*
ECCS Flow	A-1e	A-2e	A-3e	A-4e	A-5e	A-6e	A-7e

* Plots for GE13 and GE14 are included.

[[ ]]

[[

]]

Figure A-1a. Water Level in Hot and Average Channels - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-1b. Reactor Vessel Pressure - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-1c. Peak Cladding Temperature (GE13) - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-1d. Heat Transfer Coefficient (GE13) - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-1e. ECCS Flow - DBA Suction – Battery Failure (Nominal) –
2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-1f. Peak Cladding Temperature (GE14) - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-1g. Heat Transfer Coefficient (GE14) - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-2a. Water Level in Hot and Average Channels - 80% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-2b. Reactor Vessel Pressure - 80% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-2c. Peak Cladding Temperature (GE13) - 80% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-2d. Heat Transfer Coefficient (GE13) - 80% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-2e. ECCS Flow - 80% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-3a. Water Level in Hot and Average Channels - 60% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-3b. Reactor Vessel Pressure - 60% DBA Suction – Battery Failure (Nominal) – 2LPCI + LPCS + ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-3c. Peak Cladding Temperature (GE13) - 60% DBA Suction – Battery Failure (Nominal) – 2LPCI + LPCS + ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-3d. Heat Transfer Coefficient (GE13) - 60% DBA Suction – Battery Failure (Nominal) – 2LPCI + LPCS + ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-3e. ECCS Flow - 60% DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-4a. Water Level in Hot and Average Channels - [[ ]] Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-4b. Reactor Vessel Pressure - [[ ]] Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-4c. Peak Cladding Temperature (GE13) - [[ ]] Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-4d. Heat Transfer Coefficient (GE13) - [[ ]] Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-4e. ECCS Flow - [[ ]] Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure A-5a. Water Level in Hot and Average Channels - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-5b. Reactor Vessel Pressure - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-5c. Peak Cladding Temperature (GE13) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-5d. Heat Transfer Coefficient (GE14) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-5e. ECCS Flow - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-5f. Peak Cladding Temperature (GE14) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-5g. Heat Transfer Coefficient (GE14) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure A-6a. Water Level in Hot and Average Channels - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-6b. Reactor Vessel Pressure - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-6c. Peak Cladding Temperature (GE13) – DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-6d. Heat Transfer Coefficient (GE13) – DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-6e. ECCS Flow - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-6f. Peak Cladding Temperature (GE14) - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-6g. Heat Transfer Coefficient (GE14) - DBA Suction – Battery Failure (Nominal) – 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure A-7a. Water Level in Hot and Average Channels - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure A-7b. Reactor Vessel Pressure - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure A-7c. Peak Cladding Temperature (GE13) - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure A-7d. Heat Transfer Coefficient (GE13) - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure A-7e. ECCS Flow - [[ ]] (CLTP Power / Rated Flow)

[[

]]

Figure A-7f. Peak Cladding Temperature (GE14) - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure A-7g. Heat Transfer Coefficient (GE14) - [[
]] (CLTP Power / Rated Flow)

APPENDIX B

SYSTEM RESPONSE CURVES FOR APPENDIX K RECIRCULATION LINE BREAKS

Included in this appendix are the system response curves for BFNP. Table B-1 shows the figure numbering sequence for the Appendix K recirculation breaks.

Table B-1

APPENDIX K RECIRCULATION LINE BREAK FIGURE SUMMARY

Note: All Plots are for GE13 fuel, except when noted.

Break Size Break Location Single Failure Core Power Core Flow	DBA Suction Battery EPU Rated	DBA Suction Battery CLTP MELLLA ***	80% DBA Suction Battery EPU Rated	60% DBA Suction Battery EPU Rated	[[ ]]	DBA Suction Battery CLTP Rated	[[ ]]
Water Level in Hot & Average Channels	B-1a	B-2a	B-3a	B-4a	B-5a	B-6a	B-7a
Reactor Vessel Pressure	B-1b	B-2b	B-3b	B-4b	B-5b	B-6b	B-7b
Peak Cladding Temperature	B-1c,h*	B-2c	B-3c	B-4c	B-5c,f*	B-6c,f*	B-7c,f*
Heat Transfer Coefficient	B-1d,i*	B-2d	B-3d	B-4d	B-5d,g*	B-6d,g*	B-7d,g*
ECCS Flow	B-1e	B-2e	B-3e	B-4e	B-5e		B-7e
Core Inlet Flow	B-1f					B-6e	
MCPR	B-1g						

* Plots for GE13 and GE14 are included.

[[ ]]

*** At CLTP power, the core flow on the MELLLA rod line is 81% of rated

[[

]]

Figure B-1a. Water Level in Hot and Average Channels - DBA Suction – Battery Failure (App. K) – 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1b. Reactor Vessel Pressure - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1c. Peak Cladding Temperature (GE13) - DBA Suction – Battery Failure (App. K) —
2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1d. Heat Transfer Coefficient (GE13) - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1e. ECCS Flow - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1f. Core Inlet Flow - DBA Suction – Battery Failure (App. K) —
2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1g. Minimum Critical Power Ratio (GE13) - DBA Suction – Battery Failure (App. K) —2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1h. Peak Cladding Temperature (GE14) - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-1i. Heat Transfer Coefficient (GE14) - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-2a. Water Level in Hot and Average Channels - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / 81% Flow)

[[

]]

Figure B-2b. Reactor Vessel Pressure - DBA Suction – Battery Failure (App. K) —
2LPCI+LPCS+ADS Available (CLTP Power / 81% Flow)

[[

]]

Figure B-2c. Peak Cladding Temperature (GE13) - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / 81% Flow)

[[

]]

Figure B-2d. Heat Transfer Coefficient (GE13) - DBA Suction – Battery Failure (App. K) —
2LPCI+LPCS+ADS Available(CLTP Power / 81% Flow)

[[

]]

Figure B-2e. ECCS Flow - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / 81% Flow)

[[

]]

Figure B-3a. Water Level in Hot and Average Channels - 80% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-3b. Reactor Vessel Pressure - 80% DBA Suction –Battery Failure (App. K) —
2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-3c. Peak Cladding Temperature (GE13) - 80% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-3d. Heat Transfer Coefficient (GE13) - 80% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-3e. ECCS Flow - 80% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-4a. Water Level in Hot and Average Channels - 60% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-4b. Reactor Vessel Pressure - 60% DBA Suction –Battery Failure (App. K) —
2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-4c. Peak Cladding Temperature (GE13) - 60% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-4d. Heat Transfer Coefficient (GE13) - 60% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-4e. ECCS Flow - 60% DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (EPU Power / Rated Flow)

[[

]]

Figure B-5a. Water Level in Hot and Average Channels - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure B-5b. Reactor Vessel Pressure - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure B-5c. Peak Cladding Temperature (GE13) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure B-5d. Heat Transfer Coefficient (GE13) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure B-5e. ECCS Flow - [[ ]] (EPU Power / Rated Flow)

[[

]]

Figure B-5f. Peak Cladding Temperature (GE14) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure B-5g. Heat Transfer Coefficient (GE14) - [[
]] (EPU Power / Rated Flow)

[[

]]

Figure B-6a. Water Level in Hot and Average Channels - DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-6b. Reactor Vessel Pressure - DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-6c. Peak Cladding Temperature (GE13) - DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-6d. Heat Transfer Coefficient (GE13) - DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-6e. ECCS Flow -DBA Suction –Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-6f. Peak Cladding Temperature (GE14) - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-6g. Heat Transfer Coefficient (GE14) - DBA Suction – Battery Failure (App. K) — 2LPCI+LPCS+ADS Available (CLTP Power / Rated Flow)

[[

]]

Figure B-7a. Water Level in Hot and Average Channels - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure B-7b. Reactor Vessel Pressure - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure B-7c. Peak Cladding Temperature (GE13) - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure B-7d. Heat Transfer Coefficient (GE13) - [[
]] (CLTP Power / Rated Flow)

]]

]]

Figure B-7e. ECCS Flow - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure B-7f. Peak Cladding Temperature (GE14) - [[
]] (CLTP Power / Rated Flow)

[[

]]

Figure B-7g. Heat Transfer Coefficient (GE14) - [[
]] (CLTP Power / Rated Flow)

APPENDIX C

COMPARISON OF BROWNS FERRY 105% POWER UPRATE AND EPU/MELLLA+ ECCS-LOCA SAFER/GESTR ANALYSES

Requirements

The NRC approved SAFER/GESTR application methodology is defined in NEDC-23785P (Ref. 3). This document defines the overall approach to applying the SAFER/GESTR analytical model to the ECCS-LOCA analysis.

Methodology

The SAFER/GESTR methodology is summarized in Section 3.1 of the Browns Ferry Unit 1/2/3 EPU/MELLLA+ T0407 Task Report (Ref. 1) (hereinafter referred to as the current analysis). This SAFER/GESTR ECCS-LOCA analysis was performed in accordance with the NRC approved methods listed in Item 1 of Section 3.1 of the Task Report. The list of NRC approved methodology is the same for the previous Browns Ferry Unit 1/2/3 ECCS-LOCA analysis at the current licensing thermal power (CLTP) of 3458 MWt (Ref. 2) (hereinafter referred to as the previous analysis) as for the current analysis with the exception of the governing Licensing Topical Report (LTR) for the EPU analysis which applies at the EPU thermal power level. The previous analysis was performed using the SAFER/GESTR-LOCA Application Methodology approved by the NRC (Ref. 3). The current analysis was performed using this methodology, supplemented by Refs. 8 and 9, under the Extended Licensing Topical Report (ELTR) (Ref. 4) with a number of process updates, 10 CFR 50.46 error corrections, and plant configuration changes. Application of the methodology by ELTR requirements in the current analysis is similar to that of the previous analysis, including confirmation of the limiting single failure and the analysis of a full break spectrum. The same set of Level 2 codes was used for both analyses. The current analysis also employs additional non-Level 2 automation codes as identified in Section 3.1, Item 3 of Reference 1.

Process Updates

Process changes between the previous analysis and the current analysis that had a significant peak cladding temperature (PCT) impact were made in the areas of the power distribution calculation, break modeling assumptions, dryout time calculations and the calculation of gamma smearing coefficients. Each of these areas is described below.

<u>*Power Distribution Calculation*</u> – In both the previous GE14 analysis (Ref. 2) and the current GE13 and GE14 analyses (Ref. 1), the power distribution was calculated to place the hot bundle power on both the LOCA initial CPR and the PLHGR limits with a mid-peaked axial power shape. The current GE14 analysis used a bounding fuel-specific R-factor to establish a maximum bundle power whereas the previous GE14 analysis relied on a maximum radial peaking factor to establish a maximum bundle power. In the

previous GE13 analysis no initial MCPR was considered because assumed dryout times were used. Also a conservatively flat axial power shape was applied to both the GE13 nominal and Appendix K cases. Finally, in the previous GE13 and GE14 analyses, the Appendix K axial power shape was applied to the nominal case while in the current analysis, separate axial power shapes were calculated for nominal and Appendix K cases consistent with their respective thermal hydraulic conditions. All the power distribution calculation changes were implemented in order to generate a more realistic hot bundle power while keeping the hot node on the PLHGR and initial CPR limits with a mid-peaked axial power shape. Power distribution changes affect dryout times, core uncovery times and core reflooding times. [[

]]

Recirculation Discharge Valve Modeling – In the previous GE14 analysis, the recirculation suction DBA break area was adjusted to reflect the closure of the recirculation discharge valve for break area reduction during the LOCA event. This modeling was used to provide margin to the 1600°F Upper Bound PCT limit. Justification for elimination of this Upper Bound PCT restriction for the current analysis is contained in Attachment 1 of the current analysis task report. With the Upper Bound PCT restriction eliminated, the current analysis did not take any credit for break area reduction upon closure of the recirculation discharge valve. This modeling change simplified the analytical assumptions and justifications. It also reduced the risk of error by eliminating manual input and reducing the number of SAFER cases required. In both the previous and current GE13 analyses, no credit was taken for break area reduction upon closure of the recirculation discharge valve. [[

]]

Bottom Head Drain Modeling – In the previous GE14 small break evaluation, the bottom head drain break path was not activated until the recirculation suction line uncovered (based on the water level in the downcomer). In the current GE14 small break evaluation, as well as in the previous and current GE13 small break evaluations, the bottom head drain break flow path was activated at the start of the LOCA event. The break flow from the bottom head drain has higher subcooling than the break flow from the annulus. Thus, for a given small break size, the total break flow is higher when there is a larger contribution from the bottom head drain. The contribution of the bottom head drain break flow path throughout the LOCA event added conservatism to the PCT results. [[

]]

Dryout Time Calculation – The previous GE13 analysis used assumed dryout times. In the current GE13 analysis, as well as in the previous and current GE14 analyses, dryout times were calculated based on EPU conditions and on the power distribution calculated for the analysis. [[

]] Since the small break cases are assumed to remain in nucleate boiling until core uncovery, changes in the dryout time have no effect on small break PCTs.

Gamma Smearing Coefficients – The previous analysis used heat source distribution coefficients calculated from representative 9x9 and 10x10 bundles whereas the current analysis used coefficients calculated from actual Browns Ferry GE13 and GE14 bundles. Changes in gamma smearing coefficients affect the ratio of hot rod power to average rod power in the hot bundle. [[
]]

10 CFR 50.46 Error Corrections

Three 10 CFR 50.46 errors contained in the previous analysis were corrected in the current analysis.

10 CFR 50.46 Error Notification 2002-05 (Downcomer Volume Error)

[[

]] The Licensing Basis PCT change for Browns Ferry was 0°F. [[
]]

10 CFR 50.46 Error Notification 2003-01 (SAFER Water Level / Volume Table Error)

[[

]] The Licensing Basis PCT change for Browns Ferry was +5°F. [[
]]

10 CFR 50.46 Error Notification 2003-02 (SAFER Exposure Error)

[[

]] The Licensing Basis PCT change for Browns Ferry was 0°F.

[[ ]]

[[

]]

10 CFR 50.46 Error Notification MFN-020-96 (Vessel Bottom Head Drain Effect)

[[

]] The GE13 Licensing Basis PCT change for Browns Ferry was +10°F.

10 CFR 50.46 Error Notification 2000-04 (SAFER Time Step Size)

[[

]] The GE13 Licensing Basis PCT change for Browns Ferry was -5°F.

10 CFR 50.46 Error Notification 2001-01 (SAFER Condensation Error)

[[

]] The GE13 Licensing Basis PCT change for Browns Ferry was +45°F.

10 CFR 50.46 Error Notification 2001-02 (SAFER Pressure Rate Inconsistency Error)

[[

]] The GE13 Licensing Basis PCT change for Browns Ferry was +10°F.

Plant Configuration Changes

The current analysis ECCS performance parameters are documented in the OPL-4/5 (Ref. 6). Differences between previous analysis ECCS performance parameters and current analysis ECCS performance parameters are discussed below.

VFD Installation – The effect of the VFD recirculation system modification on ECCS performance is directly related to the change in the inertia of the recirculation system rotating elements. With the replacement of the M-G set by the VFD, the coastdown of the recirculation pumps is faster because it only includes the inertia of the pump and motor. The early boiling transition times (boiling transitions that occur before jet pump uncovery) occur earlier in the event and may penetrate lower in the fuel bundle as the core flow coastdown is accelerated, but the impact of the earlier boiling transition on the overall LOCA PCT depends on several factors. [[

]]

HPCI Steam Flow – The HPCI steam flow at maximum pressure was updated from 184,000 lbm/hr to 204,850 lbm/hr. [[

]]

Access Hole Cover (AHC) Leakage – An AHC leakage of 160 gpm was assumed for the current analysis. The AHC leakage flow includes both manhole covers and was based on the post-LOCA condition with no lost AHC bolts. There was no AHC leakage modeled in the previous analysis. [[

]]

LPCS Leakage – The LPCS leakage flow was changed from 100 gpm at 105 psid in the previous analysis to 165 gpm at 105 psid in the current analysis. This core spray leakage is assumed to reduce the core spray flow injected inside the shroud. Since this increase in core spray leakage only reduces the total core spray flow by about 1%, [[

]]

ECCS Initiation Delay Times – The signal processing time was increased from 0 to 2 seconds. This affected LPCI and LPCS pressure permissive delay times, HPCI activation delay times, and ADS bypass timer delay times. The maximum delay time (non-pressure permissive path) for LPCI initiation was increased from 69 to 73 seconds. The maximum delay time (non-pressure permissive path) for LPCS initiation was increased from 62 to

66 seconds. [[

]]

In the previous analysis the ECCS ready permissive was required after the ADS timer had elapsed as a necessary condition for opening the ADS valves. In the current analysis, the ADS delay timer was changed from 150 seconds to 120 seconds and the ADS initiation logic was corrected to reflect the BFN logic so the ECCS ready permissive is required prior to ADS timer activation. The Browns Ferry ADS initiation logic results in a 21 second delay relative to the standard BWR/4 ADS initiation logic. This additional delay includes signal processing delay (2 seconds), ECCS retrip logic delay (11 seconds), and a delay of 8 seconds from power at the bus until the ECCS ready permissive is achieved. [[

]]

Fuel Type Effects

[[

]]

Results Summary

Recalculation of Baseline PCTs

Nominal, Appendix K and Licensing Basis PCT results from the previous analysis (Ref. 2) and the current analysis (Ref. 1) are summarized in the Table C-1. The process updates and configuration changes that affected each of the 105% OLTP limiting cases in the current analysis are identified in C-2. The 10 CFR 50.46 error corrections incorporated into the current analysis are not shown in Table C-2. Applicability of 10 CFR 50.46 errors to the GE13 and GE14 analysis is discussed above.

[[

]]

Effect of the Power Increase on PCT

Nominal, Appendix K and Licensing Basis PCT results from the current analysis (Ref. 1) at both CLTP and EPU power are summarized in the Table C-3. The effect of the increase in core thermal power on the limiting large break nominal and Appendix K PCTs was small. The PCT changes ranged from +2 °F to –54 °F. The hot bundle power was held constant while the average bundle power increased. This caused a minor change in flow distribution between the hot and average bundles, which resulted in slightly lower nominal and Appendix K PCTs.

The effect of the power increase on the limiting small break nominal and Appendix K PCTs was significant, ranging from +71 °F to +230 °F. The increased decay heat associated with EPU resulted in more steam generation and a longer ADS blowdown time. This resulted in a later ECCS system injection and a higher PCT for the small break LOCA.

The effect of the power increase on the GE13 Licensing Basis PCT was –30 °F. Since the Licensing Basis PCT is primarily based on the Appendix K PCT, this change is consistent with the GE13 Appendix K PCT change of –31 °F. The effect of the power increase on the GE14 Licensing Basis PCT was +70 °F. This substantial GE14 Licensing Basis PCT increase is due to the change in limiting break size from large (DBA) break in the previous analysis to small break in the current analysis. The reasons for this shift are discussed below.

Limiting Break Sizes

[[

]]

Table C-1: Comparison of Previous Analysis and Current Analysis PCTs at 105% OLTP

Fuel Type	Limiting Break Size (1)	PCT Calculation Type	105% OLTP PCT (°F) (previous analysis) (3)	105% OLTP PCT (°F) (current analysis)	ΔPCT (°F) (105% new – 105% old)
[[					
					]]

[[

]]

Table C-2: Summary of Changes Between Previous and Current Analyses at 105% OLTP

Case Description			Process Updates					Configuration Changes		
Fuel Type	Limiting Break Size (1)	PCT Calc. Type	Power Dist. Calc.	Recirc. DV	Bottom Head Drain	Dryout Times	Gamma Smear. Coeff.	VFD	AHC/CS Leakage	ECCS Init. Delay
GE13	DBA	Nominal	X			X	X		X	X
GE14	DBA	Nominal	X	X			X	X	X	X
GE13	DBA	App. K	X			X	X		X	X
GE14	DBA	App. K	X	X			X	X	X	X
GE13	Small Break (2)	Nominal	X				X		X	X
GE14	Small Break (2)	Nominal	X		X		X	X	X	X
GE13	Small Break (2)	App. K	X				X		X	X
GE14	Small Break (2)	App. K	X		X		X	X	X	X
GE13	DBA	Licensing Basis	X			X	X		X	X
GE14	DBA	Licensing Basis	X	X	X		X		X	X

[[

]]

Table C-3: Comparison of 105% OLTP (Current Analysis) and EPU PCTs

Fuel Type	Limiting Break Size (1)	Type of PCT Calc.	105% OLTP PCT (°F) (current analysis)	EPU PCT (°F)	ΔPCT (°F) (EPU – 105% OLTP)
[[					
					]]

[[

]]

References

1. GE Nuclear Energy, Project Task Report "Tennessee Valley Authority Browns Ferry Units 1, 2, 3 Asset Enhancement Program EPU and MELLLA+ Task T0407: ECCS-LOCA SAFER/GESTR," GE-NE-0000-0011-1721, March 2004.

2. "Browns Ferry Nuclear Plant Units 1,2 and 3 SAFER/GESTR-LOCA Loss-of-Coolant Accident Analysis," NEDC-32484P, Revision 5, January 2002.

3. "The GESTR-LOCA and SAFER Models for the Evaluation of the Loss-of-Coolant Accident, Volume III, SAFER/GESTR Application Methodology," NEDC-23785-1-PA, Revision 1, General Electric Company, October 1984.

4. "Generic Guidelines for General Electric Boiling Water Reactor Extended Power Uprate", NEDC-32424P-A, Class III, February 1999 (ELTR-1).

5. Deleted.

6. "Browns Ferry Nuclear Plant (BFN) - Extended Power Uprate - Unit 1, 2, and 3 Asset Enhancement Program – FTR T0407 – Transmittal of Comments and Design Input Request T0407 Revision 1 for LOCA Reanalysis," Letter R05 031208 001 from J. Valente (TVA) to L. King (GE), December 8, 2003.

7. GE Nuclear Energy, Project Task Report, "Tennessee Valley Authority Browns Ferry Unit 2 and Unit 3 Variable Frequency Drive ECCS-LOCA SAFER/GESTR," GE-NE-0000-0006-8351-01, Revision 0, November 2002.

8. "GESTR-LOCA and SAFER Models For Evaluation of Loss-of-Coolant Accident, Additional Information For Upper Bound PCT Calculation," NEDE-23785P-A Volume III Supplement 1, Revision 1, March 2002.

9. Review of NEDE-23785P, Vol.III, Supplement 1, Revision 1 "GESTR LOCA and SAFER Models for Evaluation of Loss-of-Coolant Accident Volume III, Supplement 1, Additional Information for Upper Bound PCT Calculation", US NRC, TAC No. MB27774, February 1, 2002.