10 CFR 50.46(a)(3)(ii)

CP&L
A Progress Energy Company

Serial: RNP-RA/01-0062
APR 2 3 2001

United States Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
DOCKET NO. 50-261/LICENSE NO. DPR-23

REPORT OF SIGNIFICANT CHANGE IN THE
EVALUATION OF A LARGE BREAK LOSS-OF-COOLANT
ACCIDENT TRANSFER FROM INJECTION TO RECIRCULATION

Ladies and Gentlemen:

The purpose of this letter is to report a significant change in the evaluation of the transfer of the Emergency Core Cooling System (ECCS) from injection mode to recirculation mode during a Large Break Loss-of-Coolant Accident (LBLOCA) at the H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2.

This letter also includes the Siemens Power Corporation (SPC) Topical Report EMF-2286(P), "H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA," which describes the evaluation of the transfer of the ECCS from injection mode to recirculation mode on Peak Clad Temperature (PCT). The effect of this change on PCT for HBRSEP, Unit No. 2 is summarized in Attachment I.

The latest PCT estimates for the LBLOCA, Small Break Loss-of-Coolant Accident (SBLOCA), and transfer of the ECCS from the injection mode to the recirculation mode for both accidents are included in Attachment II. The PCTs associated with transfer of the ECCS from the injection mode to the recirculation mode for both accidents are at acceptably low temperatures.

SPC Topical Report EMF-2286(P), "H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA," proprietary version, is provided as Attachment III.

The information contained in Attachment III is considered by the preparer to contain in part trade secret information designated as proprietary and requests exemption from public disclosure in accordance with 10 CFR 2.790(b). Attachment IV contains an affidavit and application for withholding from public disclosure executed by Mr. Jerald S. Holm, Manager of

Robinson Nuclear Plant
3581 West Entrance Road
Hartsville, SC 29550

APOl

Product Licensing for SPC who is authorized to apply for the withholding of the proprietary information for SPC.

SPC Topical Report EMF-2286(NP), "H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA," non-proprietary version, is provided as Attachment V.

If you have any questions concerning this matter, please contact me or Mr. H. K. Chernoff.

Sincerely,

for B. L. Fletcher III
Manager - Regulatory Affairs

ALG/alg

Attachments

I. Report of Significant Change in the Evaluation of a Loss-Of-Coolant Accident Transfer From Injection to Recirculation
II. Peak Clad Temperature Estimates
III. Siemens Power Corporation Topical Report EMF-2286(P), "H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA," Proprietary Version
IV. Siemens Power Corporation Affidavit and Application for Withholding from Public Disclosure
V. Siemens Power Corporation Topical Report EMF-2286(NP), "H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA," Non-Proprietary Version

c: L. A. Reyes, USNRC, Region II
R. Subbaratnam, NRC, NRR
NRC Resident Inspector, HBRSEP

REPORT OF SIGNIFICANT CHANGE IN THE EVALUATION OF A LOSS-OF-COOLANT ACCIDENT TRANSFER FROM INJECTION TO RECIRCULATION

This report provides the Peak Cladding Temperature (PCT) results of a significant change in the evaluation of the transfer of the Emergency Core Cooling System (ECCS) from injection mode to recirculation mode during a Large Break Loss-of-Coolant Accident (LBLOCA) at the H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2.

Change in Application of Large Break Loss-Of-Coolant Accident Evaluation Model

Since October 16, 1997, Carolina Power & Light (CP&L) Company has been reporting a PCT of 2102°F in the reactor core during the transfer of the ECCS from the injection mode to the recirculation mode during a LBLOCA. Transfer of the ECCS from the injection mode to the recirculation mode is accomplished manually from the Control Room. By letter dated October 14, 1997, CP&L provided information to the NRC describing the analysis methods and assumptions associated with the 2102°F result. The principle assumption in the analysis was that the operators took 30.5 minutes to complete the manual operation.

By letters dated November 17, 2000, and January 11, 2001, CP&L stated that upon acceptance by CP&L of a new Siemens Power Corporation (SPC) analysis of the ECCS PCT during the transfer to recirculation, the results would be reported to the NRC in accordance with 10 CFR 50.46(a)(3)(ii). The new analysis assumes that the time to accomplish the manual operation is 20 minutes based upon the time limitations reflected in procedure documentation.

The effect on core heatup during manual transfer of the ECCS from the injection mode to the recirculation mode during a LBLOCA has been reanalyzed in SPC Topical Report EMF-2286(P), "H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA." This report has been accepted by CP&L and is provided for information with this letter as Attachment III. The effect of this new analysis on PCT during the transfer from injection to recirculation during a LBLOCA is a reduction in PCT from 2102°F to 260°F, or -1842°F.

H. B. ROBINSON STEAM ELECTRIC PLANT, UNIT NO. 2
PEAK CLAD TEMPERATURE ESTIMATES

The current Peak Clad Temperatures (PCTs) associated with Loss-of-Coolant Accidents (LOCAs) are listed below.

Event	PCT (°F)
Large Break (LB) LOCA ECCS Injection Mode	2041
LBLOCA Transfer to Recirculation Mode	260 (no substantive heatup)

Event	PCT (°F)
Small Break (SB) LOCA ECCS Injection Mode	2010
SBLOCA Transfer to Recirculation Mode	900

The PCTs associated with transfer of the ECCS from the injection mode to the recirculation mode for both accidents are at acceptably low temperatures, and these PCTs will no longer be separately reported.

U. S. Nuclear Regulatory Commission
Attachment IV to Serial RNP-RA/01-0062
4 pages

SIEMENS POWER CORPORATION

AFFIDAVIT AND APPLICATION FOR WITHHOLDING FROM PUBLIC DISCLOSURE

AFFIDAVIT

STATE OF WASHINGTON)
) ss.
COUNTY OF BENTON)

1. My name is Jerald S. Holm. I am Manager, Product Licensing, for Siemens Power Corporation ("SPC"), and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by SPC to determine whether certain SPC information is proprietary. I am familiar with the policies established by SPC to ensure the proper application of these criteria.

3. I am familiar with the SPC information included in the enclosure EMF-2286(P) Revision 0, *H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA*, which is referred to herein as "Document." Information contained in this Document has been classified by SPC as proprietary in accordance with the policies established by SPC for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by SPC and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in the Document be withheld from public disclosure.

6. The following criteria are customarily applied by SPC to determine whether information should be classified as proprietary:

(a) The information reveals details of SPC's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for SPC.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for SPC in product optimization or marketability.

(e) The information is vital to a competitive advantage held by SPC, would be helpful to competitors to SPC, and would likely cause substantial harm to the competitive position of SPC.

7. In accordance with SPC's policies governing the protection and control of information, proprietary information contained in this Document has been made available, on a limited basis, to others outside SPC only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. SPC policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

SUBSCRIBED before me this 15th day of November, 2000.

Amy R. Nixon
NOTARY PUBLIC, STATE OF WASHINGTON
MY COMMISSION EXPIRES: 12/06/03

AMY R. NIXON
COMMISSION EXPIRES
NOTARY PUBLIC
DECEMBER 6, 2003
STATE OF WASHINGTON

U. S. Nuclear Regulatory Commission
Attachment V to Serial RNP-RA/01-0062
32 Pages

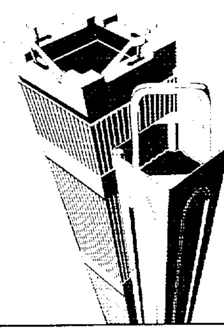
SIEMENS POWER CORPORATION TOPICAL REPORT
EMF-2286(NP), "H. B. ROBINSON UNIT 2 EXTENDED TRANSFER TO COLD LEG RECIRCULATION FOLLOWING A LBLOCA," NON-PROPRIETARY VERSION

SIEMENS

EMF-2286(NP)
Revision 0

H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA

November 2000



Siemens Power Corporation
Nuclear Division

Siemens Power Corporation

ISSUED IN SPC ON-LINE
DOCUMENT SYSTEM
DATE: 11/16/00

EMF-2286(NP)
Revision 0

H. B. Robinson Unit 2 Extended Transfer to Cold Leg Recirculation Following a LBLOCA

Prepared: RAShaw 11/15/00
R. A. Shaw, Engineer Date
PWR Safety Analysis

Prepared: S. E. Jensen 11/16/00
S. E. Jensen, Engineer Date
Safety Analysis Methods

Approved: R. C. Gottula 11/16/00
R. C. Gottula, Manager Date
PWR Safety Analysis

Approved: R. E. Collingham 11/16/00
R. E. Collingham, Manager Date
Safety Analysis Methods

Approved: J. S. Holm 11/16/00
J. S. Holm, Manager Date
Product Licensing

Approved: [signature] for 11/16/00
D. J. Denver, Manager Date
Commercial Operations

:dar

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Nature of Changes

Item	Page	Description and Justification
1.	All	This is a new document.

Contents

Tables

Figures

Nomenclature

CCFL	Counter Current Flow Limit
CFR	Code of Federal Regulations
CL	Cold Leg
CP&L	Carolina Power and Light
DECLG	Double-Ended Cold Leg Guillotine
DEGB	Double-Ended Guillotine Break
DEHLG	Double-Ended Hot Leg Guillotine
DEPSG	Double-Ended Pump Suction Guillotine
ECCS	Emergency Core Cooling System
EDG	Emergency Diesel Generator
EOC	End of Cycle
HBRSEP	H. B. Robinson Steam Electric Plant
HHSI	High Head Safety Injection
HL	Hot Leg
LBLOCA	Large Break Loss-of-Coolant Accident
LHSI	Low Head Safety Injection
LOCA	Loss-of-Coolant Accident
MOC	Middle-of-Cycle
NRC	U. S. Nuclear Regulatory Commission
PCT	Peak Clad Temperature
PS	Pump Suction
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RHR	Residual Heat Removal
RWST	Refueling Water Storage Tank
SBLOCA	Small Break Loss-of-Coolant Accident
SG	Steam Generator
SI	Safety Injection
SIAC	Safety Injection Actuation Signal
SPC	Siemens Power Corporation

1.0 Introduction

This report documents an analysis of the transfer from safety-injection phase to the Cold Leg Recirculation phase following a LBLOCA in the H. B. Robinson Steam Electric Plant (HBRSEP), Unit No. 2. This analysis was performed to demonstrate:

a. that the magnitude of a second fuel cladding heatup that could occur when the source of coolant for the ECCS is manually transferred from the RWST to the containment sump is significantly less than the limiting PCT during the injection phase of the LBLOCA; and

b. the ECCS capability to fulfill the 10CFR50.46(b)(5) criteria for "an acceptably low" core temperature for an "extended period of time."

This analysis updates a previous analysis of the transfer (Reference 1) to eliminate an inappropriately conservative assumption for operator action to transfer ECCS delivery and to take credit for a more expeditious completion of the initial switchover of the LHSI/RHR from its injection mode from RWST to its recirculation mode. The new analysis reduces the time assumed for operator action to 20 minutes versus the previously-used 30.5 minutes. In addition, the analysis has been extended to include consideration of a potential later operator action to accomplish switchover to "piggyback" mode. This second switchover may be required to support Containment Spray in the recirculation mode and would incur a 6-minute period during which no ECCS flow would be delivered to the vessel.

The analysis assumes a full core of SPC fuel assemblies, a nuclear enthalpy rise factor ($F_{\Delta H}$) of 1.80, and a total peaking factor (F_Q^T) of 2.50, as modified by a conservative, axially-dependent power peaking limit (K(z) curve). Cycle 19 plant data was used for the subject analysis, but the analysis supports operation during Cycle 20 and subsequent cycles bounded by the analysis conditions.

This report is intended to support submittal of the subject analysis to the NRC as required by 10CFR50 Appendix K, Section II.1.a; therefore, the report includes information demonstrating the "acceptability" of the ECCS model as specified in 10CFR50.46 and in 10CFR50 Appendix K.

2.0 Summary

An analysis was performed for switchover to Cold Leg Recirculation following a LBLOCA at HBRSEP, Unit No. 2. The analysis was performed using a model that was designed to be acceptable for use in demonstrating compliance with the relative ECCS performance criteria as specified by 10 CFR 50.46 and Appendix K. Effects due to break location, break size, variation in AFW conditions, and axial shape were considered. The significant conclusion was that:

- The bounding switchover scenario in which transfer began at 21 minutes and was completed at 79 minutes (with an ECCS suspension between 73 and 79 minutes) produced no fuel cladding heatup.

This result demonstrates that fuel heatup during the switchover period of the LBLOCA is significantly less than the limiting PCT with respect to 10 CFR 50.46 criteria. The results indicate the plant remains amenable to long-term cooling during and following switchover to cold leg recirculation.

3.0 Methodology

This section includes a description of the transfer to cold leg recirculation following a LBLOCA, a discussion of the evaluation model and related validation base, and a discussion of the input model.

3.1 *Description of Safety Injection Transfer for LBLOCA*

Safety Injection coolant and Containment Spray would be supplied from the RWST during the early period of a LBLOCA. Eventually, however, the inventory in the RWST could be depleted to the point that it is necessary to manually transfer the intake of the LHSI/RHR pumps from the RWST to the containment sump. During this transfer, there is potential for a second cladding heatup since the ECC flow is reduced to one HHSI pump flow while the LHSI/RHR pumps are being aligned to take suction from the containment sump. If Containment Spray is required, or if there is a need to provide flow to the primary system via the HHSI pumps subsequent to this transfer, then a short interruption in ECC flow to the primary system is required in order to align the outlet of the LHSI/RHR pump to the inlet of the HHSI pumps (and Containment Spray pumps). The objective of this analysis was to verify that any fuel cladding heatup that could occur during switchover from SI phase to recirculation phase did not exceed 10 CFR 50.46 requirements.

When the RWST liquid level has been reduced to the Low Level Setpoint during the SI phase of the LBLOCA, all but one of the HHSI pumps would be stopped, as would be all of the LHSI/RHR pumps and all but one of the Containment Spray pumps. The earlier in the LBLOCA transient that this level is reached, the more decay heat would be available. Assuming early Containment Spray activation and maximum Containment Spray flow rate, the RWST Low Level Setpoint could be reached as early as 21 minutes after the initiation of the LBLOCA.

Once the RWST Low Level Setpoint is reached, the remaining active HHSI pump would continue to inject RWST fluid into the primary system and the active Containment Spray pump would continue to provide Containment Spray while the intake of the LHSI/RHR pumps are manually transferred from the RWST to the containment sump. A time period of 20 minutes of reduced flow to the RCS has been used in the analysis to conservatively bound the actual time required to perform the realignment of the LHSI/RHR pumps and to verify that the SI flow delivered during this period would be sufficient to prevent a fuel cladding heatup.

As soon as the LHSI/RHR pumps are aligned to take suction from the containment sump, one LHSI/RHR pump would be restarted and would provide flow to the cold legs of the primary system in conjunction with the HHSI flow from the RWST. Once the LHSI/RHR pump is delivering in recirculation mode from the sump, the remaining active HHSI pump and Containment Spray pump may be stopped, leaving just the flow from the LHSI/RHR pump. Since the time in which flow is provided to the primary system from both the HHSI pump and the LHSI/RHR pump may vary, the analysis conservatively assumes that the HHSI flow is terminated at the same time the LHSI/RHR pump is restarted (41 minutes into the LBLOCA transient) and no combined flow occurs.

If Containment Spray is required subsequent to the transfer to Cold Leg Recirculation or if there is a need to provide flow to the primary system via the HHSI pumps, then all ECC flow would be suspended while the outlet of the LHSI/RHR pump is configured to the inlet of the HHSI pumps (and Containment Spray pumps). A period of 6 minutes without ECC flow was used in the analysis to conservatively bound the actual time required to perform the realignment of the LHSI/RHR and HHSI pumps. Following the 6-minute period, ECC flow would be restored through a LHSI/RHR pump in series with a HHSI pump. During the period without ECC, the core could uncover sufficiently to result in a fuel heatup. Re-activation of the ECC pumps will re-quench the core and terminate any fuel heatup.

A hold point has been implemented in the switchover procedures to ensure that the 6-minute "no-flow" period associated with the switchover to "piggyback" operation is not performed prior to 73 minutes into the accident. This delay allows time for the decay heat level to drop and the core conditions to stabilize and the vessel inventory to recover following the initial switchover from the RWST prior to entry into the 6-minute "no-flow" period.

If there is no need to reactivate Containment Spray or to provide flow to the primary system via the HHSI pumps prior to the realignment to Hot Leg Recirculation, then the single LHSI/RHR pump would continue drawing water from the containment sump and injecting into the cold leg of the primary system, at a rate sufficient to prevent a fuel cladding heatup. Several hours after the initiation of the LBLOCA, all ECC flow to the primary system would be suspended while the outlet of the LHSI/RHR pump is configured to the inlet of the HHSI pumps to provide Hot Leg Recirculation. The consequences of this evolution are bounded by the analysis results (transfer at 73 minutes).

3.2 *Evaluation Model*

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3.3 *Validation of S-RELAP5*

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3.4 *Conformance to 10 CFR 50 Appendix K Requirements*

The analysis performed by SPC incorporated the required features of Appendix K, as appropriate for the long-term cooling analysis. These required features include:

1. Sources of heat during the LOCA

   - Fission heat – during the LBLOCA, fission heat is shut down within one to two seconds and is less significant than initial stored energy. Fission heat can be neglected for long-term cooling analysis.
   - Decay of actinides – actinide decay is important and is included in the switchover analysis using the same equations (from the 1971 draft ANS standard for decay heat) as in the approved LBLOCA methodology.
   - Fission product decay – This is the dominant heat source and is calculated assuming operation at 102% rated power and 1.2 times the decay power from the 1971-73 draft ANS standard, as required by Appendix K.
   - Metal-water reaction rate – Metal-water reaction energy is negligible at cladding temperatures below 1800°F.
   - Reactor internals heat transfer – heat transfer from the reactor internals is calculated during the S-RELAP5 analysis.

[a] [

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- Pressurized water reactor primary-to-secondary heat transfer – the steam generators are modeled, and the exchange of energy between the primary and secondary coolant is calculated by S-RELAP5.

2. Swelling and Rupture of the Cladding and Fuel Rod Thermal Parameters – swelling and rupture of the cladding typically occurs when cladding temperatures exceed 1600°F and would not occur for the low temperatures calculated for the switchover analysis. Temperature-dependent fuel rod thermal parameters are used in the S-RELAP5 calculation as described in the S-RELAP5 theory manual (Reference 4).

3. Blowdown Phenomena – the switchover analysis is a long-term cooling event that occurs after the blowdown and reflood phases of the LBLOCA are completed and the core has been recovered to a quasi-steady condition near the fluid saturation temperature. The Appendix K detailed requirements for LBLOCA analyses during the blowdown phase therefore do not apply for the long-term cooling transient and would have no significant effect on the long-term cooling results.

4. Post-Blowdown Phenomena; Heat Removal by the ECCS – the switchover analysis is also a post-reflood event; therefore, the detailed Appendix K requirements for calculation during the reflood period cease to apply for the long-term cooling transient. Since the core has recovered from the initial LBLOCA event, the reflood requirements have no significant effects on the long term transient.

The subject S-RELAP5 switchover analysis incorporated the required Appendix K features applicable to long-term cooling transients.

3.5 *Input Model Description*

HBRSEP, Unit No. 2 is a Westinghouse-designed PWR. The RCS includes three hot leg pipes, three inverted U-tube steam generators, and three cold leg pipes with one RCP in each cold leg. System response to the SI injection transfer transient was modeled using the S-RELAP5 computer code, which includes governing conservation equations for mass, energy, and momentum transfer.

The RCS was nodalized in the S-RELAP5 input model into control volumes representing reasonably homogeneous regions, interconnected by flow paths or "junctions." The model included three identical accumulators, one pressurizer, and three steam generators with both primary and secondary sides. All three loops of the plant were simulated separately in this model. A steam generator tube plugging level of 6% was assumed. A nodalization diagram as used for the subject analysis is presented in Figure 3.1 Note that this figure includes representations of hot leg, cold leg, and pump suction breaks, all of which were considered in the analysis. The modeling of the individual RCS loops and ECCS injection lines, in conjunction

with specific break locations, enables the model to account for ECCS spillage through the break as appropriate for each case.

As discussed earlier, [

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The HHSI and LHSI/RHR pumps were modeled as fill junctions at the accumulator lines, with conservative flows given as a function of system back-pressure, as shown in Table 3.1. The RCP performance curves were characteristic of pumps used in this plant design.

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A general summary of key analysis parameters is presented in Table 3.2.

Table 3.1 ECCS Delivery Curves

	HHSI+LHSI	HHSI	LHSI/RHR	LHSI/RHR→HHSI
Time	SIAS-21 min.	21-41 min	41-73 min	≥ 79 min
Source	RWST	RWST	Sump	Sump
T (°F)	100	100	200	200
P (psia)	14.7	14.7	30.0	30.0
Pressure	Mass Flow Rate (lbm/s/loop)			
14.7	192.8	22.9	164.5	22.2
30.0	180.4	22.7	152.7	
65.0	147.9	22.4	121.5	
95.0	114.4	22.0	89.4	
100.0	105.2	22.0		21.3
120.0	68.6	21.9	45.3	
130.0	33.5	21.8	11.3	
132.0	21.8	21.8	0.0	
200.0	21.4	21.4		20.7
300.0	20.0	20.0		19.4
400.0	18.9	18.9		18.3
500.0	17.9	17.9		17.3
600.0	16.6	16.6		16.1
700.0	15.3	15.3		14.8
800.0	14.1	14.1		13.7
900.0	12.6	12.6		12.2
1000.0	11.2	11.2		10.9
1100.0	9.6	9.6		9.3
1200.0	7.4	7.4		7.1
1300.0	4.8	4.8		4.7
1380.0	0.0	0.0		0.0

Table 3.2 General Summary of Key Analysis Parameters

Parameter	Value
Core Power	2346 MW[a]
Primary Pressure	2250 psia
Pressurizer Liquid Level	53%
Cold Leg Temperature	548.4°F
Hot Leg Temperature	609.8°F
Primary Flow Rate Per Loop (lbm/s)	9009.3 lbm/s[b]
Secondary Pressure (psia)	808 psia
SG Secondary Fluid Mass	91000 lbm/SG
MFW Temperature	441.5°F
[ ]	[ ]
[ ]	[ ]
Break locations and flow areas:	
[ ]	[ ]
[ ]	[ ]
[ ]	[ ]
SG tube plugging	6%
Single-failure	LHSI/RHR or EDG[c]

a Includes 2% uncertainty.

b This value represents the minimum Technical Specification loop flow rate.

c The switchover analysis was performed under the assumptions of a single ECC train, thereby satisfying either loss-of-EDG or loss-of-LHSI/RHR-pump single-failures.

Figure 3.1 S-RELAP5 Nodalization for HBRSEP, Unit No. 2 LBLOCA Switchover

4.0 Analyses and Discussion of Results

Prior to break initiation, steady-state conditions were established at full system pressure and 102% core power. Full LBLOCA simulations (from break initiation) were then performed to ensure appropriate structural and hydraulic boundary conditions at the onset of switchover. During the pre-switchover blowdown, only one HHSI pump and one LHSI/RHR pump were assumed to be available. This was done to provide conservatively high structural temperatures at the initiation of switchover. Containment conditions were determined concurrently with the system conditions through the use of the integral ICECON/S-RELAP5 link.

4.1 *Preliminary Calculations*

A series of preliminary calculations were performed to determine the effects of various plant parameters and to identify the overall limiting scenario. For example, preliminary calculations were performed as listed below:

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None of these calculations resulted in fuel cladding temperature excursion during the LHSI/RHR pump switchover from RWST to sump. During the subsequent suspension of all SI when the LHSI/RHR discharge is transferred to HHSI piggyback operation, minor cladding temperature excursions were recorded. The maximum cladding temperature produced during that period was 482°F, which resulted during a DEHLG break simulation, [

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[a] [ ]

4.2 *Base Calculations and Sensitivity Study*

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Base DEHLG and DECLG calculations were re-run with [

] Additionally, the worst-case scenario discussed in the previous subsection [

] None of these calculations produced a fuel cladding temperature heatup during either the initial switchover period (21-41 minutes) or the switchover to piggyback operation (73-79 minutes). General results from the DEHLG and DECLG calculations are presented in the following figures.

4.2.1 DEHLG Results

Figure 4.1 shows the SI history during the DEHLG switchover. Beginning at 21 minutes, the SI was reduced from one HHSI and one LHSI/RHR pump to a single HHSI pump. At 41 minutes, that HHSI pump was stopped and one LHSI/RHR pump (drawing from the containment sump) was activated. Between 73 and 79 minutes, all SI was suspended. At 79 minutes, switchover was complete and piggyback operation (LHSI/RHR delivering SI through a HHSI pump) began. All calculations were extended to 200 minutes to verify the core remained amenable to long-term cooling and to observe crossover pipe conditions.

Figure 4.2 shows that the DEHLG break flow rates were primarily a function of SI injection rate.
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During the DEHLG, the core was full of liquid and the downcomer collapsed liquid level was near the cold leg centerline when switchover began, as shown in Figure 4.3. Those collapsed liquid levels generally followed the SI flow rate, decreasing during the single-HHSI pump period (21-41 minutes), recovering during the period of LHSI/RHR flow (41-73 minutes); decreasing during the no-flow period (73-79 minutes), and gradually increasing following completion of

switchover. That slow increase in core collapsed liquid level following switchover can be attributed to the decreasing decay power.

Figure 4.4 shows that the two-phase heat transfer was sufficient to prevent a fuel temperature excursion during the switchover period. The maximum cladding temperatures for the DEHLG case remained below approximately 260°F.

4.2.2 DECLG Results

Figure 4.5 shows the SI history during the DECLG switchover. The only difference between the DEHLG (Figure 4.1) and DECLG SI flow rates was the assumption that all of the SI provided to the broken cold leg was assumed to exit through the break.

Figure 4.6 shows that the DECLG break flow rates were primarily a function of SI injection rate.
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During the DECLG, the core collapsed liquid level was at approximately mid-core and the downcomer collapsed liquid level was near the cold leg centerline when switchover began, as shown in Figure 4.7. Although the downcomer collapsed liquid level recovered during the period of high LHSI/RHR flow (41-73 minutes), the core collapsed liquid level did not. This occurred because more steam was generated in the core after RHR injection from the sump began at 41 minutes. The increased steam generation was due to the higher injection rate and hotter fluid (both relative to the earlier HHSI flow from the RWST). Increased steam generation caused an increase in upper plenum pressure, which resulted in a manometric level difference between the core and downcomer.

Comparing Figures 4.3 (DEHLG) and 4.7 (DECLG) shows that there was less core level recovery following the switch to LHSI/RHR pump operation during the DECLG than occurred during the DEHLG. This resulted for two reasons. First, all of the SI entered the core during the DEHLG, whereas only about two-thirds reached the core during the DECLG due to loss through the cold leg break. Secondly, the upper plenum pressure was always higher during the DECLG break than during the DEHLG break; i.e., the differential pressure between the upper plenum and the break was greater during the DECLG than during the DEHLG. This tended to depress the core collapsed liquid level more in the DECLG than occurred in the DEHLG. Following

switchover to piggyback operation, however, the DECLG and DEHLG had comparable core collapsed liquid levels.

Similar to the DEHLG results, Figure 4.8 shows that the two-phase heat transfer was sufficient to prevent a fuel temperature excursion during the switchover period. The maximum cladding temperatures for the DECLG calculation remained below approximately 260°F.

4.2.3 Loop Seal Considerations

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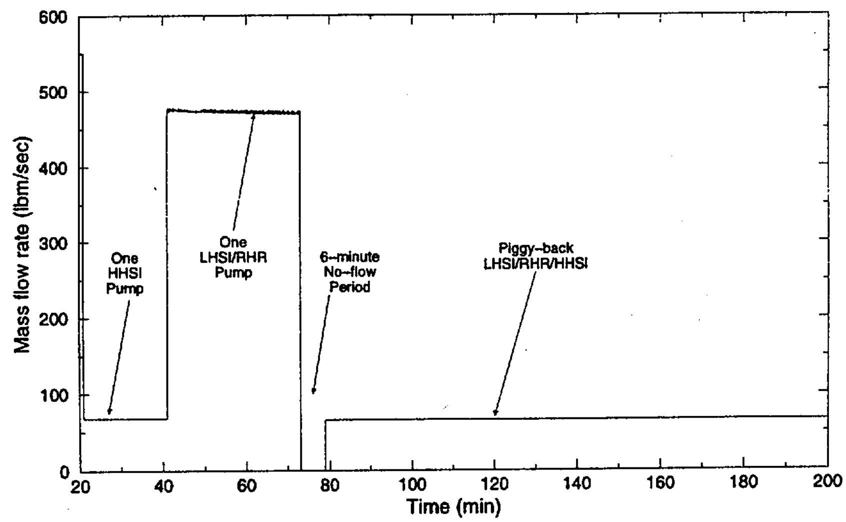

Figure 4.1 Total SI Flow Rate During the DEHLG

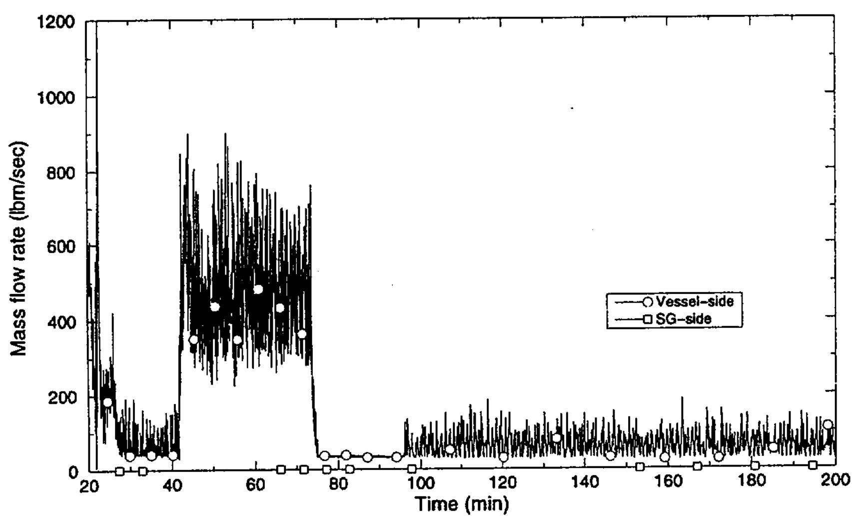

Figure 4.2 Break Flow Rates During the DEHLG

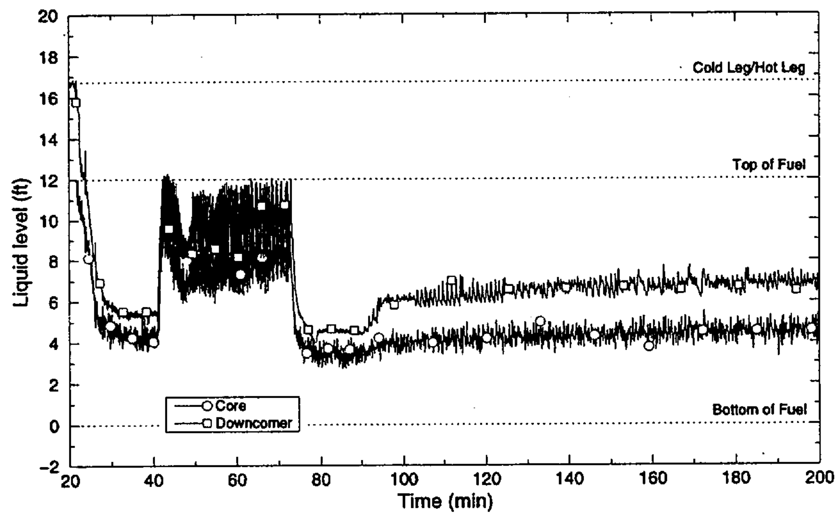

Figure 4.3 Core and Downcomer Collapsed Liquid Levels During the DEHLG

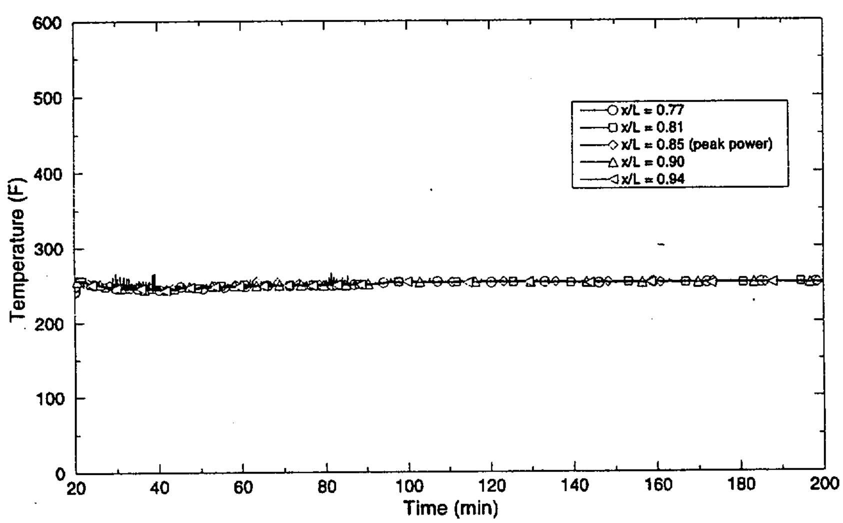

Figure 4.4 Fuel Cladding Temperatures During the DEHLG

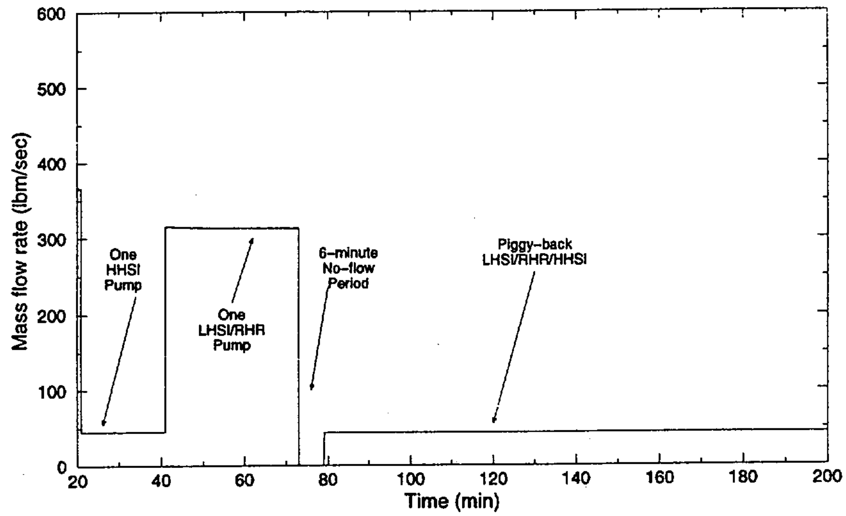

Figure 4.5 Total SI Flow Rate During the DECLG

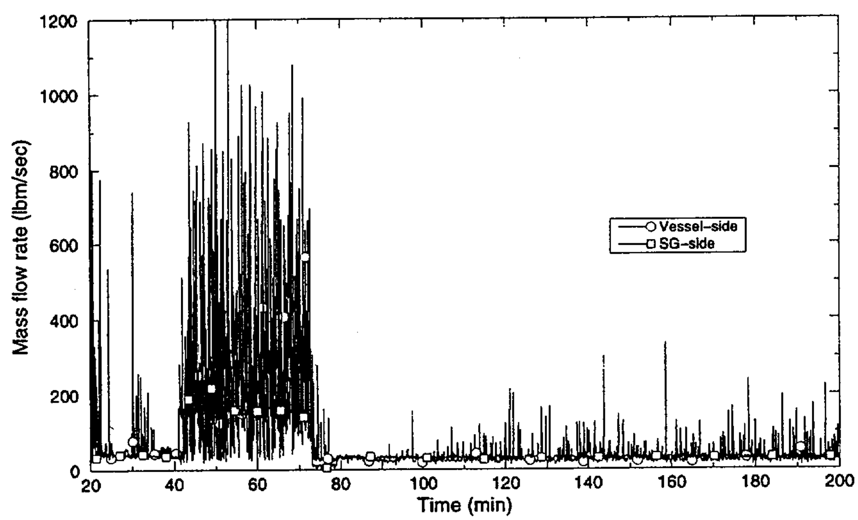

Figure 4.6 Break Flow Rates During the DECLG

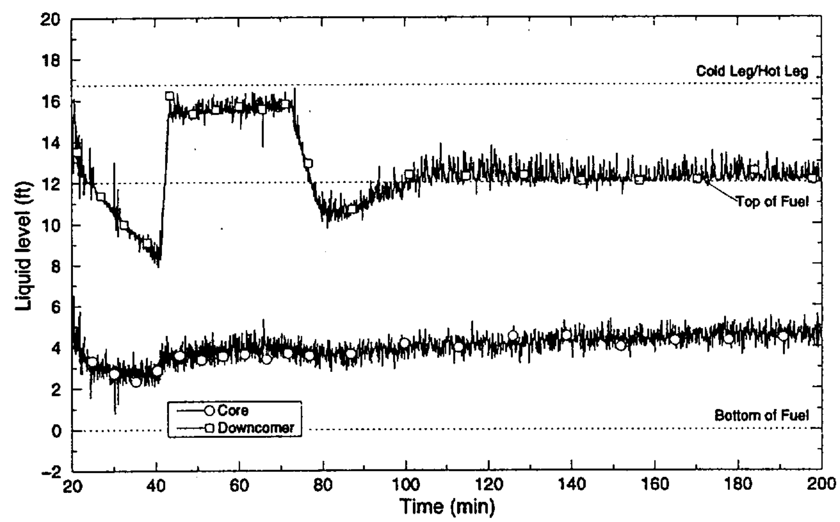

Figure 4.7 Core and Downcomer Collapsed Liquid Levels During the DECLG

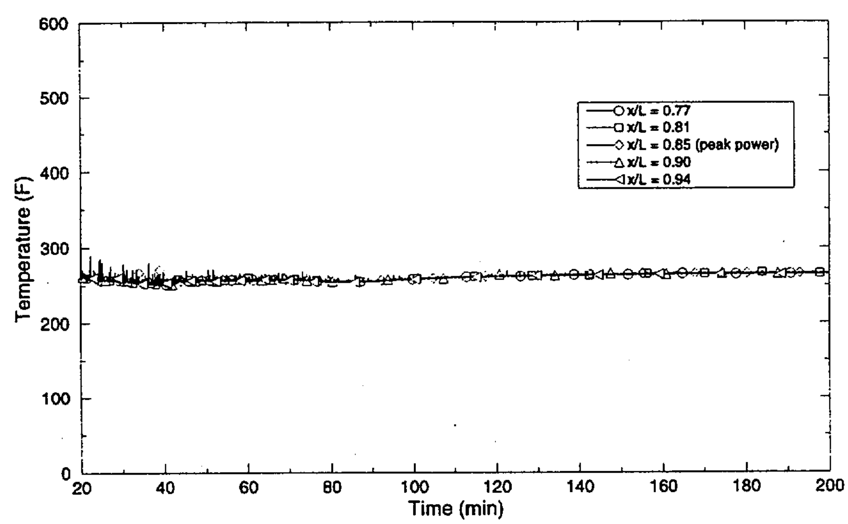

Figure 4.8 Fuel Cladding Temperatures During the DECLG

5.0 Conclusions

This analysis provides a conservative evaluation of system and core responses during LBLOCA transfer to recirculation. The results indicate that 10 CFR 50.46(b) limiting cladding temperature, oxidation, and long-term decay heat removal criteria will be satisfied during switchover.[a]

The analysis in this report supports the operation of H. B. Robinson Unit 2 during Cycle 20 and for subsequent cycles bounded by the assumptions made in this analysis.

[a] Since the fuel cladding did not experience a temperature excursion during this analysis, oxidation and metal-water reaction were not calculated. The LBLOCA analysis of record PCT and metal-water reaction results for the injection phase remain limiting.

6.0 References

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8. Letter, R. A. Copeland (SPC) to U.S. Nuclear Regulatory Commission, "Sensitivity of the ANF CCFL Constants in the ANF SBLOCA Methodology," RAC:020:88, April 25,1988.

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