Virginia Electric and Power Company
Richmond, Virginia 23261

July 25, 2002

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Serial No. 02-167B
Docket Nos. 50-338
50-339
License Nos. NPF-4
NPF-7

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNITS 1 AND 2
REFLOD3B CODE UPDATE IN SUPPORT OF
PROPOSED TECHNICAL SPECIFICATIONS CHANGES AND EXEMPTION REQUEST
TO USE FRAMATOME ANP ADVANCED MARK-BW FUEL

In a March 28, 2002 letter (Serial No. 02-167), Virginia Electric and Power Company (Dominion) requested: 1) an amendment to Facility Operating License Numbers NPF-4 and NPF-7 for North Anna Power Station Units 1 and 2, and 2) associated exemptions from 10 CFR 50.44 and 10 CFR 50.46. The amendments and exemptions will permit North Anna Units 1 and 2 to use Framatome ANP Advanced Mark-BW fuel. This fuel design has been evaluated by Framatome and Dominion for compatibility with the resident Westinghouse fuel and for compliance with fuel design limits. The attachment to this letter documents a necessary change to the REFLOD3B code in support of the large break LOCA evaluation for the Advanced Mark-BW fuel. This information is provided in accordance with the proposed documentation for the transition effort as stated in our June 19, 2002 letter (Serial No. 02-305A). The remainder of the documentation required to establish compliance with the emergency core cooling system (ECCS) requirements of 10 CFR 50.46 for the transition to Advanced Mark-BW fuel will be submitted in separate correspondence as soon as possible.

As indicated in our June 19, 2002 letter, the North Anna LBLOCA analysis relies upon application of a modified version of the REFLOD3B computer code. The attachment to this letter describes and justifies the change to the REFLOD3B code. The code change is not generic. It is intended for use only in the North Anna LBLOCA analysis. Therefore, the REFLOD3B topical report (Reference 1) will not be updated.

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As noted in previous correspondence, the initial reload batch of Advanced Mark-BW fuel is currently planned for North Anna Unit 1 Cycle 17, which is scheduled to begin operation in April 2003. We continue to request your assistance to achieve this reload schedule.

If you have any questions or require additional information on this, please contact us.

Very truly yours,

L. N. Hartz
Vice President - Nuclear Engineering

Attachment

Commitments made in this letter: None

References:

1. BAW-10171P-A, "REFLOD3B - Model for Multinode Core Reflooding Analysis," Revision 3, December 1995.

cc: U.S. Nuclear Regulatory Commission
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Mr. M. J. Morgan
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North Anna Power Station

SN: 02-167B
Docket Nos.: 50-338/339
Subject: Proposed TS Changes & Exemption Request
Framatome ANP Advanced Mark-BW Fuel

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by Leslie N. Hartz, who is Vice President - Nuclear Engineering, of Virginia Electric and Power Company. She has affirmed before me that she is duly authorized to execute and file the foregoing document in behalf of that Company, and that the statements in the document are true to the best of her knowledge and belief.

Acknowledged before me this 25th day of July, 2002.

My Commission Expires: March 31, 2004.

Maggie McClure
Notary Public

(SEAL)

ATTACHMENT

REFLOD3B Code Update for Large Break LOCA Analysis
Framatome Fuel Transition Program

Virginia Electric and Power Company
(Dominion)
North Anna Power Station Units 1 and 2

A REFLOD3B CODE UPDATE
FOR USE IN THE NORTH ANNA POWER STATION UNITS 1 and 2 LARGE BREAK LOCA ANALYSIS

Framatome ANP will be delivering Advanced Mark-BW reload fuel to the North Anna Power Station (NAPS) Units 1 and 2 starting in the first quarter of 2003. The units are Westinghouse-designed, three-loop plants operating at a rated thermal power of 2,893 MWt. The units have conventional ECCS systems and dry, sub-atmospheric containments. In accordance with 10CFR50.46 and 10CFR50, Appendix K, an evaluation of ECCS performance is being performed for the Framatome ANP reload fuel.

One component of the overall LOCA evaluation is a large break LOCA (LBLOCA) analysis for the Framatome ANP Advanced Mark-BW reload fuel. For the North Anna analysis, the LBLOCA assessment required a modification to the REFLOD3B computer code. The following sections describe and justify the REFLOD3B code change. The code change is not generic. It is intended for use only in the NAPS LBLOCA reload analysis. The REFLOD3B topical report (Reference 1) will not be updated.

REFLOD3B Computer Code

REFLOD3B is an equilibrium code that simulates the thermal-hydraulic behavior of the primary coolant system during the vessel refill and reflood phases of LBLOCA. It predicts system behavior and average core flooding rate. Core calculations are largely based on uncoupled heat transfer and carryout rate fraction correlations. The code was reviewed and approved (Reference 1) by the NRC for use in Framatome ANP's LBLOCA recirculating steam generator (RSG) evaluation model (Reference 2).

RELAP5/MOD2-B&W end-of-blowdown (EOB) results provide initial conditions to REFLOD3B. REFLOD3B output provides transient boundary conditions—pressure, temperature, and flooding rate—used to drive the BEACH computation of hot channel heat transfer and cladding temperature. Figure 1 illustrates the placement of REFLOD3B within the overall structure of the LBLOCA computer codes employed in the RSG evaluation model. Actual minimum containment backpressure time histories (Reference 3), calculated specifically for this NAPS application, are used in the REFLOD3B analysis.

REFLOD3B Modification

The approved version of REFLOD3B incorporates an option, denoted CRFCKN, to calculate carryout from the core exit flow rate during reflood. For proper transient simulation of North Anna, a carryout rate fraction (CRF) option was incorporated to mitigate the prediction of excessive, non-physical core carryout obtained with the existing CRFCKN option in REFLOD3B. The newly added option within CRFCKN will only be used for the North Anna LBLOCA analysis for Framatome ANP Advanced Mark-

BW reload fuel. The code modification is discussed in further detail and its North Anna-specific use justified below.

Current NRC-Approved CRFCKN Option

The LBLOCA evaluation model (Reference 2) requires the use of the CRFCKN option as described in Section 2.6.3 of the REFLOD3B topical report, Reference 1. This option divides the reflood period into three segments: (1) a developing segment, (2) a transition segment, and (3) a quasi-steady segment. When the option is selected, CRF is generally determined from the CRFCKN correlation described in Appendix F-3 of Reference 1. The CRFCKN correlation was developed based on data from various FLECHT and FLECHT-SEASET tests.

During the development of REFLOD3B for application to U-tube type plants, occasional numerical difficulties resulting in non-physical flow instabilities were encountered. The problem occurs in the region, termed Region 1R, immediately above the core liquid volume. If Region 1R is superheated, liquid droplets entrained in this equilibrium region are instantaneously evaporated. This results in the potential for numerical instabilities. To eliminate the numerical instabilities, the logic within CRFCKN was written to allow sufficient core carryout to maintain Region 1R in a two-phase state. Thus, during the quasi-steady portion (described in Section 2.7 of Reference 1) of the reflood transient, the core exit flow, W_{OUT}, is calculated from the following term:

$$\textbf{MAX}\ \{CRF \times W_{CORE},\ W_{OUTQM}\},$$

where CRF is determined from the CRFCKN correlation, W_{CORE} is the core inlet flow (flooding rate), and W_{OUTQM} is the amount of steam generated if all core heat transfer is used to generate saturated steam from saturated liquid (the assumed state of the core liquid). Hence, on the occasions when the CRFCKN-predicted carryout is not sufficient to maintain Region 1R in a two-phase state, the core exit flow is set equal to W_{OUTQM}.

Prior Analyses Experience

The CRF logic described above, as implemented in the approved version of REFLOD3B, was shown to work properly in prior analyses (i.e., Trojan, McGuire/Catawba, and Sequoyah). Those analyses indicated that only short excursions from the carryout calculated by CRFCKN were necessary to maintain Region 1R two-phase. A typical example of CRF from past work is shown in Figure 2. The 'ACTUAL' is W_{OUT}/W_{CORE} and the 'CORRELATION' refers to CRFCKN. The figure shows that after about 70 seconds W_{OUT} is based only on the CRFCKN correlation value.

However, for North Anna cases, CRF was found to be limited by W_{OUTQM} for most of the quasi-steady period of the transient. Figure 3 illustrates the North Anna situation. The sustained use of W_{OUTQM} results in excessive non-physical steam binding, suppressed flooding rates, increased clad temperature predictions, and delayed clad temperature turnaround times. This is clearly an unintended consequence of the quasi-steady CRF logic. CRFCKN was intended to be the basis for core carryout predictions. Departures from the CRFCKN correlation to insure numerical stability were expected to be few and brief in duration. This is clearly inconsistent with the behavior shown in Figure 3.

The difference in REFLOD3B behavior between prior analyses and the North Anna calculations are primarily attributable to plant design differences, notably in the upper head and containment. The previously analyzed designs promote lower steam binding and higher core flooding through use of large spray nozzles (providing a direct steam vent path from the reactor vessel upper head to the break) or a high-pressure containment. The large spray nozzles are integral to the design of T_{COLD} plants, like McGuire/Catawba and Sequoyah, while Trojan is representative of a T_{HOT} plant with a high-pressure containment design. Consequently, for the plants with prior Framatome ANP fuel reload work, the core exit flow rate calculated using the CRFCKN correlation was sufficient to maintain Region 1R in a two-phase state.

The NAPS design differs in that the units have both small spray nozzles (T_{HOT} upper heads) and sub-atmospheric (low-pressure) containments. Overall, this results in higher steam binding and lower flooding rates than experienced in prior analyses. Core liquid carryover calculated using the CRFCKN correlation is insufficient to prevent Region 1R from superheating. Hence, the internal CRFCKN logic sets the core outlet flow equal to W_{OUTQM} to derive sufficient core carryout to maintain Region 1R two-phase. The non-physical, sustained switch to W_{OUTQM} substantially aggravates an already challenging steam binding situation inherent in the North Anna design. The higher core outflow associated with W_{OUTQM} relative to that based on CRFCKN artificially increases steam binding and suppresses the core flooding rate to unrealistic levels.

New Option within CRFCKN

To correct this unrealistic behavior, a North Anna-specific CRF option was incorporated into the CRFCKN option. The option was designed to adhere to the original REFLOD3B development goal - during the quasi-steady period, CRF should be based on the CRFCKN correlation. The new option allows superheated steam to reside in Region 1R during the quasi-steady period. When the option is chosen, core exit flow is calculated using

$$W_{OUT} = CRF \times W_{CORE},$$

where CRF is calculated from the CRFCKN correlation. No other REFLOD3B code modifications were made. The reflood developing and transition periods remain unchanged. The new option was tested using the North Anna model. No numerical instabilities—non-physical core flooding rate oscillations—were noted.

The Impact on Benchmarks

Previous REFLOD3B and LBLOCA evaluation model benchmark cases were reviewed to assess the impact of the code modification on this work. FLECHT-SEASET Test 33338 was benchmarked against REFLOD3B and the results were reported in Appendix I of Reference 1. Semiscale MOD-1 Test S-04-06 was simulated using the Framatome ANP LBLOCA evaluation model methodology. The results of this integral benchmark are presented on pages LA-80 through LA-94 of Reference 2. The REFLOD3B results from both of these benchmarks were reviewed. It was found that in each case W_{OUT} was limited by CRF x W_{CORE} during the quasi-steady period. Therefore, use of the new REFLOD3B CRF modification would not impact existing benchmark results.

Impact on North Anna Results

The results of a North Anna case, run using the new CRF option, are shown in Figures 4 through 8. Figure 4 shows the CRF calculated using the CRFCKN correlation as well as the actual code-used value. During the quasi-steady period, the actual code-used CRF value is the same as the CRFCKN correlation. Figure 5 shows the core flooding rates calculated using the base option and the new option. After about 150 seconds, the core flooding rate calculated using the new option is higher than that calculated using the base option. The decrease in the flooding rate in the base case coincides precisely with the increase in actual CRF as shown in Figure 3. Figure 6 shows the cladding temperature response at the PCT locations in the base and modified cases. The PCT was lower and the PCT transient exhibited a significant turnaround using the new option relative to the case using the base option. The PCT location in the new option case is at a lower elevation than in the base case. This is due to the relatively faster quench front advancement stemming from the higher flooding rate in the new option case. The clad temperature responses at the 8.01 foot core elevation in the hot and average pins are shown in Figures 7 and 8, respectively. As in Figure 6, the post-peak cooldown rate is faster in the new option case than that in the base option case.

It needs to be emphasized that what appears as 'conservatism' (the lower flooding rate, for example) in the base option results is illusory. The 'conservatism' is artificial and directly due to inappropriately carrying out substantially more core fluid than would be predicted by the data-based CRFCKN correlation. The introduction of the new option within the CRFCKN option is a code improvement and is not removal of conservatism from the REFLOD3B calculation.

Appendix K Compliance

Allowing W_{OUT} to exceed the CRFCKN-based carryout by using W_{OUTQM} was a non-physically-based artifact meant to eliminate REFLOD3B numerical stability problems. To date, the artificial nature of the CRF logic during the quasi-steady period was of little concern since noted deviations from the CRFCKN correlation were few, of short duration, and added no conservatism to the calculation. Removal of this CRF contrivance and basing core carryout during the quasi-steady period solely on the CRFCKN correlation is consistent with Appendix K requirements, and it retains the conservatism of the approved LBLOCA evaluation model. Framatome ANP concludes that use of this new CRF option continues to meet all Appendix K requirements. It is further concluded that all conservatism in the current approved LBLOCA evaluation model, including REFLOD3B calculations, are retained with the use of this new option. The new CRF option will be used in all REFLOD3B predictions for the NAPS LBLOCA assessment with Advanced Mark-BW reload fuel. Approval of this new CRF option is requested for use only on the North Anna LBLOCA reload analysis.

References

1. BAW-10171P-A, "REFLOD3B - Model for Multinode Core Reflooding Analysis, " Revision 3, December 1995.

2. BAW-10168P-A, "RSG LOCA - BWNT Loss-of-Coolant Accident Evaluation Model for Recirculating Steam Generator Plants," Revision 3, December 1996. Augmented by NRC Staff SER transmitted via letter from Leslie W. Barnett, NRC, to James F. Mallay, Framatome ANP, April 9, 2002.

3. Letter: L. N. Hartz to USNRC, "Virginia Electric And Power Company - North Anna Power Station Units 1 and 2 - Minimum Containment Pressure Analysis To Support Proposed Technical Specifications Changes and Exemption Request, Use Of Framatome ANP Advanced Mark-BW Fuel," Serial No. 02-167A, July 9, 2002.

Figure 1. LBLOCA Computer Code Interface.

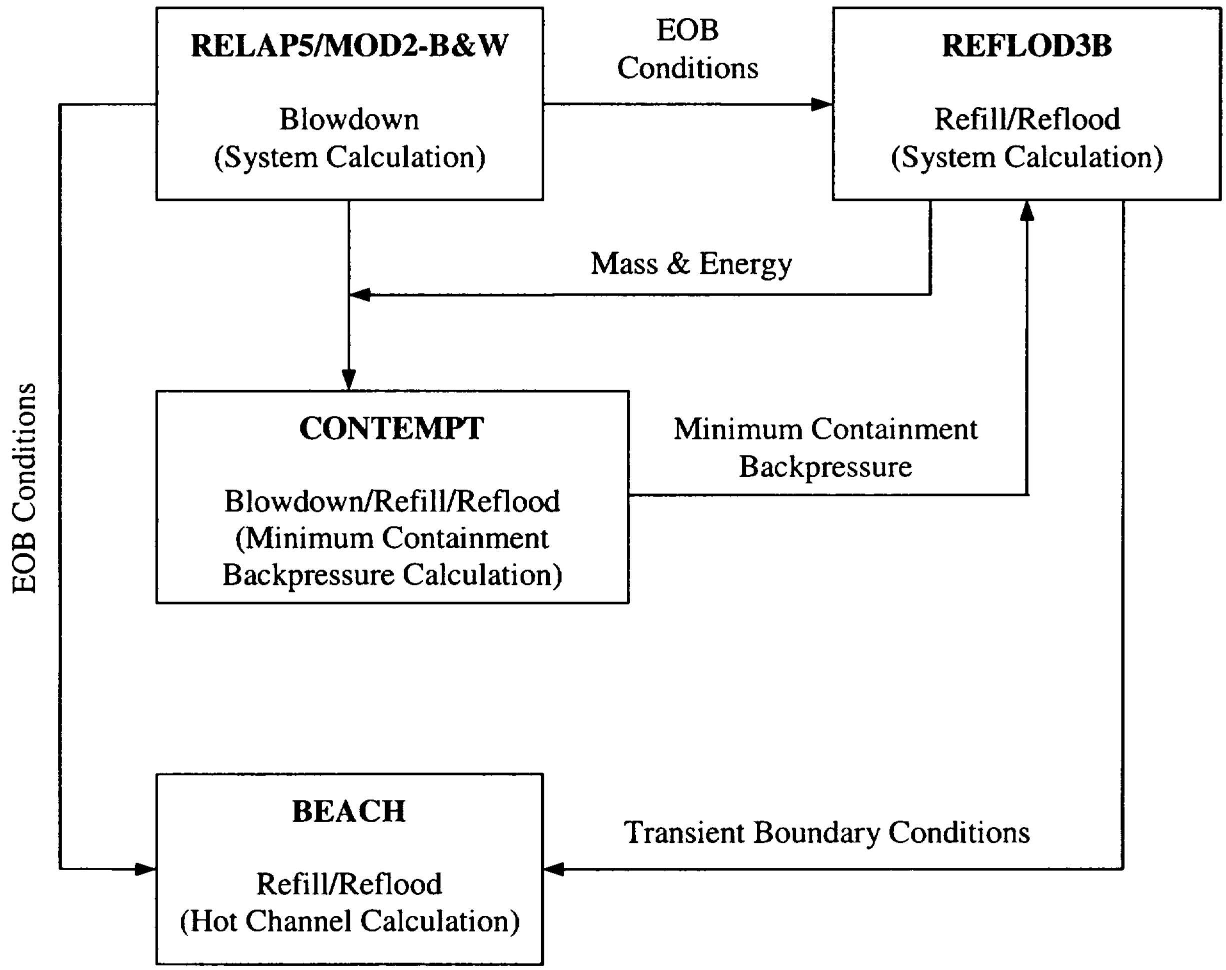

Figure 2. Typical CRF for a 4-Loop Plant Case.

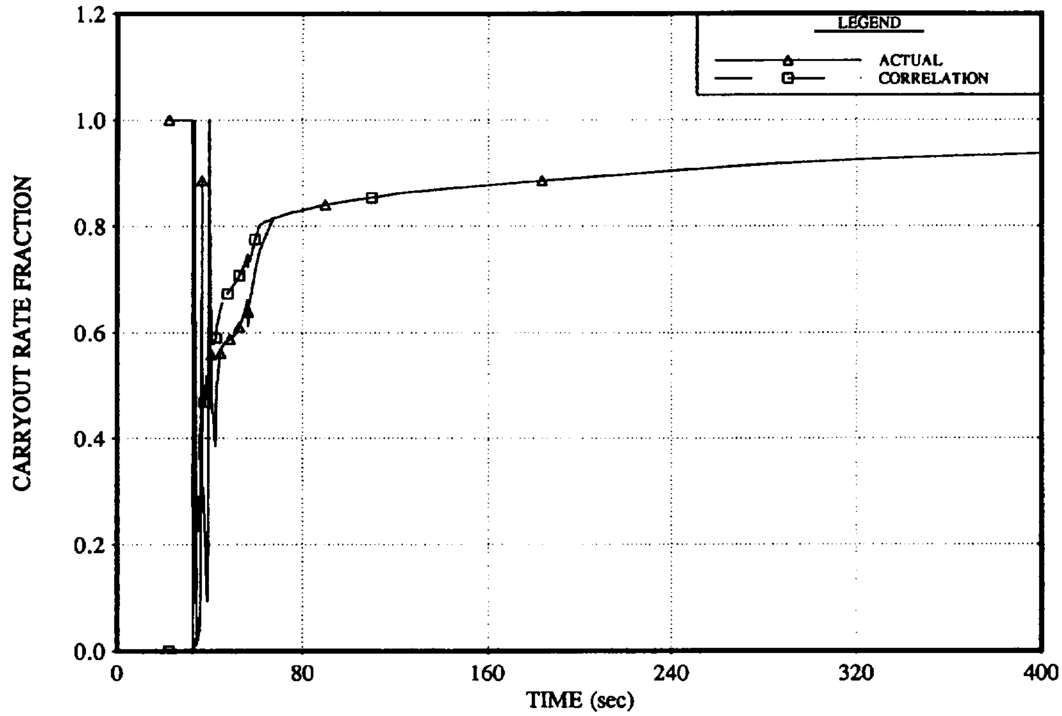

Figure 3. CRF for NAPS Units before REFLOD3B Modification.

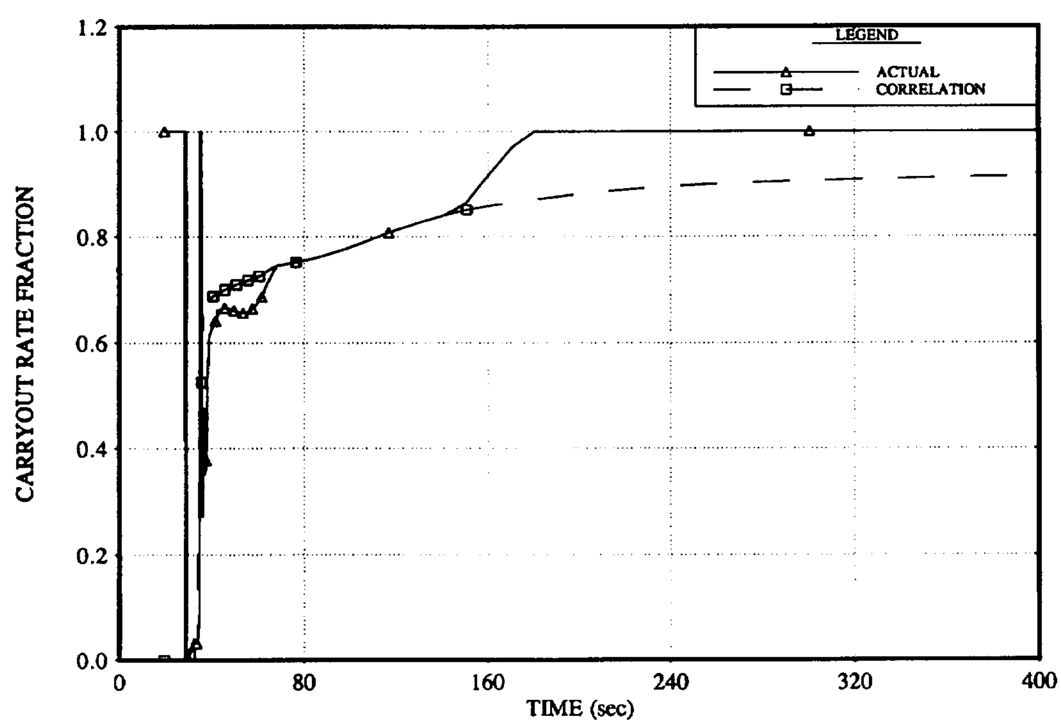

Figure 4. CRF for NAPS Units after REFLOD3B Modification.

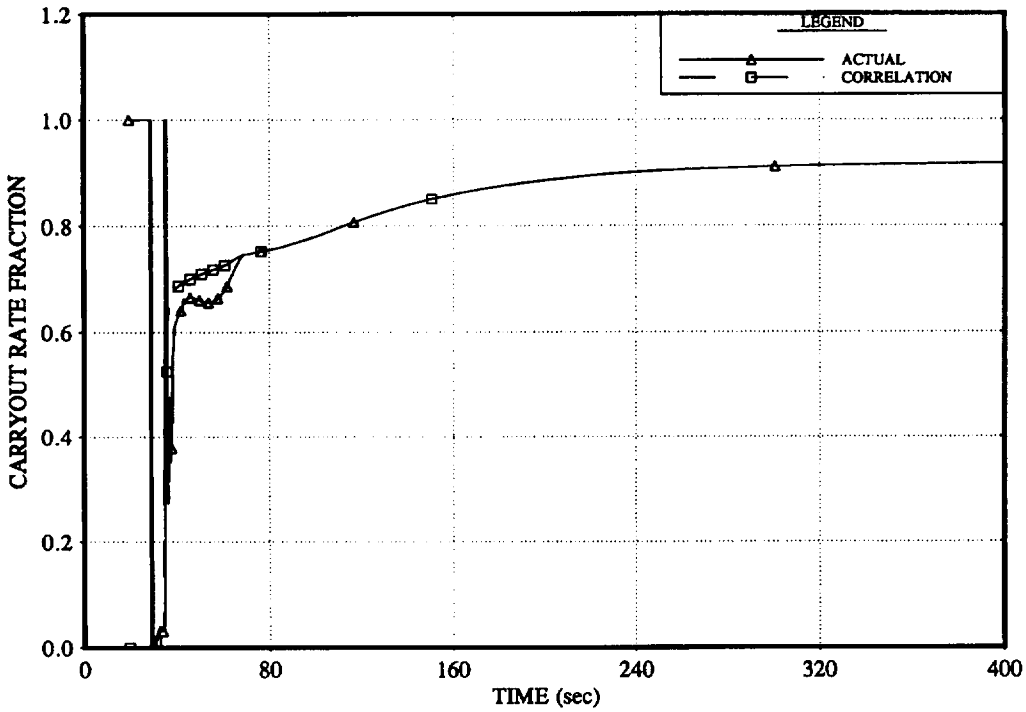

Figure 5. Core Inlet Flooding Rate for NAPS Units before/after REFLOD3B Modification.

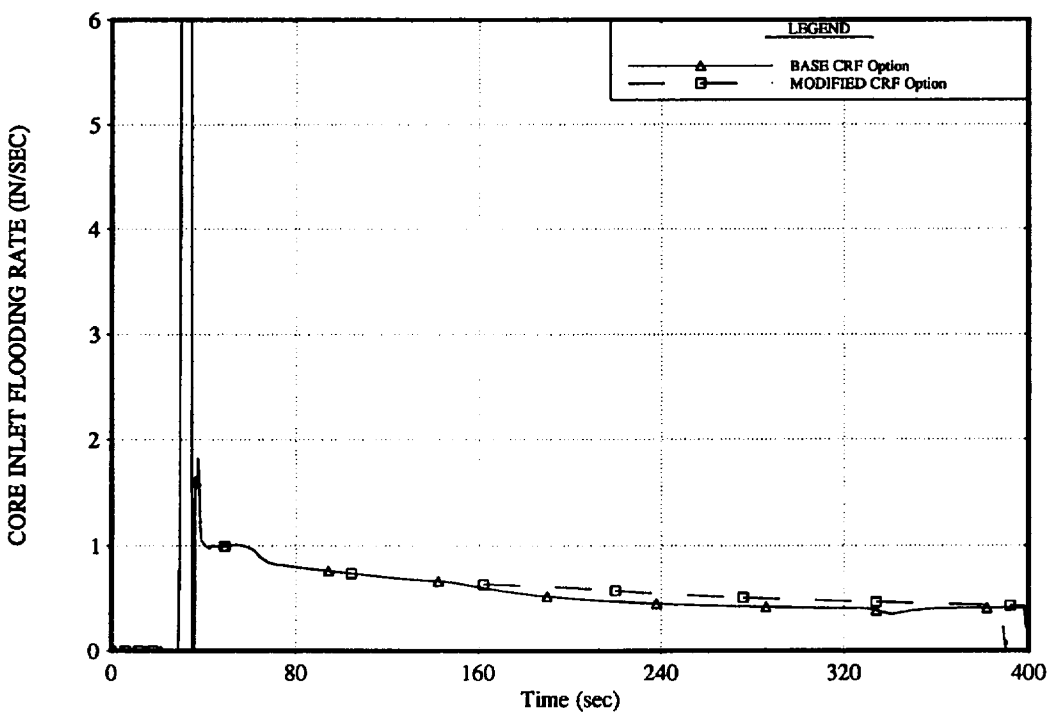

Figure 6. Peak Cladding Temperature for NAPS Units before/after REFLOD3B Modification.

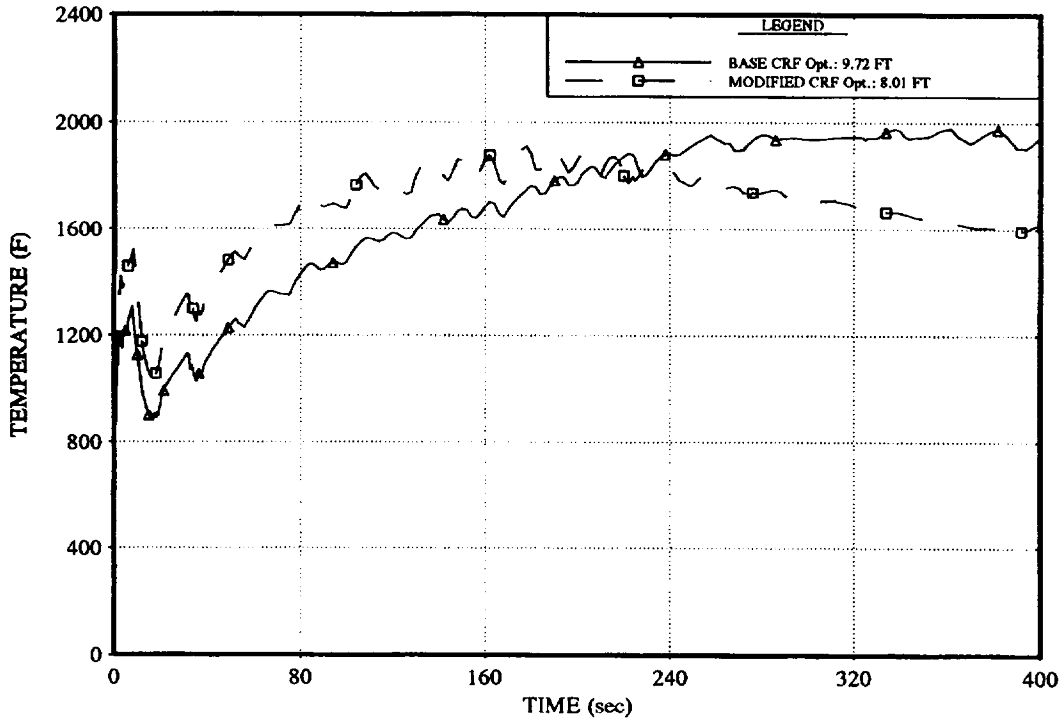

Figure 7. Hot Pin Clad Temperature at 8.01' for NAPS Units before/after REFLOD3B Modification.

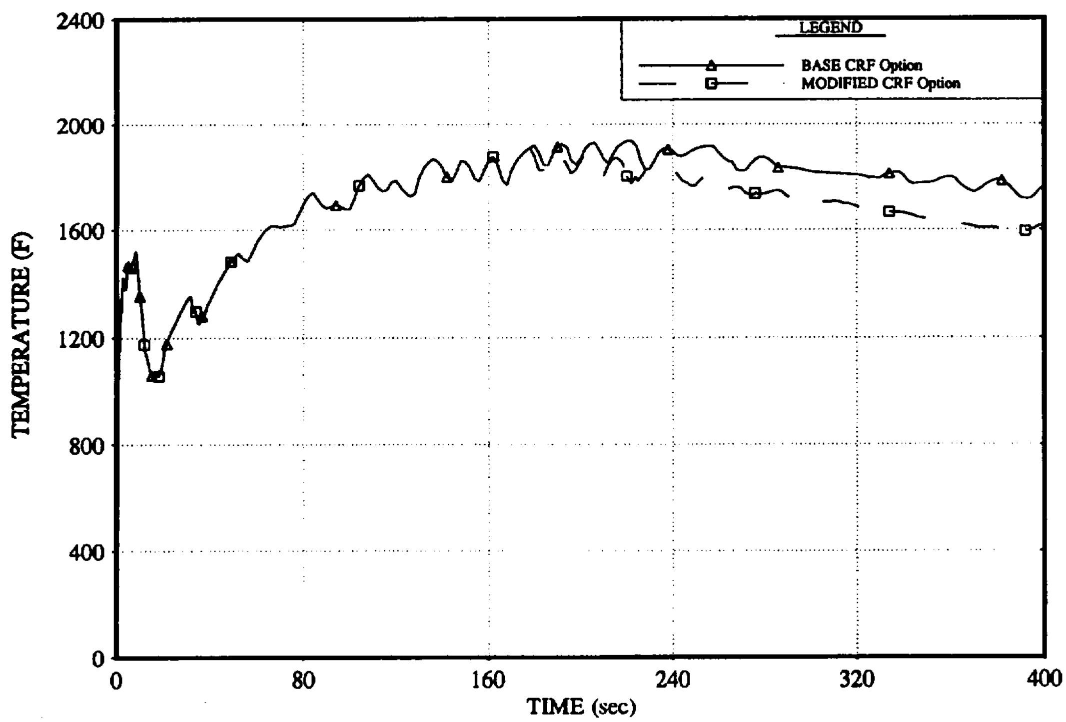

Figure 8. Average Core Clad Temperature at 8.01' for NAPS Units before/after REFLOD3B Modification.