Effect of Startup Ramp Rate on Pellet-Cladding Interaction of PWR Fuel Rods

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REPORT SUMMARY

A wide range of startup strategies and restart times currently exists for commercially operated pressurized water reactors (PWRs). This report summarizes an analytical evaluation to assess the technical basis for PWR restart ramp rate restrictions. It also provides technical justification for less restrictive power ramp rate conditions.

Background

Restart time is the interval required to reach or exceed 90% rated thermal power (RTP) following refueling outages. Variability in PWR restart strategies is a function of several factors. These include reactor system instrument calibration, primary and secondary water chemistry control, and vendor-specified fuel rod ramp rate limitations. To mitigate pellet-cladding interaction (PCI) leading to fuel rod failures, fuel vendors specify reactor power ramp rate limitations following a refueling outage. Typical restart ramp rates range between 3% and 4% per hour of full reactor power above a threshold reactor power level between 20% and 40% full power. Since higher capacity factors for nuclear power plant operation translate into improved plant economics, refinements in plant restart strategies are desirable. To analyze ramp rate limitations in relation to PWR restart strategies, EPRI cosponsored this research with Electricité de France and KEPRI (Korea Electric Power Corporation).

Objectives

- To establish the technical basis for PWR restart ramp rate restrictions imposed by fuel vendors or Nuclear Steam Supply System (NSSS) suppliers.
- To provide technical justification for relaxing currently accepted PWR ramp rate restrictions.

Approach

The project team envisioned that by either increasing threshold power, ramp rate, or a combination of these parameters, improvements in reactor startup times could be achieved. The team used three different combinations of PWR reactor types and fuel rod designs to evaluate the impact of ramp rate and threshold power conditions on PCI behavior of once- and twice-burned fuel rods. To determine fuel rod condition at reactor restart, the team used the ESCORE steady state fuel performance program. Detailed PCI calculations were performed using the FREY fuel rod behavior program.

The three PWRs in the study were Yonggwang 2 (Westinghouse 3-Loop), Yonggwang 4 (Combustion Engineering), and Diablo Canyon 2 (Westinghouse 4-Loop)

Results
The study identified significant margin to PCI failure for current ramp rate conditions in the U.S. and Korean reactors. Results indicate that PCI behavior is more affected by ramp rate and threshold power than fuel design. However, the analyses found that the most important parameter was the fuel's power history. For example, the fuel rod damage probability—and, thus, the probability of PCI failure—was proportional to the expected rod peak power. Based on the similar trend of cladding damage index for all three fuel designs, the optimum threshold power and ramp rate limitations were determined. Ramp rates up to 5% per hour above threshold power levels up to 60% of full reactor power can be used without concern for fuel rod integrity during reactor restarts following a refueling outage.

EPRI Perspective
By improving procedures for instrumentation calibration and primary and secondary water chemistry control, plant operators could potentially shorten PWR restart times following a refueling outage. However, unless increased power ramp rates can be combined with these improvements, ramp rate restrictions imposed by fuel vendors will continue to limit reactor restart times. This study's recommended changes in ramp rate and threshold power could solve this problem, shifting the emphasis of restart restrictions from the fuel to balance-of-plant systems. Relaxation of threshold power and ramp rate restrictions has potential to improve current plant startup strategies and plant economics.

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ABSTRACT

A wide range of startup strategies and restart times currently exists for commercially operated pressurized water reactors (PWRs). The variability in PWR restart strategies is a function of several factors, including reactor system instrument calibration, primary and secondary water chemistry control, and vendor specified fuel rod ramp rate limitations. Fuel vendors, as a means to mitigate pellet-cladding interaction (PCI) leading to fuel rod failures, specify reactor power ramp rate limitations following a refueling outage. Typical restart ramp rates range between 3% per hour and 4% per hour of full reactor power above a threshold reactor power level between 20% and 40% full power. This report summarizes an analytical evaluation performed to assess the technical basis for PWR restart ramp rate restrictions and to provide the technical justification to propose less restrictive power ramp rate conditions. Three combinations of PWR reactor types and fuel rod designs were used to evaluate the impact of ramp rate and threshold power conditions on the PCI behavior of once-burned and twice-burned fuel rods. The fuel rod condition at the reactor restart of interest was established using the ESCORE steady state fuel performance program. Detailed PCI calculations were performed using the FREY fuel rod behavior program. The assessment identified significant margin to PCI failure for current ramp rate conditions used in reactors operated in the U.S. and Korea. Based on the analytical evaluation presented, ramp rates up to 5% per hour above threshold power levels up to 60% of full reactor power can be used without concern for fuel rod integrity during reactor restarts following a refueling outage.

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INTRODUCTION

1.1 Background

A broad spectrum of startup strategies and restart times exists in currently operated pressurized water reactors (PWRs). Restart time is defined as the time required to reach or exceed 90% rated thermal power (RTP) following refueling outages. The variability in PWR restart strategies is a function of several factors, including instrument calibration, primary and secondary water chemistry control, and fuel related ramp rate limitations during power escalation.

Table 1-1 contains a survey of plant power levels (% rated power) as a function of time during reactor startup following a refueling outage. Included in the table are both U.S. and German reactors manufactured by Westinghouse, Combustion Engineering (CE), Babcock and Wilcox (B&W) and Siemens. An evaluation of this data indicate that US plants take three to fifteen days to reach power levels above 90% rated power following a refueling outage. In contrast, German plants restart to above 90% rated power in less than three days in most cases. Operation below 50% power for more than one day represents about 0.1% to 0.3% loss in capacity or utilization factor per day, depending on cycle length (12 or 18 month cycles). Because higher capacity factors for nuclear power plant operation translate into improved plant economics, enhancements in plant restart strategies are desirable.

An important component of a plant's restart strategy is power ramp rate restrictions. The intention of power ramp rate restrictions is to prevent fuel rod damage and/or failure by pellet-cladding interaction (PCI). Typically, fuel vendors or Nuclear Steam Supply System (NSSS) suppliers provide fuel conditioning (ramp rate restriction) guidelines to utilities. A summary of the ramp rate restriction practices used by plants in four countries (U.S., France, Germany, and South Korea) are shown in Table 1-2 (Ref. 1). These ramp rate restrictions are developed from fuel vendor or NSSS supplier guidelines. The ramp rate restrictions consist of two parts: (1) the threshold power above which the restrictions apply, and (2) the maximum rate of reactor power escalation. As seen in Table 1-2, these guidelines (restrictions) are normally defined as a percentage of full rated thermal power for the reactor, i.e. the ramp rate is 3%/hr beyond a threshold power of 20% reactor terminal power. In some instances, the ramp rate restrictions will be defined in terms of a fuel rod linear power, i.e. 0.3 kW/ft/hr.

Table 1-1
Comparison of Restart Time (U.S. vs. German PWRs)

Plant	Days to >90%	1	2	3	4	5	6	7	8	9	10	11	12	13	15
U.S PWRs															
BW 3	3	NA	NA	91%											
W 8	4	10%	40%	58%	90%										
W 27	4	5%	30%	70%	90%										
BW 1	4	10%	55%	67%	95%										
W 42	4	22%	51%	72%	90%										
CE 13	4	32%	76%	78%	98%										
CE 11	4	2%	31%	80%	90%										
CE 8	4	20%	32%	69%	90%										
BW 7	4	NA	45%	80%	100%										
W 17	5	22%	31%	45%	85%	100%									
W 32	5	1%	28%	59%	81%	99%									
W 46	5	23%	NA	58%	82%	90%									
CE 6	5	17%	34%	0	46%	90%									
CE 7	5	15%	NA	60%	69%	99%									
W 9	5	15%	23%	30%	75%	100%									
W 19	5	3%	5%	28%	60%	90%									
W 30	5	21%	25%	48%	61%	98%									
W 35	5	7%	24%	45%	58%	90%									
W 45	5	15%	30%	61%	75%	92%									
W 48	5	13%	29%	48%	72%	100%									
CE 1	5	18%	30%	37%	68%	98%									
CE 14	5	18%	15%	53%	72%	100%									
CE 11	5	18%	56%	82%	86%	97%									
W 1	6	22%	30%	30%	75%	74%	90%								
W 15	6	NA	NA	45%	49%	90%	92%								
W 23	6	15%	NA	NA	NA	75%	98%								
CE 2	6	NA	NA	11%	20%	83%	90%								
BW 2	6	15%	21%	35%	53%	71%	95%								
W 14	6	NA	30%	48%	69%	NA	100%								
W 16	6	2%	33%	33%	NA	NA	100%								
W 23	6	15%	19%	22%	29%	78%	98%								
W 43	6	1%	30%	30%	42%	64%	98%								
W 44	6	17%	30%	50%	50%	79%	98%								
CE 9	6	5%	18%	32%	55%	68%	95%								
CE 3	6	28%	55%	83%	86%	89%	95%								
W 28	7	16%	23%	33%	NA	NA	NA	100%							
CE 4	7	26%	NA	NA	60%	69%	74%	98%							

Table 1-2(cont.)
Comparison of Restart Time (U.S. vs. German PWRs)

Plant	Days to >90%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
W 26	7	30%	54%	80%	63%	76%	84%	100%								
W 29	7	5%	28%	29%	46%	65%	89%	91%								
W 37	7	5%	30%	30%	31%	68%	75%	98%								
W 39	7	1%	29%	58%	77%	NA	NA	100%								
W 47	7	10%	27%	30%	40%	55%	86%	94%								
W 6	8	29%	30%	55%	73%	NA	NA	NA	100%							
W 10	8	15%	29%	50%	70%	70%	75%	80%	100%							
CE 12	8	1%	19%	75%	52%	0	45%	80%	100%							
W 12	8	10%	8%	1%	29%	45%	52%	86%	98%							
W 18	8	2%	30%	55%	78%	79%	100%	45%	97%							
W 23	8	4%	30%	29%	29%	1%	57%	88%	98%							
W 36	8	4%	30%	30%	48%	70%	77%	88%	97%							
W 38	8	10%	40%	69%	0%	7%	57%	77%	98%							
W 40	9	3%	22%	22%	30%	41%	58%	73%	84%	100%						
W 3	10	16%	30%	30%	30%	45%	50%	50%	50%	61%	100%					
W 20	10	6%	15%	18%	30%	57%	57%	57%	57%	70%	90%					
W 31	10	20%	35%	35%	36%	36%	36%	38%	50%	82%	100%					
W 11	11	7%	16%	28%	35%	53%	52%	55%	72%	80%	80%	90%				
BW 6	11	17%	25%	45%	63%	64%	64%	73%	0%	70%	68%	90%				
W 4	12	NA	NA	29%	29%	37%	46%	47%	NA	NA	79%	80%	90%			
W 22	12	3%	38%	38%	38%	39%	38%	38%	49%	68%	72%	78%	89%			
W 25	13	1%	NA	NA	NA	20%	30%	33%	45%	47%	NA	NA	75%	97%		
W 33	13	47%	47%	NA	NA	47%	47%	NA	NA	75%	76%	75%	88%	100%		
BW 4	13	25%	65%	65%	NA	NA	NA	0	0	31%	70%	NA	NA	100%		
W 21	13	10%	21%	10%	30%	0	0	0	0	10%	49%	70%	80%	90%		
W 41	14	2%	21%	1%	2%	49%	55%	59%	63%	58%	56%	45%	1%	80%	98%	
W 5	15	12%	29%	29%	40%	47%	NA	NA	60%	60%	63%	75%	70%	NA	NA	100%
BW 5	15	5%	18%	25%	28%	52%	60%	58%	75%	80%	81%	81%	0	0	40%	100%
W 34	25	7%	17%	15%	35%	47%	47%	47%	47%	47%	46%	45%	47%	42%	43%	43%
Median	6	13%	30%	45%	60%	76%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%

GERMAN PWRs

D 3	1	100%	
D 4 (Konvoi)	1	100%	
D 9 (Konvoi)	1	100%	
D 13	1	100%	
D 1	2	50%	100%

Table 1-3(cont.)
Comparison of Restart Time (U.S. vs. German PWRs)

Plant	Days to >90%	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
D 2	2	50%	100%													
D 5 (14)	2	55%	91%													
D 6 (13)	2	85%	99%													
D 7 (Konvoi)	2	70%	95%													
D 11	2	80%	99%													
Median	2	83%	100%	100%	100%	100%	100%	100%								
Diff. of medians		70%	70%	55%	40%	25%	5%	0%								

Table 1-4
PWR Restart Practices

Combustion Engineering NSSS

Restart Limits	Fuel Characteristics
SONGS 2 & 3 • Ref.: CE per Op Instruction SO23-5-1.7 • Ramp: 3%/hr • Threshold: 20%(recommended); 50%(required) • Also rod (CEA) movement limits	• ABB/CE fuel • 3,390 MWt • 49,820 rods • 12.5 ft active length • Avg. 68 kw/rod • Avg. 5.4 kw/ft
YGN 3 & 4 (Korea) • Ref.: CE Fuel Preconditioning Guidelines • Ramp: 3%/hr • Ramp basis: 0.3kw/ft/hr • Threshold: 20%(recommended); 50%(required) • Threshold basis: 5 kw/ft • Also limits on Axial Shape Index (ASI)	• CE/KNFC fuel • 2,815 MWt • 41,772 rods • 12.5 ft active length • Avg. 67 kw/rod • Avg. 5.4 kw/ft

Westinghouse NSSS

Diablo Canyon 1 • Ref.: Westinghouse • Ramp: 3%/hr • Threshold: 20% • 5MW/min limit after conditioning	• Westinghouse fuel • 3,338 MWt • 50,952 rods • 12 ft active length • Avg. 66 kw/rod • Avg. 5.5 kw/ft
Diablo Canyon 1 • Ref.: Westinghouse • Ramp: 3%/hr • Threshold: 20% • 5MW/min limit after conditioning	• Westinghouse fuel • 3,338 MWt • 50,952 rods • 12 ft active length • Avg. 66 kw/rod • Avg. 5.5 kw/ft

Table 1-5(cont.)
PWR Restart Practices

Restart Limits	Fuel Characteristics
Callaway • Ref.: 1981 Westinghouse Limits & Conditions • Ramp: 3%/hr • Threshold: 20% • Also Limits on Rod (RCCA) Movement	• Westinghouse fuel • 3,565 MWt • 50,952 rods • 12 ft active length • Avg. 70 kw/rod • Avg. 5.8 kw/ft
Sequoyah 2 • Ref.: FCF endorsed Westinghouse limit. • Ramp: 3%/hr • Threshold: 20%	• FCF fuel • 3,411 MWt • 50,952 rods • 12 ft active length • Avg. 67 kw/rod • Avg. 5.6 kw/ft
YGN 1 & 2 (Korea) • Ref.: 1981 Westinghouse Limits & Conditions • Ramp: 3%/hr • Threshold: 20% • Also Limits on Rod (RCCA) Movement	• Westinghouse/KNFC fuel • 2,775 MWt • 41,448 rods • 12 ft active length • Avg. 67 kw/rod • Avg. 5.5 kw/ft

Babcock & Wilcox NSSS

Restart Limits	Fuel Characteristics
TMI • Ref.: BWNT 32-1239735-00 "Generic Mk-B Restart MMRs" 11/30/95 • Ramp: 3%/hr • Threshold: 40% • Ramp: 30%/hr from 0 to 40%	• FCF fuel • 2,568 MWt • 36,816 rods • 12 ft active length • Avg. 70 kw/rod • Avg. 5.8 kw/ft

Framatome (EdF)

Restart Limits	Fuel Characteristics
CP-1/CP-2 • Ref.: 1975 Westinghouse • Ramp: 3%/hr • Threshold: 15% • also limit rods to 3 steps /hr above 50%	• 2,785 MWt • 41,448 rods • 12 ft active length • Avg. 67 kw/rod • Avg. 5.6 kw/ft
REP 1300 • Ref.: 1975 Westinghouse • Ramp: 3%/hr • Threshold: 15% • Also Limit Rods to 3 steps /hr above 50%	• 2,785 MWt • 41,448 rods • 12 ft active length • Avg. 67 kw/rod • Avg. 5.6 kw/ft

Table 1-6(cont.)
PWR Restart Practices

Restart Limits	Fuel Characteristics
REP 1300 • Ref.: 1975 Westinghouse • Ramp: 3%/hr • Threshold: 15% • Also Limit Rods to 3 steps /hr above 50%	• 2,785 MWt • 41,448 rods • 12 ft active length • Avg. 67 kw/rod • Avg. 5.6 kw/ft

Siemens/KWU (Germany)

Restart Limits	Fuel Characteristics
Biblis A • Ramp: 5%/hr • Threshold: 80% • Threshold basis: 350 w/cm (390 w/cm with margin) • 10%/hr after conditioning for 72 hrs	• Siemens fuel • 3,517 MWt • 45,548 rods • 12.8 ft active length • Avg. 77 kw/rod • Avg. 6.0 kw/ft
Biblis B • Ramp: 5%/hr • Threshold: 80% • Threshold basis: 350 w/cm (390 w/cm with margin) • 10%/hr after conditioning for 72 hrs	• Siemens fuel • 3,733 MWt • 45,548 rods • 12.8 ft active length • Avg. 82 kw/rod • Avg. 6.4 kw/ft
Grafenrheinfeld • Ramp: - 10%/hr up to 30% - 2%/hr up to 65% - 1.5%/hr up to 80% - 1%/hr to 100% • Conditioning Ends after 30 hrs at 100%	• Siemens fuel • 3,765 MWt • 45,548 rods • 12.8 ft active length • Avg. 83 kw/rod • Avg. 6.4 kw/ft
Phillippsburg 2 • Ref.: PCI-RELEB. Limit 465 W/cm. • Ramp: 1%/min from 1-70% • "no limit" above 70%	• Siemens/Fragema fuel • 3,850 MWt • 45,548 rods • 12.8 ft active length • Avg. 85 kw/rod • Avg. 6.6 kw/ft
Emsland(Konvoi) • Ref.: PCI-RELEB • Ramp: 0.5%/min from 0-100% • Turbine is Limiting	• 3,850 MWt • 57,900 rods • 12.8 ft active length • Avg. 66 kw/rod • Avg. 5.2 kw/ft

Table 1-7(cont.)
PWR Restart Practices

Restart Limits	Fuel Characteristics
Isar 2 (Konvoi) • Ref.: PCI-RELEB • Ramp: - 10%/hr from 0-30 or 40% - 2%/hr there to 85% - 1.5%/hr there to 95% - 1%/hr to 100%	• Siemens fuel • 3,850 MWt • 57,900 rods • 12.8 ft active length • Avg. 66 kw/rod • Avg. 5.2 kw/ft
Unterweser • Ramp: 10%/hr from 0-30 or 40% - 2%/hr there to 85% - 1.5%/hr there to 95% - 1%/hr to 100%	• Siemens fuel • 3,733 MWt • 45,548 rods • 12.8 ft active length • Avg. 82 kw/rod • Avg. 6.4 kw/ft
Grohnde • Ref: GLAD System • Ramp: - 1%/min from 0-30 or 40% - 0.5%/min there to 65% - 2%/hr there to 85%(Cyc.13) or 95%(Cyc.14) - 1%/hr to 100%	• Siemens & ABB fuel • 3,765 MWt • 45,548 rods • 12.8 ft active length • Avg. 83 kw/rod • Avg. 6.5 kw/ft
Brokdorf • Ramp: - 1%/min from 0-30% - 10%/hr there to 75% - 5.0%/hr there to 90% - "up to 5%/hr" there to 100%	• Siemens, ANF and Fragema fuel • 3,765 MWt • 45,548 rods • 12.8 ft active length • Avg. 83 kw/rod • Avg. 6.5 kw/ft
Neckarwestheim 2 (Konvoi) • Ramp: - 0.4%/min (5 MWe/min)from 0-90% - 2%/hr there to 100%	• Siemens fuel • 3,850 MWt • 57,900 rods • 12.8 ft active length • Avg. 66 kw/rod • Avg. 5.2 kw/ft

If more efficient restart strategies can be developed by improving the procedures used for instrumentation calibration and primary and secondary water chemistry control, plant operators could potentially shorten PWR restart times by several days following a refueling outage. However, unless increased power ramp rates can be combined with the improvements in non-fuel related areas, the ramp rate restrictions imposed by the fuel vendors will continue to limit reactor restart times.

1.2 Objectives and Approach

An analytical evaluation was performed to:

- Establish the technical basis for the PWR restart ramp rate restrictions imposed by the fuel vendors or NSSS suppliers.

- Provide the technical justification to relax the currently accepted ramp rate restrictions used in PWRs.

It is envisioned that by either increasing the threshold power, the ramp rate, or a combination of these parameters, improvements in reactor startup times can be achieved.

To accomplish the above stated objectives, fuel behavior analyses were conducted to identify the PCI response during reactor startup following a refueling outage for three different PWR fuel types, W 17x17 VANTAGE-5H, VANTAGE-5, and CE 16x16. Three reactor candidates were used to obtain the necessary fuel rod and reactor power information to conduct the analysis. Data describing the fuel rods and steady-state and restart power histories for once-burned and twice-burned assemblies were obtained from three PWRs:

- Yonggwang 2 (Westinghouse 3-Loop)

- Yonggwang 4 (Combustion Engineering)

- Diablo Canyon 2 (Westinghouse 4-Loop)

In addition to the restart power history information (i.e. fuel rod power peaking factors and terminal power levels), similar information was obtained for the first cycle of operation (once-burned fuel) or for both cycles of operation (twice-burned fuel). This information was used in the analysis to establish the peak fuel rod condition after operation for one cycle (once-burned) or two cycles (twice-burned). After the initial conditions were established, detailed PCI analyses were conducted using a matrix of restart conditions, i.e. threshold power levels and ramp rates. A base set of conditions was established that were derived from the vendor recommendations. The threshold power was 20% of the full reactor power and the ramp rate was set to 3% per hr above the threshold. After the base conditions were analyzed, a series of sensitivity studies were performed with threshold powers varying between 20% and 90% and ramp rates varying between 3% per hr to 30% per hr. These analyses were conducted for once-burned and twice-burned fuel, representing the start of the start second and third cycle of operation, respectively.

The steady-state cycle analyses, used to establish the fuel rod initial conditions at reactor restart, were conducted using the ESCORE computer code. The detailed PCI calculations were performed using the FREY computer code. Both ESCORE and FREY are single fuel rod analysis codes designed to calculate the response of light water reactor (LWR) fuel during normal operation, transients (power ramps), and design basis accidents. An overview of both programs and a discussion of their use in this project are presented in Section 2.

1.3 PCI Mechanisms

In general, three types of cladding failure can occur under normal operating conditions: (1) manufacturing defects, (2) debris fretting, and (3) PCI. Cladding failures induced during normal fuel rod operation (i.e. power changes) are generally PCI related. PCI fuel failure results from a combination of mechanical and chemical interactions between the UO_2 fuel pellets and Zircaloy cladding. The primary mechanism of PCI-induced cladding fractures is intergranular stress corrosion cracking (ISCC). ISCC is an operative failure mode that exists over a broad range of reactor duty cycles and mechanical and chemical conditions within nuclear fuel rods.

Under long service, fuel pellets experience a complex history of cracking, relocation, and crack healing. At low power levels (well below the average rod power) during reactor startup, hard fuel-to-cladding contact can exist at one or more local points within a fuel rod. This contact can be the result of movement of the fuel stack due during normal operation (relocation) or vibration/shock experienced during fuel shuffling and reloading operations. If a relatively high power increase is experienced in the region of contact, the resulting hoop stress can be high enough to initiate ISCC. This type of failure is highly random, and therefore, the prediction of this type of failure is partly a statistical problem.

Reactors undergoing restart operations are potentially vulnerable to PCI failures. Under restart conditions, the pellet/cladding gap may be closed at relatively low linear powers for fuel rods beyond a threshold burnup level. If the power level increases rapidly under these conditions, differential thermal expansion can result in stress concentrations in the cladding that may cause cladding failure. As discussed above, the susceptibility of fuel rods to PCI failures during restart has resulted in the development of power ramp rate restrictions by fuel vendors.

2

ANALYSIS CAPABILITIES AND MODELING APPROACH

Section 2 presents an overview of the analysis tools and modeling approach used to evaluate the PCI behavior of irradiated PWR fuel rods during a reactor startup following a refueling outage. The fuel rod modeling codes used in this evaluation allow for an analysis of the peak fuel rod response to power changes introduced during reactor startup. By performing calculations of the cladding stress state during a power ramp, it is possible to identify the power conditions that may preclude PCI failure.

The modeling approach consisted of two steps. First, the condition of the peak power fuel rod was established at the end of one and two cycles of operation, once-burned or twice-burned fuel, respectively. This step was accomplished using the ESCORE steady state fuel performance program developed by EPRI. Second, the PCI behavior during reactor start-up was established for either the second or third cycle of operation. The second step was performed using the PCI capabilities of the FREY fuel behavior program combined with the initial conditions provided by ESCORE.

The following provides a brief discussion of the ESCORE and FREY programs, the method used to initialize FREY with the results from ESCORE, and the analysis approach used in the project.

2.1 ESCORE Description

ESCORE is a best-estimate FORTRAN computer code that calculates the steady-state response of an LWR fuel rod. The code calculates both the thermal and mechanical response of a fuel rod as a function of time-dependent rod power. ESCORE's applications include, but are not limited to, fuel design, and technical specification and setpoint licensing.

ESCORE was designed to perform best-estimate predictions of fuel rod behavior across a broad range of steady-state conditions, and as such, provides the user with a versatile tool that can be used to evaluate numerous operational alternatives. Examples of the ESCORE applications include: (1) determination of fuel characteristics after long-term, steady-state irradiation for subsequent use in transient analyses; (2) calculation of fuel thermal limit data for use in safety analyses; (3) trade studies for evaluation of new fuel design configurations; and (4) establishment of technical specifications on permissible linear heat rates, peaking factors, and other thermal and mechanical limits to preclude fuel damage. For example, ESCORE can determine the power required to attain the centerline melt temperature of fuel rod given a specific set of conditions accounting for the effects of burnup and temperature on fuel fission-product composition, axial densification, and fuel-cladding gap size.

Computationally, ESCORE calculates the steady-state thermal and mechanical response of a fuel rod by approximating it as a series of discrete, axial segments. The thermal and mechanical solutions are coupled to provide the overall fuel rod solution. For the thermal computations, independent radial thermal equilibrium calculations are performed for each axial segment. These are then coupled over the length of the entire fuel rod with the assumption of complete mixing of the free gases within the rod. For the mechanical solution, ESCORE calculates the hot and cold internal rod pressures, the rod internal open void volume, the fuel and cladding outer and inner diameter changes for each axial segment, and the axial fuel and cladding length changes.

Required inputs to initialize ESCORE include the fuel rod geometric parameters, the actual or projected irradiation history, and the core thermal-hydraulic conditions. The fuel rod power history is input as local power that is a function of either axially averaged burnup or time in user-supplied timesteps. Burnup is calculated where time is the independent, user-input variable. Alternatively, time is calculated if burnup is the independent, user-input variable. Core average linear heat rate, a radial peaking factor, and an axial power shape can be input at each time step to calculate local rod power. Three options are available to calculate cladding outer-surface temperatures. The recommended first option is to input subchannel geometry, coolant inlet temperature, coolant pressure, and coolant mass flow rate and allow ESCORE to calculate the cladding outer-surface temperature assuming a closed subchannel with either single-phase convection, subcooled boiling, or saturated flow boiling. The heat transfer coefficient is calculated with either the Dittus-Boelter or Jens-Lottes correlations. The second option is identical to the first with the exception that the user supplies the "convective" and "boiling" heat transfer coefficients rather than use those calculated by ESCORE. The third alternative requires the user to directly input the cladding outer-surface temperature at each axial node and at each timestep. For further information on ESCORE’s fuel rod modeling technique, input requirements, output information, code structure, and calculational procedure, a detailed description is available in the ESCORE Theory and User’s Manuals (Ref. 2, 3).

2.2 FREY Description

The FREY computer program is a fuel rod evaluation system for the transient and steady-state analysis of light water reactor fuel. FREY models the thermomechanical behavior of a single fuel rod, in detail, utilizing a closed-channel thermal-hydraulic simulation of the rod-coolant heat transfer. In addition, it provides the capability of user-defined heat transfer coefficient and bulk temperature as functions of position and time, thus extending the program's utility to a wide range of transients for which passive coupling of thermal-hydraulic and thermomechanical responses is valid. As a general purpose fuel rod evaluation system, FREY contains models for best-estimate predictions as well as licensing evaluation.

An important area of fuel performance evaluation in which FREY provides unique capabilities is pellet-cladding interaction (PCI). It provides a comprehensive tool for diagnostic analysis of PCI-related problems, such as the determination of failure threshold, the evaluation of the effects of ramp rates, power cycling and abnormal power maneuvers on fuel failures, and the assessment of cladding defects on fuel rod integrity.

The theoretical foundation of FREY is derived from basic principles. The program utilizes the MATPRO material models[4] and the computational structure is based on the finite element method with a backward time difference stepping procedure. Deterministic failure models for cladding integrity evaluations are provided for application to design basis transients, as well as normal, steady-state operation. Under steady-state conditions, a cladding failure criterion based on ISCC is used; for transients, cladding failure is predicted using a cladding rupture criterion. The failure analysis method utilizes a cumulative damage concept. For safety evaluation under accident conditions, cladding rupture and oxidation criteria are applied to large deformation ballooning-type failures at high temperatures.

FREY contains models for steady-state analyses to define transient initial conditions or fuel diagnostic evaluations. These models include fission gas release, burnup, fuel cracking and relocation, local gap thickness and conductance, cladding and fuel visco-plasticity, fuel hot-pressing, swelling and densification, and pellet-cladding interaction (PCI). Because of FREY's finite element structure, these calculations can be carried out for full-length rods, short segments, or slices. FREY provides geometric models in r-z or r-θ grids as appropriate. FREY's PCI analysis capabilities are unique in that it permits the detailed simulation in the r-θ plane of discrete pellet cracks and pellet-cladding interfacial forces. The following is a list of parameters, computed by FREY, which are generally needed for licensing and fuel performance evaluation:

- Fuel Stored Energy
- Fuel Centerline Temperature
- Fuel Temperature Distribution
- Thermal Margins

- Cladding Inner and Outer Surface Temperatures
- Gap Thickness and Conductance Distributions
- Void Volume
- Fission Gas Release Fraction and Composition
- Gas Pressure
- PCI Damage Index
- Oxide Thickness
- Cladding Stress and Strain Distribution
- Axial Growth

A key element of FREY is the ability to estimate cladding failure by ISCC. Clad failure calculations in FREY are based on a time-temperature-stress failure criterion fashioned after the cumulative damage concept. Such a concept assumes that the material undergoes cumulative damage due to sustained stress -- the higher the stress, the shorter the time to failure. This implies that an applied stress of magnitude σ_0 lasting for a fraction of time Δt will cause the fractional damage ΔD as:

$$\Delta D = \Delta t \; / \; t_f(\sigma_0) \qquad \text{(eq. 2-1)}$$

where $t_f(\sigma_0)$ is the time to failure had the stress, σ_0, been applied for the total time. Equation (2-1) depends implicitly on the temperature, hence for a given constant temperature T_0, equation (2-1) takes the form

$$\Delta D(\sigma_0, T_0) = \Delta t \; / \; t_f(\sigma_0, T_0) \qquad \text{(eq. 2-2)}$$

The relationship for the time to failure used in FREY has been developed from pressurized Zircaloy tube tests containing iodine gas. These tests provide the time to failure as a function of stress level, temperature, burnup and material type. The expression used in FREY is;

$$t_f = \bar{t}\, e^{\left[(A_1\sigma_y + A_2\sigma_{ref} - A_3\sigma\right]} \qquad \text{(eq. 2-3)}$$

where

$$\bar{t} = A_4(A_5 \cdot Bu - A_6)^{-A_7} e^{[A_8(1-611/T)]} \qquad \text{(eq. 2-4)}$$

and

σ_{ref} : $A_9(Bu - 5000)^{-A_{10}}$ for Zircaloy-2

$A_{11}(Bu - 5000)^{-A_{12}}$ for Zircaloy-4

σ_y : Yield Stress

Bu : Burnup

T : Temperature

σ : Stress

A_n : Model Coefficients

A threshold stress, σ_{ref}, and a minimum burn (>5000 MWd/tU) are used in the model and both of these values must be exceeded before SCC is initiated. As shown, the threshold stress decreases as function of burnup and reaches a minimum value near 25 ksi above 20 GWd/tU.

The damage index is calculated in FREY at each clad element to indicate the potential for cladding failure as a function of time and stress level. The damage index is given by;

$$D = \int_0^{t_n} \frac{dt}{t_f(\sigma, Bu, T)} \qquad \text{(eq. 2-5)}$$

where D is the amount of damage at t_n, and t_f is the failure time at stress σ, temperature T, and burnup Bu. Damage index values range between zero and 100 in typical PCI analyses. A value of unity represents the best-estimate measure of cladding failure, i.e., 50% probability of failure, provided the uncertainties have been account for in the analysis. In the analyses presented in this report, a 0.5 damage index value indicate a high potential for PCI failure. Recommendations for modifying the ramp rate limitations for PWR fuel will be based on this limit.

For further information on FREY's fuel rod modeling technique, input requirements, output information, code structure, and calculational procedure, a detailed description is available in the FREY Theory and User's Manuals (Ref. 5, 6).

2.3 ESCORE/FREY Linkage Methodology

The following section describes a passive linkage methodology (Ref. 7) between the ESCORE and FREY computer codes. The procedure was developed to use ESCORE as an initialization tool providing steady-state fuel rod irradiation history to FREY in order to conduct transient fuel rod analyses from a non-zero burnup condition. The philosophy behind the linkage methodology is to initialize the FREY transient analysis at some non-zero burnup using the results from an ESCORE steady-state analysis. A key requirement of this methodology is to maintain a consistent thermal, mechanical, and material fuel rod state at the linkage point in time. The primary parameters required to convey the irradiation history from the ESCORE steady-state analysis output to the FREY transient analysis input are the fuel-cladding gap status, cladding permanent strains, and burnup-dependent fuel properties. By using these parameters with FREY, consistency in the overall fuel rod condition is preserved at the linkage point, minimizing the uncertainties introduced into the transient analysis.

The linkage process is initiated by conducting an ESCORE full-length (spatial) analysis up to the time and burnup at which the detailed transient analysis is to begin. At the end of the steady-state irradiation period of interest, the power in the ESCORE analysis is brought down to a hot zero power condition. At this point, the fuel-cladding gap condition, cladding permanent strain state, and the fuel property state are transferred to FREY using the appropriate output summary tables. Once the information has been input, the FREY analysis is started by increasing the linear power to a level matching that used prior to the ramp down in ESCORE. The primary ESCORE output data required for linkage are the fuel-clad gap thickness, burnup, fast fluence, fission gas release, internal rod pressure, and cladding strain.

The following is a step by step summary of the procedure used in the linkage methodology between the results of the ESCORE cycle analysis and the FREY PCI analysis.(FREY input cards are in **bold** characters).

Step 1: Conduct ESCORE analysis with the following output summary edits activated:

(i) Gap Conductance Summary

(ii) Detailed Fission Gas Release

(iii) Rod Pressure – Whole Rod Summary

(iv) Cladding Dimension Summary

Step 2: Ramp ESCORE to hot zero power conditions.

Step 3: Obtain THERMAL GAP from ESCORE gap conductance summary.

Step 4: Divide THERMAL GAP by as-manufactured radial gap to calculate relative gap thickness. Input on **GAPFAC** set card.

Step 5: Determine COLD ROD PRESSURE and GAP FRACTIONS from rod pressure – whole rod summary. Input on **GAP** command card.

Step 6: Obtain CREEP HOOP STRAIN and AXIAL GROWTH STRAIN distributions from cladding dimension summary.

Step 7: Input strain distribution on **STRAIN** set card.

Step 8: Determine rod average fast fluence, rod average actual fuel density, and rod average porosity and input on **FUEL** command card.

Step 9: Determine rod average burnup and input on **CORE** command card.

2.4 General Modeling Approach

The general approach (Ref. 8) used this evaluation contained four main steps: (1) identify the range of threshold power levels and ramp rates; (2) identify the fuel rod designs and power histories; (3) perform the ESCORE steady state analysis for the once and twice burnup fuel; and (4) perform the FREY PCI analysis of the reactor startup following a refueling outage. By using this approach, the evaluation was performed using a variety of cladding designs (17x17 and 16x16), fuel rod burnup levels, and operating conditions. It was envisioned that the results gained from this approach would allow for more general conclusions and recommendations regarding the effect of ramp rate limitations on PWR fuel rod behavior.

The ramp rate limitations specified by the fuel vendors shown in Table 1-2 vary from plant to plant. Variations are seen in the threshold power level and the ramp rate after the threshold power, as well as, the power increase rate to the threshold power level from hot zero power. Generally, the threshold power level in Westinghouse and CE type plants is 20% of full power (FP). And it is known to be 15%FP in Framatome type plants. However, Siemens/KWU plants show a much higher level of threshold power such as 30 to 90%FP or even 100%FP. In these cases, Siemens restrict the power increase rate to these threshold power levels generally below 10%FP/hr. As for the ramp rate after the threshold power, most of the vendors recommend 3%FP/hr except the German Siemens/KWU which applies various values of ramp rate ranging from 0.5%FP/hr to 5%FP/hr.

To evaluate the effects of the threshold power level and the ramp rate on fuel integrity, an analysis matrix consisting of fourteen combinations of parameter was developed for use in the evaluation. The analysis matrix used in the evaluation is shown in Table 2-1. The analysis matrix was applied to each reactor and fuel type selected. Current practice of ramp rate restrictions was considered to be a threshold power of 20%FP and a ramp rate 3%FP/hr after the threshold power. This combination of threshold power and ramp rate is referred to as the base case condition. From the matrix of analysis cases, an optimum threshold power level and ramp rate was sought for each fuel and plant type.

Table 2-1
Analysis Matrix

Threshold Power (%FP)	Ramp Rate after Threshold Power (%FP/hr)				
	1	3	5	10	30
20		✔	✔	✔	✔
40		✔	✔	✔	
60		✔	✔	✔	
90	✔	✔	✔	✔	

In an attempt to span a variety of fuel rod designs and plant operating conditions (fuel rod power level), several different plants were chosen for analysis. In this report three types of fuel in three different plants have been analyzed: 17×17 Vantage-5H fuel in Yonggwang 2, 16×16 ABB-CE fuel in Yonggwang 4, and 17×17 Vantage-5 fuel in Diablo Canyon 2.

The fuel rod modeling approach employed in the evaluation used the ESCORE fuel performance program to analyze the one or two cycles of operation prior to the power ramp following a refueling outage. By selecting both once- and twice-burned fuel, an assessment of the impact of burnup was performed. The ESCORE analysis required information describing the fuel rod design, (pellet and clad dimensions, etc.) and the maximum fuel rod power history of each cycle of operation. A full-length axisymmetric analysis was conducted to establish the fuel rod condition at the beginning of the reactor startup power ramp. The parameters of interest were the peak power and burnup location on the fuel rod (axial height), the minimum fuel-cladding gap thickness, rod internal pressure, and fast fluence. These conditions were used to define the axial location that may experience the highest potential for PCI failure (largest cladding stresses).

Once the cycle calculation was performed, the FREY PCI analysis was initiated using the information from ESCORE. The FREY PCI analysis was conducted at the axial slice identified in ESCORE that had the highest potential for PCI failure (i.e. highest burnup and minimum fuel-cladding gap thickness). The FREY analysis was performed using an r-θ representation of the fuel and cladding. Figure 2-1 contains a schematic of the model. The small wedge of the fuel and cladding shown in Figure 2-1 is used to calculate the cladding stress and damage index response during the power change. The PCI model contains a discrete fuel crack as indicated in the figure. This fuel crack establishes stress and strain localization in the cladding once fuel-cladding gap closure occurs during a power ramp. These localized stresses are used to calculate the potential for cladding failure using the cumulative damage model. The cladding hoop stress and damage index results were calculated for each case defined in the analysis matrix. From these results, it was possible to define ramp rate conditions that precluded PCI failure.

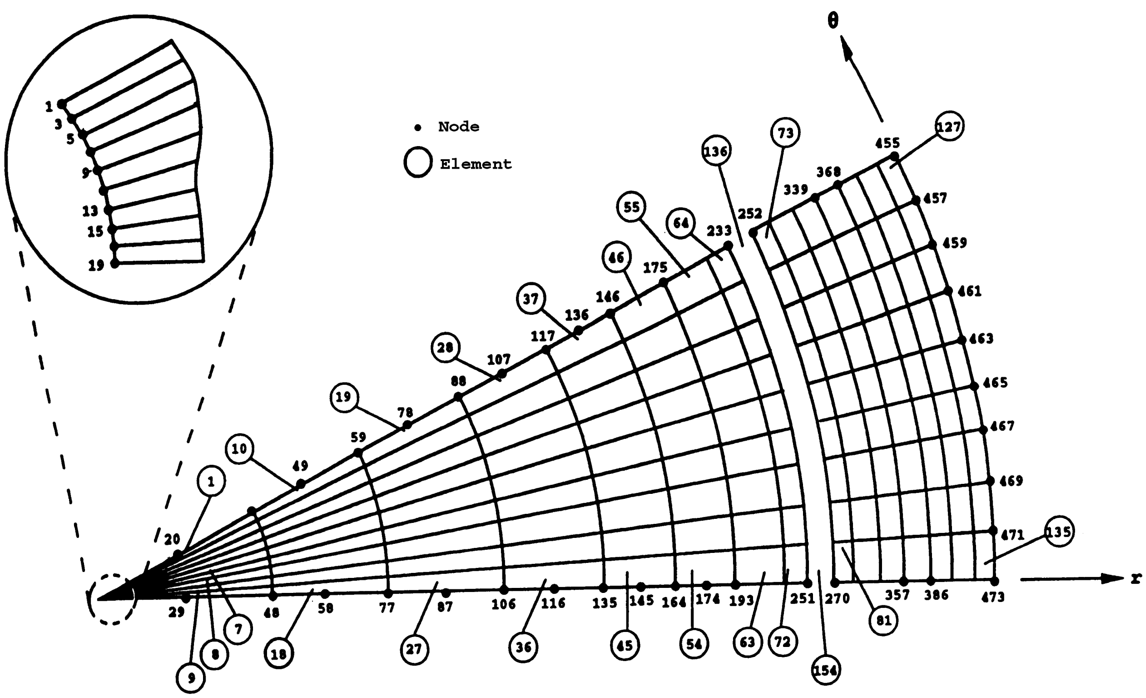

Figure 2-1
FREY Fuel Rod Library PCI Model

3

ANALYSIS CASES

This section presents an overview of the analysis cases used in the evaluation of the ramp rate limitations imposed on PWR fuel following a refueling outage. A total of three different reactor and fuel type combinations were used to evaluate the impact of ramp rate limitations on the PCI behavior of PWR fuel. The cases used in the PCI analyses were two Korean PWR plants, Yonggwang 2 (YGN-2) and Yonggwang 4 (YGN-4), and one U.S. PWR plant, Diablo Canyon 2. Each reactor case provided information describing the fuel rod design, the peak fuel rod power history and the reactor coolant conditions. The purpose of using three different plants was to span a spectrum of different fuel designs (cladding diameter and wall thickness variations) and operating conditions (peak rod power history).

The following sections present the data used to construct the ESCORE and FREY input data for each analysis case. The information was obtained from discussions with plant personnel and open literature sources.

3.1 YGN-2

YGN-2 is a Westinghouse-type 3-loop PWR with a core rated power of 2775 MWth. The reactor core is loaded with 157 Vantage-5H fuel assemblies (17x17) manufactured by Korean Nuclear Fuel Company (KNFC). YGN-2 operates using restart ramp rate restrictions similar to those imposed by Westinghouse. A ramp rate limit of 3%/hr is required above a threshold power of 20% of reactor terminal power. The power history and fuel rod data used in the analysis were obtained for Cycle 9 and Cycle 10.

3.1.1 Fuel and Coolant Data

A summary of the key parameters for the VANTAGE-5H fuel rod design irradiated in YGN-2 are shown in Table 3-1. This information was used to develop the ESCORE and FREY input data.

Table 3-1
YGN-2 Fuel Rod Parameters

Fuel Rod Parameters	
Fuel Stack Height (in.)	144
Cladding Length (in.)	151.53
Cladding Outer Diameter (in.)	0.374
Cladding Inner Diameter (in.)	0.329
Cold Rod Internal Pressure (psia)	379.5
Mole Fraction of He in Fill Gas	1.0
Fuel Pellet Outer Diameter (in.)	0.3225
Fuel Pellet Length (in.)	0.387
Fuel Enrichment (w/o U^{235})	4.2
Fuel Grain Size (μm)	22.0
Initial Fuel Density (% T.D.)	95.0
Fraction of Heat Generated in the Fuel	0.974
Coolant Parameters	
Coolant Inlet Temperature (°F)	556.5
Coolant Pressure (psia)	2250.0
Coolant Mass Velocity (Mlbm/ft^2/sec)	2.39
Subchannel Equivalent Hydraulic Diameter (in.)	0.464

3.1.2 Power History Data

An important element in the PCI analysis is the power history used to establish the fuel rod condition at the time of Cycle 11 reactor startup. The power history data for YGN-2 was obtained from in-core measurements and core follow calculations for Cycles 9 and 10. Plant personnel performed these calculations and provided the core power history and the peak assembly axial power distribution. This information was used to construct the power history of the highest power rod in the core during Cycles 9 and 10. Two separate power histories were constructed from the data provided by KEPCO. The power history for the highest power once-burned fuel rod was developed for Cycle 10. For the twice-burned fuel, a power history was developed for Cycles 9 and 10. This power history was based on the highest power twice-burned fuel assembly in Cycle 10; therefore, the assembly power during Cycle 9 was more typical of an average assembly.

The fuel rod power and the fast flux history and distribution were calculated as follows:

$$P_{rod}(t,z) = P_{core}(t) \cdot F_a(t,z) \cdot F_{ass}(t) \cdot F_r(t) \qquad \text{(eq. 3-1)}$$

where;

$P_{rod}(t,z)$: fuel rod power at time t and at axial position z (kw/ft)

$P_{core}(t)$: core average linear heat generation rate (LHGR) at time t (kw/ft)

$F_a(t,z)$: axial power shape at time t and axial position z

$F_{ass}(t)$: assembly peaking factor at time t

$F_r(t)$: fuel rod radial peaking factor at time t

and

$$\Phi_{rod}(t,z) = P_{core}(t) \cdot F_a(t,z) \cdot F_{ass}(t) \cdot F_r(t) \cdot \Phi_{mult}(t) \qquad \text{(eq. 3-2)}$$

where

$\Phi_{rod}(t,z)$: Fuel rod fast flux at time t and axial position, z ($n/cm^2 \cdot sec$)

$\Phi_{mult}(t)$: Fast-flux-to-local-linear-heat-rate-multiplier at time, t ($n/cm^2 \cdot sec$)/(kw/ft).

The reactor core power (P_{core}) and the axial power shape (F_a) were calculated by the INCORE core follow code from flux map measurements during Cycles 9 and 10. The core average linear heat generation rate for Cycles 9 and 10 in YGN-2 was 5.434 kW/ft at 100% power level. The assembly peaking factor, F_{ass}, was included in the axial power shape (F_a) data provided by KEPCO (i.e. F_{ass} = 1.0). Therefore, the axial power shape data shown in Appendix A for YGN-2 normalizes to a value greater than unity. The axial power shape data were provided at 49 axial positions for each time increment. Each axial power shape was reduced to 24 axial positions using an averaging technique for use with ESCORE. The peaking factor (F_r) for highest power fuel rod in the assembly was calculated using the ratio of the peak rod burnup and the assembly burnup. The fuel rod peaking factors for the once-burned and twice-burned fuel were 1.17 and 1.11, respectively. The fuel rod average power and the core average power calculated using this method are shown in Figure 3-1 for the once-burned fuel and Figure 3-2 for the twice-burned fuel. The axial power distribution data is presented in Appendix A.

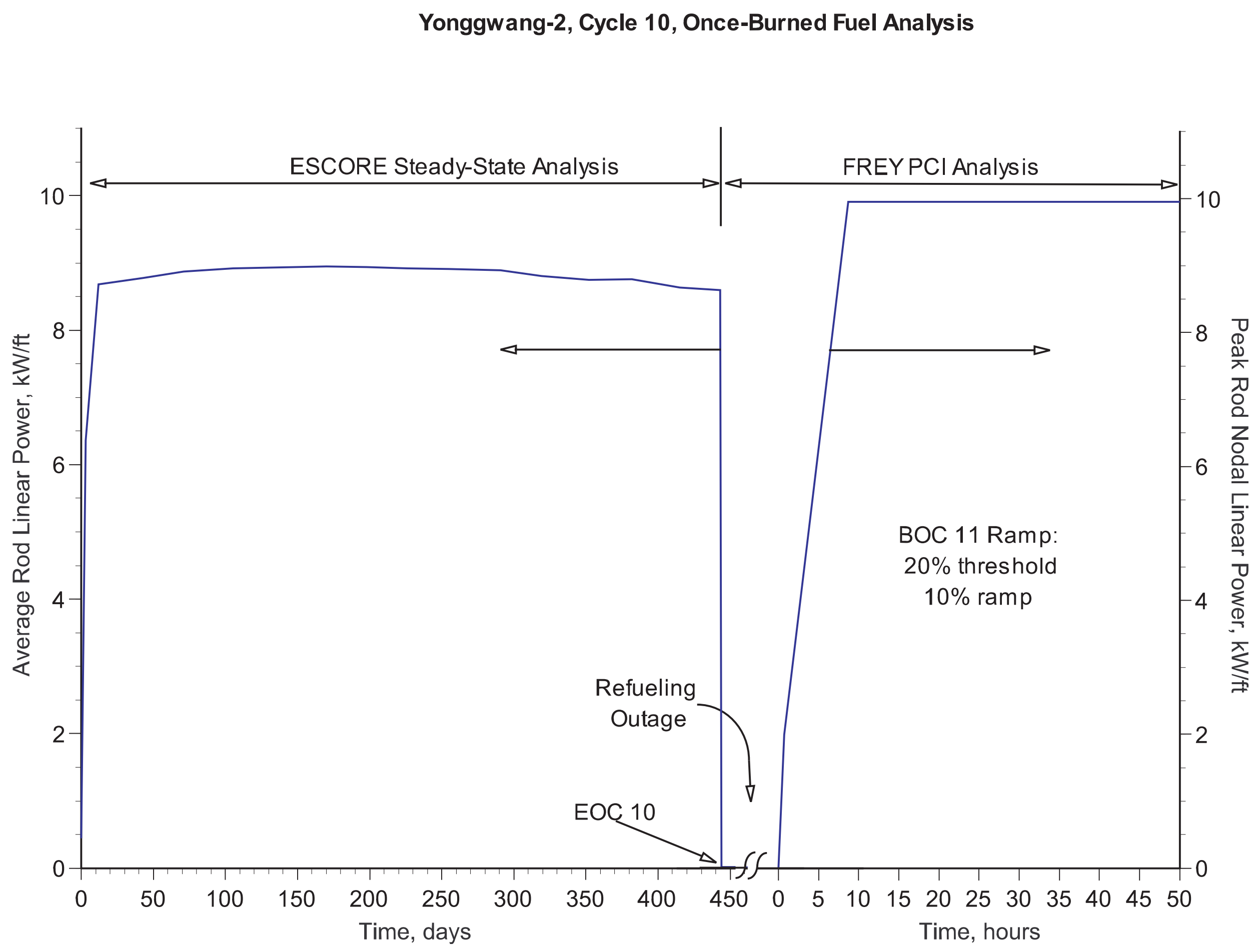

Figure 3-1
Power History for Once-Burned Fuel in Yonggwang-2 Cycle 10

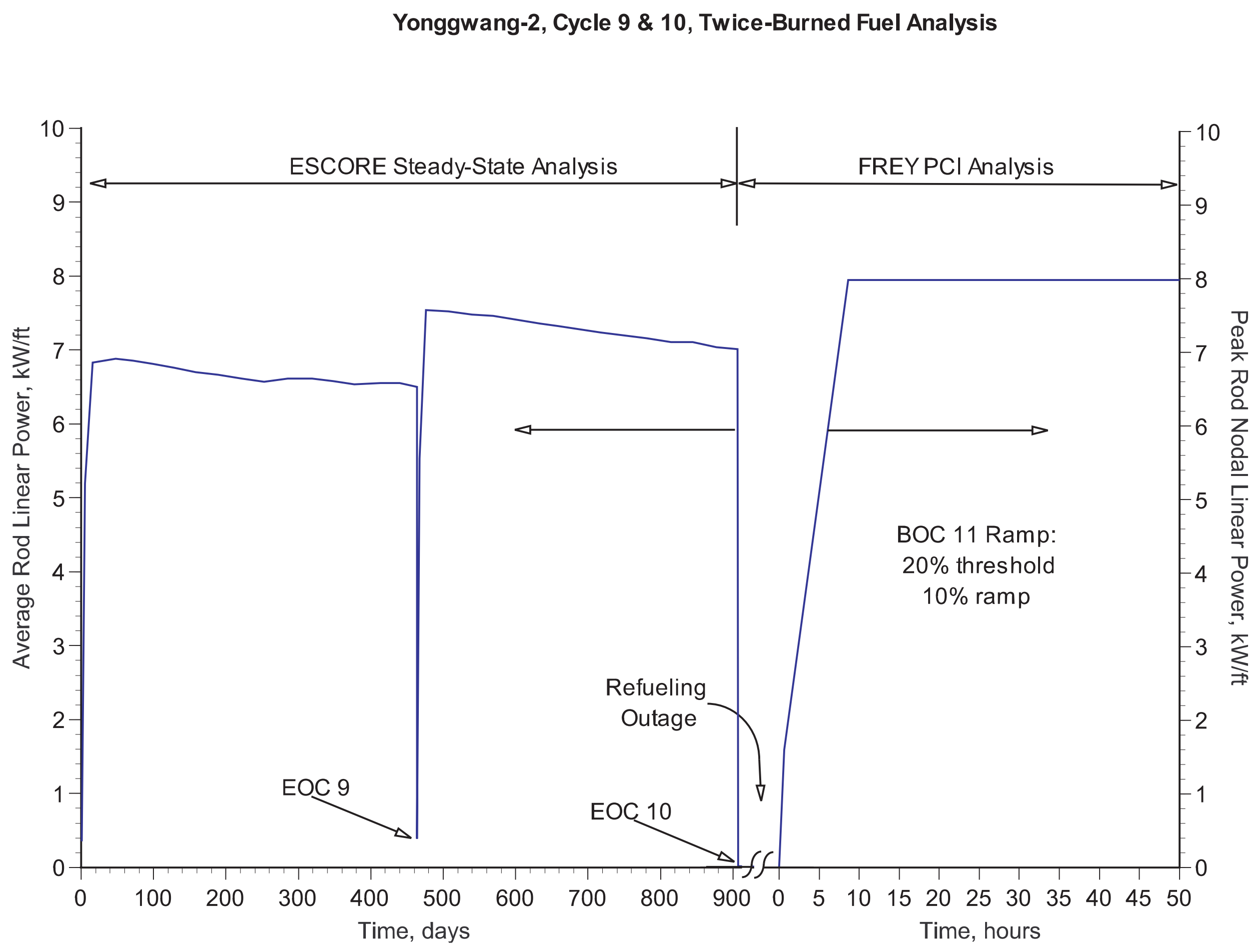

Figure 3-2
Power History for Once-Burned Fuel in Yonggwang-2 Cycle 9 and 10

The core average thermal and fast flux values, calculated by the Westinghouse ANC core depletion code, were used to obtain the fast flux multiplier used in the ESCORE analysis (Φ_{mult}). However, the fast flux calculated by ANC contains a broader energy spectrum than that required by ESCORE. The models in ESCORE are based on a fast flux that contains energy levels above 1 MeV. The thermal flux level provided by ANC was combined with a typical value of the fast-to-thermal flux ratio of 2.9 to estimate the fast flux with energies higher than 1 MeV. These fast flux values were used along with the core average power to calculate Φ_{mult} as a function of irradiation for both Cycles 9 and 10. Values near 2.1×10^{13} n/cm^2-sec per kW/ft were used in ESCORE for the YGN-2 analysis of the once-burned and twice-burned fuel. These values are higher than typical values reported for Westinghouse plants (1.4-1.8×10^{13} n/cm^2-sec per kW/ft). As a consequence, the fast fluence accumulation may be overestimated for the YGN-2 calculations.

The peak nodal power history used in the PCI analysis for YGN-2 Cycle 11 startup is also shown in Figure 3-1 and 3-2 for the once-burned and twice-burned assemblies, respectively. Each figure depicts the peak nodal power history at the vendor prescribed ramp rate restriction, i.e. 30%/hr below a threshold power of 20% and 3%/hr to full power above the threshold. This power history was used in the FREY analysis, along with the fuel rod condition at the EOC 10 calculated by ESCORE, to evaluate the PCI failure potential during the Cycle 11 startup.

3.2 YGN-4

YGN-4 is an ABB-CE-type PWR with a core rated power of 2,815 MWth. The core is loaded with 177 ABB-CE fuel assemblies (16x16) manufactured by KNFC. YGN-4 operates using Fuel Preconditioning Guidelines (FPG's) during power escalation defined by ABB-CE to insure fuel rod integrity. During a reactor restart subsequent to a refueling outage, the FPG's specified by ABB-CE state that above a threshold core power of 50%, the maximum change in core power is 3%/hr. It is further recommended by ABB-CE that a threshold power of 20% be used to ensure fuel rod integrity. For core operation below 50% full power, a 5%/hr maximum power change is specified in the operation procedure. The power history and fuel rod data used in the analysis for YGN-4 were obtained for Cycle 1 and Cycle 2.

3.2.1 Fuel and Coolant Data

A summary of the key parameters for the CE 16x16 fuel rod design irradiated in YGN-4 are shown in Table 3-2. This information was used to develop the ESCORE and FREY input data.

Table 3-2
YGN-4 Fuel Rod Parameters

Fuel Rod Parameters	
Fuel Stack Height (in.)	150
Cladding Length (in.)	161.17
Cladding Outer Diameter (in.)	0.382
Cladding Inner Diameter (in.)	0.332
Cold Rod Internal Pressure (psia)	379.5
Mole Fraction of He in Fill Gas	1.0
Fuel Pellet Outer Diameter (in.)	0.325
Fuel Pellet Length (in.)	0.390
Fuel Enrichment (once-burned / twice-burned, w/o U^{235})	4.1 / 3.36
Fuel Grain Size (µm)	22.0
Initial Fuel Density (% T.D.)	95.25
Fraction of Heat Generated in the Fuel	0.965
Coolant Parameters	
Coolant Inlet Temperature (°F)	564.8
Coolant Pressure (psia)	2245.0
Coolant Mass Velocity (Mlbm/ft^2/sec)	2.65
Subchannel Equivalent Hydraulic Diameter (in.)	0.471

3.2.2 Power History Data

The power history used in the YGN-4 analysis to establish the fuel rod condition at the time of the Cycle 3 startup was obtained from plant personnel at KEPCO. The power history data for YGN-4 was determined using in-core flux measurements and core follow calculations for Cycles 1 and 2. This information was used to construct the power history for the highest power fuel rod in the core during Cycles 1 and 2. As with YGN-2, two separate power histories were constructed from the data provided by KEPCO. The power history for the highest power once-burned fuel rod was constructed for Cycle 2. The twice-burned fuel rod power history was constructed for Cycles 1 and 2. This power history was based on the highest power twice-burned assembly in Cycle 2.

The approach described above for YGN-2 was used to calculate the power history for YGN-4 Cycles 1 and 2. The time histories of the core average LHGR (P_{core}) and the axial power distribution (F_a) were obtained during flux map measurements and were calculated by the CECOR core follow code for Cycles 1 and 2. The core average LHGR for Cycles 1 and 2 in YGN-4 was 5.2608 kW/ft at 100% power. The assembly peaking factor (F_{ass}) for the high power assembly varied between 1.31 and 1.40 for the once-burned fuel, and varied between 1.13 and 1.32 during Cycle 1 and between 1.03 and 1.06 during Cycle 2 for the twice-burnup fuel. The fuel rod peaking factor (F_r) for the high power rod in the assembly was calculated using the ratio of the peak rod burnup and the assembly burnup. The fuel rod peaking factor was 1.15 for both once-burned and twice-burned fuel. The fuel rod average power and the core average power calculated using the information defined above and eq. 3-1 are shown in Figure 3-3 for the once-burned fuel and Figure 3-4 for the twice-burned fuel. The axial power distribution is presented in Appendix A.

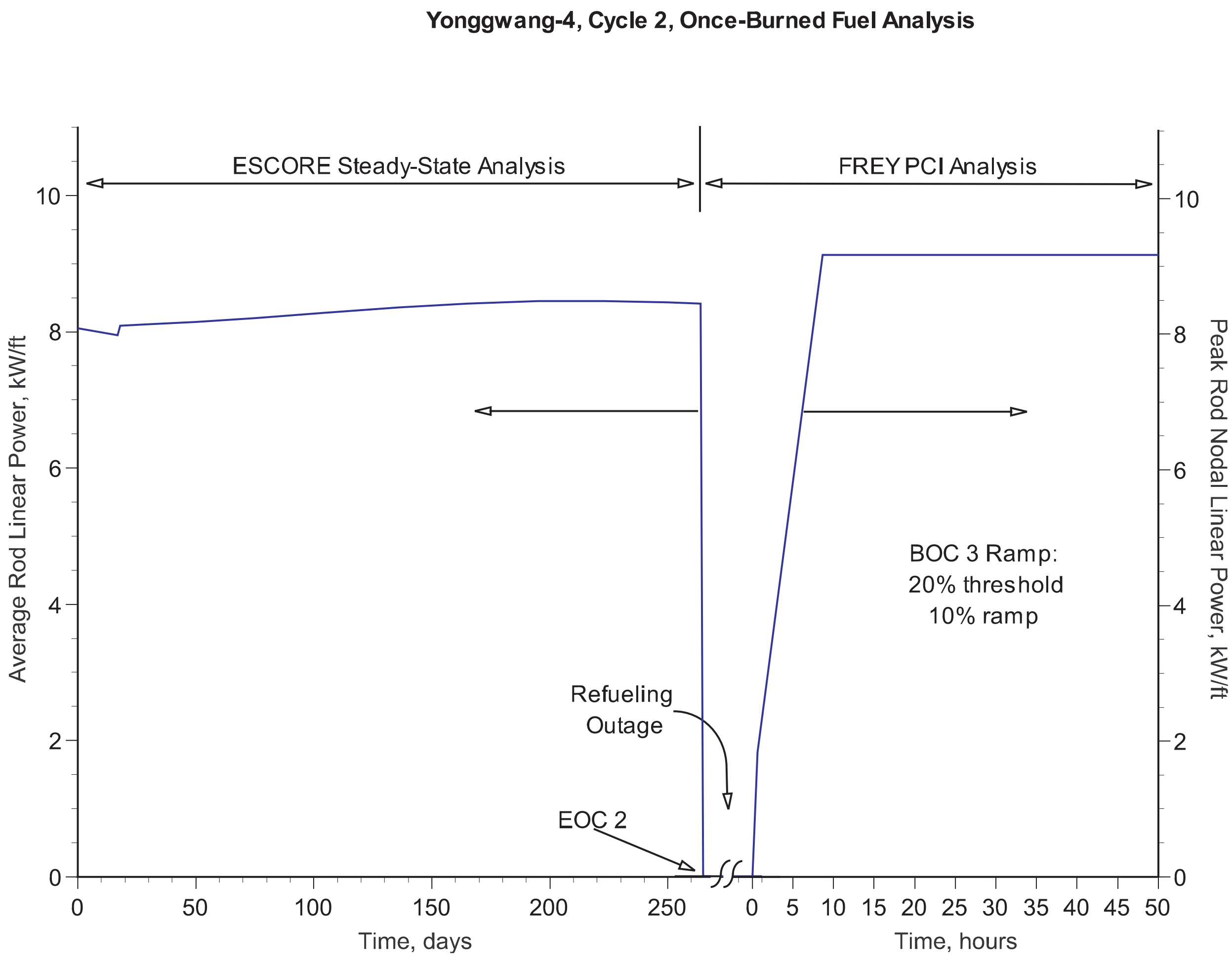

Figure 3-3
Power History for Once-Burned Fuel in Yonggwang-4 Cycle 2

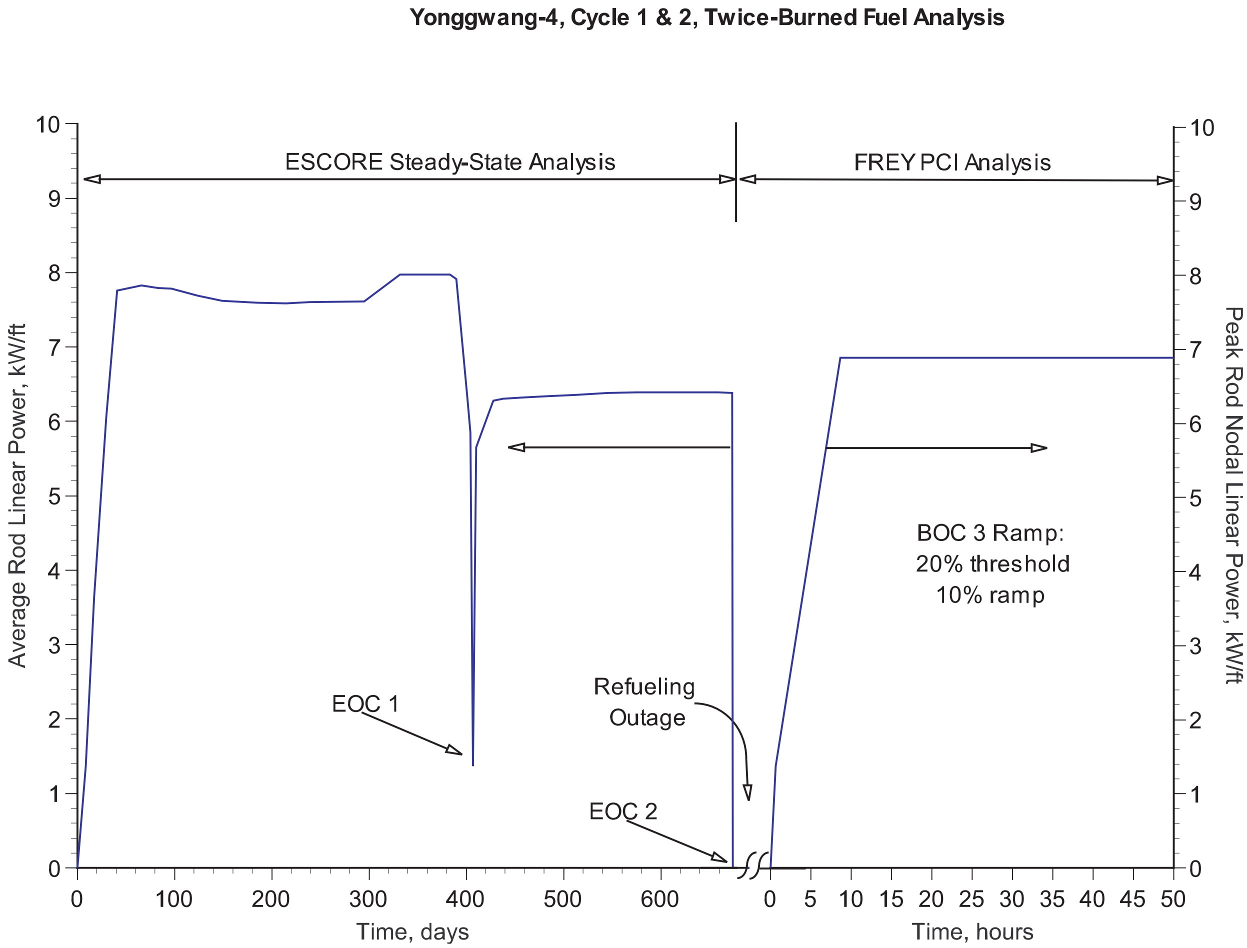

Figure 3-4
Power History for Twice-Burned Fuel in Yonggwang-4 Cycle 1 and 2

The core average thermal and fast flux values calculated by the ABB-CE ROCS core depletion code were used to obtain the fast flux multiplier used in the ESCORE analysis (Φ_{mult}). However, the fast flux calculated by ROCS contains a broader energy spectrum than that required by ESCORE. The material models in ESCORE are based on a fast flux that contains energy levels above 1 MeV. The thermal flux level provided by ROCS was combined with a typical value of the fast-to-thermal flux ratio of 2.9 to estimate the fast flux with energies higher than 1 MeV. These fast flux values were used along with the core average power to calculate Φ_{mult} as a function of irradiation for both Cycles 1 and 2. Using this method, values for Φ_{mult} near 1×10^{14} n/cm^2-sec per kW/ft were used in ESCORE for the YGN-4 analysis of the once-burned and twice-burned fuel. As with YGN-2, these values are also higher than those typically reported for ABB-CE plants. As a consequence, the fast fluence accumulation may be overestimated for the YGN-4 calculations.

The peak nodal power history used in the PCI analysis for the Cycle 3 startup following a refueling outage is also shown in Figure 3-3 and 3-4 for the once-burned and twice-burned assemblies, respectively. Shown in each figure is the peak nodal power history at ramp rate conditions of 30%/hr below a threshold power of 20% and 3%/hr to full power above the threshold. These conditions actually represent the Westinghouse startup requirements and deviate from the ABB-CE FPG's defined for YGN-4. However, calculations under these conditions serve as a baseline for comparison to the YGN-2 and Diablo Canyon 2 results. As with the YGN-2 case, this power history was used in the FREY analysis, along with the fuel rod condition at the EOC 2 calculated by ESCORE, to evaluate the PCI failure potential during the Cycle 3 startup.

3.3 Diablo Canyon 2

Diablo Canyon 2 is a Westinghouse 4-loop PWR with a rated core power of 3,411 MWth. The reactor core consists of 193 Vantage-5 fuel assemblies (17x17) manufactured by Westinghouse. Diablo Canyon 2 operates using restart ramp rate restrictions that have been developed and recommended by Westinghouse. Following a refueling outage, the rate of reactor power increase is limited to 3%/hr above a threshold power of 20% of full reactor power. The power history and fuel rod data used in the analysis of Diablo Canyon Unit 2 were obtained for Cycle 8. The Diablo Canyon 2 analysis only considered once-burned fuel because of limited power history data.

3.3.1 Fuel and Coolant Data

A summary of the key parameters for the VANTAGE-5 fuel rod design irradiated in Diablo Canyon 2, Cycle 8 are shown in Table 3-3. This information was used to develop the ESCORE and FREY input data.

Table 3-3
Diablo Canyon 2 Fuel Rod Parameters

Fuel Rod Parameters	
Fuel Stack Height (in.)	144
Cladding Length (in.)	151.6
Cladding Outer Diameter (in.)	0.360
Cladding Inner Diameter (in.)	0.315
Cold Rod Internal Pressure (psia)	350.0
Mole Fraction of He in Fill Gas	1.0
Fuel Pellet Outer Diameter (in.)	0.3088
Fuel Pellet Length (in.)	0.370
Fuel Enrichment (w/o U^{235})	3.6
Fuel Grain Size (μm)	22.0
Initial Fuel Density (% T.D.)	95.67
Fraction of Heat Generated in the Fuel	0.974
Coolant Parameters	
Coolant Inlet Temperature (°F)	540.7
Coolant Pressure (psia)	2250.0
Coolant Mass Velocity (Mlbm/ft^2/sec)	2.26
Subchannel Equivalent Hydraulic Diameter (in.)	0.510

3.3.2 Power History Data

The time history of the core axial and radial power distributions for Cycle 8 were obtained from ANC code calculations which had been performed by Pacific Gas and Electric (PG&E) personnel and transferred to EPRI. This information was used to establish the conditions of the peak fuel rod at the start of Cycle 9 following the refueling outage. The power history information was provided as a function of the core average burnup. The axial distribution (F_a) and assembly peaking (F_{ass}) factors defined in eq. 3-1 were obtained from the ANC results. Using a core average LHGR of 5.44 kW/ft for Diablo Canyon 2, Cycle 8, the peak assembly power history was calculated. An estimated fuel rod peaking factor (F_{rod}) of 1.1 was used in the power history calculation based on discussions with PG&E personnel. A plot of the peak rod average power and the core average power history for Cycle 8 is shown in Figure 3-5. The data used to construct the power history and axial power shape is provided in Appendix A.

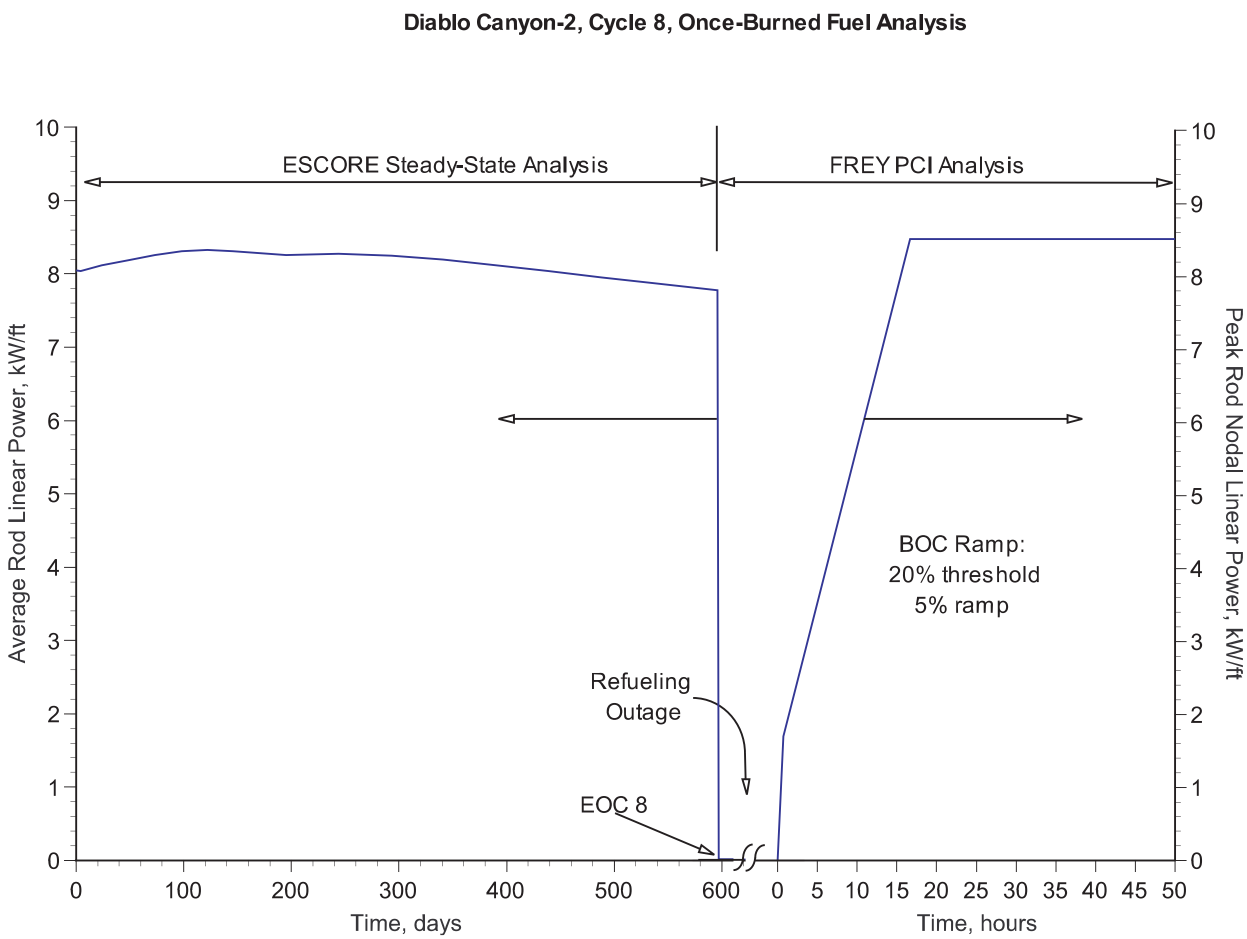

Figure 3-5
Power History for Once-Burned Fuel in Diablo Canyon Unit 2 Cycle 8

The fast flux multiplier (Φ_{mult}) was estimated from information on the North Anna plant reported in EPRI TR-100408. A value of 1.6×10^{13} n/cm^2-sec per kW/ft was used in the power history calculation for Diablo Canyon 2 to estimate the fast fluence accumulation during Cycle 8.

The peak nodal power history used in the PCI analysis for the Cycle 9 startup following a refueling outage is also shown in Figure 3-5. Shown in the figure is the peak nodal power history at the Westinghouse prescribed fuel rod ramp rate restriction, i.e. 30%/hr below a threshold power of 20% and 3%/hr to full power above the threshold. This power history was used in the FREY analysis, along with the fuel rod condition at the EOC 8 calculated by ESCORE, to evaluate the PCI failure potential during the Cycle 9 startup.

4

RESULTS AND DISCUSSIONS

This section summarizes the key results of both the steady-state and PCI analyses used to assess the effect of restart ramp rate limitations on PCI-induced fuel failures. For the evaluations in this study, FREY restart ramp rate analyses were initialized using applicable fuel and coolant data from ESCORE steady-state analyses. Both once- and twice-burned fuel, representing three different reactor, fuel type, and power history combinations were used. Following the overview of the results, a discussion of PCI-induced fuel failure via ISCC is presented. Also discussed is the impact of threshold power and ramp rate on the cladding damage index, the parameter used in FREY as the predictive indicator for fuel failure, and recommendations for threshold power and ramp rate limitations.

4.1 Steady-State Cycle Analysis Results

ESCORE is a best-estimate steady-state computer code that predicts the mechanical and thermal response of LWR fuel rods. Response data are provided as a function of axial nodal position as well as for the entire rod. The axial node data include burnup, LHGR, effective fast fluence, cladding hoop stress, creep hoop strain, fuel centerline temperature, gap conductance, oxide thickness, and coolant temperature. Whole rod data include core average burnup, peak rod average burnup, peak rod average LHGR, fission gas release, hot rod internal pressure, cold rod pressure, helium mole fraction, and internal gaseous fission product inventories. As mentioned above, ESCORE was used to perform steady-state cycle analyses for either one or two cycles of operation. The calculated fuel rod state information was then used as the starting point for the FREY PCI analyses. The steady-state analyses were initiated with a time step corresponding to the first in-core burnup measurement of the cycle of interest for each reactor/fuel combination and run to the end of that cycle. The following sections discuss in detail the three steady-state cycle analyses conducted using ESCORE.

4.1.1 YGN-2

Once- and twice-burned fuel cases were analyzed for the YGN-2 Vantage-5H fuel. The once-burned fuel chosen was the peak burnup, single cycle fuel assembly at the end of Cycle 10. This assembly had a relative assembly power level between 1.33 and 1.41 during the cycle. The twice-burned fuel assembly chosen was the assembly that achieved the highest peak burnup at the end of Cycle 10. This assembly had a relative assembly power level between 1.16 and 1.24 during Cycle 10. The twice-burned fuel assembly had been located in the lower power core region during Cycle 9 with a relative assembly power level between 1.08 and 1.16. The key results for YGN-2 are summarized in Table 4-1.

Table 4-1
YGN-2 Steady-State Analysis Results

Key Parameters	Once-Burned Fuel	Twice-Burned Fuel	FREY Input
Core Average Burnup (MWd/MtU)	16,490	33,797	
Rod Average Burnup (MWd/MtU)	26,792	43,258	
Rod Average LHGR (kW/ft)	8.597	7.017	
Fission Gas Release (%)	2.329	0.304	
Hot Rod Internal Pressure (psi)	1182.4	1109.4	•
Cold Rod Pressure (psi)	432.809	431.954	•
Mole Fraction of He/Kr/Xe	0.933/0.008/0.059	0.985/0.002/0.013	•
Node Burnup (MWd/MtU)	31,990	51,620	•
Node LHGR (kW/ft)	9.95	7.98	•
Node Effective Fast Fluence (n/m^2)	8.651E21	1.408E22	•
Max. Cladding Hoop Stress (psi)	7753.7	6608.2	
Creep Hoop Strain ($\Delta R/R$)	See Figure 4-1	See Figure 4-1	
Max. Fuel Centerline Temperature (°F)	2378.3	1867.97	
Max. Gap Conductance (Btu/hr/ft^2/F)	7759.3	8858.5	
Max. Oxide Thickness (mil)	0.95	3.46	
Bulk Coolant Temperature (°F)	588.19	582.40	•

4.1.2 YGN-4

As with YGN-2, both once- and twice-burned fuel assemblies were analyzed for the YGN-4 CE fuel case. The once-burned fuel assembly chosen was the peak burnup, single cycle fuel assembly at the end of Cycle 2. This assembly had a relative assembly power level between 1.31 and 1.40 during the cycle. The twice-burned fuel assembly chosen was the assembly that achieved the highest peak burnup at the end of Cycle 2. This assembly had a relative assembly power level between 1.03 and 1.06 during Cycle 2. The twice-burned fuel assembly had been located in a higher power core region during Cycle 1 with a relative assembly power level between 1.13 and 1.32. The key results for YGN-4 are summarized in Table 4-2.

Table 4-2
YGN-4 Steady-State Analysis Results

Key Parameters	Once-Burned Fuel	Twice-Burned Fuel	FREY Input
Core Average Burnup (MWd/MtU)	9,530	23,673	
Rod Average Burnup (MWd/MtU)	15,066	32,315	
Rod Average LHGR (kW/ft)	8.414	6.382	
Fission Gas Release (%)	0.213	0.207	
Hot Rod Internal Pressure (psi)	1082.0	1022.3	•
Cold Rod Pressure (psi)	393.903	408.127	•
Mole Fraction of He/Kr/Xe	0.997/0.0/0.002	0.995/0.001/0.005	•
Node Burnup (MWd/MtU)	16,420	35,350	•
Node LHGR (kW/ft)	9.17	6.89	•
Node Effective Fast Fluence (n/m^2)	5.847E21	1.429E22	•
Max. Cladding Hoop Stress (psi)	1409.5	5152.7	
Creep Hoop Strain (ΔR/R)	See Figure 4-2	See Figure 4-2	
Max. Fuel Centerline Temperature (°F)	1999.4	1668.0	
Max. Gap Conductance (Btu/hr/ft^2/F)	8751.9	8906.6	
Max. Oxide Thickness (mil)	0.32	1.73	
Bulk Coolant Temperature (°F)	587.24	584.59	•

4.1.3 Diablo Canyon 2

Because it was determined that the fuel rod failure response was bounded by the once-burned fuel case, only a once-burned assembly was analyzed for Diablo Canyon 2. The once-burned assembly chosen was the peak burnup, single cycle fuel assembly at the end of Cycle 8. This assembly had a relative assembly power level between 1.30 and 1.39 during the cycle. The key results for Diablo Canyon 2 are summarized in Table 4-3.

Table 4-3
Diablo Canyon 2 Steady-State Analysis Results

Key Parameters	Once-Burned Fuel	FREY Input
Core Average Burnup (MWd/MtU)	24,542	
Rod Average Burnup (MWd/MtU)	36,478	
Rod Average LHGR (kW/ft)	7.773	
Fission Gas Release (%)	0.291	
Hot Rod Internal Pressure (psi)	1131.0	•
Cold Rod Pressure (psi)	407.433	•
Mole Fraction of He/Kr/Xe	0.988/0.001/0.010	•
Node Burnup (MWd/MtU)	40,280	•
Node LHGR (kW/ft)	8.51	•
Node Effective Fast Fluence (n/m^2)	7.388E21	•
Max. Cladding Hoop Stress (psi)	8138.1	
Creep Hoop Strain (ΔR/R)	See Figure 4-1	
Max. Fuel Centerline Temperature (°F)	2000.6	
Max. Gap Conductance ($Btu/hr/ft^2/F$)	8825.7	
Max. Oxide Thickness (mil)	1.46	
Bulk Coolant Temperature (°F)	562.06	•

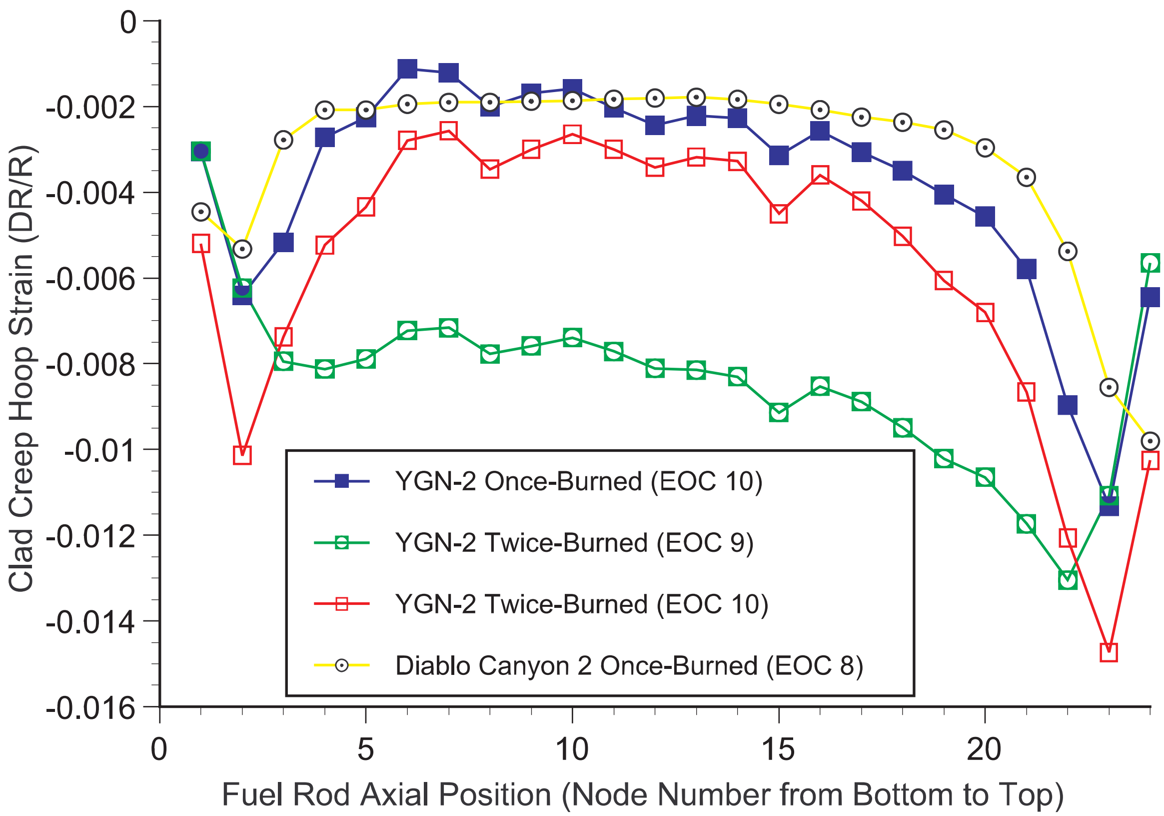

Figure 4-1
Clad Creep Hoop Strain in YGN-2 and Diablo Canyon 2

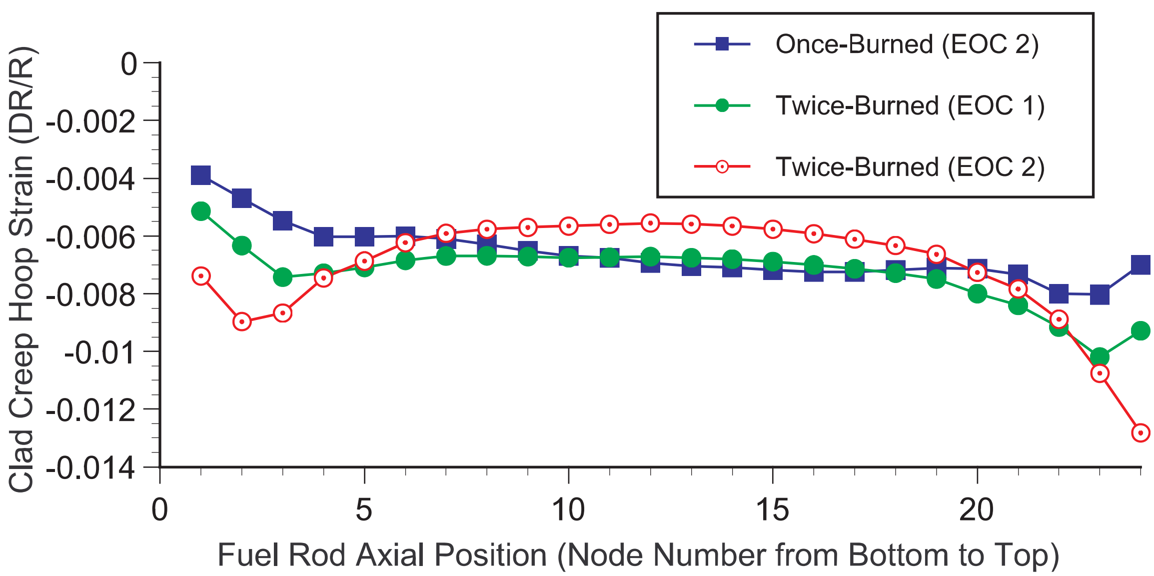

Figure 4-2
Clad Creep Hoop Strain in YGN-4

4.2 PCI Analysis Results

PCI analyses were performed using FREY based on each of the ESCORE steady-state analysis cases described above. The objective of the PCI analyses was to assess the cladding stress state and ISCC failure potential (damage index) under various power ramp conditions at the peak power node location. The PCI runs were constructed to represent the reactor restart power ramp. The rate of power increase at reactor restart up to the threshold power from hot zero power (HZP) was fixed at 30%/hr or 0.5%/min. The geometric model used was the FREY PCI r-θ library model shown in Figure 2-1. This model is designed to simulate the detailed pellet-cladding mechanical interaction at the peak power location.

After the initial set of PCI analyses was completed, a second set was performed using a reduced gap width (one-half the gap width computed by ESCORE). Because the pellet-cladding gap is a primary factor affecting the PCI behavior of a fuel rod, the one-half gap width analyses represented a more conservative treatment of the gap condition. This phase of the study was performed to accommodate the uncertainties inherent in fuel performance modeling and to provide assurance that the results obtained bound those expected to occur under actual operation. Sources of fuel performance modeling uncertainties include the utilization of abbreviated and/or compressed power histories, estimation of the fast flux fraction, variance and uncertainty in the fuel and coolant data such as manufacturing variables, and the inherent simplification employed in the computational models and solution techniques. The following sections discuss in detail the PCI analysis cases performed using FREY.

4.2.1 YGN-2

The PCI analysis of the YGN-2 17x17 Vantage-5H fuel utilized a matrix of fourteen combinations of threshold power and ramp rate for both once- and twice-burned fuel with the ESCORE-predicted and one-half gap conditions. The results for the maximum cladding hoop stress and the maximum cladding damage index as functions of threshold power and ramp rate are presented in Tables 4-4 through 4-7.

This data is also illustrated in Figures 4-3 through 4-6 and 4-8. The values are plotted for the base case (20% threshold power and 3%/hr ramp rate) and the most severe ramp rate case (20% threshold power and 30%/hr ramp rate) over 100 hours from the restart to a stabilized hot full power (HFP) condition. All other combinations of threshold power and ramp rate values are bounded by these two cases.

Table 4-4
Max. Clad Hoop Stress (normal gap condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		33.268/ 26.923	34.991/ 28.022	36.998/ 29.367	39.278/ 30.958
40		32.655/ 26.188	34.547/ 27.532	36.786/ 29.183	
60		31.817/ 25.464	33.995/ 27.102	36.576/ 29.033	
90	26.729/ 2.362	32.557/ 26.559	34.818/ 28.171	37.194/ 29.749	

Table 4-5
Max. Clad Damage Index (Normal Gap Condition)

(Once-Burned Fuel / Twice-Burned Fuel)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		5.78E-02/ 0.0	5.76E-02/ 1.40E-03	6.68E-02/ 2.80E-03	6.85E-02/ 3.70E-03
40		5.16E-02/ 0.0	5.31E-02/ 0.0	6.43E-02/ 2.70E-03	
60		3.41E-02/ 0.0	4.80E-02/ 0.0	5.51E-02/ 2.10E-03	
90	0.0/ 0.0	4.31E-02/ 0.0	5.59E-02/ 1.70E-03	5.94E-02/ 3.90E-03	

Table 4-6
Max. Clad Hoop Stress (Half-Gap Condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		41.900/ 35.066	46.311/ 38.409	52.614/ 43.079	62.367/ 49.830
40		41.626/ 34.759	46.092/ 38.189	52.498/ 42.983	
60		41.373/ 34.553	45.935/ 38.106	52.483/ 43.042	
90	54.497/ 43.444	54.497/ 43.444	54.497/ 43.444	55.403/ 45.611	

Table 4-7
Max. Clad Damage Index (Half Gap Condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		0.4832/ 5.68E-02	0.6534/ 7.04E-02	1.0362/ 0.1007	2.1940/ 0.1545
40		0.4582/ 5.24E-02	0.6281/ 6.75E-02	1.0150/ 9.89E-02	
60		0.4272/ 5.22E-02	0.6172/ 6.79E-02	1.0147/ 0.1001	
90	0.5728/ 6.82E-02	0.9508/ 9.61E-02	1.1814/ 0.1140	1.5842/ 0.1333	

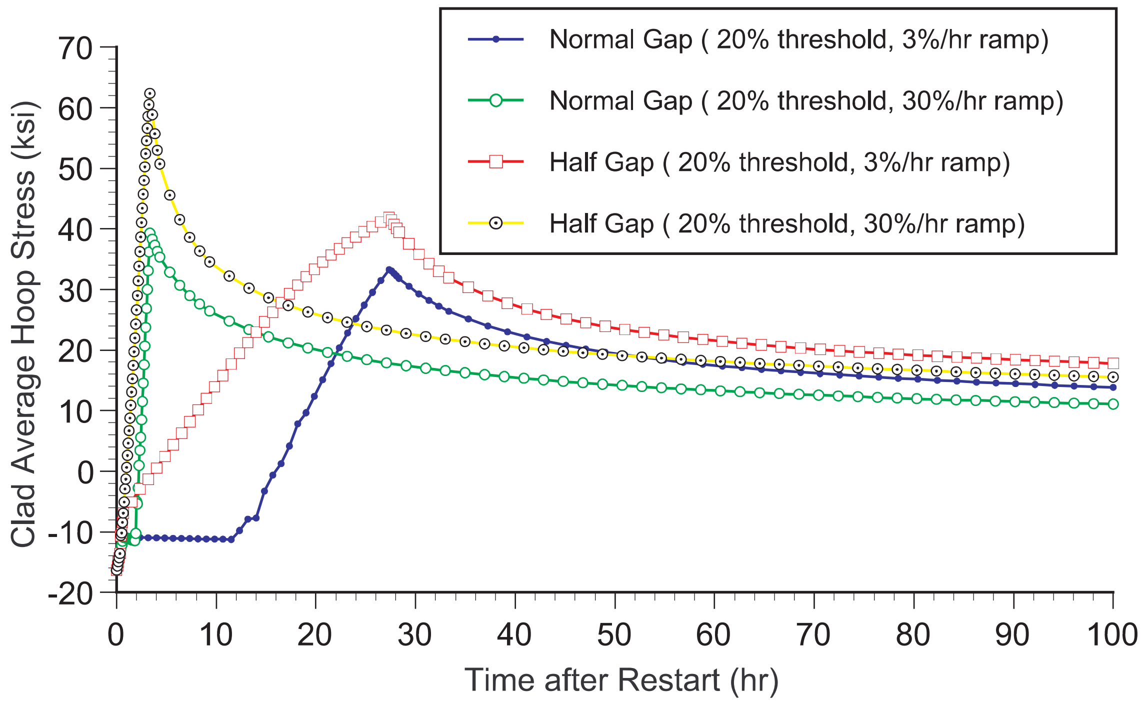

Figure 4-3
Clad Average Hoop Stress in YGN-2 (Once-Burned Fuel)

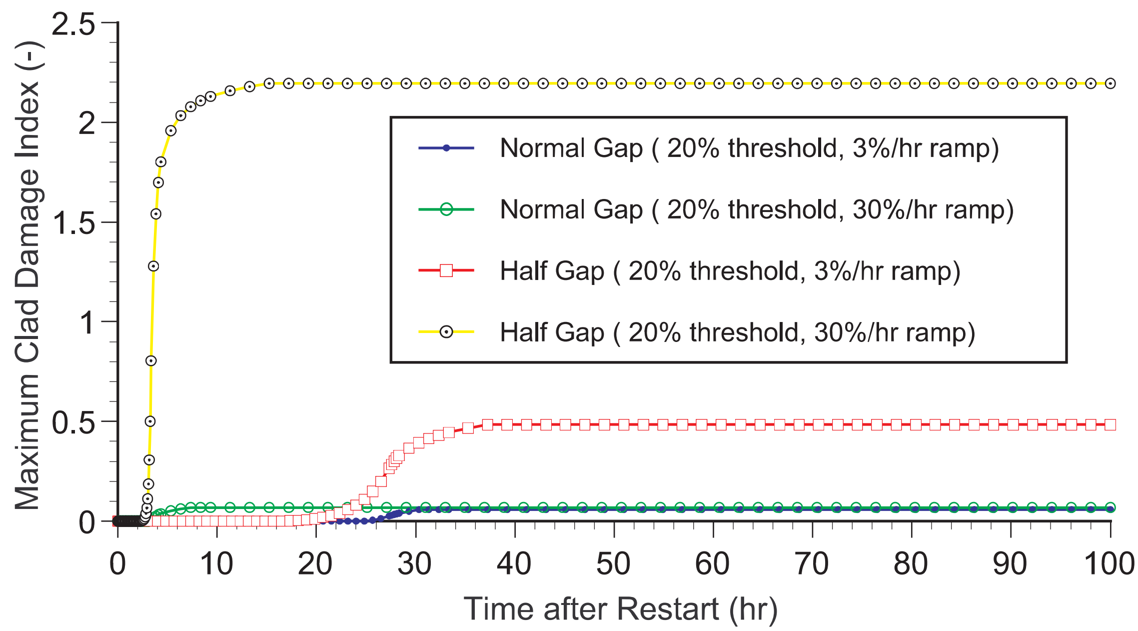

Figure 4-4
Maximum Clad Damage Index in YGN-2 (Once-Burned Fuel)

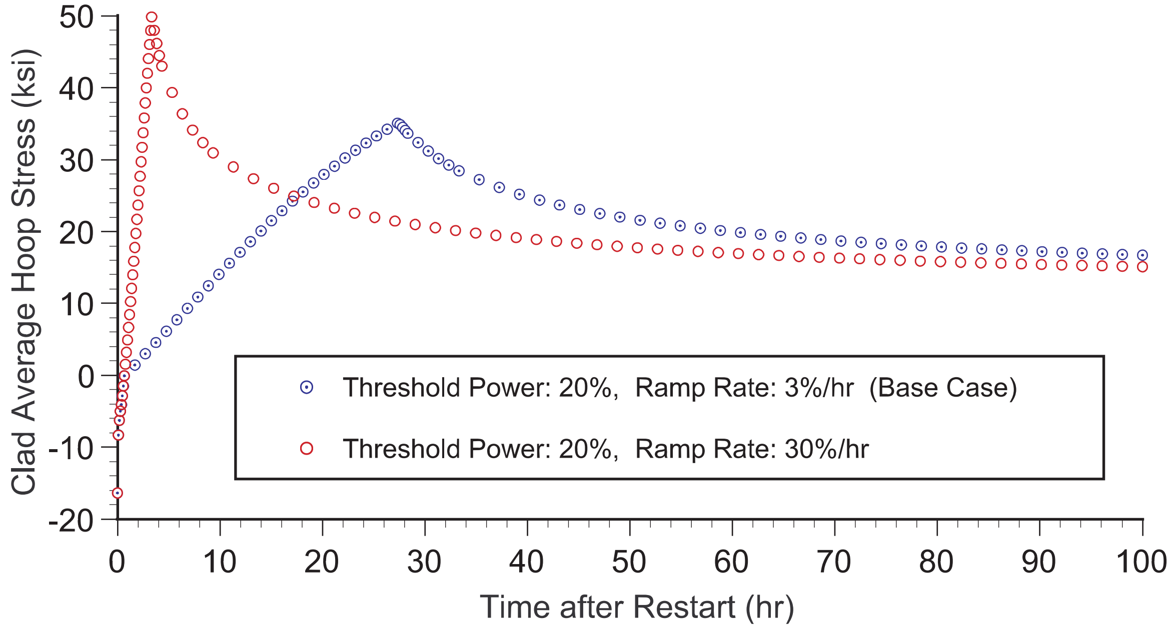

Figure 4-5
Clad Average Hoop Stress in YGN-2 (Twice-Burned Fuel, Half Gap)

4.2.2 YGN-4

As with YGN-2, the analysis of the YGN-4 16x16 CE fuel used a matrix of fourteen combinations of threshold power and ramp rate for both once- and twice-burned fuel with the ESCORE-predicted and one-half gap conditions. The results for the maximum cladding hoop stress and the maximum cladding damage index as functions of threshold power and ramp rate are presented in Tables 4-8 through 4-11.

This data is also shown in Figures 4-6 and 4-9. As in the previously cited figures, the values are plotted for the base case (20% threshold power and 3%/hr ramp rate) and the most severe ramp rate case (20% threshold power and 30%/hr ramp rate) over 100 hours from the restart to a HFP condition. All other combinations of threshold power and ramp rate values are bounded by these two cases.

Table 4-8
Max. Clad Hoop Stress (normal gap condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		24.033/ 23.880	24.382/ 24.891	24.875/ 26.117	25.422/ 27.583
40		23.417/ 23.132	23.999/ 24.388	24.677/ 25.927	
60		22.465/ 22.612	23.400/ 24.107	24.459/ 25.852	
90	19.404/ 20.245	22.490/ 23.894	23.598/ 25.252	24.651/ 26.543	

Table 4-9
Maximum Clad Damage Index (Normal Gap Condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		0.0/ 0.0	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0
40		0.0/ 0.0	0.0/ 0.0	0.0/ 0.0	
60		0.0/ 0.0	0.0/ 0.0	0.0/ 0.0	
90	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0	

Table 4-10
Maximum Clad Hoop Stress (Half-Gap Condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		36.793/ 31.177	40.260/ 34.004	45.260/ 37.878	51.861/ 43.340
40		36.424/ 30.882	39.987/ 33.805	44.899/ 37.815	
60		36.130/ 30.743	39.842/ 33.816	44.905/ 37.936	
90	44.403/ 37.989	44.403/ 37.989	44.403/ 37.989	47.264/ 40.214	

Table 4-11
Maximum Clad Damage Index (Half Gap Condition)

Once-Burned Fuel /Twice-Burned Fuel (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		8.38E-02/ 8.90E-03	0.1112/ 1.49E-02	0.1515/ 2.11E-02	0.2351/ 3.06E-02
40		7.43E-02/ 8.30E-03	0.1061/ 1.43E-02	0.1482/ 2.07E-02	
60		7.03E-02/ 8.20E-03	9.92E-02/ 1.38E-02	0.1467/ 2.11E-02	
90	9.11E-02/ 1.27E-02	0.1375/ 2.06E-02	0.1647/ 2.36E-02	0.1987/ 2.72E-02	

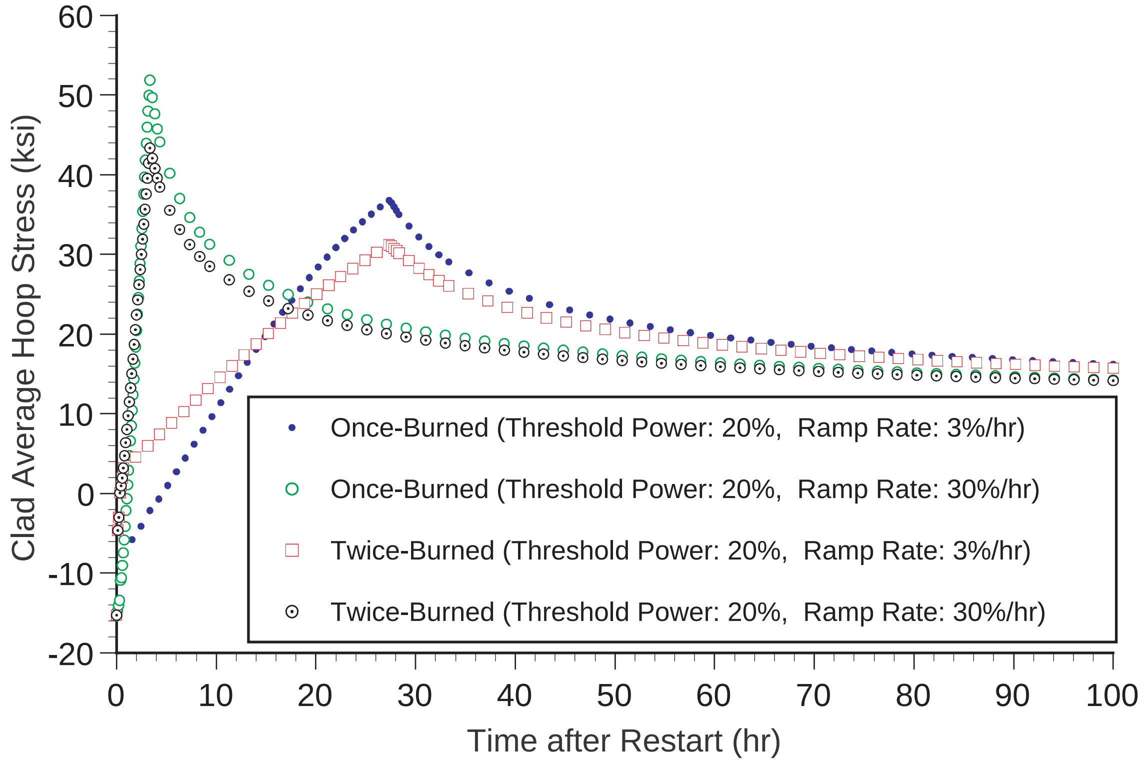

Figure 4-6
Clad Average Hoop Stress in YGN-4 (Half Gap)

4.2.3 Diablo Canyon 2

As with YGN-2 and 4, the analysis of the Diablo Canyon 2 17x17 Vantage-5 fuel used a matrix of fourteen combinations of threshold power and ramp rate for once-burned fuel with the ESCORE-predicted and one-half gap conditions. The results for the maximum cladding hoop stress and the maximum cladding damage index as functions of threshold power and ramp rate are summarized in Tables 4-12 and 4-13.

This data is also illustrated in Figures 4-7 and 4-10. The values are plotted for the base case (20% threshold power and 3%/hr ramp rate) and the most severe ramp rate case (20% threshold power and 30%/hr ramp rate) over 100 hours from the restart to a stabilized HFP condition. All other combinations of threshold power and ramp rate values are bounded by these two cases.

Table 4-12
Maximum Clad Hoop Stress (Once-Burned Fuel)

Normal Gap / Half Gap (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		25.988/ 35.685	26.841/ 39.055	27.872/ 43.754	29.019/ 50.438
40		25.374/ 35.370	26.432/ 38.842	27.688/ 43.657	
60		24.564/ 35.137	25.943/ 38.745	27.506/ 43.683	
90	21.461/ 43.601	25.264/ 43.601	26.664/ 43.601	28.017/ 46.108	

Table 4-13
Maximum Clad Hoop Stress (Once-Burned Fuel)

Normal Gap / Half Gap (ksi)	Ramp Rate after Threshold Power (%FP/hr)				
Threshold Power (%FP)	**1**	**3**	**5**	**10**	**30**
20		0.0/ 5.65E-02	0.0/ 7.04E-02	0.0/ 0.1005	0.80E-03/ 0.1533
40		0.0/ 5.23E-02	0.0/ 6.76E-02	0.0/ 9.87E-02	
60		0.0/ 4.93E-02	0.0/ 6.72E-02	0.0/ 9.92E-02	
90	0.0/ 6.46E-02	0.0/ 9.30E-02	0.0/ 0.1070	0.0/ 0.1313	

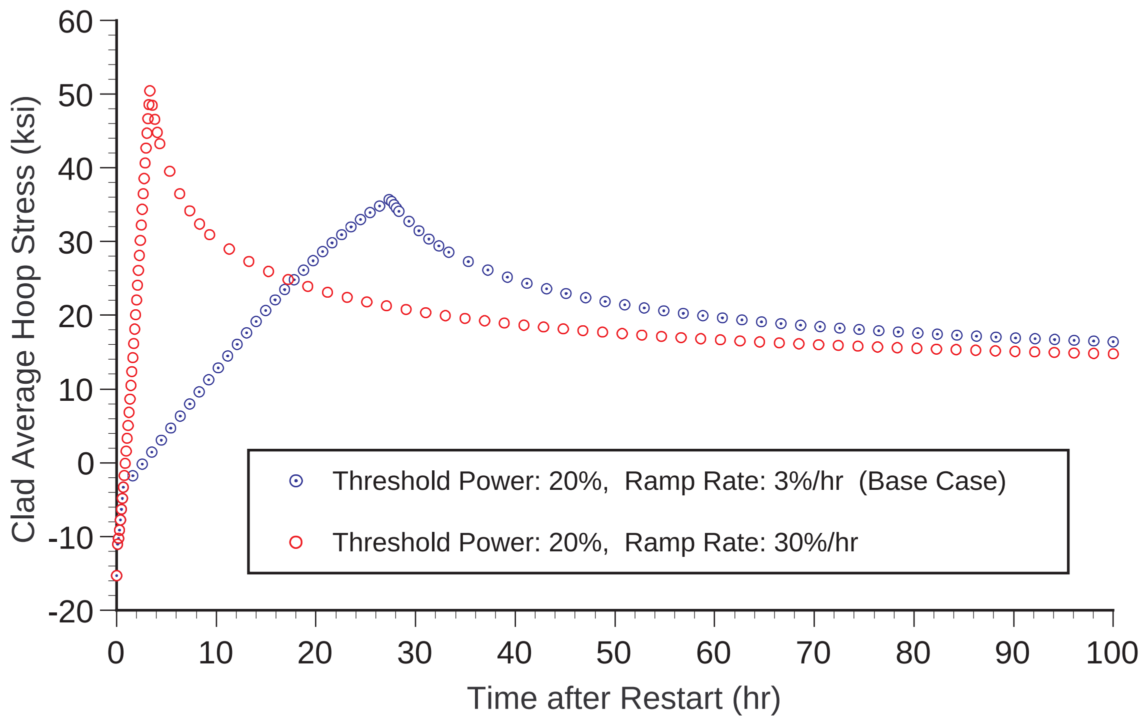

Figure 4-7
Clad Average Hoop Stress in Diablo Canyon 2 (Half Gap)

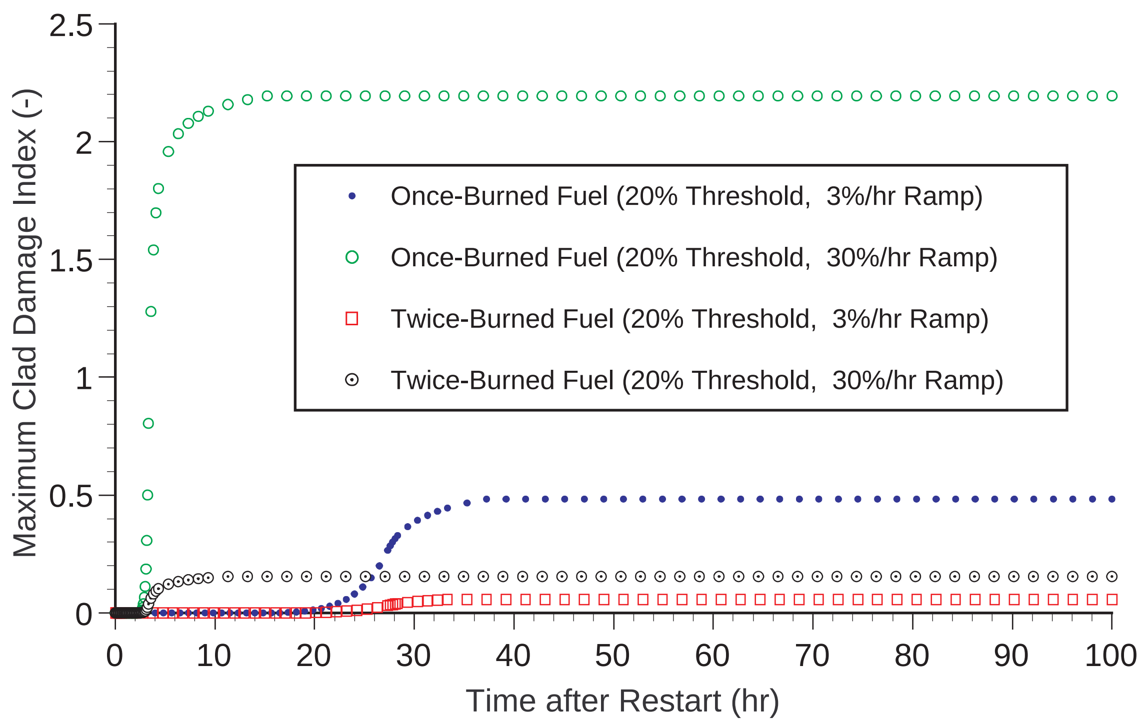

Figure 4-8
Maximum Clad Damage Index in YGN-2 (Half Gap)

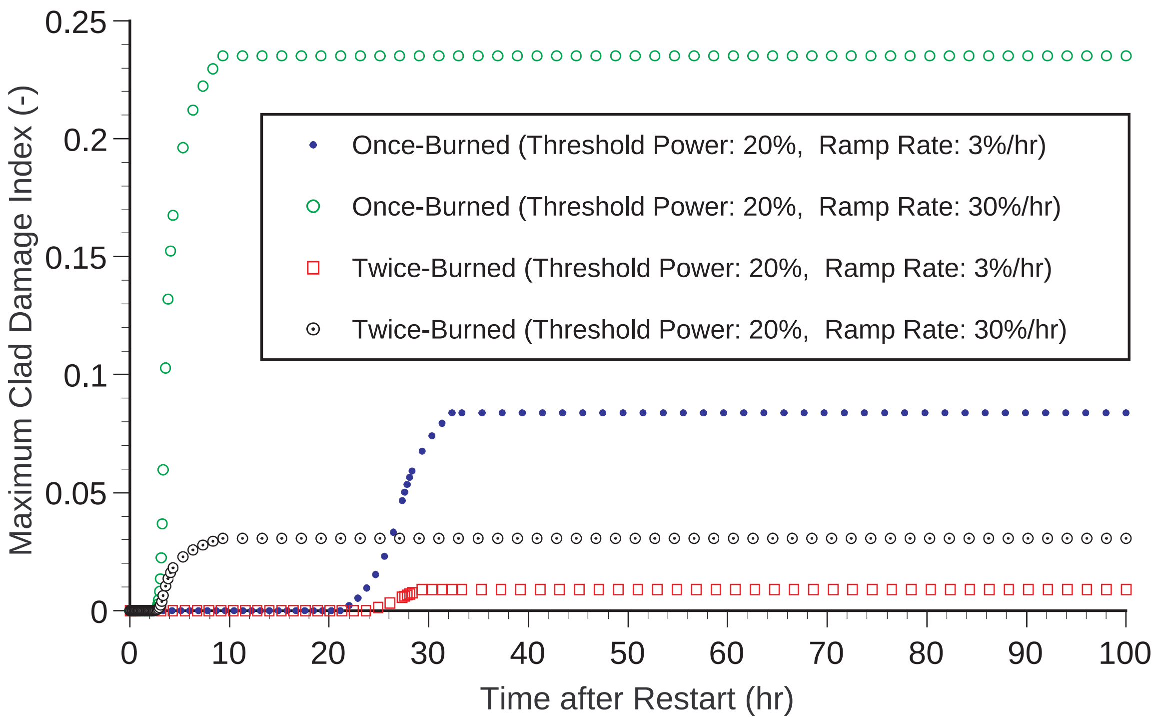

Figure 4-9
Maximum Clad Damage Index in YGN-4 (Half Gap)

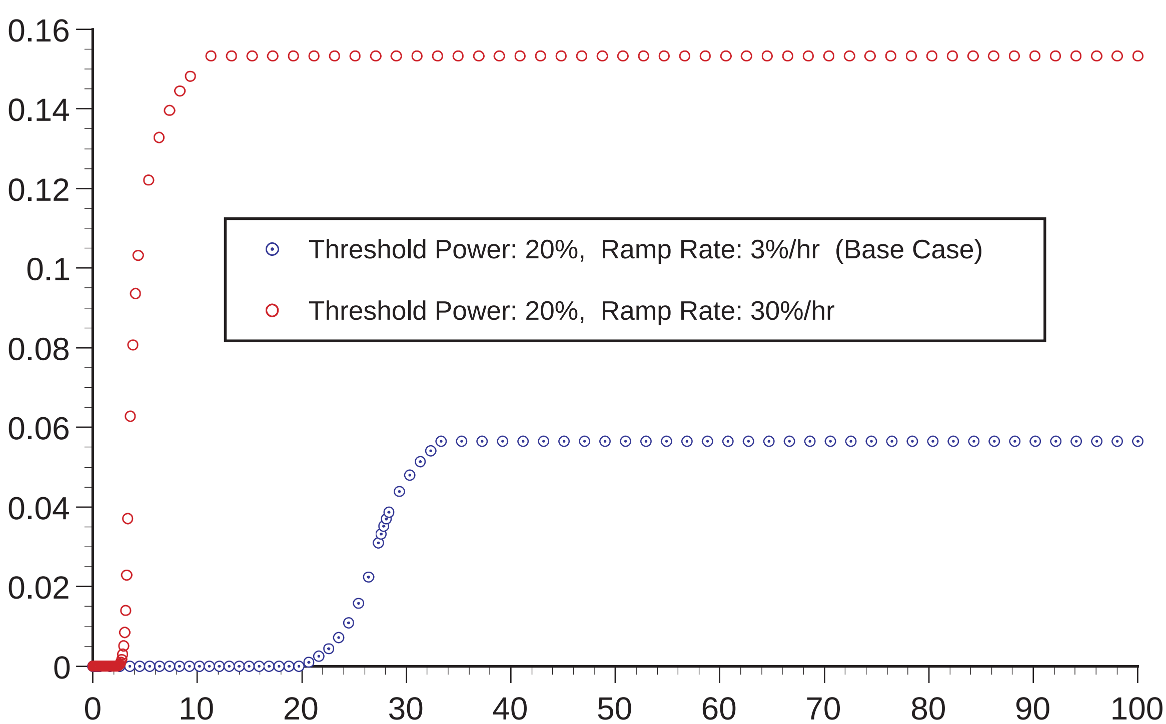

Figure 4-10
Maximum Clad Damage Index in Diablo Canyon 2 (Half Gap)

4.3 Discussions

As the primary mechanism of PCI-induced cladding failures, ISCC can be caused by localized stresses from a cracked fuel pellet impinging on the cladding inner surface. Cracked pellets often contact the cladding during normal cycle operation, however, barring sudden power changes, the stresses are too low to initiate ISCC and the fuel-cladding gap typically reopens when the power level is decreased, e.g. during refueling operations. For instance, ESCORE predicted fuel-cladding gap closure for the once-burned fuel in YGN-2 at HFP with a rod average burnup of 6,307 MWd/MtU during normal cycle operation. During a startup power ramp, the fuel-cladding gap may also close depending on the target power level. Once gap closure occurs, the cladding hoop stress begins to increase at a rate that depends on the power ascension rate. Elevated cladding stresses can cause the initiation of ISCC if the local stresses exceed a critical threshold stress level that depends on burnup and cladding material type. Because of this effect, the cladding hoop stress is a key factor in the prediction of ISCC. The cladding hoop stress and the cladding damage index parameter, which incorporates the effect of cladding hoop stress, were used as the bases of comparison to determine the effect that threshold power level and ramp rate have on PCI.

4.3.1. Clad Hoop Stress

For the cases analyzed in this study, plots of the predicted average cladding hoop stress as a function of time after restart and tabular data of the predicted maximum cladding hoop stress as a function of threshold power and ramp rate were presented in previous sections. (See Figures 4-3, 4-5 through 4-7, and Tables 4-4, 4-6, 4-8, 4-10, and 4-12.) Evaluation of Figures 4-3, 4-5 through 4-7 reveals that the behavior of the cladding hoop stress followed a consistent pattern for the three fuel types analyzed. During the restart power ramp from HZP to HFP, the cladding hoop stress in the cladding peak power node increased almost linearly with ramp rate. It reached a maximum value at HFP and then decreased exponentially, as the cladding “relaxed” toward an equilibrium thermal and mechanical condition (attained at approximately 70 hours) while core power remained at HFP out to 100 hours (end of the analysis).

The effect of fuel-cladding gap width on cladding hoop stress is illustrated in Figure 4-3 where the results for both the ESCORE-predicted and one-half gap conditions are plotted. Comparing the two cases for the 30% per hour ramp rate, the one-half gap case resulted in an almost immediate gap closure and increasing cladding hoop stress up to a peak value near 64 ksi at 2 hours into the ramp. During the constant power hold time, the cladding hoop stress decreased due to stress relaxation effects in the fuel and cladding, approaching an equilibrium value of 15 ksi. In the ESCORE-predicted gap case, the gap stayed open to a higher power level, closing at just under 2 hours into the restart ramp. It reached a peak stress level of 39 ksi almost immediately, and then dropped off to a near equilibrium value of 10 ksi during the constant power hold time. Comparing the two cases for the 3% per hour ramp rate, the one-half gap case again resulted in an almost immediate gap closure and an increase in cladding hoop stress up to a peak value near 42 ksi at 26 hours into the ramp. As before, the cladding hoop stress then dropped off as it approached an equilibrium value of 18 ksi. In the ESCORE-predicted gap case, however, the gap stayed open until approximately 12 hours after the restart ramp with the cladding hoop stress reaching a peak value of 34 ksi at 26 hours into the ramp. It then dropped off as it approached an equilibrium value of 14 ksi. Similar results for the restart ramp response of the cladding average hoop stress for the one-half gap cases for YGN-2, YGN-4 and Diablo Canyon 2 are presented in Figures 4-4 through 4-7.

As would be expected, in all cases the one-half gap size resulted in gap closure at a lower power level and higher peak cladding hoop stress values, bounding the results of the ESCORE-predicted gap cases. Another result of note was that for both YGN-2 and YGN-4, the once-burned fuel showed higher maximum stresses than the twice-burned fuel. This was due to the higher maximum power achieved during startup for the once-burned fuel in each of these cases.

4.3.2 Damage Index

The PCI failure criterion used in FREY is based on a cumulative damage concept in which incremental damage is calculated at each time step as a non-dimensional parameter, the cladding damage index, as time progresses through a power ramp or transient. For the cases analyzed in this study, plots and tabular summaries of the damage index as a function of time after restart and of threshold power and ramp rate were presented in previous sections. (See Figures 4-4, 4-8 through 4-10, and Tables 4-5, 4-7, 4-9, 4-11, and 4-13.) As with the cladding average hoop stress data, only the baseline and most extreme ramp rate cases were plotted (3% per hour and 30% per hour, respectively) since all other cases were bounded by these two cases.

Evaluation of Figures 4-4, and 4-8 through 4-10 revealed that the cladding damage index in the peak power node increased rapidly as the core power approached HFP and peaked just after HFP was attained. Because the cladding damage index is cumulative, it either continues to increase indicating further cladding damage or plateaus at a maximum value if no further fuel damage occurs. For all three fuel types analyzed in this study, the cladding damage index plateaued at a maximum value just after HFP was attained. The peak value corresponded to the initiation of the reduction in cladding hoop stress throughout the remainder of the restart power ramp noted in the stress plots discussed previously. The increase in the cladding damage index occurs in these analyses once the cladding hoop stress exceeds the critical threshold stress level. Based on the results present, this threshold stress level is near 28 ksi for the cladding type and burnup levels investigated.

Figure 4-4 illustrates the effect of fuel-cladding gap width and ramp rate on the cladding damage index. As would be expected, the cladding damage index peaked at a higher value for the one-half gap case versus the ESCORE-predicted gap. However, the effect on the damage index of reducing the gap width was more dramatic than that noted on the cladding hoop stress. Similar results are shown in Figures 4-8 through 4-10 for the one-half gap cases for YGN-2, YGN-4 and Diablo Canyon 2. As with the cladding hoop stress, the once-burned fuel had a higher maximum damage index than the twice-burned fuel due to the higher maximum power achieved during startup. Higher ramp rates also resulted in higher maximum damage index values. As a final note, although the absolute value of the damage index obtained was different, in general the trend in the change of the damage index among the three fuel types analyzed was similar.

4.3.3 Threshold Power

In order to analyze how PCI fuel failure is affected by both threshold power and ramp rate, it is necessary to fix one of these parameters while modifying the other to determine their effects independently. The effect of threshold power was isolated fixing its value and performing a series of runs verying the ramp rate. Figure 4-11 through 4-13 provide plots of the cladding damage index as a function of threshold power level for once-burned fuel at constant ramp rates for YGN-2, YGN-4, and Diablo Canyon 2, respectively. In all three cases, the damage index remained stable up to a threshold power of 60% of full power. Above this value, a significant increase in the damage index occurred, indicating stronger pellet cladding mechanical interaction stress and a higher potential for PCI failure. Based on these results it is recommended that the threshold power should be limited to 60% of full power.

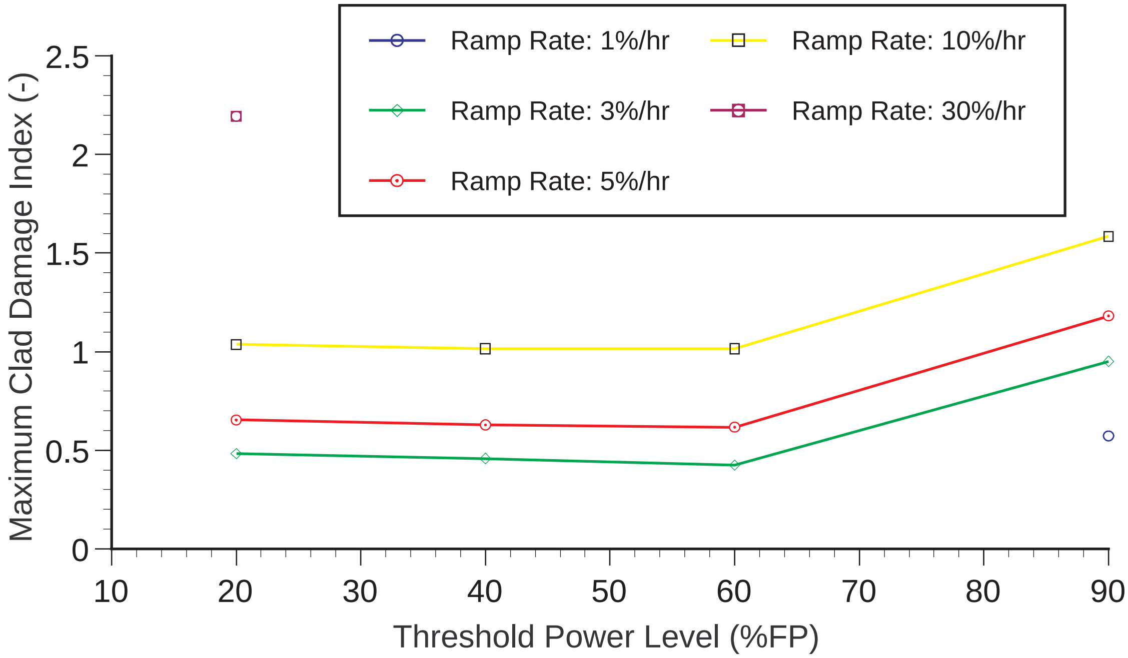

Figure 4-11
YGN-2 Maximum Damage Index vs. Threshold Power

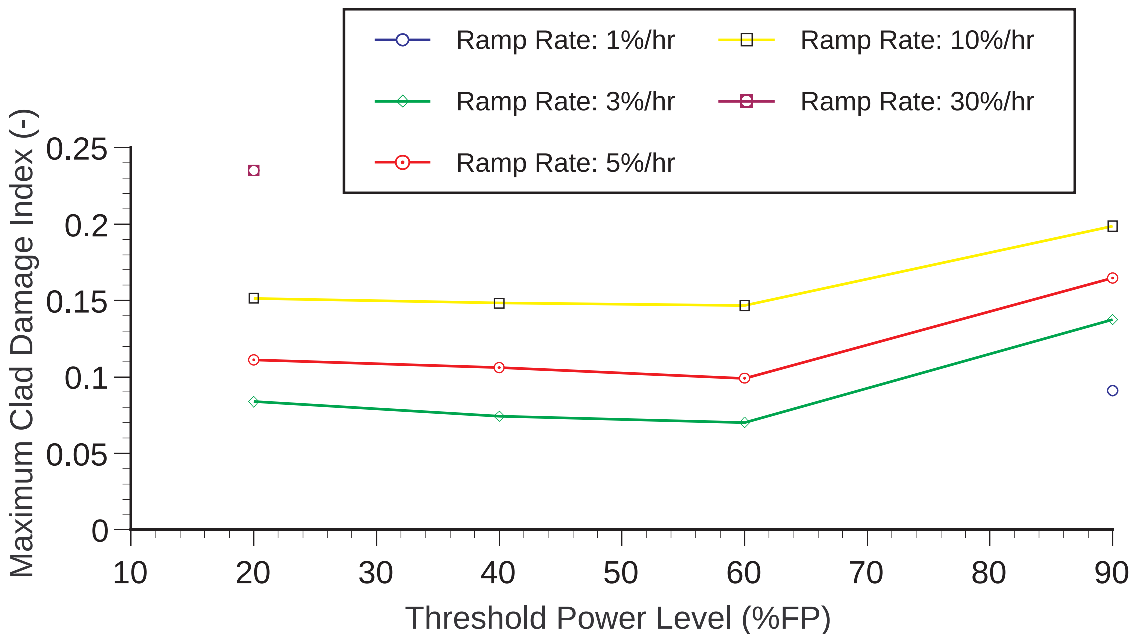

Figure 4-12
YGN-4 Maximum Damage Index vs. Threshold Power

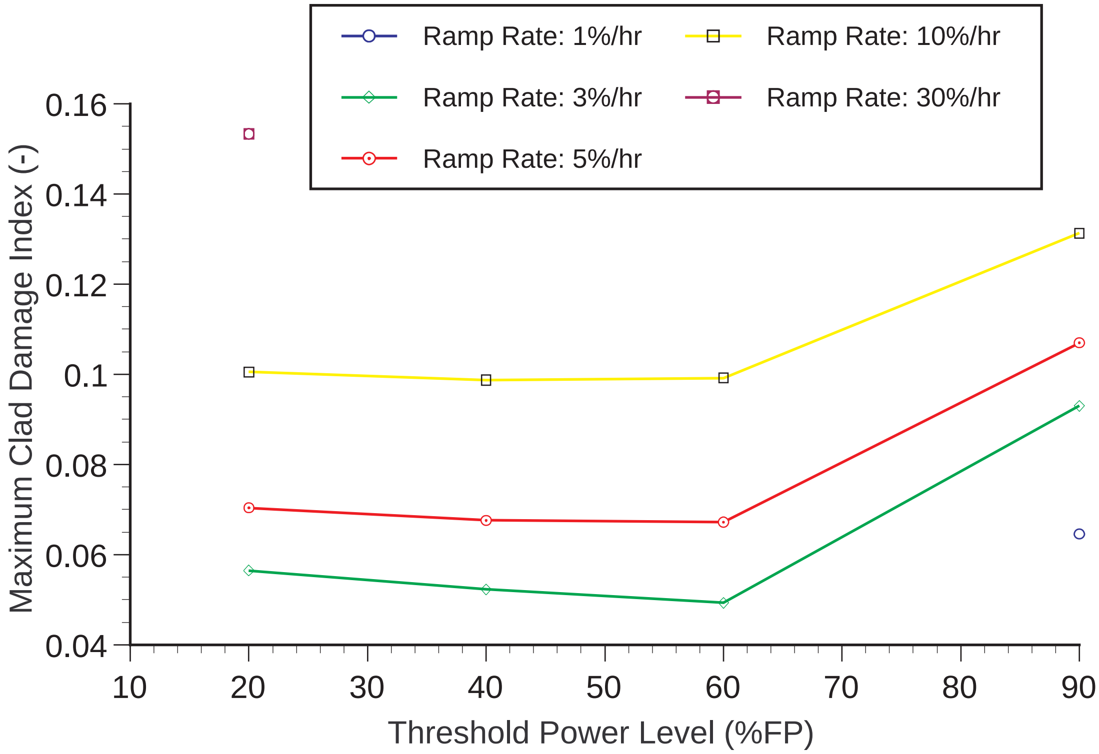

Figure 4-13
Diablo Canyon 2 Fuel Maximum Damage Index vs. Threshold Power

4.3.4 Ramp Rate

Similarly, the effect of ramp rate was isolated by fixing its value and performing a series of runs varying the threshold power. Figures 4-14 through 4-16 present plots of the cladding damage index as a function of ramp rate at constant threshold power levels for once-burned fuel in YGN-2, YGN-4, and Diablo Canyon 2, respectively. The cladding damage index increased almost linearly with ramp rate above 3%/hr, indicating that a limitation on ramp rate is needed to prevent PCI fuel failures. For YGN-2, the case with the highest LHGR, the cladding damage index reached a value of 1 at a ramp rate of 10%/hr, increasing almost linearly with ramp rate above this level. For the base case condition (3%/hr) a significant margin to PCI failure is indicated. This margin was not reduced significantly until the threshold power was increased beyond 60% and the ramp rate beyond 5%/hr. Reviewing the results for YGN-4 and Diablo Canyon 2, at a 60% threshold power level, a ramp rate up to 10%/hr provided sufficient margin to PCI failure. However, both YGN-4 and Diablo Canyon-2 have different power histories as compared to YGN-2. Because the most limiting condition was represented by YGN-2, it is recommended that the ramp rate be limited to 5%/hr above a threshold power level of 60%.

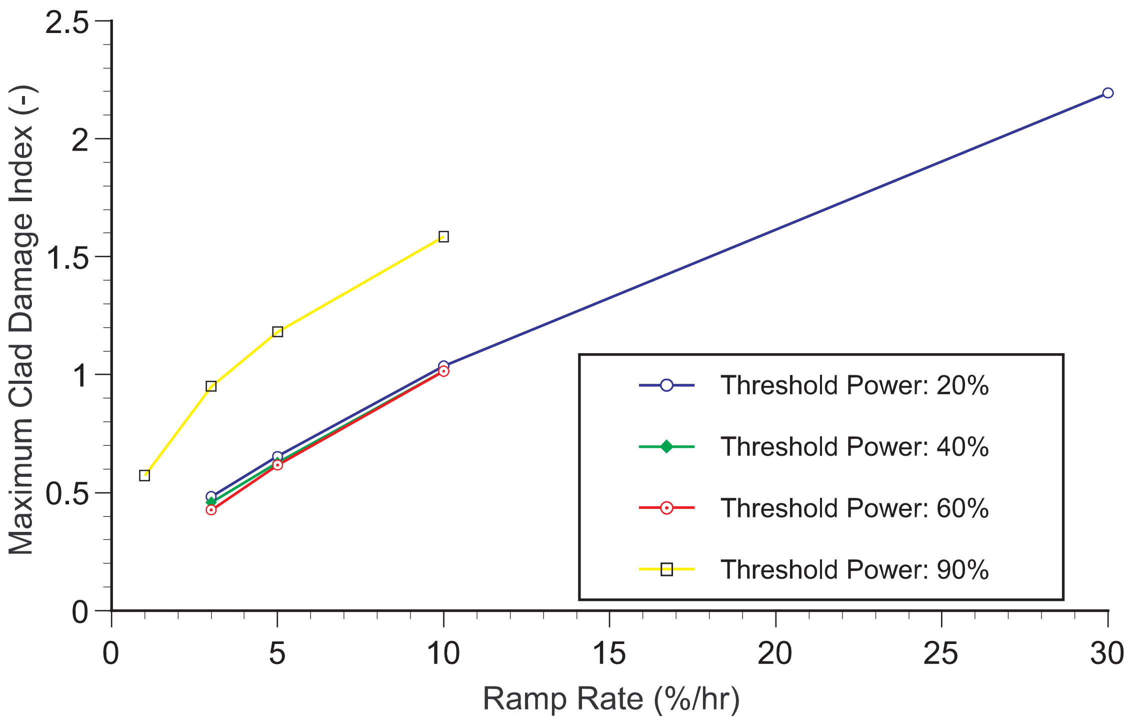

Figure 4-14
YGN-2 Vantage-5H Fuel Maximum Damage Index vs. Ramp Rate

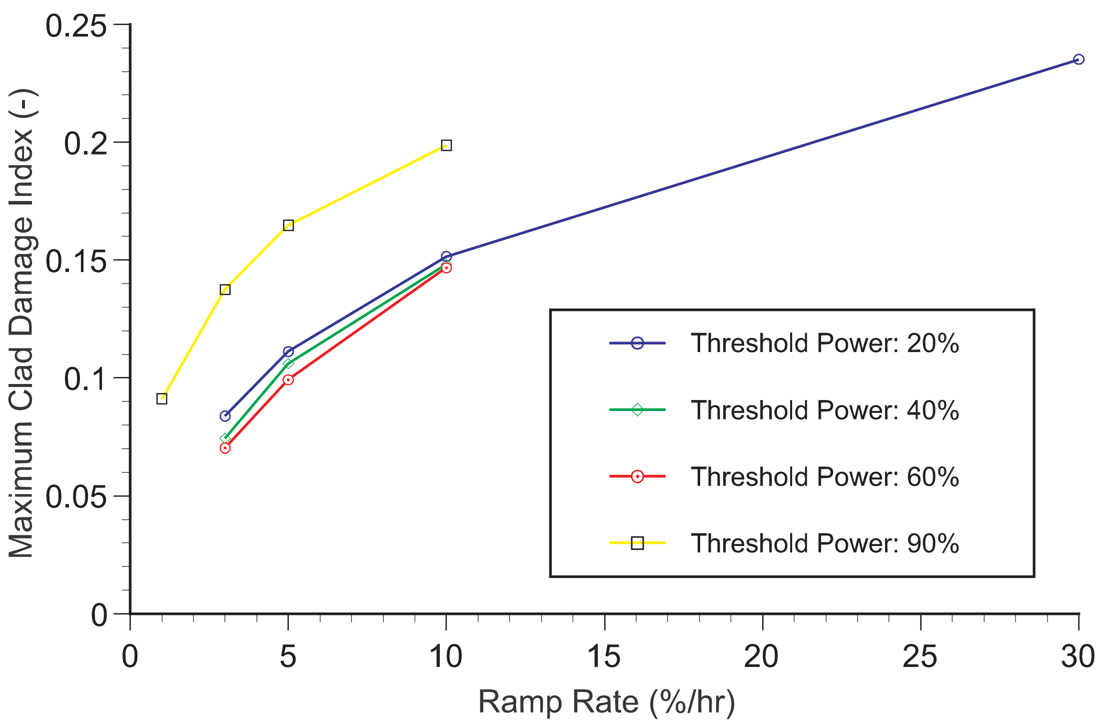

Figure 4-15
YGN-4 CE Fuel Maximum Damage Index vs. Ramp Rate

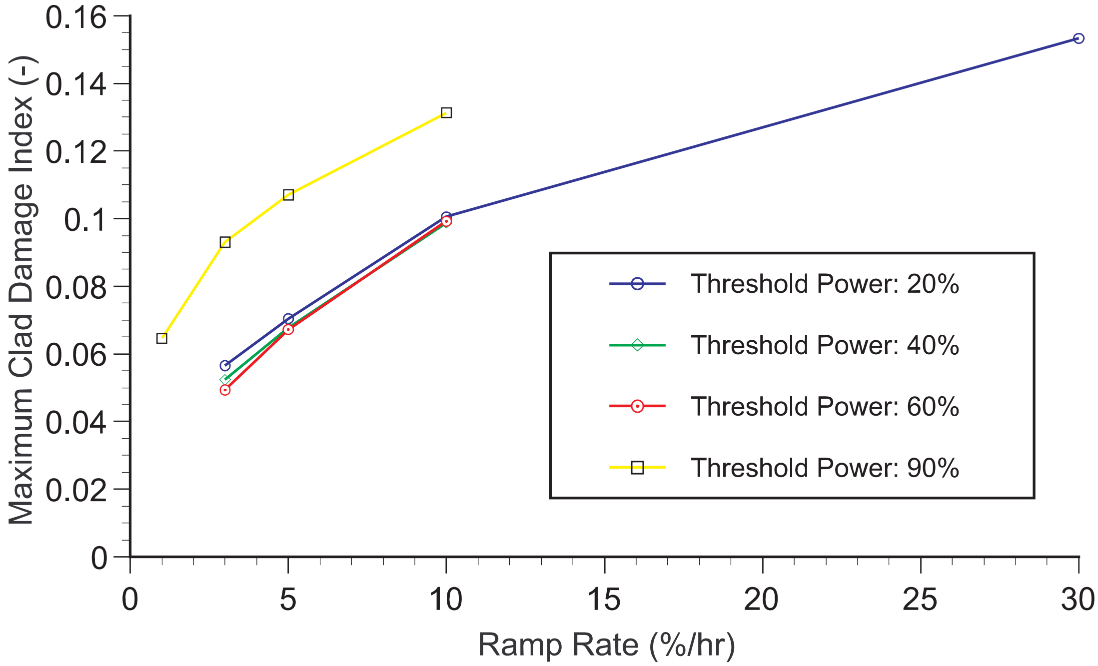

Figure 4-16
Diablo Canyon 2 Vantage-5 Fuel Maximum Damage Index vs. Ramp Rate

5

SUMMARY

5.1 Conclusions

Three different types of fuel (YGN-2 17x17 Vantage-5H, YGN-4 16x16 ABB-CE, Diablo Canyon 2 Vantage-5) were analyzed to determine the effect of threshold power and ramp rate on the PCI fuel failure. The ESCORE code was used for steady-state cycle analyses for both once- and twice-burned fuel. Output data from the steady-state analyses were used to initialize the restart analyses conducted using the FREY code. Numerous parametric studies varying threshold power and ramp rate were then conducted to determine the optimum startup ramp rate restrictions.

The results of these studies indicate that PCI behavior is more affected by ramp rate and threshold power than fuel design. However, it was found that the most important parameter was the power history of the fuel. For example, the fuel rod damage probability, and thus the probability of PCI failure, was proportional to the expected rod peak power. Based on the similar trend of cladding damage index for all three fuel designs, the optimum threshold power and ramp rate limitations were determined.

5.2 Recommendations

Using the available data from the three plants used in this study and considering the uncertainties involved, a conservative PCI analysis has shown that the reliable threshold power and ramp rate are 60% and 5%/hr, respectively, for all three of these plants. Since PCI behavior is greatly affected by the peak fuel node power, it is important to keep track of the fuel rod power history for a best-estimate PCI analysis. It is further recommended that once a startup ramp rate restriction is modified, it should be verified that the original PCI analysis bounds the reload core design for the next cycle.

As discussed in the introductory section of this report, data indicate that typical U.S. plants take from three to fifteen days to reach power levels above 90% rated power following a refueling outage. Implementing the recommended changes in ramp rate and threshold power could significantly reduce restart times, likely shifting the emphasis of restart restrictions from the fuel to balance-of-plant systems. The relaxation of threshold power and ramp rate restrictions offers the possibility to improve current plant startup strategies and may allow more better utilization of PWR plants thereby improving plant economics.

6

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A

POWER HISTORY DATA: ONCE-BURNED / TWICE-BURNED

The axial power distribution of the peak power rod along the core average burnup with the core average power for the once-burned fuel and the twice-burned fuel in the PWRs (YGN 2, YGN 4, Diablo Canyon 2) analyzed in this project are summarized in the following subsections. The power in each axial node is written from the bottom to the top.

A.1 YGN 2 - Once-Burned Vantage-5H Fuel (Cycle 10)

0.8 MwD/MtU (Core Avg. Power: 5%FP)

0.0873	0.3563	0.5346	0.6672	0.7787	0.9328	1.0597	1.1840
1.3341	1.4824	1.6174	1.7313	1.8962	2.0102	2.0658	2.1646
2.1829	2.2053	2.1830	2.1305	1.9778	1.6794	1.2490	0.3249

66 MwD/MtU (Core Avg. Power: 75%FP)

0.1752	0.6740	0.9401	1.1108	1.2005	1.3282	1.3992	1.4446
1.5101	1.5650	1.5954	1.6146	1.6629	1.6980	1.6910	1.7357
1.7274	1.7038	1.6508	1.5995	1.4740	1.2581	0.9777	0.2741

391 MwD/MtU (Core Avg. Power: 100%FP)

0.2178	0.8120	1.1112	1.2883	1.3775	1.4904	1.5454	1.5645
1.6067	1.6458	1.6489	1.6452	1.6623	1.6738	1.6484	1.6776
1.6507	1.6246	1.5724	1.5074	1.4005	1.1919	0.9213	0.2707

1,572 MwD/MtU (Core Avg. Power: 100%FP)

0.2279	0.8290	1.1477	1.3289	1.4192	1.5282	1.5799	1.5991
1.6397	1.6709	1.6720	1.6659	1.6797	1.6885	1.6547	1.6893
1.6586	1.6228	1.5670	1.5063	1.3940	1.1750	0.9029	0.2767

2,780 MwD/MtU (Core Avg. Power: 100%FP)

0.2471	0.8573	1.2005	1.3841	1.4599	1.5785	1.6254	1.6273
1.6691	1.6993	1.6962	1.6782	1.6914	1.6957	1.6689	1.6846
1.6506	1.6134	1.5550	1.4979	1.3767	1.1561	0.8630	0.2795

3,885 MwD/MtU (Core Avg. Power: 100%FP)

0.2659	0.9093	1.2611	1.4452	1.5225	1.6187	1.6567	1.6484
1.6836	1.7020	1.6906	1.6757	1.6830	1.6789	1.6289	1.6592

1.6305 1.5926 1.5355 1.4823 1.3715 1.1484 0.8683 0.2826
6,278 MwD/MtU (Core Avg. Power: 100%FP)
0.2998 0.9668 1.3431 1.5327 1.5941 1.6771 1.6992 1.6768
1.7018 1.7052 1.6808 1.6564 1.6586 1.6461 1.5923 1.6161
1.5816 1.5422 1.4891 1.4451 1.3444 1.1344 0.8645 0.2932
7,250 MwD/MtU (Core Avg. Power: 100%FP)
0.3212 1.0051 1.3871 1.5769 1.6338 1.7092 1.7183 1.6828
1.6981 1.6988 1.6661 1.6327 1.6313 1.6229 1.5740 1.5907
1.5535 1.5154 1.4657 1.4192 1.3286 1.1288 0.8655 0.2998
8,324 MwD/MtU (Core Avg. Power: 100%FP)
0.3406 1.0348 1.4222 1.6080 1.6540 1.7281 1.7301 1.6820
1.6878 1.6882 1.6544 1.6157 1.6138 1.6022 1.5466 1.5661
1.5267 1.4903 1.4459 1.3998 1.3176 1.1233 0.8671 0.3095
9,411 MwD/MtU (Core Avg. Power: 100%FP)
0.3574 1.0587 1.4486 1.6270 1.6612 1.7254 1.7198 1.6673
1.6721 1.6657 1.6219 1.5902 1.5947 1.5797 1.5284 1.5605
1.5225 1.4830 1.4404 1.4028 1.3292 1.1369 0.8833 0.3231
10,779 MwD/MtU (Core Avg. Power: 100%FP)
0.3901 1.1093 1.4894 1.6493 1.6707 1.7157 1.7036 1.6418
1.6472 1.6343 1.5949 1.5637 1.5646 1.5534 1.5038 1.5278
1.4908 1.4629 1.4348 1.4075 1.3410 1.1632 0.9192 0.3494
11,805 MwD/MtU (Core Avg. Power: 100%FP)
0.4046 1.1150 1.4998 1.6500 1.6619 1.7046 1.6834 1.6153
1.6165 1.6044 1.5672 1.5299 1.5385 1.5318 1.4804 1.5071
1.4752 1.4488 1.4198 1.3948 1.3373 1.1651 0.9253 0.3565
13,036 MwD/MtU (Core Avg. Power: 100%FP)
0.4207 1.1286 1.5068 1.6478 1.6476 1.6818 1.6554 1.5871
1.5876 1.5727 1.5339 1.4981 1.5181 1.5115 1.4589 1.4933
1.4669 1.4410 1.4126 1.3937 1.3462 1.1807 0.9479 0.3772
14,169 MwD/MtU (Core Avg. Power: 100%FP)
0.4476 1.1698 1.5137 1.6366 1.6281 1.6593 1.6293 1.5617
1.5625 1.5518 1.5194 1.4922 1.5060 1.4960 1.4487 1.4850
1.4629 1.4430 1.4239 1.4101 1.3760 1.2111 0.9896 0.4074
15,433 MwD/MtU (Core Avg. Power: 100%FP)
0.4688 1.1789 1.5157 1.6045 1.5945 1.6129 1.5842 1.5191
1.5195 1.5145 1.4779 1.4569 1.4717 1.4709 1.4198 1.4587
1.4434 1.4196 1.4066 1.4048 1.3769 1.2265 1.0152 0.4234
16,490 MwD/MtU (Core Avg. Power: 100%FP)
0.4808 1.1829 1.5042 1.5984 1.5751 1.5968 1.5642 1.4933
1.4948 1.4893 1.4595 1.4370 1.4558 1.4552 1.4037 1.4436
1.4303 1.4186 1.4119 1.4138 1.3922 1.2484 1.0395 0.4446

A.2 YGN 2 - Twice-Burned Vantage-5H Fuel (Cycle 9 & 10)

1.5 MwD/MtU (Core Avg. Power: 5%FP)

0.0898	0.3986	0.6165	0.7517	0.8670	0.9954	1.1066	1.1620
1.2566	1.3684	1.4277	1.4849	1.5248	1.5668	1.5578	1.6374
1.6495	1.6294	1.5713	1.5387	1.4287	1.1766	0.8041	0.2018

126 MwD/MtU (Core Avg. Power: 75%FP)

0.1621	0.6284	0.9636	1.1039	1.1993	1.3028	1.3555	1.3524
1.4022	1.4495	1.4554	1.3942	1.4449	1.4470	1.3750	1.4208
1.3857	1.3310	1.2630	1.2013	1.1054	0.9482	0.6442	0.1860

508 MwD/MtU (Core Avg. Power: 100%FP)

0.1810	0.7345	1.0405	1.1727	1.2553	1.3486	1.3910	1.3656
1.3963	1.4304	1.4289	1.4076	1.3841	1.3673	1.2975	1.3344
1.3028	1.2507	1.1817	1.1456	1.0669	0.8606	0.6198	0.1915

1,712 MwD/MtU (Core Avg. Power: 100%FP)

0.1894	0.7449	1.0498	1.1822	1.2667	1.3699	1.4129	1.3851
1.4217	1.4594	1.4523	1.4302	1.4034	1.3865	1.3159	1.3541
1.3138	1.2549	1.1820	1.1339	1.0450	0.8311	0.5944	0.1848

2,620 MwD/MtU (Core Avg. Power: 100%FP)

0.1954	0.7520	1.0520	1.1900	1.2745	1.3694	1.4107	1.3817
1.4113	1.4548	1.4408	1.4178	1.3952	1.3847	1.3094	1.3462
1.3101	1.2473	1.1801	1.1297	1.0306	0.8205	0.5846	0.1857

3,640 MwD/MtU (Core Avg. Power: 100%FP)

0.2058	0.7622	1.0593	1.1850	1.2600	1.3610	1.3975	1.3645
1.3932	1.4294	1.4156	1.3962	1.3767	1.3608	1.2864	1.3274
1.2970	1.2416	1.1706	1.1239	1.0389	0.8271	0.6000	0.1971

4,745 MwD/MtU (Core Avg. Power: 100%FP)

0.2148	0.7805	1.0737	1.1947	1.2650	1.3509	1.3753	1.3440
1.3686	1.3938	1.3845	1.3668	1.3505	1.3390	1.2678	1.3085
1.2805	1.2310	1.1669	1.1250	1.0469	0.8339	0.6090	0.2031

5,900 MwD/MtU (Core Avg. Power: 100%FP)

0.2234	0.7874	1.0738	1.1989	1.2602	1.3458	1.3710	1.3240
1.3509	1.3773	1.3580	1.3274	1.3259	1.3155	1.2494	1.2956
1.2656	1.2174	1.1503	1.1205	1.0438	0.8407	0.6215	0.2109

7,020 MwD/MtU (Core Avg. Power: 100%FP)

0.2344	0.8031	1.0817	1.2006	1.2586	1.3403	1.3560	1.3081
1.3242	1.3508	1.3355	1.3063	1.3043	1.2935	1.2286	1.2757
1.2557	1.2113	1.1441	1.1199	1.0495	0.8501	0.6424	0.2229

8,254 MwD/MtU (Core Avg. Power: 100%FP)

0.2598	0.8224	1.0966	1.2068	1.2165	1.3224	1.3309	1.2683
1.3029	1.3351	1.3028	1.2524	1.2829	1.2744	1.1920	1.2472
1.2502	1.1871	1.1505	1.1483	1.0688	0.8745	0.6827	0.2198

9,409 MwD/MtU (Core Avg. Power: 100%FP)

0.2721	0.8220	1.1138	1.2310	1.2495	1.3168	1.3175	1.2660
1.2898	1.2933	1.2559	1.2239	1.2544	1.2475	1.1908	1.2372
1.2267	1.1764	1.1528	1.1349	1.0570	0.8756	0.6761	0.2328

10,605 MwD/MtU (Core Avg. Power: 100%FP)

0.3039	0.8924	1.1984	1.3129	1.3126	1.3760	1.3613	1.2997
1.3047	1.3037	1.2586	1.2169	1.2462	1.2258	1.1714	1.2016
1.1810	1.1379	1.1029	1.0936	1.0256	0.8643	0.6787	0.2365

11,886 MwD/MtU (Core Avg. Power: 100%FP)

0.3313	0.9251	1.2128	1.3143	1.3096	1.3557	1.3314	1.2607
1.2759	1.2762	1.2246	1.1966	1.2165	1.2072	1.1518	1.2026
1.1840	1.1459	1.1286	1.1268	1.0612	0.8990	0.7157	0.2550

12,992 MwD/MtU (Core Avg. Power: 100%FP)

0.3389	0.9289	1.2042	1.2942	1.2829	1.3223	1.2945	1.2294
1.2450	1.2444	1.1992	1.1729	1.2027	1.1953	1.1400	1.1925
1.1832	1.1538	1.1387	1.1432	1.0880	0.9310	0.7519	0.2754

14,072 MwD/MtU (Core Avg. Power: 100%FP)

0.3402	0.9130	1.1764	1.2577	1.2371	1.2861	1.2586	1.1961
1.2133	1.2147	1.1865	1.1608	1.1951	1.1908	1.1451	1.1959
1.1891	1.1638	1.1547	1.1620	1.1142	0.9598	0.7851	0.2948

15,382 MwD/MtU (Core Avg. Power: 100%FP)

0.3711	0.9355	1.1845	1.2587	1.2353	1.2726	1.2471	1.1867
1.1993	1.2135	1.1776	1.1438	1.1820	1.1867	1.1386	1.1935
1.1838	1.1637	1.1563	1.1786	1.1359	0.9871	0.8201	0.3212

16,419 MwD/MtU (Core Avg. Power: 100%FP)

0.3711	0.9355	1.1845	1.2587	1.2353	1.2726	1.2471	1.1867
1.1993	1.2135	1.1776	1.1438	1.1820	1.1867	1.1386	1.1935
1.1838	1.1637	1.1563	1.1786	1.1359	0.9871	0.8201	0.3212

17,306 MwD/MtU (Core Avg. Power: 100%FP)

0.3679	0.9274	1.1743	1.2478	1.2246	1.2616	1.2363	1.1765
1.1889	1.2030	1.1674	1.1339	1.1718	1.1765	1.1288	1.1832
1.1736	1.1536	1.1463	1.1684	1.1261	0.9786	0.8130	0.3184

17,307 MwD/MtU (Core Avg. Power: 5%FP)

0.0953	0.3137	0.4831	0.6059	0.7023	0.8436	0.9542	1.0641
1.1991	1.3310	1.4566	1.5534	1.6889	1.7978	1.8697	1.9777
2.0009	2.0341	2.0182	1.9702	1.8262	1.5464	1.1115	0.3445

17,372 MwD/MtU (Core Avg. Power: 75%FP)

0.1899	0.5906	0.8532	1.0170	1.0922	1.2123	1.2744	1.3165
1.3731	1.4215	1.4518	1.4629	1.5134	1.5444	1.5445	1.5787
1.5694	1.5607	1.5224	1.4843	1.3799	1.1845	0.8942	0.3024

17,697 MwD/MtU (Core Avg. Power: 100%FP)

0.2371	0.7257	1.0168	1.1830	1.2605	1.3638	1.4123	1.4287

1.4667 1.4994 1.5015 1.4995 1.5159 1.5276 1.5002 1.5311
1.5071 1.4834 1.4372 1.3799 1.2845 1.0940 0.8276 0.2922

18,878 MwD/MtU (Core Avg. Power: 100%FP)
0.2439 0.7395 1.0360 1.1997 1.2800 1.3771 1.4207 1.4368
1.4750 1.5008 1.5007 1.4937 1.5143 1.5251 1.4919 1.5204
1.4918 1.4620 1.4112 1.3591 1.2622 1.0639 0.8113 0.2926
20,086 MwD/MtU (Core Avg. Power: 100%FP)
0.2616 0.7647 1.0730 1.2279 1.3121 1.3996 1.4404 1.4352
1.4699 1.4984 1.4938 1.4769 1.5014 1.5069 1.4713 1.4953
1.4634 1.4345 1.3862 1.3234 1.2257 1.0316 0.7682 0.2917
21,191 MwD/MtU (Core Avg. Power: 100%FP)
0.2799 0.8020 1.1067 1.2697 1.3306 1.4214 1.4492 1.4424
1.4673 1.4863 1.4789 1.4632 1.4783 1.4795 1.4419 1.4659
1.4360 1.4074 1.3576 1.3112 1.2131 1.0234 0.7825 0.2912
23,584 MwD/MtU (Core Avg. Power: 100%FP)
0.3142 0.8543 1.1627 1.3169 1.3712 1.4433 1.4587 1.4344
1.4555 1.4585 1.4356 1.4163 1.4304 1.4238 1.3789 1.4026
1.3738 1.3396 1.2996 1.2603 1.1708 0.9922 0.7776 0.2807
24,556 MwD/MtU (Core Avg. Power: 100%FP)
0.3300 0.8890 1.1948 1.3469 1.3907 1.4589 1.4679 1.4354
1.4444 1.4446 1.4198 1.3941 1.4042 1.4008 1.3587 1.3730
1.3409 1.3129 1.2712 1.2319 1.1533 0.9847 0.7839 0.2862
25,630 MwD/MtU (Core Avg. Power: 100%FP)
0.3498 0.9168 1.2198 1.3682 1.4046 1.4667 1.4687 1.4265
1.4299 1.4259 1.3988 1.3695 1.3861 1.3779 1.3279 1.3496
1.3150 1.2858 1.2521 1.2136 1.1431 0.9756 0.7850 0.2924
26,717 MwD/MtU (Core Avg. Power: 100%FP)
0.3640 0.9325 1.2272 1.3700 1.4013 1.4604 1.4541 1.4036
1.4055 1.4001 1.3640 1.3394 1.3616 1.3494 1.3064 1.3377
1.3040 1.2761 1.2415 1.2092 1.1458 0.9915 0.8020 0.3254
28,085 MwD/MtU (Core Avg. Power: 100%FP)
0.3974 0.9817 1.2607 1.3835 1.4094 1.4516 1.4360 1.3774
1.3793 1.3663 1.3372 1.3182 1.3291 1.3193 1.2776 1.3037
1.2741 1.2561 1.2325 1.2107 1.1523 1.0043 0.8318 0.3126
29,111 MwD/MtU (Core Avg. Power: 100%FP)
0.4063 0.9807 1.2636 1.3887 1.3939 1.4399 1.4177 1.3603
1.3531 1.3476 1.3191 1.2898 1.3096 1.3064 1.2679 1.2935
1.2647 1.2469 1.2214 1.2026 1.1537 1.0196 0.8469 0.3599
30,342 MwD/MtU (Core Avg. Power: 100%FP)
0.4289 1.0148 1.2817 1.3868 1.3909 1.4211 1.3986 1.3343
1.3329 1.3186 1.2872 1.2610 1.2896 1.2890 1.2401 1.2767
1.2551 1.2359 1.2147 1.1986 1.1577 1.0245 0.8665 0.3496

31,475 MwD/MtU (Core Avg. Power: 100%FP)

0.4552	1.0451	1.2770	1.3669	1.3726	1.4047	1.3771	1.3099
1.3094	1.2965	1.2698	1.2574	1.2798	1.2719	1.2276	1.2677
1.2531	1.2363	1.2229	1.2157	1.1802	1.0435	0.9060	0.4073

32,739 MwD/MtU (Core Avg. Power: 100%FP)

0.4663	1.0484	1.2791	1.3537	1.3486	1.3661	1.3396	1.2804
1.2764	1.2759	1.2449	1.2316	1.2553	1.2559	1.2168	1.2521
1.2385	1.2237	1.2136	1.2079	1.1841	1.0625	0.9262	0.4198

33,796 MwD/MtU (Core Avg. Power: 100%FP)

0.4782	1.0554	1.2800	1.3487	1.3310	1.3556	1.3214	1.2568
1.2614	1.2572	1.2322	1.2170	1.2509	1.2523	1.2044	1.2427
1.2309	1.2178	1.2122	1.2147	1.1980	1.0837	0.9534	0.4413

A.3 YGN 4 - Once-Burned CE Fuel (Cycle 2)

608 MwD/MtU (Core Avg. Power: 100%FP)

0.5853	0.7926	0.9579	1.0609	1.1105	1.1226	1.1139	1.0991
1.0870	1.0805	1.0776	1.0739	1.0661	1.0541	1.0407	1.0313
1.0305	1.0388	1.0501	1.0519	1.0278	0.9601	0.8359	0.6508

662 MwD/MtU (Core Avg. Power: 100%FP)

0.5523	0.7396	0.8892	0.9845	1.0341	1.0516	1.0524	1.0488
1.0483	1.0526	1.0593	1.0645	1.0653	1.0623	1.0592	1.0612
1.0719	1.0913	1.1128	1.1230	1.1043	1.0388	0.9125	0.7204

1,020 MwD/MtU (Core Avg. Power: 100%FP)

0.5888	0.7709	0.9159	1.0081	1.0557	1.0717	1.0706	1.0646
1.0611	1.0620	1.0652	1.0674	1.0657	1.0608	1.0550	1.0531
1.0584	1.0709	1.0846	1.0881	1.0662	1.0028	0.8849	0.7076

1,792 MwD/MtU (Core Avg. Power: 100%FP)

0.6157	0.7900	0.9287	1.0169	1.0628	1.0787	1.0781	1.0721
1.0676	1.0666	1.0677	1.0678	1.0648	1.0589	1.0525	1.0491
1.0517	1.0603	1.0692	1.0688	1.0454	0.9841	0.8739	0.7087

2,707 MwD/MtU (Core Avg. Power: 100%FP)

0.6398	0.8071	0.9402	1.0249	1.0689	1.0842	1.0836	1.0772
1.0718	1.0693	1.0685	1.0668	1.0628	1.0563	1.0493	1.0449
1.0456	1.0511	1.0568	1.0538	1.0297	0.9705	0.8661	0.7108

3,730 MwD/MtU (Core Avg. Power: 100%FP)

0.6582	0.8196	0.9478	1.0295	1.0724	1.0876	1.0870	1.0806
1.0743	1.0706	1.0689	1.0664	1.0618	1.0550	1.0480	1.0432
1.0427	1.0460	1.0490	1.0432	1.0175	0.9597	0.8594	0.7115

4,905 MwD/MtU (Core Avg. Power: 100%FP)

0.6706	0.8283	0.9535	1.0331	1.0750	1.0901	1.0896	1.0830
1.0764	1.0717	1.0688	1.0657	1.0605	1.0533	1.0457	1.0401
1.0388	1.0410	1.0427	1.0362	1.0106	0.9541	0.8570	0.7142

6,003 MwD/MtU (Core Avg. Power: 100%FP)

0.6792	0.8344	0.9575	1.0359	1.0771	1.0919	1.0912	1.0846
1.0775	1.0722	1.0686	1.0648	1.0593	1.0519	1.0439	1.0380
1.0361	1.0375	1.0385	1.0315	1.0060	0.9506	0.8557	0.7162

7,033 MwD/MtU (Core Avg. Power: 100%FP)

0.6865	0.8397	0.9611	1.0381	1.0783	1.0923	1.0913	1.0843
1.0770	1.0715	1.0675	1.0632	1.0574	1.0498	1.0418	1.0360
1.0339	1.0352	1.0360	1.0290	1.0041	0.9498	0.8566	0.7196

8,059 MwD/MtU (Core Avg. Power: 100%FP)

0.6933	0.8451	0.9648	1.0402	1.0791	1.0923	1.0906	1.0827
1.0747	1.0690	1.0650	1.0608	1.0552	1.0478	1.0400	1.0343
1.0323	1.0337	1.0348	1.0280	1.0035	0.9503	0.8589	0.7236

9,014 MwD/MtU (Core Avg. Power: 100%FP)

0.6963	0.8466	0.9648	1.0393	1.0775	1.0901	1.0881	1.0802
1.0725	1.0672	1.0633	1.0594	1.0541	1.0471	1.0399	1.0345
1.0326	1.0339	1.0353	1.0292	1.0053	0.9529	0.8621	0.7277

9,530 MwD/MtU (Core Avg. Power: 100%FP)

0.6963	0.8466	0.9648	1.0393	1.0775	1.0901	1.0881	1.0802
1.0725	1.0672	1.0633	1.0594	1.0541	1.0471	1.0399	1.0345
1.0326	1.0339	1.0353	1.0292	1.0053	0.9529	0.8621	0.7277

A.4 YGN 4 - Twice-Burned CE Fuel (Cycle 1 & 2)

68 MwD/MtU (Core Avg. Power: 20%FP)

0.3712	0.5377	0.6975	0.8348	0.9492	1.0420	1.1155	1.1726
1.2160	1.2470	1.2671	1.2776	1.2788	1.2710	1.2545	1.2291
1.1944	1.1483	1.0880	1.0098	0.9102	0.7863	0.6370	0.4643

208 MwD/MtU (Core Avg. Power: 50%FP)

0.3841	0.5559	0.7194	0.8582	0.9719	1.0623	1.1325	1.1860
1.2256	1.2530	1.2699	1.2769	1.2741	1.2622	1.2419	1.2132
1.1758	1.1283	1.0680	0.9913	0.8939	0.7728	0.6265	0.4563

579 MwD/MtU (Core Avg. Power: 80%FP)

0.3753	0.5469	0.7109	0.8513	0.9673	1.0606	1.1342	1.1909
1.2332	1.2631	1.2820	1.2898	1.2870	1.2741	1.2521	1.2208
1.1801	1.1288	1.0646	0.9841	0.8839	0.7608	0.6139	0.4444

1,005 MwD/MtU (Core Avg. Power: 100%FP)

0.3879	0.5675	0.7383	0.8831	1.0014	1.0948	1.1664	1.2195
1.2573	1.2821	1.2950	1.2968	1.2880	1.2689	1.2402	1.2026
1.1558	1.0993	1.0310	0.9481	0.8473	0.7260	0.5830	0.4197

1,920 MwD/MtU (Core Avg. Power: 100%FP)

0.3689	0.5447	0.7132	0.8574	0.9767	1.0727	1.1481	1.2054
1.2478	1.2771	1.2944	1.3005	1.2957	1.2805	1.2552	1.2203
1.1759	1.1206	1.0525	0.9685	0.8652	0.7405	0.5931	0.4249

2,514 MwD/MtU (Core Avg. Power: 100%FP)

0.3691	0.5466	0.7169	0.8633	0.9848	1.0825	1.1592	1.2176
1.2603	1.2892	1.3052	1.3087	1.3007	1.2817	1.2525	1.2139
1.1662	1.1088	1.0391	0.9545	0.8517	0.7282	0.5828	0.4166

3,023 MwD/MtU (Core Avg. Power: 100%FP)

0.3620	0.5385	0.7090	0.8566	0.9803	1.0806	1.1597	1.2202
1.2641	1.2933	1.3093	1.3131	1.3049	1.2860	1.2572	1.2188
1.1709	1.1125	1.0414	0.9552	0.8507	0.7252	0.5785	0.4120

4,027 MwD/MtU (Core Avg. Power: 100%FP)

0.3844	0.5723	0.7492	0.8962	1.0117	1.0971	1.1564	1.1948
1.2174	1.2291	1.2335	1.2335	1.2305	1.2246	1.2148	1.1990
1.1745	1.1374	1.0834	1.0078	0.9070	0.7789	0.6234	0.4433

4,944 MwD/MtU (Core Avg. Power: 100%FP)

0.4308	0.6392	0.8226	0.9582	1.0476	1.0974	1.1179	1.1206
1.1156	1.1101	1.1081	1.1113	1.1192	1.1308	1.1446	1.1577
1.1664	1.1655	1.1472	1.1025	1.0227	0.9013	0.7354	0.5274

6,262 MwD/MtU (Core Avg. Power: 100%FP)

0.5224	0.7670	0.9631	1.0833	1.1346	1.1339	1.1031	1.0628
1.0277	1.0054	0.9963	0.9968	1.0027	1.0122	1.0263	1.0474
1.0766	1.1109	1.1406	1.1490	1.1167	1.0255	0.8639	0.6317

7,355 MwD/MtU (Core Avg. Power: 100%FP)

0.5857	0.8195	0.9990	1.0992	1.1306	1.1126	1.0694	1.0222
0.9851	0.9638	0.9572	0.9597	0.9665	0.9760	0.9902	1.0135
1.0489	1.0941	1.1395	1.1684	1.1581	1.0868	0.9398	0.7141

8,199 MwD/MtU (Core Avg. Power: 100%FP)

0.6670	0.8772	1.0339	1.1170	1.1382	1.1165	1.0734	1.0273
0.9900	0.9666	0.9559	0.9534	0.9552	0.9596	0.9689	0.9871
1.0168	1.0565	1.0986	1.1284	1.1267	1.0732	0.9528	0.7598

10,151 MwD/MtU (Core Avg. Power: 100%FP)

0.7626	0.9331	1.0560	1.1179	1.1304	1.1101	1.0742	1.0364
1.0056	0.9851	0.9739	0.9692	0.9676	0.9678	0.9709	0.9800
0.9970	1.0215	1.0487	1.0685	1.0667	1.0276	0.9382	0.7909

11,507 MwD/MtU (Core Avg. Power: 100%FP)

0.7794	0.9311	1.0428	1.1026	1.1199	1.1080	1.0806	1.0484
1.0197	0.9983	0.9848	0.9778	0.9757	0.9777	0.9837	0.9943
1.0096	1.0282	1.0456	1.0537	1.0419	0.9989	0.9145	0.7828

12,534 MwD/MtU (Core Avg. Power: 100%FP)

0.7880	0.9320	1.0375	1.0939	1.1105	1.0998	1.0748	1.0458
1.0201	1.0010	0.9888	0.9823	0.9798	0.9803	0.9842	0.9927
1.0066	1.0242	1.0414	1.0506	1.0416	1.0026	0.9236	0.7979

13,380 MwD/MtU (Core Avg. Power: 100%FP)

0.7782	0.9207	1.0242	1.0787	1.0947	1.0844	1.0610	1.0347
1.0121	0.9960	0.9863	0.9809	0.9785	0.9785	0.9818	0.9906
1.0062	1.0275	1.0501	1.0658	1.0629	1.0289	0.9522	0.8251

13,599 MwD/MtU (Core Avg. Power: 100%FP)

0.6988	0.8315	0.9309	0.9875	1.0105	1.0111	1.0007	0.9885
0.9804	0.9784	0.9822	0.9902	1.0008	1.0133	1.0285	1.0479
1.0720	1.0990	1.1241	1.1384	1.1308	1.0891	1.0022	0.8633

13,916 MwD/MtU (Core Avg. Power: 80%FP)

0.7210	0.8596	0.9618	1.0180	1.0381	1.0343	1.0187	1.0011
0.9879	0.9811	0.9799	0.9824	0.9873	0.9942	1.0042	1.0200
1.0430	1.0716	1.1010	1.1217	1.1211	1.0853	1.0023	0.8645

14,008 MwD/MtU (Core Avg. Power: 74%FP)

0.7588	0.9051	1.0123	1.0697	1.0870	1.0775	1.0545	1.0288
1.0069	0.9922	0.9844	0.9817	0.9819	0.9844	0.9903	1.0015
1.0187	1.0408	1.0637	1.0786	1.0736	1.0354	0.9529	0.8193

14,143 MwD/MtU (Core Avg. Power: 100%FP)

0.6705	0.8044	0.9069	0.9686	0.9984	1.0077	1.0073	1.0061
1.0094	1.0183	1.0313	1.0457	1.0591	1.0700	1.0785	1.0862
1.0946	1.1029	1.1079	1.1029	1.0783	1.0237	0.9300	0.7914

14,751 MwD/MtU (Core Avg. Power: 100%FP)

0.5632	0.7462	0.8979	1.0012	1.0619	1.0909	1.0997	1.0989

1.0960	1.0947	1.0952	1.0962	1.0961	1.0939	1.0905	1.0878
1.0865	1.0850	1.0781	1.0575	1.0120	0.9308	0.8056	0.6340

14,805 MwD/MtU (Core Avg. Power: 100%FP)

0.5629	0.7445	0.8950	0.9976	1.0579	1.0865	1.0955	1.0953
1.0930	1.0922	1.0933	1.0948	1.0950	1.0930	1.0901	1.0880
1.0875	1.0869	1.0812	1.0618	1.0175	0.9370	0.8124	0.6409

15,163 MwD/MtU (Core Avg. Power: 100%FP)

0.5682	0.7483	0.8973	0.9985	1.0577	1.0855	1.0939	1.0931
1.0905	1.0899	1.0912	1.0927	1.0927	1.0908	1.0881	1.0860
1.0857	1.0854	1.0804	1.0617	1.0186	0.9398	0.8170	0.6469

15,935 MwD/MtU (Core Avg. Power: 100%FP)

0.5745	0.7529	0.8998	0.9991	1.0571	1.0840	1.0916	1.0906
1.0881	1.0876	1.0891	1.0907	1.0906	1.0885	1.0856	1.0835
1.0833	1.0835	1.0793	1.0620	1.0203	0.9431	0.8218	0.6534

16,850 MwD/MtU (Core Avg. Power: 100%FP)

0.5824	0.7586	0.9034	1.0007	1.0570	1.0829	1.0899	1.0884
1.0858	1.0851	1.0865	1.0879	1.0879	1.0860	1.0830	1.0808
1.0807	1.0811	1.0774	1.0610	1.0208	0.9456	0.8267	0.6605

17,873 MwD/MtU (Core Avg. Power: 100%FP)

0.5912	0.7649	0.9070	1.0024	1.0571	1.0817	1.0879	1.0861
1.0835	1.0827	1.0838	1.0852	1.0851	1.0831	1.0803	1.0783
1.0783	1.0789	1.0755	1.0599	1.0210	0.9477	0.8310	0.6674

19,048 MwD/MtU (Core Avg. Power: 100%FP)

0.5994	0.7708	0.9108	1.0040	1.0571	1.0808	1.0866	1.0843
1.0813	1.0804	1.0815	1.0829	1.0828	1.0805	1.0774	1.0752
1.0751	1.0760	1.0732	1.0587	1.0212	0.9498	0.8355	0.6745

20,146 MwD/MtU (Core Avg. Power: 100%FP)

0.6072	0.7762	0.9137	1.0049	1.0566	1.0796	1.0851	1.0829
1.0799	1.0790	1.0800	1.0809	1.0804	1.0781	1.0750	1.0728
1.0728	1.0740	1.0717	1.0575	1.0210	0.9512	0.8391	0.6806

21,176 MwD/MtU (Core Avg. Power: 100%FP)

0.6148	0.7811	0.9164	1.0059	1.0565	1.0787	1.0838	1.0811
1.0779	1.0768	1.0776	1.0786	1.0781	1.0758	1.0727	1.0704
1.0706	1.0719	1.0698	1.0565	1.0213	0.9534	0.8432	0.6870

22,202 MwD/MtU (Core Avg. Power: 100%FP)

0.6211	0.7856	0.9189	1.0069	1.0562	1.0775	1.0818	1.0791
1.0759	1.0746	1.0754	1.0765	1.0760	1.0736	1.0706	1.0686
1.0688	1.0703	1.0687	1.0561	1.0221	0.9554	0.8472	0.6931

23,157 MwD/MtU (Core Avg. Power: 100%FP)

0.6245	0.7877	0.9196	1.0067	1.0555	1.0762	1.0802	1.0774
1.0743	1.0734	1.0743	1.0753	1.0748	1.0725	1.0695	1.0676
1.0681	1.0700	1.0688	1.0566	1.0231	0.9571	0.8498	0.6969

23,673 MwD/MtU (Core Avg. Power: 100%FP)

0.6245	0.7877	0.9196	1.0067	1.0555	1.0762	1.0802	1.0774
1.0743	1.0734	1.0743	1.0753	1.0748	1.0725	1.0695	1.0676
1.0681	1.0700	1.0688	1.0566	1.0231	0.9571	0.8498	0.6969

A.5 Diablo Canyon 2 - Once-Burned Vantage-5 Fuel (Cycle 8)

0 MwD/MtU (Core Avg. Power: 100%FP)

0.3300	0.5820	0.7240	0.8240	0.9010	0.9670	1.0260	1.0790
1.1260	1.1670	1.2010	1.2270	1.2460	1.2560	1.2580	1.2510
1.2340	1.2060	1.1670	1.1120	1.0330	0.9150	0.7370	0.4330

150 MwD/MtU (Core Avg. Power: 100%FP)

0.4020	0.6920	0.8410	0.9370	1.0030	1.0540	1.0960	1.1300
1.1570	1.1780	1.1930	1.2020	1.2050	1.2010	1.1910	1.1750
1.1530	1.1240	1.0860	1.0350	0.9650	0.8600	0.7010	0.4190

1,000 MwD/MtU (Core Avg. Power: 100%FP)

0.3650	0.6490	0.8070	0.9160	0.9960	1.0590	1.1120	1.1540
1.1890	1.2140	1.2310	1.2410	1.2410	1.2340	1.2190	1.1960
1.1650	1.1260	1.0770	1.0150	0.9340	0.8210	0.6570	0.3820

2,000 MwD/MtU (Core Avg. Power: 100%FP)

0.3260	0.5950	0.7570	0.8780	0.9740	1.0550	1.1230	1.1790
1.2250	1.2590	1.2820	1.2930	1.2920	1.2810	1.2580	1.2250
1.1830	1.1300	1.0670	0.9910	0.8970	0.7750	0.6090	0.3460

3,000 MwD/MtU (Core Avg. Power: 100%FP)

0.3140	0.5840	0.7520	0.8790	0.9800	1.0640	1.1330	1.1900
1.2350	1.2680	1.2880	1.2980	1.2960	1.2830	1.2600	1.2270
1.1840	1.1300	1.0660	0.9870	0.8900	0.7640	0.5950	0.3320

4,000 MwD/MtU (Core Avg. Power: 100%FP)

0.3170	0.5950	0.7680	0.8980	0.9980	1.0790	1.1440	1.1950
1.2340	1.2620	1.2780	1.2850	1.2810	1.2690	1.2470	1.2160
1.1760	1.1260	1.0640	0.9880	0.8920	0.7660	0.5940	0.3290

5,000 MwD/MtU (Core Avg. Power: 100%FP)

0.3270	0.6190	0.7980	0.9290	1.0250	1.0980	1.1540	1.1950
1.2240	1.2430	1.2540	1.2560	1.2520	1.2410	1.2230	1.1980
1.1650	1.1220	1.0670	0.9960	0.9030	0.7770	0.6030	0.3320

6,000 MwD/MtU (Core Avg. Power: 100%FP)

0.3490	0.6600	0.8470	0.9760	1.0630	1.1220	1.1620	1.1870
1.2020	1.2100	1.2130	1.2110	1.2060	1.1980	1.1860	1.1690
1.1470	1.1150	1.0720	1.0110	0.9250	0.8010	0.6250	0.3430

8,000 MwD/MtU (Core Avg. Power: 100%FP)

0.4100	0.7710	0.9670	1.0790	1.1350	1.1570	1.1600	1.1530
1.1420	1.1290	1.1190	1.1110	1.1060	1.1040	1.1040	1.1050
1.1040	1.0970	1.0810	1.0460	0.9820	0.8700	0.6890	0.3790

10,000 MwD/MtU (Core Avg. Power: 100%FP)

0.4640	0.8640	1.0560	1.1420	1.1660	1.1590	1.1380	1.1130
1.0890	1.0680	1.0520	1.0430	1.0400	1.0420	1.0490	1.0600
1.0720	1.0820	1.0850	1.0730	1.0310	0.9350	0.7550	0.4190

12,000 MwD/MtU (Core Avg. Power: 100%FP)

0.5100	0.9370	1.1160	1.1760	1.1730	1.1450	1.1090	1.0750
1.0460	1.0230	1.0080	0.9990	0.9980	1.0030	1.0130	1.0290
1.0490	1.0700	1.0880	1.0940	1.0720	0.9930	0.8180	0.4590

14,000 MwD/MtU (Core Avg. Power: 100%FP)

0.5480	0.9900	1.1530	1.1880	1.1650	1.1240	1.0830	1.0470
1.0200	1.0000	0.9870	0.9800	0.9790	0.9830	0.9930	1.0080
1.0290	1.0540	1.0810	1.1000	1.0950	1.0350	0.8680	0.4940

16,000 MwD/MtU (Core Avg. Power: 100%FP)

0.5780	1.0270	1.1710	1.1850	1.1500	1.1050	1.0630	1.0300
1.0050	0.9870	0.9760	0.9710	0.9700	0.9730	0.9820	0.9960
1.0170	1.0430	1.0720	1.0990	1.1070	1.0630	0.9070	0.5230

18,000 MwD/MtU (Core Avg. Power: 100%FP)

0.6040	1.0530	1.1770	1.1740	1.1320	1.0850	1.0470	1.0190
0.9990	0.9860	0.9770	0.9720	0.9710	0.9730	0.9790	0.9900
1.0060	1.0300	1.0590	1.0900	1.1090	1.0800	0.9380	0.5490

20,000 MwD/MtU (Core Avg. Power: 100%FP)

0.6250	1.0690	1.1760	1.1620	1.1160	1.0720	1.0390	1.0150
1.0000	0.9890	0.9820	0.9780	0.9760	0.9770	0.9800	0.9870
0.9990	1.0190	1.0460	1.0780	1.1030	1.0860	0.9580	0.5690

22,000 MwD/MtU (Core Avg. Power: 100%FP)

0.6460	1.0810	1.1730	1.1500	1.1040	1.0640	1.0350	1.0160
1.0040	0.9960	0.9900	0.9860	0.9830	0.9810	0.9810	0.9840
0.9920	1.0080	1.0320	1.0630	1.0910	1.0850	0.9700	0.5850

24,450 MwD/MtU (Core Avg. Power: 100%FP)

0.6690	1.0920	1.1660	1.1390	1.0950	1.0600	1.0370	1.0230
1.0140	1.0080	1.0040	0.9990	0.9940	0.9890	0.9860	0.9840
0.9860	0.9950	1.0130	1.0400	1.0680	1.0700	0.9710	0.5980

B

PCI ANALYSIS INPUT DECKS FOR FREY

PCI analyses for each fuel type in the three different PWRs (Yonggwang 2: Vantage-5H, Yonggwang 4: CE, Diablo Canyon: Vantage-5) have been performed using the FREY code. Some input data were derived from the output of ESCORE calculations. Since the general input format for the FREY code is similar in these three different plant cases, only the fourteen analysis matrix cases of once-burned fuel in Yonggwang 2 cycle 10 have been described in the following subsections.

B.1 Base Case (Threshold Power: 20%FP, Ramp Rate: 3%FP/hr)

```
C*
C*   Mesh test file for PWR ramp rate restriction analysis using FREY.
C*   An r-theta (axial slice) model is used to evaluate the power ramp rate and
C*   threshold power levels
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod Base Case (threshold-20%  ramp-3%/hr)
C*  Program Control Parameters
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 9,0.67, 41,27.33, 45,28.33, 50,33.33, 84,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 1.99,0.67, 9.95,27.33, 9.95,100
```

```
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,0.67, 2.731,100
C*
C* Cladding Material Parameters
C*
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,0.67,27.33,28.33,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.2 Threshold Power: 20%FP, Ramp Rate: 5%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-20%  ramp-5%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 9,0.67, 41,16.67, 45,17.67, 50,22.67, 89,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 1.99,0.67, 9.95,16.67, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,0.67, 2.731,100
C*
C* Cladding Material Parameters
C*
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
```

```
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
     TIME=0,0.67,16.67,17.67,100
*POST
  PLOT
     GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.3 Threshold Power: 20%FP, Ramp Rate: 10%FP/hr

```
C*
C*   Mesh test file for PWR ramp rate restriction analysis
C*   using FREY.  An r-theta (axial slice) model is used to
C*   evaluate the power ramp rate and threshold power levels
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-20%  ramp-10%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 9,0.67, 41,8.67, 45,9.67, 50,14.67, 93,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 1.99,0.67, 9.95,8.67, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
```

```
  INTGASPR, NO, FUNCTION, 1,0, 2.731,0.67, 2.731,100
C*
C* Cladding Material Parameters
C*
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,0.67,8.67,9.67,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.4 Threshold Power: 20%FP, Ramp Rate: 30%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-20%  ramp-30%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 9,0.67, 41,3.33, 45,4.33, 50,9.33, 96,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 1.99,0.67, 9.95,3.33, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,0.67, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,0.67,3.33,4.33,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.5 Threshold Power: 40%FP, Ramp Rate: 3%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-40%  ramp-3%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 17,1.33, 41,21.33, 45,22.33, 50,27.33, 87,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 3.98,1.33, 9.95,21.33, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,1.33, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,1.33,21.33,22.33,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.6 Threshold Power: 40%FP, Ramp Rate: 5%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-40%  ramp-5%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 17,1.33, 41,13.33, 45,14.33, 50,19.33, 91,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 3.98,1.33, 9.95,13.33, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,1.33, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
     TIME=0,1.33,13.33,14.33,100
*POST
  PLOT
     GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.7 Threshold Power: 40%FP, Ramp Rate: 10%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-40%  ramp-10%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 17,1.33, 41,7.33, 45,8.33, 50,13.33, 94,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 3.98,1.33, 9.95,7.33, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,1.33, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,1.33,7.33,8.33,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.8 Threshold Power: 60%FP, Ramp Rate: 3%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-60%  ramp-3%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 25,2.0, 41,15.33, 45,16.33, 50,21.33, 90,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 5.97,2.0, 9.95,15.33, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,2.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,2.0,15.33,16.33,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.9 Threshold Power: 60%FP, Ramp Rate: 5%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-60%  ramp-5%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 25,2.0, 41,10.0, 45,11.0, 50,16.0, 92,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 5.97,2.0, 9.95,10.0, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,2.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
     TIME=0,2.0,10.0,11.0,100
*POST
  PLOT
     GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.10 Threshold Power: 60%FP, Ramp Rate: 10%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-60%  ramp-10%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 25,2.0, 41,6.0, 45,7.0, 50,12.0, 94,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 5.97,2.0, 9.95,6.0, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,2.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,2.0,6.0,7.0,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.11 Threshold Power: 90%FP, Ramp Rate: 1%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-90%  ramp-1%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 37,3.0, 41,13.0, 45,14.0, 50,19.0, 91,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 8.955,3.0, 9.95,13.0, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,3.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,3.0,13.0,14.0,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.12 Threshold Power: 90%FP, Ramp Rate: 3%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-90%  ramp-3%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 37,3.0, 41,6.33, 45,7.33, 50,12.33, 94,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 8.955,3.0, 9.95,6.33, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,3.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,3.0,6.33,7.33,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.13 Threshold Power: 90%FP, Ramp Rate: 5%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-90%  ramp-5%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 37,3.0, 41,5.0, 45,6.0, 50,11.0, 95,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 8.955,3.0, 9.95,5.0, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,3.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

```
*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,3.0,5.0,6.0,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

B.14 Threshold Power: 90%FP, Ramp Rate: 10%FP/hr

```
C*
*HEADING
$Mesh Test for PWR Ramp Rate Restriction Analysis 17x17 Fuel Rod
C*
C*  Set up Finite element model using FREY Model Library
C*  Westinghouse 17x17 V-5H Design Parameters
C*  Once-burned Fuel Rod (threshold-90%  ramp-10%/hr)
C*
*UNITS,BU
  INPUT,1,HR,3600
*CONTROL, IGEOM=1, IPLANE=2, ISTRN=SLICE
*RESTART, SAVE=41
C*
C* Time History and Time Step Control
C*
*TIME, NEND=100, TEND=100, DPLIM=50
   TIME,FUNCTION, 1,0, 37,3.0, 41,4.0, 45,5.0, 50,10.0, 95,100.
C*
C* Power History Parameters
C*
*POWER
  AVERAGE,FUNCTION, 0,0, 8.955,3.0, 9.95,4.0, 9.95,100
C*
C* Reactor Parameters
C*
*CORE, PWR, 556.5, 2250, 31990, 9.95, 0
C*
C* Fuel pellet material parameters
C*
*FUEL, NCRACK=321, FRADEN=0.95, FNCK=8.651E21, ENRCH=4.2, FGRN=22
C*
C* Fuel-Cladding gap parameters
C*
*GAP, FILPRS=432.809, FRICTN=0.5,
GAPFAC=0.2554,HELIUM=0.933,KRYPTON=0.008:
  XENON=0.059, RGHF=0.079, RGHC=0.016
  INTGASPR, NO, FUNCTION, 1,0, 2.731,3.0, 2.731,100
C*
C* Cladding Material Parameters
C*
```

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*CLAD, CFLUX=1.2810E14, CWKF=0, MATNDX=ZIRC4, DAMNDX=10000
C*
C* Reactor Coolant Conditions and Boundary Conditions
C*
*FLOW, HYDIAM=.46353, PRESLP=2250, TEMPLP=556.5, FLOWLP=2.39E6
*THERMAL, NPUTHT=1
  BULK TEMP, NO, FUNCTION, 588.19,0, 588.19,100
  FILM COEF, NO, FUNCTION, 4.00E3,0, 4.00E3,100
C*
C*  Printing and Post-Processing Control
C*
*PRINT, MESHDATA=3, DELSTEP=5
      TIME=0,3.0,4.0,5.0,100
*POST
  PLOT
      GRID, ELEMENTS, GRID, NODES
  TABLE, AVGPOWER, MAXTEMP, GAPCON=134,135,136,137,138
  TABLE, GAPTHK=136,137,138,139,140,154, RUPSTRESS=73
  TABLE, STRESS=73,74,81,127,128,135, YIELDSTRESS=73
  TABLE, STRAIN=73,74,81,127,128,135, DAMAGEINDEX
*MODEL, PCI, ,.3225,.3290,.3740,15
C*
*END
```

C

PCI ANALYSIS RESULT DATA - NORMAL GAP / HALF GAP

The key results in the FREY output for the PCI analysis of three different types of fuel (Yonggwang 2: Vantage-5H, Yonggwang 4: ABB-CE, Diablo Canyon: Vantage-5) have been obtained. Since the output format of the FREY code is similar in these plant cases, only the 14 analysis matrix cases of once-burned fuel in Yonggwang 2 cycle 10 have been summarized in the following subsections.

C.1 Base Case (Threshold Power: 20%FP, Ramp Rate: 3%FP/hr)

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0837500	-15.633	-15.633	91.454	91.454	-1.45069E-04	-1.45069E-04	0.00000	0.00000
0.1675000	-14.960	-14.960	91.155	91.156	-9.32445E-05	-9.32445E-05	0.00000	0.00000
0.2512500	-14.279	-14.279	90.858	90.858	-4.14201E-05	-4.14201E-05	0.00000	0.00000
0.3350000	-13.593	-13.593	90.560	90.560	1.12846E-05	1.12846E-05	0.00000	0.00000
0.4187500	-12.926	-10.624	90.263	90.263	6.32865E-05	2.69631E-04	0.00000	0.00000
0.5025000	-12.240	-10.207	89.966	89.959	1.16228E-04	3.26217E-04	0.00000	0.00000
0.5862500	-11.560	-8.4556	89.669	89.657	1.68933E-04	4.25142E-04	0.00000	0.00000
0.6700000	-10.886	-6.9267	89.372	89.358	2.21875E-04	5.52964E-04	0.00000	0.00000
1.5031250	-10.921	-5.1046	89.076	89.057	2.16405E-04	6.96866E-04	0.00000	0.00000
2.3362500	-10.948	-2.9345	88.780	88.756	2.10698E-04	8.66406E-04	0.00000	0.00000
3.1693750	-10.982	-1.3548	88.485	88.457	2.05228E-04	9.95769E-04	0.00000	0.00000
4.0025000	-11.009	0.51662	88.190	88.159	1.99698E-04	1.14866E-03	0.00000	0.00000
4.8356250	-11.043	2.4298	87.895	87.859	1.94346E-04	1.30561E-03	0.00000	0.00000
5.6687500	-11.071	4.3499	87.600	87.559	1.89933E-04	1.46655E-03	0.00000	0.00000
6.5018750	-11.105	6.2632	87.305	87.260	1.84581E-04	1.63161E-03	0.00000	0.00000
7.3350000	-11.133	8.1900	87.011	86.961	1.80346E-04	1.80090E-03	0.00000	0.00000
8.1681250	-11.167	10.124	86.717	86.662	1.75874E-04	1.97560E-03	0.00000	0.00000
9.0012500	-11.194	12.037	86.423	86.363	1.71639E-04	2.15424E-03	0.00000	0.00000
9.8343750	-11.215	13.930	86.129	86.065	1.67344E-04	2.33947E-03	0.00000	0.00000
10.6675000	-11.242	15.810	85.835	85.767	1.63049E-04	2.53092E-03	0.00000	0.00000
11.5006250	-11.276	17.661	85.542	85.469	1.58052E-04	2.72861E-03	0.00000	0.00000
12.3337500	-9.8009	19.466	85.262	85.171	4.66164E-04	2.93388E-03	0.00000	0.00000
13.1668750	-7.9088	21.230	84.821	84.874	5.82694E-04	3.14697E-03	0.00000	0.00000
14.0000000	-7.7430	22.941	84.529	84.578	6.04941E-04	3.36971E-03	0.00000	0.00000
14.8331250	-3.3018	24.626	84.206	84.282	9.15304E-04	3.60076E-03	0.00000	0.00000
15.6662500	-0.6588	26.254	83.982	83.987	1.12098E-03	3.84068E-03	0.00000	0.00000
16.4993750	1.2182	27.815	83.648	83.694	1.27308E-03	4.08855E-03	0.00000	0.00000
17.3325000	4.1528	29.322	83.359	83.401	1.50628E-03	4.34617E-03	0.00000	1.60000E-03
18.1656250	7.8185	30.734	83.065	83.109	1.79740E-03	4.61262E-03	0.00000	3.90000E-03
18.9987500	9.6381	32.086	82.768	82.817	1.95706E-03	4.89006E-03	0.00000	7.30000E-03
19.8318750	12.359	33.342	82.483	82.525	2.19114E-03	5.17620E-03	0.00000	1.21000E-02
20.6650000	15.092	34.544	82.190	82.232	2.43703E-03	5.47264E-03	0.00000	1.88000E-02
21.4981250	17.766	35.685	81.896	81.937	2.68974E-03	5.77990E-03	0.00000	2.81000E-02
22.3312500	20.346	36.729	81.599	81.640	2.95056E-03	6.09498E-03	0.00000	4.07000E-02
23.1643750	22.817	37.714	81.295	81.335	3.22056E-03	6.42075E-03	0.00000	5.76000E-02
23.9975000	25.179	38.657	80.977	81.018	3.50302E-03	6.75600E-03	0.00000	8.02000E-02

24.8306250	27.413	39.532	80.634	80.677	3.79583E-03	7.10219E-03	0.00000	0.10990
25.6637500	29.516	40.367	80.250	80.295	4.10222E-03	7.45732E-03	5.00000E-03	0.14880
26.4968750	31.471	41.154	79.801	79.853	4.42096E-03	7.82338E-03	1.32000E-02	0.19950
27.3300000	33.268	41.900	79.265	79.323	4.75205E-03	8.19874E-03	2.61000E-02	0.26540
27.5800000	33.057	41.462	78.897	78.963	4.78881E-03	8.25243E-03	3.00000E-02	0.28420
27.8300000	32.657	40.786	78.784	78.852	4.81212E-03	8.28726E-03	3.36000E-02	0.30080
28.0800000	32.249	40.097	78.672	78.740	4.83225E-03	8.31785E-03	3.69000E-02	0.31550
28.3300000	31.827	39.440	78.559	78.629	4.85151E-03	8.34464E-03	4.00000E-02	0.32860
29.3300000	30.528	37.541	78.448	78.519	4.92509E-03	8.45495E-03	4.99000E-02	0.36550
30.3300000	29.264	35.784	78.015	78.090	4.97338E-03	8.52699E-03	5.78000E-02	0.39270
31.3300000	28.176	34.286	77.601	77.679	5.01104E-03	8.58187E-03	5.78000E-02	0.41380
32.3300000	27.217	33.025	77.207	77.286	5.04235E-03	8.62729E-03	5.78000E-02	0.43080
33.3300000	26.374	31.928	76.832	76.912	5.06861E-03	8.66437E-03	5.78000E-02	0.44510
35.2908824	25.124	30.351	76.474	76.555	5.11674E-03	8.72895E-03	5.78000E-02	0.46630
37.2517647	23.963	28.929	75.819	75.900	5.14494E-03	8.76790E-03	5.78000E-02	0.48320
39.2126471	22.978	27.745	75.220	75.301	5.16479E-03	8.79463E-03	5.78000E-02	0.48320
41.1735294	22.142	26.752	74.670	74.750	5.17982E-03	8.81308E-03	5.78000E-02	0.48320
43.1344118	21.402	25.888	74.163	74.241	5.19074E-03	8.82517E-03	5.78000E-02	0.48320
45.0952941	20.749	25.146	73.693	73.769	5.19955E-03	8.83410E-03	5.78000E-02	0.48320
47.0561765	20.172	24.494	73.257	73.331	5.20548E-03	8.83908E-03	5.78000E-02	0.48320
49.0170588	19.642	23.902	72.851	72.923	5.21011E-03	8.84172E-03	5.78000E-02	0.48320
50.9779412	19.174	23.385	72.473	72.542	5.21275E-03	8.84247E-03	5.78000E-02	0.48320
52.9388235	18.746	22.916	72.119	72.186	5.21462E-03	8.84123E-03	5.78000E-02	0.48320
54.8997059	18.352	22.486	71.787	71.851	5.21532E-03	8.83870E-03	5.78000E-02	0.48320
56.8605882	17.993	22.092	71.476	71.538	5.21496E-03	8.83440E-03	5.78000E-02	0.48320
58.8214706	17.660	21.745	71.184	71.243	5.21396E-03	8.82999E-03	5.78000E-02	0.48320
60.7823529	17.355	21.413	70.908	70.965	5.21348E-03	8.82445E-03	5.78000E-02	0.48320
62.7432353	17.070	21.106	70.649	70.703	5.21142E-03	8.81810E-03	5.78000E-02	0.48320
64.7041176	16.812	20.821	70.404	70.456	5.20913E-03	8.81151E-03	5.78000E-02	0.48320
66.6650000	16.554	20.563	70.173	70.222	5.20689E-03	8.80410E-03	5.78000E-02	0.48320
68.6258824	16.317	20.318	69.954	70.000	5.20447E-03	8.79645E-03	5.78000E-02	0.48320
70.5867647	16.107	20.094	69.747	69.790	5.20130E-03	8.78793E-03	5.78000E-02	0.48320
72.5476471	15.889	19.883	69.550	69.591	5.19800E-03	8.77940E-03	5.78000E-02	0.48320
74.5085294	15.693	19.673	69.363	69.401	5.19494E-03	8.77093E-03	5.78000E-02	0.48320
76.4694118	15.517	19.489	69.185	69.221	5.19165E-03	8.76129E-03	5.78000E-02	0.48320
78.4302941	15.334	19.306	69.016	69.049	5.18835E-03	8.75170E-03	5.78000E-02	0.48320
80.3911765	15.171	19.136	68.854	68.885	5.18412E-03	8.74241E-03	5.78000E-02	0.48320
82.3520588	15.001	18.973	68.700	68.729	5.18088E-03	8.73283E-03	5.78000E-02	0.48320
84.3129412	14.852	18.824	68.552	68.579	5.17647E-03	8.72307E-03	5.78000E-02	0.48320
86.2738235	14.704	18.688	68.411	68.435	5.17324E-03	8.71354E-03	5.78000E-02	0.48320
88.2347059	14.568	18.532	68.275	68.298	5.16906E-03	8.70402E-03	5.78000E-02	0.48320
90.1955882	14.432	18.396	68.145	68.165	5.16471E-03	8.69449E-03	5.78000E-02	0.48320
92.1564706	14.310	18.274	68.020	68.038	5.16059E-03	8.68497E-03	5.78000E-02	0.48320
94.1173529	14.189	18.138	67.899	67.916	5.15642E-03	8.67656E-03	5.78000E-02	0.48320
96.0782353	14.067	18.016	67.783	67.798	5.15206E-03	8.66797E-03	5.78000E-02	0.48320
98.0391176	13.945	17.900	67.671	67.684	5.14795E-03	8.65956E-03	5.78000E-02	0.48320
100.0000000	13.843	17.778	67.563	67.574	5.14360E-03	8.65210E-03	5.78000E-02	0.48320

C.2 Threshold Power: 20%FP, Ramp Rate: 5%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0837500	-15.633	-15.633	91.454	91.454	-1.45069E-04	-1.45069E-04	0.00000	0.00000
0.1675000	-14.960	-14.960	91.155	91.156	-9.32445E-05	-9.32445E-05	0.00000	0.00000
0.2512500	-14.279	-14.279	90.858	90.858	-4.14201E-05	-4.14201E-05	0.00000	0.00000
0.3350000	-13.593	-13.593	90.560	90.560	1.12846E-05	1.12846E-05	0.00000	0.00000
0.4187500	-12.926	-10.624	90.263	90.263	6.32865E-05	2.69631E-04	0.00000	0.00000
0.5025000	-12.240	-10.207	89.966	89.959	1.16228E-04	3.26217E-04	0.00000	0.00000
0.5862500	-11.560	-8.4556	89.669	89.657	1.68933E-04	4.25142E-04	0.00000	0.00000
0.6700000	-10.886	-6.9267	89.372	89.358	2.21875E-04	5.52964E-04	0.00000	0.00000
1.1700000	-10.921	-5.1055	89.076	89.057	2.18935E-04	6.96281E-04	0.00000	0.00000
1.6700000	-10.961	-2.9345	88.780	88.756	2.15758E-04	8.64821E-04	0.00000	0.00000
2.1700000	-10.996	-1.3421	88.484	88.457	2.12818E-04	9.92421E-04	0.00000	0.00000
2.6700000	-11.030	0.55665	88.189	88.158	2.09580E-04	1.14431E-03	0.00000	0.00000
3.1700000	-11.071	2.4895	87.894	87.858	2.06581E-04	1.30056E-03	0.00000	0.00000
3.6700000	-11.105	4.4505	87.599	87.558	2.03641E-04	1.46056E-03	0.00000	0.00000
4.1700000	-11.133	6.4107	87.304	87.258	2.00641E-04	1.62374E-03	0.00000	0.00000
4.6700000	-11.167	8.4058	87.010	86.959	1.97641E-04	1.79121E-03	0.00000	0.00000
5.1700000	-11.194	10.393	86.715	86.660	1.95581E-04	1.96291E-03	0.00000	0.00000
5.6700000	-11.229	12.382	86.421	86.361	1.92521E-04	2.13891E-03	0.00000	0.00000
6.1700000	-11.269	14.369	86.127	86.062	1.89521E-04	2.32096E-03	0.00000	0.00000
6.6700000	-11.304	16.357	85.834	85.764	1.86699E-04	2.50842E-03	0.00000	0.00000
7.1700000	-11.338	18.324	85.540	85.466	1.84639E-04	2.70141E-03	0.00000	0.00000
7.6700000	-9.3809	20.272	85.255	85.168	4.87435E-04	2.90227E-03	0.00000	0.00000
8.1700000	-10.126	22.171	84.843	84.870	4.94915E-04	3.10966E-03	0.00000	0.00000
8.6700000	-5.8600	24.065	84.514	84.573	7.44122E-04	3.32560E-03	0.00000	0.00000
9.1700000	-3.1221	25.921	84.224	84.278	9.58711E-04	3.54900E-03	0.00000	0.00000
9.6700000	-1.8998	27.760	83.947	83.984	1.05773E-03	3.78076E-03	0.00000	0.00000
10.1700000	0.68328	29.541	83.648	83.690	1.26170E-03	4.02087E-03	0.00000	9.00000E-04
10.6700000	5.2821	31.245	83.354	83.398	1.60120E-03	4.26822E-03	0.00000	2.30000E-03
11.1700000	7.6139	32.889	83.058	83.106	1.79838E-03	4.52585E-03	0.00000	4.40000E-03
11.6700000	9.3142	34.452	82.765	82.814	1.94553E-03	4.79307E-03	0.00000	7.60000E-03
12.1700000	13.040	35.947	82.476	82.523	2.24971E-03	5.06817E-03	0.00000	1.23000E-02
12.6700000	14.786	37.389	82.179	82.231	2.40948E-03	5.35539E-03	0.00000	1.92000E-02
13.1700000	17.540	38.734	81.896	81.940	2.65432E-03	5.64978E-03	0.00000	2.91000E-02
13.6700000	20.329	39.991	81.603	81.646	2.91156E-03	5.95551E-03	0.00000	4.32000E-02
14.1700000	23.032	41.208	81.308	81.350	3.17521E-03	6.26978E-03	0.00000	6.29000E-02
14.6700000	25.639	42.336	81.007	81.049	3.44692E-03	6.59481E-03	0.00000	9.00000E-02
15.1700000	28.152	43.417	80.695	80.738	3.72957E-03	6.92901E-03	0.00000	0.12720
15.6700000	30.563	44.436	80.363	80.408	4.02285E-03	7.27298E-03	3.60000E-03	0.17720
16.1700000	32.838	45.394	79.999	80.045	4.32767E-03	7.62830E-03	9.90000E-03	0.24430
16.6700000	34.991	46.311	79.583	79.634	4.64489E-03	7.99267E-03	2.04000E-02	0.33350
16.9200000	34.602	45.485	79.381	79.437	4.68782E-03	8.06635E-03	2.54000E-02	0.37230
17.1700000	34.073	44.435	79.271	79.329	4.71736E-03	8.11551E-03	2.99000E-02	0.40440
17.4200000	33.523	43.424	79.160	79.219	4.74301E-03	8.15668E-03	3.41000E-02	0.43120
17.6700000	32.970	42.474	79.046	79.108	4.76533E-03	8.19393E-03	3.78000E-02	0.45370
18.6700000	31.352	39.900	78.933	78.996	4.85424E-03	8.34091E-03	4.89000E-02	0.50950
19.6700000	29.857	37.605	78.485	78.554	4.90976E-03	8.43164E-03	5.76000E-02	0.54670
20.6700000	28.571	35.731	78.051	78.124	4.95300E-03	8.49892E-03	5.76000E-02	0.57370
21.6700000	27.469	34.204	77.636	77.712	4.98737E-03	8.55175E-03	5.76000E-02	0.59440
22.6700000	26.524	32.917	77.240	77.318	5.01463E-03	8.59511E-03	5.76000E-02	0.61100
24.6528205	25.118	31.068	76.863	76.942	5.06675E-03	8.67115E-03	5.76000E-02	0.63490
26.6356410	23.869	29.462	76.167	76.247	5.09671E-03	8.71434E-03	5.76000E-02	0.65340
28.6184615	22.795	28.142	75.532	75.613	5.11656E-03	8.74294E-03	5.76000E-02	0.65340
30.6012821	21.898	27.026	74.951	75.031	5.13048E-03	8.76239E-03	5.76000E-02	0.65340
32.5841026	21.110	26.087	74.417	74.496	5.14116E-03	8.77554E-03	5.76000E-02	0.65340
34.5669231	20.410	25.284	73.924	74.001	5.14791E-03	8.78440E-03	5.76000E-02	0.65340
36.5497436	19.806	24.569	73.467	73.542	5.15272E-03	8.78939E-03	5.76000E-02	0.65340
38.5325641	19.262	23.944	73.042	73.116	5.15624E-03	8.79108E-03	5.76000E-02	0.65340
40.5153846	18.773	23.386	72.647	72.718	5.15799E-03	8.79060E-03	5.76000E-02	0.65340
42.4982051	18.325	22.883	72.278	72.347	5.15875E-03	8.78912E-03	5.76000E-02	0.65340
44.4810256	17.931	22.427	71.933	71.999	5.15833E-03	8.78571E-03	5.76000E-02	0.65340
46.4638462	17.551	22.019	71.610	71.673	5.15685E-03	8.78029E-03	5.76000E-02	0.65340
48.4466667	17.205	21.639	71.307	71.368	5.15567E-03	8.77470E-03	5.76000E-02	0.65340
50.4294872	16.886	21.305	71.022	71.080	5.15314E-03	8.76829E-03	5.76000E-02	0.65340
52.4123077	16.601	20.972	70.754	70.809	5.14996E-03	8.76076E-03	5.76000E-02	0.65340
54.3951282	16.310	20.687	70.501	70.553	5.14749E-03	8.75311E-03	5.76000E-02	0.65340

56.3779487	16.058	20.415	70.262	70.312	5.14437E-03	8.74452E-03	5.76000E-02	0.65340
58.3607692	15.814	20.157	70.036	70.083	5.14102E-03	8.73506E-03	5.76000E-02	0.65340
60.3435897	15.591	19.912	69.823	69.867	5.13678E-03	8.72629E-03	5.76000E-02	0.65340
62.3264103	15.374	19.688	69.620	69.662	5.13231E-03	8.71688E-03	5.76000E-02	0.65340
64.3092308	15.177	19.477	69.428	69.467	5.12901E-03	8.70730E-03	5.76000E-02	0.65340
66.2920513	14.988	19.280	69.245	69.282	5.12460E-03	8.69654E-03	5.76000E-02	0.65340
68.2748718	14.804	19.097	69.072	69.106	5.12043E-03	8.68701E-03	5.76000E-02	0.65340
70.2576923	14.621	18.913	68.906	68.938	5.11507E-03	8.67631E-03	5.76000E-02	0.65340
72.2405128	14.459	18.750	68.748	68.778	5.11096E-03	8.66584E-03	5.76000E-02	0.65340
74.2233333	14.303	18.581	68.597	68.624	5.10654E-03	8.65520E-03	5.76000E-02	0.65340
76.2061538	14.153	18.431	68.453	68.478	5.10219E-03	8.64450E-03	5.76000E-02	0.65340
78.1889744	14.018	18.296	68.314	68.337	5.09690E-03	8.63409E-03	5.76000E-02	0.65340
80.1717949	13.869	18.139	68.181	68.202	5.09278E-03	8.62433E-03	5.76000E-02	0.65340
82.1546154	13.748	18.003	68.054	68.072	5.08749E-03	8.61480E-03	5.76000E-02	0.65340
84.1374359	13.612	17.868	67.931	67.948	5.08314E-03	8.60528E-03	5.76000E-02	0.65340
86.1202564	13.490	17.732	67.813	67.828	5.07785E-03	8.59575E-03	5.76000E-02	0.65340
88.1030769	13.388	17.596	67.699	67.712	5.07355E-03	8.58711E-03	5.76000E-02	0.65340
90.0858974	13.266	17.474	67.589	67.600	5.06920E-03	8.57870E-03	5.76000E-02	0.65340
92.0687179	13.157	17.352	67.483	67.492	5.06397E-03	8.57029E-03	5.76000E-02	0.65340
94.0515385	13.056	17.236	67.380	67.387	5.05961E-03	8.56283E-03	5.76000E-02	0.65340
96.0343590	12.947	17.127	67.281	67.286	5.05462E-03	8.55442E-03	5.76000E-02	0.65340
98.0171795	12.860	17.004	67.184	67.187	5.05033E-03	8.54695E-03	5.76000E-02	0.65340
100.0000000	12.765	16.903	67.090	67.092	5.04503E-03	8.53942E-03	5.76000E-02	0.65340

C.3 Threshold Power: 20%FP, Ramp Rate: 10%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0837500	-15.633	-15.633	91.454	91.454	-1.45069E-04	-1.45069E-04	0.00000	0.00000
0.1675000	-14.960	-14.960	91.155	91.156	-9.32445E-05	-9.32445E-05	0.00000	0.00000
0.2512500	-14.279	-14.279	90.858	90.858	-4.14201E-05	-4.14201E-05	0.00000	0.00000
0.3350000	-13.593	-13.593	90.560	90.560	1.12846E-05	1.12846E-05	0.00000	0.00000
0.4187500	-12.926	-10.624	90.263	90.263	6.32865E-05	2.69631E-04	0.00000	0.00000
0.5025000	-12.240	-10.207	89.966	89.959	1.16228E-04	3.26217E-04	0.00000	0.00000
0.5862500	-11.560	-8.4556	89.669	89.657	1.68933E-04	4.25142E-04	0.00000	0.00000
0.6700000	-10.886	-6.9267	89.372	89.358	2.21875E-04	5.52964E-04	0.00000	0.00000
0.9200000	-10.934	-5.1055	89.076	89.057	2.21288E-04	6.96398E-04	0.00000	0.00000
1.1700000	-10.968	-2.9354	88.780	88.756	2.19463E-04	8.64176E-04	0.00000	0.00000
1.4200000	-11.009	-1.3293	88.484	88.456	2.18875E-04	9.90775E-04	0.00000	0.00000
1.6700000	-11.043	0.58994	88.189	88.157	2.17110E-04	1.14097E-03	0.00000	0.00000
1.9200000	-11.091	2.5501	87.893	87.857	2.16523E-04	1.29621E-03	0.00000	0.00000
2.1700000	-11.119	4.5444	87.598	87.557	2.14758E-04	1.45463E-03	0.00000	0.00000
2.4200000	-11.167	6.5659	87.304	87.257	2.14110E-04	1.61593E-03	0.00000	0.00000
2.6700000	-11.194	8.6011	87.009	86.957	2.12346E-04	1.78152E-03	0.00000	0.00000
2.9200000	-11.242	10.664	86.714	86.658	2.11758E-04	1.95146E-03	0.00000	0.00000
3.1700000	-11.276	12.747	86.420	86.359	2.09933E-04	2.12516E-03	0.00000	0.00000
3.4200000	-11.317	14.835	86.126	86.060	2.09346E-04	2.30363E-03	0.00000	0.00000
3.6700000	-11.352	16.946	85.832	85.761	2.07581E-04	2.48704E-03	0.00000	0.00000
3.9200000	-11.380	19.042	85.539	85.463	2.06933E-04	2.67585E-03	0.00000	0.00000
4.1700000	-9.6940	21.152	85.249	85.165	4.33999E-04	2.87002E-03	0.00000	0.00000
4.4200000	-10.884	23.235	84.878	84.867	4.54018E-04	3.07054E-03	0.00000	0.00000
4.6700000	-5.6020	25.346	84.521	84.570	8.03741E-04	3.27942E-03	0.00000	0.00000
4.9200000	-3.0609	27.434	84.210	84.274	9.98397E-04	3.49290E-03	0.00000	0.00000
5.1700000	-1.6421	29.547	83.969	83.980	1.10269E-03	3.71579E-03	0.00000	4.00000E-04
5.4200000	3.50230	31.620	83.641	83.687	1.23772E-03	3.94491E-03	0.00000	1.10000E-03
5.6700000	4.6380	33.618	83.350	83.395	1.57558E-03	4.18027E-03	0.00000	2.10000E-03
5.9200000	7.0671	35.582	83.054	83.103	1.77664E-03	4.42575E-03	0.00000	3.90000E-03
6.1700000	8.8056	37.473	82.758	82.812	1.91731E-03	4.67781E-03	0.00000	6.70000E-03
6.4200000	11.630	39.316	82.476	82.522	2.14327E-03	4.93975E-03	0.00000	1.12000E-02
6.6700000	14.589	41.086	82.184	82.232	2.38264E-03	5.21080E-03	0.00000	1.81000E-02
6.9200000	17.527	42.766	81.894	81.942	2.62483E-03	5.48957E-03	0.00000	2.88000E-02
7.1700000	20.447	44.392	81.604	81.651	2.87226E-03	5.77926E-03	0.00000	4.50000E-02
7.4200000	23.346	45.937	81.313	81.360	3.12686E-03	6.07690E-03	0.00000	6.91000E-02
7.6700000	26.206	47.400	81.022	81.068	3.38964E-03	6.38478E-03	0.00000	0.10450
7.9200000	29.020	48.808	80.727	80.773	3.66001E-03	6.70165E-03	1.20000E-03	0.15590
8.1700000	31.758	50.135	80.426	80.472	3.93837E-03	7.02834E-03	3.50000E-03	0.22930
8.4200000	34.415	51.401	80.114	80.159	4.22838E-03	7.36521E-03	7.70000E-03	0.33300
8.6700000	36.998	52.614	79.782	79.829	4.52768E-03	7.71255E-03	1.53000E-02	0.47850
8.9200000	36.378	50.996	79.707	79.757	4.58242E-03	7.82531E-03	2.21000E-02	0.58620
9.1700000	35.645	49.250	79.614	79.665	4.62219E-03	7.90045E-03	2.81000E-02	0.66440
9.4200000	34.904	47.639	79.513	79.566	4.65401E-03	7.96072E-03	3.33000E-02	0.72250
9.6700000	34.174	46.224	79.406	79.462	4.68044E-03	8.01330E-03	3.79000E-02	0.76710
10.6700000	32.155	42.600	79.297	79.354	4.78875E-03	8.21413E-03	5.05000E-02	0.85800
11.6700000	30.340	39.569	78.848	78.913	4.85290E-03	8.32783E-03	5.97000E-02	0.91070
12.6700000	28.830	37.225	78.402	78.473	4.89937E-03	8.40845E-03	6.68000E-02	0.94550
13.6700000	27.584	35.358	77.972	78.047	4.93662E-03	8.47068E-03	6.68000E-02	0.97070
14.6700000	26.523	33.832	77.560	77.638	4.96682E-03	8.51933E-03	6.68000E-02	0.99000
16.6544186	24.995	31.723	77.168	77.248	5.02181E-03	8.60572E-03	6.68000E-02	1.0165
18.6388372	23.637	29.920	76.444	76.526	5.05153E-03	8.65183E-03	6.68000E-02	1.0362
20.6232558	22.516	28.444	75.784	75.867	5.07021E-03	8.68256E-03	6.68000E-02	1.0362
22.6076744	21.544	27.245	75.182	75.265	5.08395E-03	8.70282E-03	6.68000E-02	1.0362
24.5920930	20.729	26.225	74.629	74.712	5.09357E-03	8.71591E-03	6.68000E-02	1.0362
26.5765116	20.016	25.361	74.120	74.201	5.09915E-03	8.72401E-03	6.68000E-02	1.0362
28.5609302	19.377	24.612	73.649	73.728	5.10378E-03	8.72876E-03	6.68000E-02	1.0362
30.5453488	18.820	23.946	73.212	73.289	5.10530E-03	8.72928E-03	6.68000E-02	1.0362
32.5297674	18.317	23.368	72.805	72.880	5.10594E-03	8.72886E-03	6.68000E-02	1.0362
34.5141860	17.863	22.837	72.426	72.498	5.10552E-03	8.72556E-03	6.68000E-02	1.0362
36.4986047	17.441	22.368	72.071	72.141	5.10404E-03	8.72097E-03	6.68000E-02	1.0362
38.4830233	17.062	21.932	71.740	71.807	5.10262E-03	8.71537E-03	6.68000E-02	1.0362
40.4674419	16.716	21.538	71.429	71.493	5.09939E-03	8.70890E-03	6.68000E-02	1.0362
42.4518605	16.383	21.171	71.136	71.198	5.09691E-03	8.70107E-03	6.68000E-02	1.0362
44.4362791	16.084	20.838	70.862	70.921	5.09350E-03	8.69266E-03	6.68000E-02	1.0362
46.4206977	15.806	20.538	70.603	70.659	5.08920E-03	8.68408E-03	6.68000E-02	1.0362

48.4051163	15.542	20.247	70.358	70.412	5.08567E-03	8.67437E-03	6.68000E-02	1.0362
50.3895349	15.298	19.988	70.128	70.179	5.08143E-03	8.66467E-03	6.68000E-02	1.0362
52.3739535	15.053	19.730	69.909	69.958	5.07696E-03	8.65502E-03	6.68000E-02	1.0362
54.3583721	14.843	19.506	69.703	69.748	5.07161E-03	8.64450E-03	6.68000E-02	1.0362
56.3427907	14.634	19.282	69.507	69.550	5.06720E-03	8.63373E-03	6.68000E-02	1.0362
58.3272093	14.437	19.085	69.320	69.361	5.06278E-03	8.62303E-03	6.68000E-02	1.0362
60.3116279	14.254	18.888	69.143	69.181	5.05749E-03	8.61139E-03	6.68000E-02	1.0362
62.2960465	14.078	18.691	68.974	69.010	5.05214E-03	8.60075E-03	6.68000E-02	1.0362
64.2804651	13.908	18.521	68.813	68.847	5.04779E-03	8.58916E-03	6.68000E-02	1.0362
66.2648837	13.759	18.358	68.660	68.691	5.04249E-03	8.57758E-03	6.68000E-02	1.0362
68.2493023	13.597	18.188	68.513	68.541	5.03726E-03	8.56694E-03	6.68000E-02	1.0362
70.2337209	13.454	18.038	68.372	68.398	5.03197E-03	8.55629E-03	6.68000E-02	1.0362
72.2181395	13.305	17.889	68.237	68.261	5.02761E-03	8.54559E-03	6.68000E-02	1.0362
74.2025581	13.170	17.733	68.108	68.130	5.02238E-03	8.53495E-03	6.68000E-02	1.0362
76.1869767	13.048	17.597	67.984	68.003	5.01685E-03	8.52542E-03	6.68000E-02	1.0362
78.1713953	12.926	17.448	67.864	67.881	5.01162E-03	8.51566E-03	6.68000E-02	1.0362
80.1558140	12.811	17.325	67.748	67.764	5.00639E-03	8.50637E-03	6.68000E-02	1.0362
82.1402326	12.689	17.190	67.637	67.650	5.00115E-03	8.49773E-03	6.68000E-02	1.0362
84.1246512	12.581	17.054	67.529	67.541	4.99680E-03	8.48820E-03	6.68000E-02	1.0362
86.1090698	12.479	16.931	67.425	67.435	4.99157E-03	8.47979E-03	6.68000E-02	1.0362
88.0934884	12.371	16.809	67.325	67.332	4.98633E-03	8.47233E-03	6.68000E-02	1.0362
90.0779070	12.269	16.708	67.227	67.233	4.98110E-03	8.46392E-03	6.68000E-02	1.0362
92.0623256	12.174	16.585	67.132	67.136	4.97657E-03	8.45645E-03	6.68000E-02	1.0362
94.0467442	12.086	16.476	67.040	67.043	4.97134E-03	8.44892E-03	6.68000E-02	1.0362
96.0311628	11.991	16.374	66.951	66.951	4.96610E-03	8.44146E-03	6.68000E-02	1.0362
98.0155814	11.903	16.266	66.863	66.862	4.96181E-03	8.43511E-03	6.68000E-02	1.0362
100.0000000	11.829	16.157	66.779	66.776	4.95658E-03	8.42758E-03	6.68000E-02	1.0362

C.4 Threshold Power: 20%FP, Ramp Rate: 30%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0837500	-15.633	-15.633	91.454	91.454	-1.45069E-04	-1.45069E-04	0.00000	0.00000
0.1675000	-14.960	-14.960	91.155	91.156	-9.32445E-05	-9.32445E-05	0.00000	0.00000
0.2512500	-14.279	-14.279	90.858	90.858	-4.14201E-05	-4.14201E-05	0.00000	0.00000
0.3350000	-13.593	-13.593	90.560	90.560	1.12846E-05	1.12846E-05	0.00000	0.00000
0.4187500	-12.926	-10.624	90.263	90.263	6.32865E-05	2.69631E-04	0.00000	0.00000
0.5025000	-12.240	-10.207	89.966	89.959	1.16228E-04	3.26217E-04	0.00000	0.00000
0.5862500	-11.560	-8.4556	89.669	89.657	1.68933E-04	4.25142E-04	0.00000	0.00000
0.6700000	-10.886	-6.9267	89.372	89.358	2.21875E-04	5.52964E-04	0.00000	0.00000
0.7531250	-10.934	-5.1055	89.076	89.057	2.22523E-04	6.95636E-04	0.00000	0.00000
0.8362500	-10.982	-2.9354	88.780	88.756	2.22230E-04	8.62590E-04	0.00000	0.00000
0.9193750	-11.009	-1.3165	88.484	88.456	2.22640E-04	9.89190E-04	0.00000	0.00000
1.0025000	-11.057	0.61634	88.188	88.157	2.22348E-04	1.13868E-03	0.00000	0.00000
1.0856250	-11.105	2.5970	87.893	87.856	2.22758E-04	1.29298E-03	0.00000	0.00000
1.1687500	-11.147	4.6177	87.598	87.556	2.23405E-04	1.45040E-03	0.00000	0.00000
1.2518750	-11.181	6.6871	87.303	87.256	2.22875E-04	1.61100E-03	0.00000	0.00000
1.3350000	-11.229	8.7632	87.008	86.956	2.23523E-04	1.77547E-03	0.00000	0.00000
1.4181250	-11.276	10.893	86.714	86.657	2.22993E-04	1.94236E-03	0.00000	0.00000
1.5012500	-11.304	13.057	86.420	86.358	2.23640E-04	2.11454E-03	0.00000	0.00000
1.5843750	-11.352	15.248	86.125	86.058	2.23110E-04	2.28983E-03	0.00000	0.00000
1.6675000	-11.400	17.460	85.831	85.760	2.23758E-04	2.46941E-03	0.00000	0.00000
1.7506250	-11.427	19.713	85.538	85.461	2.24168E-04	2.65329E-03	0.00000	0.00000
1.8337500	-11.475	21.985	85.244	85.163	2.23876E-04	2.84140E-03	0.00000	0.00000
1.9168750	-10.277	24.272	84.967	84.865	5.30549E-04	3.03529E-03	0.00000	0.00000
2.0000000	-5.0060	26.614	84.549	84.568	8.82439E-04	3.23530E-03	0.00000	0.00000
2.0831250	-5.3925	28.989	84.229	84.272	8.31902E-04	3.43962E-03	0.00000	1.00000E-04
2.1662500	-2.7727	31.415	83.925	83.978	1.04129E-03	3.64964E-03	0.00000	3.00000E-04
2.2493750	0.95211	33.842	83.647	83.685	1.31828E-03	3.86560E-03	0.00000	6.00000E-04
2.3325000	3.4415	36.249	83.341	83.393	1.51239E-03	4.08586E-03	0.00000	1.20000E-03
2.4156250	5.5718	38.664	83.048	83.102	1.67720E-03	4.31282E-03	0.00000	2.30000E-03
2.4987500	8.4878	41.032	82.762	82.811	1.90112E-03	4.54655E-03	0.00000	4.10000E-03
2.5818750	11.486	43.395	82.472	82.521	2.13097E-03	4.78704E-03	0.00000	7.30000E-03
2.6650000	14.527	45.723	82.181	82.233	2.36500E-03	5.03466E-03	0.00000	1.29000E-02
2.7481250	17.575	47.997	81.892	81.944	2.60144E-03	5.28914E-03	0.00000	2.25000E-02
2.8312500	20.645	50.232	81.603	81.656	2.84312E-03	5.55222E-03	0.00000	3.88000E-02
2.9143750	23.736	52.419	81.315	81.368	3.08938E-03	5.82336E-03	0.00000	6.62000E-02
2.9975000	26.862	54.545	81.027	81.080	3.34247E-03	6.10203E-03	0.00000	0.11180
3.0806250	29.982	56.583	80.740	80.793	3.59997E-03	6.38887E-03	5.00000E-04	0.18640
3.1637500	33.089	58.574	80.452	80.504	3.86430E-03	6.68466E-03	1.50000E-03	0.30710
3.2468750	36.196	60.512	80.163	80.215	4.13491E-03	6.98962E-03	3.40000E-03	0.50020
3.3300000	39.278	62.367	79.870	79.923	4.41388E-03	7.30369E-03	7.30000E-03	0.80430
3.5800000	38.311	58.864	79.863	79.915	4.48514E-03	7.50598E-03	1.70000E-02	1.2788
3.8300000	37.299	55.699	79.801	79.851	4.53689E-03	7.63578E-03	2.50000E-02	1.5405
4.0800000	36.299	52.974	79.721	79.771	4.57782E-03	7.73155E-03	3.18000E-02	1.6980
4.3300000	35.338	50.727	79.629	79.681	4.61025E-03	7.81022E-03	3.74000E-02	1.8013
5.3300000	32.849	45.562	79.529	79.583	4.73965E-03	8.08758E-03	5.16000E-02	1.9580
6.3300000	30.700	41.536	79.093	79.156	4.81179E-03	8.22808E-03	6.13000E-02	2.0332
7.3300000	28.972	38.584	78.644	78.713	4.86290E-03	8.32145E-03	6.85000E-02	2.0776
8.3300000	27.584	36.349	78.204	78.279	4.90209E-03	8.39066E-03	6.85000E-02	2.1074
9.3300000	26.422	34.563	77.782	77.861	4.93322E-03	8.44455E-03	6.85000E-02	2.1293
11.3010870	24.792	32.210	77.380	77.462	4.98910E-03	8.53598E-03	6.85000E-02	2.1577
13.2721739	23.365	30.222	76.641	76.727	5.01770E-03	8.58410E-03	6.85000E-02	2.1782
15.2432609	22.175	28.630	75.969	76.057	5.03620E-03	8.61376E-03	6.85000E-02	2.1940
17.2143478	21.177	27.350	75.355	75.444	5.04882E-03	8.63308E-03	6.85000E-02	2.1940
19.1854348	20.341	26.269	74.793	74.882	5.05733E-03	8.64506E-03	6.85000E-02	2.1940
21.1565217	19.600	25.364	74.274	74.363	5.06272E-03	8.65180E-03	6.85000E-02	2.1940
23.1276087	18.969	24.574	73.795	73.883	5.06530E-03	8.65473E-03	6.85000E-02	2.1940
25.0986957	18.392	23.887	73.351	73.437	5.06664E-03	8.65531E-03	6.85000E-02	2.1940
27.0697826	17.876	23.282	72.938	73.022	5.06616E-03	8.65277E-03	6.85000E-02	2.1940
29.0408696	17.406	22.737	72.553	72.635	5.06469E-03	8.64812E-03	6.85000E-02	2.1940
31.0119565	16.986	22.234	72.193	72.273	5.06321E-03	8.64264E-03	6.85000E-02	2.1940
32.9830435	16.606	21.791	71.856	71.934	5.06067E-03	8.63593E-03	6.85000E-02	2.1940
34.9541304	16.246	21.384	71.540	71.616	5.05726E-03	8.62834E-03	6.85000E-02	2.1940
36.9252174	15.927	21.024	71.244	71.317	5.05384E-03	8.61964E-03	6.85000E-02	2.1940
38.8963043	15.608	20.677	70.965	71.035	5.04931E-03	8.61105E-03	6.85000E-02	2.1940
40.8673913	15.337	20.358	70.702	70.770	5.04508E-03	8.60128E-03	6.85000E-02	2.1940

42.8384783	15.066	20.065	70.454	70.519	5.04060E-03	8.59070E-03	6.85000E-02	2.1940
44.8095652	14.822	19.779	70.220	70.283	5.03613E-03	8.57988E-03	6.85000E-02	2.1940
46.7806522	14.585	19.535	69.999	70.059	5.03078E-03	8.56935E-03	6.85000E-02	2.1940
48.7517391	14.361	19.297	69.789	69.846	5.02643E-03	8.55859E-03	6.85000E-02	2.1940
50.7228261	14.165	19.066	69.590	69.645	5.02107E-03	8.54695E-03	6.85000E-02	2.1940
52.6939130	13.954	18.855	69.402	69.454	5.01554E-03	8.53507E-03	6.85000E-02	2.1940
54.6650000	13.771	18.658	69.222	69.272	5.01025E-03	8.52348E-03	6.85000E-02	2.1940
56.6360870	13.588	18.461	69.051	69.098	5.00496E-03	8.51166E-03	6.85000E-02	2.1940
58.6071739	13.426	18.285	68.888	68.933	4.99967E-03	8.50008E-03	6.85000E-02	2.1940
60.5782609	13.256	18.115	68.733	68.775	4.99414E-03	8.48832E-03	6.85000E-02	2.1940
62.5493478	13.107	17.952	68.584	68.623	4.98890E-03	8.47674E-03	6.85000E-02	2.1940
64.5204348	12.958	17.782	68.442	68.479	4.98343E-03	8.46492E-03	6.85000E-02	2.1940
66.4915217	12.823	17.633	68.305	68.340	4.97814E-03	8.45427E-03	6.85000E-02	2.1940
68.4626087	12.687	17.476	68.174	68.207	4.97291E-03	8.44363E-03	6.85000E-02	2.1940
70.4336957	12.552	17.327	68.049	68.079	4.96744E-03	8.43293E-03	6.85000E-02	2.1940
72.4047826	12.430	17.178	67.928	67.956	4.96220E-03	8.42340E-03	6.85000E-02	2.1940
74.3758696	12.308	17.042	67.811	67.837	4.95697E-03	8.41388E-03	6.85000E-02	2.1940
76.3469565	12.186	16.906	67.699	67.723	4.95150E-03	8.40435E-03	6.85000E-02	2.1940
78.3180435	12.077	16.784	67.590	67.612	4.94627E-03	8.39483E-03	6.85000E-02	2.1940
80.2891304	11.976	16.648	67.485	67.505	4.94103E-03	8.38618E-03	6.85000E-02	2.1940
82.2602174	11.868	16.525	67.384	67.402	4.93580E-03	8.37777E-03	6.85000E-02	2.1940
84.2313043	11.766	16.403	67.285	67.301	4.93033E-03	8.37031E-03	6.85000E-02	2.1940
86.2023913	11.671	16.280	67.190	67.204	4.92510E-03	8.36190E-03	6.85000E-02	2.1940
88.1734783	11.570	16.179	67.097	67.109	4.91987E-03	8.35443E-03	6.85000E-02	2.1940
90.1445652	11.482	16.057	67.007	67.017	4.91557E-03	8.34696E-03	6.85000E-02	2.1940
92.1156522	11.401	15.948	66.919	66.928	4.91034E-03	8.33943E-03	6.85000E-02	2.1940
94.0867391	11.313	15.846	66.834	66.841	4.90511E-03	8.33220E-03	6.85000E-02	2.1940
96.0578261	11.225	15.737	66.750	66.756	4.90087E-03	8.32562E-03	6.85000E-02	2.1940
98.0289130	11.150	15.649	66.669	66.673	4.89564E-03	8.31833E-03	6.85000E-02	2.1940
100.0000000	11.069	15.540	66.590	66.592	4.89041E-03	8.31174E-03	6.85000E-02	2.1940

C.5 Threshold Power: 40%FP, Ramp Rate: 3%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0831250	-16.008	-16.008	91.454	91.454	-1.70716E-04	-1.70716E-04	0.00000	0.00000
0.1662500	-15.681	-15.681	91.155	91.156	-1.45539E-04	-1.45539E-04	0.00000	0.00000
0.2493750	-15.369	-15.369	90.858	90.858	-1.20539E-04	-1.20539E-04	0.00000	0.00000
0.3325000	-15.056	-12.224	90.560	90.560	-9.44218E-05	1.41837E-04	0.00000	0.00000
0.4156250	-14.730	-11.734	90.263	90.258	-6.83045E-05	1.99543E-04	0.00000	0.00000
0.4987500	-14.417	-10.050	89.966	89.957	-4.28900E-05	3.03161E-04	0.00000	0.00000
0.5818750	-14.091	-8.3830	89.669	89.657	-1.67727E-05	4.36435E-04	0.00000	0.00000
0.6650000	-13.778	-6.3162	89.372	89.357	9.34467E-06	5.97039E-04	0.00000	0.00000
0.7481250	-13.452	-4.8269	89.076	89.057	3.54021E-05	7.14766E-04	0.00000	0.00000
0.8312500	-13.139	-2.9972	88.780	88.757	6.17567E-05	8.55846E-04	0.00000	0.00000
0.9143750	-12.813	-1.1325	88.484	88.456	8.81113E-05	1.00104E-03	0.00000	0.00000
0.9975000	-12.507	0.77308	88.188	88.156	1.15109E-04	1.15017E-03	0.00000	0.00000
1.0806250	-12.181	2.7187	87.893	87.856	1.41404E-04	1.30078E-03	0.00000	0.00000
1.1637500	-11.868	4.6994	87.598	87.556	1.67758E-04	1.45620E-03	0.00000	0.00000
1.2468750	-11.542	6.7133	87.303	87.256	1.94993E-04	1.61409E-03	0.00000	0.00000
1.3300000	-11.229	8.7682	87.008	86.956	2.21288E-04	1.77581E-03	0.00000	0.00000
2.1633333	-11.242	10.559	86.714	86.656	2.15403E-04	1.95145E-03	0.00000	0.00000
2.9966667	-11.276	12.351	86.420	86.358	2.08816E-04	2.13314E-03	0.00000	0.00000
3.8300000	-11.290	14.128	86.126	86.060	2.03406E-04	2.32131E-03	0.00000	0.00000
4.6633333	-11.317	15.907	85.832	85.762	1.97639E-04	2.51458E-03	0.00000	0.00000
5.4966667	-11.339	17.637	85.539	85.464	1.92346E-04	2.71526E-03	0.00000	0.00000
6.3300000	-9.4767	19.360	85.253	85.167	4.93046E-04	2.92235E-03	0.00000	0.00000
7.1633333	-10.085	21.037	84.841	84.870	5.04486E-04	3.13639E-03	0.00000	0.00000
7.9966667	-5.8269	22.672	84.514	84.573	7.55911E-04	3.36007E-03	0.00000	0.00000
8.8300000	-3.0394	24.296	84.225	84.278	9.75684E-04	3.59206E-03	0.00000	0.00000
9.6633333	-1.9861	25.877	83.935	83.983	1.06229E-03	3.83104E-03	0.00000	0.00000
10.4966667	0.61083	27.397	83.650	83.690	1.27043E-03	4.07873E-03	0.00000	0.00000
11.3300000	5.1277	28.884	83.355	83.397	1.61064E-03	4.33617E-03	0.00000	1.50000E-03
12.1633333	7.3094	30.282	83.060	83.105	1.80293E-03	4.60162E-03	0.00000	3.60000E-03
12.9966667	8.8808	31.621	82.766	82.813	1.94896E-03	4.87659E-03	0.00000	6.70000E-03
13.8300000	12.581	32.883	82.478	82.521	2.25925E-03	5.16080E-03	0.00000	1.11000E-02
14.6633333	14.407	34.091	82.179	82.228	2.44054E-03	5.45571E-03	0.00000	1.73000E-02
15.4966667	16.971	35.247	81.892	81.933	2.68566E-03	5.75967E-03	0.00000	2.58000E-02
16.3300000	19.577	36.313	81.595	81.636	2.94866E-03	6.07263E-03	0.00000	3.75000E-02
17.1633333	22.068	37.317	81.291	81.331	3.21912E-03	6.39529E-03	0.00000	5.32000E-02
17.9966667	24.443	38.281	80.973	81.014	3.49958E-03	6.72913E-03	0.00000	7.42000E-02
18.8300000	26.690	39.184	80.630	80.672	3.79086E-03	7.07197E-03	0.00000	0.10210
19.6633333	28.814	40.046	80.245	80.291	4.09532E-03	7.42498E-03	4.40000E-03	0.13870
20.4966667	30.810	40.866	79.796	79.848	4.41164E-03	7.78799E-03	1.16000E-02	0.18670
21.3300000	32.655	41.626	79.259	79.318	4.74056E-03	8.16088E-03	2.31000E-02	0.24930
21.5800000	32.457	41.188	78.891	78.958	4.77603E-03	8.21469E-03	2.66000E-02	0.26710
21.8300000	32.064	40.527	78.778	78.846	4.79851E-03	8.24934E-03	2.98000E-02	0.28290
22.0800000	31.670	39.851	78.666	78.735	4.81841E-03	8.27781E-03	3.28000E-02	0.29700
22.3300000	31.240	39.194	78.553	78.623	4.83656E-03	8.30466E-03	3.56000E-02	0.30950
23.3300000	29.976	37.309	78.442	78.513	4.90713E-03	8.41279E-03	4.44000E-02	0.34480
24.3300000	28.746	35.559	78.009	78.084	4.95319E-03	8.48284E-03	5.16000E-02	0.37090
25.3300000	27.671	34.067	77.595	77.673	4.98962E-03	8.53736E-03	5.16000E-02	0.39120
26.3300000	26.726	32.814	77.201	77.281	5.01987E-03	8.58073E-03	5.16000E-02	0.40760
27.3300000	25.904	31.731	76.825	76.906	5.04414E-03	8.61692E-03	5.16000E-02	0.42130
29.2940541	24.668	30.153	76.468	76.549	5.09009E-03	8.68121E-03	5.16000E-02	0.44180
31.2581081	23.534	28.745	75.812	75.894	5.11699E-03	8.71904E-03	5.16000E-02	0.45820
33.2221622	22.563	27.561	75.212	75.293	5.13484E-03	8.74372E-03	5.16000E-02	0.45820
35.1862162	21.727	26.568	74.661	74.741	5.14882E-03	8.76198E-03	5.16000E-02	0.45820
37.1502703	20.986	25.704	74.153	74.232	5.15862E-03	8.77408E-03	5.16000E-02	0.45820
39.1143243	20.348	24.962	73.683	73.760	5.16631E-03	8.78212E-03	5.16000E-02	0.45820
41.0783784	19.777	24.309	73.247	73.322	5.17206E-03	8.78693E-03	5.16000E-02	0.45820
43.0424324	19.261	23.731	72.841	72.913	5.17488E-03	8.78956E-03	5.16000E-02	0.45820
45.0064865	18.793	23.200	72.462	72.532	5.17763E-03	8.78938E-03	5.16000E-02	0.45820
46.9705405	18.378	22.731	72.108	72.175	5.17833E-03	8.78790E-03	5.16000E-02	0.45820
48.9345946	17.992	22.302	71.777	71.841	5.17885E-03	8.78566E-03	5.16000E-02	0.45820
50.8986486	17.625	21.922	71.466	71.527	5.17879E-03	8.78113E-03	5.16000E-02	0.45820
52.8627027	17.306	21.562	71.173	71.232	5.17731E-03	8.77671E-03	5.16000E-02	0.45820
54.8267568	16.994	21.228	70.898	70.954	5.17613E-03	8.77030E-03	5.16000E-02	0.45820
56.7908108	16.716	20.923	70.639	70.692	5.17389E-03	8.76365E-03	5.16000E-02	0.45820
58.7548649	16.444	20.651	70.394	70.445	5.17160E-03	8.75712E-03	5.16000E-02	0.45820

60.7189189	16.207	20.379	70.163	70.211	5.16918E-03	8.74965E-03	5.16000E-02	0.45820
62.6829730	15.963	20.134	69.944	69.989	5.16600E-03	8.74113E-03	5.16000E-02	0.45820
64.6470270	15.753	19.910	69.737	69.780	5.16265E-03	8.73372E-03	5.16000E-02	0.45820
66.6110811	15.543	19.700	69.540	69.580	5.15935E-03	8.72501E-03	5.16000E-02	0.45820
68.5751351	15.346	19.489	69.354	69.391	5.15630E-03	8.71560E-03	5.16000E-02	0.45820
70.5391892	15.162	19.306	69.176	69.211	5.15300E-03	8.70690E-03	5.16000E-02	0.45820
72.5032432	14.987	19.122	69.006	69.039	5.14953E-03	8.69755E-03	5.16000E-02	0.45820
74.4672973	14.817	18.959	68.845	68.875	5.14529E-03	8.68803E-03	5.16000E-02	0.45820
76.4313514	14.668	18.790	68.691	68.718	5.14112E-03	8.67844E-03	5.16000E-02	0.45820
78.3954054	14.499	18.640	68.543	68.569	5.13788E-03	8.66892E-03	5.16000E-02	0.45820
80.3594595	14.363	18.490	68.402	68.425	5.13353E-03	8.65915E-03	5.16000E-02	0.45820
82.3235135	14.228	18.348	68.267	68.288	5.12936E-03	8.64963E-03	5.16000E-02	0.45820
84.2875676	14.092	18.212	68.137	68.155	5.12518E-03	8.64010E-03	5.16000E-02	0.45820
86.2516216	13.956	18.077	68.012	68.028	5.12083E-03	8.63058E-03	5.16000E-02	0.45820
88.2156757	13.834	17.954	67.891	67.906	5.11671E-03	8.62217E-03	5.16000E-02	0.45820
90.1797297	13.719	17.818	67.775	67.788	5.11236E-03	8.61358E-03	5.16000E-02	0.45820
92.1437838	13.611	17.703	67.664	67.675	5.10824E-03	8.60518E-03	5.16000E-02	0.45820
94.1078378	13.503	17.580	67.556	67.565	5.10389E-03	8.59677E-03	5.16000E-02	0.45820
96.0718919	13.401	17.472	67.451	67.458	5.09978E-03	8.58930E-03	5.16000E-02	0.45820
98.0359459	13.293	17.350	67.350	67.355	5.09636E-03	8.58177E-03	5.16000E-02	0.45820
100.0000000	13.205	17.248	67.252	67.256	5.09225E-03	8.57431E-03	5.16000E-02	0.45820

C.6 Threshold Power: 40%FP, Ramp Rate: 5%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0831250	-16.008	-16.008	91.454	91.454	-1.70716E-04	-1.70716E-04	0.00000	0.00000
0.1662500	-15.681	-15.681	91.155	91.156	-1.45539E-04	-1.45539E-04	0.00000	0.00000
0.2493750	-15.369	-15.369	90.858	90.858	-1.20539E-04	-1.20539E-04	0.00000	0.00000
0.3325000	-15.056	-12.224	90.560	90.560	-9.44218E-05	1.41837E-04	0.00000	0.00000
0.4156250	-14.730	-11.734	90.263	90.258	-6.83045E-05	1.99543E-04	0.00000	0.00000
0.4987500	-14.417	-10.050	89.966	89.957	-4.28900E-05	3.03161E-04	0.00000	0.00000
0.5818750	-14.091	-8.3830	89.669	89.657	-1.67727E-05	4.36435E-04	0.00000	0.00000
0.6650000	-13.778	-6.3162	89.372	89.357	9.34467E-06	5.97039E-04	0.00000	0.00000
0.7481250	-13.452	-4.8269	89.076	89.057	3.54021E-05	7.14766E-04	0.00000	0.00000
0.8312500	-13.139	-2.9972	88.780	88.757	6.17567E-05	8.55846E-04	0.00000	0.00000
0.9143750	-12.813	-1.1325	88.484	88.456	8.81113E-05	1.00104E-03	0.00000	0.00000
0.9975000	-12.507	0.77308	88.188	88.156	1.15109E-04	1.15017E-03	0.00000	0.00000
1.0806250	-12.181	2.7187	87.893	87.856	1.41404E-04	1.30078E-03	0.00000	0.00000
1.1637500	-11.868	4.6994	87.598	87.556	1.67758E-04	1.45620E-03	0.00000	0.00000
1.2468750	-11.542	6.7133	87.303	87.256	1.94993E-04	1.61409E-03	0.00000	0.00000
1.3300000	-11.229	8.7682	87.008	86.956	2.21288E-04	1.77581E-03	0.00000	0.00000
1.8300000	-11.256	10.695	86.714	86.656	2.18170E-04	1.94781E-03	0.00000	0.00000
2.3300000	-11.290	12.629	86.420	86.357	2.14993E-04	2.12468E-03	0.00000	0.00000
2.8300000	-11.317	14.569	86.126	86.059	2.11816E-04	2.30791E-03	0.00000	0.00000
3.3300000	-11.352	16.496	85.832	85.761	2.07698E-04	2.49625E-03	0.00000	0.00000
3.8300000	-11.380	18.409	85.538	85.462	2.04758E-04	2.69112E-03	0.00000	0.00000
4.3300000	-9.7697	20.288	85.249	85.165	4.32662E-04	2.89316E-03	0.00000	0.00000
4.8300000	-10.840	22.148	84.876	84.867	4.56592E-04	3.10161E-03	0.00000	0.00000
5.3300000	-5.0268	23.994	84.519	84.571	8.36577E-04	3.31848E-03	0.00000	0.00000
5.8300000	-3.6860	25.796	84.219	84.275	9.56302E-04	3.54301E-03	0.00000	0.00000
6.3300000	-2.4356	27.602	83.929	83.981	1.04602E-03	3.77576E-03	0.00000	0.00000
6.8300000	0.23032	29.355	83.646	83.688	1.25564E-03	4.01588E-03	0.00000	9.00000E-04
7.3300000	4.7258	31.011	83.351	83.396	1.59014E-03	4.26322E-03	0.00000	2.20000E-03
7.8300000	6.9767	32.643	83.056	83.103	1.77973E-03	4.52062E-03	0.00000	4.20000E-03
8.3300000	8.7264	34.206	82.763	82.812	1.93041E-03	4.78790E-03	0.00000	7.20000E-03
8.8300000	12.473	35.666	82.475	82.520	2.23600E-03	5.06188E-03	0.00000	1.17000E-02
9.3300000	14.396	37.115	82.178	82.229	2.41100E-03	5.34798E-03	0.00000	1.83000E-02
9.8300000	17.089	38.453	81.894	81.937	2.65154E-03	5.64219E-03	0.00000	2.77000E-02
10.3300000	19.872	39.718	81.601	81.644	2.90878E-03	5.94593E-03	0.00000	4.10000E-02
10.8300000	22.553	40.934	81.305	81.348	3.17226E-03	6.25984E-03	0.00000	5.97000E-02
11.3300000	25.168	42.077	81.005	81.047	3.44397E-03	6.58282E-03	0.00000	8.56000E-02
11.8300000	27.688	43.171	80.692	80.735	3.72644E-03	6.91578E-03	0.00000	0.12100
12.3300000	30.099	44.190	80.361	80.405	4.01861E-03	7.25869E-03	3.30000E-03	0.16880
12.8300000	32.381	45.162	79.996	80.043	4.32331E-03	7.61177E-03	9.10000E-03	0.23310
13.3300000	34.547	46.092	79.580	79.631	4.63941E-03	7.97485E-03	1.87000E-02	0.31880
13.5800000	34.159	45.272	79.378	79.434	4.68128E-03	8.04765E-03	2.33000E-02	0.35610
13.8300000	33.643	44.236	79.268	79.327	4.71059E-03	8.09669E-03	2.75000E-02	0.38700
14.0800000	33.093	43.226	79.157	79.216	4.73536E-03	8.13693E-03	3.13000E-02	0.41280
14.3300000	32.540	42.289	79.043	79.105	4.75680E-03	8.17399E-03	3.48000E-02	0.43450
15.3300000	30.950	39.729	78.930	78.993	4.84353E-03	8.31787E-03	4.51000E-02	0.48840
16.3300000	29.461	37.448	78.482	78.551	4.89870E-03	8.40747E-03	5.31000E-02	0.52450
17.3300000	28.189	35.580	78.048	78.121	4.94018E-03	8.47370E-03	5.31000E-02	0.55070
18.3300000	27.114	34.047	77.633	77.709	4.97255E-03	8.52547E-03	5.31000E-02	0.57080
19.3300000	26.169	32.760	77.237	77.315	5.00063E-03	8.56771E-03	5.31000E-02	0.58700
21.2975610	24.798	30.945	76.860	76.939	5.04957E-03	8.64176E-03	5.31000E-02	0.61010
23.2651220	23.568	29.339	76.169	76.249	5.07730E-03	8.68458E-03	5.31000E-02	0.62810
25.2326829	22.502	28.033	75.538	75.619	5.09633E-03	8.71231E-03	5.31000E-02	0.62810
27.2002439	21.605	26.924	74.961	75.041	5.11007E-03	8.73175E-03	5.31000E-02	0.62810
29.1678049	20.837	25.991	74.430	74.508	5.11963E-03	8.74379E-03	5.31000E-02	0.62810
31.1353659	20.151	25.189	73.939	74.016	5.12644E-03	8.75265E-03	5.31000E-02	0.62810
33.1029268	19.547	24.474	73.484	73.559	5.13102E-03	8.75740E-03	5.31000E-02	0.62810
35.0704878	19.017	23.855	73.062	73.135	5.13365E-03	8.75916E-03	5.31000E-02	0.62810
37.0380488	18.535	23.304	72.668	72.739	5.13523E-03	8.75891E-03	5.31000E-02	0.62810
39.0056098	18.093	22.807	72.301	72.369	5.13505E-03	8.75655E-03	5.31000E-02	0.62810
40.9731707	17.686	22.352	71.957	72.022	5.13445E-03	8.75290E-03	5.31000E-02	0.62810
42.9407317	17.306	21.944	71.635	71.697	5.13321E-03	8.74749E-03	5.31000E-02	0.62810
44.9082927	16.973	21.564	71.332	71.392	5.13179E-03	8.74189E-03	5.31000E-02	0.62810
46.8758537	16.654	21.216	71.048	71.105	5.12950E-03	8.73548E-03	5.31000E-02	0.62810
48.8434146	16.369	20.897	70.780	70.834	5.12608E-03	8.72795E-03	5.31000E-02	0.62810
50.8109756	16.084	20.591	70.528	70.579	5.12273E-03	8.72024E-03	5.31000E-02	0.62810

52.7785366	15.841	20.319	70.289	70.338	5.11937E-03	8.71166E-03	5.31000E-02	0.62810
54.7460976	15.597	20.061	70.064	70.110	5.11602E-03	8.70313E-03	5.31000E-02	0.62810
56.7136585	15.372	19.823	69.850	69.894	5.11272E-03	8.69366E-03	5.31000E-02	0.62810
58.6812195	15.149	19.592	69.648	69.689	5.10849E-03	8.68496E-03	5.31000E-02	0.62810
60.6487805	14.953	19.382	69.456	69.494	5.10431E-03	8.67443E-03	5.31000E-02	0.62810
62.6163415	14.756	19.185	69.273	69.309	5.09984E-03	8.66485E-03	5.31000E-02	0.62810
64.5839024	14.573	19.001	69.100	69.133	5.09543E-03	8.65508E-03	5.31000E-02	0.62810
66.5514634	14.410	18.825	68.934	68.965	5.09131E-03	8.64456E-03	5.31000E-02	0.62810
68.5190244	14.240	18.655	68.776	68.804	5.08690E-03	8.63392E-03	5.31000E-02	0.62810
70.4865854	14.091	18.492	68.625	68.651	5.08255E-03	8.62345E-03	5.31000E-02	0.62810
72.4541463	13.943	18.336	68.480	68.504	5.07743E-03	8.61281E-03	5.31000E-02	0.62810
74.4217073	13.794	18.187	68.342	68.364	5.07308E-03	8.60211E-03	5.31000E-02	0.62810
76.3892683	13.658	18.050	68.209	68.229	5.06873E-03	8.59264E-03	5.31000E-02	0.62810
78.3568293	13.536	17.901	68.082	68.099	5.06343E-03	8.58288E-03	5.31000E-02	0.62810
80.3243902	13.400	17.765	67.959	67.974	5.05914E-03	8.57335E-03	5.31000E-02	0.62810
82.2919512	13.278	17.643	67.841	67.854	5.05409E-03	8.56400E-03	5.31000E-02	0.62810
84.2595122	13.156	17.507	67.727	67.738	5.04973E-03	8.55542E-03	5.31000E-02	0.62810
86.2270732	13.048	17.385	67.617	67.626	5.04544E-03	8.54677E-03	5.31000E-02	0.62810
88.1946341	12.947	17.263	67.511	67.518	5.04015E-03	8.53837E-03	5.31000E-02	0.62810
90.1621951	12.838	17.140	67.408	67.413	5.03585E-03	8.53090E-03	5.31000E-02	0.62810
92.1297561	12.737	17.018	67.308	67.312	5.03056E-03	8.52249E-03	5.31000E-02	0.62810
94.0973171	12.642	16.916	67.211	67.214	5.02627E-03	8.51502E-03	5.31000E-02	0.62810
96.0648780	12.554	16.807	67.118	67.118	5.02215E-03	8.50773E-03	5.31000E-02	0.62810
98.0324390	12.466	16.699	67.026	67.025	5.01692E-03	8.50115E-03	5.31000E-02	0.62810
100.0000000	12.371	16.597	66.938	66.935	5.01263E-03	8.49391E-03	5.31000E-02	0.62810

C.7 Threshold Power: 40%FP, Ramp Rate: 10%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.008	91.752	91.454	-1.98011E-04	-1.70716E-04	0.00000	0.00000
0.0831250	-16.008	-16.348	91.454	91.752	-1.70716E-04	-1.98011E-04	0.00000	0.00000
0.1662500	-15.681	-15.681	91.155	91.156	-1.45539E-04	-1.45539E-04	0.00000	0.00000
0.2493750	-15.369	-15.369	90.858	90.858	-1.20539E-04	-1.20539E-04	0.00000	0.00000
0.3325000	-15.056	-12.224	90.560	90.560	-9.44218E-05	1.41837E-04	0.00000	0.00000
0.4156250	-14.730	-11.734	90.263	90.258	-6.83045E-05	1.99543E-04	0.00000	0.00000
0.4987500	-14.417	-10.050	89.966	89.957	-4.28900E-05	3.03161E-04	0.00000	0.00000
0.5818750	-14.091	-8.3830	89.669	89.657	-1.67727E-05	4.36435E-04	0.00000	0.00000
0.6650000	-13.778	-6.3162	89.372	89.357	9.34467E-06	5.97039E-04	0.00000	0.00000
0.7481250	-13.452	-4.8269	89.076	89.057	3.54021E-05	7.14766E-04	0.00000	0.00000
0.8312500	-13.139	-2.9972	88.780	88.757	6.17567E-05	8.55846E-04	0.00000	0.00000
0.9143750	-12.813	-1.1325	88.484	88.456	8.81113E-05	1.00104E-03	0.00000	0.00000
0.9975000	-12.507	0.77308	88.188	88.156	1.15109E-04	1.15017E-03	0.00000	0.00000
1.0806250	-12.181	2.7187	87.893	87.856	1.41404E-04	1.30078E-03	0.00000	0.00000
1.1637500	-11.868	4.6994	87.598	87.556	1.67758E-04	1.45620E-03	0.00000	0.00000
1.2468750	-11.542	6.7133	87.303	87.256	1.94993E-04	1.61409E-03	0.00000	0.00000
1.3300000	-11.229	8.7682	87.008	86.956	2.21288E-04	1.77581E-03	0.00000	0.00000
1.5800000	-11.256	10.803	86.714	86.656	2.20463E-04	1.94387E-03	0.00000	0.00000
1.8300000	-11.304	12.852	86.420	86.357	2.18698E-04	2.11787E-03	0.00000	0.00000
2.0800000	-11.339	14.935	86.126	86.058	2.17170E-04	2.29658E-03	0.00000	0.00000
2.3300000	-11.366	17.032	85.832	85.760	2.16346E-04	2.47998E-03	0.00000	0.00000
2.5800000	-11.414	19.107	85.538	85.461	2.14581E-04	2.66897E-03	0.00000	0.00000
2.8300000	-9.8131	21.204	85.247	85.163	4.34682E-04	2.86408E-03	0.00000	0.00000
3.0800000	-10.889	23.273	84.880	84.866	4.56792E-04	3.06478E-03	0.00000	0.00000
3.3300000	-6.1492	25.358	84.522	84.569	7.83581E-04	3.27460E-03	0.00000	0.00000
3.5800000	-1.5001	27.433	84.211	84.273	1.10456E-03	3.48908E-03	0.00000	0.00000
3.8300000	-2.5130	29.524	83.964	83.979	1.05384E-03	3.71214E-03	0.00000	4.00000E-04
4.0800000	-0.0251	31.584	83.641	83.686	1.24620E-03	3.94127E-03	0.00000	1.10000E-03
4.3300000	2.7996	33.554	83.347	83.394	1.46482E-03	4.17757E-03	0.00000	2.10000E-03
4.5800000	7.5758	35.520	83.054	83.102	1.81710E-03	4.42210E-03	0.00000	3.90000E-03
4.8300000	10.007	37.375	82.760	82.811	2.01617E-03	4.67510E-03	0.00000	6.60000E-03
5.0800000	12.799	39.206	82.468	82.520	2.24208E-03	4.93704E-03	0.00000	1.10000E-02
5.3300000	14.406	40.976	82.174	82.230	2.38374E-03	5.20810E-03	0.00000	1.79000E-02
5.5800000	17.324	42.656	81.893	81.940	2.62570E-03	5.48686E-03	0.00000	2.83000E-02
5.8300000	20.242	44.268	81.603	81.650	2.87489E-03	5.77538E-03	0.00000	4.41000E-02
6.0800000	23.128	45.813	81.312	81.359	3.12979E-03	6.07426E-03	0.00000	6.77000E-02
6.3300000	25.988	47.276	81.021	81.067	3.39139E-03	6.38095E-03	0.00000	0.10230
6.5800000	28.801	48.686	80.726	80.772	3.66200E-03	6.69765E-03	1.20000E-03	0.15250
6.8300000	31.539	49.999	80.425	80.470	3.94130E-03	7.02434E-03	3.40000E-03	0.22410
7.0800000	34.203	51.278	80.113	80.158	4.22943E-03	7.36033E-03	7.40000E-03	0.32560
7.3300000	36.786	52.498	79.781	79.828	4.52973E-03	7.70725E-03	1.47000E-02	0.46780
7.5800000	36.180	50.873	79.706	79.756	4.58359E-03	7.81913E-03	2.12000E-02	0.57330
7.8300000	35.447	49.141	79.613	79.664	4.62318E-03	7.89339E-03	2.70000E-02	0.64980
8.0800000	34.692	47.537	79.512	79.565	4.65500E-03	7.95349E-03	3.20000E-02	0.70680
8.3300000	33.963	46.115	79.405	79.460	4.68126E-03	8.00613E-03	3.64000E-02	0.75060
9.3300000	31.958	42.512	79.296	79.353	4.78750E-03	8.20490E-03	4.86000E-02	0.83970
10.3300000	30.142	39.481	78.847	78.912	4.85078E-03	8.31819E-03	5.74000E-02	0.89160
11.3300000	28.646	37.136	78.401	78.472	4.89707E-03	8.39798E-03	6.43000E-02	0.92580
12.3300000	27.408	35.269	77.971	78.045	4.93320E-03	8.45904E-03	6.43000E-02	0.95060
13.3300000	26.353	33.736	77.559	77.637	4.96322E-03	8.50775E-03	6.43000E-02	0.96960
15.2997727	24.839	31.661	77.167	77.246	5.01622E-03	8.59214E-03	6.43000E-02	0.99560
17.2695455	23.501	29.859	76.448	76.529	5.04482E-03	8.63808E-03	6.43000E-02	1.0150
19.2393182	22.366	28.395	75.793	75.875	5.06356E-03	8.66786E-03	6.43000E-02	1.0150
21.2090909	21.421	27.198	75.194	75.276	5.07642E-03	8.68818E-03	6.43000E-02	1.0150
23.1788636	20.606	26.191	74.644	74.726	5.08604E-03	8.70127E-03	6.43000E-02	1.0150
25.1486364	19.893	25.326	74.138	74.217	5.09144E-03	8.70920E-03	6.43000E-02	1.0150
27.1184091	19.268	24.585	73.668	73.747	5.09513E-03	8.71301E-03	6.43000E-02	1.0150
29.0881818	18.711	23.918	73.233	73.309	5.09665E-03	8.71446E-03	6.43000E-02	1.0150
31.0579545	18.208	23.340	72.828	72.902	5.09735E-03	8.71310E-03	6.43000E-02	1.0150
33.0277273	17.760	22.810	72.450	72.521	5.09669E-03	8.70957E-03	6.43000E-02	1.0150
34.9975000	17.332	22.340	72.096	72.166	5.09545E-03	8.70615E-03	6.43000E-02	1.0150
36.9672727	16.960	21.898	71.766	71.832	5.09380E-03	8.69962E-03	6.43000E-02	1.0150
38.9370455	16.606	21.504	71.455	71.519	5.09056E-03	8.69315E-03	6.43000E-02	1.0150
40.9068182	16.281	21.143	71.164	71.225	5.08809E-03	8.68532E-03	6.43000E-02	1.0150
42.8765909	15.989	20.810	70.889	70.948	5.08467E-03	8.67785E-03	6.43000E-02	1.0150
44.8463636	15.704	20.504	70.631	70.686	5.08044E-03	8.66926E-03	6.43000E-02	1.0150

46.8161364	15.446	20.219	70.387	70.440	5.07684E-03	8.65950E-03	6.43000E-02	1.0150
48.7859091	15.189	19.961	70.156	70.206	5.07261E-03	8.64985E-03	6.43000E-02	1.0150
50.7556818	14.965	19.702	69.938	69.986	5.06820E-03	8.64021E-03	6.43000E-02	1.0150
52.7254545	14.755	19.471	69.731	69.776	5.06278E-03	8.62962E-03	6.43000E-02	1.0150
54.6952273	14.545	19.248	69.535	69.577	5.05843E-03	8.61892E-03	6.43000E-02	1.0150
56.6650000	14.348	19.037	69.349	69.389	5.05402E-03	8.60839E-03	6.43000E-02	1.0150
58.6347727	14.165	18.854	69.172	69.209	5.04867E-03	8.59769E-03	6.43000E-02	1.0150
60.6045455	13.982	18.657	69.003	69.038	5.04337E-03	8.58611E-03	6.43000E-02	1.0150
62.5743182	13.820	18.494	68.842	68.874	5.03902E-03	8.57547E-03	6.43000E-02	1.0150
64.5440909	13.650	18.324	68.689	68.718	5.03373E-03	8.56364E-03	6.43000E-02	1.0150
66.5138636	13.501	18.160	68.542	68.569	5.02843E-03	8.55300E-03	6.43000E-02	1.0150
68.4836364	13.353	18.004	68.401	68.426	5.02320E-03	8.54136E-03	6.43000E-02	1.0150
70.4534091	13.217	17.855	68.266	68.288	5.01885E-03	8.53166E-03	6.43000E-02	1.0150
72.4231818	13.081	17.706	68.136	68.157	5.01362E-03	8.52125E-03	6.43000E-02	1.0150
74.3929545	12.959	17.570	68.012	68.030	5.00832E-03	8.51149E-03	6.43000E-02	1.0150
76.3627273	12.837	17.421	67.892	67.908	5.00285E-03	8.50196E-03	6.43000E-02	1.0150
78.3325000	12.715	17.277	67.776	67.791	4.99756E-03	8.49244E-03	6.43000E-02	1.0150
80.3022727	12.593	17.155	67.665	67.677	4.99327E-03	8.48285E-03	6.43000E-02	1.0150
82.2720455	12.492	17.027	67.557	67.568	4.98803E-03	8.47450E-03	6.43000E-02	1.0150
84.2418182	12.384	16.904	67.453	67.462	4.98280E-03	8.46610E-03	6.43000E-02	1.0150
86.2115909	12.282	16.782	67.352	67.359	4.97757E-03	8.45839E-03	6.43000E-02	1.0150
88.1813636	12.174	16.673	67.255	67.259	4.97328E-03	8.44998E-03	6.43000E-02	1.0150
90.1511364	12.086	16.551	67.160	67.163	4.96804E-03	8.44246E-03	6.43000E-02	1.0150
92.1209091	11.991	16.449	67.068	67.069	4.96369E-03	8.43523E-03	6.43000E-02	1.0150
94.0906818	11.903	16.340	66.978	66.978	4.95846E-03	8.42776E-03	6.43000E-02	1.0150
96.0604545	11.815	16.232	66.891	66.889	4.95322E-03	8.42023E-03	6.43000E-02	1.0150
98.0302273	11.734	16.129	66.806	66.802	4.94893E-03	8.41388E-03	6.43000E-02	1.0150
100.0000000	11.646	16.021	66.723	66.718	4.94370E-03	8.40659E-03	6.43000E-02	1.0150

C.8 Threshold Power: 60%FP, Ramp Rate: 3%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.130	-16.130	91.454	91.454	-1.79599E-04	-1.79599E-04	0.00000	0.00000
0.1666667	-15.926	-15.926	91.155	91.156	-1.63244E-04	-1.63244E-04	0.00000	0.00000
0.2500000	-15.722	-15.722	90.858	90.858	-1.46246E-04	-1.46246E-04	0.00000	0.00000
0.3333333	-15.539	-12.299	90.560	90.560	-1.29892E-04	1.36367E-04	0.00000	0.00000
0.4166667	-15.335	-11.721	90.263	90.258	-1.12657E-04	2.00423E-04	0.00000	0.00000
0.5000000	-15.131	-9.9612	89.966	89.956	-9.53618E-05	3.09334E-04	0.00000	0.00000
0.5833333	-14.935	-8.2867	89.669	89.657	-7.81269E-05	4.43013E-04	0.00000	0.00000
0.6666667	-14.744	-6.2071	89.372	89.357	-6.08920E-05	6.04558E-04	0.00000	0.00000
0.7500000	-14.541	-4.7033	89.076	89.056	-4.45972E-05	7.21987E-04	0.00000	0.00000
0.8333333	-14.337	-2.8873	88.780	88.757	-2.73024E-05	8.63770E-04	0.00000	0.00000
0.9166667	-14.140	-1.0098	88.484	88.456	-1.00675E-05	1.00896E-03	0.00000	0.00000
1.0000000	-13.949	0.90254	88.188	88.156	7.40474E-06	1.15780E-03	0.00000	0.00000
1.0833333	-13.745	2.8551	87.893	87.856	2.55199E-05	1.30999E-03	0.00000	0.00000
1.1666667	-13.541	4.8416	87.598	87.556	4.27548E-05	1.46517E-03	0.00000	0.00000
1.2500000	-13.344	6.8701	87.303	87.256	6.02270E-05	1.62301E-03	0.00000	0.00000
1.3333333	-13.154	8.9180	87.008	86.956	7.74619E-05	1.78542E-03	0.00000	0.00000
1.4166667	-12.950	11.021	86.714	86.656	9.48742E-05	1.95167E-03	0.00000	0.00000
1.5000000	-12.753	13.143	86.419	86.357	1.13287E-04	2.12061E-03	0.00000	0.00000
1.5833333	-12.549	15.307	86.125	86.058	1.30521E-04	2.29432E-03	0.00000	0.00000
1.6666667	-12.345	17.505	85.831	85.759	1.48874E-04	2.47303E-03	0.00000	0.00000
1.7500000	-12.141	19.730	85.538	85.460	1.66286E-04	2.65532E-03	0.00000	0.00000
1.8333333	-10.224	21.975	85.254	85.162	5.01870E-04	2.84255E-03	0.00000	0.00000
1.9166667	-9.5188	24.241	84.817	84.864	5.32270E-04	3.03480E-03	0.00000	0.00000
2.0000000	-8.7544	26.563	84.533	84.566	6.01062E-04	3.23393E-03	0.00000	0.00000
2.8331250	-4.3671	27.322	84.212	84.270	9.14997E-04	3.49706E-03	0.00000	0.00000
3.6662500	-2.2539	28.198	83.975	83.977	1.08179E-03	3.76032E-03	0.00000	0.00000
4.4993750	-0.0545	29.155	83.645	83.685	1.25977E-03	4.02670E-03	0.00000	1.40000E-03
5.3325000	2.6968	30.139	83.352	83.393	1.48237E-03	4.29736E-03	0.00000	3.30000E-03
6.1656250	5.9453	31.171	83.059	83.100	1.74973E-03	4.57410E-03	0.00000	5.80000E-03
6.9987500	9.2765	32.203	82.764	82.809	2.02442E-03	4.85653E-03	0.00000	9.30000E-03
7.8318750	11.647	33.235	82.473	82.517	2.24298E-03	5.14673E-03	0.00000	1.40000E-02
8.6650000	13.488	34.253	82.179	82.224	2.42639E-03	5.44469E-03	0.00000	2.03000E-02
9.4981250	16.086	35.272	81.890	81.929	2.67792E-03	5.75183E-03	0.00000	2.89000E-02
10.3312500	18.665	36.229	81.593	81.632	2.93821E-03	6.06567E-03	0.00000	4.04000E-02
11.1643750	21.121	37.172	81.289	81.328	3.20761E-03	6.38834E-03	0.00000	5.57000E-02
11.9975000	23.497	38.082	80.971	81.010	3.48660E-03	6.72082E-03	0.00000	7.59000E-02
12.8306250	25.757	38.958	80.627	80.669	3.77665E-03	7.06260E-03	0.00000	0.10260
13.6637500	27.895	39.792	80.243	80.287	4.07751E-03	7.41320E-03	0.00000	0.13750
14.4968750	29.923	40.600	79.794	79.844	4.39084E-03	7.77403E-03	6.10000E-03	0.18320
15.3300000	31.817	41.373	79.257	79.314	4.71699E-03	8.14480E-03	1.59000E-02	0.24300
15.5800000	31.618	40.942	78.888	78.954	4.75087E-03	8.19744E-03	1.88000E-02	0.25990
15.8300000	31.226	40.281	78.776	78.842	4.77183E-03	8.23121E-03	2.16000E-02	0.27500
16.0800000	30.831	39.606	78.663	78.731	4.78997E-03	8.25956E-03	2.41000E-02	0.28840
16.3300000	30.423	38.949	78.551	78.619	4.80705E-03	8.28529E-03	2.65000E-02	0.30040
17.3300000	29.200	37.070	78.440	78.509	4.87410E-03	8.39125E-03	3.41000E-02	0.33410
18.3300000	27.996	35.327	78.007	78.080	4.91828E-03	8.45912E-03	3.41000E-02	0.35910
19.3300000	26.957	33.856	77.593	77.669	4.95253E-03	8.51165E-03	3.41000E-02	0.37860
20.3300000	26.039	32.596	77.198	77.276	4.98061E-03	8.55372E-03	3.41000E-02	0.39430
21.3300000	25.229	31.526	76.823	76.902	5.00270E-03	8.58886E-03	3.41000E-02	0.40750
23.2967500	24.028	29.955	76.465	76.545	5.04530E-03	8.65115E-03	3.41000E-02	0.42720
25.2635000	22.914	28.547	75.808	75.888	5.07008E-03	8.68586E-03	3.41000E-02	0.42720
27.2302500	21.956	27.364	75.208	75.287	5.08688E-03	8.71018E-03	3.41000E-02	0.42720
29.1970000	21.135	26.370	74.657	74.734	5.09844E-03	8.72639E-03	3.41000E-02	0.42720
31.1637500	20.407	25.520	74.148	74.224	5.10719E-03	8.73743E-03	3.41000E-02	0.42720
33.1305000	19.790	24.778	73.678	73.752	5.11288E-03	8.74435E-03	3.41000E-02	0.42720
35.0972500	19.212	24.111	73.241	73.313	5.11752E-03	8.74805E-03	3.41000E-02	0.42720
37.0640000	18.710	23.533	72.835	72.905	5.12021E-03	8.74892E-03	3.41000E-02	0.42720
39.0307500	18.241	23.016	72.456	72.523	5.12085E-03	8.74850E-03	3.41000E-02	0.42720
40.9975000	17.834	22.547	72.102	72.166	5.12137E-03	8.74596E-03	3.41000E-02	0.42720
42.9642500	17.440	22.119	71.770	71.832	5.12107E-03	8.74255E-03	3.41000E-02	0.42720
44.9310000	17.094	21.725	71.459	71.518	5.11983E-03	8.73807E-03	3.41000E-02	0.42720
46.8977500	16.775	21.364	71.167	71.223	5.11841E-03	8.73254E-03	3.41000E-02	0.42720
48.8645000	16.470	21.045	70.892	70.945	5.11612E-03	8.72613E-03	3.41000E-02	0.42720
50.8312500	16.185	20.739	70.632	70.683	5.11388E-03	8.71860E-03	3.41000E-02	0.42720
52.7980000	15.927	20.453	70.388	70.436	5.11140E-03	8.71089E-03	3.41000E-02	0.42720

54.7647500	15.676	20.195	70.157	70.202	5.10805E-03	8.70348E-03	3.41000E-02	0.42720
56.7315000	15.446	19.937	69.938	69.981	5.10493E-03	8.69495E-03	3.41000E-02	0.42720
58.6982500	15.236	19.713	69.731	69.771	5.10164E-03	8.68619E-03	3.41000E-02	0.42720
60.6650000	15.025	19.502	69.534	69.571	5.09740E-03	8.67678E-03	3.41000E-02	0.42720
62.6317500	14.829	19.305	69.348	69.382	5.09387E-03	8.66720E-03	3.41000E-02	0.42720
64.5985000	14.646	19.108	69.170	69.202	5.08969E-03	8.65849E-03	3.41000E-02	0.42720
66.5652500	14.470	18.924	69.001	69.030	5.08646E-03	8.64803E-03	3.41000E-02	0.42720
68.5320000	14.300	18.755	68.839	68.867	5.08228E-03	8.63844E-03	3.41000E-02	0.42720
70.4987500	14.151	18.592	68.685	68.710	5.07787E-03	8.62892E-03	3.41000E-02	0.42720
72.4655000	14.002	18.443	68.538	68.560	5.07370E-03	8.61845E-03	3.41000E-02	0.42720
74.4322500	13.846	18.286	68.397	68.417	5.07028E-03	8.60875E-03	3.41000E-02	0.42720
76.3990000	13.711	18.151	68.262	68.280	5.06611E-03	8.59828E-03	3.41000E-02	0.42720
78.3657500	13.575	18.002	68.132	68.148	5.06176E-03	8.58876E-03	3.41000E-02	0.42720
80.3325000	13.453	17.880	68.007	68.021	5.05764E-03	8.58017E-03	3.41000E-02	0.42720
82.2992500	13.338	17.743	67.887	67.898	5.05329E-03	8.57059E-03	3.41000E-02	0.42720
84.2660000	13.216	17.607	67.771	67.781	5.04893E-03	8.56200E-03	3.41000E-02	0.42720
86.2327500	13.108	17.485	67.659	67.667	5.04482E-03	8.55359E-03	3.41000E-02	0.42720
88.1995000	12.986	17.363	67.552	67.557	5.03953E-03	8.54519E-03	3.41000E-02	0.42720
90.1662500	12.884	17.261	67.447	67.451	5.03541E-03	8.53772E-03	3.41000E-02	0.42720
92.1330000	12.790	17.139	67.346	67.348	5.03106E-03	8.53025E-03	3.41000E-02	0.42720
94.0997500	12.688	17.030	67.248	67.248	5.02677E-03	8.52272E-03	3.41000E-02	0.42720
96.0665000	12.600	16.929	67.153	67.152	5.02265E-03	8.51549E-03	3.41000E-02	0.42720
98.0332500	12.506	16.819	67.061	67.058	5.01830E-03	8.50796E-03	3.41000E-02	0.42720
100.0000000	12.417	16.718	66.971	66.966	5.01424E-03	8.50161E-03	3.41000E-02	0.42720

C.9 Threshold Power: 60%FP, Ramp Rate: 5%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.130	-16.130	91.454	91.454	-1.79599E-04	-1.79599E-04	0.00000	0.00000
0.1666667	-15.926	-15.926	91.155	91.156	-1.63244E-04	-1.63244E-04	0.00000	0.00000
0.2500000	-15.722	-15.722	90.858	90.858	-1.46246E-04	-1.46246E-04	0.00000	0.00000
0.3333333	-15.539	-12.299	90.560	90.560	-1.29892E-04	1.36367E-04	0.00000	0.00000
0.4166667	-15.335	-11.721	90.263	90.258	-1.12657E-04	2.00423E-04	0.00000	0.00000
0.5000000	-15.131	-9.9612	89.966	89.956	-9.53618E-05	3.09334E-04	0.00000	0.00000
0.5833333	-14.935	-8.2867	89.669	89.657	-7.81269E-05	4.43013E-04	0.00000	0.00000
0.6666667	-14.744	-6.2071	89.372	89.357	-6.08920E-05	6.04558E-04	0.00000	0.00000
0.7500000	-14.541	-4.7033	89.076	89.056	-4.45972E-05	7.21987E-04	0.00000	0.00000
0.8333333	-14.337	-2.8873	88.780	88.757	-2.73024E-05	8.63770E-04	0.00000	0.00000
0.9166667	-14.140	-1.0098	88.484	88.456	-1.00675E-05	1.00896E-03	0.00000	0.00000
1.0000000	-13.949	0.90254	88.188	88.156	7.40474E-06	1.15780E-03	0.00000	0.00000
1.0833333	-13.745	2.8551	87.893	87.856	2.55199E-05	1.30999E-03	0.00000	0.00000
1.1666667	-13.541	4.8416	87.598	87.556	4.27548E-05	1.46517E-03	0.00000	0.00000
1.2500000	-13.344	6.8701	87.303	87.256	6.02270E-05	1.62301E-03	0.00000	0.00000
1.3333333	-13.154	8.9180	87.008	86.956	7.74619E-05	1.78542E-03	0.00000	0.00000
1.4166667	-12.950	11.021	86.714	86.656	9.48742E-05	1.95167E-03	0.00000	0.00000
1.5000000	-12.753	13.143	86.419	86.357	1.13287E-04	2.12061E-03	0.00000	0.00000
1.5833333	-12.549	15.307	86.125	86.058	1.30521E-04	2.29432E-03	0.00000	0.00000
1.6666667	-12.345	17.505	85.831	85.759	1.48874E-04	2.47303E-03	0.00000	0.00000
1.7500000	-12.141	19.730	85.538	85.460	1.66286E-04	2.65532E-03	0.00000	0.00000
1.8333333	-10.224	21.975	85.254	85.162	5.01870E-04	2.84255E-03	0.00000	0.00000
1.9166667	-9.5188	24.241	84.817	84.864	5.32270E-04	3.03480E-03	0.00000	0.00000
2.0000000	-8.7544	26.563	84.533	84.566	6.01062E-04	3.23393E-03	0.00000	0.00000
2.5000000	-4.3816	27.981	84.212	84.270	9.12354E-04	3.47285E-03	0.00000	0.00000
3.0000000	-2.2420	29.406	83.975	83.977	1.07832E-03	3.71831E-03	0.00000	8.00000E-04
3.5000000	-0.0426	30.841	83.644	83.684	1.25395E-03	3.97070E-03	0.00000	1.90000E-03
4.0000000	2.7547	32.193	83.351	83.392	1.47468E-03	4.22739E-03	0.00000	3.60000E-03
4.5000000	5.8540	33.566	83.057	83.100	1.72199E-03	4.49232E-03	0.00000	6.00000E-03
5.0000000	9.7287	34.904	82.763	82.809	2.02946E-03	4.76600E-03	0.00000	9.50000E-03
5.5000000	12.169	36.181	82.468	82.518	2.24059E-03	5.04622E-03	0.00000	1.44000E-02
6.0000000	13.852	37.460	82.178	82.226	2.40225E-03	5.33555E-03	0.00000	2.14000E-02
6.5000000	16.613	38.677	81.893	81.935	2.64844E-03	5.63382E-03	0.00000	3.12000E-02
7.0000000	19.362	39.832	81.600	81.642	2.90456E-03	5.93949E-03	0.00000	4.48000E-02
7.5000000	22.037	40.961	81.305	81.346	3.16810E-03	6.25452E-03	0.00000	6.37000E-02
8.0000000	24.631	42.041	81.004	81.045	3.43963E-03	6.57837E-03	0.00000	8.94000E-02
8.5000000	27.137	43.088	80.692	80.733	3.72074E-03	6.91158E-03	0.00000	0.12420
9.0000000	29.534	44.080	80.360	80.403	4.01297E-03	7.25455E-03	3.00000E-03	0.17110
9.5000000	31.829	45.024	79.995	80.041	4.31538E-03	7.60627E-03	8.20000E-03	0.23360
10.0000000	33.995	45.935	79.579	79.629	4.63048E-03	7.96824E-03	1.69000E-02	0.31680
10.2500000	33.627	45.114	79.377	79.432	4.67218E-03	8.04109E-03	2.10000E-02	0.35300
10.5000000	33.092	44.079	79.267	79.324	4.69972E-03	8.08920E-03	2.48000E-02	0.38300
10.7500000	32.555	43.055	79.156	79.214	4.72432E-03	8.12907E-03	2.82000E-02	0.40800
11.0000000	32.023	42.119	79.042	79.102	4.74458E-03	8.16520E-03	3.14000E-02	0.42900
12.0000000	30.446	39.558	78.929	78.991	4.82920E-03	8.30802E-03	4.07000E-02	0.48130
13.0000000	28.971	37.277	78.481	78.548	4.88219E-03	8.39551E-03	4.80000E-02	0.51630
14.0000000	27.720	35.410	78.047	78.118	4.92143E-03	8.45944E-03	4.80000E-02	0.54160
15.0000000	26.645	33.890	77.632	77.706	4.95251E-03	8.51109E-03	4.80000E-02	0.56110
16.0000000	25.727	32.610	77.236	77.312	4.97859E-03	8.55128E-03	4.80000E-02	0.57690
18.0000000	24.342	30.761	76.859	76.936	5.02648E-03	8.62515E-03	4.80000E-02	0.59960
20.0000000	23.113	29.155	76.157	76.235	5.05320E-03	8.66597E-03	4.80000E-02	0.61720
22.0000000	22.059	27.836	75.517	75.596	5.07088E-03	8.69253E-03	4.80000E-02	0.61720
24.0000000	21.170	26.727	74.933	75.010	5.08262E-03	8.70973E-03	4.80000E-02	0.61720
26.0000000	20.395	25.781	74.395	74.471	5.09107E-03	8.72183E-03	4.80000E-02	0.61720
28.0000000	19.709	24.977	73.899	73.974	5.09676E-03	8.72869E-03	4.80000E-02	0.61720
30.0000000	19.118	24.263	73.440	73.513	5.10028E-03	8.73232E-03	4.80000E-02	0.61720
32.0000000	18.575	23.637	73.014	73.084	5.10180E-03	8.73320E-03	4.80000E-02	0.61720
34.0000000	18.092	23.093	72.617	72.685	5.10249E-03	8.73160E-03	4.80000E-02	0.61720
36.0000000	17.651	22.590	72.247	72.313	5.10208E-03	8.72930E-03	4.80000E-02	0.61720
38.0000000	17.257	22.141	71.901	71.964	5.10154E-03	8.72471E-03	4.80000E-02	0.61720
40.0000000	16.898	21.726	71.577	71.637	5.09918E-03	8.71911E-03	4.80000E-02	0.61720
42.0000000	16.552	21.352	71.274	71.331	5.09665E-03	8.71264E-03	4.80000E-02	0.61720
44.0000000	16.233	20.999	70.988	71.043	5.09435E-03	8.70511E-03	4.80000E-02	0.61720
46.0000000	15.948	20.687	70.720	70.771	5.09099E-03	8.69647E-03	4.80000E-02	0.61720
48.0000000	15.670	20.394	70.466	70.515	5.08764E-03	8.68782E-03	4.80000E-02	0.61720

50.0000000	15.419	20.108	70.228	70.274	5.08334E-03	8.67929E-03	4.80000E-02	0.61720
52.0000000	15.175	19.851	70.002	70.045	5.07981E-03	8.66965E-03	4.80000E-02	0.61720
54.0000000	14.965	19.626	69.788	69.829	5.07558E-03	8.66000E-03	4.80000E-02	0.61720
56.0000000	14.755	19.395	69.586	69.624	5.07116E-03	8.65036E-03	4.80000E-02	0.61720
58.0000000	14.545	19.185	69.394	69.430	5.06699E-03	8.63983E-03	4.80000E-02	0.61720
60.0000000	14.362	18.988	69.212	69.245	5.06258E-03	8.62913E-03	4.80000E-02	0.61720
62.0000000	14.178	18.791	69.038	69.068	5.05722E-03	8.61843E-03	4.80000E-02	0.61720
64.0000000	14.002	18.607	68.873	68.901	5.05287E-03	8.60796E-03	4.80000E-02	0.61720
66.0000000	13.846	18.444	68.715	68.740	5.04846E-03	8.59732E-03	4.80000E-02	0.61720
68.0000000	13.684	18.295	68.564	68.587	5.04340E-03	8.58667E-03	4.80000E-02	0.61720
70.0000000	13.535	18.125	68.420	68.441	5.03905E-03	8.57503E-03	4.80000E-02	0.61720
72.0000000	13.393	17.990	68.282	68.300	5.03376E-03	8.56533E-03	4.80000E-02	0.61720
74.0000000	13.257	17.840	68.149	68.166	5.02941E-03	8.55463E-03	4.80000E-02	0.61720
76.0000000	13.121	17.683	68.022	68.036	5.02417E-03	8.54516E-03	4.80000E-02	0.61720
78.0000000	13.006	17.548	67.900	67.912	5.01982E-03	8.53564E-03	4.80000E-02	0.61720
80.0000000	12.884	17.412	67.782	67.792	5.01459E-03	8.52605E-03	4.80000E-02	0.61720
82.0000000	12.762	17.290	67.668	67.676	5.00929E-03	8.51747E-03	4.80000E-02	0.61720
84.0000000	12.654	17.154	67.559	67.565	5.00500E-03	8.50906E-03	4.80000E-02	0.61720
86.0000000	12.553	17.039	67.453	67.457	4.99971E-03	8.50065E-03	4.80000E-02	0.61720
88.0000000	12.444	16.917	67.350	67.352	4.99542E-03	8.49200E-03	4.80000E-02	0.61720
90.0000000	12.343	16.807	67.251	67.251	4.99106E-03	8.48454E-03	4.80000E-02	0.61720
92.0000000	12.248	16.685	67.154	67.153	4.98583E-03	8.47731E-03	4.80000E-02	0.61720
94.0000000	12.160	16.583	67.061	67.058	4.98154E-03	8.46978E-03	4.80000E-02	0.61720
96.0000000	12.065	16.475	66.970	66.965	4.97654E-03	8.46231E-03	4.80000E-02	0.61720
98.0000000	11.977	16.366	66.881	66.875	4.97219E-03	8.45502E-03	4.80000E-02	0.61720
100.0000000	11.903	16.264	66.795	66.787	4.96790E-03	8.44867E-03	4.80000E-02	0.61720

C.10 Threshold Power: 60%FP, Ramp Rate: 10%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.130	-16.130	91.454	91.454	-1.79599E-04	-1.79599E-04	0.00000	0.00000
0.1666667	-15.926	-15.926	91.155	91.156	-1.63244E-04	-1.63244E-04	0.00000	0.00000
0.2500000	-15.722	-15.722	90.858	90.858	-1.46246E-04	-1.46246E-04	0.00000	0.00000
0.3333333	-15.539	-12.299	90.560	90.560	-1.29892E-04	1.36367E-04	0.00000	0.00000
0.4166667	-15.335	-11.721	90.263	90.258	-1.12657E-04	2.00423E-04	0.00000	0.00000
0.5000000	-15.131	-9.9612	89.966	89.956	-9.53618E-05	3.09334E-04	0.00000	0.00000
0.5833333	-14.935	-8.2867	89.669	89.657	-7.81269E-05	4.43013E-04	0.00000	0.00000
0.6666667	-14.744	-6.2071	89.372	89.357	-6.08920E-05	6.04558E-04	0.00000	0.00000
0.7500000	-14.541	-4.7033	89.076	89.056	-4.45972E-05	7.21987E-04	0.00000	0.00000
0.8333333	-14.337	-2.8873	88.780	88.757	-2.73024E-05	8.63770E-04	0.00000	0.00000
0.9166667	-14.140	-1.0098	88.484	88.456	-1.00675E-05	1.00896E-03	0.00000	0.00000
1.0000000	-13.949	0.90254	88.188	88.156	7.40474E-06	1.15780E-03	0.00000	0.00000
1.0833333	-13.745	2.8551	87.893	87.856	2.55199E-05	1.30999E-03	0.00000	0.00000
1.1666667	-13.541	4.8416	87.598	87.556	4.27548E-05	1.46517E-03	0.00000	0.00000
1.2500000	-13.344	6.8701	87.303	87.256	6.02270E-05	1.62301E-03	0.00000	0.00000
1.3333333	-13.154	8.9180	87.008	86.956	7.74619E-05	1.78542E-03	0.00000	0.00000
1.4166667	-12.950	11.021	86.714	86.656	9.48742E-05	1.95167E-03	0.00000	0.00000
1.5000000	-12.753	13.143	86.419	86.357	1.13287E-04	2.12061E-03	0.00000	0.00000
1.5833333	-12.549	15.307	86.125	86.058	1.30521E-04	2.29432E-03	0.00000	0.00000
1.6666667	-12.345	17.505	85.831	85.759	1.48874E-04	2.47303E-03	0.00000	0.00000
1.7500000	-12.141	19.730	85.538	85.460	1.66286E-04	2.65532E-03	0.00000	0.00000
1.8333333	-10.224	21.975	85.254	85.162	5.01870E-04	2.84255E-03	0.00000	0.00000
1.9166667	-9.5188	24.241	84.817	84.864	5.32270E-04	3.03480E-03	0.00000	0.00000
2.0000000	-8.7544	26.563	84.533	84.566	6.01062E-04	3.23393E-03	0.00000	0.00000
2.2500000	-4.3825	28.530	84.212	84.270	9.10651E-04	3.45294E-03	0.00000	0.00000
2.5000000	-2.2429	30.501	83.974	83.977	1.07521E-03	3.67912E-03	0.00000	5.00000E-04
2.7500000	-0.0307	32.452	83.643	83.684	1.24803E-03	3.91254E-03	0.00000	1.30000E-03
3.0000000	2.7939	34.321	83.350	83.392	1.46799E-03	4.15213E-03	0.00000	2.50000E-03
3.2500000	5.9528	36.172	83.056	83.101	1.71253E-03	4.40095E-03	0.00000	4.50000E-03
3.5000000	9.9103	37.939	82.762	82.810	2.01731E-03	4.65725E-03	0.00000	7.60000E-03
3.7500000	12.424	39.681	82.467	82.519	2.22250E-03	4.92230E-03	0.00000	1.23000E-02
4.0000000	14.258	41.355	82.178	82.229	2.37929E-03	5.19559E-03	0.00000	1.97000E-02
4.2500000	17.154	42.960	81.894	81.939	2.62131E-03	5.47747E-03	0.00000	3.07000E-02
4.5000000	20.080	44.498	81.603	81.649	2.87144E-03	5.76799E-03	0.00000	4.73000E-02
4.7500000	22.966	45.982	81.313	81.358	3.12652E-03	6.06792E-03	0.00000	7.16000E-02
5.0000000	25.827	47.398	81.021	81.066	3.38882E-03	6.37574E-03	0.00000	0.10700
5.2500000	28.626	48.760	80.726	80.771	3.65943E-03	6.69473E-03	1.10000E-03	0.15790
5.5000000	31.357	50.039	80.426	80.469	3.93850E-03	7.02136E-03	3.20000E-03	0.23010
5.7500000	34.007	51.278	80.113	80.157	4.22668E-03	7.35828E-03	7.10000E-03	0.33170
6.0000000	36.576	52.483	79.781	79.827	4.52651E-03	7.70539E-03	1.41000E-02	0.47330
6.2500000	35.956	50.845	79.706	79.755	4.58061E-03	7.81727E-03	2.04000E-02	0.57830
6.5000000	35.217	49.092	79.613	79.663	4.61902E-03	7.89153E-03	2.59000E-02	0.65410
6.7500000	34.482	47.488	79.512	79.564	4.64996E-03	7.95139E-03	3.08000E-02	0.71040
7.0000000	33.745	46.053	79.405	79.459	4.67622E-03	8.00402E-03	3.50000E-02	0.75370
8.0000000	31.727	42.430	79.296	79.352	4.78211E-03	8.20268E-03	4.66000E-02	0.84170
9.0000000	29.932	39.406	78.848	78.910	4.84432E-03	8.31415E-03	5.51000E-02	0.89280
10.0000000	28.428	37.041	78.402	78.470	4.88950E-03	8.39283E-03	5.51000E-02	0.92640
11.0000000	27.190	35.187	77.971	78.044	4.92475E-03	8.45376E-03	5.51000E-02	0.95080
12.0000000	26.143	33.661	77.560	77.635	4.95365E-03	8.50135E-03	5.51000E-02	0.96960
14.0000000	24.629	31.553	77.168	77.245	5.00642E-03	8.58568E-03	5.51000E-02	0.99540
16.0000000	23.277	29.736	76.438	76.517	5.03508E-03	8.63162E-03	5.51000E-02	1.0147
18.0000000	22.135	28.273	75.774	75.854	5.05269E-03	8.66011E-03	5.51000E-02	1.0147
20.0000000	21.197	27.062	75.168	75.248	5.06532E-03	8.67855E-03	5.51000E-02	1.0147
22.0000000	20.376	26.055	74.613	74.692	5.07383E-03	8.69147E-03	5.51000E-02	1.0147
24.0000000	19.662	25.190	74.101	74.178	5.07852E-03	8.69827E-03	5.51000E-02	1.0147
26.0000000	19.031	24.429	73.627	73.703	5.08203E-03	8.70208E-03	5.51000E-02	1.0147
28.0000000	18.467	23.775	73.188	73.262	5.08361E-03	8.70266E-03	5.51000E-02	1.0147
30.0000000	17.970	23.183	72.780	72.852	5.08313E-03	8.70018E-03	5.51000E-02	1.0147
32.0000000	17.516	22.653	72.400	72.469	5.08254E-03	8.69665E-03	5.51000E-02	1.0147
34.0000000	17.109	22.184	72.045	72.112	5.08106E-03	8.69211E-03	5.51000E-02	1.0147
36.0000000	16.728	21.762	71.712	71.776	5.07852E-03	8.68558E-03	5.51000E-02	1.0147
38.0000000	16.382	21.368	71.400	71.462	5.07529E-03	8.67799E-03	5.51000E-02	1.0147
40.0000000	16.049	21.001	71.108	71.167	5.07187E-03	8.67046E-03	5.51000E-02	1.0147
42.0000000	15.765	20.668	70.833	70.889	5.06828E-03	8.66181E-03	5.51000E-02	1.0147
44.0000000	15.473	20.369	70.573	70.627	5.06398E-03	8.65205E-03	5.51000E-02	1.0147

46.0000000	15.215	20.084	70.329	70.380	5.05951E-03	8.64234E-03	5.51000E-02	1.0147
48.0000000	14.978	19.812	70.098	70.146	5.05504E-03	8.63270E-03	5.51000E-02	1.0147
50.0000000	14.734	19.567	69.880	69.925	5.05086E-03	8.62217E-03	5.51000E-02	1.0147
52.0000000	14.524	19.322	69.673	69.716	5.04645E-03	8.61141E-03	5.51000E-02	1.0147
54.0000000	14.314	19.111	69.477	69.517	5.04110E-03	8.60089E-03	5.51000E-02	1.0147
56.0000000	14.118	18.901	69.291	69.328	5.03581E-03	8.58924E-03	5.51000E-02	1.0147
58.0000000	13.934	18.704	69.114	69.149	5.03145E-03	8.57836E-03	5.51000E-02	1.0147
60.0000000	13.772	18.521	68.945	68.978	5.02586E-03	8.56678E-03	5.51000E-02	1.0147
62.0000000	13.602	18.358	68.785	68.815	5.02057E-03	8.55520E-03	5.51000E-02	1.0147
64.0000000	13.440	18.188	68.631	68.659	5.01534E-03	8.54338E-03	5.51000E-02	1.0147
66.0000000	13.291	18.025	68.484	68.510	5.01004E-03	8.53273E-03	5.51000E-02	1.0147
68.0000000	13.142	17.869	68.344	68.367	5.00569E-03	8.52115E-03	5.51000E-02	1.0147
70.0000000	12.999	17.706	68.209	68.230	5.00022E-03	8.51051E-03	5.51000E-02	1.0147
72.0000000	12.864	17.570	68.080	68.099	4.99499E-03	8.50098E-03	5.51000E-02	1.0147
74.0000000	12.742	17.414	67.956	67.972	4.98970E-03	8.49028E-03	5.51000E-02	1.0147
76.0000000	12.613	17.277	67.836	67.851	4.98446E-03	8.48075E-03	5.51000E-02	1.0147
78.0000000	12.505	17.142	67.721	67.733	4.97923E-03	8.47217E-03	5.51000E-02	1.0147
80.0000000	12.383	17.006	67.610	67.620	4.97376E-03	8.46264E-03	5.51000E-02	1.0147
82.0000000	12.281	16.884	67.502	67.511	4.96847E-03	8.45424E-03	5.51000E-02	1.0147
84.0000000	12.173	16.761	67.398	67.405	4.96417E-03	8.44559E-03	5.51000E-02	1.0147
86.0000000	12.065	16.646	67.298	67.303	4.95894E-03	8.43718E-03	5.51000E-02	1.0147
88.0000000	11.963	16.523	67.200	67.203	4.95371E-03	8.42972E-03	5.51000E-02	1.0147
90.0000000	11.875	16.401	67.106	67.107	4.94942E-03	8.42225E-03	5.51000E-02	1.0147
92.0000000	11.781	16.293	67.014	67.013	4.94418E-03	8.41478E-03	5.51000E-02	1.0147
94.0000000	11.693	16.191	66.924	66.922	4.93895E-03	8.40749E-03	5.51000E-02	1.0147
96.0000000	11.604	16.082	66.837	66.833	4.93466E-03	8.40002E-03	5.51000E-02	1.0147
98.0000000	11.523	15.980	66.752	66.747	4.92942E-03	8.39273E-03	5.51000E-02	1.0147
100.0000000	11.449	15.872	66.670	66.662	4.92513E-03	8.38614E-03	5.51000E-02	1.0147

C.11 Threshold Power: 90%FP, Ramp Rate: 1%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.205	-16.205	91.454	91.454	-1.86186E-04	-1.86186E-04	0.00000	0.00000
0.1666667	-16.083	-16.083	91.155	91.156	-1.74599E-04	-1.74599E-04	0.00000	0.00000
0.2500000	-15.974	-13.714	90.858	90.858	-1.63951E-04	2.03835E-05	0.00000	0.00000
0.3333333	-15.852	-12.311	90.560	90.554	-1.53304E-04	1.44983E-04	0.00000	0.00000
0.4166667	-15.737	-11.340	90.263	90.257	-1.41716E-04	1.99836E-04	0.00000	0.00000
0.5000000	-15.615	-9.9732	89.966	89.957	-1.31069E-04	3.12279E-04	0.00000	0.00000
0.5833333	-15.506	-8.0914	89.669	89.657	-1.19481E-04	4.58591E-04	0.00000	0.00000
0.6666667	-15.383	-6.4255	89.372	89.356	-1.08597E-04	5.89670E-04	0.00000	0.00000
0.7500000	-15.255	-4.6633	89.076	89.057	-9.70691E-05	7.25805E-04	0.00000	0.00000
0.8333333	-15.146	-2.8200	88.780	88.756	-8.64217E-05	8.68467E-04	0.00000	0.00000
0.9166667	-15.024	-0.93488	88.484	88.456	-7.48341E-05	1.01413E-03	0.00000	0.00000
1.0000000	-14.915	0.98349	88.188	88.156	-6.39494E-05	1.16290E-03	0.00000	0.00000
1.0833333	-14.786	2.9436	87.893	87.856	-5.24218E-05	1.31585E-03	0.00000	0.00000
1.1666667	-14.664	4.9371	87.598	87.556	-4.05970E-05	1.47098E-03	0.00000	0.00000
1.2500000	-14.556	6.9509	87.303	87.256	-3.00095E-05	1.62928E-03	0.00000	0.00000
1.3333333	-14.426	9.0194	87.008	86.956	-1.81847E-05	1.79187E-03	0.00000	0.00000
1.4166667	-14.304	11.115	86.714	86.656	-6.65710E-06	1.95764E-03	0.00000	0.00000
1.5000000	-14.182	13.245	86.419	86.357	5.16770E-06	2.12770E-03	0.00000	0.00000
1.5833333	-14.074	15.415	86.125	86.058	1.57552E-05	2.30211E-03	0.00000	0.00000
1.6666667	-13.944	17.620	85.831	85.759	2.75800E-05	2.48076E-03	0.00000	0.00000
1.7500000	-12.380	19.838	85.540	85.460	2.44059E-04	2.66352E-03	0.00000	0.00000
1.8333333	-13.978	22.096	85.180	85.162	2.76266E-04	2.85099E-03	0.00000	0.00000
1.9166667	-8.3598	24.362	84.818	84.864	5.85692E-04	3.04300E-03	0.00000	0.00000
2.0000000	-5.6564	26.677	84.521	84.567	8.20128E-04	3.24348E-03	0.00000	0.00000
2.0833333	-1.6552	29.067	84.228	84.271	1.06532E-03	3.44715E-03	0.00000	1.00000E-04
2.1666667	-2.5109	31.480	83.947	83.977	1.04722E-03	3.65683E-03	0.00000	3.00000E-04
2.2500000	0.12907	33.900	83.642	83.685	1.25131E-03	3.87209E-03	0.00000	6.00000E-04
2.3333333	4.5385	36.294	83.349	83.393	1.57484E-03	4.09147E-03	0.00000	1.20000E-03
2.4166667	5.7069	38.697	83.054	83.101	1.67857E-03	4.31867E-03	0.00000	2.30000E-03
2.5000000	9.6840	41.050	82.764	82.811	1.97724E-03	4.55175E-03	0.00000	4.20000E-03
2.5833333	12.965	43.421	82.470	82.521	2.23126E-03	4.79154E-03	0.00000	7.40000E-03
2.6666667	14.710	45.735	82.174	82.232	2.36876E-03	5.03922E-03	0.00000	1.30000E-02
2.7500000	17.619	47.996	81.894	81.943	2.59762E-03	5.29330E-03	0.00000	2.26000E-02
2.8333333	20.723	50.217	81.605	81.655	2.84159E-03	5.55544E-03	0.00000	3.89000E-02
2.9166667	23.813	52.397	81.317	81.367	3.08891E-03	5.82564E-03	0.00000	6.63000E-02
3.0000000	26.932	54.497	81.029	81.080	3.34176E-03	6.10366E-03	0.00000	0.11160
5.5000000	25.911	43.273	80.741	80.792	3.77300E-03	7.15960E-03	0.00000	0.29270
8.0000000	25.745	38.487	80.222	80.265	4.14712E-03	7.69119E-03	0.00000	0.37520
10.5000000	26.084	36.058	79.401	79.453	4.50468E-03	8.11559E-03	0.00000	0.43490
13.0000000	26.729	34.956	78.322	78.391	4.86142E-03	8.51606E-03	0.00000	0.49160
13.2500000	26.727	34.637	77.282	77.365	4.88537E-03	8.53308E-03	0.00000	0.49740
13.5000000	26.572	34.295	77.185	77.269	4.89911E-03	8.54911E-03	0.00000	0.50280
13.7500000	26.369	33.960	77.089	77.173	4.91049E-03	8.56378E-03	0.00000	0.50790
14.0000000	26.144	33.611	76.994	77.078	4.92083E-03	8.57741E-03	0.00000	0.51280
15.0000000	25.418	32.577	76.900	76.984	4.96014E-03	8.63300E-03	0.00000	0.52880
16.0000000	24.664	31.529	76.536	76.623	4.98593E-03	8.66872E-03	0.00000	0.54230
17.0000000	23.979	30.584	76.190	76.278	5.00596E-03	8.69598E-03	0.00000	0.55380
18.0000000	23.333	29.740	75.860	75.949	5.02264E-03	8.71760E-03	0.00000	0.56390
19.0000000	22.769	28.991	75.545	75.634	5.03650E-03	8.73593E-03	0.00000	0.57280
20.9756098	21.861	27.850	75.244	75.333	5.06376E-03	8.76977E-03	0.00000	0.57280
22.9512195	21.006	26.783	74.684	74.773	5.07826E-03	8.78574E-03	0.00000	0.57280
24.9268293	20.245	25.872	74.169	74.257	5.08789E-03	8.79454E-03	0.00000	0.57280
26.9024390	19.580	25.062	73.693	73.779	5.09358E-03	8.79812E-03	0.00000	0.57280
28.8780488	18.989	24.369	73.251	73.336	5.09798E-03	8.79887E-03	0.00000	0.57280
30.8536585	18.460	23.757	72.840	72.923	5.10067E-03	8.79733E-03	0.00000	0.57280
32.8292683	17.978	23.200	72.458	72.538	5.10113E-03	8.79286E-03	0.00000	0.57280
34.8048780	17.550	22.710	72.100	72.179	5.10195E-03	8.78720E-03	0.00000	0.57280
36.7804878	17.144	22.275	71.766	71.842	5.10041E-03	8.78067E-03	0.00000	0.57280
38.7560976	16.785	21.867	71.452	71.526	5.09900E-03	8.77191E-03	0.00000	0.57280
40.7317073	16.452	21.500	71.158	71.229	5.09764E-03	8.76326E-03	0.00000	0.57280
42.7073171	16.147	21.154	70.881	70.949	5.09540E-03	8.75373E-03	0.00000	0.57280
44.6829268	15.862	20.848	70.620	70.686	5.09199E-03	8.74403E-03	0.00000	0.57280
46.6585366	15.590	20.549	70.374	70.437	5.08863E-03	8.73344E-03	0.00000	0.57280
48.6341463	15.334	20.291	70.142	70.202	5.08528E-03	8.72262E-03	0.00000	0.57280
50.6097561	15.109	20.033	69.922	69.980	5.08198E-03	8.71098E-03	0.00000	0.57280

52.5853659	14.879	19.809	69.714	69.769	5.07869E-03	8.70027E-03	0.00000	0.57280
54.5609756	14.669	19.578	69.517	69.569	5.07445E-03	8.68863E-03	0.00000	0.57280
56.5365854	14.473	19.381	69.330	69.379	5.07028E-03	8.67611E-03	0.00000	0.57280
58.5121951	14.290	19.185	69.152	69.199	5.06681E-03	8.66429E-03	0.00000	0.57280
60.4878049	14.114	19.008	68.982	69.026	5.06263E-03	8.65253E-03	0.00000	0.57280
62.4634146	13.945	18.838	68.820	68.862	5.05822E-03	8.64006E-03	0.00000	0.57280
64.4390244	13.796	18.675	68.666	68.705	5.05410E-03	8.62824E-03	0.00000	0.57280
66.4146341	13.633	18.506	68.519	68.556	5.04969E-03	8.61666E-03	0.00000	0.57280
68.3902439	13.498	18.356	68.377	68.412	5.04557E-03	8.60602E-03	0.00000	0.57280
70.3658537	13.363	18.187	68.242	68.274	5.04028E-03	8.59537E-03	0.00000	0.57280
72.3414634	13.227	18.051	68.112	68.142	5.03617E-03	8.58473E-03	0.00000	0.57280
74.3170732	13.092	17.902	67.987	68.015	5.03181E-03	8.57427E-03	0.00000	0.57280
76.2926829	12.970	17.766	67.867	67.893	5.02746E-03	8.56474E-03	0.00000	0.57280
78.2682927	12.848	17.630	67.752	67.775	5.02335E-03	8.55616E-03	0.00000	0.57280
80.2439024	12.740	17.494	67.640	67.662	5.01905E-03	8.54663E-03	0.00000	0.57280
82.2195122	12.639	17.372	67.532	67.552	5.01376E-03	8.53799E-03	0.00000	0.57280
84.1951220	12.530	17.250	67.428	67.446	5.00964E-03	8.52958E-03	0.00000	0.57280
86.1707317	12.429	17.127	67.327	67.343	5.00535E-03	8.52117E-03	0.00000	0.57280
88.1463415	12.334	17.005	67.229	67.243	5.00124E-03	8.51370E-03	0.00000	0.57280
90.1219512	12.246	16.904	67.134	67.146	4.99688E-03	8.50623E-03	0.00000	0.57280
92.0975610	12.158	16.795	67.042	67.052	4.99259E-03	8.49877E-03	0.00000	0.57280
94.0731707	12.063	16.673	66.952	66.961	4.98848E-03	8.49148E-03	0.00000	0.57280
96.0487805	11.975	16.584	66.865	66.872	4.98418E-03	8.48489E-03	0.00000	0.57280
98.0243902	11.901	16.476	66.780	66.785	4.98007E-03	8.47766E-03	0.00000	0.57280
100.0000000	11.827	16.373	66.697	66.701	4.97577E-03	8.47131E-03	0.00000	0.57280

C.12 Threshold Power: 90%FP, Ramp Rate: 3%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.205	-16.205	91.454	91.454	-1.86186E-04	-1.86186E-04	0.00000	0.00000
0.1666667	-16.083	-16.083	91.155	91.156	-1.74599E-04	-1.74599E-04	0.00000	0.00000
0.2500000	-15.974	-13.714	90.858	90.858	-1.63951E-04	2.03835E-05	0.00000	0.00000
0.3333333	-15.852	-12.311	90.560	90.554	-1.53304E-04	1.44983E-04	0.00000	0.00000
0.4166667	-15.737	-11.340	90.263	90.257	-1.41716E-04	1.99836E-04	0.00000	0.00000
0.5000000	-15.615	-9.9732	89.966	89.957	-1.31069E-04	3.12279E-04	0.00000	0.00000
0.5833333	-15.506	-8.0914	89.669	89.657	-1.19481E-04	4.58591E-04	0.00000	0.00000
0.6666667	-15.383	-6.4255	89.372	89.356	-1.08597E-04	5.89670E-04	0.00000	0.00000
0.7500000	-15.255	-4.6633	89.076	89.057	-9.70691E-05	7.25805E-04	0.00000	0.00000
0.8333333	-15.146	-2.8200	88.780	88.756	-8.64217E-05	8.68467E-04	0.00000	0.00000
0.9166667	-15.024	-0.93488	88.484	88.456	-7.48341E-05	1.01413E-03	0.00000	0.00000
1.0000000	-14.915	0.98349	88.188	88.156	-6.39494E-05	1.16290E-03	0.00000	0.00000
1.0833333	-14.786	2.9436	87.893	87.856	-5.24218E-05	1.31585E-03	0.00000	0.00000
1.1666667	-14.664	4.9371	87.598	87.556	-4.05970E-05	1.47098E-03	0.00000	0.00000
1.2500000	-14.556	6.9509	87.303	87.256	-3.00095E-05	1.62928E-03	0.00000	0.00000
1.3333333	-14.426	9.0194	87.008	86.956	-1.81847E-05	1.79187E-03	0.00000	0.00000
1.4166667	-14.304	11.115	86.714	86.656	-6.65710E-06	1.95764E-03	0.00000	0.00000
1.5000000	-14.182	13.245	86.419	86.357	5.16770E-06	2.12770E-03	0.00000	0.00000
1.5833333	-14.074	15.415	86.125	86.058	1.57552E-05	2.30211E-03	0.00000	0.00000
1.6666667	-13.944	17.620	85.831	85.759	2.75800E-05	2.48076E-03	0.00000	0.00000
1.7500000	-12.380	19.838	85.540	85.460	2.44059E-04	2.66352E-03	0.00000	0.00000
1.8333333	-13.978	22.096	85.180	85.162	2.76266E-04	2.85099E-03	0.00000	0.00000
1.9166667	-8.3598	24.362	84.818	84.864	5.85692E-04	3.04300E-03	0.00000	0.00000
2.0000000	-5.6564	26.677	84.521	84.567	8.20128E-04	3.24348E-03	0.00000	0.00000
2.0833333	-1.6552	29.067	84.228	84.271	1.06532E-03	3.44715E-03	0.00000	1.00000E-04
2.1666667	-2.5109	31.480	83.947	83.977	1.04722E-03	3.65683E-03	0.00000	3.00000E-04
2.2500000	0.12907	33.900	83.642	83.685	1.25131E-03	3.87209E-03	0.00000	6.00000E-04
2.3333333	4.5385	36.294	83.349	83.393	1.57484E-03	4.09147E-03	0.00000	1.20000E-03
2.4166667	5.7069	38.697	83.054	83.101	1.67857E-03	4.31867E-03	0.00000	2.30000E-03
2.5000000	9.6840	41.050	82.764	82.811	1.97724E-03	4.55175E-03	0.00000	4.20000E-03
2.5833333	12.965	43.421	82.470	82.521	2.23126E-03	4.79154E-03	0.00000	7.40000E-03
2.6666667	14.710	45.735	82.174	82.232	2.36876E-03	5.03922E-03	0.00000	1.30000E-02
2.7500000	17.619	47.996	81.894	81.943	2.59762E-03	5.29330E-03	0.00000	2.26000E-02
2.8333333	20.723	50.217	81.605	81.655	2.84159E-03	5.55544E-03	0.00000	3.89000E-02
2.9166667	23.813	52.397	81.317	81.367	3.08891E-03	5.82564E-03	0.00000	6.63000E-02
3.0000000	26.932	54.497	81.029	81.080	3.34176E-03	6.10366E-03	0.00000	0.11160
3.8325000	28.317	49.960	80.741	80.792	3.66690E-03	6.71372E-03	0.00000	0.32490
4.6650000	29.723	47.147	80.405	80.452	3.99480E-03	7.19178E-03	5.20000E-03	0.46480
5.4975000	31.141	45.557	79.998	80.042	4.32652E-03	7.62198E-03	1.27000E-02	0.58020
6.3300000	32.557	44.722	79.486	79.540	4.66713E-03	8.03542E-03	2.38000E-02	0.69110
6.5800000	32.264	43.881	79.128	79.190	4.70683E-03	8.09546E-03	2.71000E-02	0.72030
6.8300000	31.796	42.885	79.015	79.079	4.73202E-03	8.13769E-03	3.01000E-02	0.74460
7.0800000	31.293	41.942	78.902	78.967	4.75185E-03	8.17381E-03	3.28000E-02	0.76520
7.3300000	30.795	41.067	78.788	78.855	4.77030E-03	8.20694E-03	3.54000E-02	0.78280
8.3300000	29.355	38.679	78.676	78.743	4.84539E-03	8.33924E-03	4.31000E-02	0.82780
9.3300000	27.989	36.527	78.234	78.306	4.89221E-03	8.41727E-03	4.31000E-02	0.85870
10.3300000	26.813	34.750	77.810	77.886	4.92735E-03	8.47515E-03	4.31000E-02	0.88140
11.3300000	25.820	33.278	77.405	77.484	4.95519E-03	8.52133E-03	4.31000E-02	0.89910
12.3300000	24.937	32.045	77.019	77.100	4.97822E-03	8.55746E-03	4.31000E-02	0.91340
14.3225000	23.640	30.285	76.652	76.734	5.02087E-03	8.62387E-03	4.31000E-02	0.93440
16.3150000	22.452	28.727	75.971	76.054	5.04431E-03	8.65829E-03	4.31000E-02	0.95080
18.3075000	21.453	27.435	75.349	75.433	5.05893E-03	8.67985E-03	4.31000E-02	0.95080
20.3000000	20.584	26.360	74.779	74.863	5.06849E-03	8.69376E-03	4.31000E-02	0.95080
22.2925000	19.843	25.448	74.256	74.338	5.07500E-03	8.70256E-03	4.31000E-02	0.95080
24.2850000	19.191	24.659	73.772	73.852	5.07846E-03	8.70637E-03	4.31000E-02	0.95080
26.2775000	18.601	23.958	73.323	73.402	5.08110E-03	8.70807E-03	4.31000E-02	0.95080
28.2700000	18.085	23.353	72.906	72.983	5.08156E-03	8.70647E-03	4.31000E-02	0.95080
30.2625000	17.616	22.809	72.518	72.593	5.08120E-03	8.70317E-03	4.31000E-02	0.95080
32.2550000	17.195	22.319	72.156	72.228	5.07966E-03	8.69763E-03	4.31000E-02	0.95080
34.2475000	16.802	21.871	71.817	71.887	5.07707E-03	8.69181E-03	4.31000E-02	0.95080
36.2400000	16.442	21.470	71.500	71.567	5.07483E-03	8.68439E-03	4.31000E-02	0.95080
38.2325000	16.109	21.095	71.202	71.266	5.07135E-03	8.67663E-03	4.31000E-02	0.95080
40.2250000	15.805	20.763	70.921	70.983	5.06800E-03	8.66798E-03	4.31000E-02	0.95080
42.2175000	15.520	20.443	70.658	70.717	5.06441E-03	8.65851E-03	4.31000E-02	0.95080
44.2100000	15.249	20.158	70.409	70.465	5.06017E-03	8.64881E-03	4.31000E-02	0.95080

46.2025000	15.004	19.879	70.174	70.228	5.05570E-03	8.63916E-03	4.31000E-02	0.95080
48.1950000	14.767	19.627	69.953	70.003	5.05129E-03	8.62834E-03	4.31000E-02	0.95080
50.1875000	14.550	19.383	69.742	69.790	5.04705E-03	8.61781E-03	4.31000E-02	0.95080
52.1800000	14.340	19.173	69.543	69.589	5.04176E-03	8.60617E-03	4.31000E-02	0.95080
54.1725000	14.143	18.962	69.354	69.397	5.03735E-03	8.59547E-03	4.31000E-02	0.95080
56.1650000	13.954	18.765	69.175	69.215	5.03199E-03	8.58383E-03	4.31000E-02	0.95080
58.1575000	13.784	18.568	69.004	69.041	5.02764E-03	8.57224E-03	4.31000E-02	0.95080
60.1500000	13.602	18.398	68.841	68.876	5.02235E-03	8.56136E-03	4.31000E-02	0.95080
62.1425000	13.452	18.235	68.685	68.718	5.01706E-03	8.54984E-03	4.31000E-02	0.95080
64.1350000	13.304	18.066	68.536	68.567	5.01276E-03	8.53802E-03	4.31000E-02	0.95080
66.1275000	13.155	17.903	68.394	68.422	5.00747E-03	8.52644E-03	4.31000E-02	0.95080
68.1200000	13.012	17.747	68.258	68.283	5.00194E-03	8.51579E-03	4.31000E-02	0.95080
70.1125000	12.877	17.597	68.127	68.150	4.99671E-03	8.50533E-03	4.31000E-02	0.95080
72.1050000	12.748	17.461	68.001	68.022	4.99141E-03	8.49556E-03	4.31000E-02	0.95080
74.0975000	12.627	17.312	67.881	67.899	4.98712E-03	8.48604E-03	4.31000E-02	0.95080
76.0900000	12.505	17.176	67.764	67.781	4.98189E-03	8.47651E-03	4.31000E-02	0.95080
78.0825000	12.383	17.054	67.652	67.666	4.97666E-03	8.46699E-03	4.31000E-02	0.95080
80.0750000	12.281	16.917	67.543	67.556	4.97136E-03	8.45834E-03	4.31000E-02	0.95080
82.0675000	12.173	16.795	67.438	67.449	4.96707E-03	8.45000E-03	4.31000E-02	0.95080
84.0600000	12.065	16.674	67.337	67.345	4.96184E-03	8.44159E-03	4.31000E-02	0.95080
86.0525000	11.963	16.551	67.239	67.245	4.95660E-03	8.43412E-03	4.31000E-02	0.95080
88.0450000	11.868	16.436	67.143	67.148	4.95231E-03	8.42665E-03	4.31000E-02	0.95080
90.0375000	11.780	16.326	67.050	67.053	4.94708E-03	8.41912E-03	4.31000E-02	0.95080
92.0300000	11.692	16.218	66.960	66.961	4.94279E-03	8.41166E-03	4.31000E-02	0.95080
94.0225000	11.597	16.117	66.873	66.872	4.93749E-03	8.40437E-03	4.31000E-02	0.95080
96.0150000	11.523	16.007	66.787	66.785	4.93320E-03	8.39684E-03	4.31000E-02	0.95080
98.0075000	11.434	15.906	66.704	66.700	4.92797E-03	8.39055E-03	4.31000E-02	0.95080
100.0000000	11.360	15.810	66.622	66.617	4.92367E-03	8.38420E-03	4.31000E-02	0.95080

C.13 Threshold Power: 90%FP, Ramp Rate: 5%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.205	-16.205	91.454	91.454	-1.86186E-04	-1.86186E-04	0.00000	0.00000
0.1666667	-16.083	-16.083	91.155	91.156	-1.74599E-04	-1.74599E-04	0.00000	0.00000
0.2500000	-15.974	-13.714	90.858	90.858	-1.63951E-04	2.03835E-05	0.00000	0.00000
0.3333333	-15.852	-12.311	90.560	90.554	-1.53304E-04	1.44983E-04	0.00000	0.00000
0.4166667	-15.737	-11.340	90.263	90.257	-1.41716E-04	1.99836E-04	0.00000	0.00000
0.5000000	-15.615	-9.9732	89.966	89.957	-1.31069E-04	3.12279E-04	0.00000	0.00000
0.5833333	-15.506	-8.0914	89.669	89.657	-1.19481E-04	4.58591E-04	0.00000	0.00000
0.6666667	-15.383	-6.4255	89.372	89.356	-1.08597E-04	5.89670E-04	0.00000	0.00000
0.7500000	-15.255	-4.6633	89.076	89.057	-9.70691E-05	7.25805E-04	0.00000	0.00000
0.8333333	-15.146	-2.8200	88.780	88.756	-8.64217E-05	8.68467E-04	0.00000	0.00000
0.9166667	-15.024	-0.93488	88.484	88.456	-7.48341E-05	1.01413E-03	0.00000	0.00000
1.0000000	-14.915	0.98349	88.188	88.156	-6.39494E-05	1.16290E-03	0.00000	0.00000
1.0833333	-14.786	2.9436	87.893	87.856	-5.24218E-05	1.31585E-03	0.00000	0.00000
1.1666667	-14.664	4.9371	87.598	87.556	-4.05970E-05	1.47098E-03	0.00000	0.00000
1.2500000	-14.556	6.9509	87.303	87.256	-3.00095E-05	1.62928E-03	0.00000	0.00000
1.3333333	-14.426	9.0194	87.008	86.956	-1.81847E-05	1.79187E-03	0.00000	0.00000
1.4166667	-14.304	11.115	86.714	86.656	-6.65710E-06	1.95764E-03	0.00000	0.00000
1.5000000	-14.182	13.245	86.419	86.357	5.16770E-06	2.12770E-03	0.00000	0.00000
1.5833333	-14.074	15.415	86.125	86.058	1.57552E-05	2.30211E-03	0.00000	0.00000
1.6666667	-13.944	17.620	85.831	85.759	2.75800E-05	2.48076E-03	0.00000	0.00000
1.7500000	-12.380	19.838	85.540	85.460	2.44059E-04	2.66352E-03	0.00000	0.00000
1.8333333	-13.978	22.096	85.180	85.162	2.76266E-04	2.85099E-03	0.00000	0.00000
1.9166667	-8.3598	24.362	84.818	84.864	5.85692E-04	3.04300E-03	0.00000	0.00000
2.0000000	-5.6564	26.677	84.521	84.567	8.20128E-04	3.24348E-03	0.00000	0.00000
2.0833333	-1.6552	29.067	84.228	84.271	1.06532E-03	3.44715E-03	0.00000	1.00000E-04
2.1666667	-2.5109	31.480	83.947	83.977	1.04722E-03	3.65683E-03	0.00000	3.00000E-04
2.2500000	0.12907	33.900	83.642	83.685	1.25131E-03	3.87209E-03	0.00000	6.00000E-04
2.3333333	4.5385	36.294	83.349	83.393	1.57484E-03	4.09147E-03	0.00000	1.20000E-03
2.4166667	5.7069	38.697	83.054	83.101	1.67857E-03	4.31867E-03	0.00000	2.30000E-03
2.5000000	9.6840	41.050	82.764	82.811	1.97724E-03	4.55175E-03	0.00000	4.20000E-03
2.5833333	12.965	43.421	82.470	82.521	2.23126E-03	4.79154E-03	0.00000	7.40000E-03
2.6666667	14.710	45.735	82.174	82.232	2.36876E-03	5.03922E-03	0.00000	1.30000E-02
2.7500000	17.619	47.996	81.894	81.943	2.59762E-03	5.29330E-03	0.00000	2.26000E-02
2.8333333	20.723	50.217	81.605	81.655	2.84159E-03	5.55544E-03	0.00000	3.89000E-02
2.9166667	23.813	52.397	81.317	81.367	3.08891E-03	5.82564E-03	0.00000	6.63000E-02
3.0000000	26.932	54.497	81.029	81.080	3.34176E-03	6.10366E-03	0.00000	0.11160
3.5000000	29.011	52.128	80.741	80.792	3.63963E-03	6.58217E-03	2.40000E-03	0.30450
4.0000000	31.029	50.680	80.430	80.478	3.94550E-03	7.01283E-03	6.40000E-03	0.46750
4.5000000	32.964	49.811	80.087	80.134	4.25995E-03	7.42128E-03	1.28000E-02	0.62160
5.0000000	34.818	49.419	79.690	79.740	4.58475E-03	7.82428E-03	2.29000E-02	0.78150
5.2500000	34.354	48.149	79.501	79.557	4.63339E-03	7.91688E-03	2.76000E-02	0.84530
5.5000000	33.723	46.690	79.395	79.452	4.66586E-03	7.97668E-03	3.18000E-02	0.89410
5.7500000	33.084	45.359	79.285	79.344	4.69175E-03	8.02726E-03	3.56000E-02	0.93240
6.0000000	32.443	44.135	79.173	79.234	4.71401E-03	8.07161E-03	3.89000E-02	0.96300
7.0000000	30.670	41.003	79.061	79.123	4.80668E-03	8.24405E-03	4.86000E-02	1.0311
8.0000000	29.045	38.293	78.611	78.679	4.86161E-03	8.34183E-03	5.59000E-02	1.0731
9.0000000	27.678	36.140	78.172	78.245	4.90267E-03	8.41210E-03	5.59000E-02	1.1020
10.0000000	26.535	34.424	77.751	77.828	4.93487E-03	8.46575E-03	5.59000E-02	1.1234
11.0000000	25.542	33.000	77.349	77.428	4.96095E-03	8.50911E-03	5.59000E-02	1.1402
12.9777778	24.124	31.034	76.967	77.048	5.00842E-03	8.58398E-03	5.59000E-02	1.1636
14.9555556	22.860	29.321	76.262	76.345	5.03403E-03	8.62475E-03	5.59000E-02	1.1814
16.9333333	21.787	27.926	75.620	75.704	5.05065E-03	8.65018E-03	5.59000E-02	1.1814
18.9111111	20.876	26.769	75.033	75.117	5.06127E-03	8.66627E-03	5.59000E-02	1.1814
20.8888889	20.089	25.796	74.494	74.576	5.06867E-03	8.67637E-03	5.59000E-02	1.1814
22.8666667	19.389	24.959	73.996	74.077	5.07324E-03	8.68211E-03	5.59000E-02	1.1814
24.8444444	18.785	24.232	73.535	73.615	5.07564E-03	8.68369E-03	5.59000E-02	1.1814
26.8222222	18.255	23.578	73.107	73.185	5.07628E-03	8.68339E-03	5.59000E-02	1.1814
28.8000000	17.760	23.020	72.709	72.784	5.07680E-03	8.68097E-03	5.59000E-02	1.1814
30.7777778	17.318	22.504	72.337	72.410	5.07532E-03	8.67637E-03	5.59000E-02	1.1814
32.7555556	16.911	22.034	71.990	72.060	5.07290E-03	8.67072E-03	5.59000E-02	1.1814
34.7333333	16.544	21.613	71.664	71.732	5.07037E-03	8.66425E-03	5.59000E-02	1.1814
36.7111111	16.198	21.232	71.358	71.424	5.06695E-03	8.65666E-03	5.59000E-02	1.1814
38.6888889	15.880	20.885	71.071	71.134	5.06360E-03	8.64795E-03	5.59000E-02	1.1814
40.6666667	15.595	20.553	70.801	70.861	5.06001E-03	8.63913E-03	5.59000E-02	1.1814
42.6444444	15.324	20.247	70.547	70.604	5.05571E-03	8.62966E-03	5.59000E-02	1.1814
44.6222222	15.066	19.974	70.306	70.361	5.05124E-03	8.61901E-03	5.59000E-02	1.1814

PCI Analysis Result Data - Normal Gap / Half Gap

46.6000000	14.828	19.703	70.079	70.131	5.04683E-03	8.60919E-03	5.59000E-02	1.1814
48.5777778	14.598	19.458	69.864	69.914	5.04171E-03	8.59861E-03	5.59000E-02	1.1814
50.5555556	14.388	19.234	69.661	69.707	5.03730E-03	8.58790E-03	5.59000E-02	1.1814
52.5333333	14.177	19.023	69.467	69.511	5.03195E-03	8.57626E-03	5.59000E-02	1.1814
54.5111111	13.981	18.806	69.284	69.325	5.02736E-03	8.56556E-03	5.59000E-02	1.1814
56.4888889	13.799	18.617	69.109	69.148	5.02206E-03	8.55392E-03	5.59000E-02	1.1814
58.4666667	13.636	18.433	68.943	68.979	5.01677E-03	8.54233E-03	5.59000E-02	1.1814
60.4444444	13.466	18.263	68.784	68.818	5.01148E-03	8.53057E-03	5.59000E-02	1.1814
62.4222222	13.318	18.100	68.632	68.663	5.00618E-03	8.51899E-03	5.59000E-02	1.1814
64.4000000	13.168	17.930	68.487	68.516	5.00183E-03	8.50741E-03	5.59000E-02	1.1814
66.3777778	13.019	17.781	68.348	68.375	4.99636E-03	8.49676E-03	5.59000E-02	1.1814
68.3555556	12.883	17.631	68.215	68.239	4.99107E-03	8.48612E-03	5.59000E-02	1.1814
70.3333333	12.749	17.475	68.087	68.109	4.98584E-03	8.47542E-03	5.59000E-02	1.1814
72.3111111	12.627	17.340	67.964	67.984	4.98060E-03	8.46589E-03	5.59000E-02	1.1814
74.2888889	12.505	17.190	67.845	67.863	4.97537E-03	8.45613E-03	5.59000E-02	1.1814
76.2666667	12.383	17.054	67.731	67.747	4.96984E-03	8.44660E-03	5.59000E-02	1.1814
78.2444444	12.261	16.932	67.621	67.635	4.96555E-03	8.43826E-03	5.59000E-02	1.1814
80.2222222	12.159	16.796	67.514	67.526	4.96031E-03	8.42961E-03	5.59000E-02	1.1814
82.2000000	12.051	16.674	67.411	67.421	4.95508E-03	8.42120E-03	5.59000E-02	1.1814
84.1777778	11.950	16.552	67.312	67.320	4.94985E-03	8.41256E-03	5.59000E-02	1.1814
86.1555556	11.855	16.436	67.215	67.221	4.94556E-03	8.40509E-03	5.59000E-02	1.1814
88.1333333	11.766	16.327	67.121	67.125	4.94032E-03	8.39668E-03	5.59000E-02	1.1814
90.1111111	11.671	16.219	67.030	67.032	4.93509E-03	8.38945E-03	5.59000E-02	1.1814
92.0888889	11.584	16.103	66.941	66.942	4.93080E-03	8.38192E-03	5.59000E-02	1.1814
94.0666667	11.496	15.995	66.854	66.853	4.92556E-03	8.37540E-03	5.59000E-02	1.1814
96.0444444	11.422	15.899	66.770	66.767	4.92127E-03	8.36811E-03	5.59000E-02	1.1814
98.0222222	11.326	15.798	66.688	66.684	4.91604E-03	8.36176E-03	5.59000E-02	1.1814
100.0000000	11.252	15.688	66.608	66.602	4.91175E-03	8.35517E-03	5.59000E-02	1.1814

C.14 Threshold Power: 90%FP, Ramp Rate: 10%FP/hr

TIME (HR)	CLAD AVG HOOP STRESS (KSI)		CLAD YIELD STRESS (KSI)		CLAD AVG HOOP STRAIN (FT/FT)		MAXIMUM CLAD DAMAGE INDEX	
0.0000000	-16.348	-16.348	91.752	91.752	-1.98011E-04	-1.98011E-04	0.00000	0.00000
0.0833333	-16.205	-16.205	91.454	91.454	-1.86186E-04	-1.86186E-04	0.00000	0.00000
0.1666667	-16.083	-16.083	91.155	91.156	-1.74599E-04	-1.74599E-04	0.00000	0.00000
0.2500000	-15.974	-13.714	90.858	90.858	-1.63951E-04	2.03835E-05	0.00000	0.00000
0.3333333	-15.852	-12.311	90.560	90.554	-1.53304E-04	1.44983E-04	0.00000	0.00000
0.4166667	-15.737	-11.340	90.263	90.257	-1.41716E-04	1.99836E-04	0.00000	0.00000
0.5000000	-15.615	-9.9732	89.966	89.957	-1.31069E-04	3.12279E-04	0.00000	0.00000
0.5833333	-15.506	-8.0914	89.669	89.657	-1.19481E-04	4.58591E-04	0.00000	0.00000
0.6666667	-15.383	-6.4255	89.372	89.356	-1.08597E-04	5.89670E-04	0.00000	0.00000
0.7500000	-15.255	-4.6633	89.076	89.057	-9.70691E-05	7.25805E-04	0.00000	0.00000
0.8333333	-15.146	-2.8200	88.780	88.756	-8.64217E-05	8.68467E-04	0.00000	0.00000
0.9166667	-15.024	-0.93488	88.484	88.456	-7.48341E-05	1.01413E-03	0.00000	0.00000
1.0000000	-14.915	0.98349	88.188	88.156	-6.39494E-05	1.16290E-03	0.00000	0.00000
1.0833333	-14.786	2.9436	87.893	87.856	-5.24218E-05	1.31585E-03	0.00000	0.00000
1.1666667	-14.664	4.9371	87.598	87.556	-4.05970E-05	1.47098E-03	0.00000	0.00000
1.2500000	-14.556	6.9509	87.303	87.256	-3.00095E-05	1.62928E-03	0.00000	0.00000
1.3333333	-14.426	9.0194	87.008	86.956	-1.81847E-05	1.79187E-03	0.00000	0.00000
1.4166667	-14.304	11.115	86.714	86.656	-6.65710E-06	1.95764E-03	0.00000	0.00000
1.5000000	-14.182	13.245	86.419	86.357	5.16770E-06	2.12770E-03	0.00000	0.00000
1.5833333	-14.074	15.415	86.125	86.058	1.57552E-05	2.30211E-03	0.00000	0.00000
1.6666667	-13.944	17.620	85.831	85.759	2.75800E-05	2.48076E-03	0.00000	0.00000
1.7500000	-12.380	19.838	85.540	85.460	2.44059E-04	2.66352E-03	0.00000	0.00000
1.8333333	-13.978	22.096	85.180	85.162	2.76266E-04	2.85099E-03	0.00000	0.00000
1.9166667	-8.3598	24.362	84.818	84.864	5.85692E-04	3.04300E-03	0.00000	0.00000
2.0000000	-5.6564	26.677	84.521	84.567	8.20128E-04	3.24348E-03	0.00000	0.00000
2.0833333	-1.6552	29.067	84.228	84.271	1.06532E-03	3.44715E-03	0.00000	1.00000E-04
2.1666667	-2.5109	31.480	83.947	83.977	1.04722E-03	3.65683E-03	0.00000	3.00000E-04
2.2500000	0.12907	33.900	83.642	83.685	1.25131E-03	3.87209E-03	0.00000	6.00000E-04
2.3333333	4.5385	36.294	83.349	83.393	1.57484E-03	4.09147E-03	0.00000	1.20000E-03
2.4166667	5.7069	38.697	83.054	83.101	1.67857E-03	4.31867E-03	0.00000	2.30000E-03
2.5000000	9.6840	41.050	82.764	82.811	1.97724E-03	4.55175E-03	0.00000	4.20000E-03
2.5833333	12.965	43.421	82.470	82.521	2.23126E-03	4.79154E-03	0.00000	7.40000E-03
2.6666667	14.710	45.735	82.174	82.232	2.36876E-03	5.03922E-03	0.00000	1.30000E-02
2.7500000	17.619	47.996	81.894	81.943	2.59762E-03	5.29330E-03	0.00000	2.26000E-02
2.8333333	20.723	50.217	81.605	81.655	2.84159E-03	5.55544E-03	0.00000	3.89000E-02
2.9166667	23.813	52.397	81.317	81.367	3.08891E-03	5.82564E-03	0.00000	6.63000E-02
3.0000000	26.932	54.497	81.029	81.080	3.34176E-03	6.10366E-03	0.00000	0.11160
3.2500000	29.609	54.474	80.741	80.792	3.61542E-03	6.47285E-03	1.40000E-03	0.26190
3.5000000	32.226	54.629	80.445	80.494	3.89990E-03	6.83922E-03	3.80000E-03	0.43420
3.7500000	34.747	54.962	80.139	80.187	4.19208E-03	7.20748E-03	8.30000E-03	0.63780
4.0000000	37.194	55.403	79.813	79.862	4.49638E-03	7.57951E-03	1.62000E-02	0.88390
4.2500000	36.500	53.294	79.746	79.797	4.55471E-03	7.71649E-03	2.31000E-02	1.0503
4.5000000	35.672	51.098	79.657	79.709	4.59723E-03	7.80338E-03	2.91000E-02	1.1609
4.7500000	34.841	49.166	79.559	79.613	4.63012E-03	7.87276E-03	3.43000E-02	1.2382
5.0000000	34.051	47.478	79.455	79.510	4.65749E-03	7.93375E-03	3.87000E-02	1.2947
6.0000000	31.910	43.385	79.347	79.404	4.76961E-03	8.15638E-03	5.07000E-02	1.3998
7.0000000	29.999	40.020	78.900	78.965	4.83382E-03	8.27584E-03	5.94000E-02	1.4571
8.0000000	28.442	37.464	78.453	78.524	4.88076E-03	8.35775E-03	5.94000E-02	1.4934
9.0000000	27.162	35.475	78.021	78.096	4.91695E-03	8.41986E-03	5.94000E-02	1.5191
10.0000000	26.074	33.860	77.607	77.685	4.94515E-03	8.46945E-03	5.94000E-02	1.5385
12.0000000	24.519	31.670	77.213	77.293	4.99885E-03	8.55578E-03	5.94000E-02	1.5648
14.0000000	23.154	29.799	76.478	76.561	5.02640E-03	8.60078E-03	5.94000E-02	1.5842
16.0000000	21.999	28.275	75.811	75.895	5.04401E-03	8.62833E-03	5.94000E-02	1.5842
18.0000000	21.041	27.043	75.202	75.287	5.05552E-03	8.64659E-03	5.94000E-02	1.5842
20.0000000	20.212	26.009	74.644	74.728	5.06403E-03	8.65863E-03	5.94000E-02	1.5842
22.0000000	19.499	25.131	74.130	74.212	5.06860E-03	8.66449E-03	5.94000E-02	1.5842
24.0000000	18.860	24.369	73.654	73.735	5.07094E-03	8.66718E-03	5.94000E-02	1.5842
26.0000000	18.303	23.702	73.214	73.293	5.07158E-03	8.66664E-03	5.94000E-02	1.5842
28.0000000	17.801	23.110	72.804	72.881	5.07210E-03	8.66416E-03	5.94000E-02	1.5842
30.0000000	17.346	22.579	72.422	72.497	5.07056E-03	8.66069E-03	5.94000E-02	1.5842
32.0000000	16.925	22.097	72.065	72.138	5.06797E-03	8.65410E-03	5.94000E-02	1.5842
34.0000000	16.545	21.655	71.732	71.802	5.06567E-03	8.64762E-03	5.94000E-02	1.5842
36.0000000	16.199	21.261	71.419	71.486	5.06226E-03	8.63980E-03	5.94000E-02	1.5842
38.0000000	15.880	20.900	71.125	71.190	5.05766E-03	8.63109E-03	5.94000E-02	1.5842
40.0000000	15.581	20.567	70.849	70.911	5.05431E-03	8.62156E-03	5.94000E-02	1.5842
42.0000000	15.296	20.247	70.589	70.649	5.04984E-03	8.61186E-03	5.94000E-02	1.5842
44.0000000	15.039	19.963	70.344	70.401	5.04536E-03	8.60215E-03	5.94000E-02	1.5842

46.0000000	14.795	19.704	70.113	70.167	5.04001E-03	8.59163E-03	5.94000E-02	1.5842
48.0000000	14.558	19.446	69.894	69.945	5.03560E-03	8.58080E-03	5.94000E-02	1.5842
50.0000000	14.341	19.221	69.687	69.735	5.03025E-03	8.56916E-03	5.94000E-02	1.5842
52.0000000	14.130	18.991	69.490	69.536	5.02495E-03	8.55846E-03	5.94000E-02	1.5842
54.0000000	13.934	18.780	69.304	69.347	5.01960E-03	8.54682E-03	5.94000E-02	1.5842
56.0000000	13.758	18.583	69.126	69.167	5.01501E-03	8.53500E-03	5.94000E-02	1.5842
58.0000000	13.575	18.400	68.957	68.995	5.00972E-03	8.52341E-03	5.94000E-02	1.5842
60.0000000	13.405	18.223	68.796	68.831	5.00448E-03	8.51165E-03	5.94000E-02	1.5842
62.0000000	13.257	18.054	68.642	68.675	4.99895E-03	8.49913E-03	5.94000E-02	1.5842
64.0000000	13.094	17.891	68.495	68.526	4.99278E-03	8.48825E-03	5.94000E-02	1.5842
66.0000000	12.958	17.735	68.355	68.383	4.98749E-03	8.47667E-03	5.94000E-02	1.5842
68.0000000	12.823	17.571	68.220	68.246	4.98202E-03	8.46602E-03	5.94000E-02	1.5842
70.0000000	12.687	17.422	68.090	68.114	4.97678E-03	8.45538E-03	5.94000E-02	1.5842
72.0000000	12.553	17.279	67.966	67.987	4.97155E-03	8.44562E-03	5.94000E-02	1.5842
74.0000000	12.431	17.130	67.846	67.865	4.96602E-03	8.43515E-03	5.94000E-02	1.5842
76.0000000	12.309	16.993	67.731	67.748	4.96079E-03	8.42563E-03	5.94000E-02	1.5842
78.0000000	12.187	16.858	67.619	67.635	4.95556E-03	8.41704E-03	5.94000E-02	1.5842
80.0000000	12.085	16.736	67.512	67.525	4.95032E-03	8.40746E-03	5.94000E-02	1.5842
82.0000000	11.977	16.613	67.408	67.419	4.94485E-03	8.39911E-03	5.94000E-02	1.5842
84.0000000	11.868	16.491	67.307	67.316	4.93968E-03	8.39164E-03	5.94000E-02	1.5842
86.0000000	11.781	16.376	67.209	67.217	4.93539E-03	8.38300E-03	5.94000E-02	1.5842
88.0000000	11.678	16.253	67.115	67.120	4.93015E-03	8.37553E-03	5.94000E-02	1.5842
90.0000000	11.584	16.145	67.023	67.027	4.92492E-03	8.36730E-03	5.94000E-02	1.5842
92.0000000	11.496	16.029	66.933	66.935	4.91945E-03	8.35983E-03	5.94000E-02	1.5842
94.0000000	11.422	15.920	66.846	66.846	4.91516E-03	8.35324E-03	5.94000E-02	1.5842
96.0000000	11.327	15.812	66.761	66.760	4.90993E-03	8.34601E-03	5.94000E-02	1.5842
98.0000000	11.252	15.710	66.678	66.675	4.90469E-03	8.33942E-03	5.94000E-02	1.5842
100.0000000	11.164	15.615	66.597	66.593	4.90040E-03	8.33213E-03	5.94000E-02	1.5842

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