ATTACHMENT 13

Browns Ferry Nuclear Plant (BFN)
Units 1, 2, and 3

Technical Specifications (TS) Change 478

Addition of Analytical Methodologies to Technical Specification 5.6.5.b for Browns Ferry 1, 2, & 3, and Revision of Technical Specification 2.1.1.2 for Browns Ferry Unit 2, in Support of ATRIUM-10 XM Fuel Use at Browns Ferry

Reload Safety Analysis Report

Attached is the non proprietary version of the Reload Safety Analysis Report.

ANP-3167(NP)
Revision 0

Browns Ferry Unit 2 Cycle 19 Reload Analysis

November 2012

AREVA NP Inc.

AREVA NP Inc.

ANP-3167(NP)
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Browns Ferry Unit 2 Cycle 19 Reload Analysis

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Nature of Changes

Item	Page	Description and Justification
1.	All	This is the initial release.

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Nomenclature

2PT	two pump trip
ADS	automatic depressurization system
AOT	abnormal operational transient
APLHGR	average planar linear heat generation rate
ARO	all control rods out
ASME	American Society of Mechanical Engineers
AST	alternate source term
ATWS	anticipated transient without scram
ATWS-PRFO	anticipated transient without scram pressure regulator failure open
ATWS-RPT	anticipated transient without scram recirculation pump trip
BOC	beginning-of-cycle
BPWS	banked position withdrawal sequence
BSP	backup stability protection
BWR	boiling water reactor
BWROG	Boiling Water Reactor Owners Group
CAD	containment atmosphere dilution
CFR	Code of Federal Regulations
COLR	core operating limits report
CPR	critical power ratio
CRDA	control rod drop accident
CRWE	control rod withdrawal error
DIVOM	delta-over-initial CPR versus oscillation magnitude
ECCS	emergency core cooling system
EFPD	effective full-power days
EFPH	effective full-power hours
EFPY	effective full-power years
EOC	end-of-cycle
EOCLB	end-of-cycle licensing basis
EOC-RPT-OOS	end-of-cycle recirculation pump trip out-of-service
EOD	extended operating domain
EOFP	end of full power
EOOS	equipment out-of-service
EPU	extended power uprate
FFTR	final feedwater temperature reduction
FHOOS	feedwater heaters out-of-service
FSAR	final safety analysis report
FW	feedwater
FWCF	feedwater controller failure

Nomenclature
(Continued)

HCOM	hot channel oscillation magnitude
HFR	heat flux ratio
HPCI	high pressure coolant injection
ICF	increased core flow
IHPS	inadvertent HPCI pump start
IORV	inadvertent opening of a relief valve
LFWH	loss of feedwater heating
LHGR	linear heat generation rate
$LHGRFAC_f$	flow-dependent linear heat generation rate multipliers
$LHGRFAC_p$	power-dependent linear heat generation rate multipliers
LOCA	loss-of-coolant accident
LOFW	loss of feedwater flow
LPRM	local power range monitor
LRNB	generator load rejection with no bypass
MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio
$MCPR_f$	flow-dependent minimum critical power ratio
$MCPR_p$	power-dependent minimum critical power ratio
MELLLA	maximum extended load line limit analysis
MSIV	main steam isolation valve
MSRV	main steam relief valve
MSRVOOS	main steam relief valve out-of-service
NEOC	near end-of-cycle
NSS	nominal scram speed
NRC	Nuclear Regulatory Commission, U.S.
OLMCPR	operating limit minimum critical power ratio
OLTP	original licensed thermal power
OPRM	oscillation power range monitor
P_{bypass}	power below which direct scram on TSV/TCV closure is bypassed
PCT	peak cladding temperature
PLU	power load unbalance
PLUOOS	power load unbalance out-of-service
PRFO	pressure regulator failure open
RBM	(control) rod block monitor
RHR	residual heat removal
RPT	recirculation pump trip

Nomenclature
(Continued)

SLC	standby liquid control
SLCS	standby liquid control system
SLMCPR	safety limit minimum critical power ratio
SLO	single-loop operation
SS	steady state
TBVIS	turbine bypass valves in-service
TBVOOS	turbine bypass valves out-of-service
TCV	turbine control valve
TIP	traversing incore probe
TIPOOS	traversing incore probe out-of-service
TLO	two-loop operation
TSSS	technical specifications scram speed
TSV	turbine stop valve
TTNB	turbine trip with no bypass
ΔCPR	change in critical power ratio

1.0 Introduction

Reload licensing analyses results generated by AREVA NP Inc. (AREVA) are presented in support of cycle operation. The analyses reported in this document were performed using methodologies previously approved for generic application to boiling water reactors. The Nuclear Regulatory Commission, U.S. (NRC) technical limitations associated with the application of the approved methodologies have been satisfied by these analyses.

The core consists of a total of 764 fuel assemblies, including 272 fresh ATRIUM™ 10XM* assemblies and 492 irradiated ATRIUM-10 assemblies. Licensing analyses support the core design presented in Reference 1.

Reload licensing analyses were performed for potentially limiting events and analyses identified in Section 2. Results of analyses are used to establish the Technical Specifications/COLR limits and ensure design and licensing criteria are met. Design and safety analyses are based on both operational assumptions and plant parameters provided by the utility. The results of the reload licensing analysis support operation for the power/flow map presented in Figure 1.1 and also support operation with the equipment out-of-service (EOOS) scenarios presented in Table 1.1.

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* ATRIUM is a trademark of AREVA NP.

Table 1.1 EOD and EOOS Operating Conditions

Extended Operating Domain (EOD) Conditions
Increased core flow (ICF)
Maximum extended load line limit analysis (MELLLA)
Combined final feedwater temperature reduction (FFTR) / coastdown
Equipment Out-of-Service (EOOS) Conditions*
Turbine bypass valves out-of-service (TBVOOS)
Feedwater heaters out-of-service (FHOOS)
Power load unbalance out-of-service (PLUOOS)
Combined TBVOOS and FHOOS
Combined TBVOOS and PLUOOS
Combined FHOOS and PLUOOS
Combined TBVOOS, FHOOS, and PLUOOS
Single-loop operation (SLO)

* SLO may be combined with all of the other EOOS conditions. Base case and each EOOS condition is supported in combination with 1 MSRVOOS, EOC-RPT-OOS, up to 2 traversing incore probe (TIP) machines out-of-service (TIPOOS) or the equivalent number of TIP channels (per operating requirements defined in Section 4.2), and/or up to 50% of the LPRMs out-of-service.

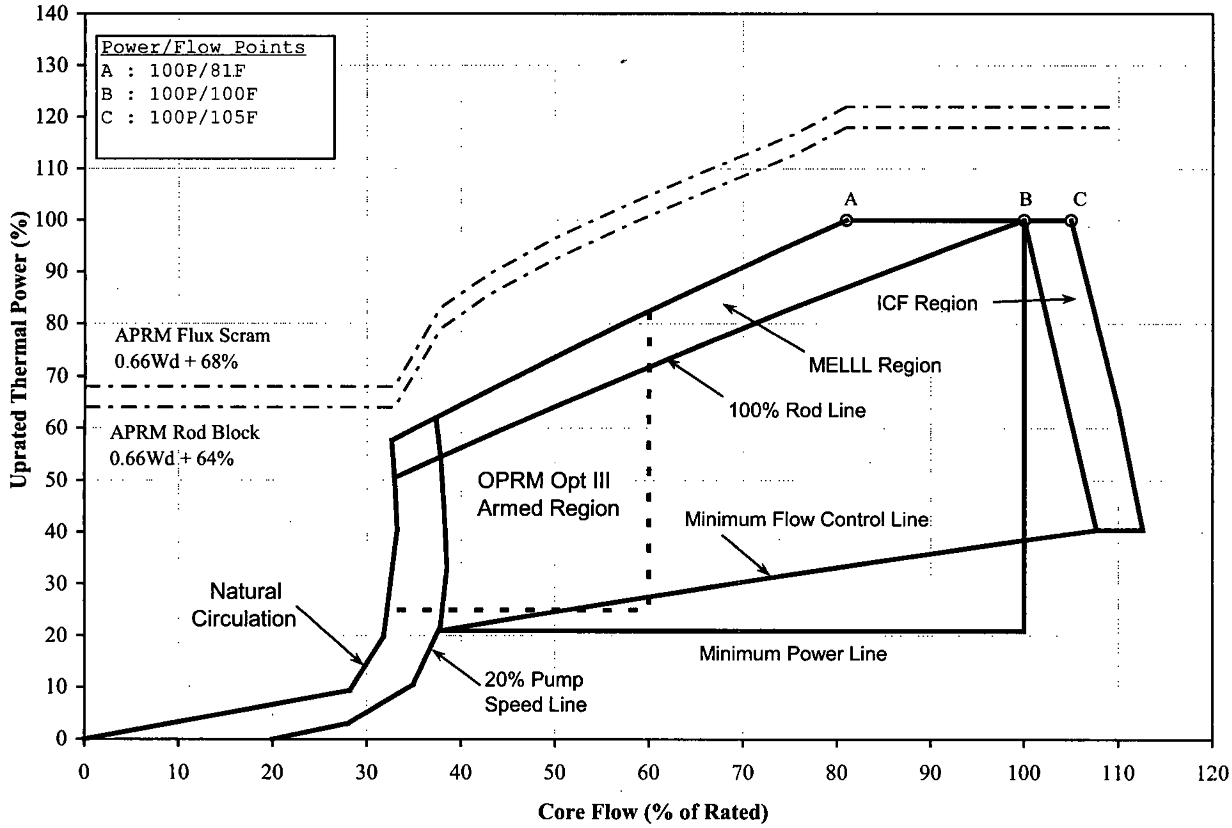

Figure 1.1 Browns Ferry Power/Flow Map – 105% OLTP

2.0 Disposition of Events

The objective of the disposition of events is to identify the limiting events which must be analyzed to support operation at the Browns Ferry Nuclear Power Station with the introduction of ATRIUM 10XM fuel. Events and analyses identified as potentially limiting are either evaluated generically for the introduction of AREVA fuel or on a cycle-specific basis.

The first step is to identify the licensing basis of the plant. Included in the licensing basis are descriptions of the postulated events/analyses and the associated criteria. Fuel-related system design criteria must be met, ensuring regulatory compliance and safe operation. The licensing basis, related to fuel and applicable for reload analysis, is contained in the Final Safety Analysis Report (FSAR), the Technical Specifications, Core Operating Limits Reports (COLR), and other reload analysis reports.

This report supports 105% OLTP operation, which is the power level currently supported in the FSAR and Technical Specifications.

AREVA reviewed all fuel-related design criteria, events, and analyses identified in the licensing basis. In many cases, when operating limits are established to ensure acceptable consequences of an abnormal operational transient (AOT) or accident, the fuel-related aspects of the system design criteria are met. All fuel-related events were reviewed and dispositioned into one of the following categories:

1. No further analysis required. This classification may result from one of the following:
    a. The consequences of the event are bound by consequences of a different event.
    b. The consequences of the event are benign, i.e., the event causes no significant change in margins to the operating limits.
    c. The event is not affected by the introduction of a new fuel design and/or the current analysis of record remains applicable.
2. Address event each reload. The consequences of the event are potentially limiting and need to be addressed each reload.
3. Address for initial reload. This classification may result from one of the following:
    a. The analysis is performed using conservative bounding assumptions and inputs such that the initial reload results will remain applicable for future reloads of the same fuel design.
    b. Results from the first reload will be used to quantitatively demonstrate that the results remain applicable for future reloads of the same fuel design because the consequences are benign or bound by those of another event.

The impact of operation in the EOOS scenarios presented in Table 1.1 was also considered.

A disposition of events summary is presented in Table 2.1. The disposition summary presents a list of the events and analyses, the corresponding FSAR section, the disposition status, and any applicable comments. In each comment, the basis of the disposition is categorized as:

- FSAR analysis
- Generic analysis. A bounding analysis that is independent of plant type.
- Plant specific analysis. The analysis is based on Browns Ferry (independent of unit) and is bounding for cycle-to-cycle variations.
- Cycle specific analysis. The analysis is specific to the Unit and Cycle.

The disposition for the EOOS scenarios is summarized in Table 2.2. ICF and MELLLA operation regions of the power/flow map are included in the disposition results presented in Table 2.1. Methodology and evaluation models used for the cycle specific analyses are provided in Table 2.3. Overpressurization analyses are performed with the NRC approved code COTRANSA2 (References 2 and 3).

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry

FSAR Section	Event /Analysis	Disposition Status	Comments
3.2	Fuel mechanical design	Address initial reload	Cycle specific analysis (results and analyses generally do not change from cycle-to-cycle, unless a design feature is modified). Refer to Reference 4 for the analysis, acceptance criteria, methodology and evaluation model. Demonstrate design criteria are met.
3.6	Nuclear design	Address each reload	Cycle specific analysis. Refer to Reference 1 for the analysis, acceptance criteria, methodology and evaluation model. Demonstrate design criteria are met.
3.7	Thermal and hydraulic design	Address each reload	Plant specific and cycle specific analysis. Demonstrate design criteria are met. Fuel hydraulic design and compatibility results are provided in Reference 5. Refer to Reference 5 for the analysis, acceptance criteria, methodology, and evaluation model. Other cycle specific criteria are presented in this report, i.e., thermal operating limits.
3.8	Standby liquid control system	Address each reload	Cycle specific analysis. Analysis performed each reload to verify adequate SLCS shutdown capacity.
4.2	Reactor vessel and appurtenances mechanical design	No further analyses required	FSAR analysis. The vessel fluence irradiation is primarily dependent upon the effective full power years (EFPY), power distribution, power level, and fuel management scheme. The neutron spectrum of the ATRIUM 10XM fuel is sufficiently similar to the spectrum applied in the licensing basis evaluation of the vessel irradiation limits. The introduction of ATRIUM 10XM fuel will have an insignificant effect on the fluence (E > 1.0 MeV) at the reactor vessel wall and internals.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
4.4	Nuclear system pressure relief system	Address each reload	Cycle specific analysis (overpresurization), plant specific analysis (LOCA). Analysis of limiting ASME and ATWS overpressurization events required each reload. Evaluations of the ADS capability are addressed as part of the LOCA analyses (References 6 and 7).
5.2	Primary containment system	No further analyses required	FSAR analysis. Except for the CAD evaluation, the primary containment characteristics following a postulated LOCA are not fuel related. The CAD system criteria were met for previous AREVA fuel. The evaluation is applicable for the introduction of ATRIUM 10XM fuel.
5.3	Secondary Containment System	No further analyses required	FSAR analysis. The secondary containment basis is independent of fuel design.
6.0	Emergency core cooling systems	Address each reload	Plant specific analysis and cycle specific analysis. LOCA is a potentially limiting accident. Limiting break characteristics are identified for the initial ATRIUM 10XM reload. Refer to References 6 and 7 for the analysis, acceptance criteria, methodology, and evaluation model. LOCA heatup analysis for reload fuel is evaluated for follow-on reloads to address changes in neutronic design.
7.5	Neutron monitoring system	Address each reload	Plant specific and cycle specific analysis. Cycle specific OPRM trip setpoint calculations. RBM setpoints evaluated for the CRWE event. Backup stability protection.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
7.19	Anticipated transient without scram	Address each reload	Cycle specific analysis. Analyses are performed to demonstrate that the peak vessel pressure for the limiting ATWS event is less than 120% of design pressure. Long term ATWS analyses remain applicable for ATRIUM 10XM (Section 7.2.2).
8.10	Station blackout	No further analyses required	FSAR analysis. The licensing basis analysis remains applicable. ATRIUM 10XM fuel is designed to perform in a manner similar to and analogous with fuel of current and previous designs.
10.2	New fuel storage	Not applicable for ATRIUM 10XM	ATRIUM 10XM will not be stored in the new fuel storage vault.
10.3	Spent fuel storage	Address each reload	Plant specific analysis. Refer to References 9 and 35 for the analysis, acceptance criteria, methodology, and evaluation model. Evaluated for spent fuel storage racks. Confirm applicability each reload.
10.11	Fire protection systems	Address initial reload	Plant specific analysis. This issue is addressed in Reference 10.
14.5.2.1	Generator trip (TCV fast closure)	No further analyses required	FSAR analysis. Bound by the generator trip with turbine bypass valve failure.
14.5.2.2	Generator trip (TCV fast closure) with turbine bypass valve failure	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.2.2.4	LRNB with EOC-RPT-OOS	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.2.3	Loss of condenser vacuum	No further analyses required	FSAR analysis. Bound by the turbine trip with turbine bypass valve failure.
14.5.2.4	Turbine trip (TSV closure)	No further analyses required	FSAR analysis. Bound by the turbine trip with turbine bypass valve failure.
14.5.2.5	Turbine bypass valves failure following turbine trip (TTNB), high power	Address initial reload	Cycle specific analysis, for initial reload. Generally bound by the generator trip with turbine bypass valve failure.
14.5.2.6	Turbine bypass valves failure following turbine trip (TTNB), low power	Address initial reload	Cycle specific analysis, for initial reload. Generally bound by the generator trip with turbine bypass valve failure. If 14.5.2.5 is bound by generator trip with turbine bypass valve failure, then 14.5.2.6 is also bound.
14.5.2.7	Main steam isolation valve closure	No further analyses required	FSAR analysis. Relative to thermal operating limits, bound by the generator trip with turbine bypass valve failure.
14.5.2.8	Pressure regulator failure (downscale)	No further analyses required	FSAR analysis. Eliminated as an AOT by the installation of a digital fault-tolerant main turbine electro-hydraulic control system.
14.5.3.1	Loss of feedwater heater (LFWH)	Address each reload	Cycle specific analysis. Generally bound by the LRNB and FWCF events. Addressed each cycle to demonstrate that it remains bound by the other events.
14.5.3.2	Shutdown cooling (RHR) malfunction – decreasing temperature	No further analyses required	FSAR analysis. Benign event.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.3.3	Inadvertent HPCI pump start (IHPS)	No further analysis required	FSAR analysis. Generally bound by the LRNB and FWCF events. The IHPS event is similar to the LFWH event. The IHPS is slightly more CPR limiting, whereas the LFWH is slightly more thermal-mechanical limiting. Both IHPS and LFWH events have considerable margin to the limiting LRNB and FWCF events. The LFWH transient is analyzed for each cycle to demonstrate, on a relative basis, that the LFWH and IHPS events remain non-limiting.
14.5.4.1	Continuous rod withdrawal during power range operation	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.4.2	Continuous rod withdrawal during reactor startup	No further analyses required	FSAR analysis. Benign event.
14.5.4.3	Control rod removal error during refueling	No further analyses required	FSAR analysis. This event is not credible.
14.5.4.4	Fuel assembly insertion error during refueling	No further analyses required	FSAR analysis. This event is not credible.
	Mislocated or misoriented fuel assembly	Address each reload	Cycle specific analysis.
14.5.5.1	Pressure regulator failure open (PRFO)	Address each reload	FSAR analysis and cycle specific analysis. Relative to AOT thermal operating limits, benign event. PRFO – maximum steam demand is a potentially limiting ATWS overpressurization event. ATWS-PRFO is considered for FSAR 7.19.
14.5.5.2	Inadvertent opening of a MSRV (IORV)	No further analysis required	FSAR analysis. Benign event.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.5.3	Loss of feedwater flow (LOFW)	No further analysis required	FSAR analysis. Benign event.
14.5.5.4	Loss of auxiliary power	No further analyses required	FSAR analysis. Benign event.
14.5.6.1	Recirculation flow control failure – decreasing flow	No further analysis required	FSAR analysis. Non-limiting event.
14.5.6.2	Trip of one recirculation pump	No further analyses required	FSAR analysis. Consequences of this event are benign and bound by the turbine trip with no bypass event.
14.5.6.3	Trip of two recirculation pumps	No further analyses required	FSAR analysis. Consequences of this event are benign and bound by the turbine trip with no bypass event.
14.5.6.4	Recirculation pump seizure	No further analysis required	FSAR analysis. The consequences of this accident are bounded by the effects of a LOCA.
14.5.7.1	Recirculation flow control failure - increasing flow	Address each reload	Cycle specific analysis. Consequences of the slow flow run-up event determine the flow-dependent MCPR and LHGR operating limits and are evaluated each reload.
14.5.7.2	Startup of idle recirculation loop	No further analysis required	FSAR analysis. Benign event.
14.5.8.1	Feedwater controller failure (FWCF) - maximum demand	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
14.5.8.2	Feedwater controller failure (FWCF) - maximum demand with EOC-RPT-OOS	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.8.3	Feedwater controller failure (FWCF) - maximum demand with TBVOOS	Address each reload	Cycle specific analysis. This event is a potentially limiting AOT.
14.5.9	Loss of habitability of the control room	No further analyses required	FSAR analysis. This is postulated as a special event to demonstrate the ability to safely shutdown the reactor from outside the control room.
14.6.2	Control rod drop accident (CRDA)	Address each reload	Cycle specific analysis. Consequences of the CRDA are evaluated to confirm that the acceptance criteria are satisfied.
14.6.3	Loss-of-coolant accident (LOCA)	Address each reload	Plant specific analysis and cycle specific analysis. Consequences of the LOCA are evaluated to determine appropriate cycle-specific MAPLHGR limits. Refer to References 6 and 7 for the analysis, acceptance criteria, methodology and evaluation model. LOCA heatup analysis for reload fuel is evaluated for follow-on reloads to address changes in neutronic design.
14.6.4	Refueling accident	Address each reload	Plant specific analysis. Refer to Reference 11 for the analysis, acceptance criteria, methodology, and evaluation model. Consequences of the refueling accident are evaluated to confirm that the acceptance criteria are satisfied.

Table 2.1 Disposition of Events Summary for ATRIUM 10XM Fuel Introduction at Browns Ferry
(Continued)

FSAR Section	Event /Analysis	Disposition Status	Comments
14.6.5	Main steam line break accident	No further analysis required	FSAR analysis. The consequences of a large steam line break are far from limiting with respect to 10 CFR 50.46 acceptance criteria. Radiological dose consequences have been performed utilizing AST in accordance with 10 CFR 50.67. The consequences of the event are not a function of fuel type since no fuel failures are calculated to occur. The dose is a function of the radionuclide inventory in the coolant itself prior to the event.

Table 2.2 Disposition of Operating Flexibility and EOOS Options on Limiting Events

Option	Affected Limiting Events/Analyses	Comments
One MSRV Out-of-Service	ASME Overpressurization FWCF LRNB TTNB ATWS	This scenario is included as part of the base case condition for the events/analyses identified.
Single-loop operation (SLO)	LOCA SLMCPR	The impact of SLO on LOCA is addressed in Section 8. The SLO SLMCPR is addressed each reload.
Final Feedwater Temperature Reduction (FFTR)/Feedwater Heater Out-of-Service (FHOOS)	FWCF Option III Stability Solution Backup Stability Protection (BSP)	This scenario is included in each reload for each of these events/analyses.
Turbine bypass valve system out-of-service (TBVOOS)	FWCF	The FWCF event with TBVOOS is evaluated each reload.
EOC-RPT out-of-service (EOC-RPT OOS)	FWCF LRNB TTNB	This scenario is included in each reload for each of these events/analyses.
Power load unbalance out-of-service (PLUOOS)	LRNB	The LRNB event with PLUOOS is evaluated each reload.
Traversing in-core probe (TIP) out-of-service	SLMCPR	TIP OOS is included in the SLMCPR analysis.

Table 2.3 Methodology and Evaluation Models for Cycle Specific Reload Analyses

FSAR Section	Event /Analysis	Analysis Methodology Reference	Evaluation Model	Acceptance Criteria and Comments
3.7	Thermal and hydraulic design	2 12 13 14 15 16	SAFLIM3D COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	SLMCPR criteria: < 0.1% fuel rods experience boiling transition. Transient criteria: Power and flow dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
3.8	Standby liquid control system	17	CASMO-4 /MICROBURN-B2	SLCS criteria: Shutdown margin of at least 0.88% Δk/k.
4.4	Nuclear system pressure relief system	2	COTRANSA2	Analyses for ASME and ATWS overpressurization. ASME overpressurization criteria: Maximum vessel pressure limit of 1375 psig and maximum dome pressure limit of 1325 psig. ATWS overpressurization criteria: Maximum vessel pressure limit of 1500 psig.
6.0	Emergency core cooling systems	18	HUXY	LOCA criteria: 10 CFR 50.46. EXEM BWR-2000 Methodology. Only heatup (HUXY) is analyzed for the reload specific neutronic design.
7.5	Neutron monitoring system	17 19 20 21 22 23 24	STAIF RAMONA5-FA CASMO-4 / MICROBURN-B2	Long term stability solution Option III criteria: OPRM setpoints are selected to ensure that the SLMCPR is not violated during the limiting stability event. CRWE criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria. Backup stability protection criteria: Stability boundaries that do not exceed acceptable global, regional and channel decay ratios as defined by the STAIF methodology.

Table 2.3 Methodology and Evaluation Models for Cycle Specific Reload Analyses *(Continued)*

FSAR Section	Event /Analysis	Analysis Methodology Reference	Evaluation Model	Acceptance Criteria and Comments
7.19	Anticipated transient without scram	2	COTRANSA2	ATWS overpressurization criteria: Maximum vessel pressure limit of 1500 psig. ATWS peak pressure only.
14.5.2.2	Generator trip (TCV fast closure) with turbine bypass valve failure	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power and flow dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.2.2.4	LRNB with EOC-RPT-OOS	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.2.5	Turbine bypass valves failure following turbine trip (TTNB), high power	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.2.6	Turbine bypass valves failure following turbine trip (TTNB), low power	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.3.1	Loss of feedwater heater (LFWH)	17 25	CASMO-4 /MICROBURN-B2	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria
14.5.4.1	Continuous rod withdrawal during power range operation	17	CASMO-4 /MICROBURN-B2	CRWE criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria
	Mislocated or misoriented fuel assembly	17 26	CASMO-4 /MICROBURN-B2	Mislocated/misoriented criteria : Small fraction of 10 CFR 50.67 limits Cycle specific analysis.

Table 2.3 Methodology and Evaluation Models for Cycle Specific Reload Analyses *(Continued)*

FSAR Section	Event /Analysis	Analysis Methodology Reference	Evaluation Model	Acceptance Criteria and Comments
14.5.7.1	Recirculation flow control failure - increasing flow	14 17	CASMO-4 /MICROBURN-B2 XCOBRA	Transient criteria: Flow dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.8.1	Feedwater controller failure (FWCF) - maximum demand	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.8.2	Feedwater controller failure (FWCF) - maximum demand with EOC-RPT-OOS	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.5.8.3	Feedwater controller failure (FWCF) - maximum demand with TBVOOS	2 13 14 15 16	COTRANSA2 XCOBRA XCOBRA-T RODEX2 RODEX4	Transient criteria: Power dependent MCPR and LHGR operating limits established to meet the fuel failure criteria.
14.6.2	Control rod drop accident (CRDA)	17	CASMO-4 /MICROBURN-B2	CRDA criteria: Maximum deposited fuel rod enthalpy is less than 280 cal/g. (The Cycle 19 analysis result is less than 230 cal/g.)
14.6.3	Loss-of-coolant accident (LOCA)	18	HUXY	LOCA criteria: 10 CFR 50.46. EXEM BWR-2000 Methodology. Only heatup (HUXY) is analyzed for the reload specific neutronic design.

3.0 Mechanical Design Analysis

Mechanical design exposure limits for ATRIUM 10XM and ATRIUM-10 fuel are presented in Reference 4, 27, and 28. The maximum exposure limits for the ATRIUM 10XM and ATRIUM-10 reload fuel are:

54.0 GWd/MTU average assembly exposure
62.0 GWd/MTU rod average exposure (full-length fuel rods)

The fuel cycle design analyses (Reference 1) verified all fuel assemblies remain within licensed burnup limits. The LHGR limits are presented in Section 8.0.

4.0 Thermal-Hydraulic Design Analysis

4.1 *Thermal-Hydraulic Design and Compatibility*

Results of thermal-hydraulic characterization and compatibility analyses are presented in Reference 5. Analysis results demonstrate the thermal-hydraulic design and compatibility criteria are satisfied for the transition core consisting of ATRIUM 10XM and ATRIUM-10 fuel.

4.2 *Safety Limit MCPR Analysis*

The safety limit MCPR (SLMCPR) is defined as the minimum value of the critical power ratio ensuring less than 0.1% of the fuel rods are expected to experience boiling transition during normal operation, or an abnormal operational transient (AOT). The SLMCPR for all fuel was determined using the methodology described in Reference 12. The analysis was performed with a power distribution conservatively representing expected reactor operation throughout the cycle.

SLMCPR analysis used the ACE/ATRIUM 10XM critical power correlation (References 29, 30, and 31) for the ATRIUM 10XM fuel while the SPCB critical power correlation (Reference 32) is used for the ATRIUM-10.

In the AREVA methodology, the effects of channel bow on the critical power performance are accounted for in the SLMCPR analysis. Reference 12 discusses the application of a realistic channel bow model.

Fuel- and plant-related uncertainties used in the SLMCPR analysis are presented in Table 4.1. The radial power uncertainty used in the analysis includes the effects of up to 40% of the TIP channels out-of-service, up to 50% of the LPRMs out-of-service, and a 2500 EFPH LPRM calibration interval.

Analysis of the Unit 2 Cycle 19 SLMCPR using the methodology in Reference 12 resulted in a value of 1.04 for two-loop operation (TLO) and a value of 1.05 for single-loop operation (SLO) as documented in Reference 8. Analysis results including the SLMCPR and the percentage of rods expected to experience boiling transition are summarized in Table 4.2. The results presented in Table 4.2 reflect the use of conservatively selected SLMCPR values of 1.06 for TLO and 1.08 for SLO.

4.3 *Core Hydrodynamic Stability*

Browns Ferry has implemented BWROG Long Term Stability Solution Option III (Oscillation Power Range Monitor-OPRM). Reload validation has been performed in accordance with Reference 19. The stability based Operating Limit MCPR (OLMCPR) is provided for two conditions as a function of OPRM amplitude setpoint in Table 4.3. The two conditions evaluated are for a postulated oscillation at 45% core flow steady state operation (SS) and following a two recirculation pump trip (2PT) from the limiting full power operation state point. Power- and Flow-dependent limits provide adequate protection against violation of the SLMCPR for postulated reactor instability as long as the operating limit is greater than or equal to the specified value for the selected OPRM setpoint. Setpoints supporting EOOS operating conditions are provided in Table 4.3.

DIVOM calculations are performed to obtain the relative change in CPR as a function of the calculated hot channel oscillation magnitude (HCOM). Analyses were performed with the RAMONA5-FA code in accordance with Reference 24. The methodology employs a coupled neutronic-thermal-hydraulic three-dimensional transient model for the purpose of determining the relationship between the relative change in ΔCPR and the HCOM on a plant specific basis. The method was developed consistent with the recommendations of the BWROG in Reference 20. Generation of plant-specific DIVOM data is consistent with Reference 21. The stability-based OLMCPRs were calculated using the most limiting calculated change in relative ΔCPR for a given oscillation magnitude.

In cases where the OPRM system is declared inoperable, Backup Stability Protection (BSP) is provided in accordance with Reference 22. BSP curves have been evaluated using an approved methodology (Reference 23) to determine endpoints meeting decay ratio criteria for the BSP Base Minimal Region I (scram region) and Base Minimal Region II (controlled entry region). Stability boundaries based on these endpoints can then be determined using the generic shape generating function from Reference 22. Analyses have been performed to support operation for both nominal, and reduced feedwater temperature conditions (both FFTR and FHOOS).

The STAIF acceptance criteria for the BSP endpoints are global decay ratios ≤ 0.85, and regional and channel decay ratios ≤ 0.80. Endpoints for the BSP regions provided in Table 4.4 have global decay ratios ≤ 0.85, and regional and channel decay ratios ≤ 0.80.

Table 4.1 Fuel- and Plant-Related Uncertainties for Safety Limit MCPR Analyses

Parameter	Uncertainty
Fuel-Related Uncertainties	
[	
	]
Plant-Related Uncertainties	
Feedwater flow rate	1.8%
Feedwater temperature	0.8%
Core pressure	0.7%
Total core flow rate TLO SLO	 2.5% 6.0%

* [ ]

Table 4.2 Results Summary for Safety Limit MCPR Analyses

SLMCPR	Percentage of Rods in Boiling Transition
TLO – 1.06	0.042
SLO – 1.08	0.034

Table 4.3 OPRM Setpoints

OPRM Setpoint	OLMCPR (SS)	OLMCPR (2PT)
1.05	1.15	1.18
1.06	1.17	1.20
1.07	1.19	1.22
1.08	1.20	1.24
1.09	1.22	1.26
1.10	1.24	1.28
1.11	1.26	1.30
1.12	1.28	1.32
1.13	1.30	1.34
1.14	1.33	1.37
1.15	1.35	1.39
Acceptance Criteria	Off-Rated OLMCPR at 45% Flow	Rated Power OLMCPR as described in Section 8.0

Table 4.4 BSP Endpoints for Browns Ferry Unit 2 Cycle 19

Feedwater Temperature Operation Mode	Region	End Point Designation	Power (% rated)	Flow (% rated)
Nominal	Scram	IA	63.72	42.00
Nominal	Scram	IB	43.88	29.00
Nominal	Controlled entry	IIA	73.46	50.00
Nominal	Controlled entry	IIB	30.72	29.00
FFTR/ FHOOS	Scram	IA	65.71	42.00
FFTR/ FHOOS	Scram	IB	43.88	29.00
FFTR/ FHOOS	Controlled entry	IIA	73.46	50.00
FFTR/ FHOOS	Controlled entry	IIB	30.72	29.00

5.0 Anticipated Operational Occurrences

This section describes the analyses performed to determine the power- and flow-dependent MCPR operating limits for base case operation.

COTRANSA2 (Reference 2), XCOBRA-T (Reference 13), XCOBRA (Reference 14), and CASMO-4/MICROBURN-B2 (Reference 17) are the major codes used in the thermal limits analyses as described in the AREVA THERMEX methodology report (Reference 14) and neutronics methodology report (Reference 17). COTRANSA2 is a system transient simulation code, which includes an axial one-dimensional neutronics model that captures the effects of axial power shifts associated with the system transients. XCOBRA-T is a transient thermal-hydraulics code used in the analysis of thermal margins for the limiting fuel assembly. XCOBRA is used in steady-state analyses. The ACE/ATRIUM 10XM critical power correlation (References 29, 30, and 31) is used to evaluate the thermal margin for the ATRIUM 10XM fuel. The SPCB critical power correlation (Reference 32) is used to evaluate the thermal margin of the ATRIUM-10 fuel. Fuel pellet-to-cladding gap conductance values are based on RODEX2 (Reference 15) calculations for the BFE2-19 core.

5.1 *System Transients*

The reactor plant parameters for the system transient analyses were provided by the utility. Analyses have been performed to determine power-dependent MCPR limits that protect operation throughout the power/flow domain depicted in Figure 1.1.

At Browns Ferry, direct scram on turbine stop valve (TSV) position and turbine control valve (TCV) fast closure are bypassed at power levels less than 30% of rated (P_{bypass}). Scram will occur when the high pressure or high neutron flux scram setpoint is reached. Reference 33 indicates that MCPR limits only need to be monitored at power levels greater than or equal to 25% of rated, which is the lowest power analyzed for this report.

The limiting exposure for rated power pressurization transients is typically at end of full power (EOFP) when the control rods are fully withdrawn. To provide additional margin to the operating limits earlier in the cycle, analyses were also performed to establish operating limits at a near end-of-cycle (NEOC) core average exposure of 29,206.3 MWd/MTU. Analyses were performed at cycle exposures prior to NEOC to ensure that the operating limits provide the necessary protection. The end-of-cycle licensing basis (EOCLB) analysis was performed at EOFP + 15

EFPD (core average exposure of 32,734 MWd/MTU). Analyses were also performed to support extended cycle operation with final feedwater temperature reduction (FFTR) and power coastdown. The licensing basis exposures used to develop the neutronics inputs to the transient analyses are presented in Table 5.1.

All pressurization transients assumed that one of the lowest setpoint main steam relief valves (MSRV) was inoperable. The basis supports operation with 1 MSRV out-of-service.

Reductions in feedwater temperature of less than 10°F from the nominal feedwater temperature and variation of ±10 psi in dome pressure are considered base case operation, not an EOOS condition. Analyses were performed to determine the limiting conditions in the allowable ranges.

FFTR is used to extend rated power operation by decreasing the feedwater temperature. The amount of feedwater temperature reduction is a function of power with the maximum decrease of 65°F (55°F + 10°F bias) at rated power. Analyses were performed to support combined FFTR/Coastdown operation to a core average exposure of 34,147.6 MWd/MTU. The analyses were performed with the limiting feedwater and dome pressure conditions in the allowable ranges.

System pressurization transient results are sensitive to scram speed assumptions. To take advantage of average scram speeds faster than those associated with the Technical Specifications requirements, scram speed-dependent $MCPR_p$ limits are provided. The nominal scram speed (NSS) insertion times and the Technical Specifications scram speed (TSSS) insertion times used in the analyses are presented in Table 5.2. The NSS $MCPR_p$ limits can only be applied if the scram speed test results meet the NSS insertion times. System transient analyses were performed to establish $MCPR_p$ limits for both NSS and TSSS insertion times. Technical Specifications (Reference 33) allow for operation with up to 13 “slow” and 1 stuck control rod. One additional control rod is assumed to fail to scram. Conservative adjustments to the NSS and TSSS scram speeds were made to the analysis inputs to appropriately account for these effects on scram reactivity. For cases below 30% power, the results are relatively insensitive to scram speed, and only TSSS analyses are performed. At 30% power (P_{bypass}), analyses were performed, both with and without bypass of the direct scram function, resulting in an operating limits step change.

5.1.1 Load Rejection No Bypass (LRNB)

Load rejection causes a fast closure of the turbine control valves. The resulting compression wave travels through the steam lines into the vessel and creates a rapid pressurization. The increase in pressure causes a decrease in core voids, which in turn causes a rapid increase in power. Fast closure of the turbine control valves also causes a reactor scram and RPT. Turbine bypass system operation, which also mitigates the consequences of the event, is not credited. The excursion of the core power due to the void collapse is terminated primarily by the reactor scram and revoiding of the core.

LRNB analyses assume the power load unbalance (PLU) is inoperable for power levels less than 50% of rated. The LRNB sequence of events is different than the standard event when the PLU is inoperable. Instead of a fast closure, the TCVs close in servo mode and there is no direct scram on TCV closure. The power and pressure excursion continues until the high pressure scram occurs.

LRNB analyses were performed for a range of power/flow conditions to support generation of the thermal limits. Base case limiting LRNB transient analysis results used to generate the NEOC and EOCLB operating limits, for both TSSS and NSS insertion times, are shown in Table 5.3. Responses of various reactor and plant parameters during the LRNB event initiated at 100% of rated power and 105% of rated core flow with TSSS insertion times are shown in Figures 5.1-5.3.

5.1.2 Turbine Trip No Bypass (TTNB)

A turbine trip event can be initiated as a result of several different signals. The initiating signal causes the TSV to close in order to prevent damage to the turbine. The TSV closure creates a compression wave traveling through the steam lines into the vessel causing a rapid pressurization. The increase in pressure results in a decrease in core voids, which in turn causes a rapid increase in power. Closure of the TSV also causes a reactor scram and an RPT which helps mitigate the pressurization effects. Turbine bypass system operation, which also mitigates the consequences of the event, is not credited. The excursion of the core power due to the void collapse is terminated primarily by the reactor scram and revoiding of the core.

In addition to closing the TSV, a signal is also sent to close the TCV in fast mode. The consequences of a fast closure of the TCV are very similar to those resulting from a TSV closure.

The main difference is the time required to close the valves. While the TCV full stroke closure time is greater than that of the TSV (0.150 sec compared to 0.100 sec), the initial position of the TCV is dependent on the initial steam flow. At rated power and lower, the initial position of the TCV is such that the closure time is less than that of the TSV. However, the TCV closure characteristics are nonlinear such that the resulting core pressurization and ΔCPR may not always bound those of the slower TSV closure.

Analyses were performed demonstrating that the TTNB event is equivalent to or bound by the LRNB event; therefore, the thermal limits established for the LRNB will also protect against the TTNB event. Base case limiting TTNB transient analysis results for NSS insertion times and at EOCLB are shown in Table 5.4. Comparison of these results with the results provided in Table 5.3 show that the LRNB event bounds the TTNB event.

5.1.3 Feedwater Controller Failure (FWCF)

The increase in feedwater flow due to a failure of the feedwater control system to maximum demand results in an increase in the water level and a decrease in the coolant temperature at the core inlet. The increase in core inlet subcooling causes an increase in core power. As the feedwater flow continues at maximum demand, the water level continues to rise and eventually reaches the high water level trip setpoint. The initial water level is conservatively assumed to be at the low level normal operating range to delay the high-level trip and maximize the core inlet subcooling resulting from the FWCF. The high water level trip causes the turbine stop valves to close in order to prevent damage to the turbine from excessive liquid inventory in the steam line. Valve closure creates a compression wave traveling back to the core, causing void collapse and subsequent rapid power excursion. The closure of the turbine stop valves also initiates a reactor scram and an RPT. In addition to the turbine stop valve closure, the turbine control valves also close in the fast closure mode. Because of the partially closed initial position of the control valves, they will typically close faster than the stop valves and control the pressurization portion of the event. However, TCV closure characteristics are nonlinear so that the resulting core pressurization and ΔCPR results may not always bound those of the slower TSV closure at rated power (steam flow increases above rated before fast TCV closure). The limiting of TCV, or TSV closure, for the initial operating conditions, was used in the FWCF analyses, based on sensitivity analyses. The turbine bypass valves are assumed operable and provide some

pressure relief. The core power excursion is mitigated in part by pressure relief, but the primary mechanisms for termination of the event are reactor scram and revoiding of the core.

FWCF analyses were performed for a range of power/flow conditions to support generation of the thermal limits. Table 5.5 presents the base case limiting FWCF transient analysis results used to generate the NEOC and EOCLB operating limits for both TSSS and NSS insertion times. Figures 5.4 – 5.6 show the responses of various reactor and plant parameters during the FWCF event initiated at 100% of rated power and 105% of rated core flow with TSSS insertion times.

5.1.4 Loss of Feedwater Heating

The loss of feedwater heating (LFWH) event analysis supports an assumed 100°F decrease in the feedwater temperature. The result is an increase in core inlet subcooling, which reduces voids, thereby increasing core power and shifting axial power distribution toward the bottom of the core. As a result of the axial power shift and increased core power, voids begin to build up in the bottom region of the core, acting as negative feedback to the increased subcooling effect. The negative feedback moderates the core power increase. Although there is a substantial increase in core thermal power during the event, the increase in steam flow is much less because a large part of the added power is used to overcome the increase in inlet subcooling. The increase in steam flow is accommodated by the pressure control system via the TCVs or the turbine bypass valves, so no pressurization occurs. A cycle-specific analysis was performed in accordance with the Reference 25 methodology to determine the change in MCPR for the event. The LFWH results are presented in Table 5.6.

5.1.5 Control Rod Withdrawal Error

The control rod withdrawal error (CRWE) transient is an inadvertent reactor operator initiated withdrawal of a control rod. This withdrawal increases local power and core thermal power, lowering the core MCPR. The CRWE transient is typically terminated by control rod blocks initiated by the rod block monitor (RBM). The CRWE event was analyzed assuming no xenon and allowing credible instrumentation out-of-service in the rod block monitor (RBM) system. The analysis further assumes that the plant could be operating in either an A or B sequence control rod pattern. The rated power CRWE results are shown in Table 5.7 for the analytical unfiltered RBM high power setpoint values of 107% to 117%. At all intermediate and lower power setpoint

values, the $MCPR_p$ values for ATRIUM 10XM and ATRIUM-10 fuel bound or are equal to the CRWE MCPR values. Analysis results indicate standard filtered RBM setpoint reductions are supported. Analyses demonstrate that the 1% strain and centerline melt criteria are met for both ATRIUM 10XM and ATRIUM-10 fuel, for the LHGR limits and their associated multipliers presented in Sections 8.2 and 8.3. Recommended operability requirements supporting unblocked CRWE operation are shown in Table 5.8, based on the SLMCPR values presented in Section 4.2.

5.2 *Slow Flow Runup Analysis*

Flow-dependent MCPR and LHGR limits are established to support operation at off-rated core flow conditions. Limits are based on the CPR and heat flux changes experienced by the fuel during slow flow excursions. The slow flow excursion event assumes recirculation flow control system failure such that core flow increases slowly to the maximum flow physically attainable by the equipment (107% of rated core flow). An uncontrolled increase in flow creates the potential for a significant increase in core power and heat flux. A conservatively steep flow runup path was used in the analysis. Analyses were performed to support operation in all the EOOS scenarios.

$MCPR_f$ limits are determined for all fuel types in the core. XCOBRA is used to calculate the change in critical power ratio during a two-loop flow runup to the maximum flow rate. The $MCPR_f$ limit is set so an increase in core power, resulting from the maximum increase in core flow, assures the TLO safety limit MCPR is not violated. Calculations were performed over a range of initial flow rates to determine the corresponding MCPR values causing the limiting assembly to be at the safety limit MCPR for the high flow condition at the end of the flow excursion.

Analysis results are presented in Table 5.9. $MCPR_f$ limits providing the required protection are presented in Table 8.3. $MCPR_f$ limits are applicable for all exposures.

Flow runup analyses were performed with CASMO-4/MICROBURN-B2 to determine flow-dependent LHGR multipliers ($LHGRFAC_f$) for ATRIUM 10XM and ATRIUM-10 fuel. The analysis assumes recirculation flow increases slowly along the limiting rod line to the maximum flow physically attainable by the equipment. A series of flow excursion analyses were performed at several exposures throughout the cycle, starting from different initial power/flow conditions.

Xenon is assumed to remain constant during the event. $LHGRFAC_f$ multipliers are established to provide protection against fuel centerline melt and overstraining of the cladding during a flow runup. $LHGRFAC_f$ multipliers are presented in Table 8.6.

The maximum flow during a flow excursion in SLO is much less than the maximum flow during TLO. Therefore, the flow-dependent MCPR limits and LHGR multipliers for TLO are applicable for SLO.

5.3 ***Equipment Out-of-Service Scenarios***

The EOOS scenarios supported are shown in Table 1.1. As noted in Table 1.1, base case and each EOOS condition is supported in combination with 1 MSRVOOS, EOC-RPT-OOS, up to 2 TIP machines out-of-service or the equivalent number of TIP channels (per operating requirements defined in Section 4.2), and/or up to 50% of the LPRMs out-of-service.

When EOC-RPT is inoperable, no credit is assumed for RPT on TSV position or TCV fast closure. The function of the EOC-RPT feature is to reduce the severity of the core power excursion caused by the pressurization transient. The RPT accomplishes this by helping revoid the core, thereby reducing the magnitude of the reactivity insertion resulting from the pressurization transient. Failure of the RPT feature can result in higher operating limits. Analyses were performed for LRNB and FWCF events assuming EOC-RPT-OOS.

The analyses presented in this section also include these EOOS conditions protected by the base case limits. No further discussion for these EOOS conditions is presented in this section. Base thermal limits presented in Section 8.0 are applicable with or without function of the EOC-RPT.

5.3.1 TBVOOS

The effect of operation with TBVOOS is a reduction in the system pressure relief capacity, which makes the pressurization events more severe. While the base case LRNB and TTNB events are analyzed assuming the turbine bypass valves out-of-service, operation with TBVOOS has an adverse effect on the FWCF event. Analyses of the FWCF event with TBVOOS were performed to establish the TBVOOS operating limits.

5.3.2 FHOOS

The FHOOS scenario assumes a feedwater temperature reduction of 65°F (55°F + 10°F bias) at rated power and steam flow. The effect of reduced feedwater temperature is an increase in core inlet subcooling, changing axial power shape and core void fraction. Additionally, steam flow for a given power level decreases because more power is required to increase coolant enthalpy to saturated conditions. Generally, LRNB and TTNB events are less severe with FHOOS conditions due to the decrease in steam flow relative to nominal conditions. FWCF events with FHOOS conditions are generally worse due to a larger change in inlet subcooling and core power prior to the pressurization phase of the event.

Separate FHOOS limits are not needed for operation beyond the EOCLB exposure since a feedwater temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure, i.e., FFTR is equivalent to FHOOS since both are based on the same feedwater temperature reduction.

5.3.3 PLUOOS

The PLU device in normal operation is assumed to not function below 50% power. PLUOOS is assumed to mean the PLU device does not function for any power level, and does not initiate fast TCV closure. The following PLUOOS scenario was assumed for the load reject event.

- Initially, the TCVs remain in pressure/speed control mode. There is no direct scram or EOC-RPT on valve motion.
- Loss of load results in increasing turbine speed. Depending on initial power, a turbine overspeed condition may be reached to initiate a turbine trip resulting in scram and EOC-RPT.
- Without a turbine trip signal, scram occurs on either high flux or high dome pressure to terminate the event.

Analyses were performed for LRNB events assuming PLUOOS.

5.3.4 Combined TBVOOS and FHOOS

FWCF analyses with both TBVOOS and FHOOS were performed. Operating limits for this combined EOOS scenario were established using these FWCF results and results previously discussed. Separate TBVOOS and FHOOS combined limits are not needed for operation

beyond the EOCLB exposure since a FW temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure.

5.3.5 Combined TBVOOS and PLUOOS

Limits were established to support operation with both TBVOOS and PLUOOS. No additional analyses are required to construct $MCPR_p$ operating limits for TBVOOS and PLUOOS since TBVOOS and PLUOOS are independent EOOS conditions (TBVOOS only impacts FWCF events; PLUOOS only impacts LRNB events).

5.3.6 Combined FHOOS and PLUOOS

LRNB analyses with both FHOOS and PLUOOS were performed. Operating limits for this combined EOOS scenario were established using these LRNB results and results previously discussed. Separate FHOOS and PLUOOS combined limits are not needed for operation beyond the EOCLB exposure since a FW temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure.

5.3.7 Combined TBVOOS, FHOOS, and PLUOOS

Limits were established to support operation with TBVOOS, FHOOS, and PLUOOS. No additional analyses are required to construct $MCPR_p$ operating limits for TBVOOS, FHOOS, and PLUOOS since TBVOOS and PLUOOS are independent EOOS conditions (TBVOOS only impacts FWCF events; PLUOOS only impacts LRNB events). Separate TBVOOS, FHOOS, and PLUOOS combined limits are not needed for operation beyond the EOCLB exposure since a FW temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure.

5.3.8 Single-Loop Operation

In SLO, the two-loop operation ΔCPRs and LHGRFAC multipliers remain applicable. The only impacts on the MCPR, LHGR, and MAPLHGR limits for SLO are an increase of 0.02 in the SLMCPR as discussed in Section 4.2, and the application of an SLO MAPLHGR multiplier discussed in Section 8.3. The net result is a 0.02 increase in the base case $MCPR_p$ limits and a decrease in the MAPLHGR limit. The same situation is true for the EOOS scenarios. Adding 0.02 to the corresponding two-loop operation EOOS $MCPR_p$ limits results in SLO $MCPR_p$ limits for the EOOS conditions. The TLO EOOS LHGRFAC multipliers remain applicable in SLO.

5.4 *Licensing Power Shape*

The licensing axial power profile used by AREVA for the plant transient analyses bounds the projected end of full power axial power profile. The conservative licensing axial power profile generated at the EOCLB core average exposure of 32,734 MWd/MTU is given in Table 5.10. Operation is considered to be in compliance when:

- The integrated normalized power generated in the bottom 7 nodes from the projected EOFP solution at the state conditions provided in Table 5.10 is greater than the integrated normalized power generated in the bottom 7 nodes in the licensing basis axial power profile, *and* the individual normalized power from the projected EOFP solution is greater than the corresponding normalized power from the licensing basis axial power profile for at least 6 of the 7 bottom nodes.
- The projected EOFP condition occurs at a core average exposure less than or equal to EOCLB.

If the criteria cannot be fully met (i.e., not all 7 nodes are at a higher power than the licensing profile), the licensing basis may nevertheless remain valid but further assessment will be required.

The licensing basis power profile in Table 5.10 was calculated using the MICROBURN-B2 code. Compliance analyses must also be performed using MICROBURN-B2 or POWERPLEX®-III*. Note that the power profile comparison should be done without incorporating instrument updates to the axial profile because the updated power is not used in the core monitoring system to accumulate assembly burnups.

* POWERPLEX is a trademark of AREVA NP registered in the United States and various other countries.

Table 5.1 Exposure Basis for Transient Analysis

Core Average Exposure (MWd/MTU)	Comments
17,206.5	Beginning of cycle
29,206.3	Break point for exposure-dependent $MCPR_p$ limits (NEOC)
32,734.0	Design basis rod patterns to EOFP + 15 EFPD (EOCLB)
34,147.6	Maximum licensing core exposure - including FFTR /Coastdown
32,520.4 (17,224.4)*	Cycle 18 EOC (nominal value)
31,984.3 (16,688.3)*	Cycle 18 EOC (short window)
32,877.7 (17,581.7)*	Cycle 18 EOC (long window)

* Corresponding Cycle 18 cycle exposure.

Table 5.2 Scram Speed Insertion Times

Control Rod Position (notch)	TSSS Analytical Time (sec)	NSS Analytical Time (sec)
48 (*full-out*)	0.00	0.00
48	0.20	0.20
46	0.46	0.421
36	1.09	0.991
26	1.86	1.62
6	3.50	3.04
0 (*full-in*)	4.0	3.5

Table 5.3 Base Case LRNB Transient Results

Power (% rated)	NEOC			EOCLB		
	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR
TSSS Insertion Times						
100	0.29	0.33	1.29	0.31	0.35	1.38
90	0.32	0.34	1.30	0.33	0.37	1.40
75	0.33	0.34	1.29	0.33	0.35	1.38
50	0.75	0.83	1.76	0.75	0.83	1.80
NSS Insertion Times						
100	0.26	0.30	1.27	0.30	0.34	1.37
90	0.29	0.32	1.29	0.31	0.35	1.39
75	0.31	0.32	1.28	0.32	0.34	1.37
50	0.75	0.82	1.75	0.75	0.82	1.79

Table 5.4 Base Case TTNB Transient Results

Power (% rated)	*EOCLB*		
	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR
NSS Insertion Times			
100	0.30	0.33	1.37
90	0.30	0.34	1.37
75	0.30	0.33	1.35

Table 5.5 Base Case FWCF Transient Results

Power (% rated)	NEOC			EOCLB		
	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR
TSSS Insertion Times						
100	0.37	0.39	1.40	0.39	0.39	1.47
90	0.43	0.45	1.47	0.44	0.45	1.53
75	0.52	0.53	1.55	0.52	0.53	1.59
65	0.59	0.60	1.63	0.60	0.60	1.64
60	0.64	0.64	1.67	0.64	0.64	1.67
50	0.77	0.82	1.82	0.77	0.82	1.82
40	0.96	1.10	2.09	0.96	1.10	2.09
30	1.26	1.45	2.37	1.26	1.45	2.37
30 at > 50%F below P_{bypass}	1.94	2.22	3.33	1.94	2.22	3.33
30 at ≤ 50%F below P_{bypass}	1.88	2.15	3.13	1.88	2.15	3.13
25 at > 50%F below P_{bypass}	2.32	2.58	3.78	2.32	2.58	3.78
25 at ≤ 50%F below P_{bypass}	2.22	2.52	3.51	2.22	2.52	3.51
NSS Insertion Times						
100	0.35	0.36	1.37	0.37	0.38	1.46
90	0.41	0.42	1.45	0.43	0.42	1.52
75	0.50	0.51	1.54	0.51	0.51	1.59
65	0.58	0.58	1.61	0.59	0.58	1.64
60	0.62	0.62	1.65	0.63	0.62	1.67
50	0.75	0.77	1.79	0.75	0.77	1.79
40	0.95	1.04	2.06	0.95	1.04	2.06
30	1.22	1.38	2.34	1.22	1.38	2.34

Table 5.6 Loss of Feedwater Heating Transient Analysis Results

Power (% rated)	ΔCPR*
100	0.21
90	0.22
80	0.23
70	0.24
60	0.25
50	0.27
40	0.29
30	0.34
25	0.38

Table 5.7 Control Rod Withdrawal Error ΔCPR Results

Analytical RBM Setpoint (without filter) (%)	ΔCPR*
107	0.11
111	0.18
114	0.29
117	0.31

* Results are for the most limiting of the ATRIUM 10XM or ATRIUM-10 fuel in the core.

Table 5.8 RBM Operability Requirements

Thermal Power (% rated)	Applicable MCPR
≥ 27% and < 90%	1.76 TLO 1.80 SLO
≥ 90%	1.39 TLO

Table 5.9 Flow-Dependent MCPR Results

Core Flow (% rated)	ATRIUM 10XM Limiting MCPR	ATRIUM-10 Limiting MCPR
30	1.43	1.48
40	1.35	1.38
50	1.34	1.35
60	1.33	1.32
70	1.29	1.27
80	1.21	1.23
90	1.18	1.19
100	1.14	1.15
107	1.06	1.06

Table 5.10 Licensing Basis Core Average Axial Power Profile

State Conditions for Power Shape Evaluation	
Power, MWt	3458.0
Core pressure, psia	1050.1
Inlet subcooling, Btu/lbm	24.2
Flow, Mlb/hr	107.6
Control state	ARO
Core average exposure (EOCLB), MWd/MTU	32,734

Licensing Axial Power Profile
(Normalized)

Node	Power
Top 25	0.242
24	0.694
23	0.898
22	1.029
21	1.102
20	1.165
19	1.223
18	1.287
17	1.335
16	1.460
15	1.502
14	1.478
13	1.520
12	1.477
11	1.397
10	1.298
9	1.190
8	1.048
7	0.886
6	0.746
5	0.615
4	0.512
3	0.441
2	0.353
Bottom 1	0.103

Sum of Bottom 7 Nodes = 3.656

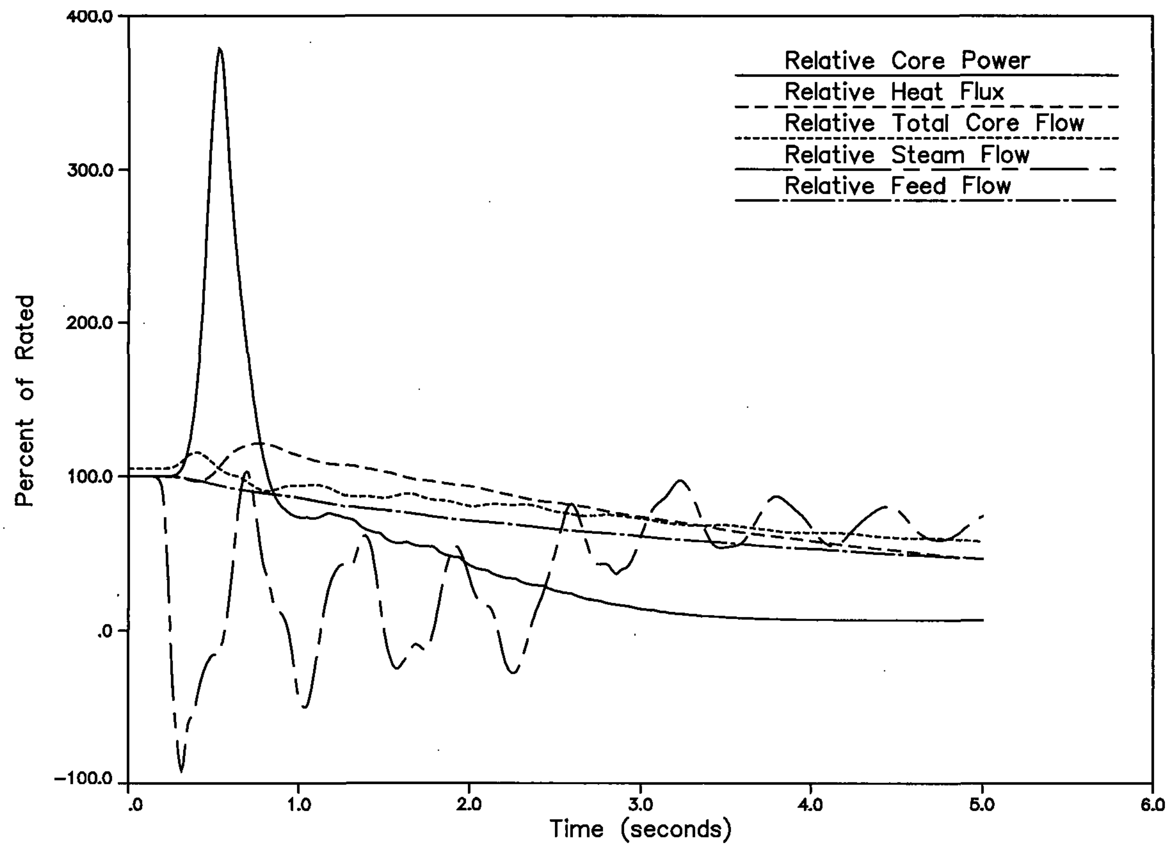

Figure 5.1 EOCLB LRNB at 100P/105F – TSSS Key Parameters

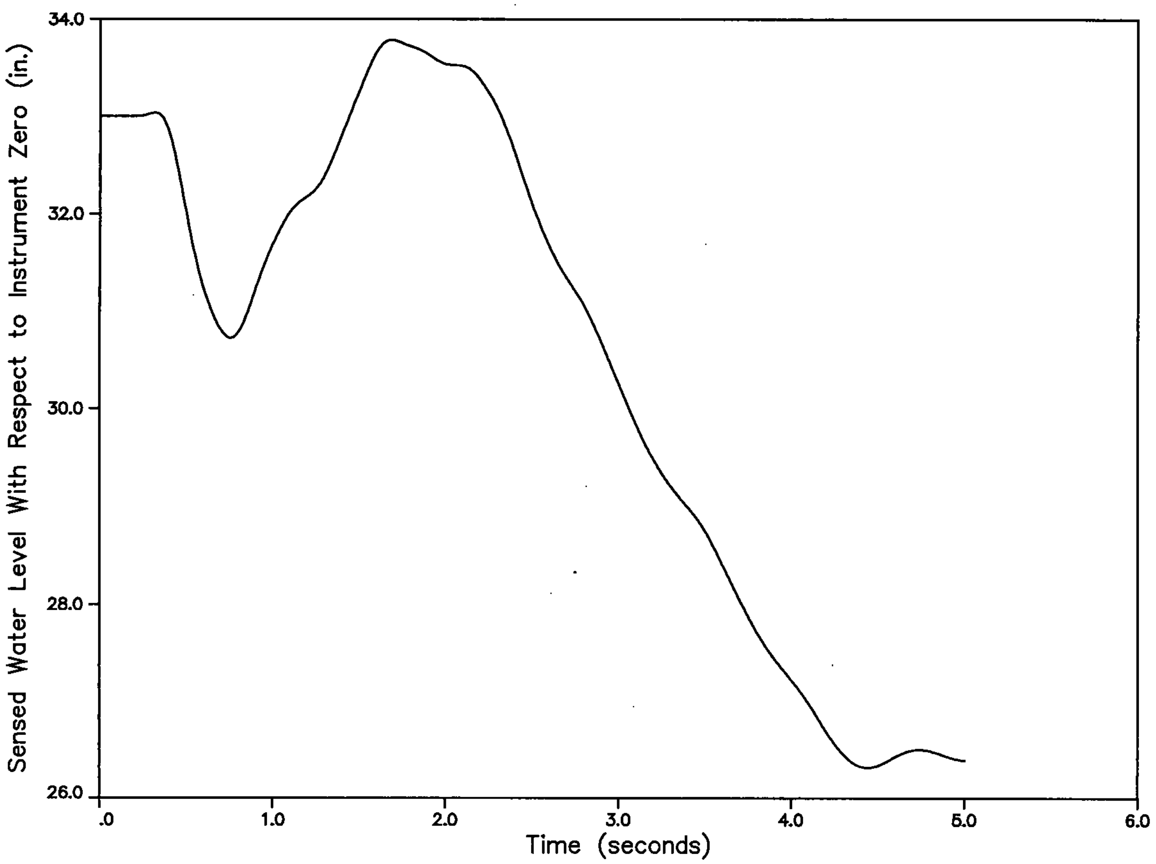

Figure 5.2 EOCLB LRNB at 100P/105F – TSSS Sensed Water Level

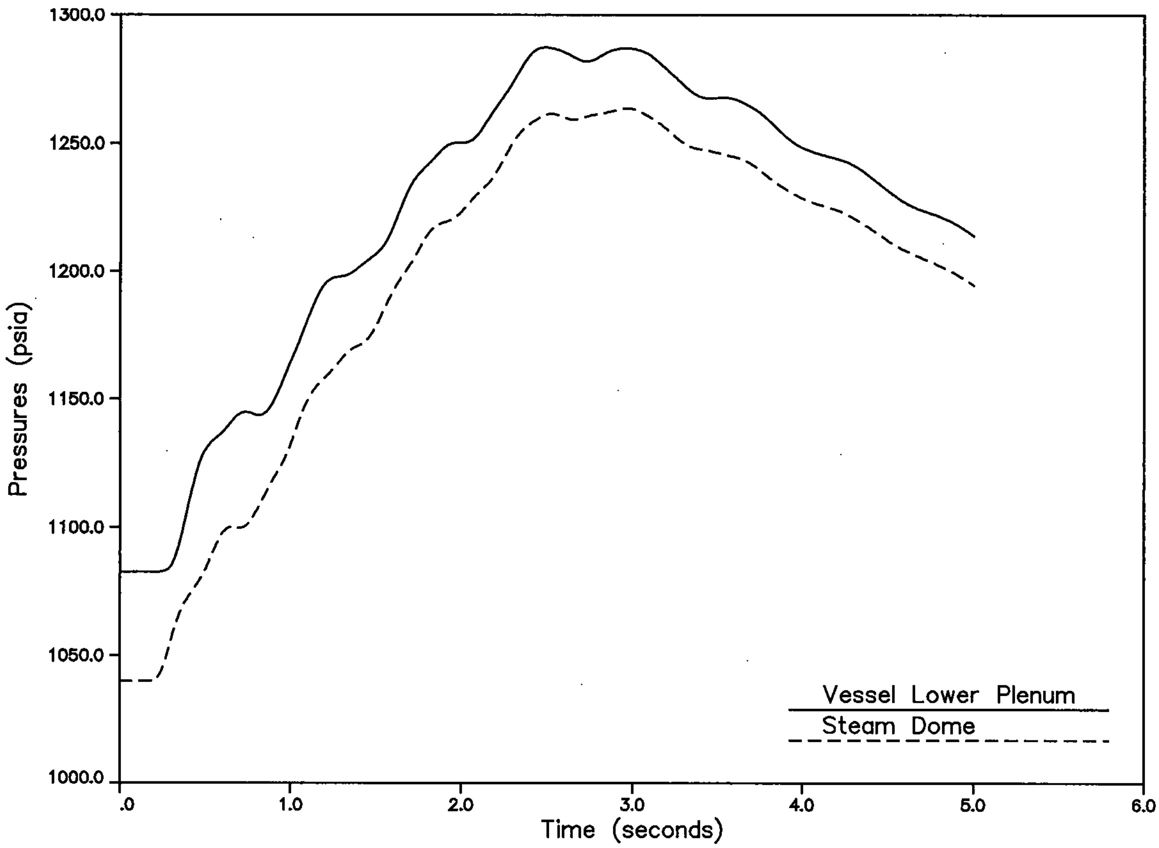

Figure 5.3 EOCLB LRNB at 100P/105F – TSSS
Vessel Pressures

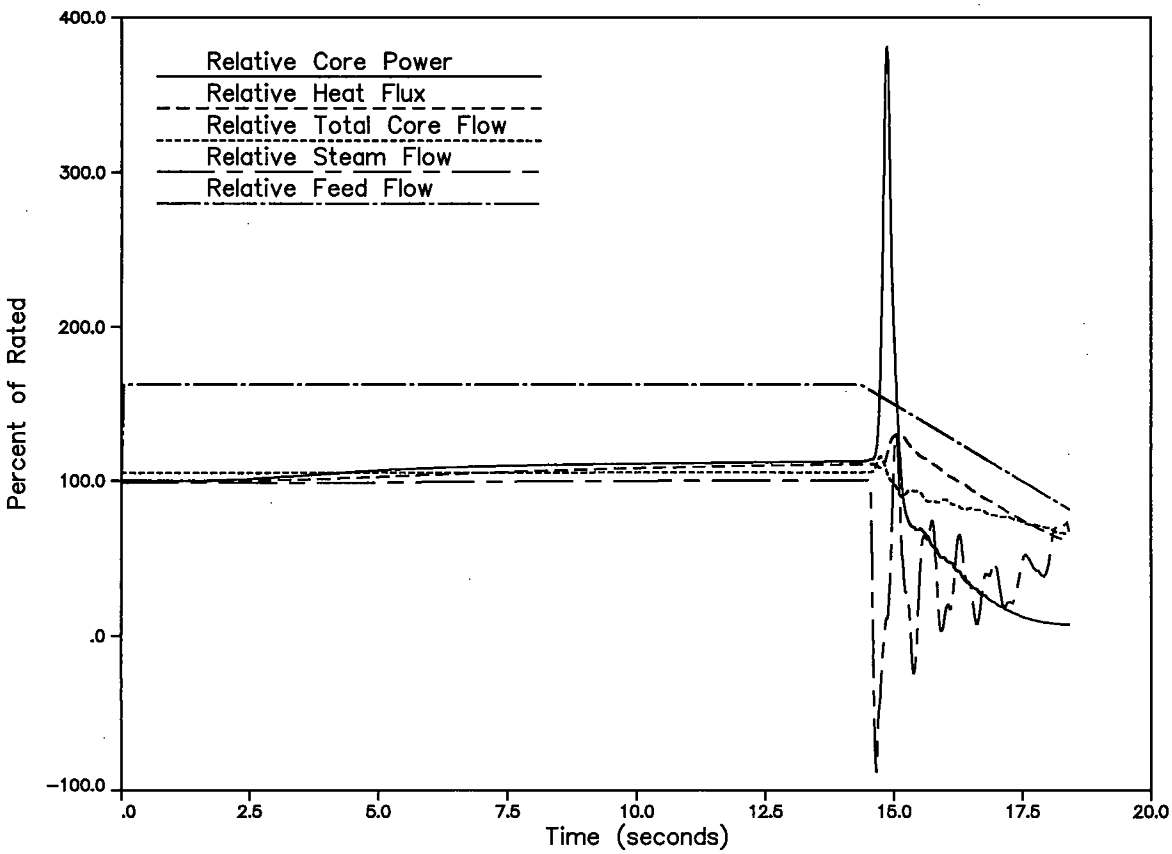

Figure 5.4 EOCLB FWCF at 100P/105F – TSSS Key Parameters

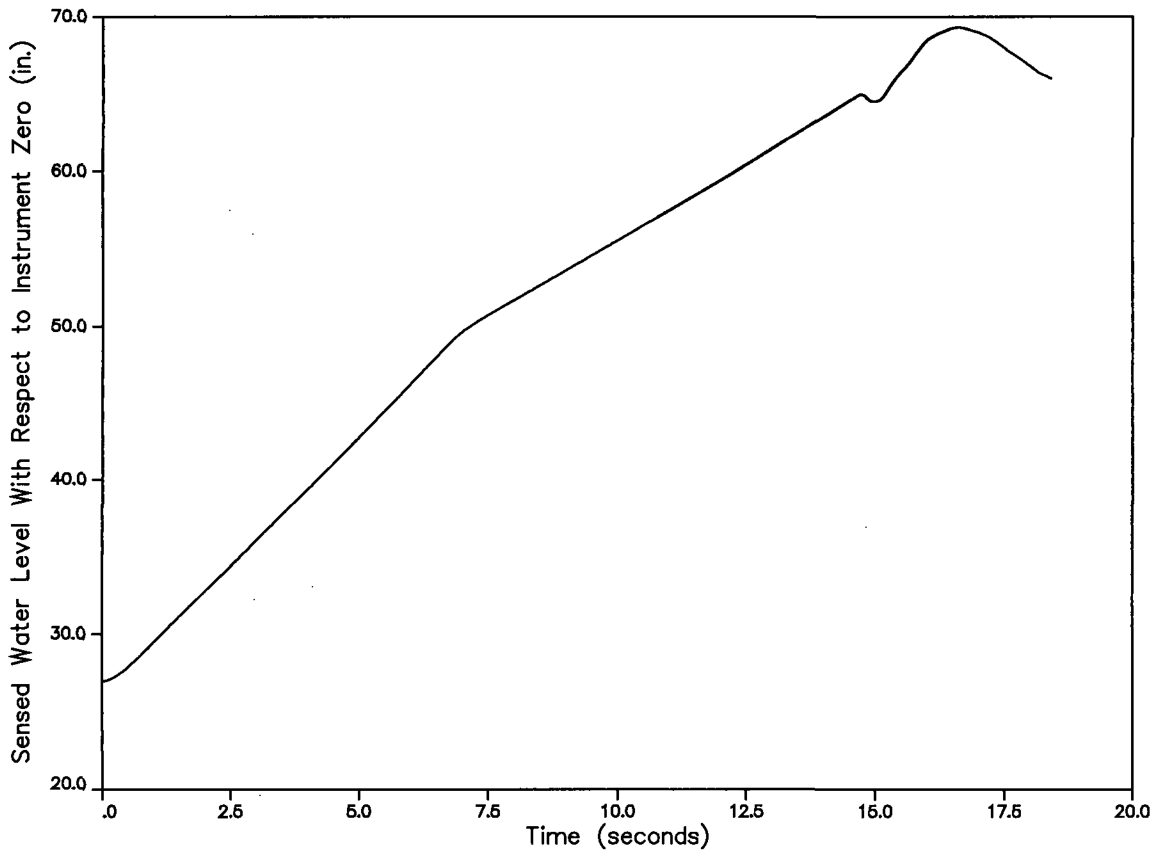

Figure 5.5 EOCLB FWCF at 100P/105F – TSSS
Sensed Water Level

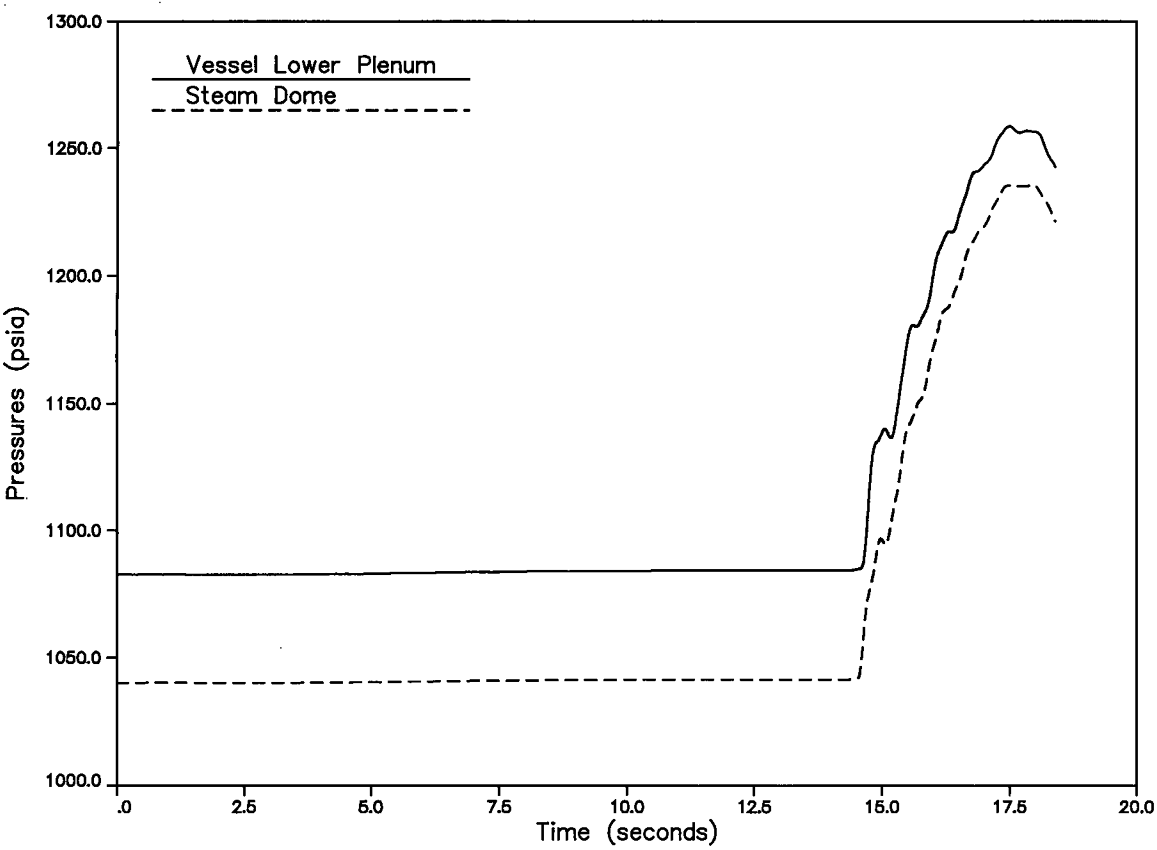

**Figure 5.6 EOCLB FWCF at 100P/105F – TSSS
Vessel Pressures**

6.0 Postulated Accidents

6.1 *Loss-of-Coolant-Accident (LOCA)*

The results of the ATRIUM 10XM LOCA analysis are presented in References 6 and 7. The ATRIUM 10XM PCT is 1903°F. The peak local metal water reaction is 1.16% and the maximum core wide metal-water reaction (for hydrogen generation) for a full ATRIUM 10XM core is <1.0%.

Thermal-hydraulic characteristics of the ATRIUM-10 and ATRIUM 10XM fuel designs are similar as presented in Reference 5. Therefore, the core response during a LOCA will not be significantly different for a full core of ATRIUM-10 fuel or a mixed core of ATRIUM-10 and ATRIUM 10XM fuel. In addition, since about 95% of the reactor system volume is outside the core region, slight changes in core volume and fluid energy due to fuel design differences will produce an insignificant change in total system volume and energy. Reference 34 results for ATRIUM-10 LOCA remain applicable.

Analyses and results support the EOD and EOOS conditions listed in Table 1.1. Note: TBVOOS, EOC-RPT-OOS, PLUOOS, and TIPOOS/LPRM out-of-service have no direct influence on the LOCA events.

6.2 *Control Rod Drop Accident (CRDA)*

Plant startup utilizes a bank position withdrawal sequence (BPWS) including rod worth minimization strategies. CRDA evaluation was performed for both A and B sequence startups consistent with the withdrawal sequences specified by TVA. Approved AREVA generic CRDA methodology is described in Reference 36. Subsequent calculations have shown the methodology is applicable to fuel modeled with the CASMO-4/MICROBURN-B2 code system and is applicable to ATRIUM-10 and ATRIUM 10XM fuel.

Maximum deposited fuel rod enthalpy is less than both the current core coolability limit of 280 cal/g and the 230 cal/g limit identified in Standard Review Plan 4.2, Revision 3, Appendix B, Section C, Item 1. Fuel rods conservatively estimated to exceed the existing fuel damage threshold of 170 cal/g are within the UFSAR basis (850 rods). The CRDA analysis results are summarized below.

Maximum dropped control rod worth, mk	9.37
Core average Doppler coefficient, Δk/k/°F	-10.0×10^{-6}
Effective delayed neutron fraction	0.0053
Four-bundle local peaking factor	1.467
Maximum deposited fuel rod enthalpy, cal/g	170.7
Maximum number of rods exceeding 170 cal/g	91

6.3 *Fuel and Equipment Handling Accident*

The fuel handling accident radiological analysis implementing the alternate source term (AST) as approved in Reference 11 was performed with consideration of ATRIUM-10 core source terms. The ATRIUM 10XM source terms have been dispositioned relative to those in the AST analysis of record and found to support the same conclusions. Fuel assembly and reactor core isotopic inventories used as input to design basis radiological accident analyses are applicable to all three units (Reference 11).The number of failed fuel rods for the ATRIUM-10 fuel as previously provided to TVA in Reference 37 for use in the AST analysis is unchanged. The number of failed fuel rods for the ATRIUM 10XM fuel is 163, which remains bounded by the analysis of record. No other aspect of utilizing the ATRIUM-10 and ATRIUM 10XM fuel affects the current analysis; therefore, the AST analysis remains applicable.

6.4 *Fuel Loading Error (Infrequent Event)*

There are two types of fuel loading errors possible in a BWR – the mislocation of a fuel assembly in a core position prescribed to be loaded with another fuel assembly, and the misorientation of a fuel assembly with respect to the control blade. As described in Reference 26, the fuel loading error is characterized as an infrequent event. The acceptance criteria is that the offsite dose consequences due to the event shall not exceed a small fraction of the 10 CFR 50.67 limits.

6.4.1 Mislocated Fuel Bundle

AREVA has performed a fuel mislocation error analysis for Browns Ferry Unit 2 Cycle 19. The analysis evaluated the impact of a mislocated assembly against potential fuel rod failure mechanisms due to increased LHGR and reduced CPR. Based on the analyses, the offsite dose criteria (a small fraction of 10 CFR 50.67) is conservatively satisfied. A dose consequence

evaluation is not necessary since no rod approaches the fuel centerline melt or 1% strain limits, and less than 0.1% of the fuel rods are expected to experience boiling transition.

6.4.2 Misoriented Fuel Bundle

AREVA has performed a fuel assembly misorientation analysis for the ATRIUM 10XM fuel assemblies in Browns Ferry Unit 2 Cycle 19. The analysis was performed assuming that the limiting assembly was loaded in the worst orientation (rotated 180°), and depleted through the cycle without operator interaction. AREVA has also performed a bounding fuel assembly misorientation analysis for 10 x 10 fuel monitored with the SPCB critical power correlation. These analyses demonstrate that the small fraction of 10 CFR 50.67 offsite dose criteria is conservatively satisfied. A dose consequence evaluation is not necessary since no rod approaches fuel centerline melt or 1% strain limits, and less than 0.1% of the fuel rods are expected to experience boiling transition.

7.0 Special Analyses

7.1 *ASME Overpressurization Analysis*

This section describes the maximum overpressurization analyses performed to demonstrate compliance with the ASME Boiler and Pressure Vessel Code. The analysis shows that the safety/relief valves have sufficient capacity and performance to prevent the reactor vessel pressure from reaching the safety limit of 110% of the design pressure.

MSIV closure, TSV closure, and TCV closure (without bypass) analyses were performed with the AREVA plant simulator code COTRANSA2 (Reference 2) for 102% power and both 81% and 105% flow at the highest cycle exposure. The MSIV closure event is similar to the other steam line valve closure events in that the valve closure results in a rapid pressurization of the core. The increase in pressure causes a decrease in void which in turn causes a rapid increase in power. The turbine bypass valves do not impact the system response and are not modeled in the analysis. The following assumptions were made in the analysis.

- The most critical active component (direct scram on valve position) was assumed to fail. However, scram on high neutron flux and high dome pressure is available.
- To support operation with 1 MSRVOOS, the plant configuration analyzed assumed that one of the lowest setpoint MSRVs was inoperable.
- TSSS insertion times were used.
- The initial dome pressure was set at the maximum allowed by the Technical Specifications plus an additional 5 psi bias, 1070 psia (1055 psig).
- A fast MSIV closure time of 3.0 seconds was used.
- The analytical limit ATWS-RPT setpoint and function were assumed.

Results of the MSIV closure, TCV closure, and TSV closure overpressurization analyses are presented in Table 7.1. Various reactor plant parameters during the limiting MSIV closure event are presented in Figures 7.1—7.4. The maximum pressure of 1336 psig occurs in the lower plenum. The maximum dome pressure for the same event is 1301 psig. Results demonstrate the maximum vessel pressure limit of 1375 psig and dome pressure limit of 1325 psig are not exceeded for any analyses.

Pressure results include a 7-psi increase to bound a bias in the void-quality correlations. The void-quality bias is further discussed in Reference 38. Margin to the pressure limits shown in

Table 7.1 are more than adequate to compensate for NRC concerns related to Doppler-effects and exposure-dependent thermal conductivity degradation.

7.2 *ATWS Event Evaluation*

7.2.1 ATWS Overpressurization Analysis

This section describes analyses performed to demonstrate that the peak vessel pressure for the limiting ATWS event is less than the ASME Service Level C limit of 120% of the design pressure (1500 psig). Overpressurization analyses were performed at 100% power at both 81% and 105% flow over the cycle exposure range for both the MSIV closure event and the pressure regulator failure open (PRFO) events. The PRFO event assumes a step decrease in pressure demand such that the pressure control system opens the turbine control and turbine bypass valves. Steam flow demand is assumed to increase to 125% demand (equivalent to 132.6% of rated steam flow) allowing a maximum TCV flow of 106.1% and a maximum bypass system flow of 25.2%. The system pressure decreases until the low pressure setpoint is reached resulting in the closure of the MSIVs. The subsequent pressurization wave collapses core voids, thereby increasing core power.

The following assumptions were made in the analyses.

- The analytical limit ATWS-RPT setpoint and function were assumed.
- To support operation with 1 MSRVOOS, the plant configuration analyzed assumed that one of the lowest setpoint MSRVs was inoperable.
- All scram functions were disabled.
- The initial dome pressure was set to the nominal pressure of 1050 psia.
- A nominal MSIV closure time of 4.0 seconds was used for both events.

Analyses results are presented in Table 7.2. The response of various reactor plant parameters during the limiting PRFO event are shown in Figures 7.5 - 7.8. The maximum lower plenum pressure is 1399 psig and the maximum dome pressure is 1379 psig. The results demonstrate that the ATWS maximum vessel pressure limit of 1500 psig is not exceeded.

Pressure results include a 10-psi increase to bound a bias in the void-quality correlations. The void-quality bias is further discussed in Reference 38. Margin to the pressure limits shown in Table 7.2 are more than adequate to compensate for NRC concerns related to Doppler-effects and exposure-dependent thermal conductivity degradation.

7.2.2 Long-Term Evaluation

Fuel design differences may impact the power and pressure excursion experienced during the ATWS event. This in turn may impact the amount of steam discharged to the suppression pool and containment.

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7.3 *Standby Liquid Control System*

In the event that the control rod scram function becomes incapable of rendering the core in a shutdown state, the standby liquid control (SLC) system is required to be capable of bringing the reactor from full power to a cold shutdown condition at any time in the core life. The Browns Ferry Unit 2 SLC system is required to be able to inject 660 ppm natural boron equivalent at 70°F into the reactor coolant. AREVA has performed an analysis demonstrating the SLC system

meets the required shutdown capability for the cycle. The analysis was performed at a coolant temperature of 366°F, with a boron concentration equivalent to 660 ppm at 68°F*. The temperature of 366°F corresponds to the low pressure permissive for the RHR shutdown cooling suction valves, and represents the maximum reactivity condition with soluble boron in the coolant. The analysis shows the core to be subcritical throughout the cycle by at least 1.65% Δk/k based on the Cycle 18 EOC short window, which is the most limiting exposure bound by the short and long Cycle 18 exposure window.

7.4 *Fuel Criticality*

The spent fuel pool criticality analysis for ATRIUM-10 and ATRIUM 10XM fuel are presented in References 9 and 35, respectively. The ATRIUM-10 and ATRIUM-10 XM fuel assemblies identified for the cycle meet the spent fuel storage requirements. ATRIUM-10 and ATRIUM 10XM fuel assemblies will not be stored in the new fuel storage vault.

* TVA Browns Ferry SLC licensing basis documents indicate a minimum of 660 ppm boron at a temperature of 70°F. The AREVA cold analysis basis of 68°F represents a negligible difference and the results are adequate to protect the 70°F licensing basis for the plant.

Table 7.1 ASME Overpressurization Analysis Results*

Event	Peak Neutron Flux (% rated)	Peak Heat Flux (% rated)	Maximum Vessel Pressure Lower-Plenum (psig)	Maximum Dome Pressure (psig)
MSIV closure (102P/105F)	272	127	1336	1301
TSV closure without bypass (102P/105F)	454	135	1329	1291
TCV closure without bypass (102P/105F)	454	135	1330	1291
Pressure Limit	---	---	1375	1325

* Pressure results include a 7-psi increase to bound a bias in the void-quality correlations (Reference 38).

Table 7.2 ATWS Overpressurization Analysis Results*

Event	Peak Neutron Flux (% rated)	Peak Heat Flux (% rated)	Maximum Vessel Pressure Lower-Plenum (psig)	Maximum Dome Pressure (psig)
MSIV closure (100P/105F)	251	139	1377	1355
MSIV closure (100P/81F)	271	136	1390	1370
PRFO (100P/105F)	260	151	1384	1362
PRFO (100P/81F)	236	143	1399	1379
Pressure Limit	---	---	1500	1500

* Pressure results include a 10-psi increase to bound a bias in the void-quality correlations (Reference 38).

Table 7.3 [

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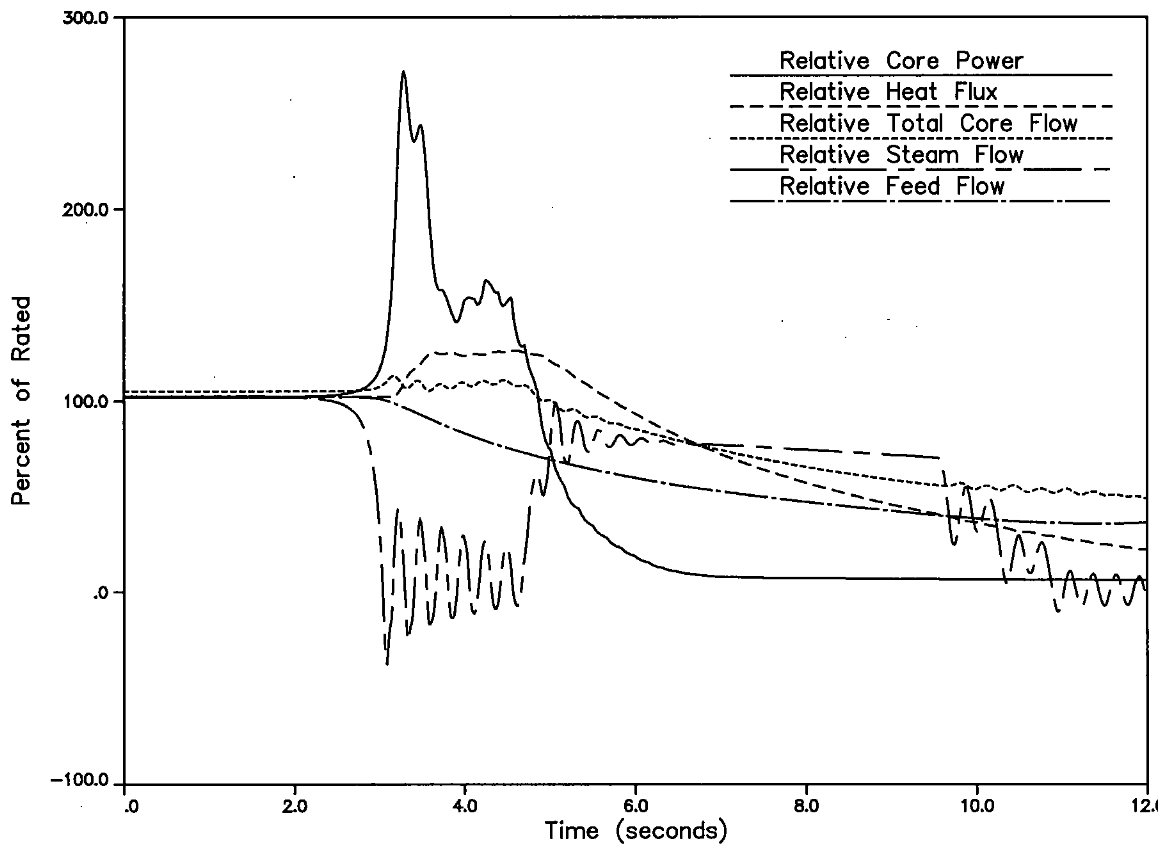

Figure 7.1 MSIV Closure Overpressurization Event at 102P/105F – Key Parameters

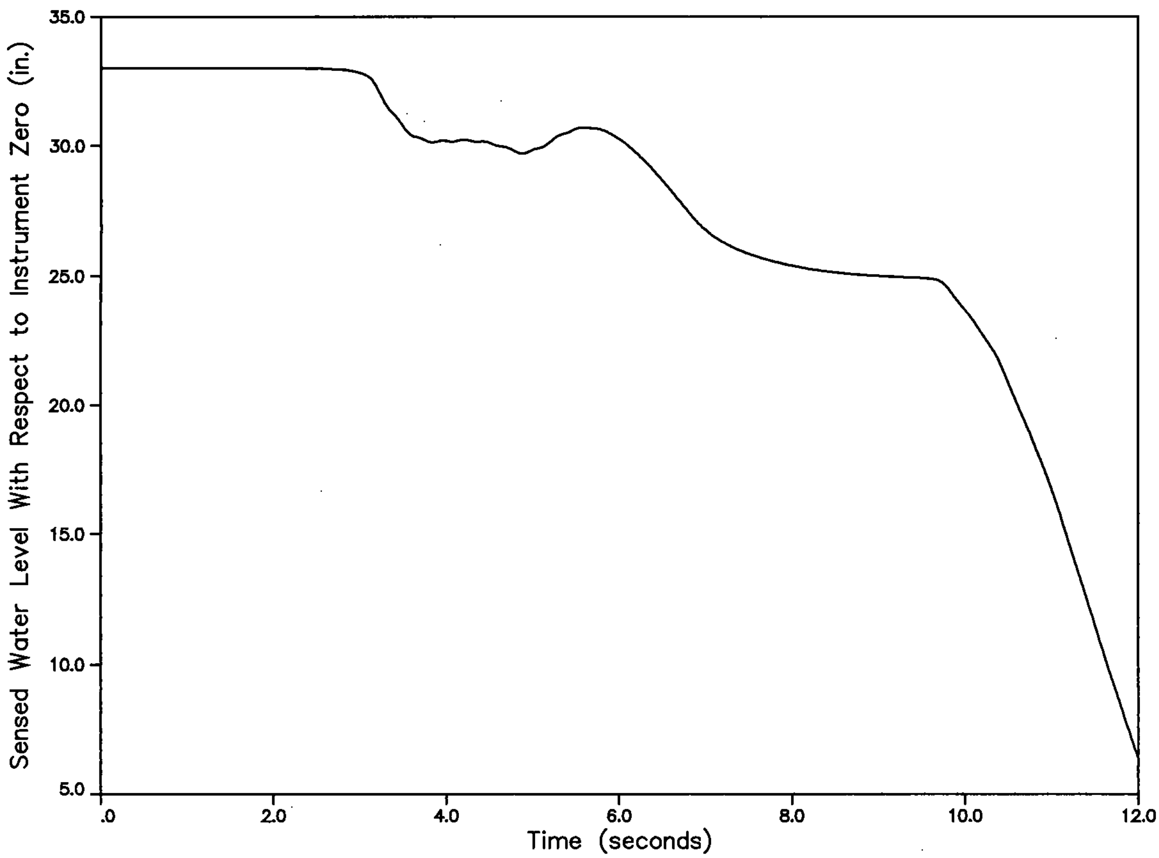

Figure 7.2 MSIV Closure Overpressurization Event at 102P/105F – Sensed Water Level

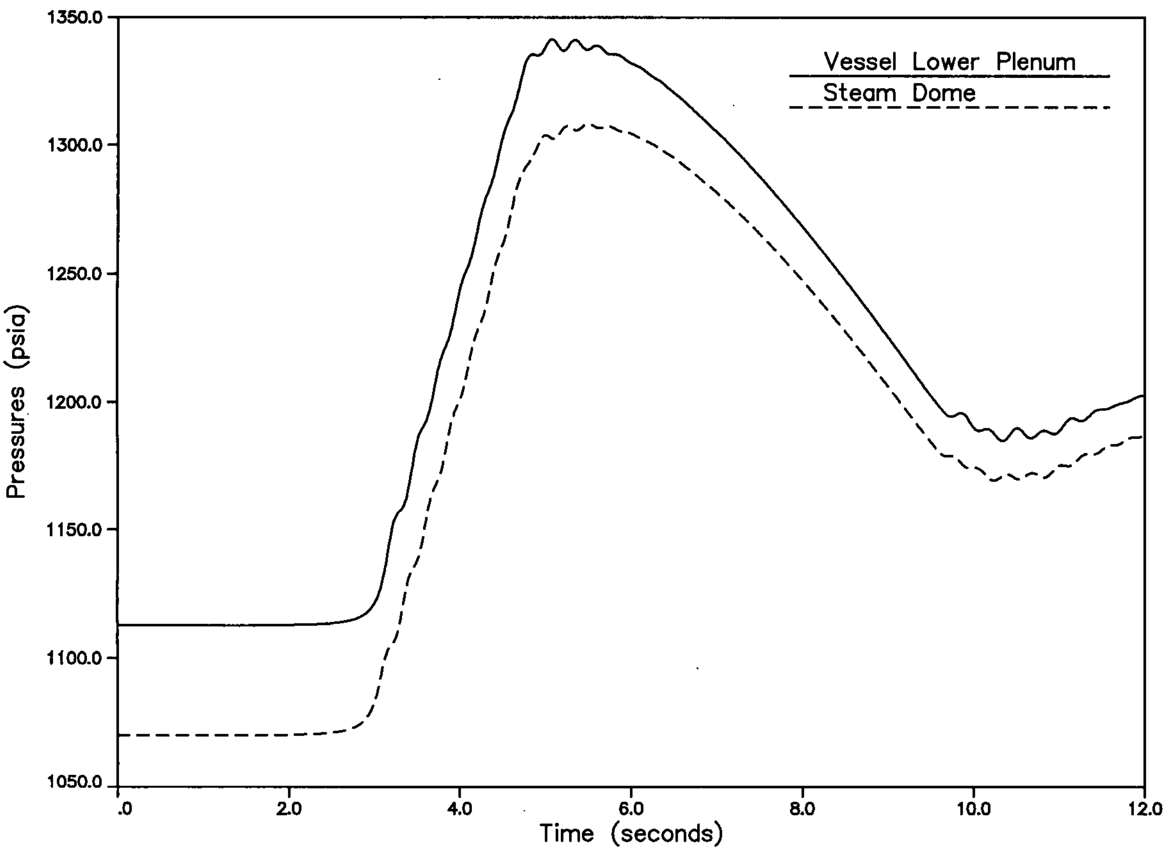

Figure 7.3 MSIV Closure Overpressurization Event at 102P/105F – Vessel Pressures

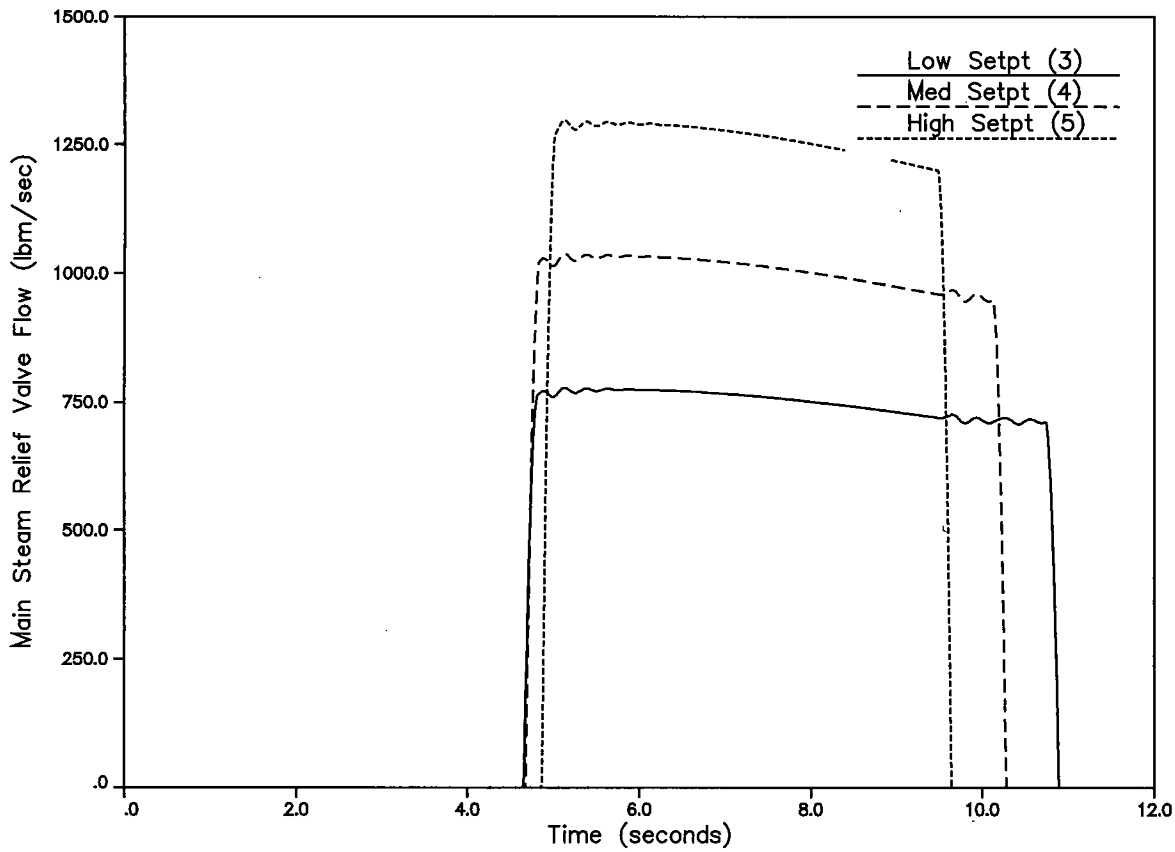

Figure 7.4 MSIV Closure Overpressurization Event at 102P/105F – Safety/Relief Valve Flow Rates

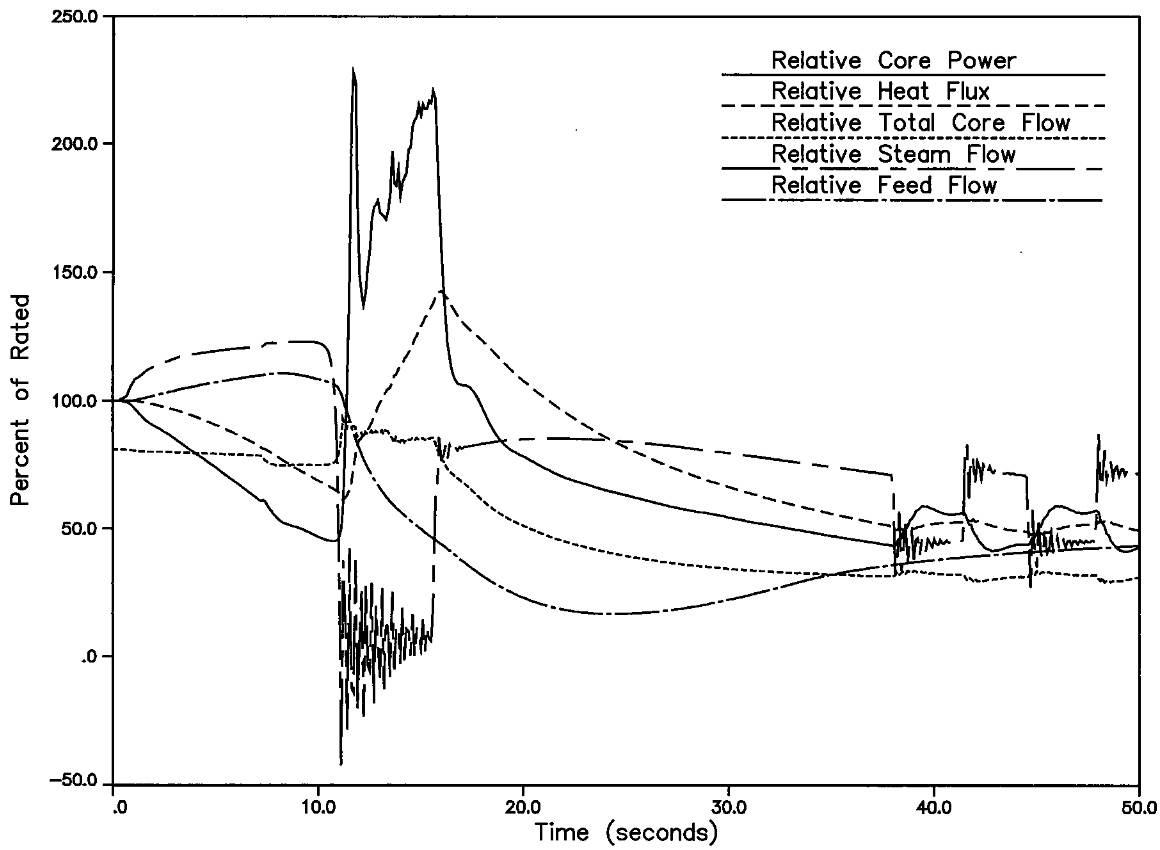

Figure 7.5 PRFO ATWS Overpressurization Event at 100P/81F – Key Parameters

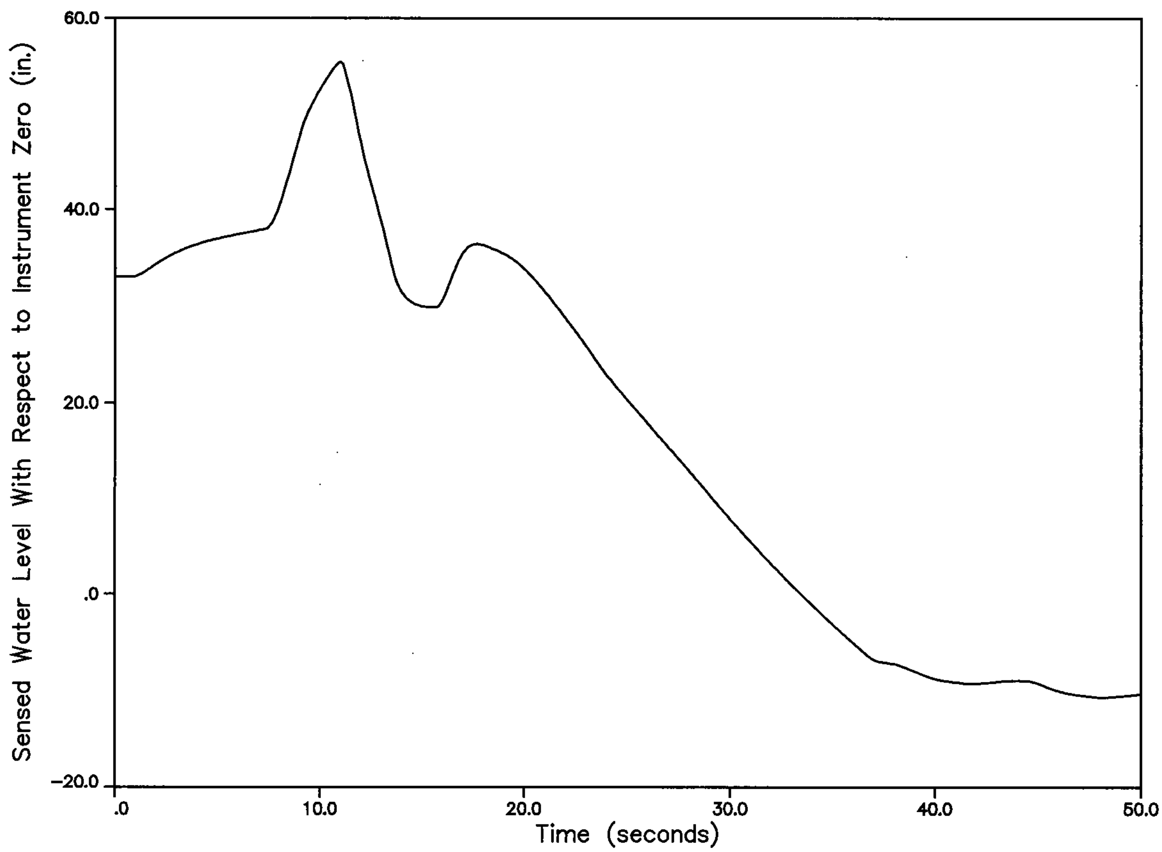

Figure 7.6 PRFO ATWS Overpressurization Event at 100P/81F – Sensed Water Level

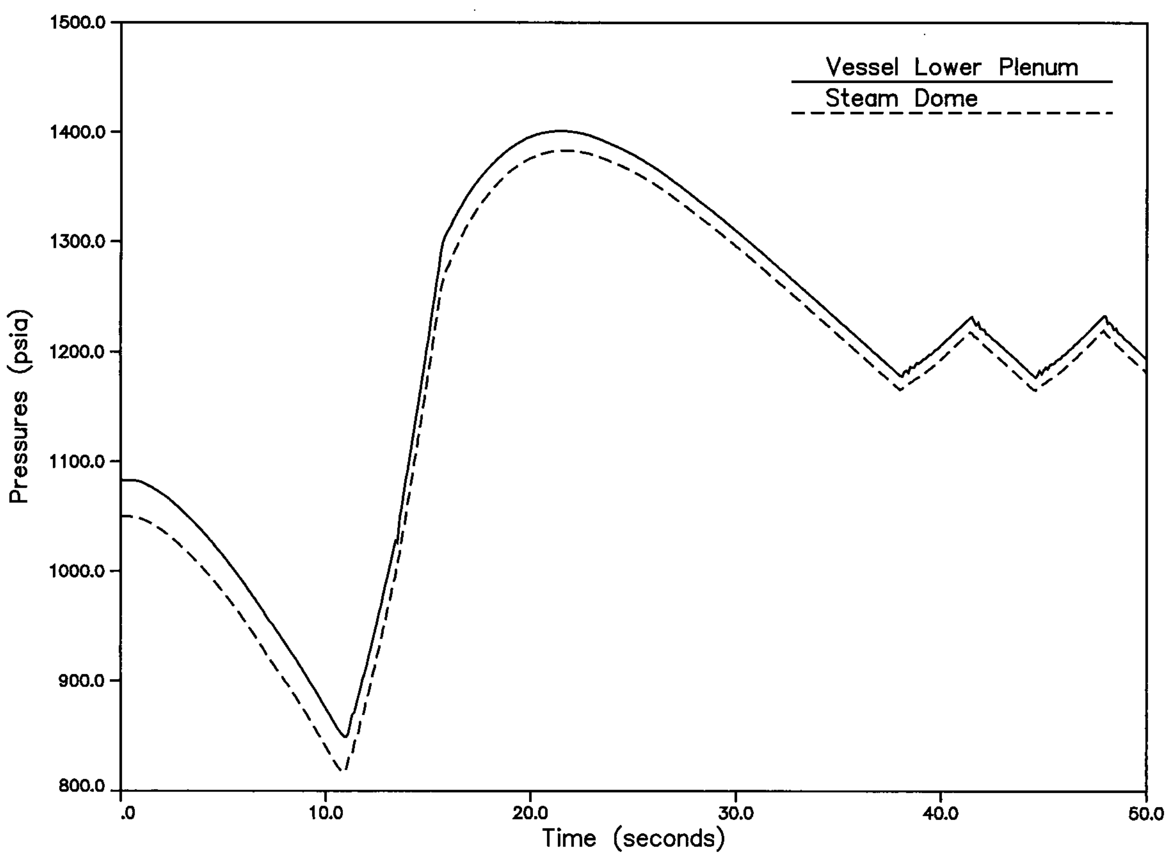

Figure 7.7 PRFO ATWS Overpressurization Event at 100P/81F – Vessel Pressures

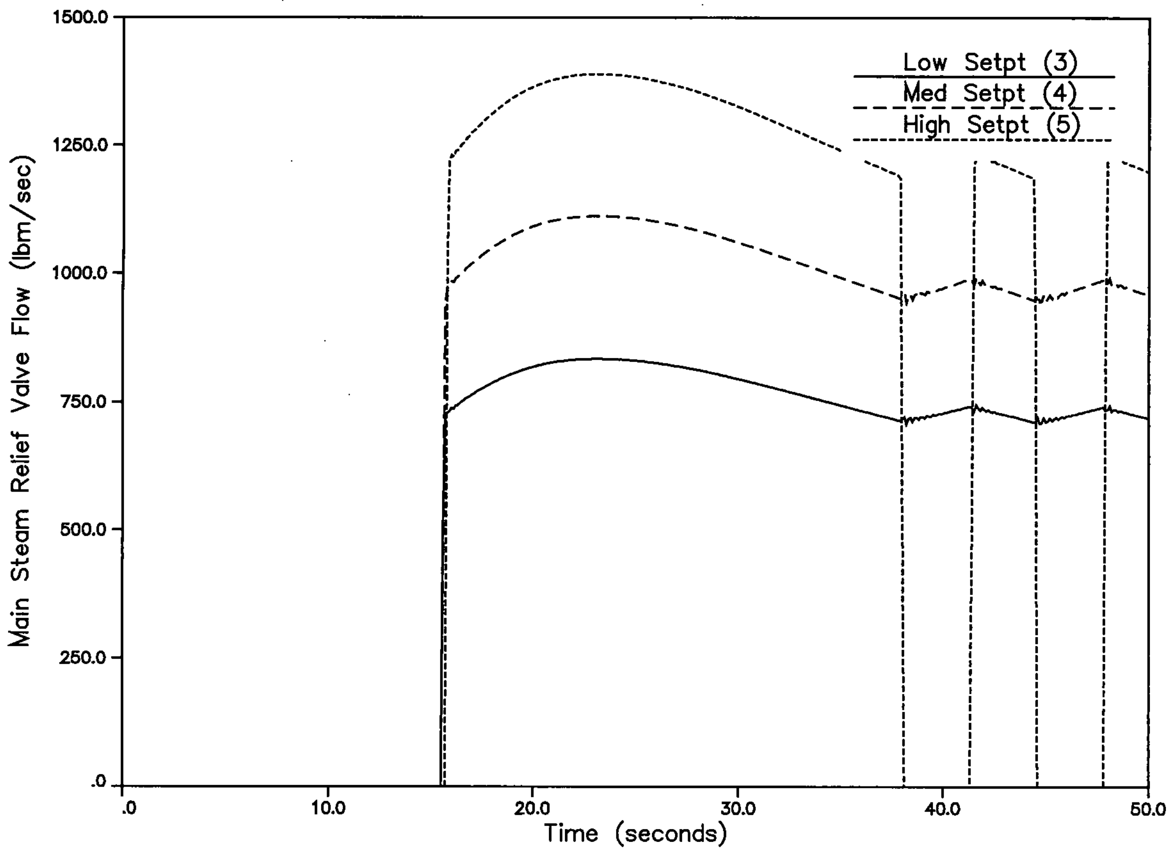

Figure 7.8 PRFO ATWS Overpressurization Event at 100P/81F – Safety/Relief Valve Flow Rates

8.0 Operating Limits and COLR Input

8.1 *MCPR Limits*

Determination of MCPR limits are based on analyses of the limiting abnormal operational transients (AOTs). The MCPR operating limits are established so that less than 0.1% of the fuel rods in the core are expected to experience boiling transition during an AOT initiated from rated or off-rated conditions and are based on the Technical Specifications TLO SLMCPR of 1.06 and a SLO SLMCPR of 1.08. Exposure-dependent MCPR limits were established to support operation from BOC to near end-of-cycle (NEOC), NEOC to end-of-cycle licensing basis (EOCLB) and combined FFTR/Coastdown. MCPR limits are established to support base case operation and the EOOS scenarios presented in Table 1.1.

TLO $MCPR_p$ limits for ATRIUM 10XM and ATRIUM-10 fuel are presented for NSS (Table 8.1) and TSSS (Table 8.2) insertion times for the exposure ranges considered. $MCPR_p$ limits for SLO are 0.02 higher for all cases. Comparisons of the limiting AOT analysis results and the $MCPR_p$ limits for ATRIUM 10XM and ATRIUM-10 fuel are presented in Appendix A.

$MCPR_f$ limits protect against fuel failures during a postulated slow flow excursion. ATRIUM 10XM and ATRIUM-10 fuel limits are presented in Table 8.3 and are applicable for all cycle exposures and EOOS conditions identified in Table 1.1.

8.2 *LHGR Limits*

The LHGR limits for ATRIUM 10XM and ATRIUM-10 fuel are presented in Table 8.4. Power- and flow-dependent multipliers ($LHGRFAC_p$ and $LHGRFAC_f$) are applied directly to the LHGR limits to protect against fuel melting and overstraining of the cladding during an AOT.

The ATRIUM 10XM $LHGRFAC_p$ multipliers are determined using the RODEX4 thermal-mechanical methodology (Reference 16). The ATRIUM-10 $LHGRFAC_p$ multipliers are determined using the heat flux ratio results from the transient analyses.

$LHGRFAC_p$ multipliers were established to support operation at all cycle exposures for both NSS and TSSS insertion times and for the EOOS conditions identified in Table 1.1 with and without TBVOOS. $LHGRFAC_p$ limits are presented in Table 8.5 for both ATRIUM 10XM and ATRIUM-10 fuel. Comparisons of the limiting results and the $LHGRFAC_p$ limits are presented in Appendix A.

$LHGRFAC_f$ multipliers are established to provide protection against fuel centerline melt and overstraining of the cladding during a postulated slow flow excursion. $LHGRFAC_f$ limits are presented in Table 8.6 for both ATRIUM 10XM and ATRIUM-10 fuel. $LHGRFAC_f$ multipliers are applicable for all cycle exposures and EOOS conditions identified in Table 1.1.

8.3 ***MAPLHGR Limits***

ATRIUM 10XM and ATRIUM-10 MAPLHGR limits are discussed in References 7 and 34, respectively. The TLO limits for ATRIUM 10XM and ATRIUM-10 fuel are presented in Table 8.7. For SLO, a multiplier of 0.85 must be applied to the TLO MAPLHGR limits of both fuel designs. Power and flow dependent MAPFAC setdowns are not required; therefore, MAPFAC=1.0.

Table 8.1 MCPR$_p$ Limits for NSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Base case operation	100.0	1.41	1.46	1.43	1.48	1.47	1.51
	75.0	1.56	1.60	1.58	1.60	1.61	1.65
	65.0	1.64	1.67	1.65	1.67	1.70	1.73
	50.0	---	1.86	---	1.86	---	---
	50.0	1.81	1.91	1.81	1.91	1.88	1.96
	40.0	2.01	2.13	2.01	2.13	2.10	2.27
	30.0	2.28	2.47	2.28	2.47	2.40	2.62
	30.0 at > 50%F	3.00	3.31	3.00	3.31	3.12	3.48
	25.0 at > 50%F	3.38	3.67	3.38	3.67	3.53	3.92
	30.0 at ≤ 50%F	2.94	3.24	2.94	3.24	3.06	3.50
	25.0 at ≤ 50%F	3.28	3.61	3.28	3.61	3.44	3.90
TBVOOS	100.0	1.44	1.51	1.46	1.53	1.49	1.56
	75.0	1.59	1.65	1.61	1.66	1.64	1.70
	65.0	1.67	1.72	1.68	1.73	1.73	1.78
	50.0	---	1.87	---	1.87	---	---
	50.0	1.84	1.91	1.84	1.91	1.90	1.96
	40.0	2.04	2.13	2.04	2.13	2.13	2.27
	30.0	2.29	2.47	2.29	2.47	2.41	2.62
	30.0 at > 50%F	3.44	3.74	3.44	3.74	3.62	3.96
	25.0 at > 50%F	4.02	4.28	4.02	4.28	4.21	4.57
	30.0 at ≤ 50%F	2.97	3.24	2.97	3.24	3.16	3.50
	25.0 at ≤ 50%F	3.52	3.77	3.52	3.77	3.76	4.00
FHOOS	100.0	1.44	1.49	1.47	1.51	---	---
	75.0	1.61	1.64	1.61	1.65	---	---
	65.0	1.69	1.73	1.70	1.73	---	---
	50.0	---	---	---	---	---	---
	50.0	1.88	1.96	1.88	1.96	---	---
	40.0	2.10	2.27	2.10	2.27	---	---
	30.0	2.40	2.62	2.40	2.62	---	---
	30.0 at > 50%F	3.12	3.48	3.12	3.48	---	---
	25.0 at > 50%F	3.53	3.92	3.53	3.92	---	---
	30.0 at ≤ 50%F	3.06	3.50	3.06	3.50	---	---
	25.0 at ≤ 50%F	3.44	3.90	3.44	3.90	---	---
PLUOOS	100.0	1.41	1.46	1.43	1.48	1.47	1.51
	75.0	1.56	1.60	1.58	1.60	1.61	1.65
	65.0	1.71	1.82	1.72	1.84	1.73	1.84
	50.0	---	---	---	---	---	---
	50.0	1.81	1.91	1.81	1.91	1.88	1.96
	40.0	2.01	2.13	2.01	2.13	2.10	2.27
	30.0	2.28	2.47	2.28	2.47	2.40	2.62
	30.0 at > 50%F	3.00	3.31	3.00	3.31	3.12	3.48
	25.0 at > 50%F	3.38	3.67	3.38	3.67	3.53	3.92
	30.0 at ≤ 50%F	2.94	3.24	2.94	3.24	3.06	3.50
	25.0 at ≤ 50%F	3.28	3.61	3.28	3.61	3.44	3.90

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. BOC to End of COAST limits also support operation with FFTR/FHOOS which bounds operation with feedwater heaters in-service. SLO MCPR$_p$ limits will be 0.02 higher.

Table 8.1 MCPR$_p$ Limits for NSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
TBVOOS and FHOOS	100.0	1.46	1.53	1.49	1.56	---	---
	75.0	1.64	1.69	1.64	1.70	---	---
	65.0	1.72	1.77	1.73	1.78	---	---
	50.0	---	---	---	---	---	---
	50.0	1.90	1.96	1.90	1.96	---	---
	40.0	2.13	2.27	2.13	2.27	---	---
	30.0	2.41	2.62	2.41	2.62	---	---
	30.0 at > 50%F	3.62	3.96	3.62	3.96	---	---
	25.0 at > 50%F	4.21	4.57	4.21	4.57	---	---
	30.0 at ≤ 50%F	3.16	3.50	3.16	3.50	---	---
	25.0 at ≤ 50%F	3.76	4.00	3.76	4.00	---	---
TBVOOS and PLUOOS	100.0	1.44	1.51	1.46	1.53	1.49	1.56
	75.0	1.59	1.65	1.61	1.66	1.64	1.70
	65.0	1.71	1.82	1.72	1.84	1.73	1.84
	50.0	---	---	---	---	---	---
	50.0	1.84	1.91	1.84	1.91	1.90	1.96
	40.0	2.04	2.13	2.04	2.13	2.13	2.27
	30.0	2.29	2.47	2.29	2.47	2.41	2.62
	30.0 at > 50%F	3.44	3.74	3.44	3.74	3.62	3.96
	25.0 at > 50%F	4.02	4.28	4.02	4.28	4.21	4.57
	30.0 at ≤ 50%F	2.97	3.24	2.97	3.24	3.16	3.50
	25.0 at ≤ 50%F	3.52	3.77	3.52	3.77	3.76	4.00
FHOOS and PLUOOS	100.0	1.44	1.49	1.47	1.51	---	---
	75.0	1.61	1.64	1.61	1.65	---	---
	65.0	1.71	1.82	1.72	1.84	---	---
	50.0	---	---	---	---	---	---
	50.0	1.88	1.96	1.88	1.96	---	---
	40.0	2.10	2.27	2.10	2.27	---	---
	30.0	2.40	2.62	2.40	2.62	---	---
	30.0 at > 50%F	3.12	3.48	3.12	3.48	---	---
	25.0 at > 50%F	3.53	3.92	3.53	3.92	---	---
	30.0 at ≤ 50%F	3.06	3.50	3.06	3.50	---	---
	25.0 at ≤ 50%F	3.44	3.90	3.44	3.90	---	---
TBVOOS, FHOOS, and PLUOOS	100.0	1.46	1.53	1.49	1.56	---	---
	75.0	1.64	1.69	1.64	1.70	---	---
	65.0	1.72	1.82	1.73	1.84	---	---
	50.0	---	---	---	---	---	---
	50.0	1.90	1.96	1.90	1.96	---	---
	40.0	2.13	2.27	2.13	2.27	---	---
	30.0	2.41	2.62	2.41	2.62	---	---
	30.0 at > 50%F	3.62	3.96	3.62	3.96	---	---
	25.0 at > 50%F	4.21	4.57	4.21	4.57	---	---
	30.0 at ≤ 50%F	3.16	3.50	3.16	3.50	---	---
	25.0 at ≤ 50%F	3.76	4.00	3.76	4.00	---	---

Table 8.2 MCPR$_p$ Limits for TSSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Base case operation	100.0	1.43	1.49	1.45	1.50	1.48	1.53
	75.0	1.58	1.62	1.58	1.62	1.63	1.66
	65.0	1.65	1.69	1.66	1.69	1.71	1.75
	50.0	---	1.91	---	1.91	---	---
	50.0	1.83	1.92	1.83	1.92	1.89	2.01
	40.0	2.02	2.19	2.02	2.19	2.13	2.33
	30.0	2.32	2.54	2.32	2.54	2.45	2.70
	30.0 at > 50%F	3.00	3.31	3.00	3.31	3.12	3.48
	25.0 at > 50%F	3.38	3.67	3.38	3.67	3.53	3.92
	30.0 at ≤ 50%F	2.94	3.24	2.94	3.24	3.06	3.50
	25.0 at ≤ 50%F	3.28	3.61	3.28	3.61	3.44	3.90
TBVOOS	100.0	1.47	1.54	1.48	1.55	1.51	1.58
	75.0	1.61	1.67	1.63	1.67	1.66	1.71
	65.0	1.69	1.74	1.69	1.75	1.74	1.79
	50.0	---	---	---	---	---	---
	50.0	1.85	1.92	1.85	1.92	1.92	2.02
	40.0	2.06	2.20	2.06	2.20	2.15	2.33
	30.0	2.32	2.54	2.32	2.54	2.45	2.70
	30.0 at > 50%F	3.44	3.74	3.44	3.74	3.62	3.96
	25.0 at > 50%F	4.02	4.28	4.02	4.28	4.21	4.57
	30.0 at ≤ 50%F	2.97	3.24	2.97	3.24	3.16	3.50
	25.0 at ≤ 50%F	3.52	3.77	3.52	3.77	3.76	4.00
FHOOS	100.0	1.46	1.51	1.48	1.53	---	---
	75.0	1.62	1.66	1.63	1.66	---	---
	65.0	1.71	1.75	1.71	1.75	---	---
	50.0	---	---	---	---	---	---
	50.0	1.89	2.01	1.89	2.01	---	---
	40.0	2.13	2.33	2.13	2.33	---	---
	30.0	2.45	2.70	2.45	2.70	---	---
	30.0 at > 50%F	3.12	3.48	3.12	3.48	---	---
	25.0 at > 50%F	3.53	3.92	3.53	3.92	---	---
	30.0 at ≤ 50%F	3.06	3.50	3.06	3.50	---	---
	25.0 at ≤ 50%F	3.44	3.90	3.44	3.90	---	---
PLUOOS	100.0	1.43	1.49	1.45	1.50	1.48	1.53
	75.0	1.58	1.62	1.58	1.62	1.63	1.66
	65.0	1.72	1.83	1.73	1.86	1.75	1.86
	50.0	---	---	---	---	---	---
	50.0	1.83	1.92	1.83	1.92	1.89	2.01
	40.0	2.02	2.19	2.02	2.19	2.13	2.33
	30.0	2.32	2.54	2.32	2.54	2.45	2.70
	30.0 at > 50%F	3.00	3.31	3.00	3.31	3.12	3.48
	25.0 at > 50%F	3.38	3.67	3.38	3.67	3.53	3.92
	30.0 at ≤ 50%F	2.94	3.24	2.94	3.24	3.06	3.50
	25.0 at ≤ 50%F	3.28	3.61	3.28	3.61	3.44	3.90

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. BOC to End of COAST limits also support operation with FFTR/FHOOS which bounds operation with feedwater heaters in-service. SLO MCPR$_p$ limits will be 0.02 higher.

Table 8.2 MCPR$_p$ Limits for TSSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
TBVOOS and FHOOS	100.0	1.49	1.56	1.51	1.58	---	---
	75.0	1.65	1.71	1.66	1.71	---	---
	65.0	1.74	1.79	1.74	1.79	---	---
	50.0	---	---	---	---	---	---
	50.0	1.92	2.02	1.92	2.02	---	---
	40.0	2.15	2.33	2.15	2.33	---	---
	30.0	2.45	2.70	2.45	2.70	---	---
	30.0 at > 50%F	3.62	3.96	3.62	3.96	---	---
	25.0 at > 50%F	4.21	4.57	4.21	4.57	---	---
	30.0 at ≤ 50%F	3.16	3.50	3.16	3.50	---	---
	25.0 at ≤ 50%F	3.76	4.00	3.76	4.00	---	---
TBVOOS and PLUOOS	100.0	1.47	1.54	1.48	1.55	1.51	1.58
	75.0	1.61	1.67	1.63	1.67	1.66	1.71
	65.0	1.72	1.83	1.73	1.86	1.75	1.86
	50.0	---	---	---	---	---	---
	50.0	1.85	1.92	1.85	1.92	1.92	2.02
	40.0	2.06	2.20	2.06	2.20	2.15	2.33
	30.0	2.32	2.54	2.32	2.54	2.45	2.70
	30.0 at > 50%F	3.44	3.74	3.44	3.74	3.62	3.96
	25.0 at > 50%F	4.02	4.28	4.02	4.28	4.21	4.57
	30.0 at ≤ 50%F	2.97	3.24	2.97	3.24	3.16	3.50
	25.0 at ≤ 50%F	3.52	3.77	3.52	3.77	3.76	4.00
FHOOS and PLUOOS	100.0	1.46	1.51	1.48	1.53	---	---
	75.0	1.62	1.66	1.63	1.66	---	---
	65.0	1.72	1.83	1.73	1.86	---	---
	50.0	---	---	---	---	---	---
	50.0	1.89	2.01	1.89	2.01	---	---
	40.0	2.13	2.33	2.13	2.33	---	---
	30.0	2.45	2.70	2.45	2.70	---	---
	30.0 at > 50%F	3.12	3.48	3.12	3.48	---	---
	25.0 at > 50%F	3.53	3.92	3.53	3.92	---	---
	30.0 at ≤ 50%F	3.06	3.50	3.06	3.50	---	---
	25.0 at ≤ 50%F	3.44	3.90	3.44	3.90	---	---
TBVOOS, FHOOS, and PLUOOS	100.0	1.49	1.56	1.51	1.58	---	---
	75.0	1.65	1.71	1.66	1.71	---	---
	65.0	1.74	1.83	1.74	1.86	---	---
	50.0	---	---	---	---	---	---
	50.0	1.92	2.02	1.92	2.02	---	---
	40.0	2.15	2.33	2.15	2.33	---	---
	30.0	2.45	2.70	2.45	2.70	---	---
	30.0 at > 50%F	3.62	3.96	3.62	3.96	---	---
	25.0 at > 50%F	4.21	4.57	4.21	4.57	---	---
	30.0 at ≤ 50%F	3.16	3.50	3.16	3.50	---	---
	25.0 at ≤ 50%F	3.76	4.00	3.76	4.00	---	---

Table 8.3 Flow-Dependent MCPR Limits ATRIUM 10XM and ATRIUM-10 Fuel

Core Flow (% of rated)	$MCPR_f$
30.0	1.61
78.0	1.28
107.0	1.28

Table 8.4 Steady-State LHGR Limits

Peak Pellet Exposure (GWd/MTU)	ATRIUM 10XM LHGR (kW/ft)	ATRIUM-10 LHGR (kW/ft)
0.0	14.1	13.4
18.9	14.1	13.4
74.4	7.4	7.1

Table 8.5 LHGRFAC$_p$ Multipliers*

EOOS Condition	Power (% rated)	ATRIUM 10XM LHGRFAC$_p$	ATRIUM-10 LHGRFAC$_p$
Base case operation (TBVIS) †	100.0	1.00	1.00
	30.0	0.60	0.52
	30.0 at > 50%F	0.32	0.38
	25.0 at > 50%F	0.28	0.33
	30.0 at ≤ 50%F	0.36	0.40
	25.0 at ≤ 50%F	0.30	0.36
TBVOOS‡	100.0	1.00	0.95
	30.0	0.58	0.52
	30.0 at > 50%F	0.32	0.34
	25.0 at > 50%F	0.27	0.29
	30.0 at ≤ 50%F	0.36	0.40
	25.0 at ≤ 50%F	0.30	0.36

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. Base case supports single-loop operation.

† Limits are applicable for all the EOOS scenarios presented in Table 1.1 except those that include TBVOOS.

‡ Limits are applicable for all the EOOS scenarios presented in Table 1.1 including those with TBVOOS.

Table 8.6 LHGRFAC$_f$ Multipliers

Core Flow (% of rated)	ATRIUM 10XM LHGRFAC$_f$	ATRIUM-10 LHGRFAC$_f$
0.0	0.66	0.93
30.0	0.66	0.93
44.2	---	1.00
73.0	1.00	---
107.0	1.00	1.00

Table 8.7 MAPLHGR Limits

Average Planar Exposure (GWd/MTU)	ATRIUM 10XM MAPLHGR (kW/ft)	ATRIUM-10 MAPLHGR (kW/ft)
0.0	13.0	12.5
15.0	13.0	12.5
67.0	7.6	7.3

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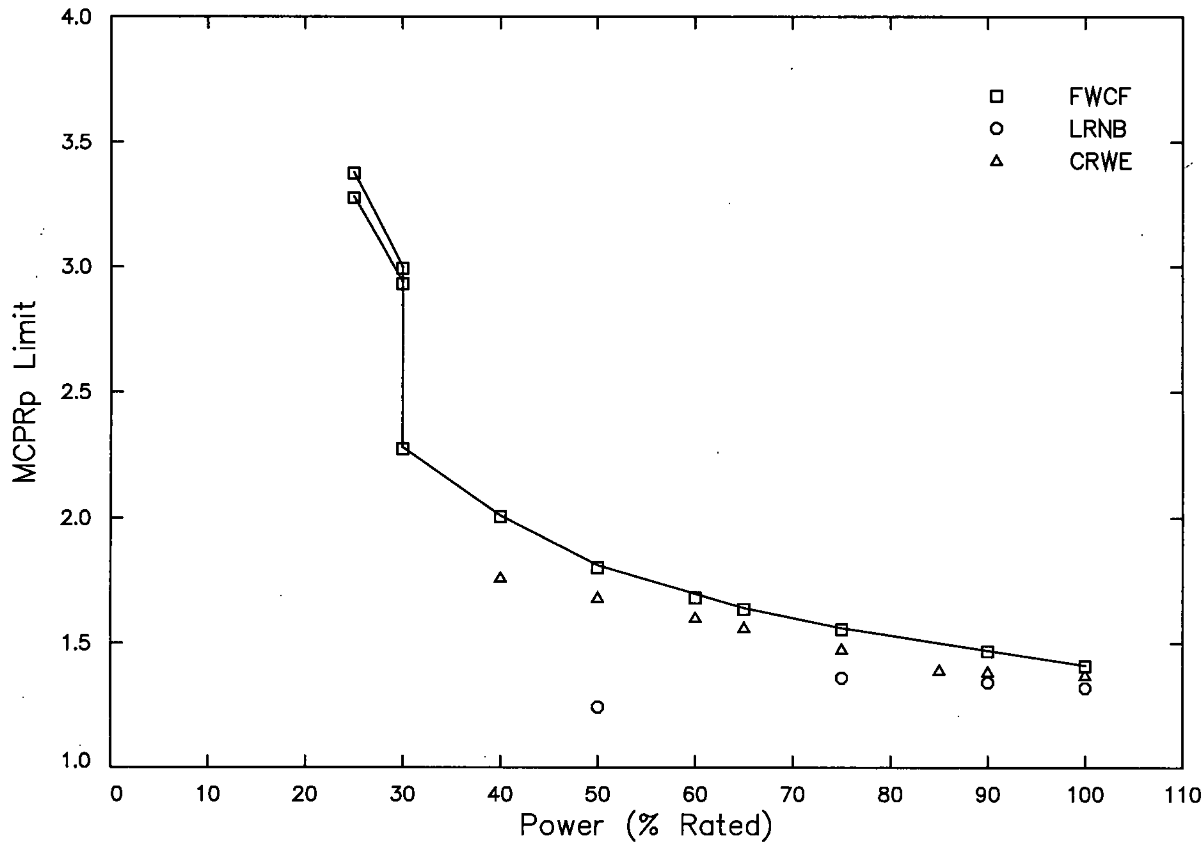
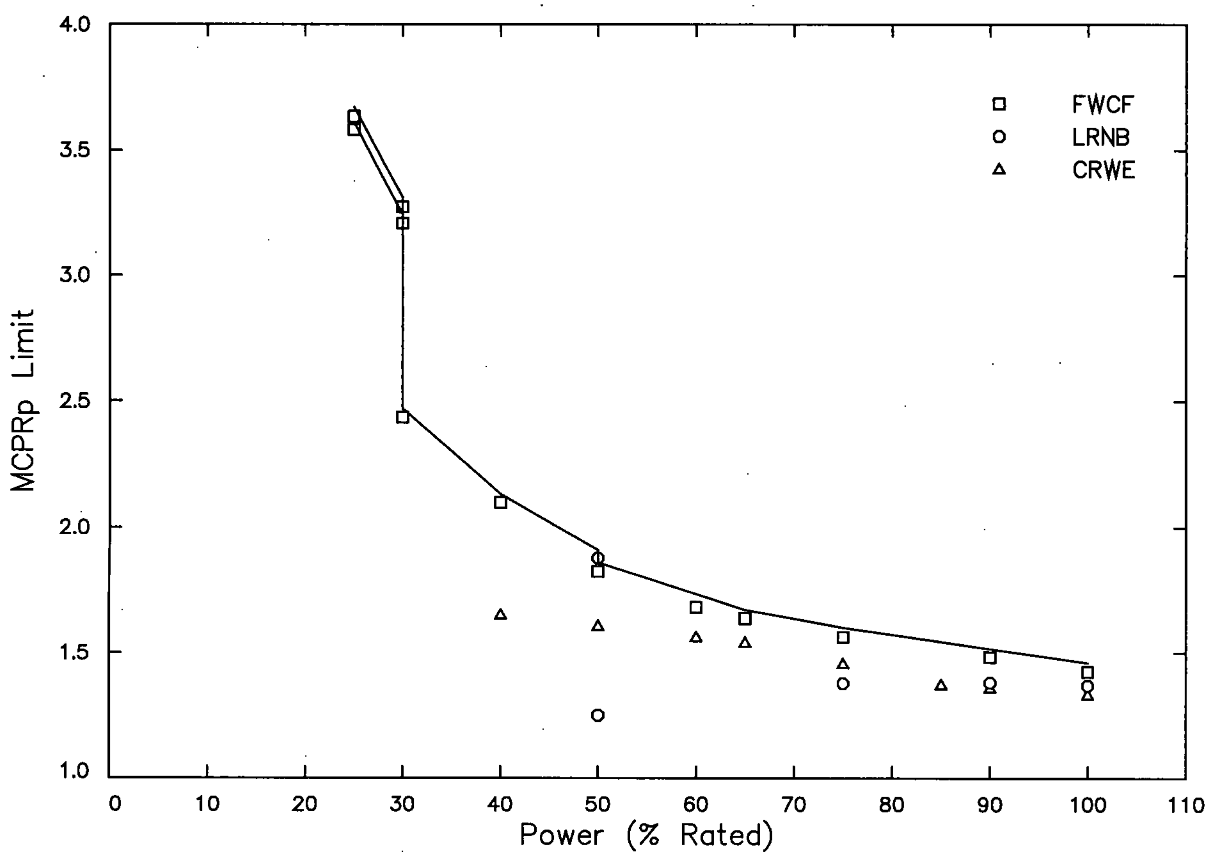
Appendix A Operating Limits and Results Comparisons

The figures and tables presented in this appendix show comparisons of the Browns Ferry Unit 2 Cycle 19 operating limits and the transient analysis results. Comparisons are presented for the ATRIUM 10XM and ATRIUM-10 $MCPR_p$ limits and $LHGRFAC_p$ multipliers.



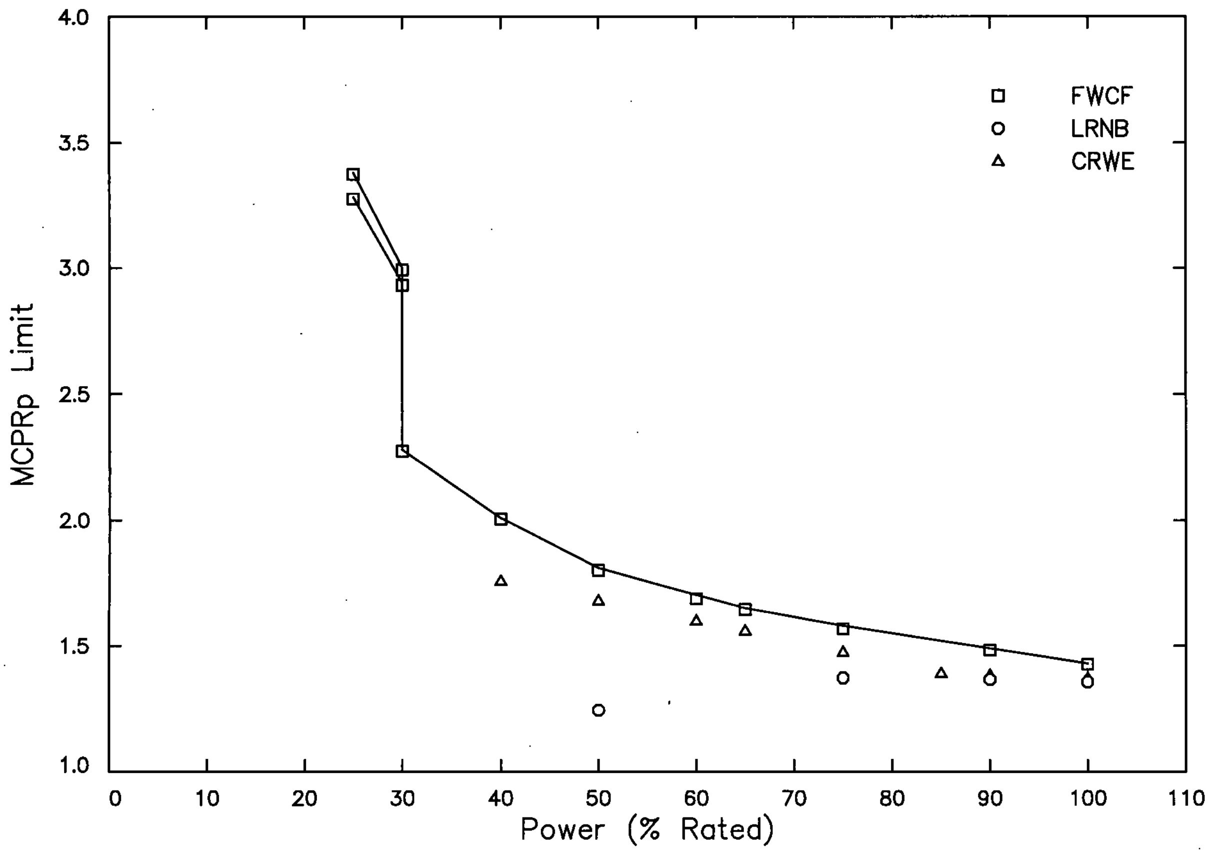
Power (% of rated)	$MCPR_p$ Limit
100	1.41
75	1.56
65	1.64
50	---
50	1.81
40	2.01
30	2.28
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.1 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - Base Case



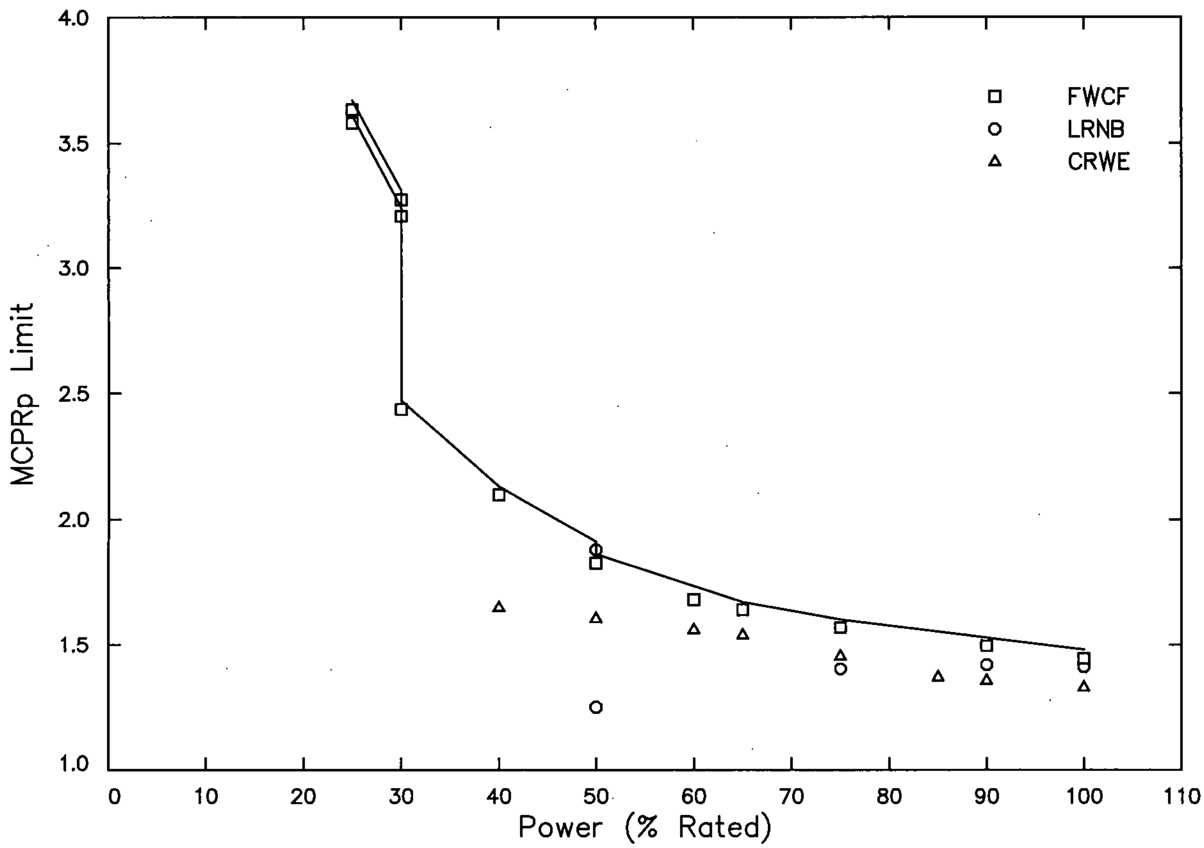
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.60
65	1.67
50	1.86
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.2 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - Base Case



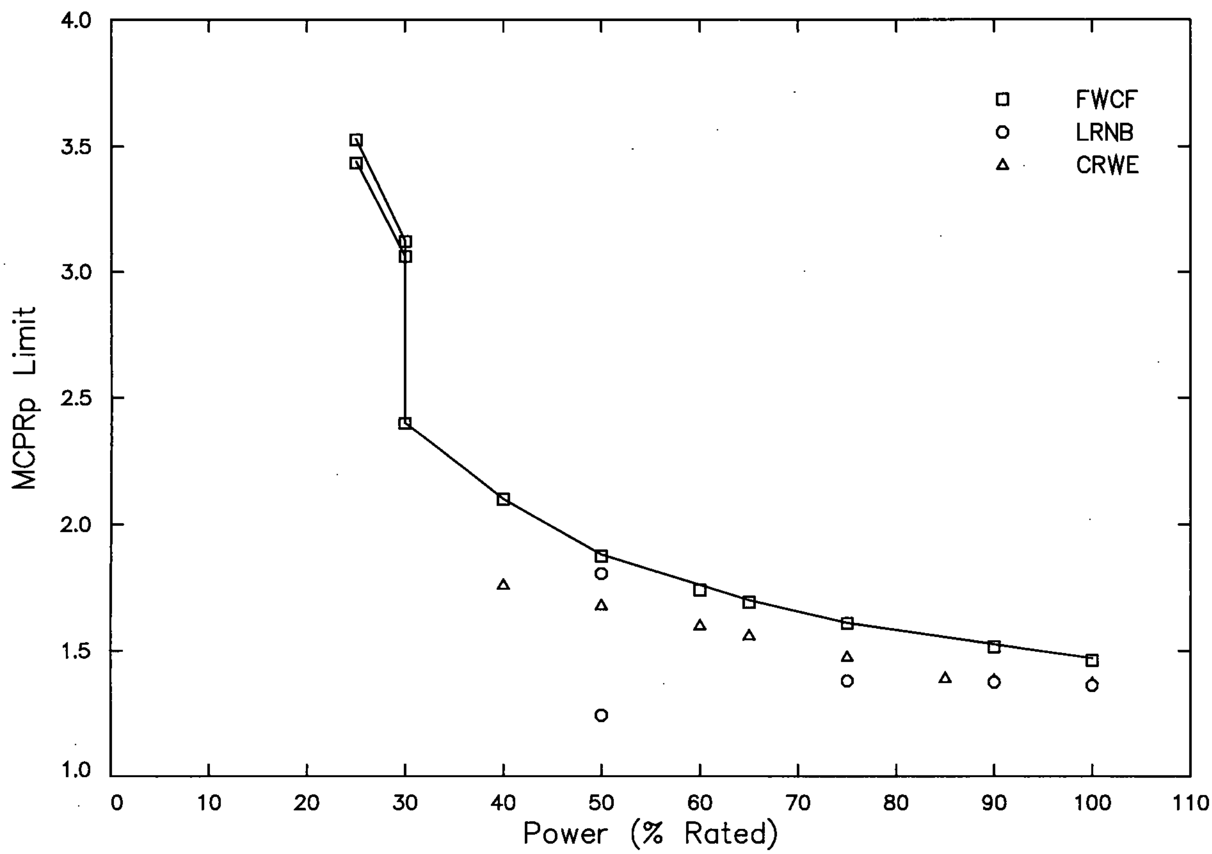
Power (% of rated)	$MCPR_p$ Limit
100	1.43
75	1.58
65	1.65
50	---
50	1.81
40	2.01
30	2.28
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.3 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - Base Case



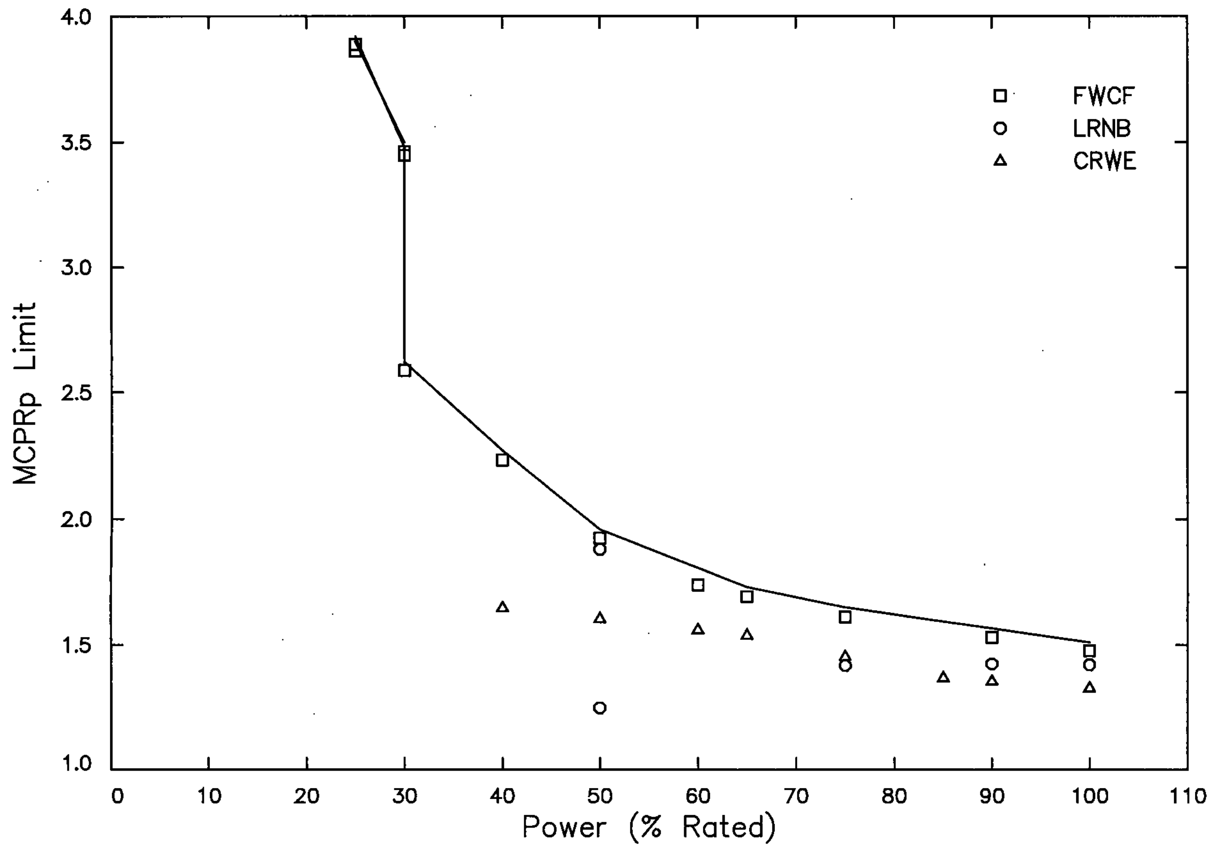
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.60
65	1.67
50	1.86
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.4 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - Base Case



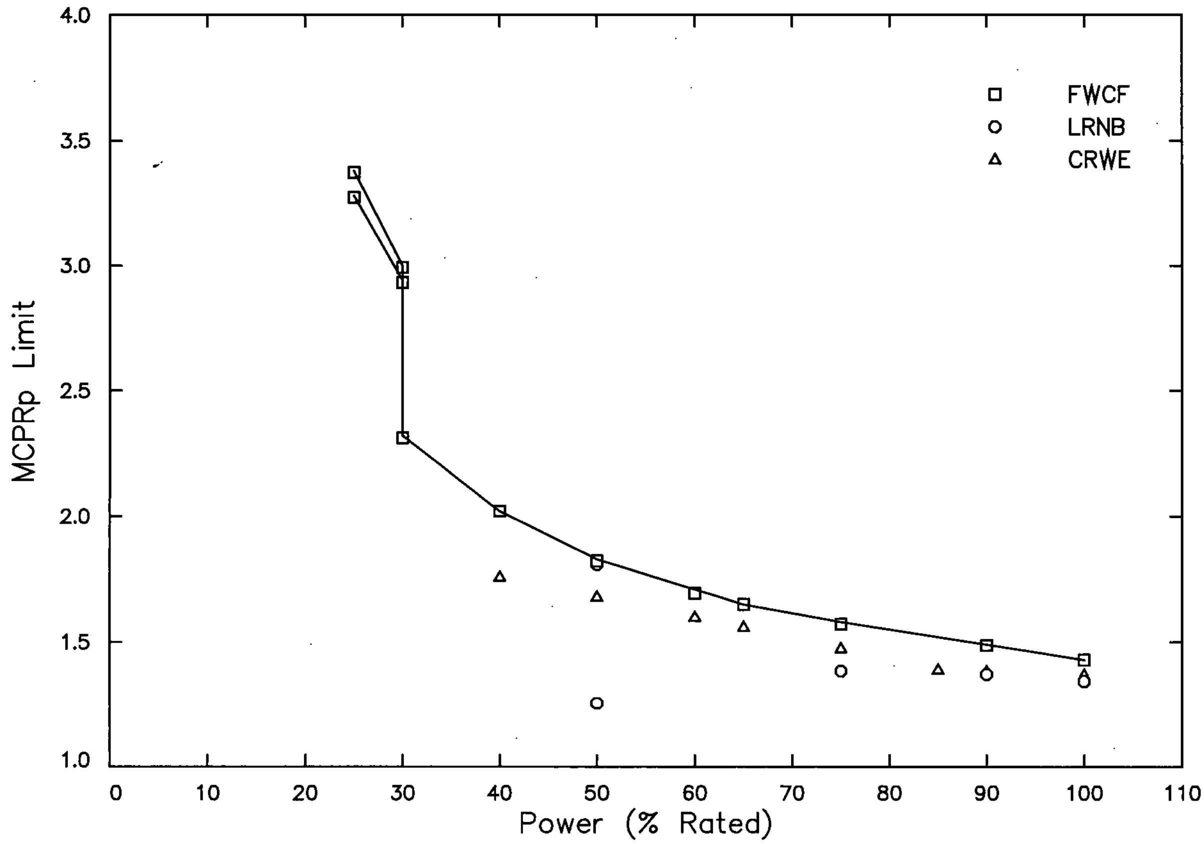
Power (% of rated)	$MCPR_p$ Limit
100	1.47
75	1.61
65	1.70
50	---
50	1.88
40	2.10
30	2.40
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.5 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - Base Case



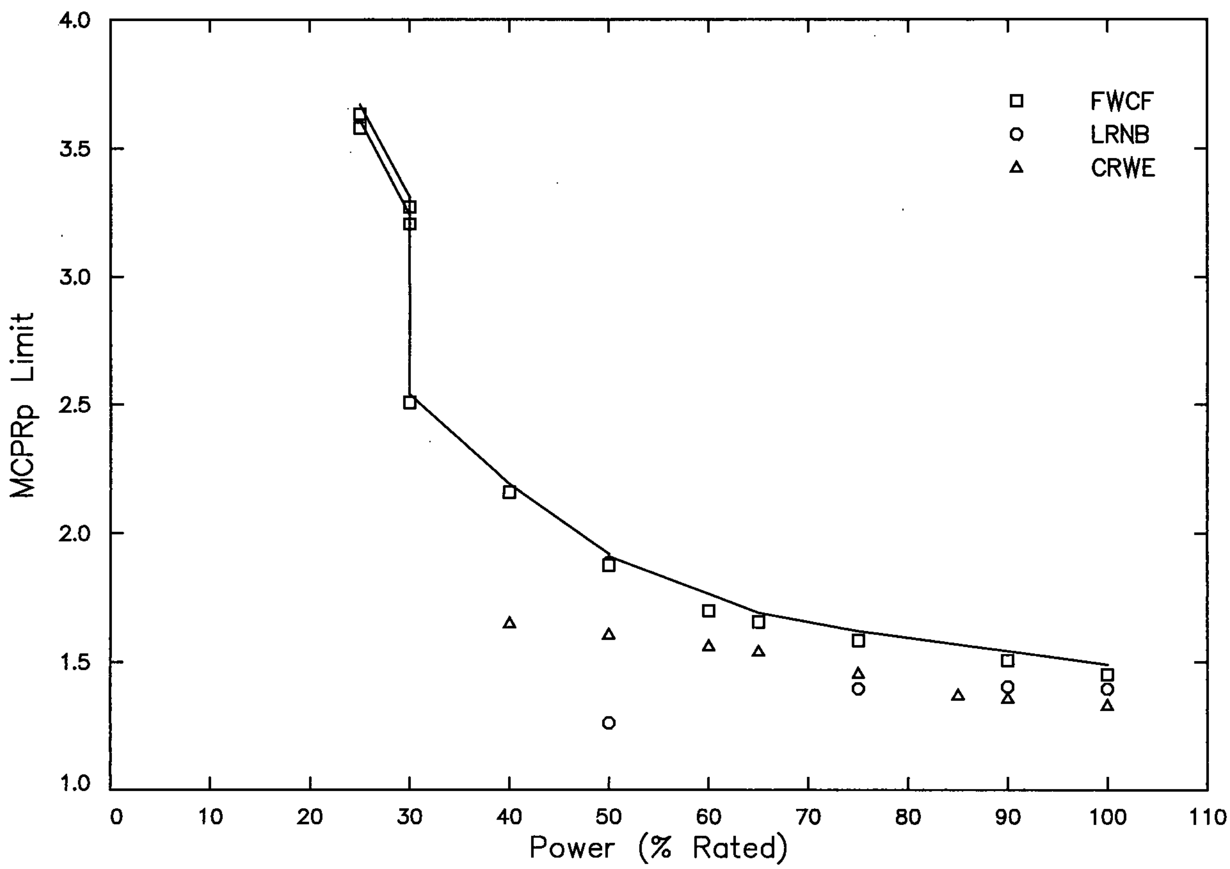
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.65
65	1.73
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.6 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - Base Case



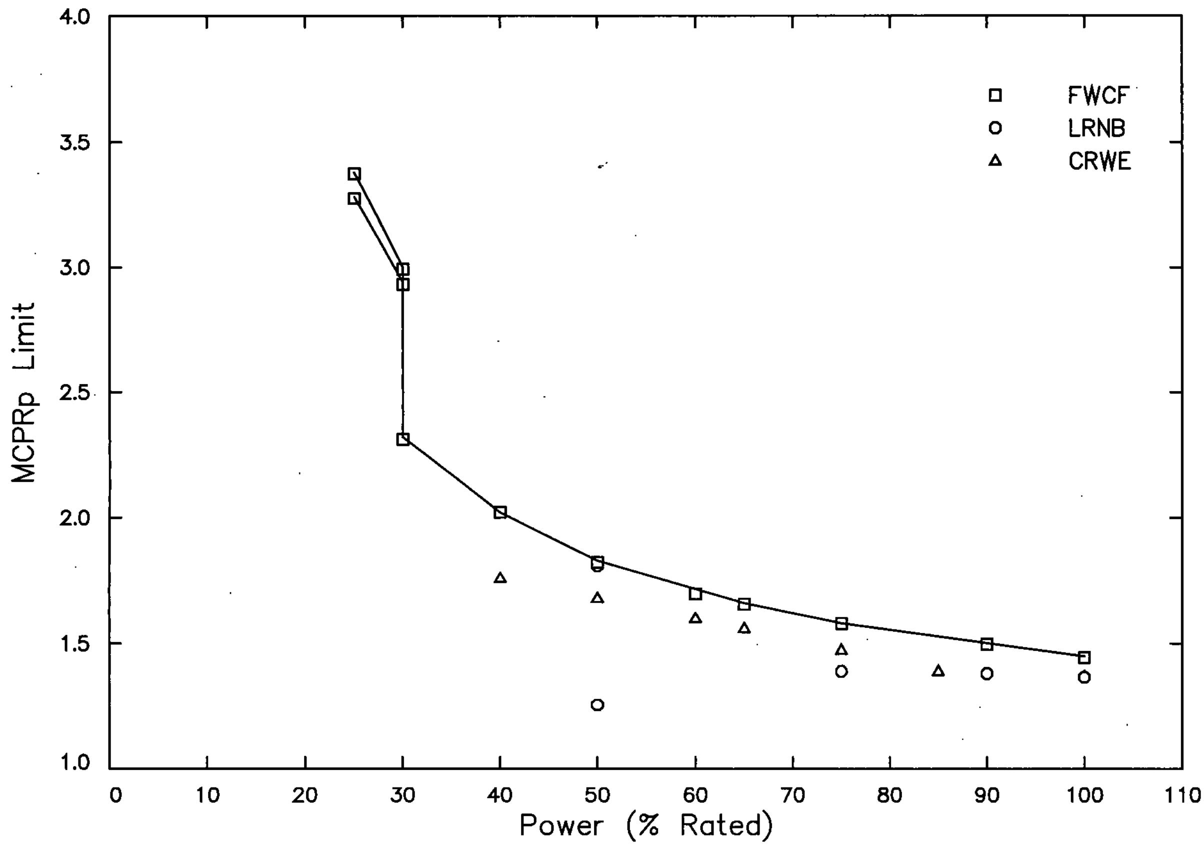
Power (% of rated)	$MCPR_p$ Limit
100	1.43
75	1.58
65	1.65
50	---
50	1.83
40	2.02
30	2.32
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.7 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - Base Case



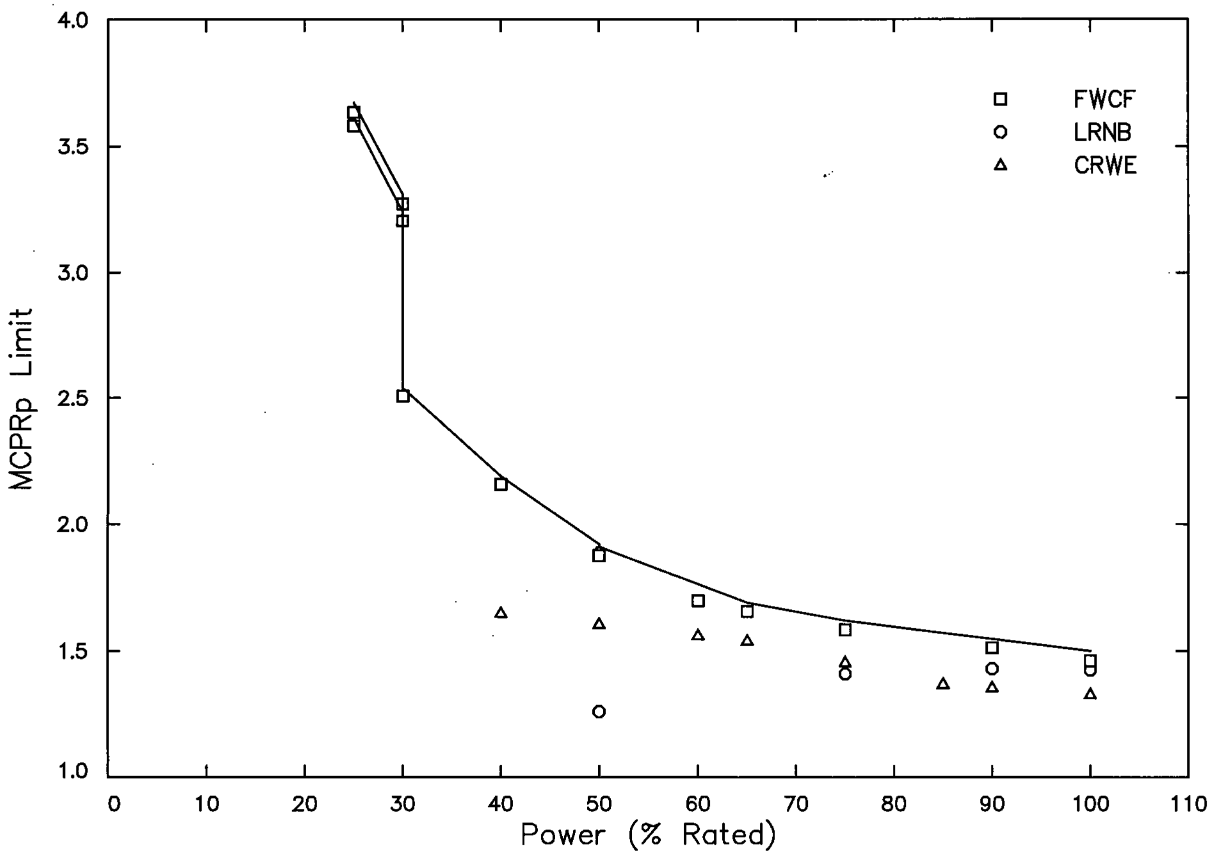
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.62
65	1.69
50	1.91
50	1.92
40	2.19
30	2.54
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.8 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - Base Case



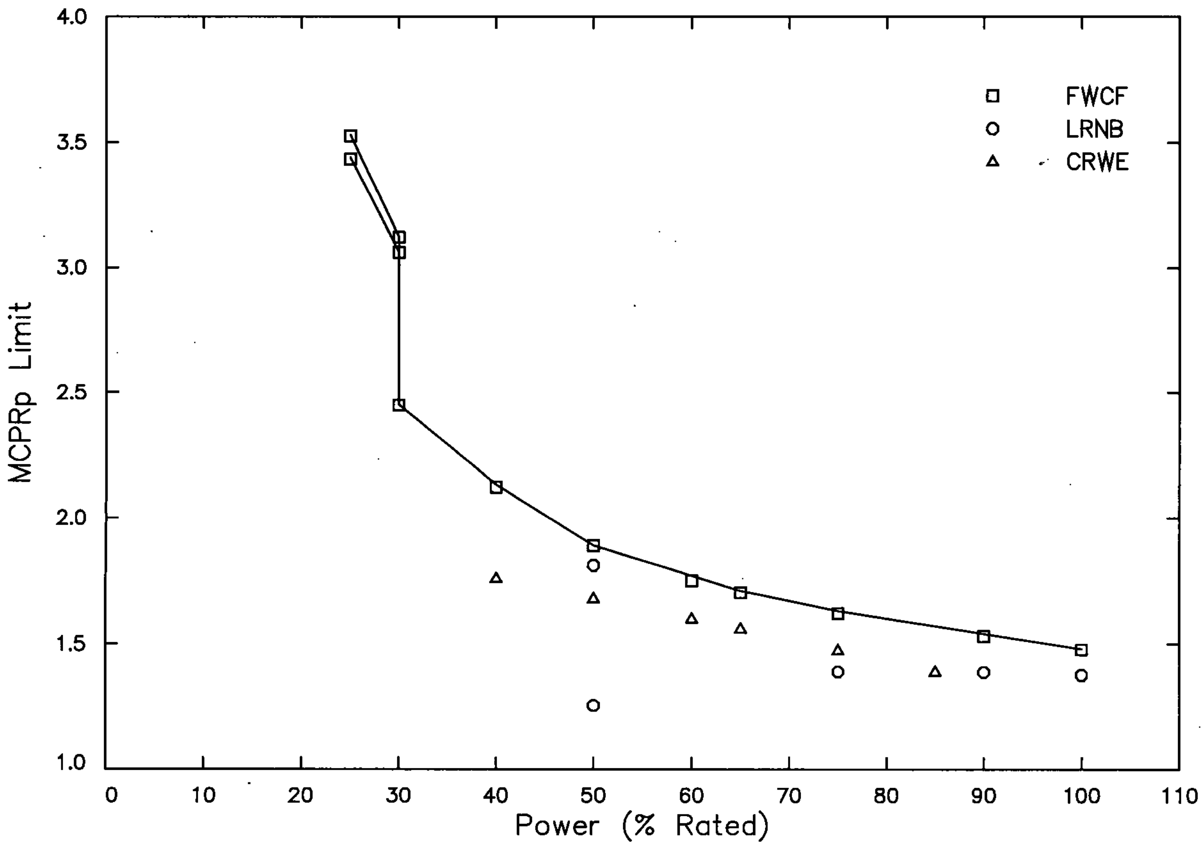
Power (% of rated)	$MCPR_p$ Limit
100	1.45
75	1.58
65	1.66
50	---
50	1.83
40	2.02
30	2.32
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.9 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - Base Case



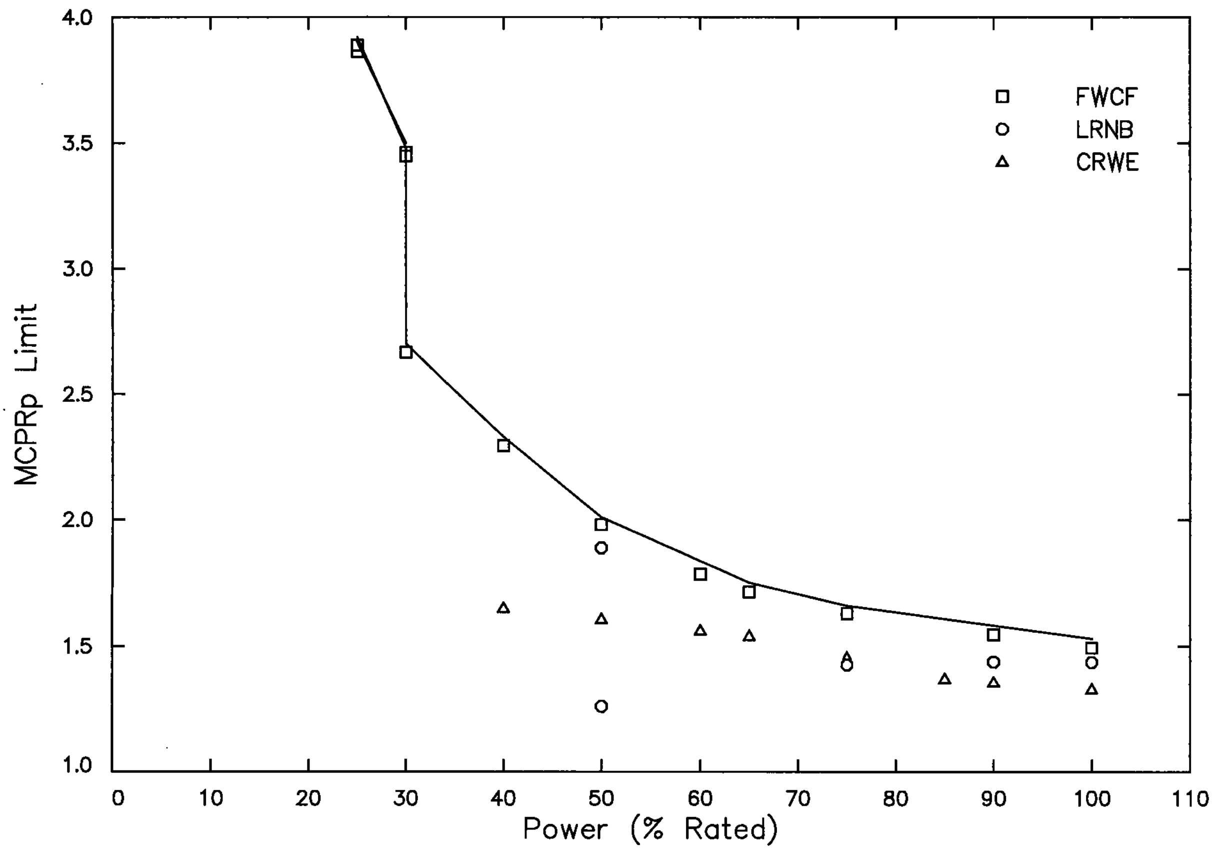
Power (% of rated)	$MCPR_p$ Limit
100	1.50
75	1.62
65	1.69
50	1.91
50	1.92
40	2.19
30	2.54
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.10 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - Base Case



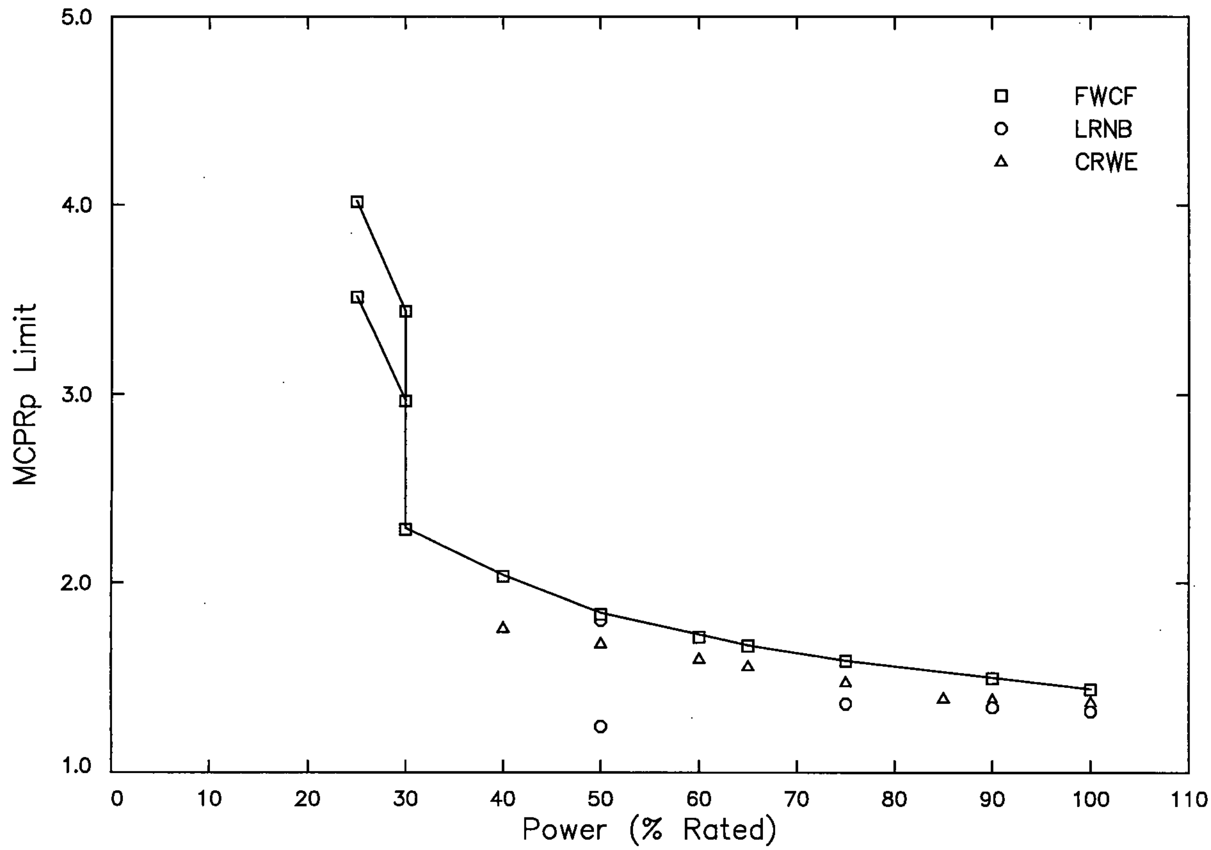
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.63
65	1.71
50	---
50	1.89
40	2.13
30	2.45
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.11 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - Base Case



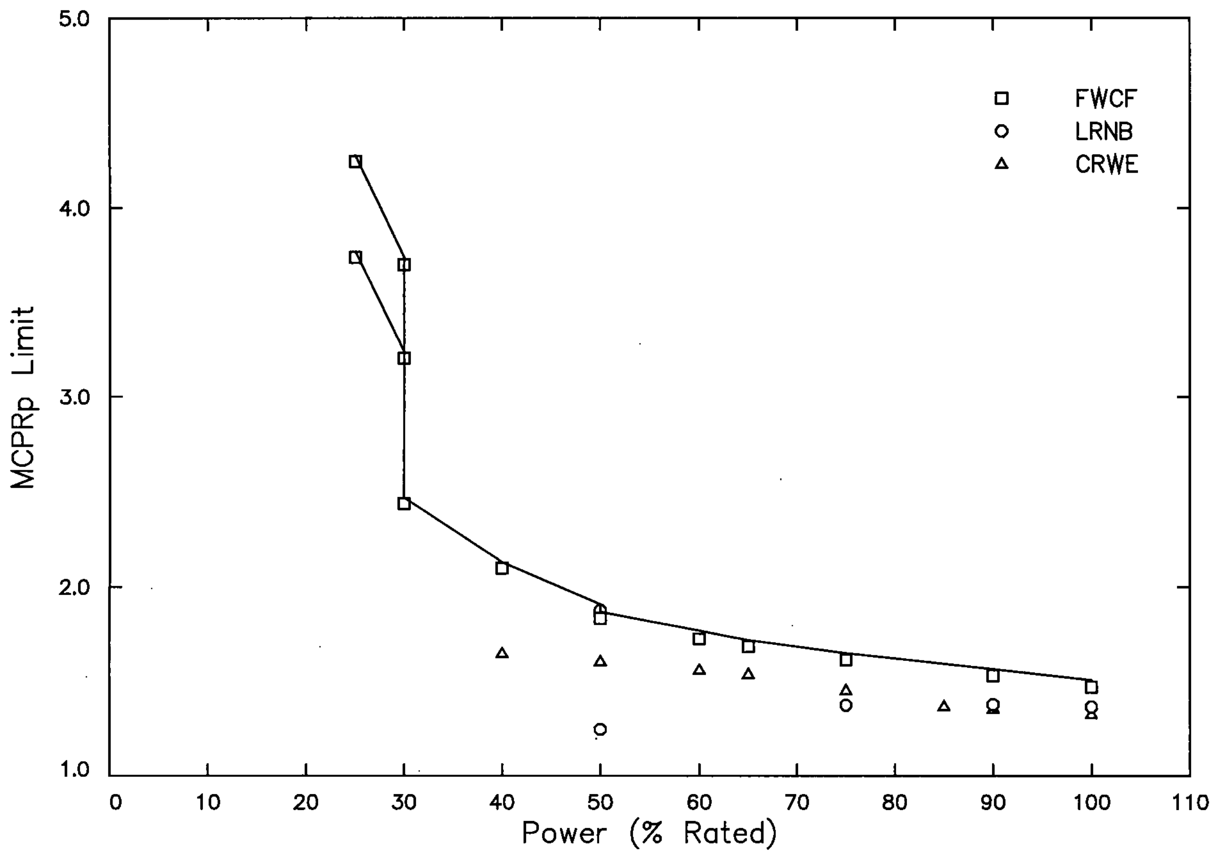
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.66
65	1.75
50	---
50	2.01
40	2.33
30	2.70
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.12 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - Base Case



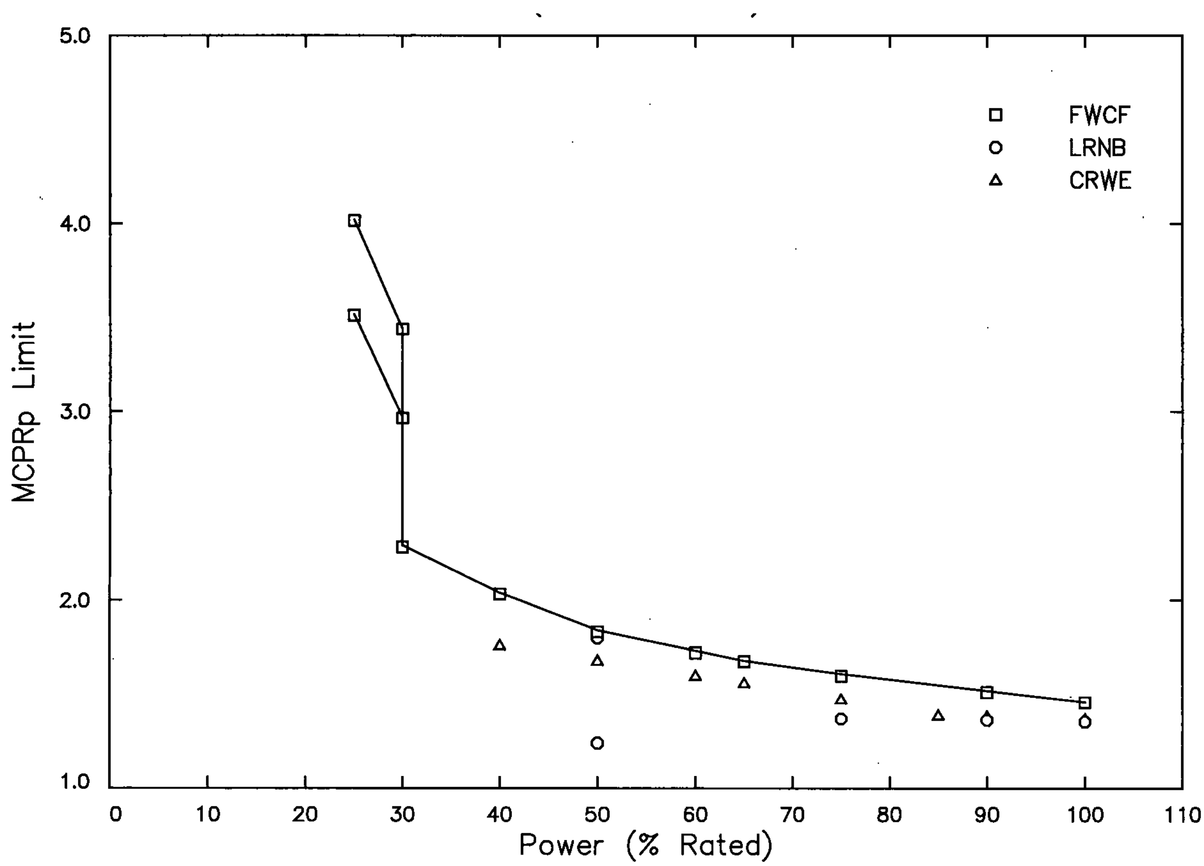
Power (% of rated)	$MCPR_p$ Limit
100	1.44
75	1.59
65	1.67
50	---
50	1.84
40	2.04
30	2.29
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.13 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS



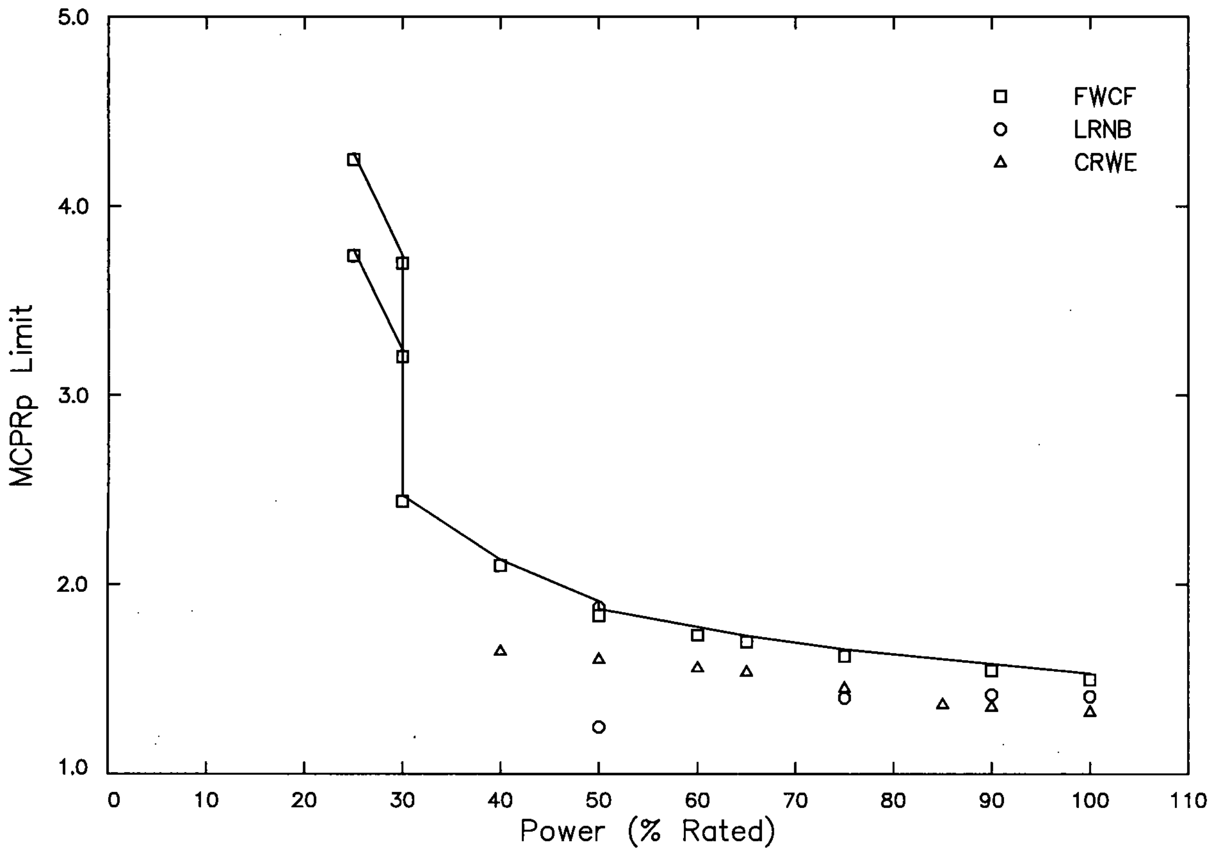
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.65
65	1.72
50	1.87
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.14 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS



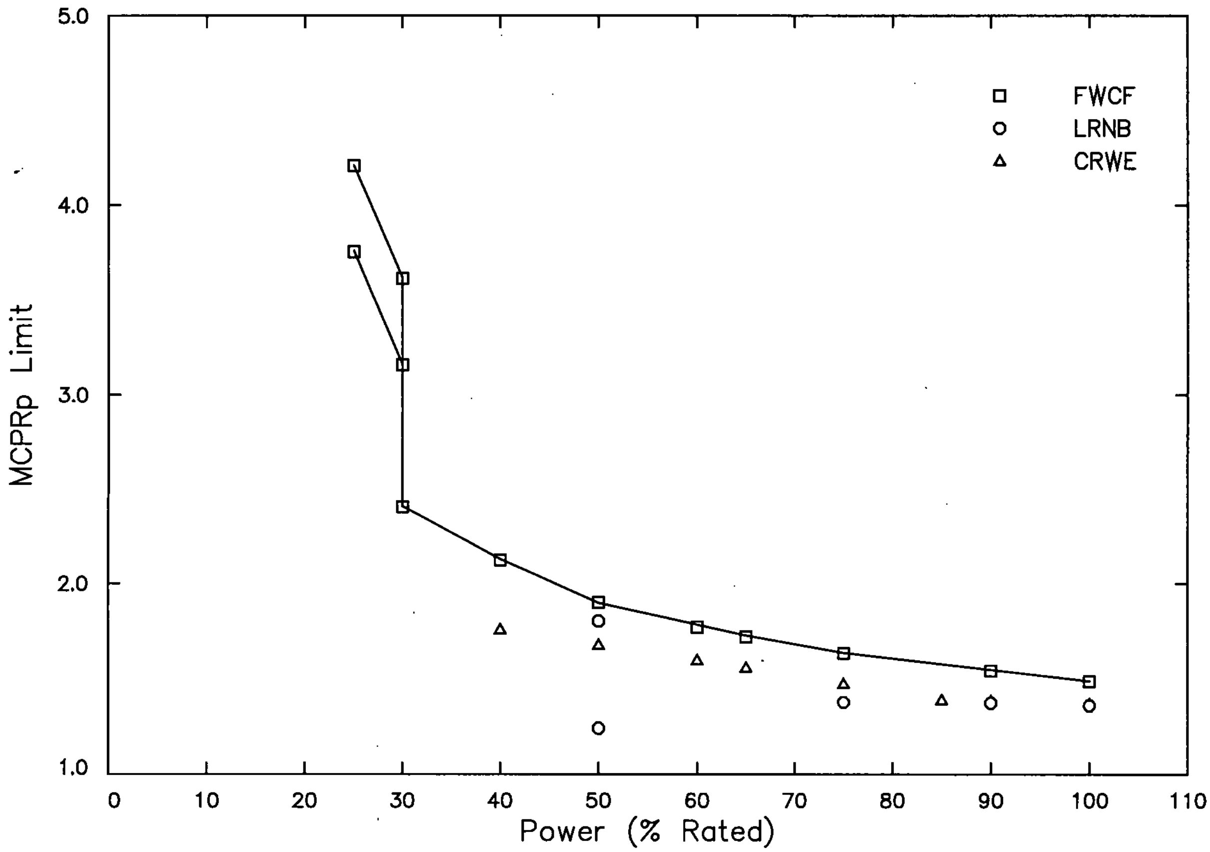
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.61
65	1.68
50	---
50	1.84
40	2.04
30	2.29
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.15 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS



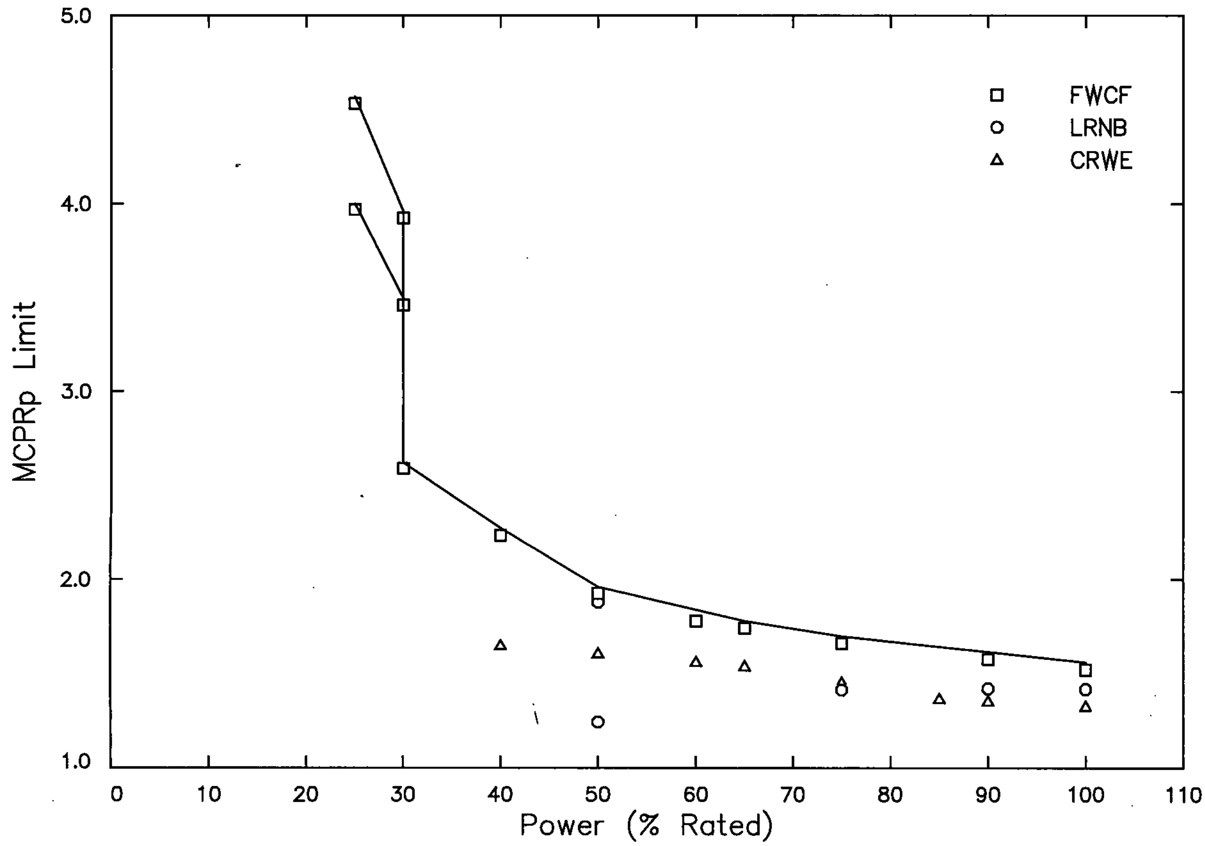
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.66
65	1.73
50	1.87
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.16 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS



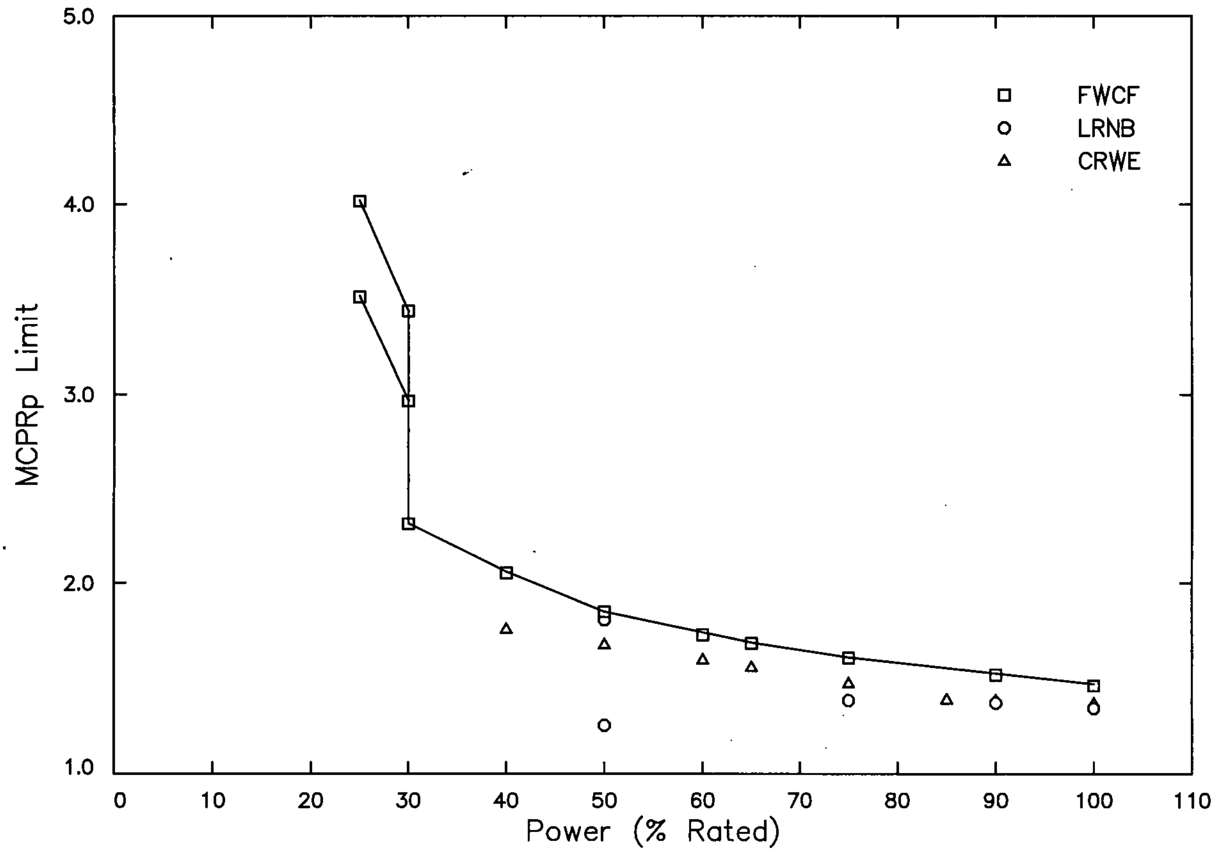
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.64
65	1.73
50	---
50	1.90
40	2.13
30	2.41
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.17 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS



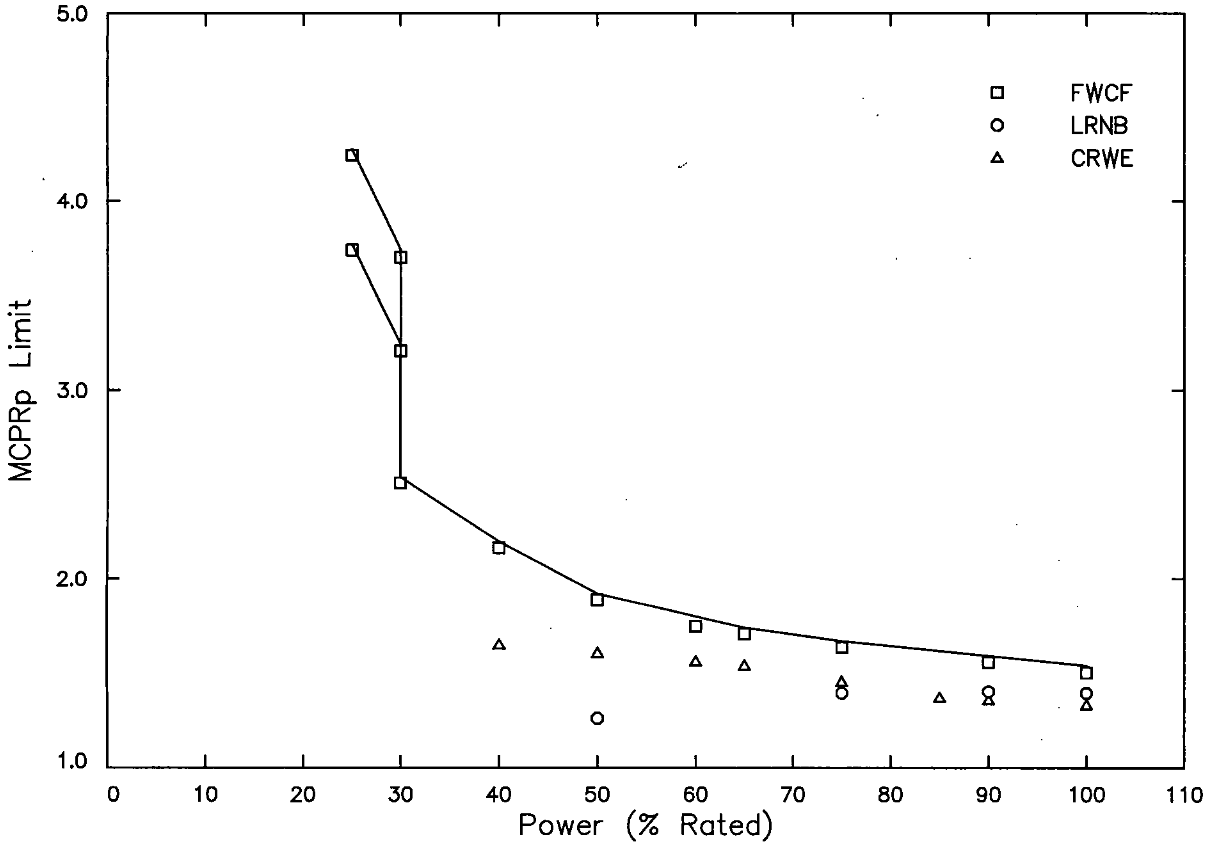
Power (% of rated)	$MCPR_p$ Limit
100	1.56
75	1.70
65	1.78
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.18 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS



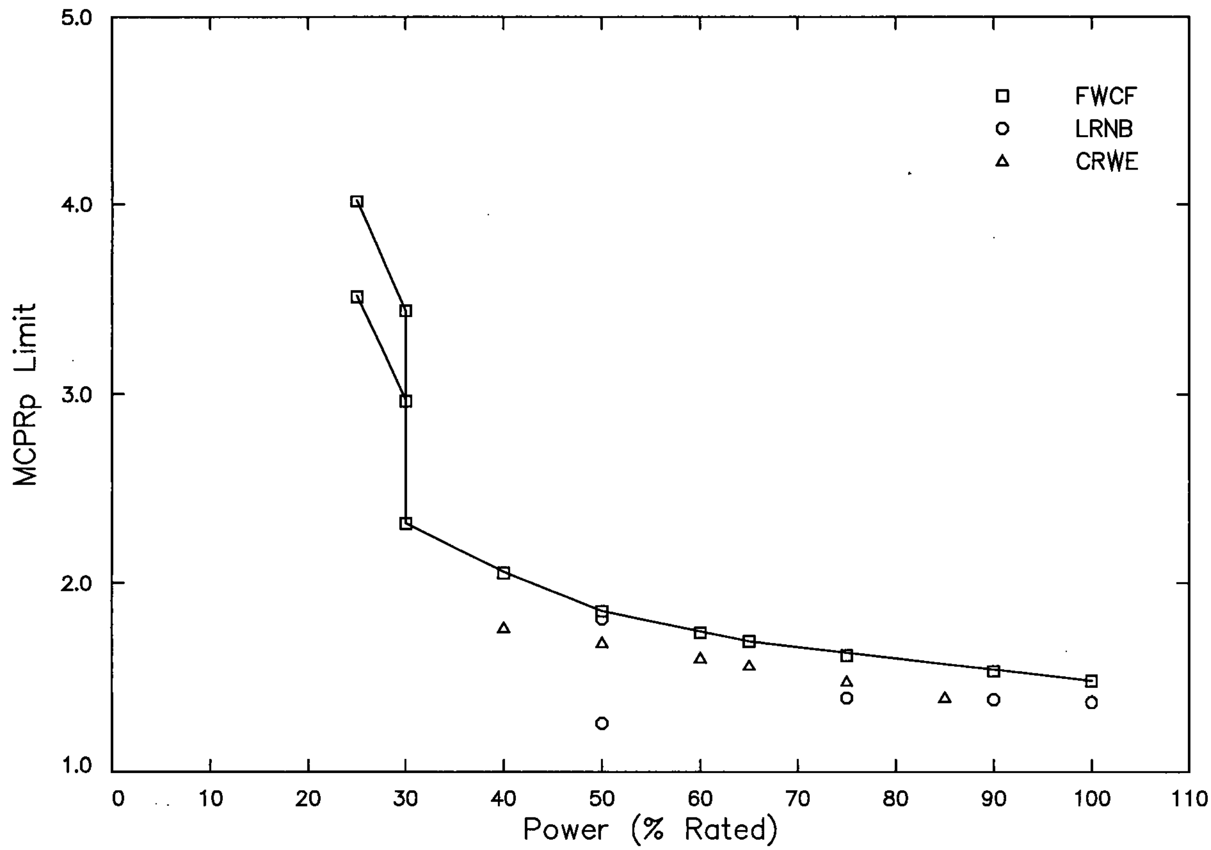
Power (% of rated)	$MCPR_p$ Limit
100	1.47
75	1.61
65	1.69
50	---
50	1.85
40	2.06
30	2.32
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.19 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS



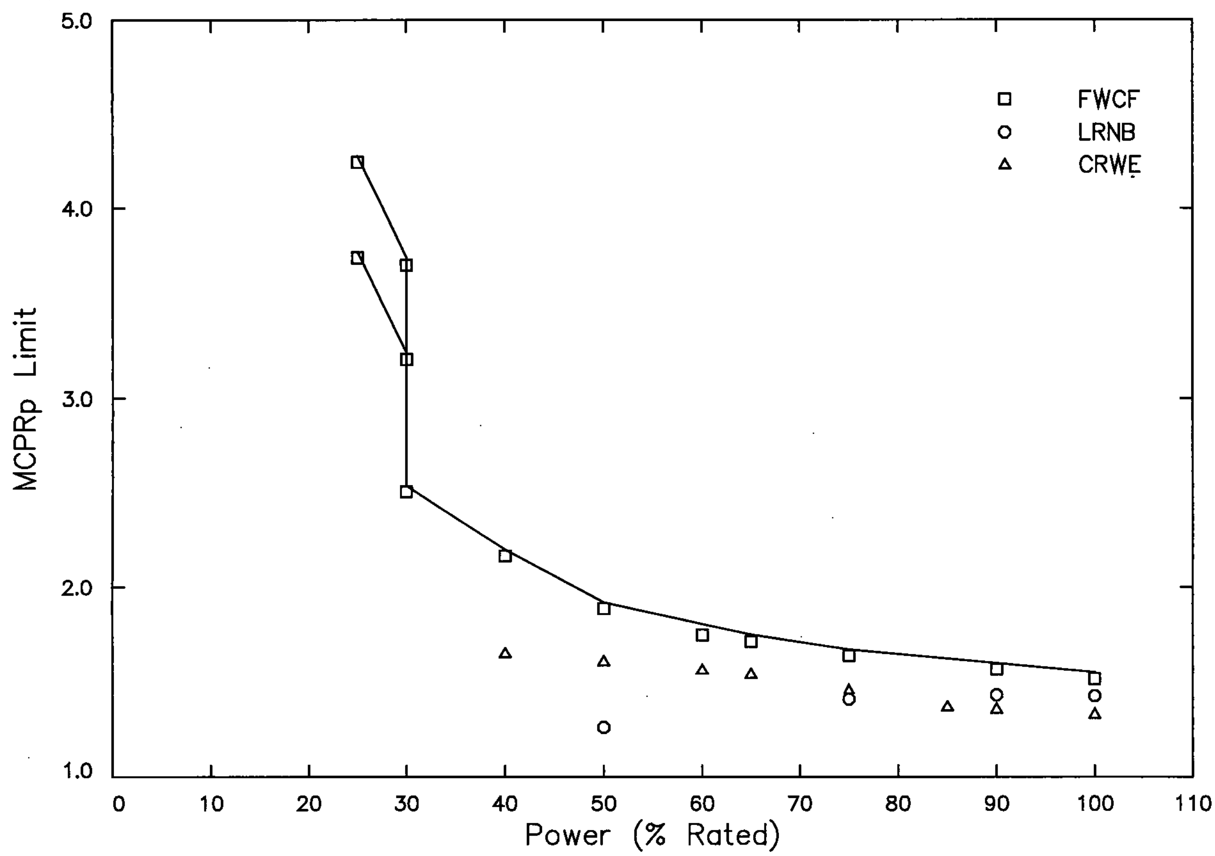
Power (% of rated)	$MCPR_p$ Limit
100	1.54
75	1.67
65	1.74
50	---
50	1.92
40	2.20
30	2.54
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.20 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS



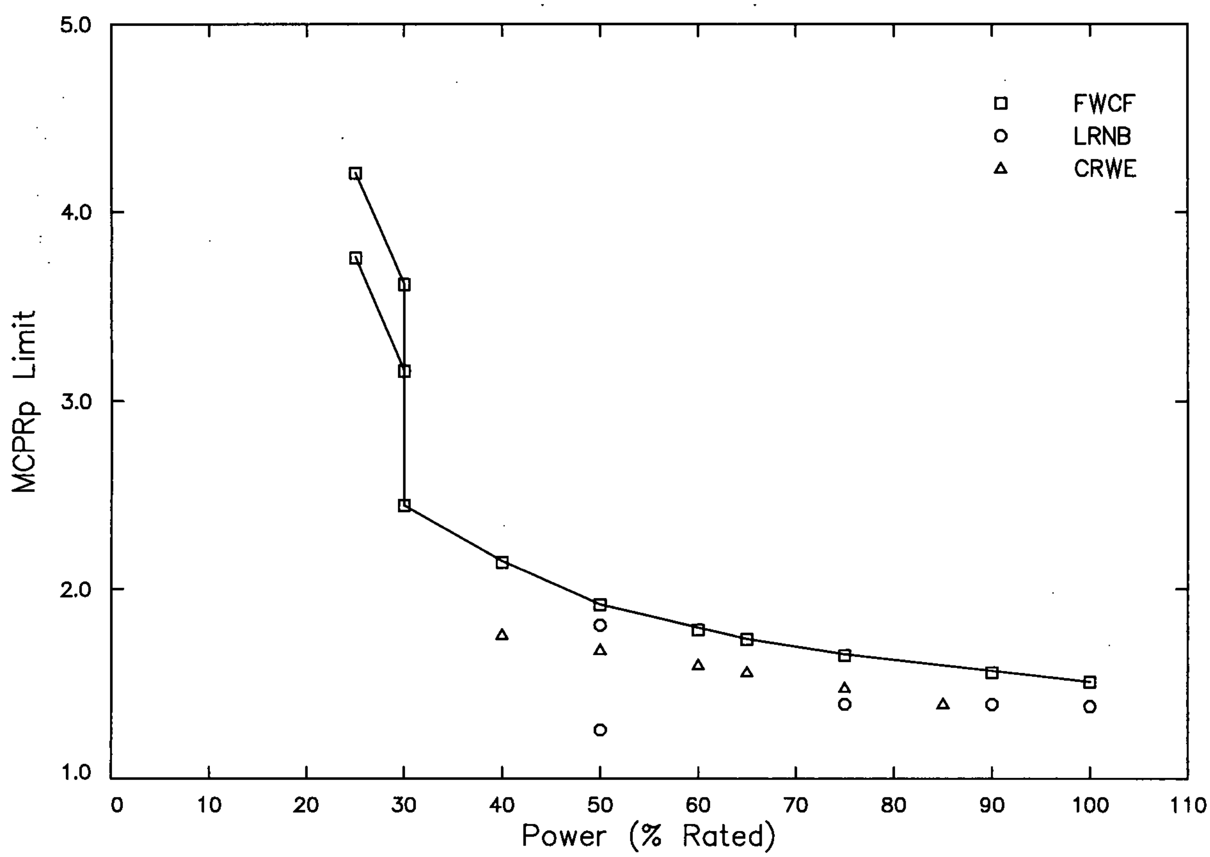
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.63
65	1.69
50	---
50	1.85
40	2.06
30	2.32
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.21 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS



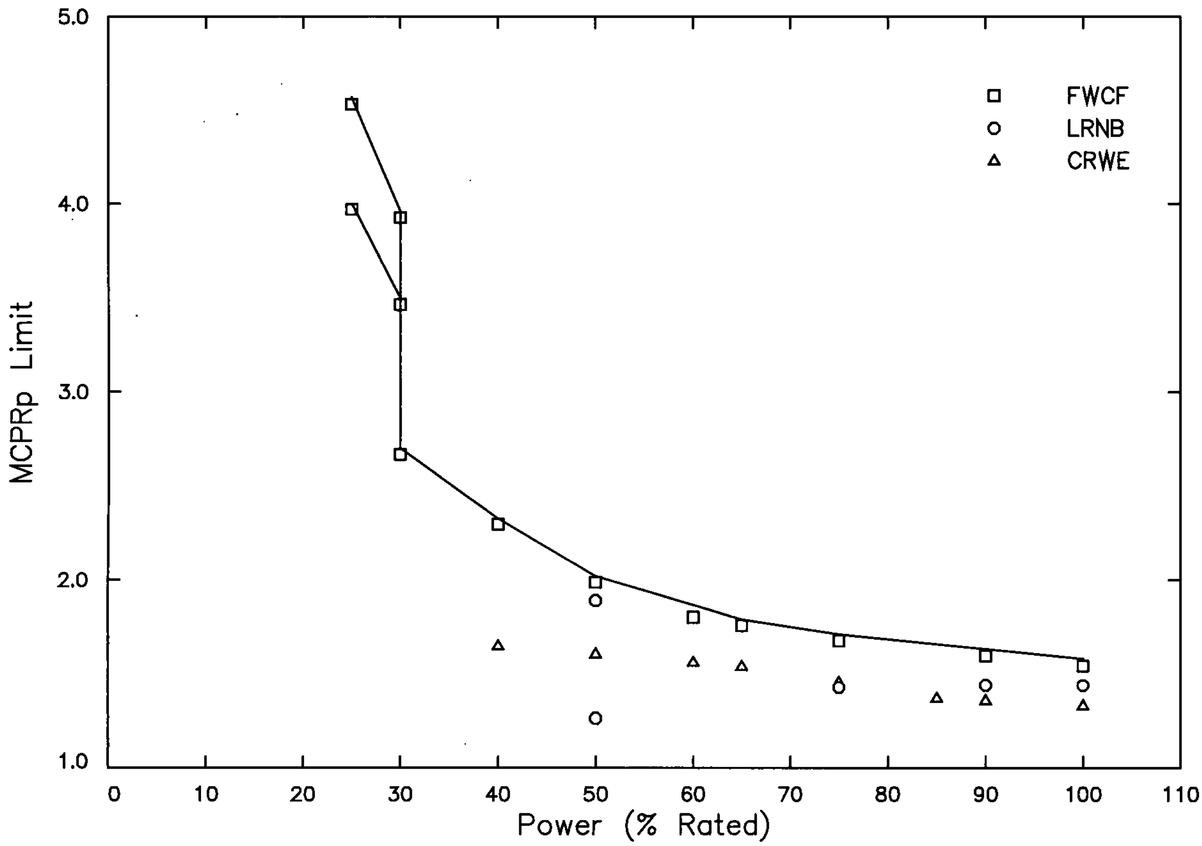
Power (% of rated)	$MCPR_p$ Limit
100	1.55
75	1.67
65	1.75
50	---
50	1.92
40	2.20
30	2.54
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.22 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS



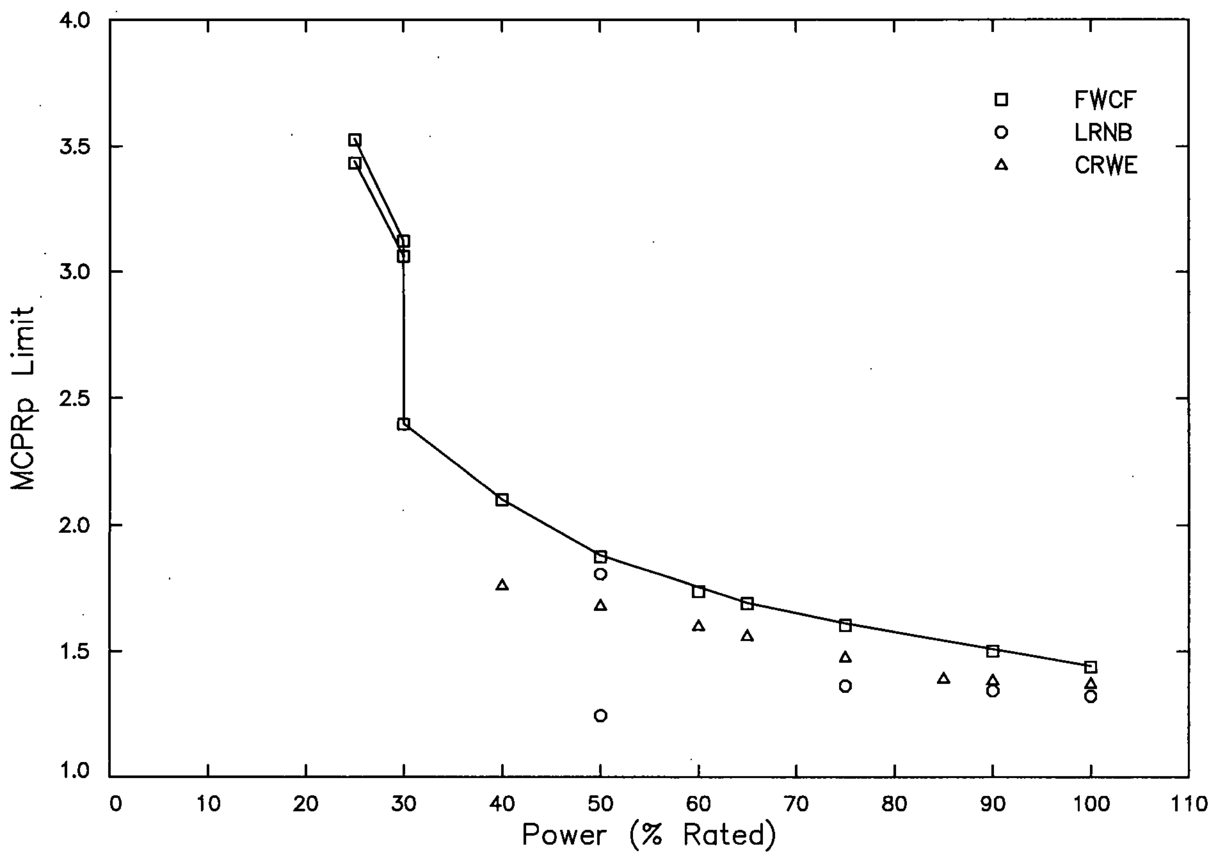
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.66
65	1.74
50	---
50	1.92
40	2.15
30	2.45
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.23 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS



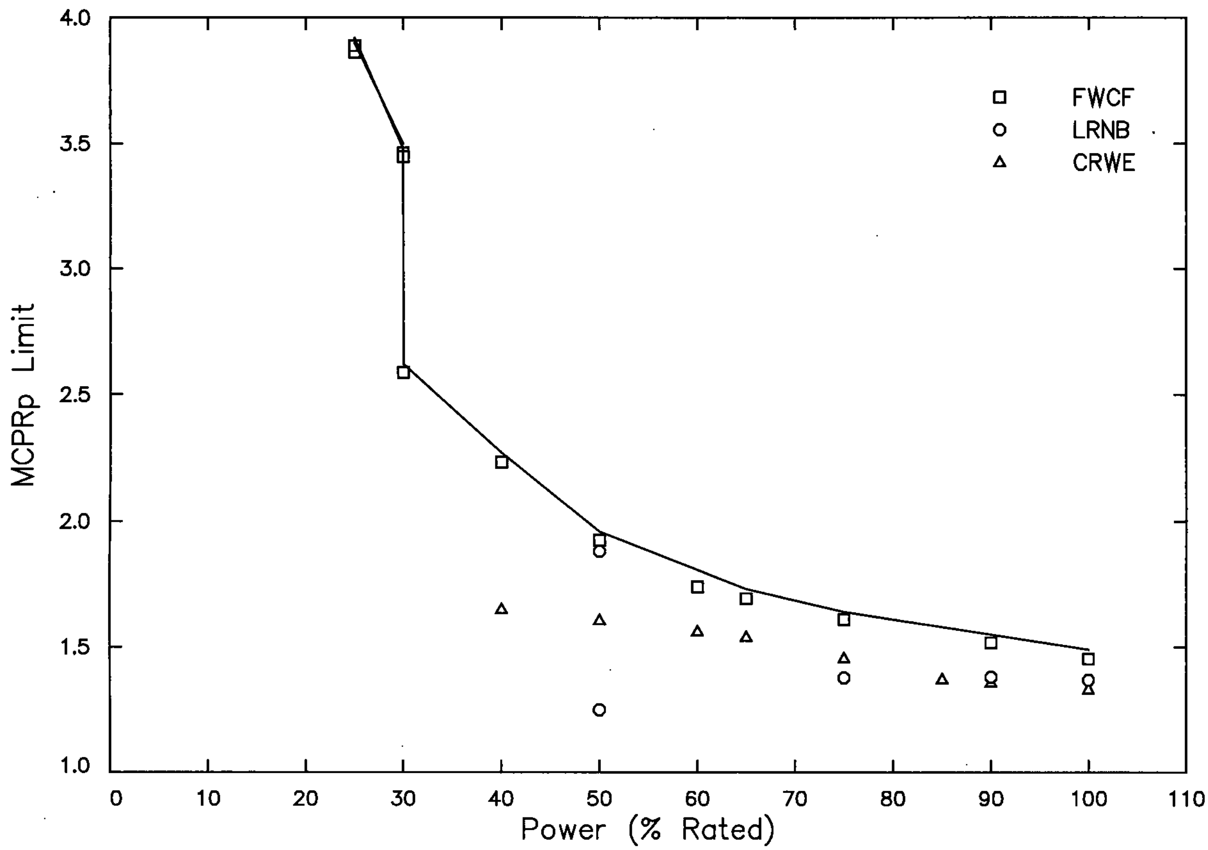
Power (% of rated)	$MCPR_p$ Limit
100	1.58
75	1.71
65	1.79
50	---
50	2.02
40	2.33
30	2.70
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.24 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS



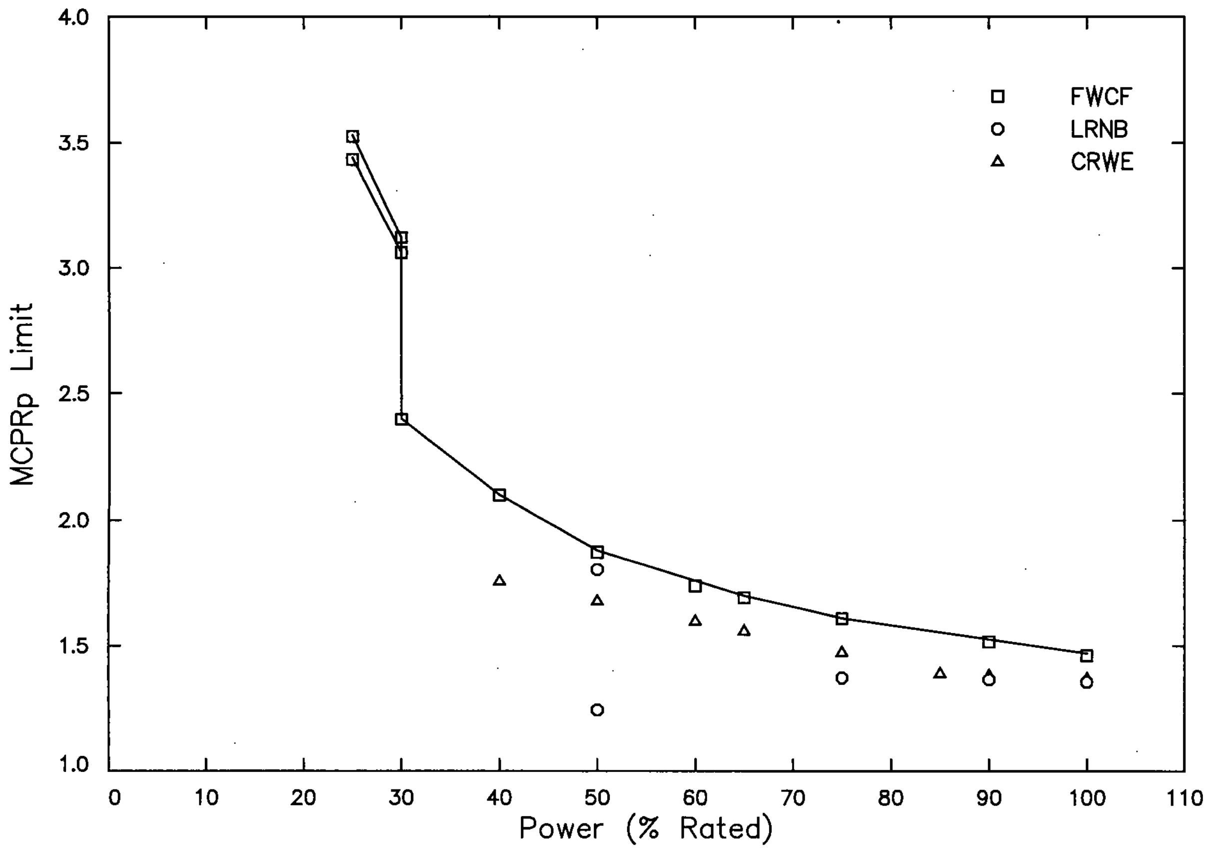
Power (% of rated)	$MCPR_p$ Limit
100	1.44
75	1.61
65	1.69
50	---
50	1.88
40	2.10
30	2.40
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.25 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - FHOOS



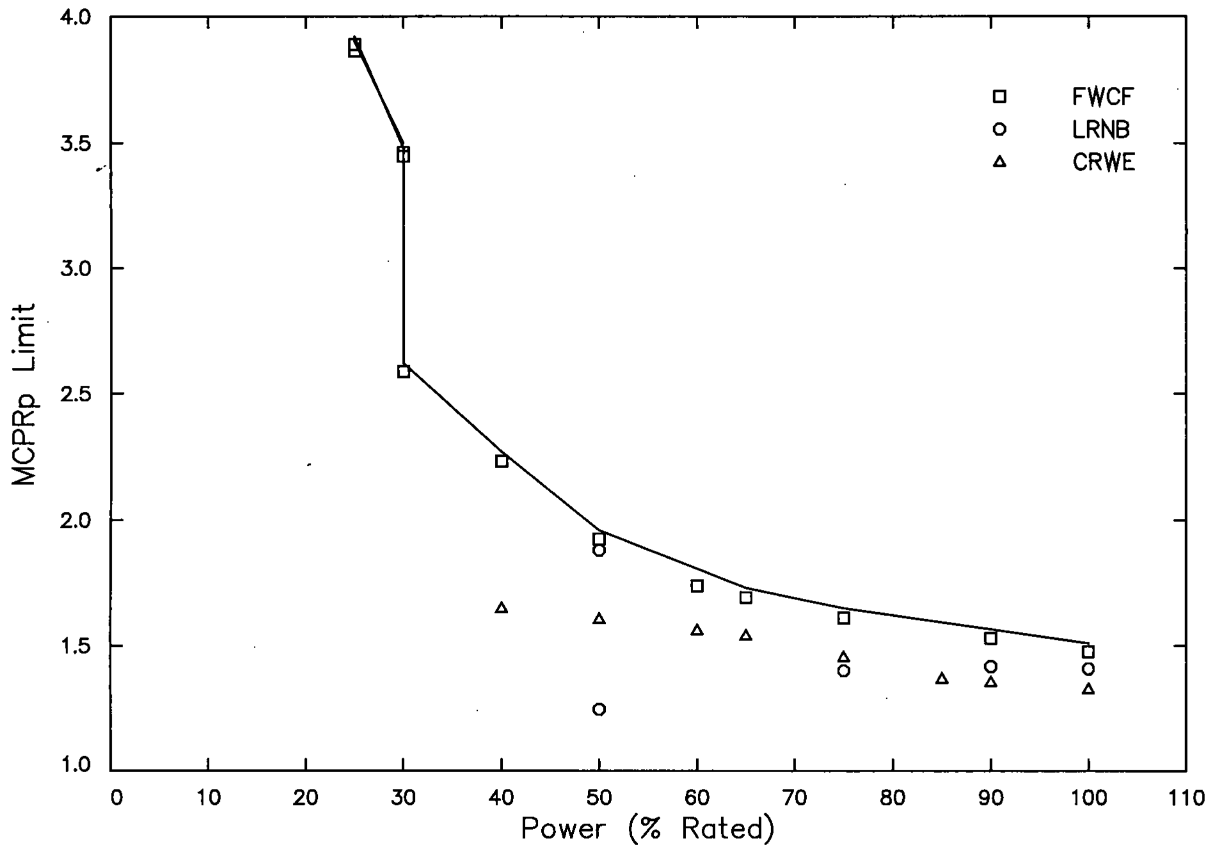
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.64
65	1.73
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.26 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - FHOOS



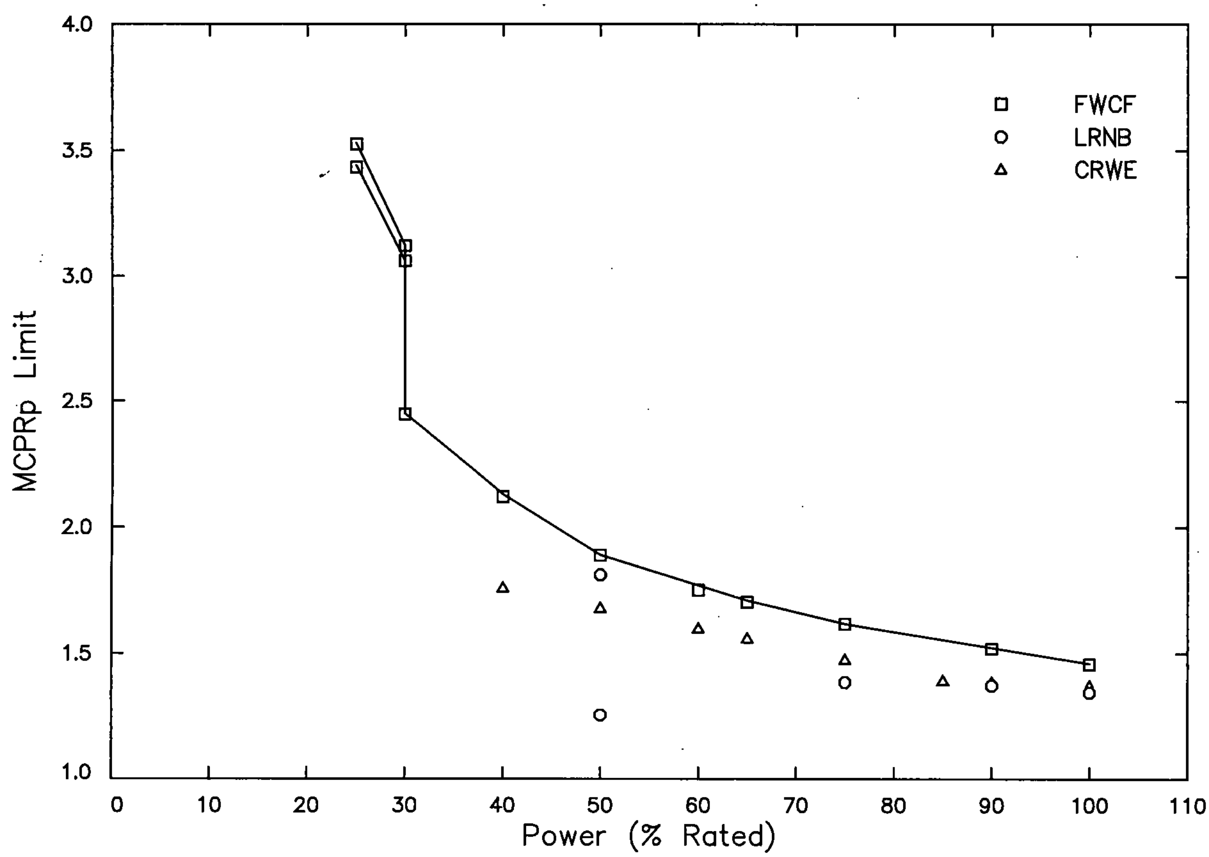
Power (% of rated)	$MCPR_p$ Limit
100	1.47
75	1.61
65	1.70
50	---
50	1.88
40	2.10
30	2.40
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.27 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - FHOOS



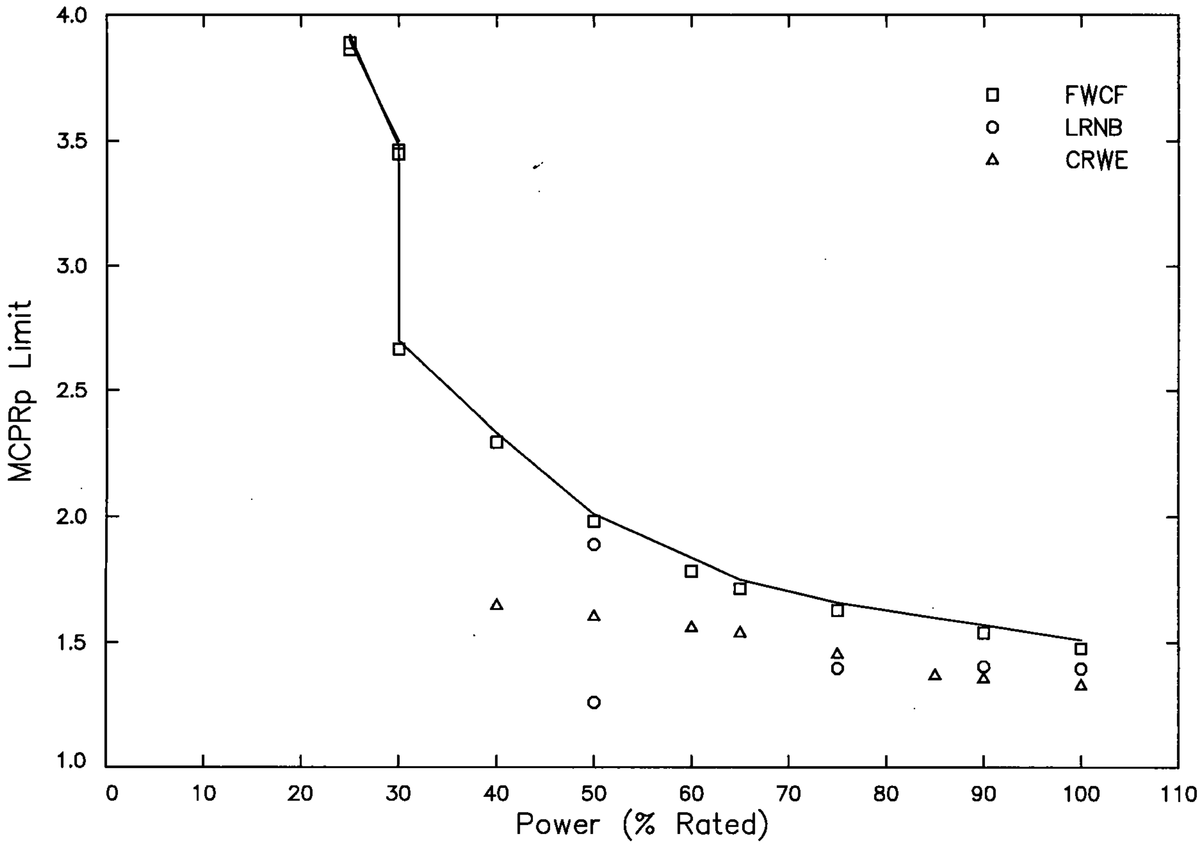
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.65
65	1.73
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.28 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - FHOOS



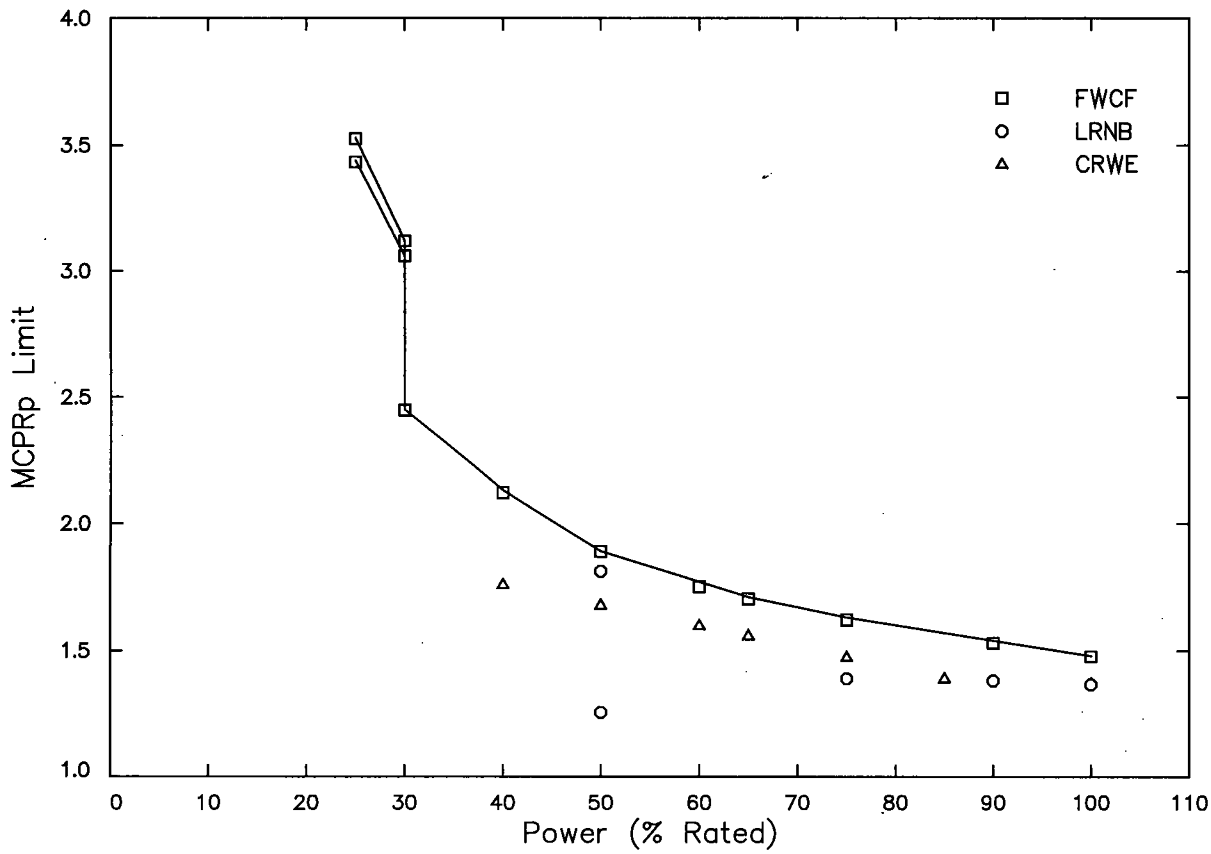
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.62
65	1.71
50	---
50	1.89
40	2.13
30	2.45
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.29 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - FHOOS



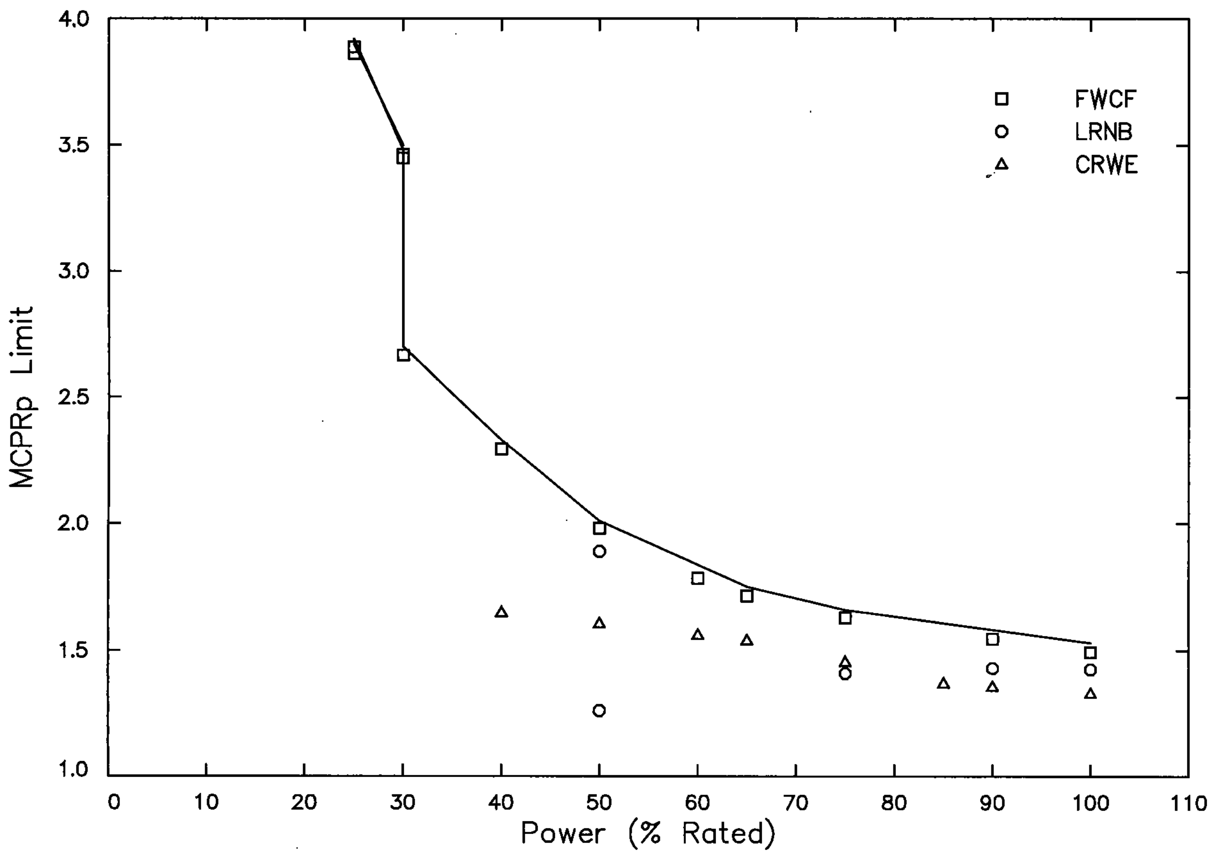
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.66
65	1.75
50	---
50	2.01
40	2.33
30	2.70
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.30 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - FHOOS



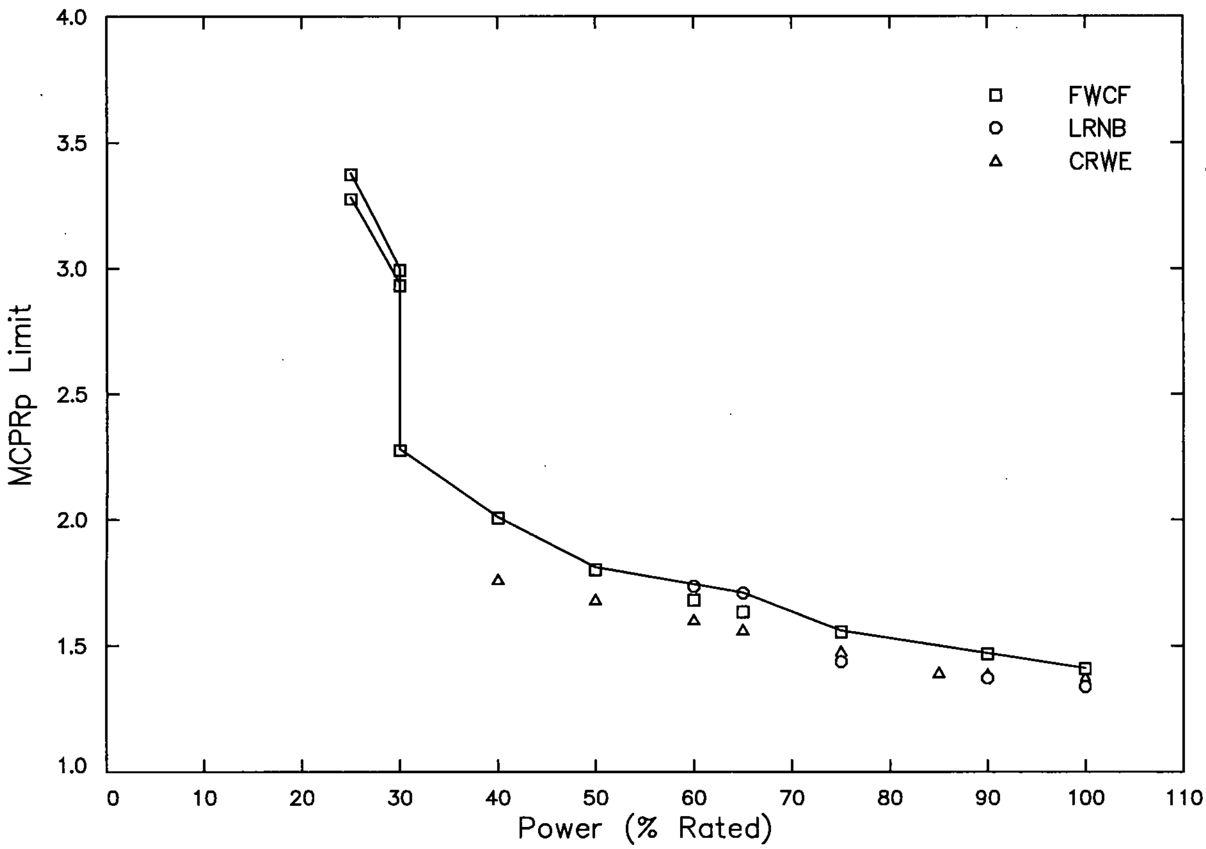
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.63
65	1.71
50	---
50	1.89
40	2.13
30	2.45
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.31 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - FHOOS



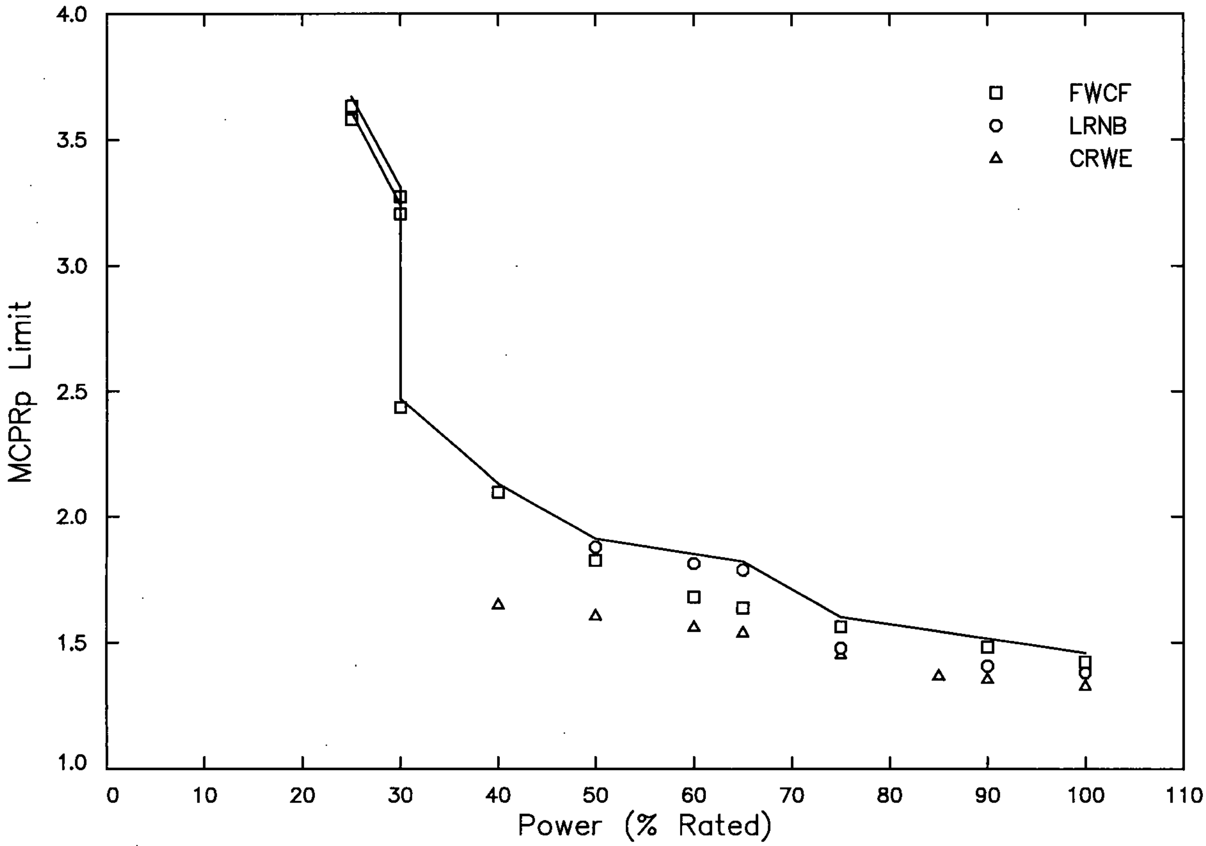
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.66
65	1.75
50	---
50	2.01
40	2.33
30	2.70
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.32 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - FHOOS



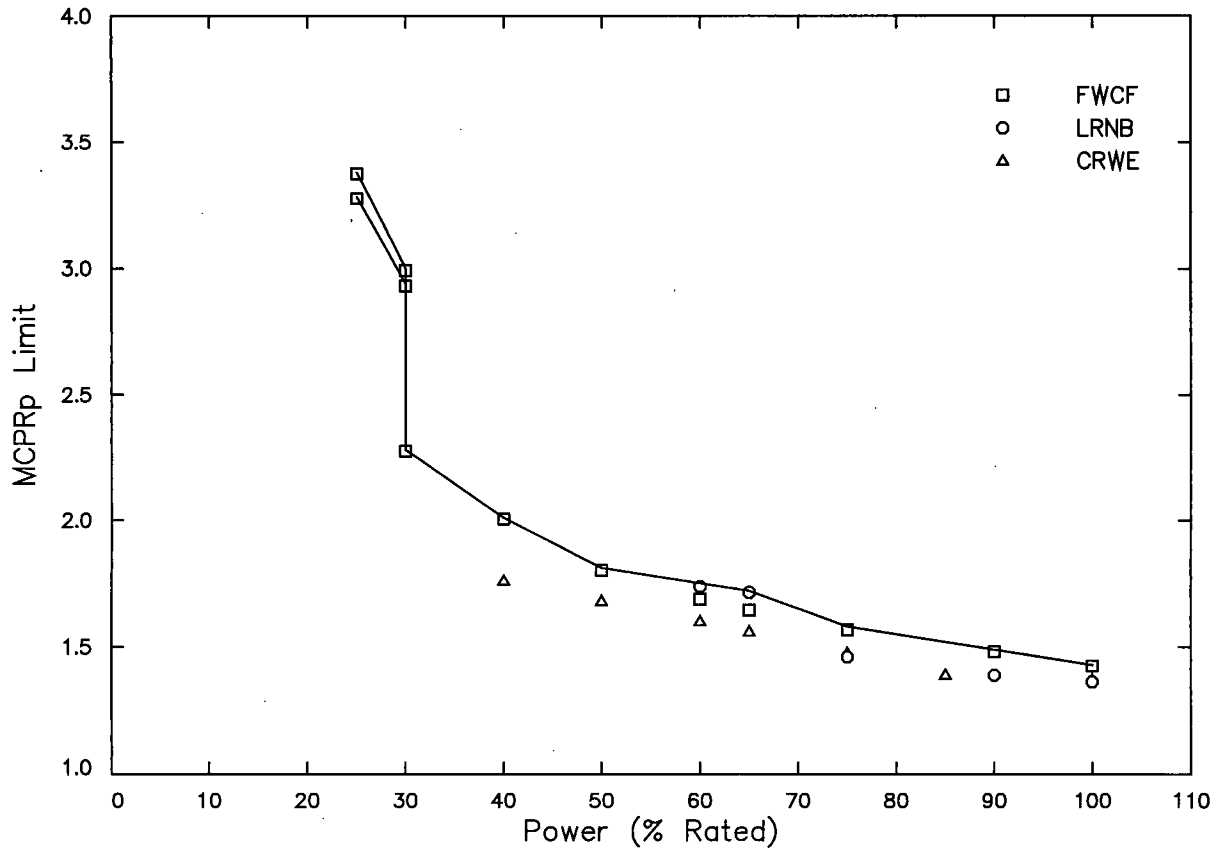
Power (% of rated)	$MCPR_p$ Limit
100	1.41
75	1.56
65	1.71
50	---
50	1.81
40	2.01
30	2.28
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.33 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - PLUOOS



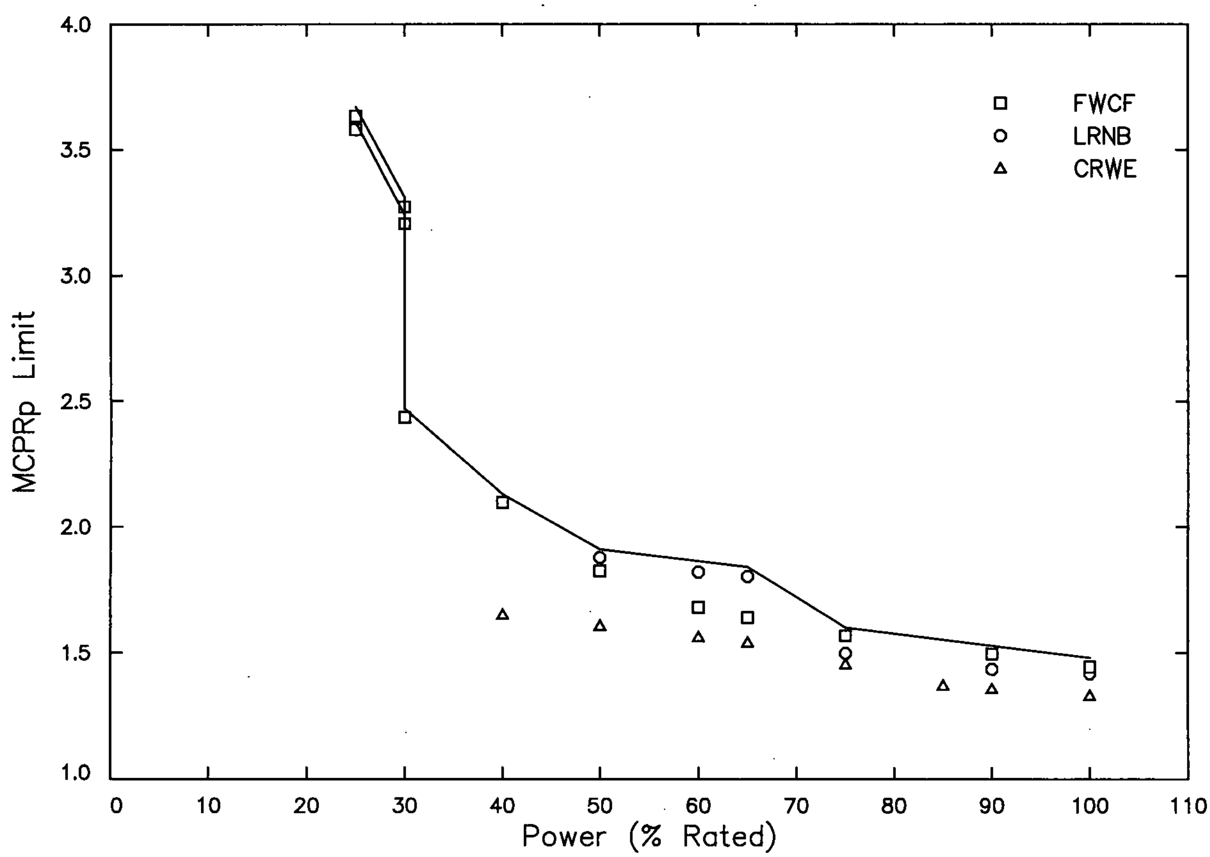
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.60
65	1.82
50	---
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.34 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - PLUOOS



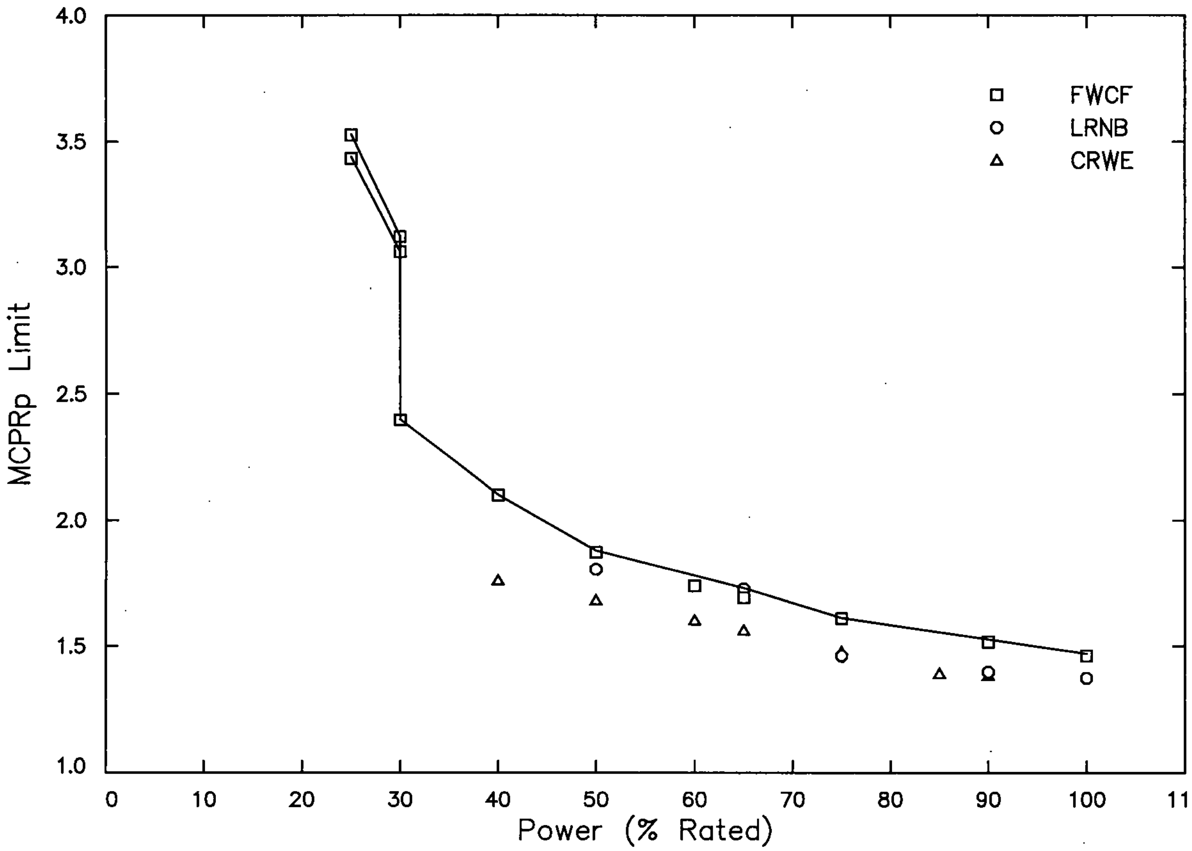
Power (% of rated)	$MCPR_p$ Limit
100	1.43
75	1.58
65	1.72
50	---
50	1.81
40	2.01
30	2.28
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.35 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - PLUOOS



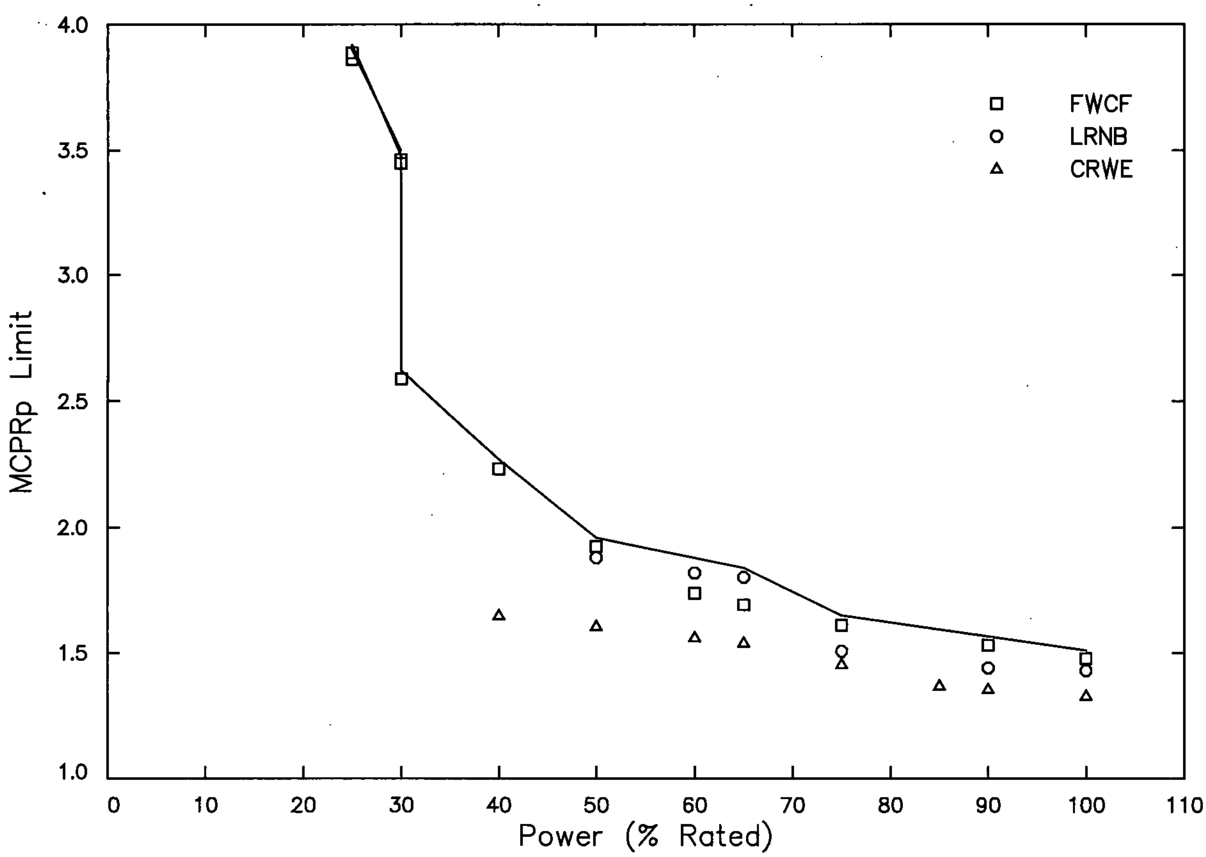
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.60
65	1.84
50	---
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.36 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - PLUOOS



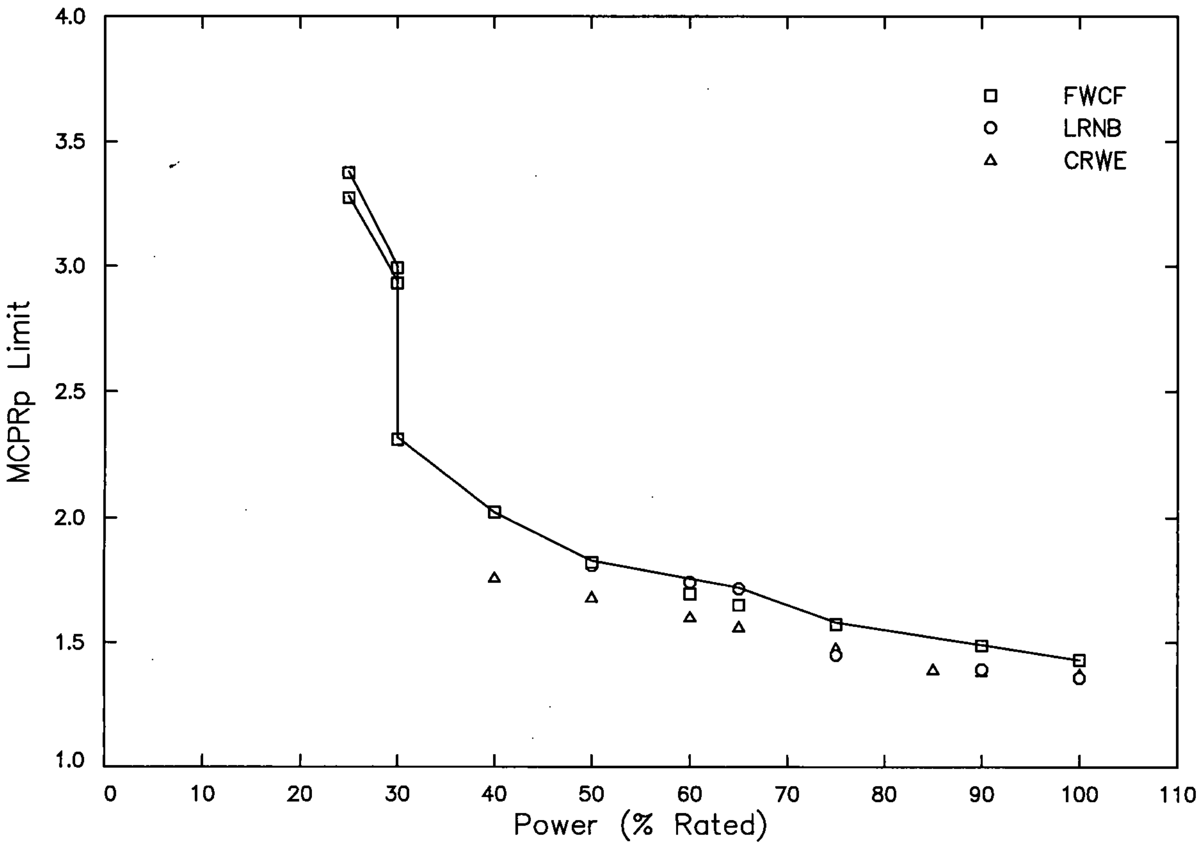
Power (% of rated)	$MCPR_p$ Limit
100	1.47
75	1.61
65	1.73
50	---
50	1.88
40	2.10
30	2.40
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.37 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - PLUOOS



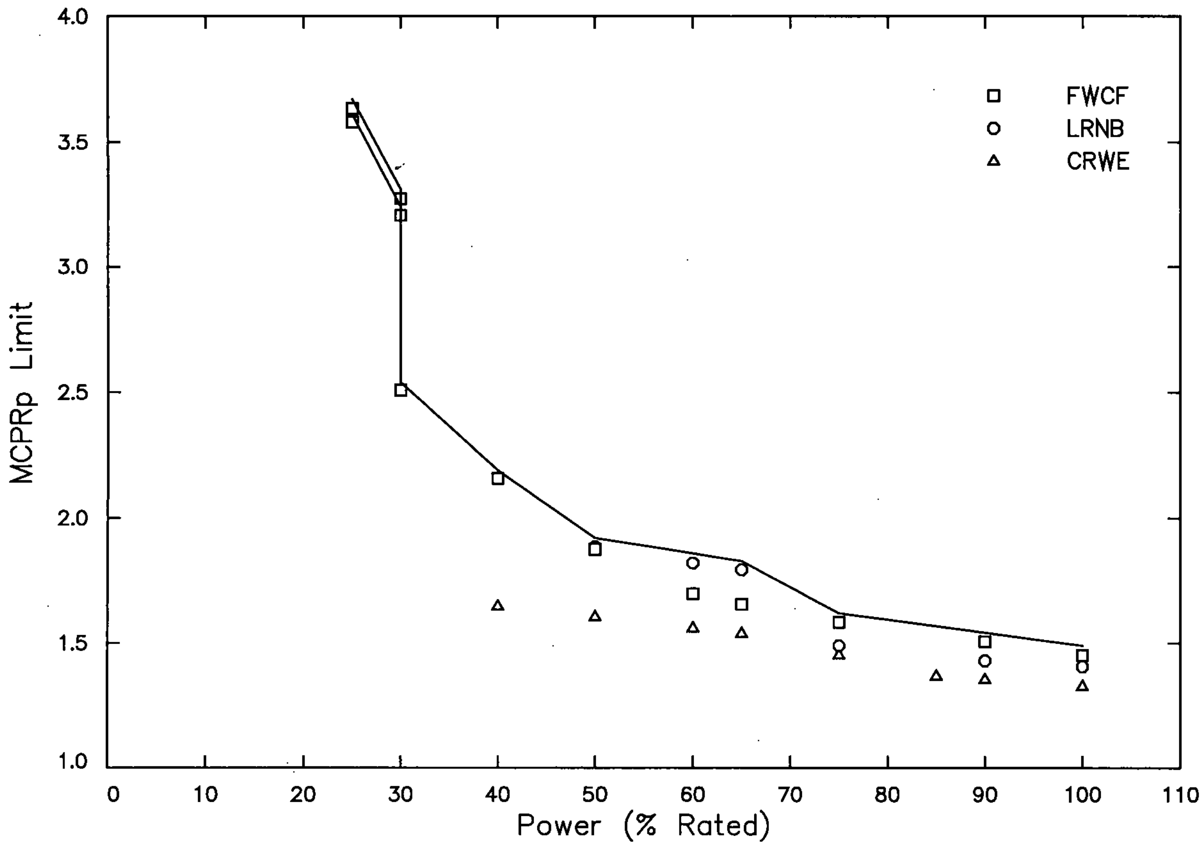
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.65
65	1.84
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.38 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - PLUOOS



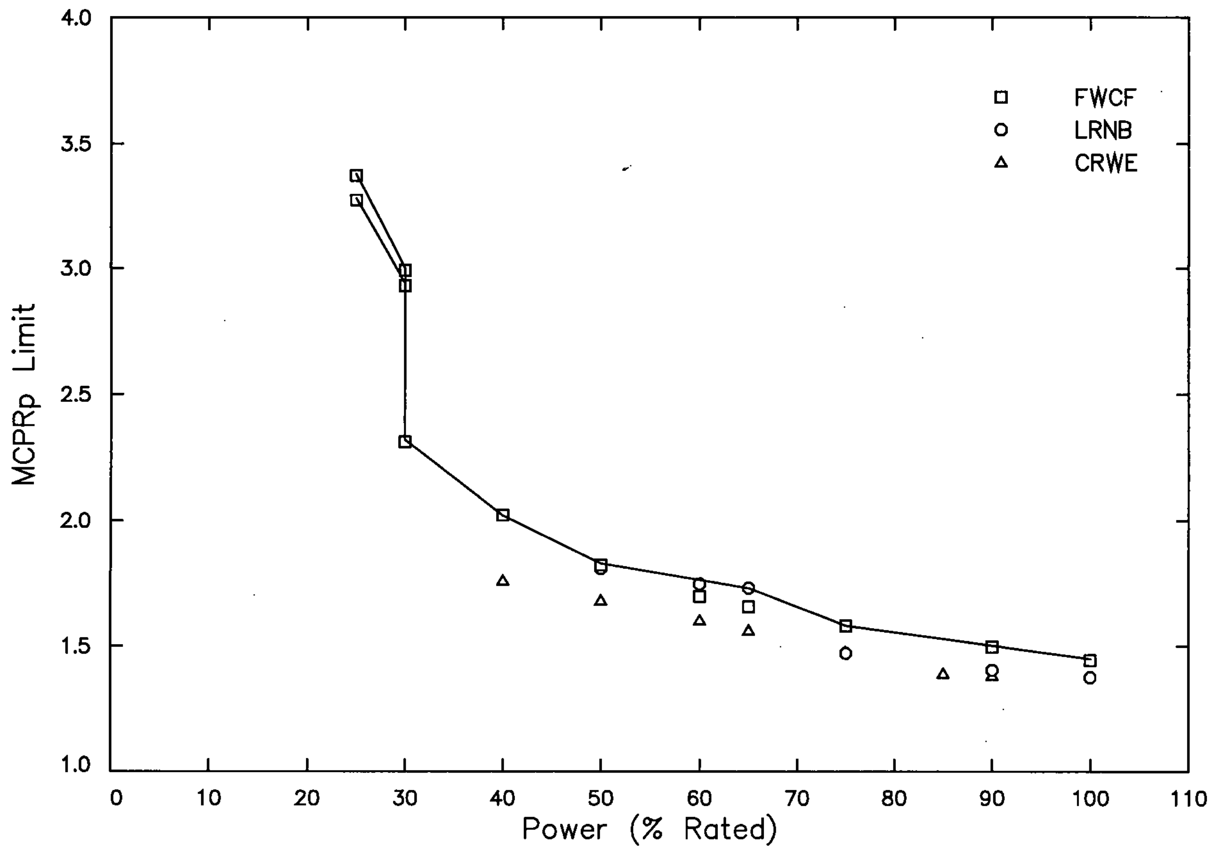
Power (% of rated)	$MCPR_p$ Limit
100	1.43
75	1.58
65	1.72
50	---
50	1.83
40	2.02
30	2.32
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.39 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - PLUOOS



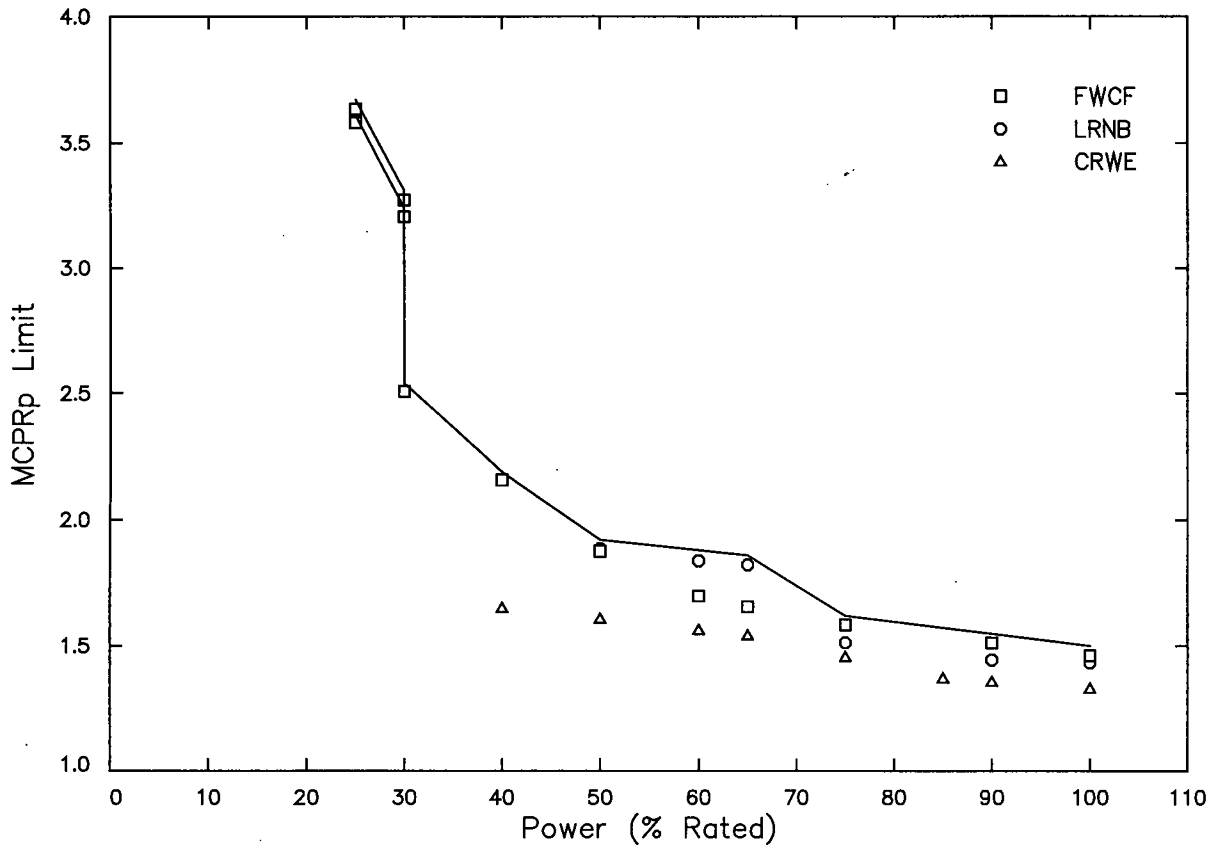
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.62
65	1.83
50	---
50	1.92
40	2.19
30	2.54
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.40 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - PLUOOS



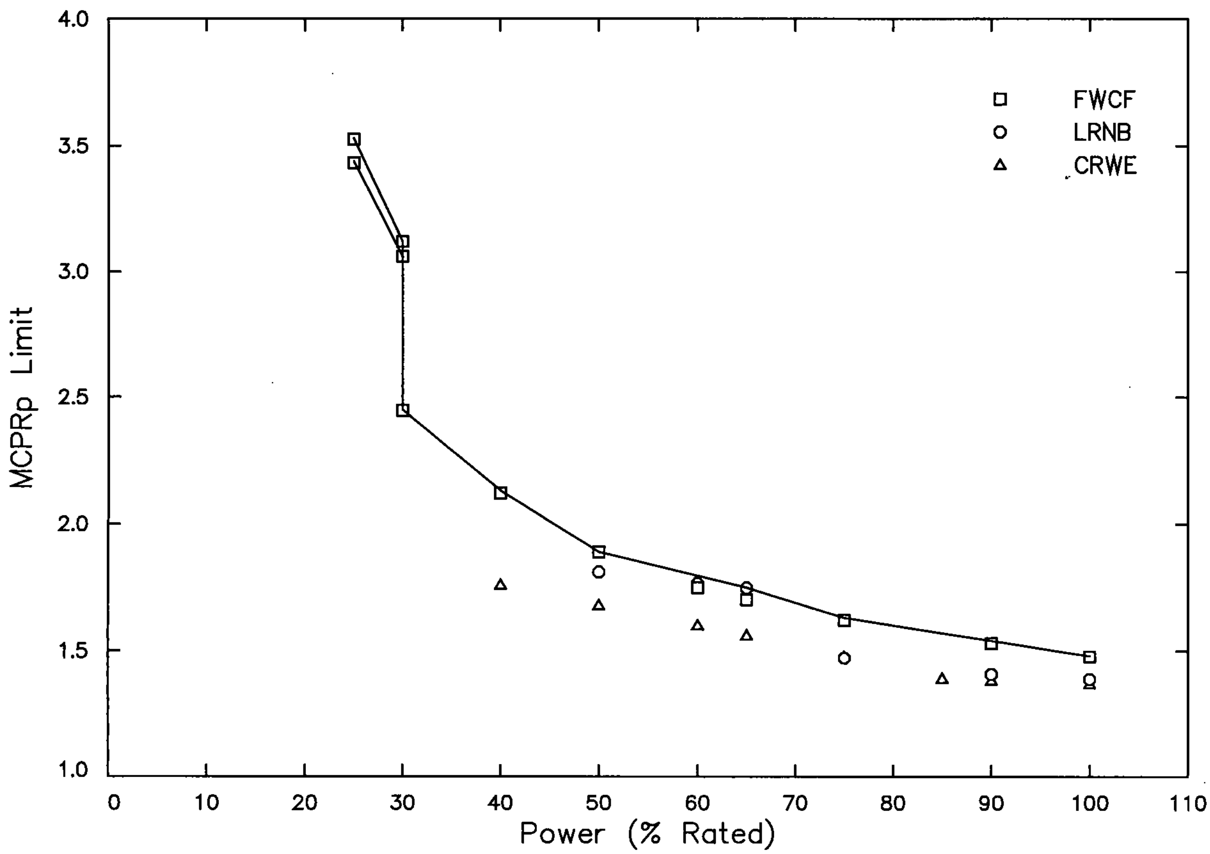
Power (% of rated)	$MCPR_p$ Limit
100	1.45
75	1.58
65	1.73
50	---
50	1.83
40	2.02
30	2.32
30 at > 50%F	3.00
25 at > 50%F	3.38
30 at ≤ 50%F	2.94
25 at ≤ 50%F	3.28

Figure A.41 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - PLUOOS



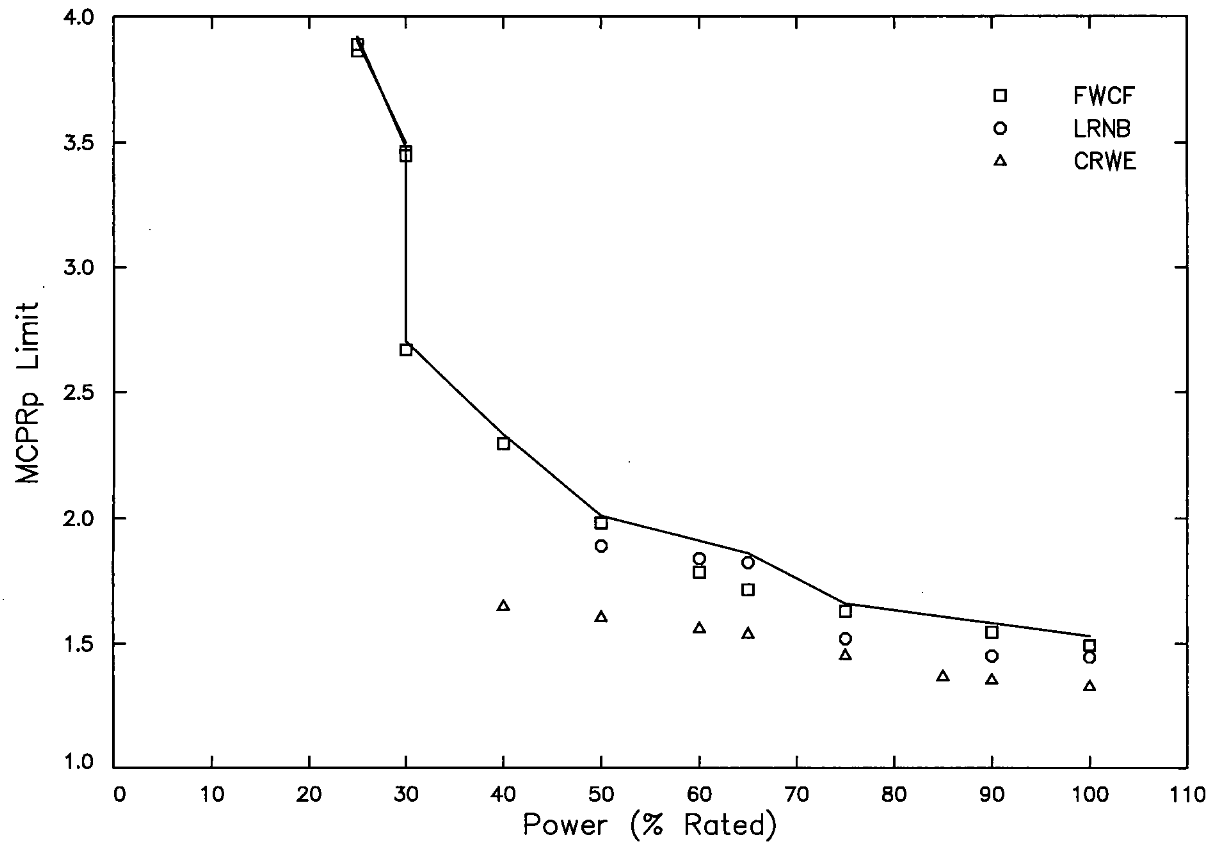
Power (% of rated)	MCPR$_p$ Limit
100	1.50
75	1.62
65	1.86
50	---
50	1.92
40	2.19
30	2.54
30 at > 50%F	3.31
25 at > 50%F	3.67
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.61

Figure A.42 BOC to EOCLB MCPR$_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - PLUOOS



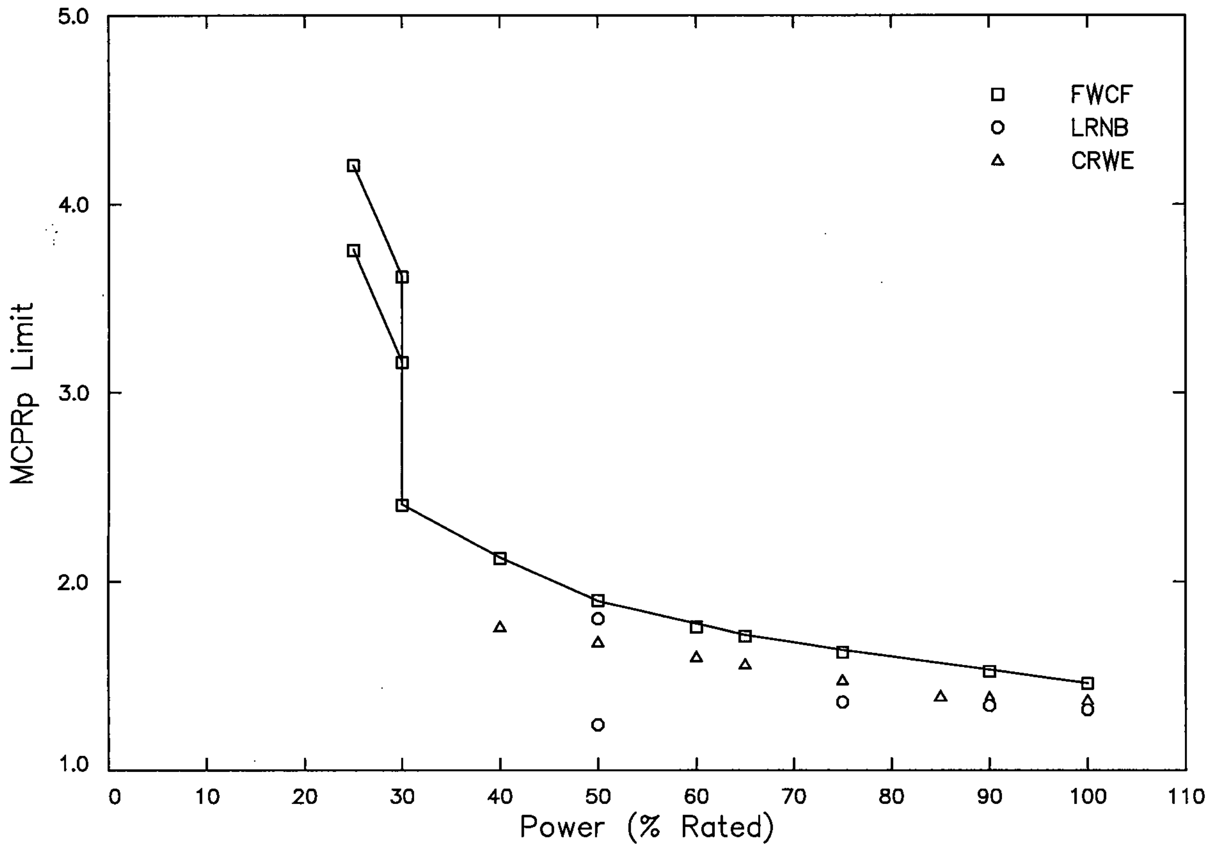
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.63
65	1.75
50	---
50	1.89
40	2.13
30	2.45
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.43 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - PLUOOS



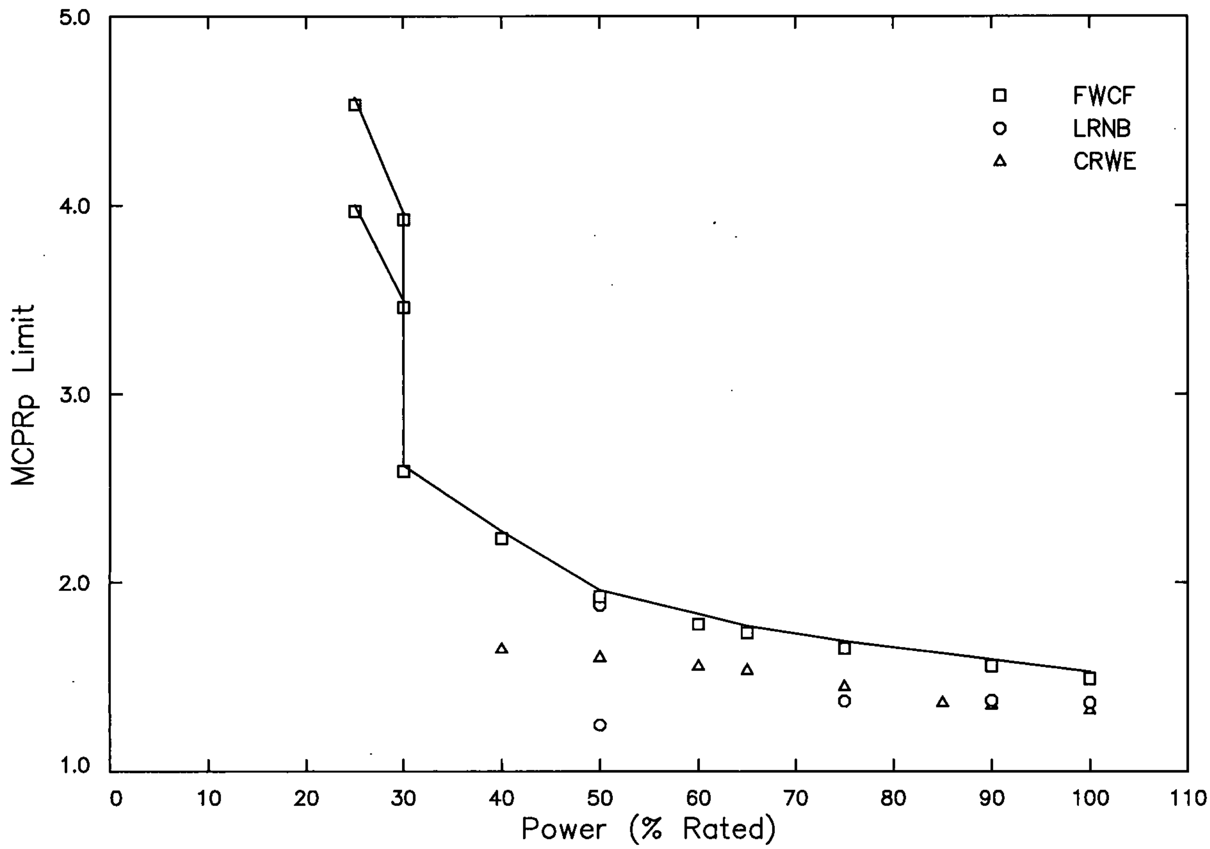
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.66
65	1.86
50	---
50	2.01
40	2.33
30	2.70
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.44 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - PLUOOS



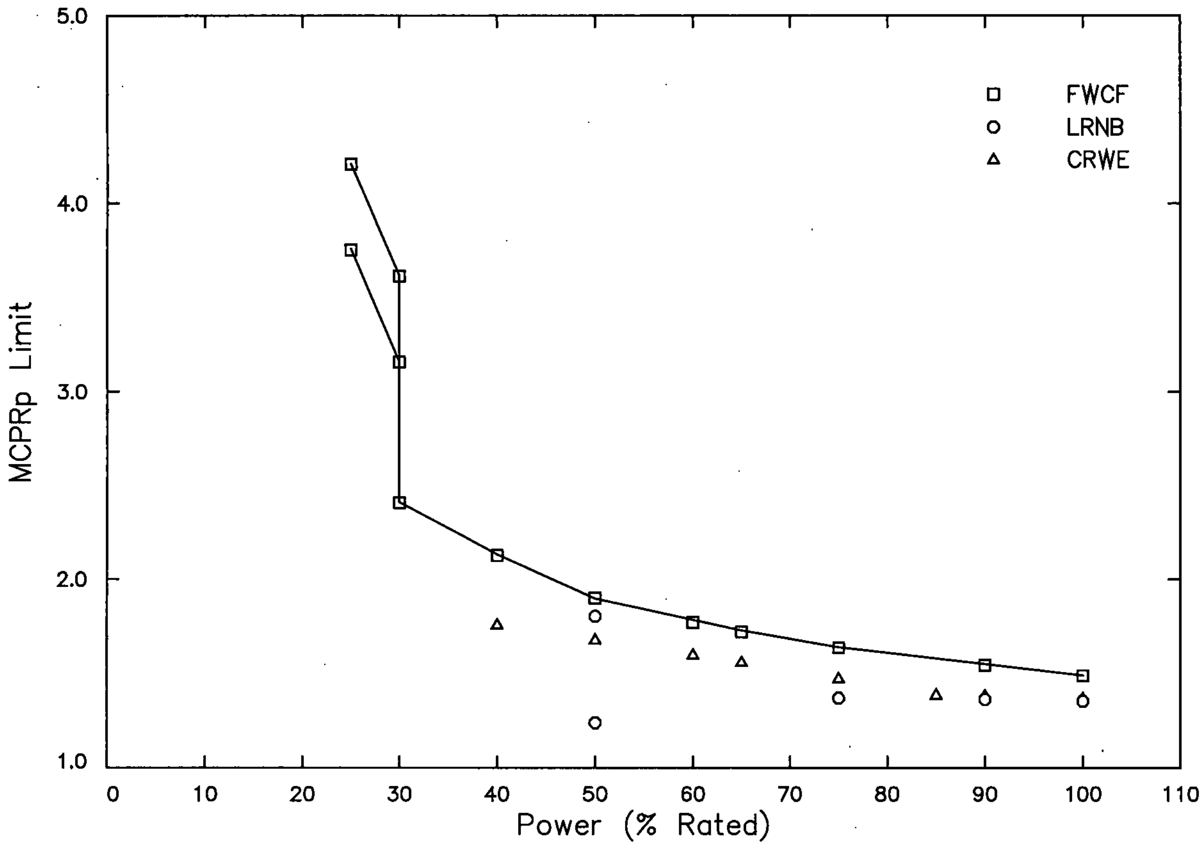
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.64
65	1.72
50	---
50	1.90
40	2.13
30	2.41
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.45 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS and FHOOS Combined



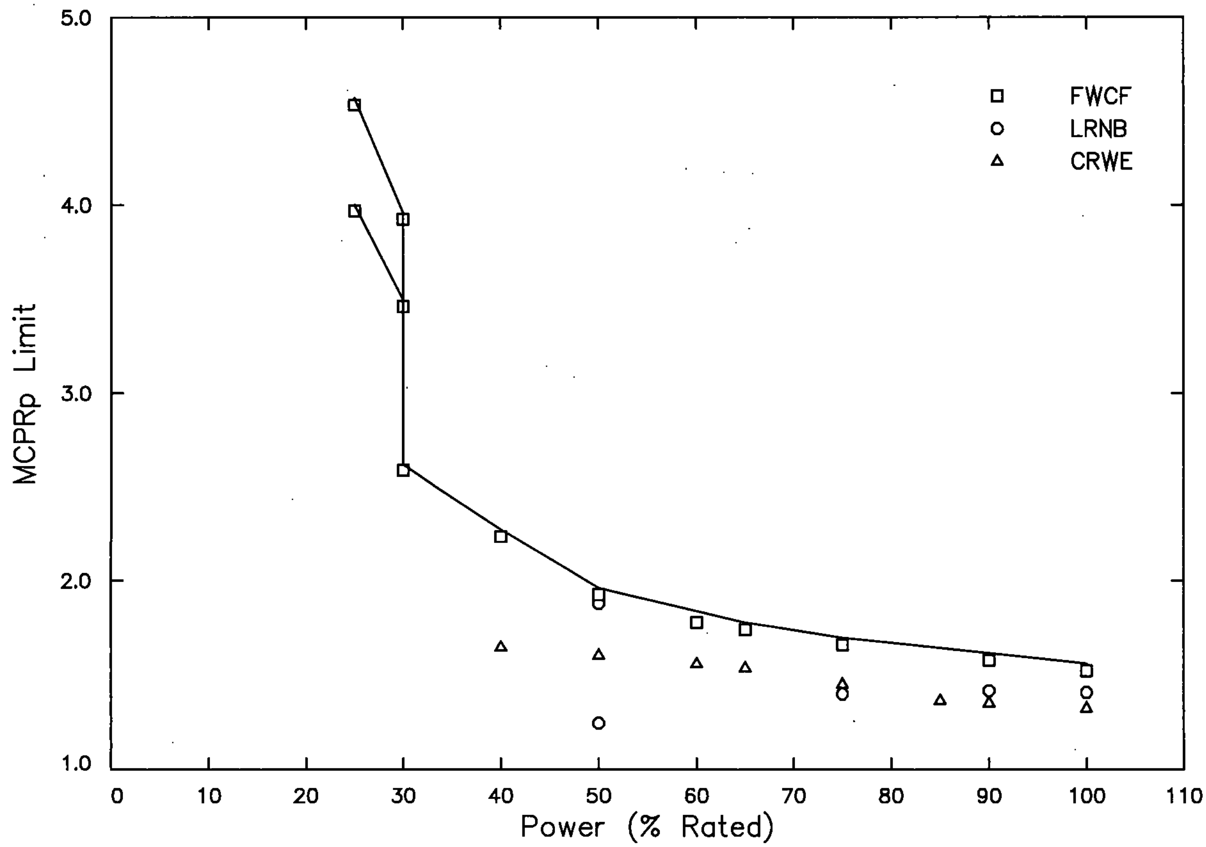
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.69
65	1.77
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.46 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS and FHOOS Combined



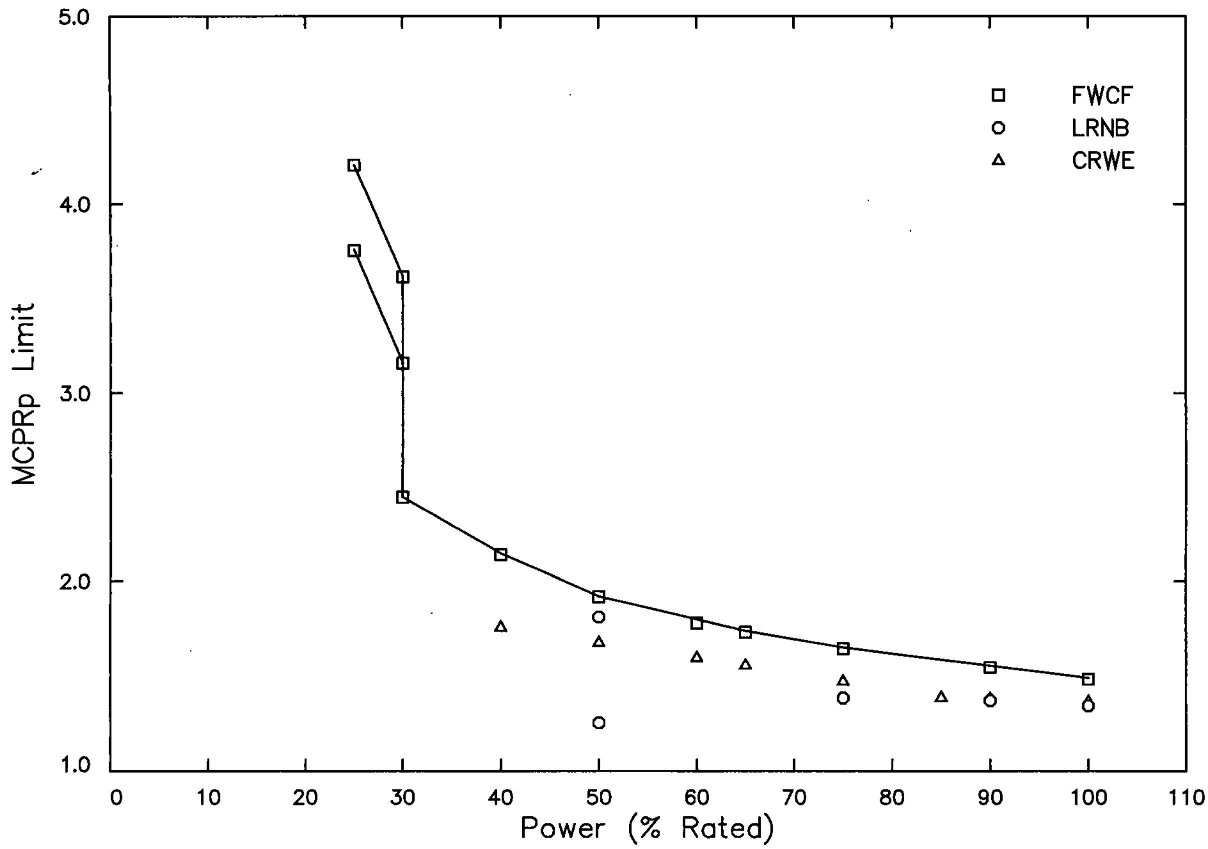
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.64
65	1.73
50	---
50	1.90
40	2.13
30	2.41
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.47 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS and FHOOS Combined



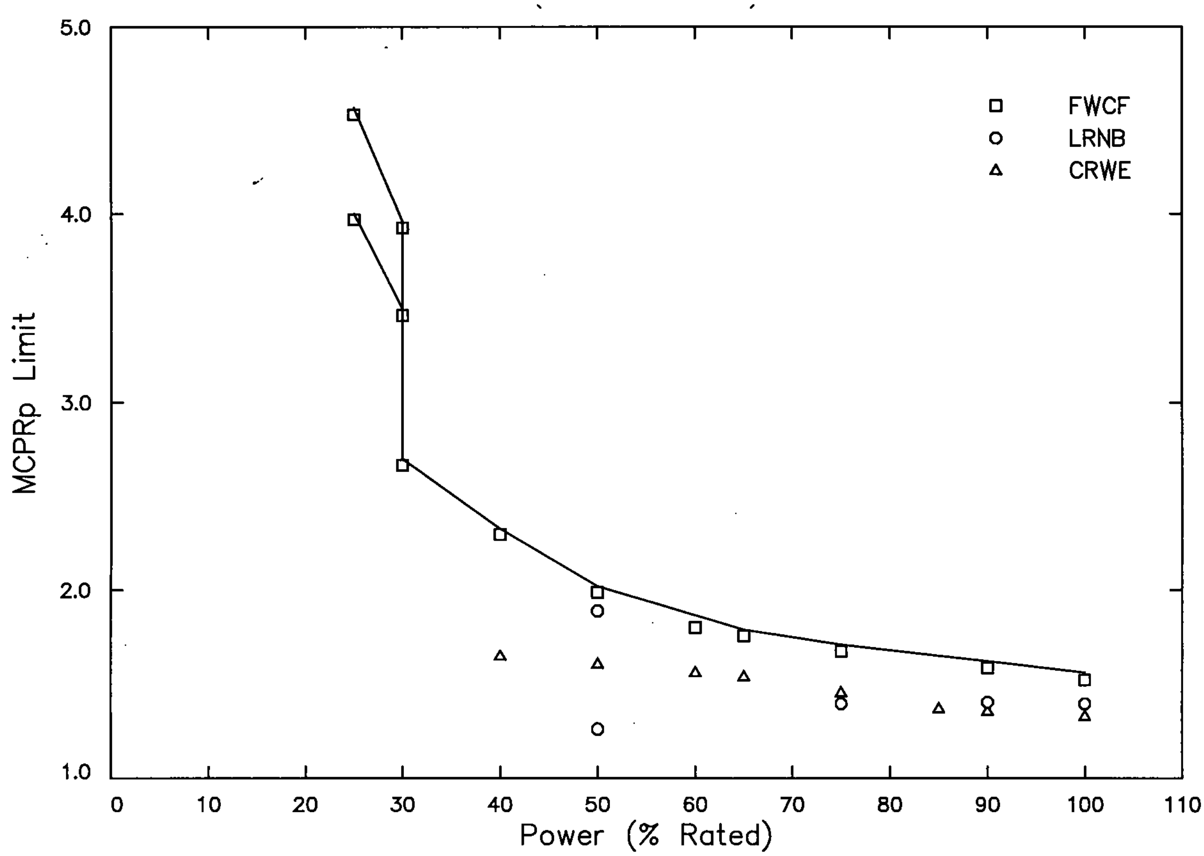
Power (% of rated)	$MCPR_p$ Limit
100	1.56
75	1.70
65	1.78
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.48 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS and FHOOS Combined



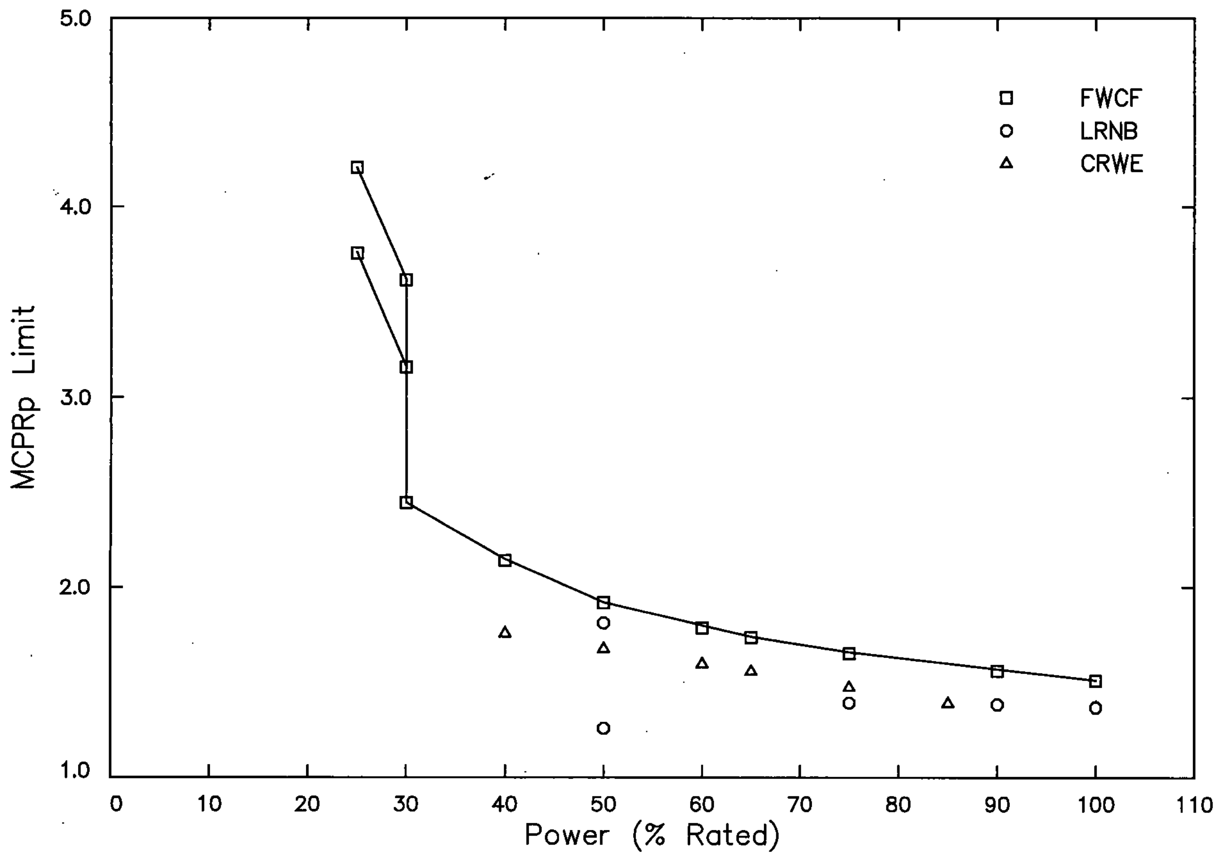
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.65
65	1.74
50	---
50	1.92
40	2.15
30	2.45
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.49 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS and FHOOS Combined



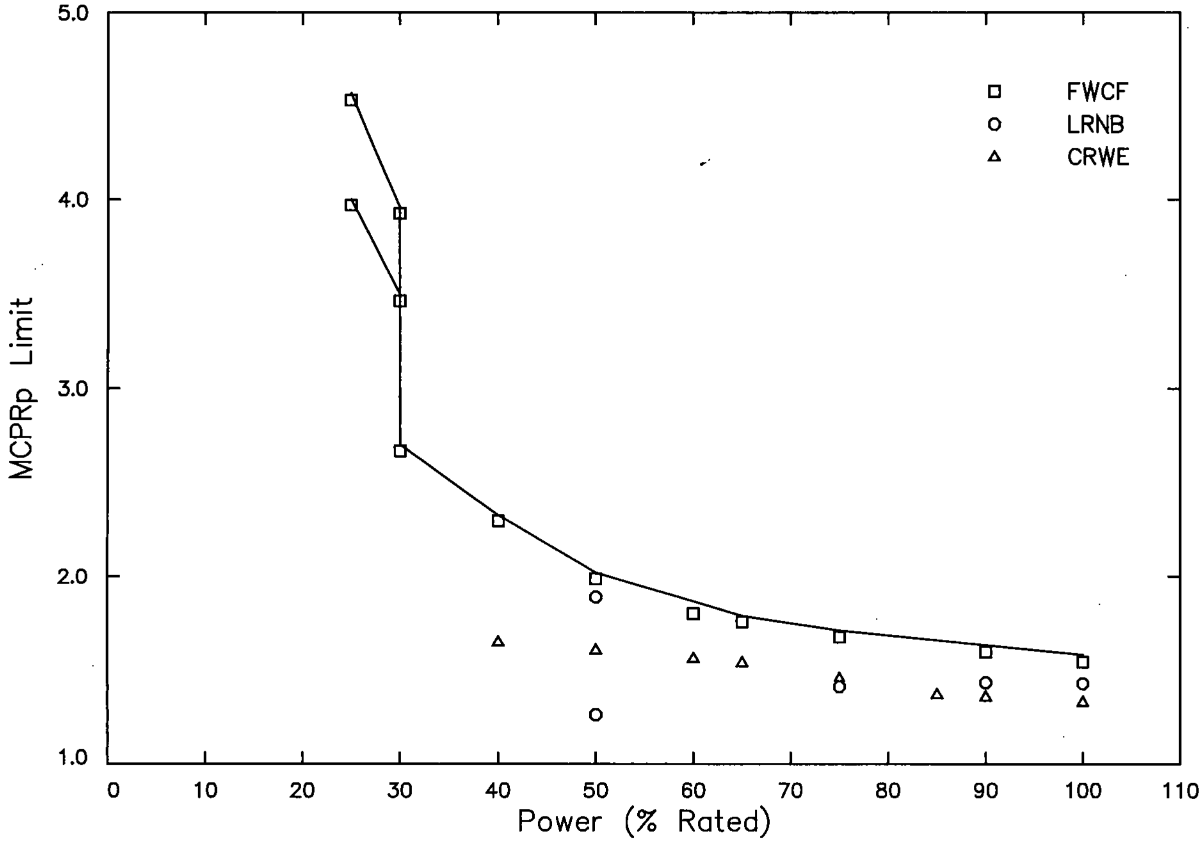
Power (% of rated)	$MCPR_p$ Limit
100	1.56
75	1.71
65	1.79
50	---
50	2.02
40	2.33
30	2.70
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.50 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS and FHOOS Combined



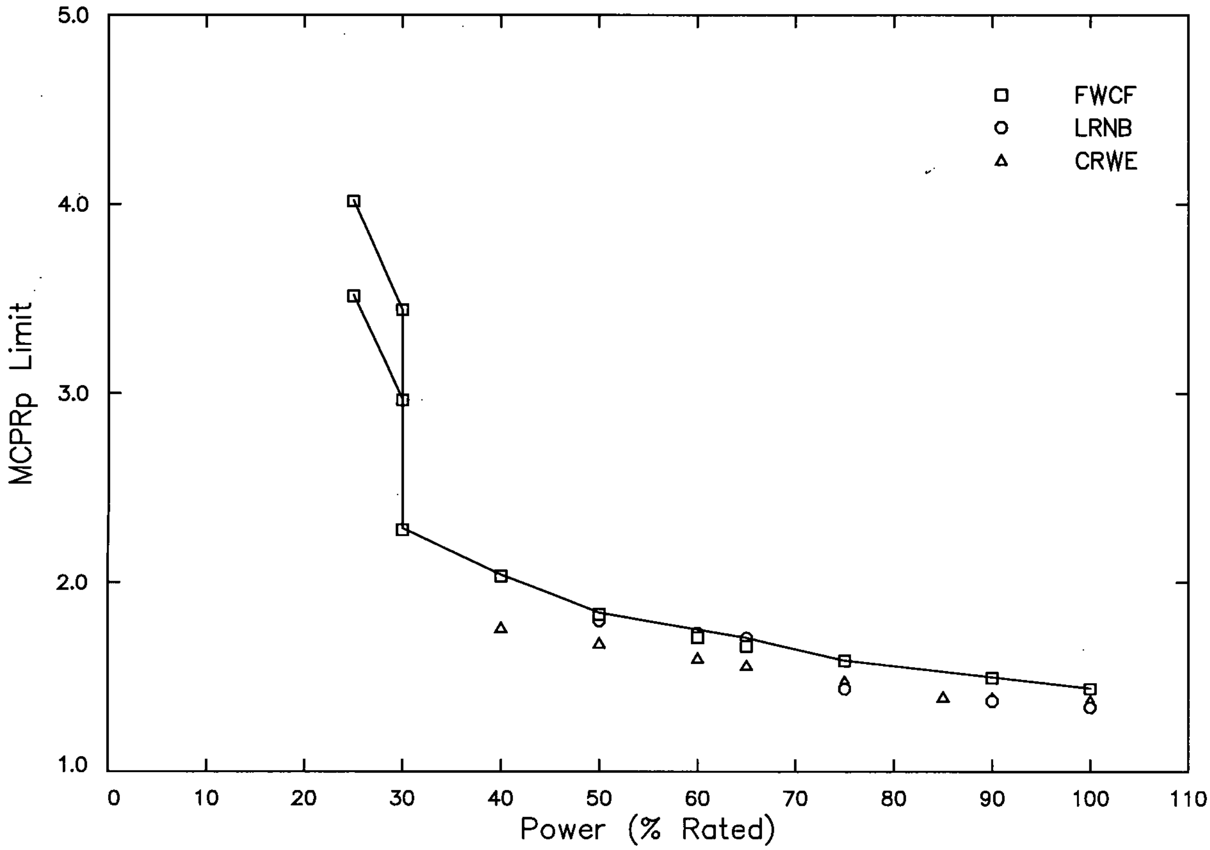
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.66
65	1.74
50	---
50	1.92
40	2.15
30	2.45
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.51 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS and FHOOS Combined



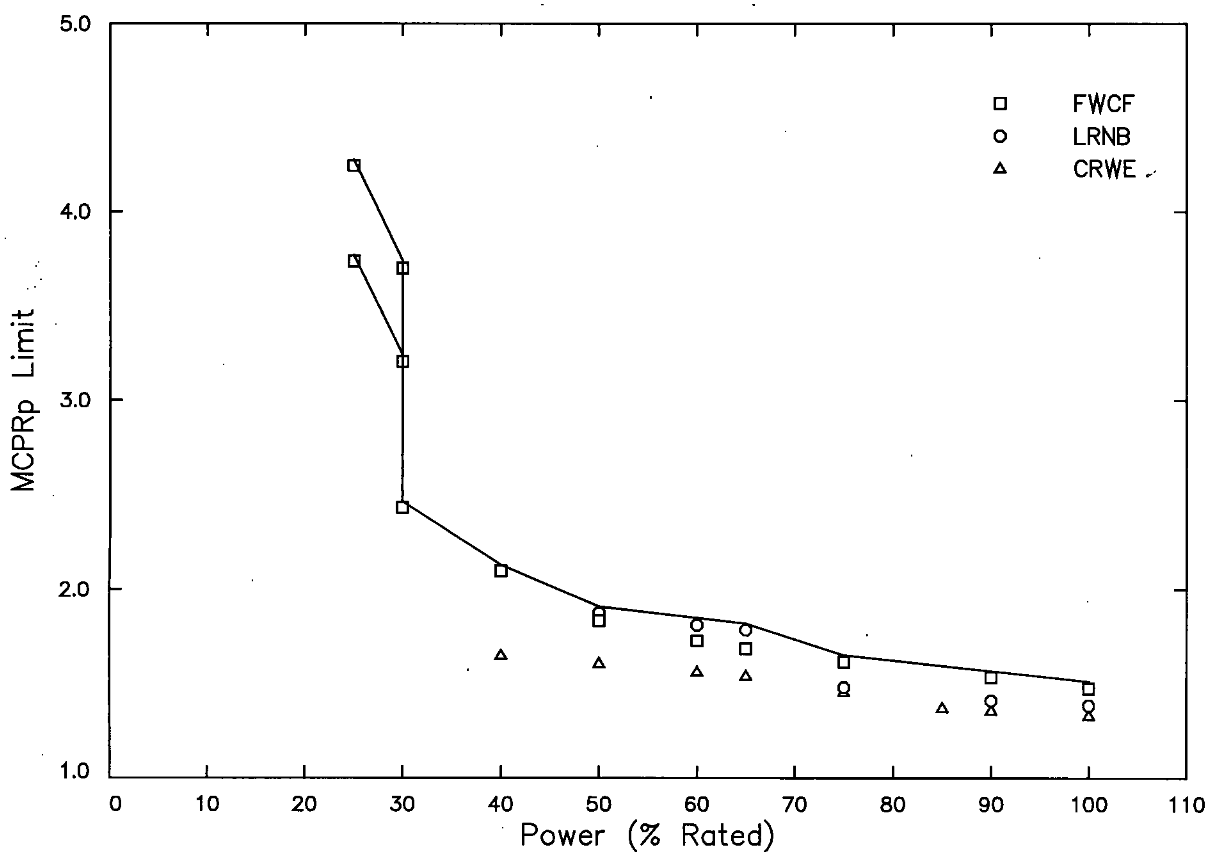
Power (% of rated)	$MCPR_p$ Limit
100	1.58
75	1.71
65	1.79
50	---
50	2.02
40	2.33
30	2.70
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.52 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS and FHOOS Combined



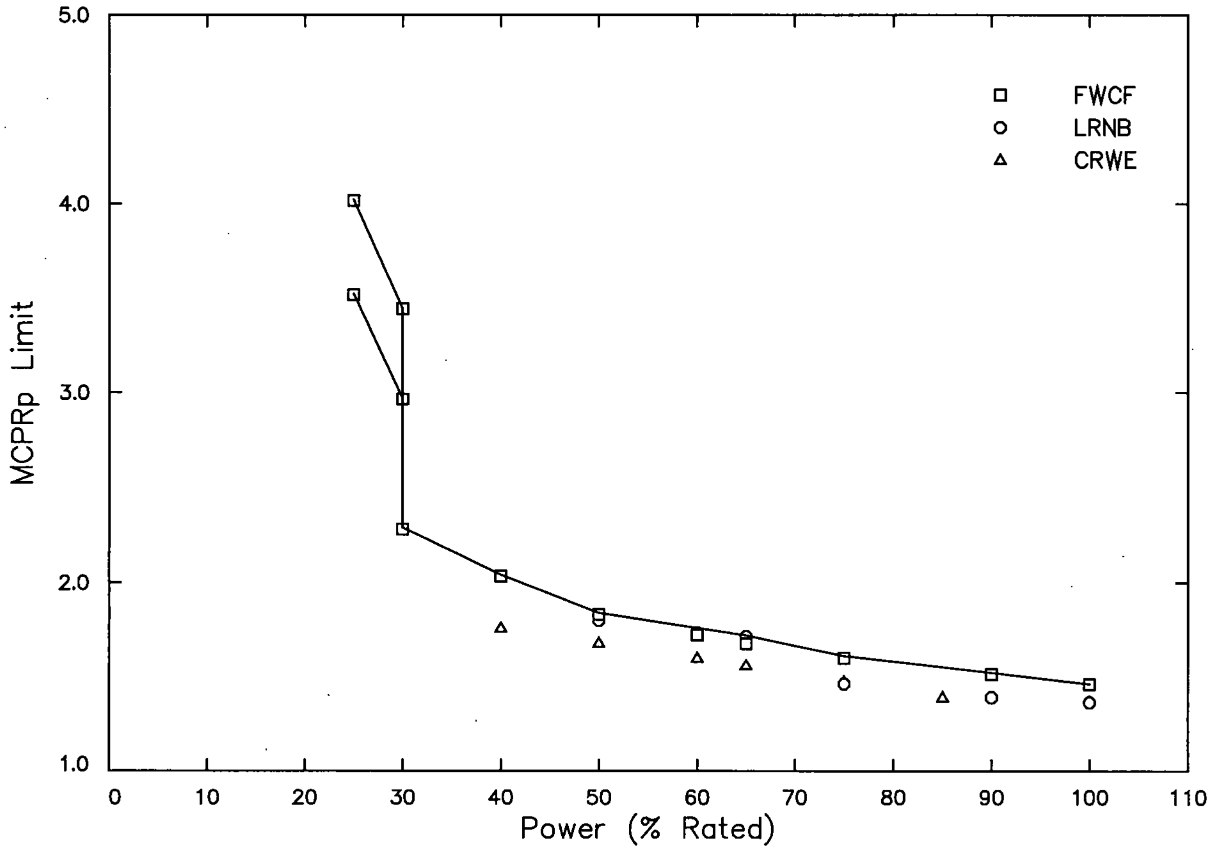
Power (% of rated)	$MCPR_p$ Limit
100	1.44
75	1.59
65	1.71
50	---
50	1.84
40	2.04
30	2.29
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.53 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS and PLUOOS Combined



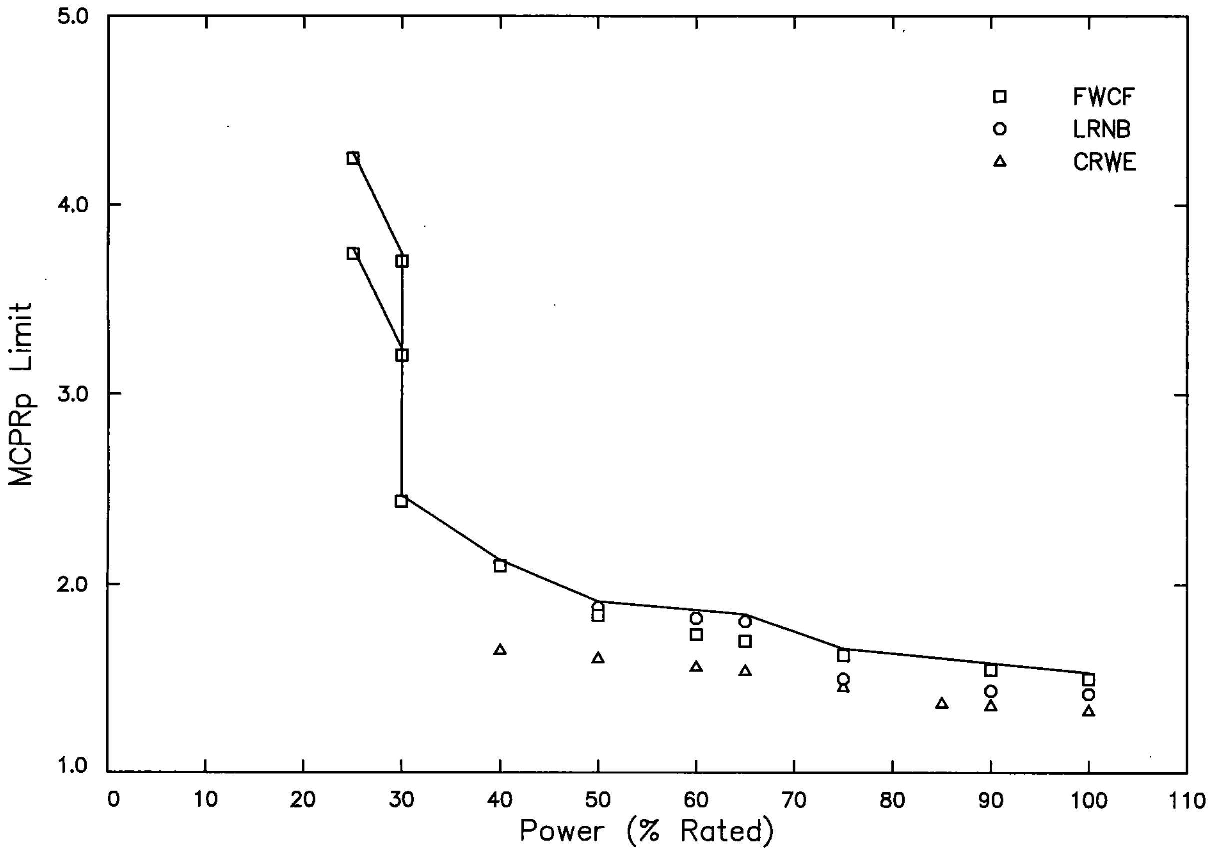
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.65
65	1.82
50	---
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.54 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS and PLUOOS Combined



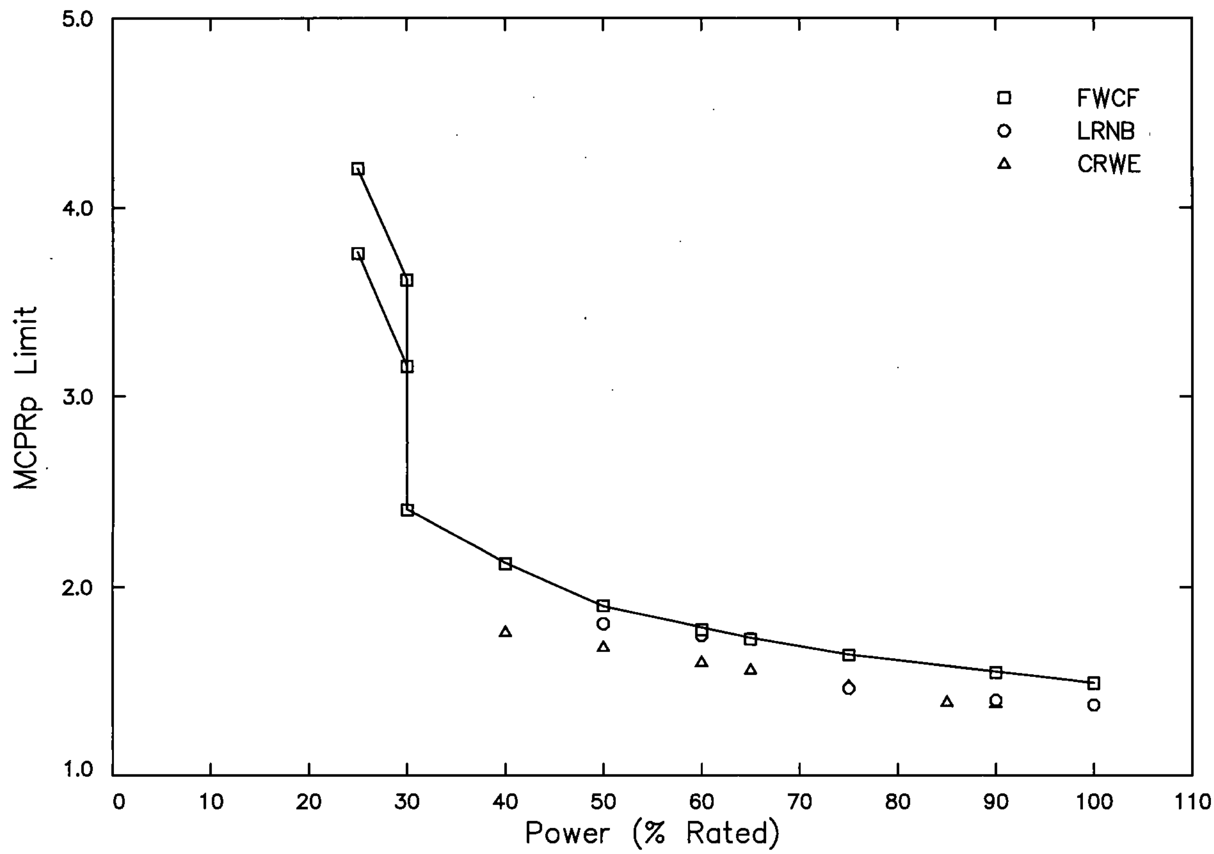
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.61
65	1.72
50	---
50	1.84
40	2.04
30	2.29
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.55 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS and PLUOOS Combined



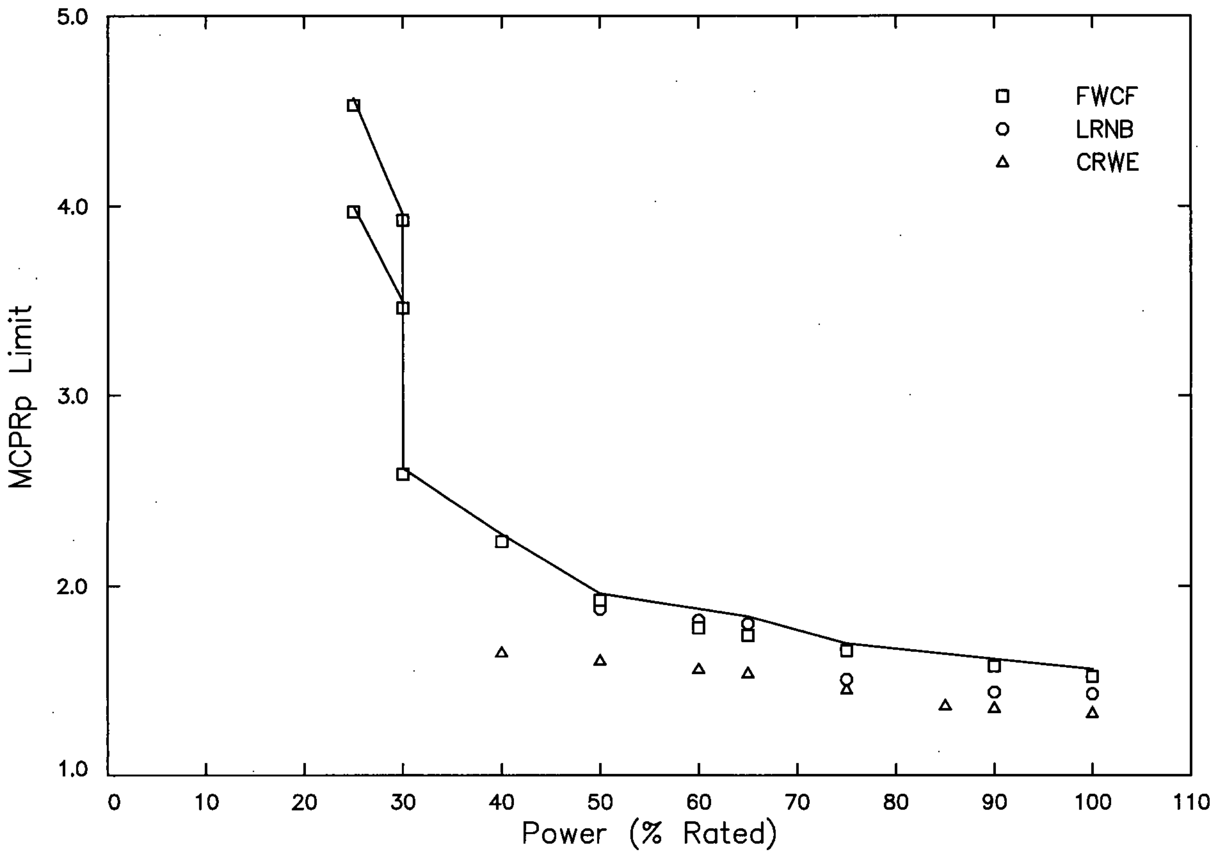
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.66
65	1.84
50	---
50	1.91
40	2.13
30	2.47
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.56 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS and PLUOOS Combined



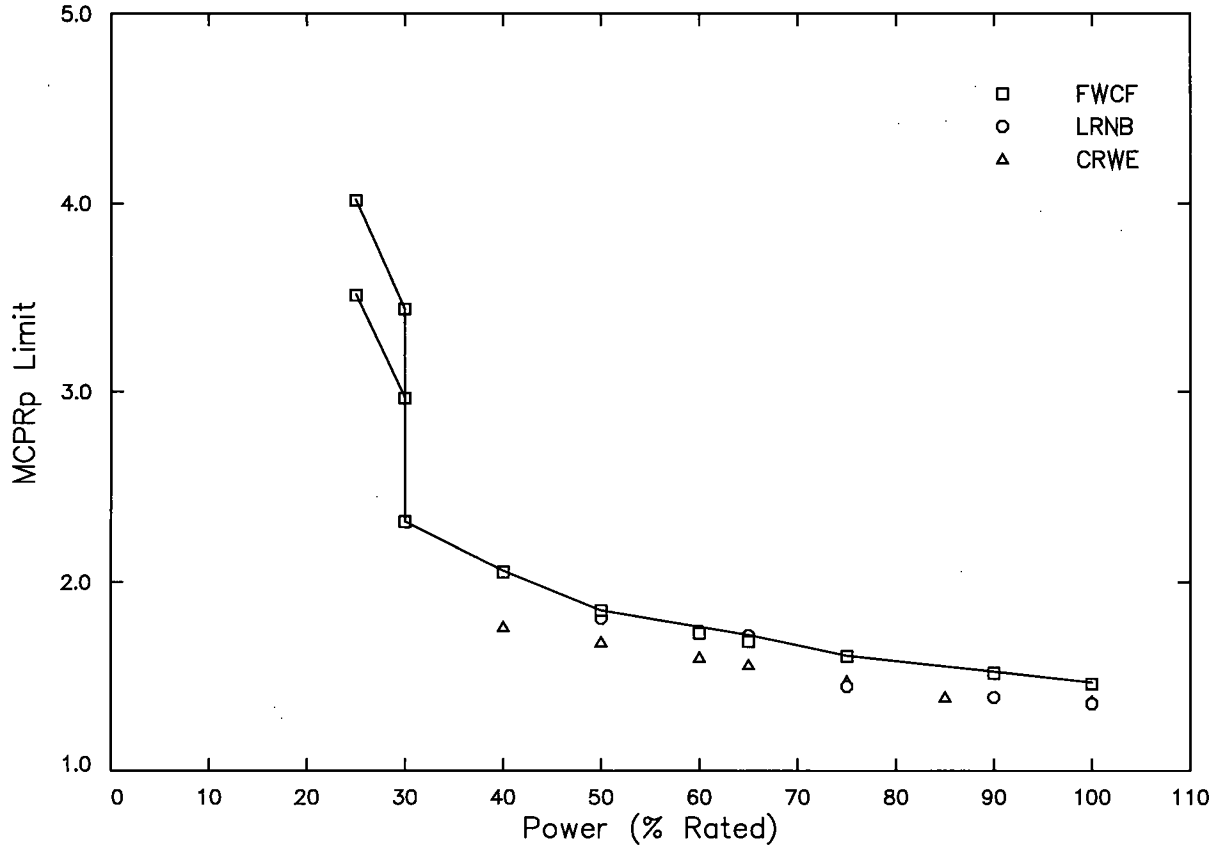
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.64
65	1.73
50	---
50	1.90
40	2.13
30	2.41
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.57 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS and PLUOOS Combined



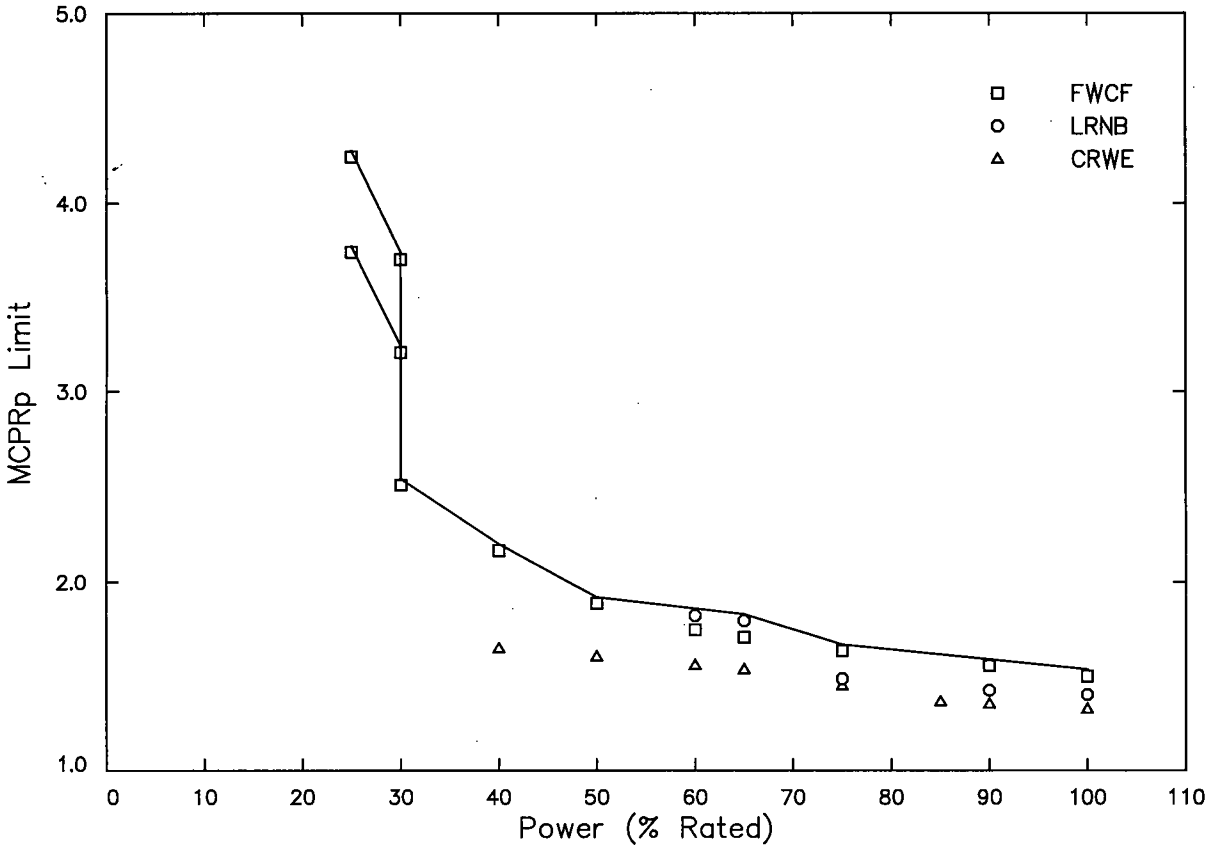
Power (% of rated)	$MCPR_p$ Limit
100	1.56
75	1.70
65	1.84
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.58 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS and PLUOOS Combined



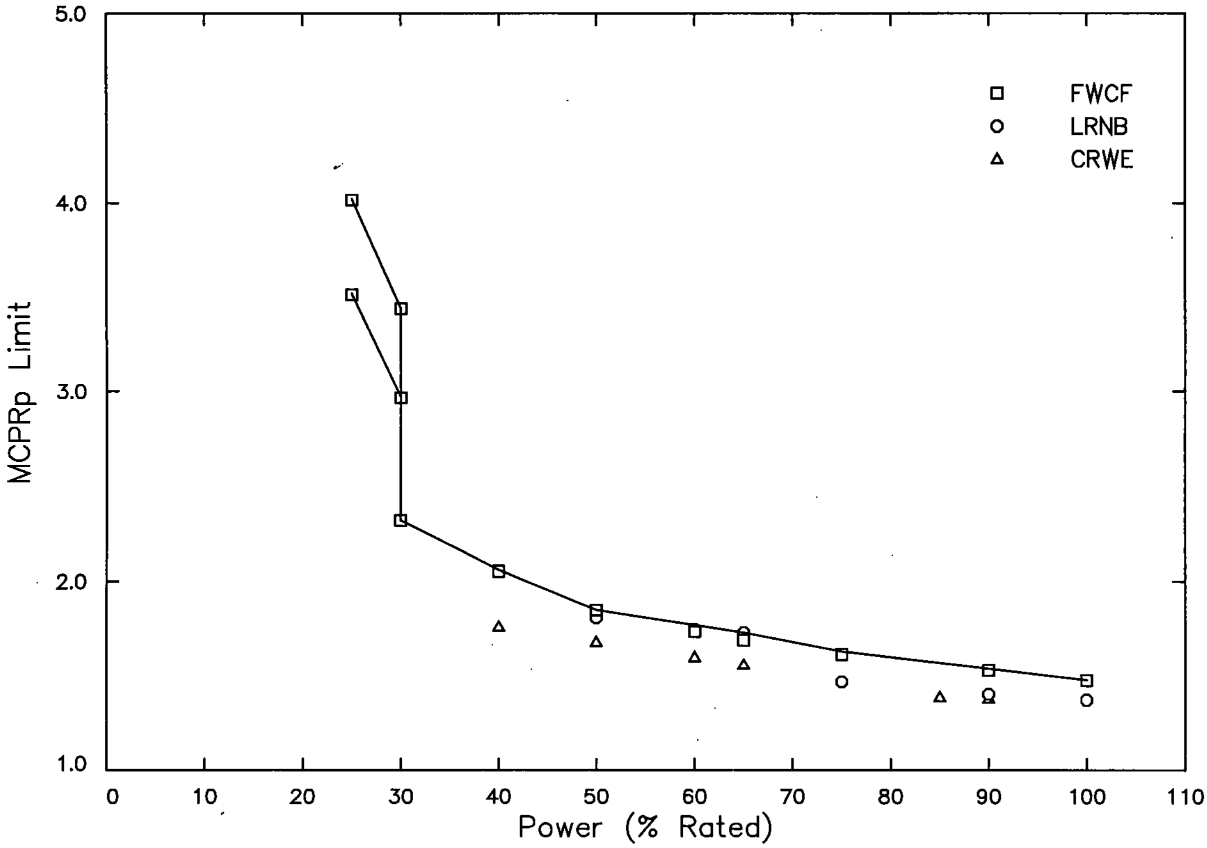
Power (% of rated)	$MCPR_p$ Limit
100	1.47
75	1.61
65	1.72
50	---
50	1.85
40	2.06
30	2.32
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.59 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS and PLUOOS Combined



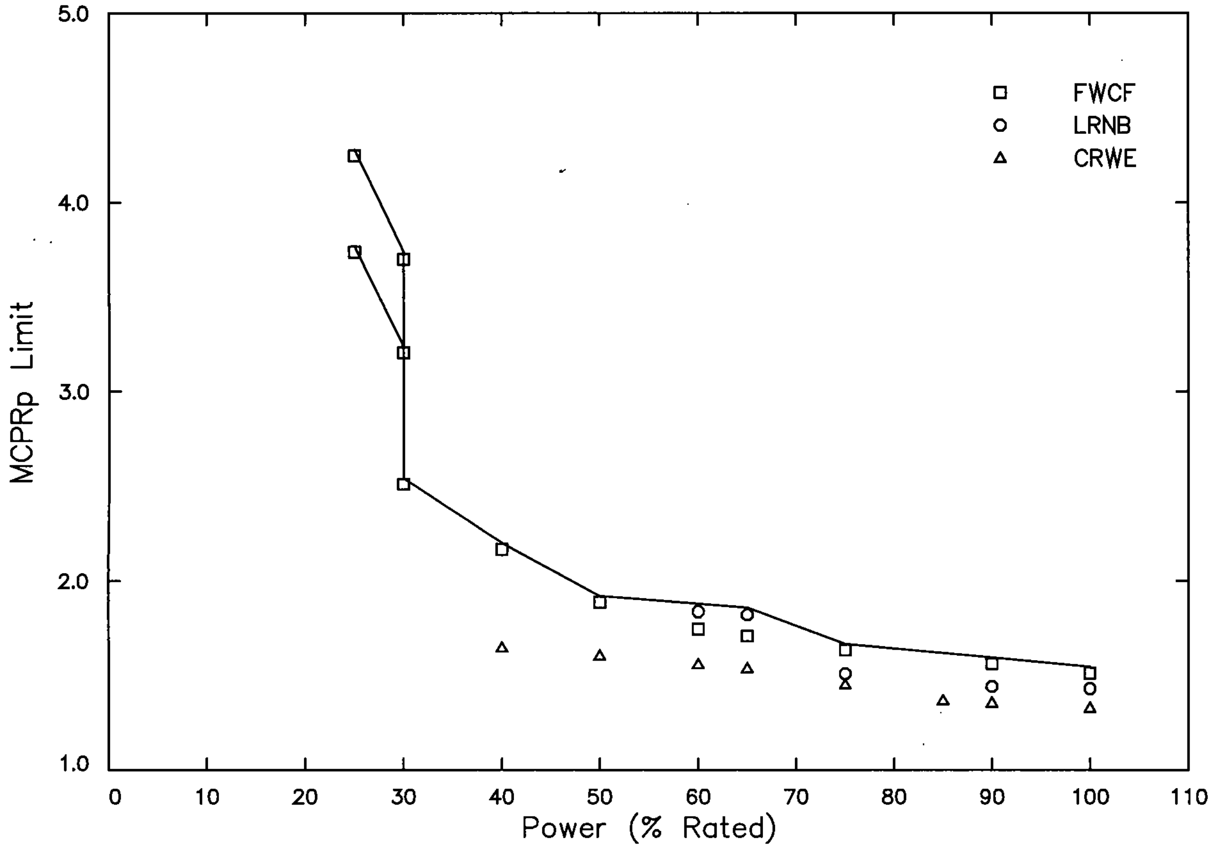
Power (% of rated)	$MCPR_p$ Limit
100	1.54
75	1.67
65	1.83
50	---
50	1.92
40	2.20
30	2.54
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.60 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS and PLUOOS Combined



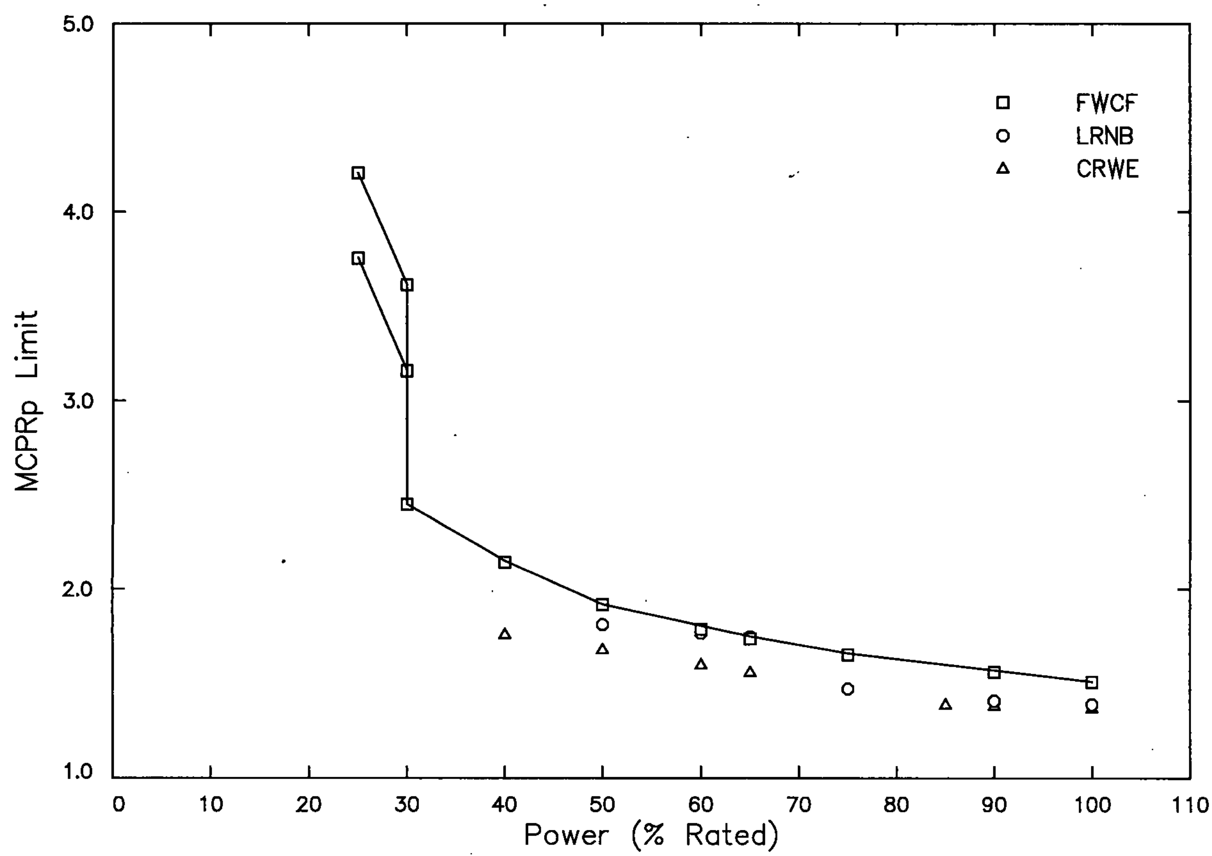
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.63
65	1.73
50	---
50	1.85
40	2.06
30	2.32
30 at > 50%F	3.44
25 at > 50%F	4.02
30 at ≤ 50%F	2.97
25 at ≤ 50%F	3.52

Figure A.61 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS and PLUOOS Combined



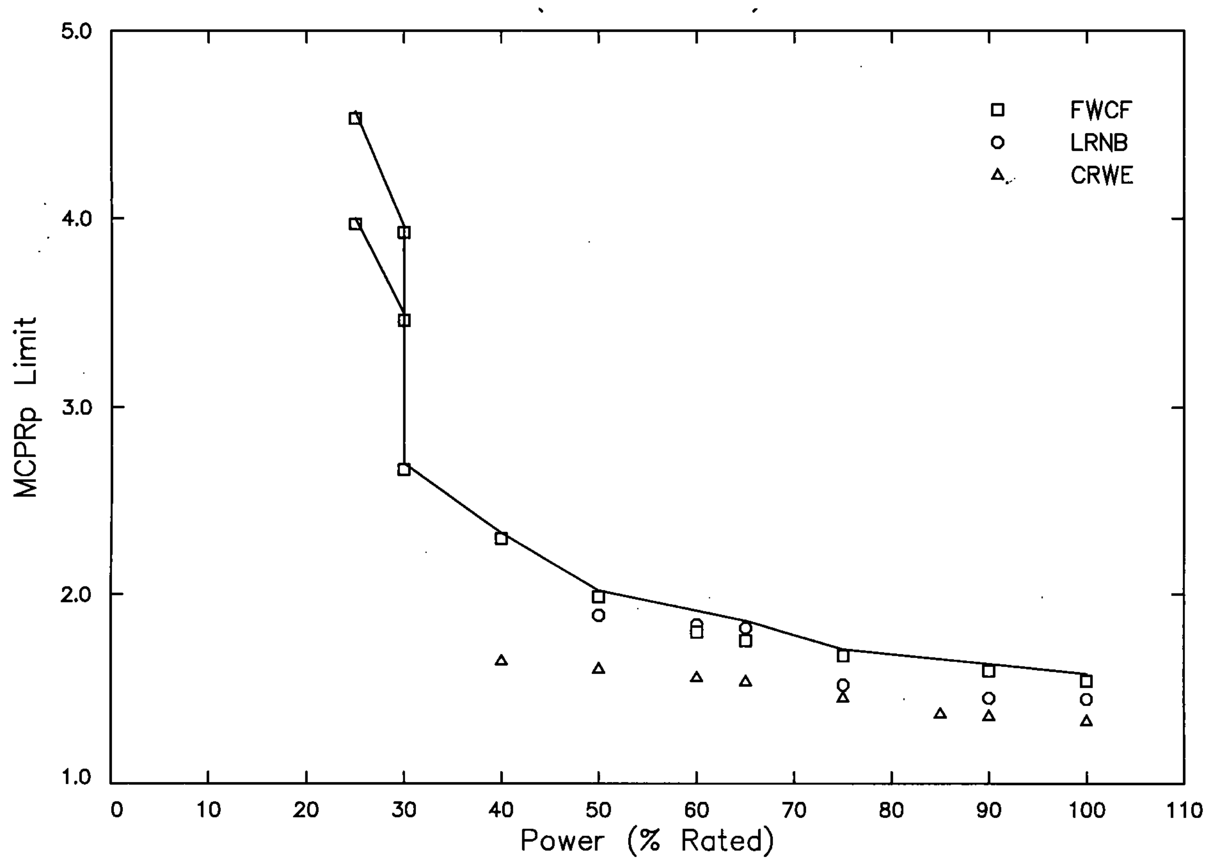
Power (% of rated)	$MCPR_p$ Limit
100	1.55
75	1.67
65	1.86
50	---
50	1.92
40	2.20
30	2.54
30 at > 50%F	3.74
25 at > 50%F	4.28
30 at ≤ 50%F	3.24
25 at ≤ 50%F	3.77

Figure A.62 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS and PLUOOS Combined



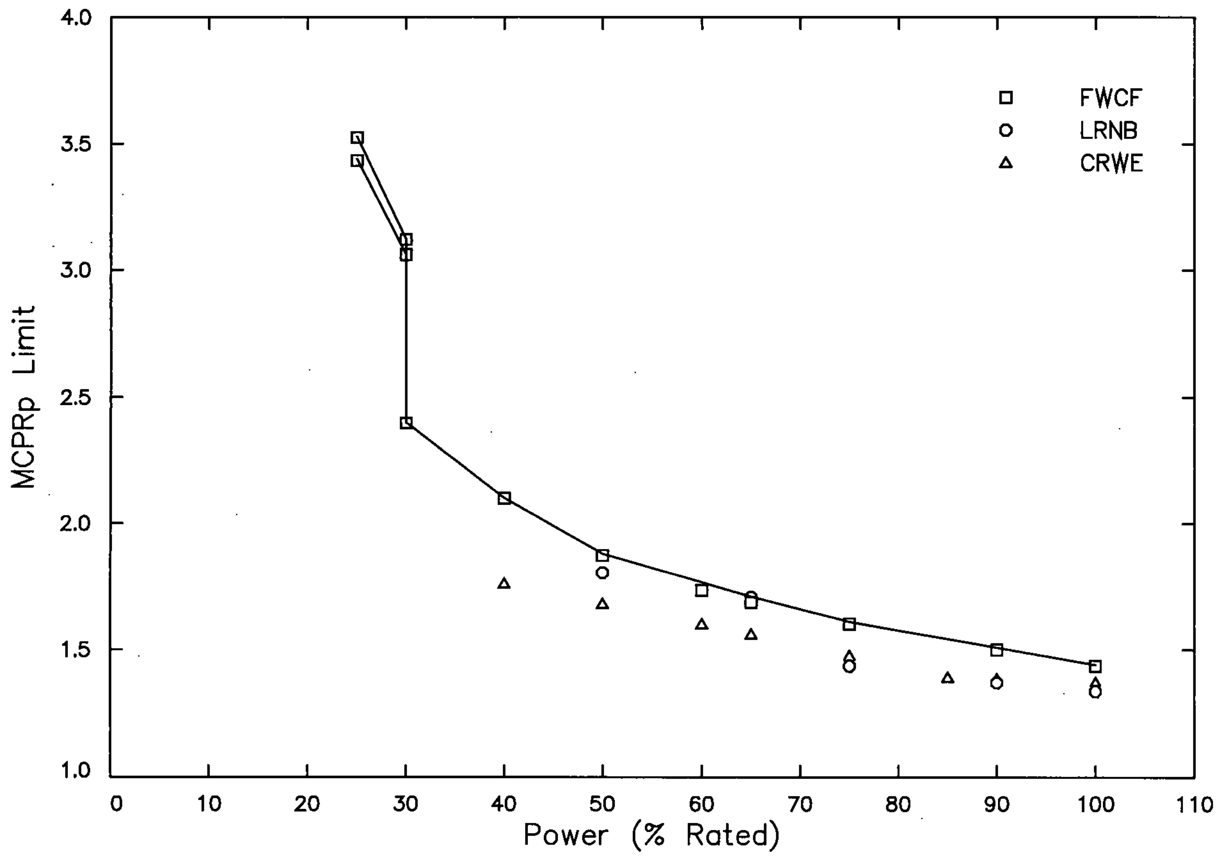
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.66
65	1.75
50	---
50	1.92
40	2.15
30	2.45
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.63 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS and PLUOOS Combined



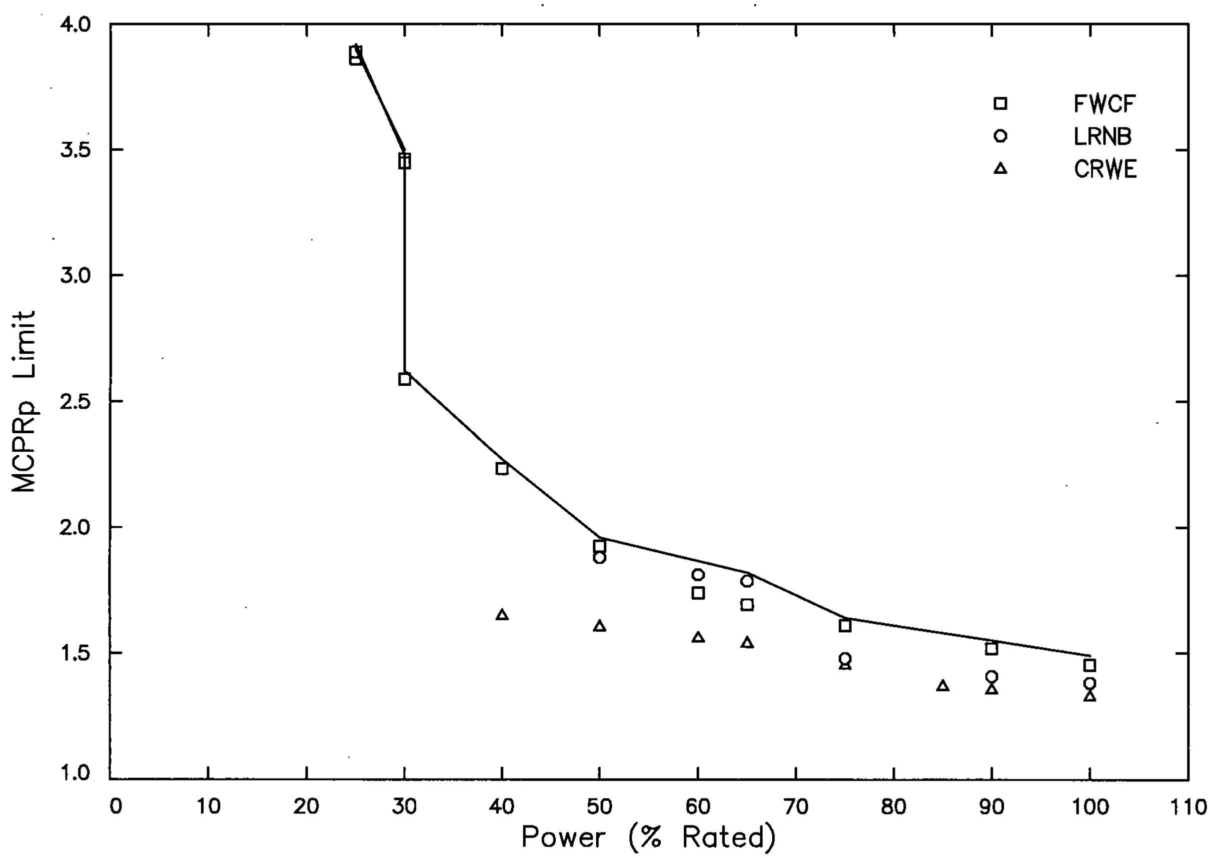
Power (% of rated)	$MCPR_p$ Limit
100	1.58
75	1.71
65	1.86
50	---
50	2.02
40	2.33
30	2.70
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.64 BOC to FFTR/Coastdown $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS and PLUOOS Combined



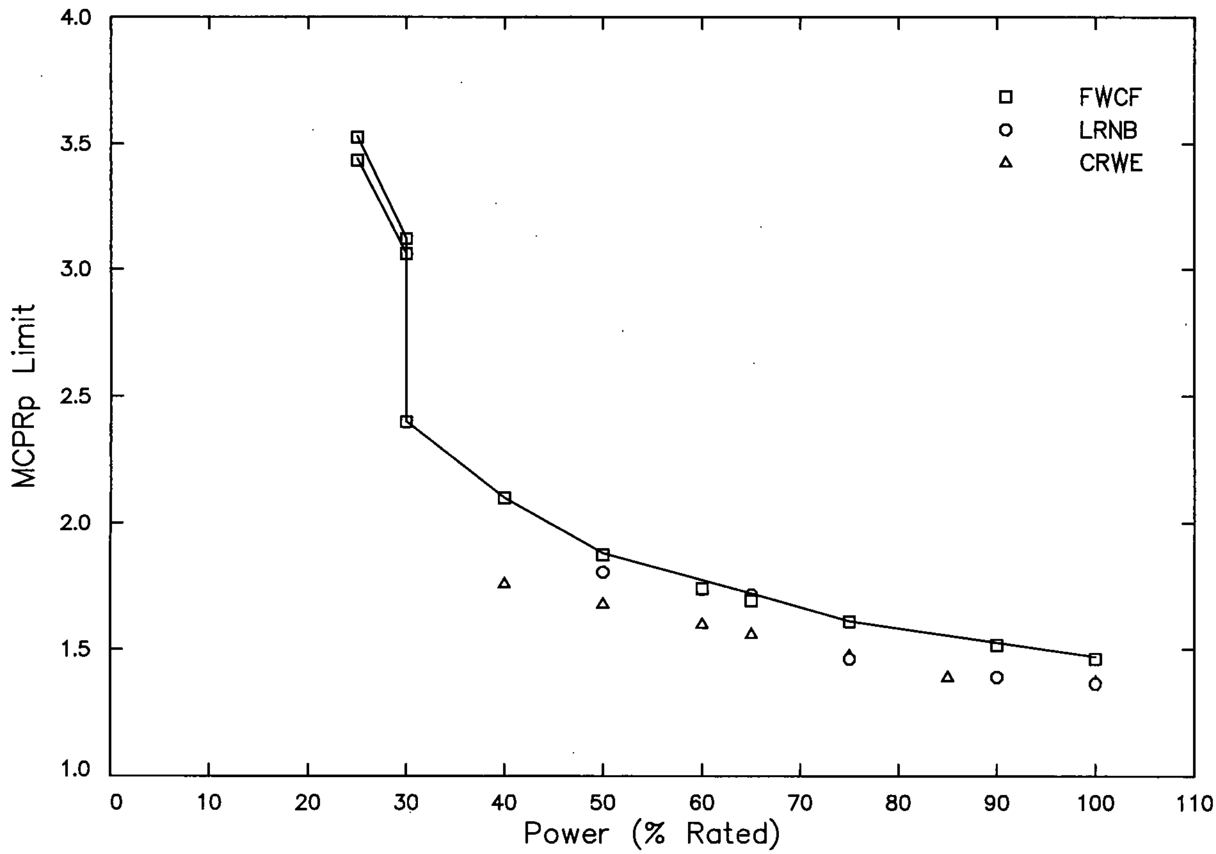
Power (% of rated)	$MCPR_p$ Limit
100	1.44
75	1.61
65	1.71
50	---
50	1.88
40	2.10
30	2.40
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.65 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - FHOOS and PLUOOS Combined



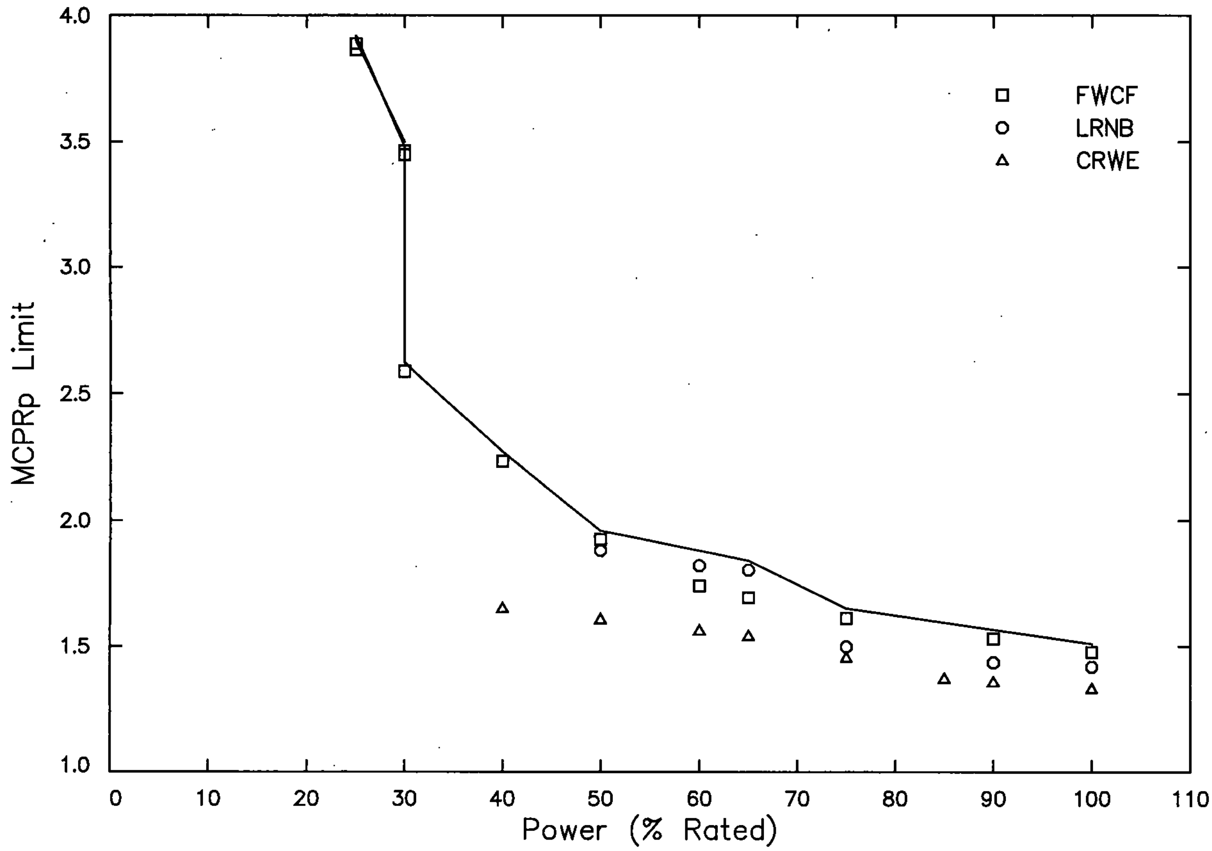
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.64
65	1.82
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.66 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - FHOOS and PLUOOS Combined



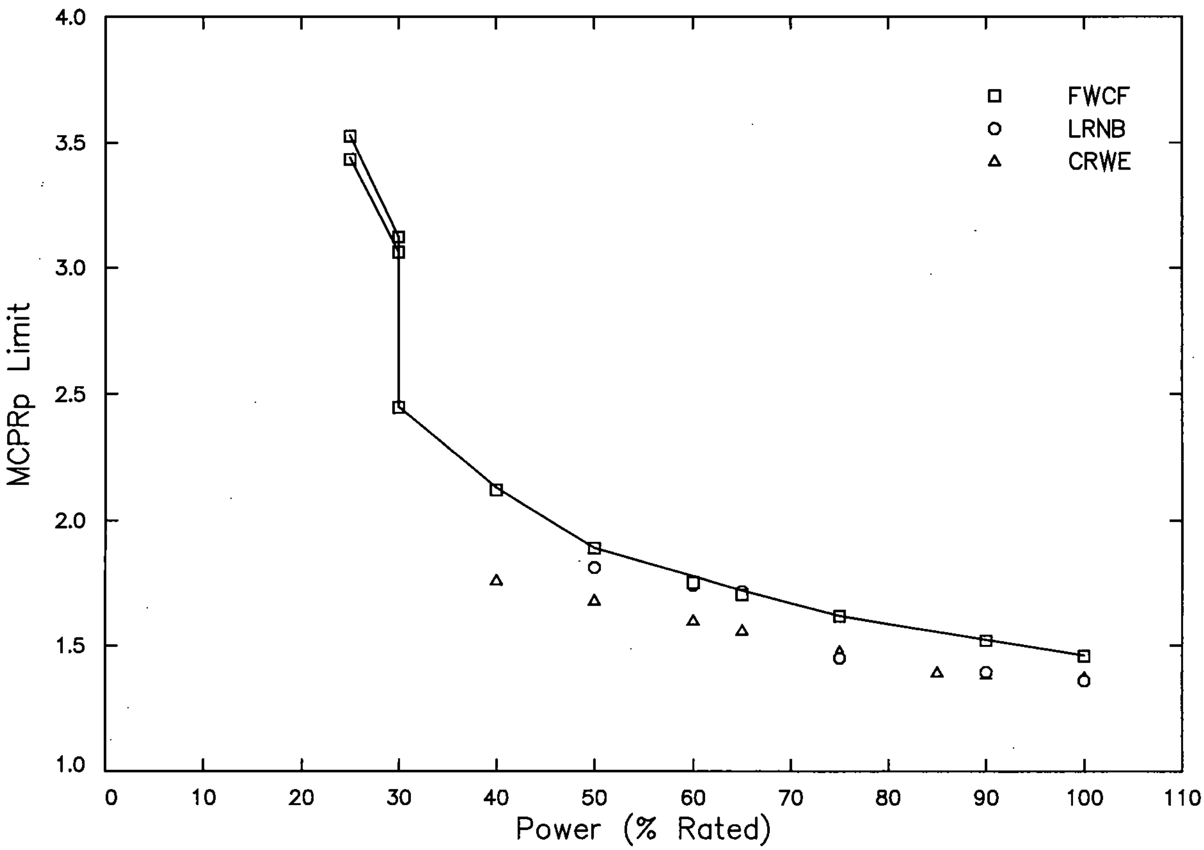
Power (% of rated)	$MCPR_p$ Limit
100	1.47
75	1.61
65	1.72
50	---
50	1.88
40	2.10
30	2.40
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.67 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - FHOOS and PLUOOS Combined



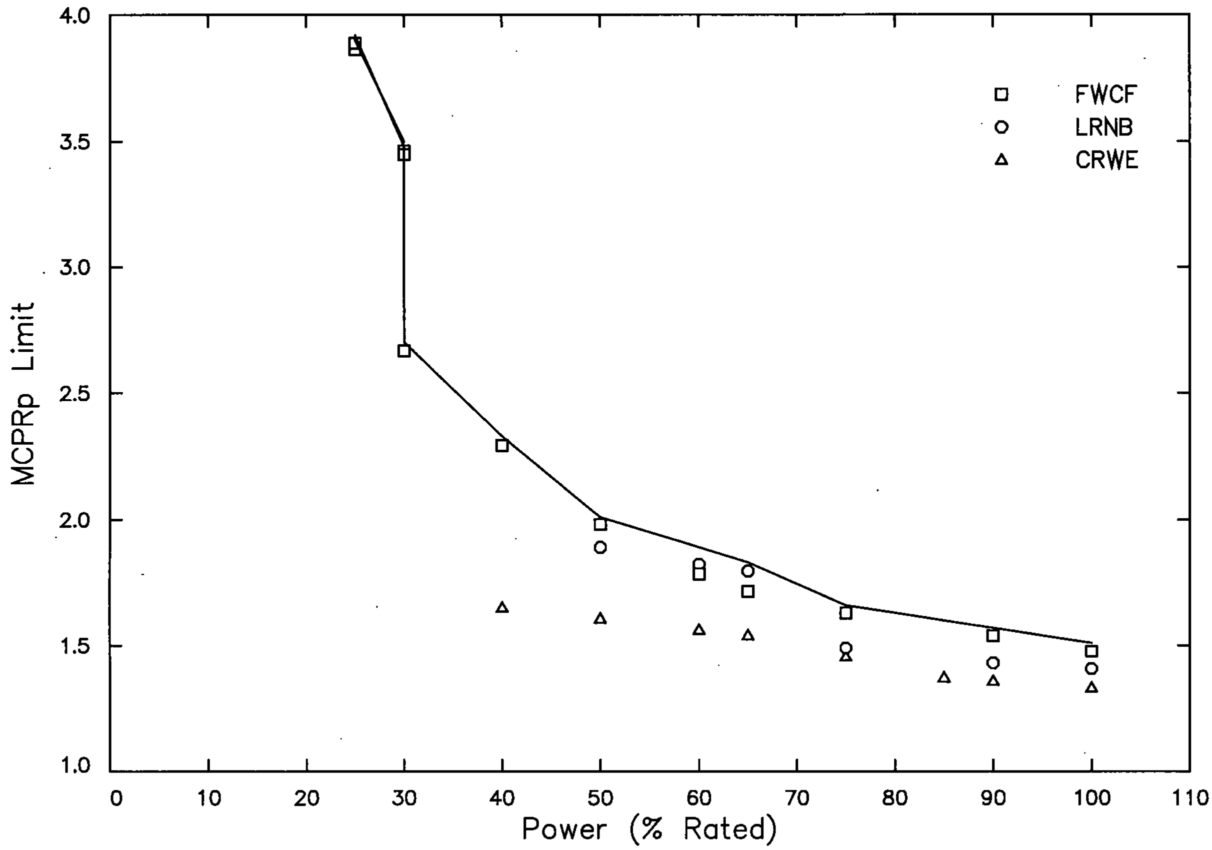
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.65
65	1.84
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.68 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - FHOOS and PLUOOS Combined



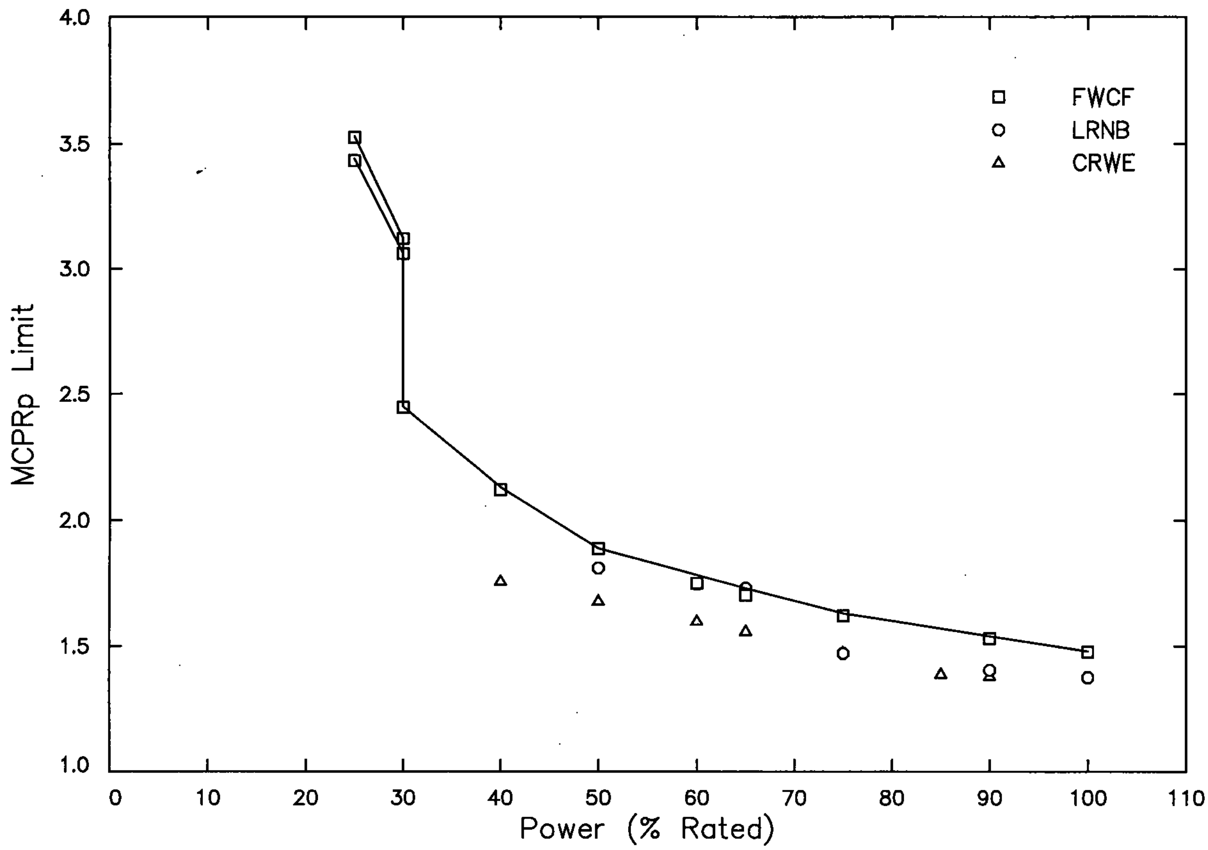
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.62
65	1.72
50	---
50	1.89
40	2.13
30	2.45
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.69 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - FHOOS and PLUOOS Combined



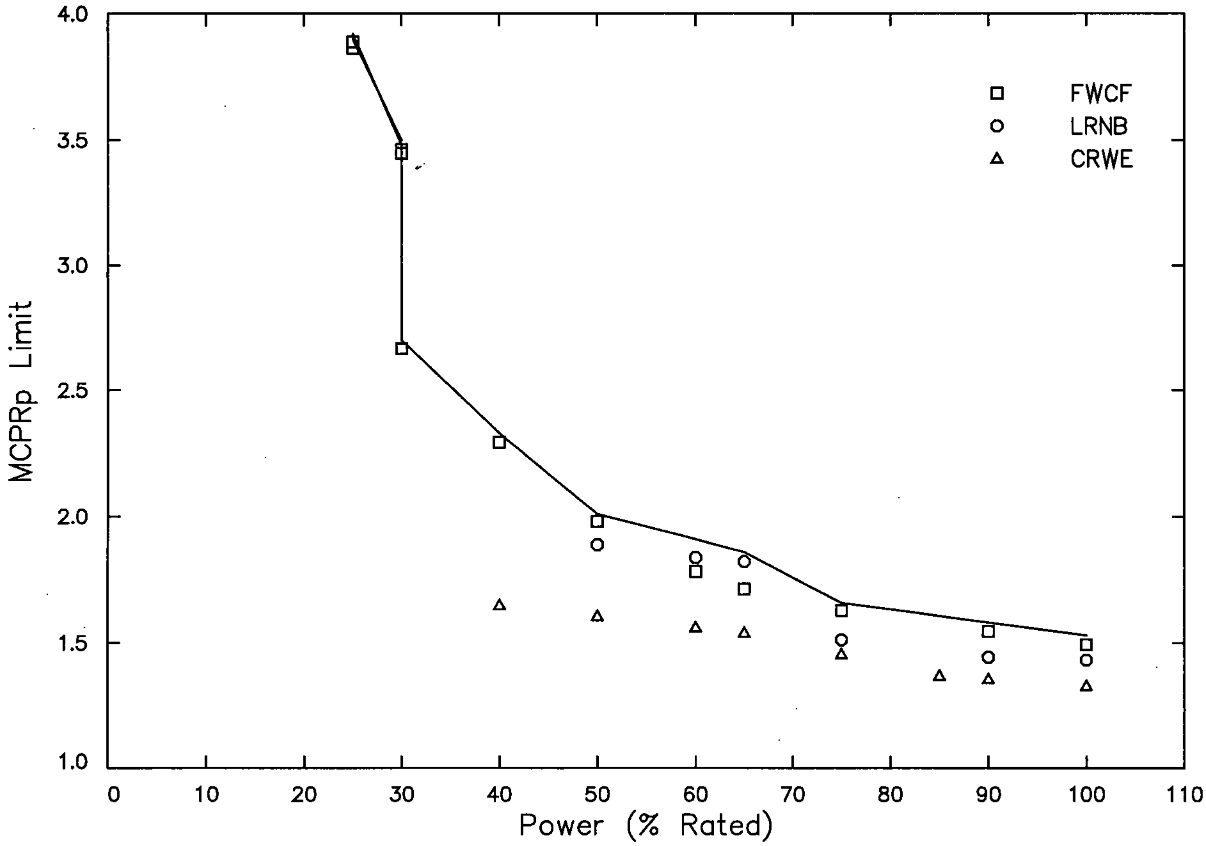
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.66
65	1.83
50	---
50	2.01
40	2.33
30	2.70
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.70 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - FHOOS and PLUOOS Combined



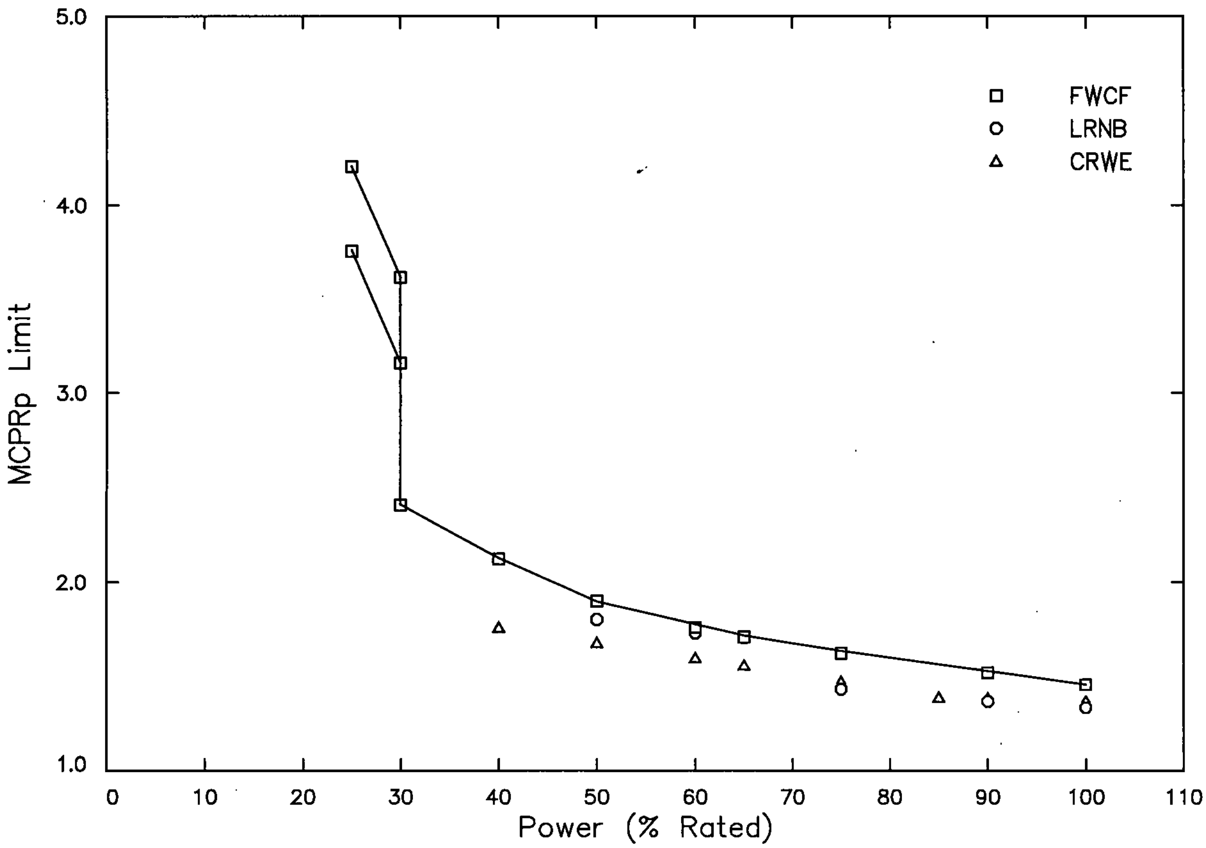
Power (% of rated)	$MCPR_p$ Limit
100	1.48
75	1.63
65	1.73
50	---
50	1.89
40	2.13
30	2.45
30 at > 50%F	3.12
25 at > 50%F	3.53
30 at ≤ 50%F	3.06
25 at ≤ 50%F	3.44

Figure A.71 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - FHOOS and PLUOOS Combined



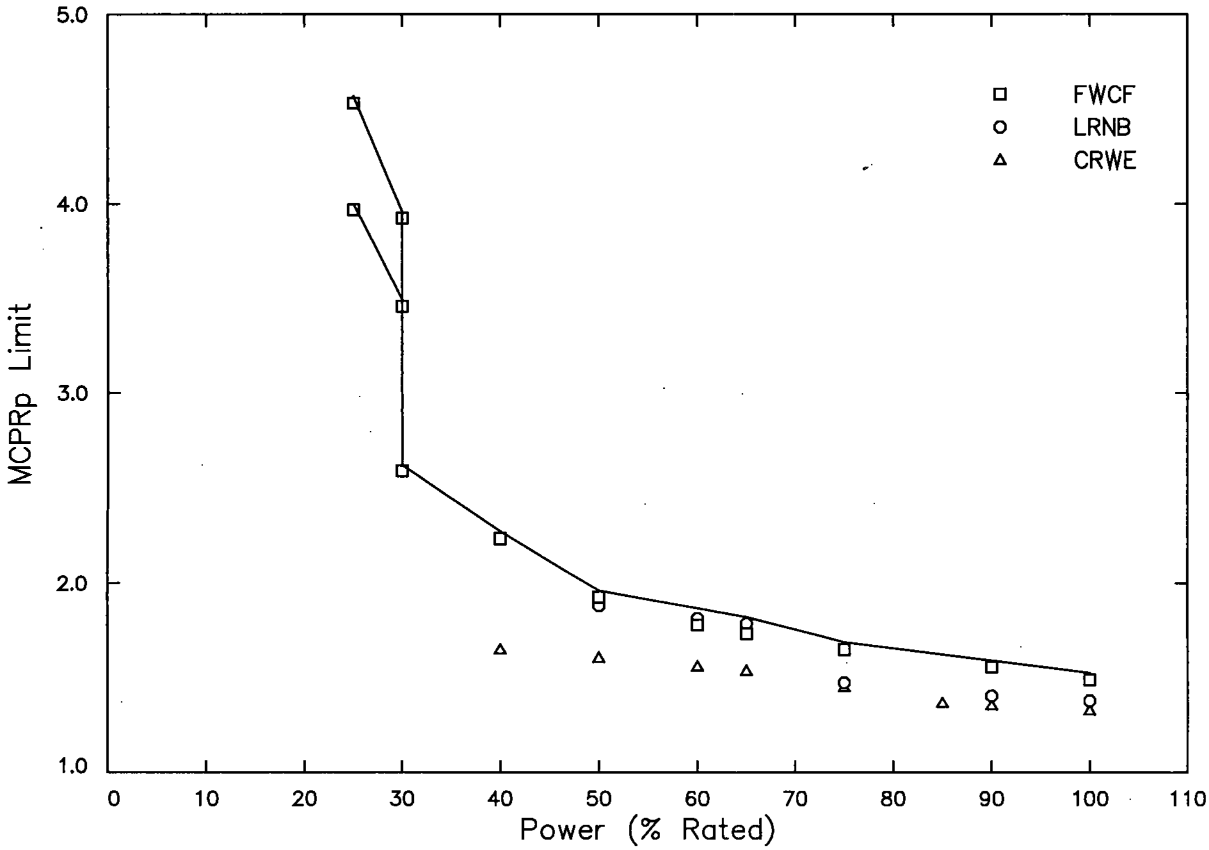
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.66
65	1.86
50	---
50	2.01
40	2.33
30	2.70
30 at > 50%F	3.48
25 at > 50%F	3.92
30 at ≤ 50%F	3.50
25 at ≤ 50%F	3.90

Figure A.72 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - FHOOS and PLUOOS Combined



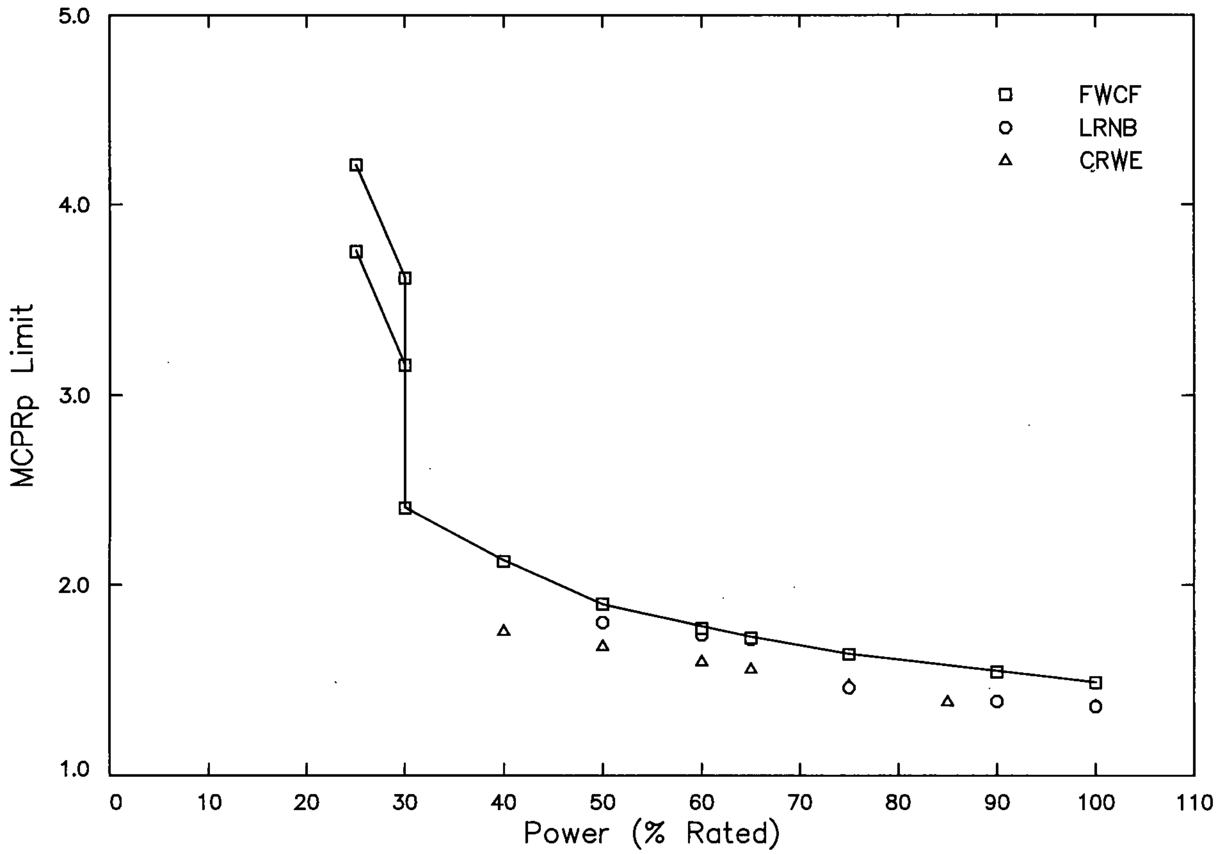
Power (% of rated)	$MCPR_p$ Limit
100	1.46
75	1.64
65	1.72
50	---
50	1.90
40	2.13
30	2.41
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.73 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



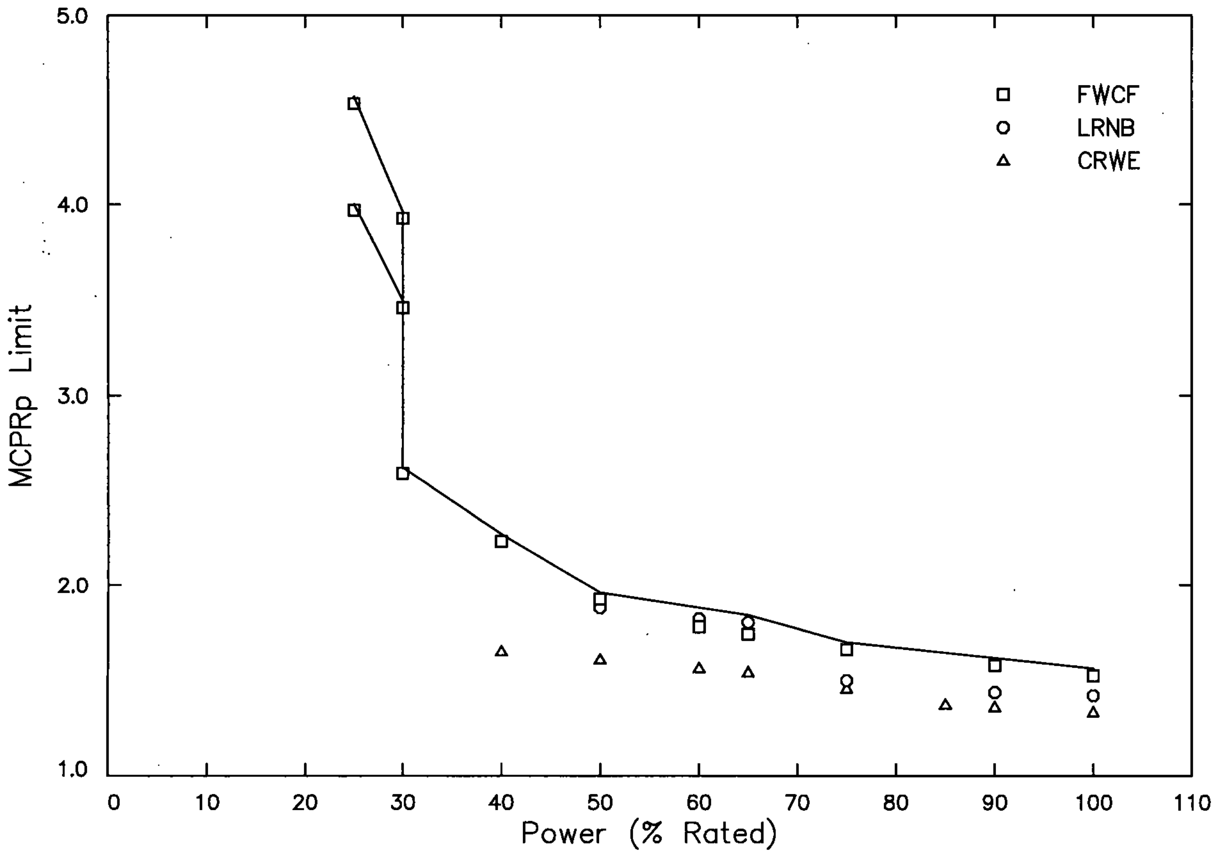
Power (% of rated)	$MCPR_p$ Limit
100	1.53
75	1.69
65	1.82
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.74 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



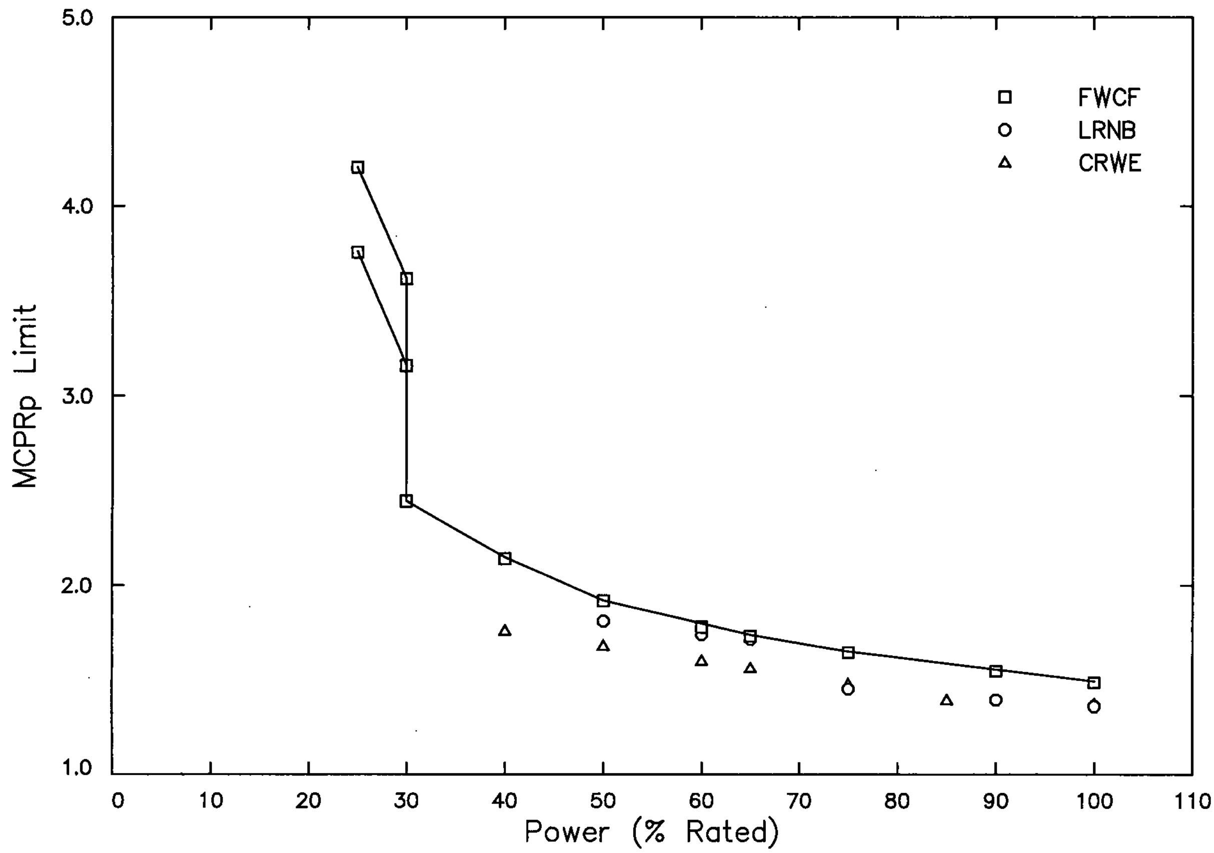
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.64
65	1.73
50	---
50	1.90
40	2.13
30	2.41
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.75 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - NSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



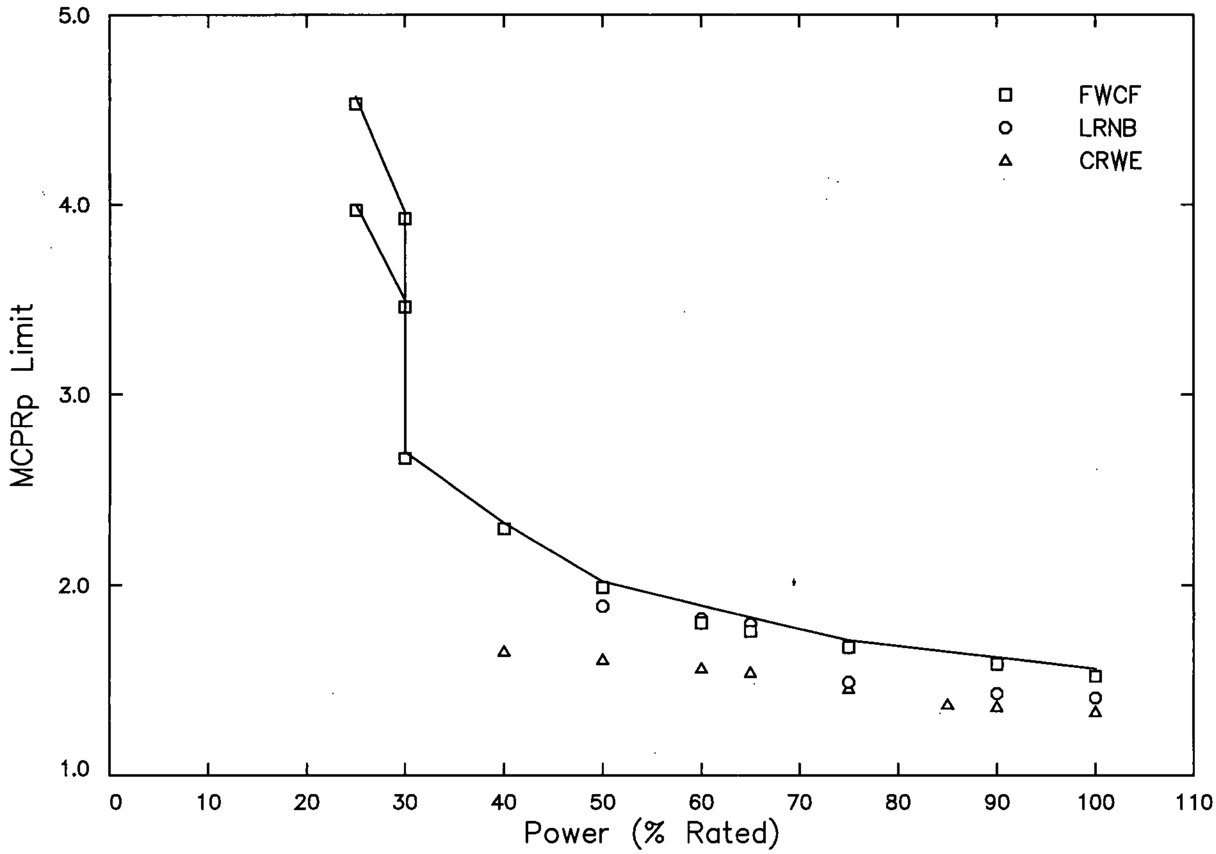
Power (% of rated)	$MCPR_p$ Limit
100	1.56
75	1.70
65	1.84
50	---
50	1.96
40	2.27
30	2.62
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.76 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - NSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



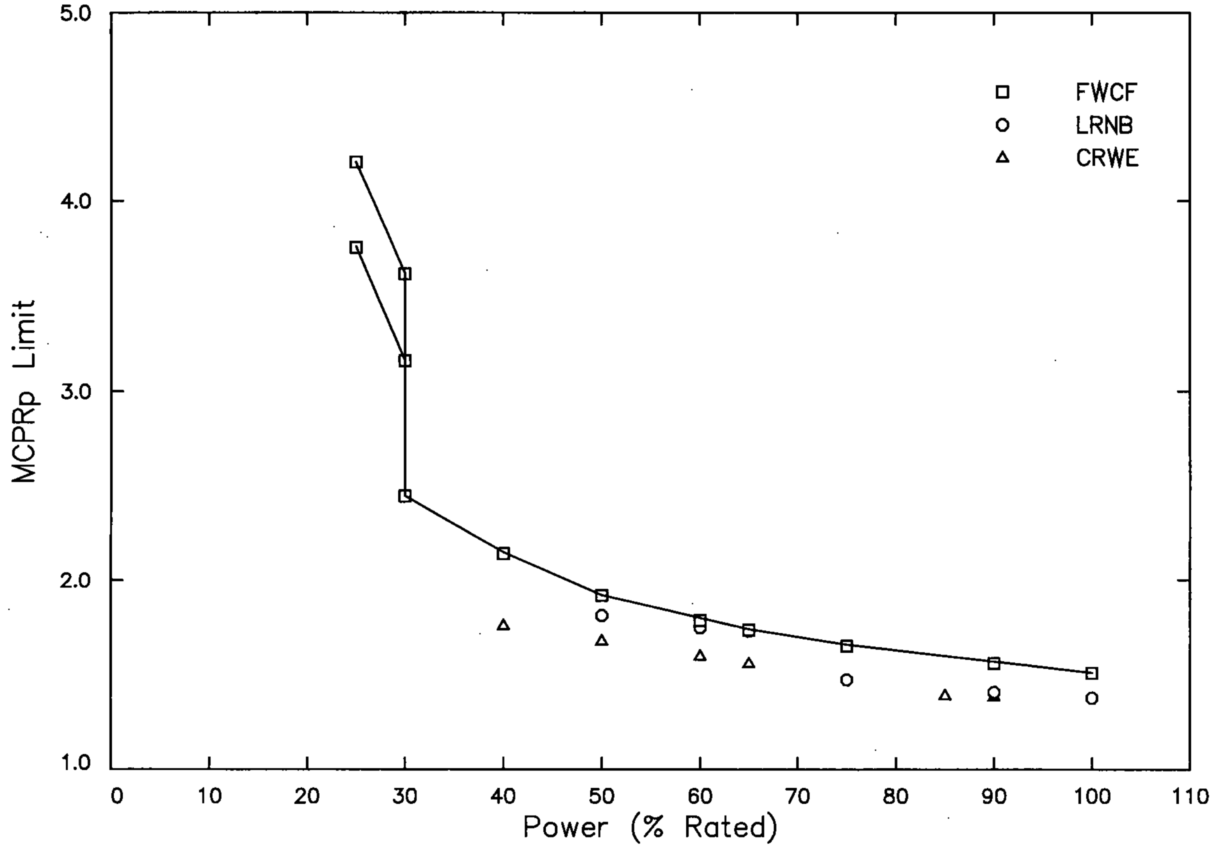
Power (% of rated)	$MCPR_p$ Limit
100	1.49
75	1.65
65	1.74
50	---
50	1.92
40	2.15
30	2.45
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.77 BOC to NEOC $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



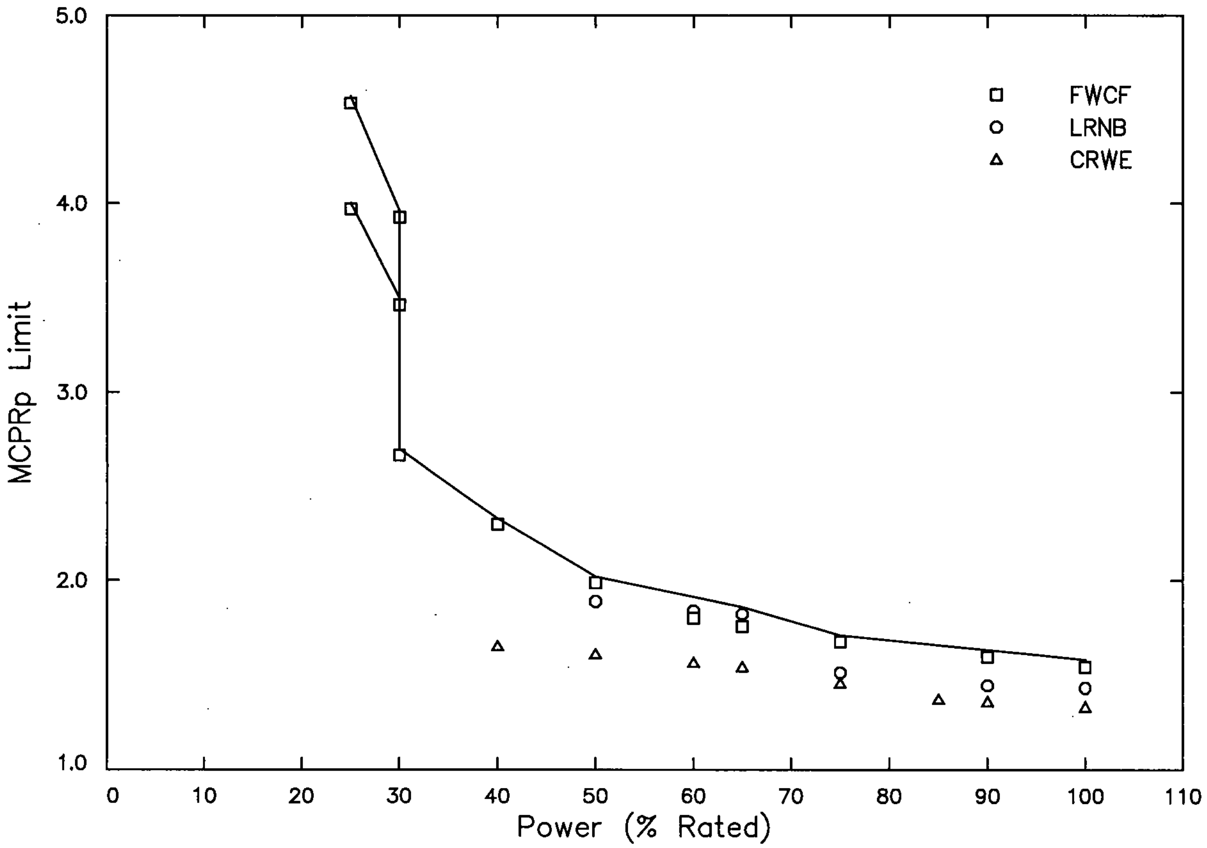
Power (% of rated)	$MCPR_p$ Limit
100	1.56
75	1.71
65	1.83
50	---
50	2.02
40	2.33
30	2.70
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.78 BOC to NEOC $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



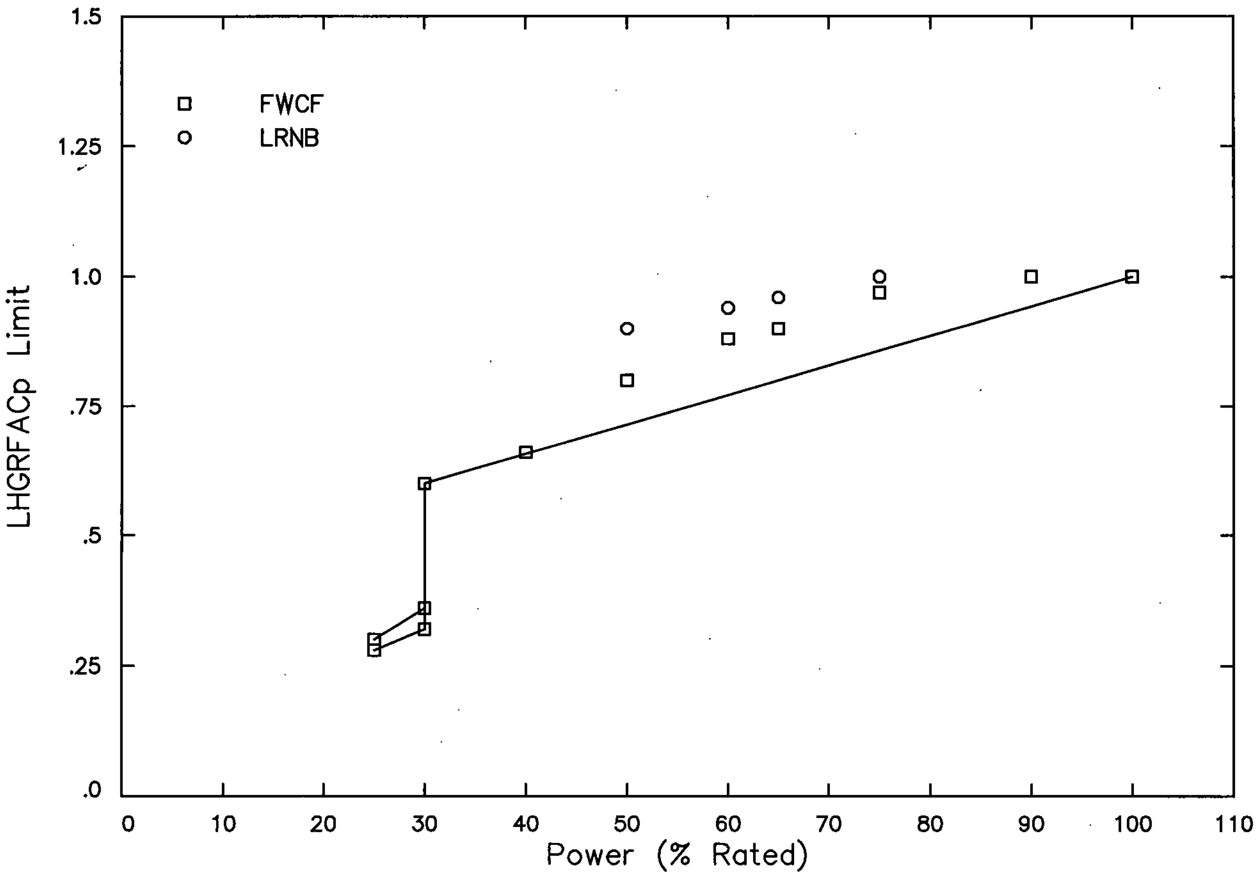
Power (% of rated)	$MCPR_p$ Limit
100	1.51
75	1.66
65	1.74
50	---
50	1.92
40	2.15
30	2.45
30 at > 50%F	3.62
25 at > 50%F	4.21
30 at ≤ 50%F	3.16
25 at ≤ 50%F	3.76

Figure A.79 BOC to EOCLB $MCPR_p$ Limits for ATRIUM 10XM Fuel - TSSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



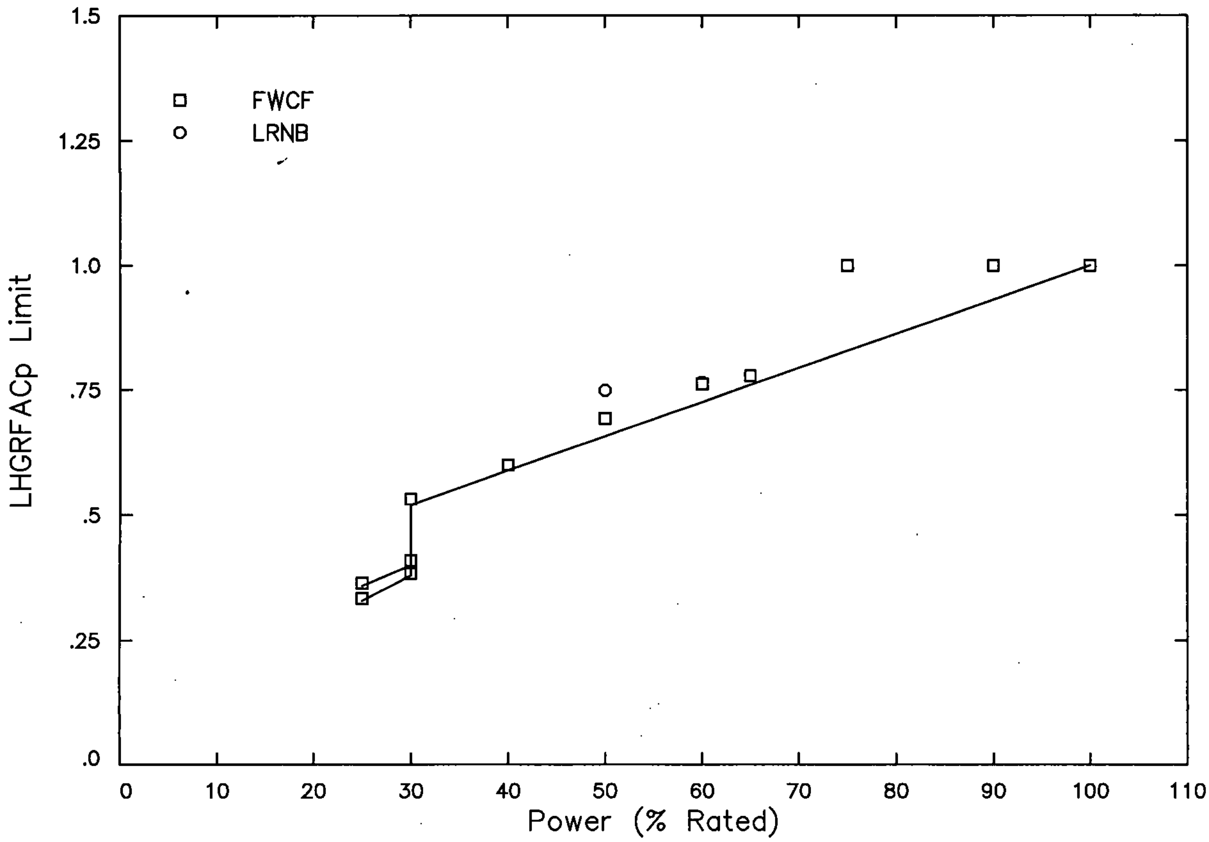
Power (% of rated)	$MCPR_p$ Limit
100	1.58
75	1.71
65	1.86
50	---
50	2.02
40	2.33
30	2.70
30 at > 50%F	3.96
25 at > 50%F	4.57
30 at ≤ 50%F	3.50
25 at ≤ 50%F	4.00

Figure A.80 BOC to EOCLB $MCPR_p$ Limits for ATRIUM-10 Fuel - TSSS Insertion Times - TBVOOS, FHOOS, and PLUOOS Combined



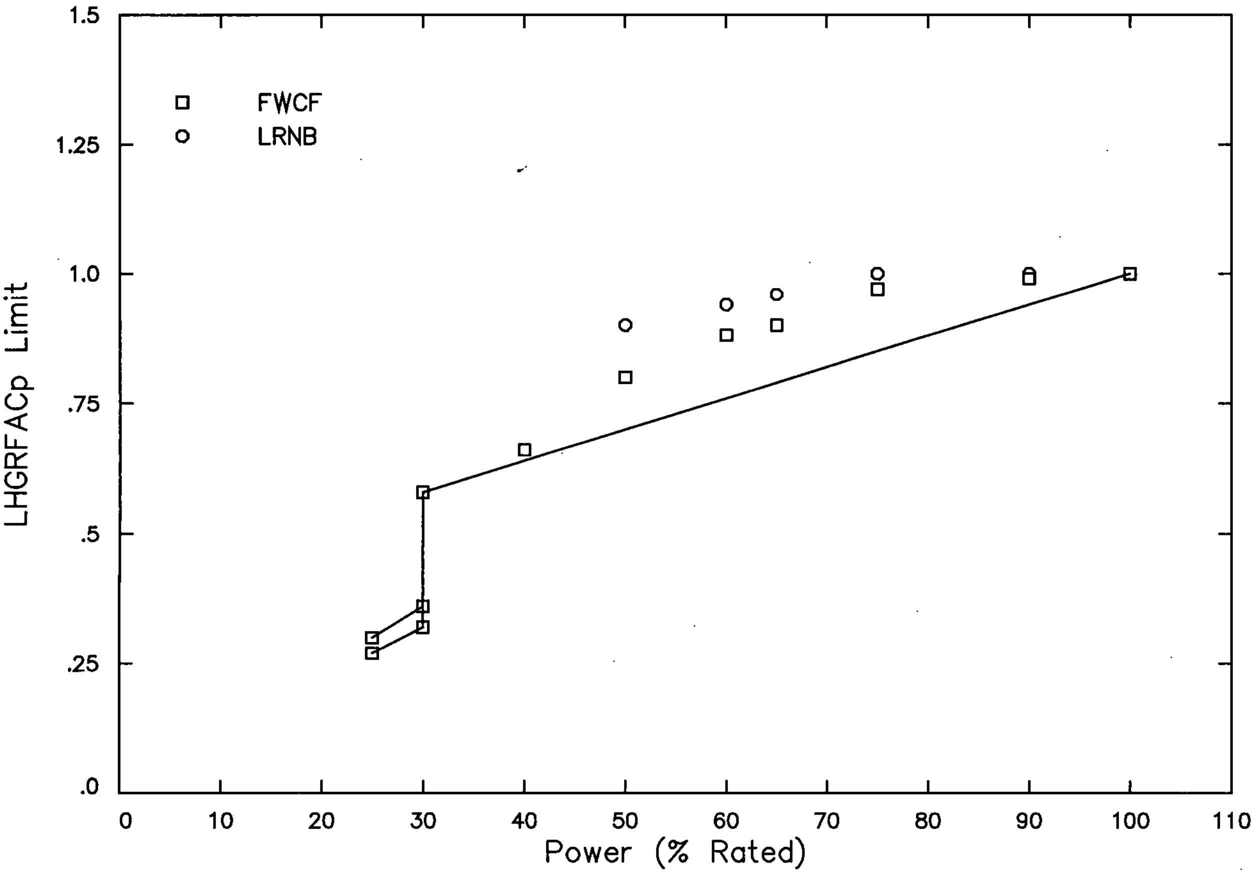
Power (% of rated)	$LHGRFAC_p$ Multiplier
100	1.00
30	0.60
30 at > 50%F	0.32
25 at > 50%F	0.28
30 at ≤ 50%F	0.36
25 at ≤ 50%F	0.30

Figure A.81 All Exposures $LHGRFAC_p$ Multipliers for ATRIUM 10XM Fuel - NSS/TSSS Insertion Times EOOS with TBVIS



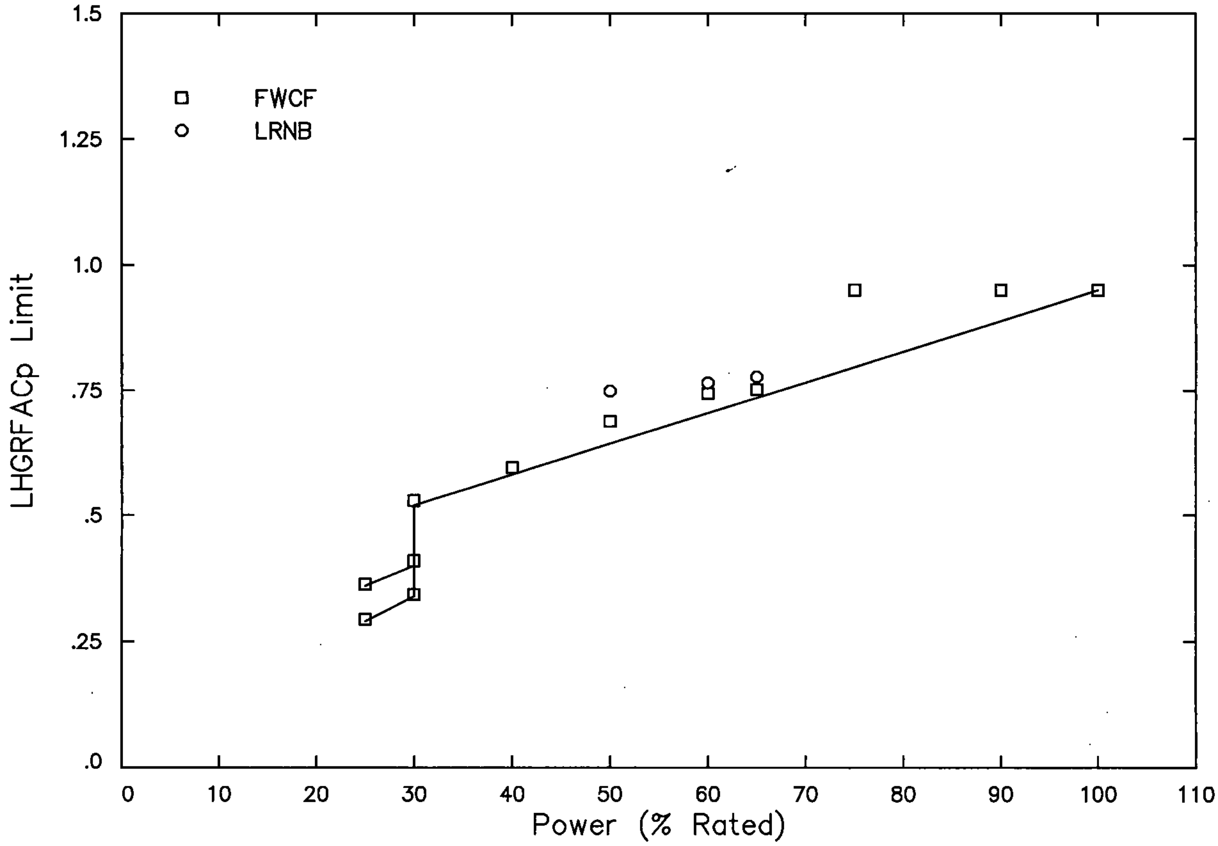
Power (% of rated)	LHGRFAC$_p$ Multiplier
100	1.00
30	0.52
30 at > 50%F	0.38
25 at > 50%F	0.33
30 at ≤ 50%F	0.40
25 at ≤ 50%F	0.36

Figure A.82 All Exposures LHGRFAC$_p$ Multipliers for ATRIUM-10 Fuel - NSS/TSSS Insertion Times EOOS with TBVIS



Power (% of rated)	$LHGRFAC_p$ Multiplier
100	1.00
30	0.58
30 at > 50%F	0.32
25 at > 50%F	0.27
30 at ≤ 50%F	0.36
25 at ≤ 50%F	0.30

Figure A.83 All Exposures $LHGRFAC_p$ Multipliers for ATRIUM 10XM Fuel - NSS/TSSS Insertion Times EOOS with TBVOOS



Power (% of rated)	$LHGRFAC_p$ Multiplier
100	0.95
30	0.52
30 at > 50%F	0.34
25 at > 50%F	0.29
30 at ≤ 50%F	0.40
25 at ≤ 50%F	0.36

Figure A.84 All Exposures $LHGRFAC_p$ Multipliers for ATRIUM-10 Fuel – NSS/TSSS Insertion Times EOOS with TBVOOS