Proj. 702

SIEMENS

March 9, 2000
NRC:00:018

Document Control Desk
ATTN: Chief, Planning, Program and Management Support Branch
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Approval of SER Conditions for EMF-CC-074(P) Volume 4 Revision 0, "BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2"

Ref.: 1. Letter, James F. Mallay (SPC) to Document Control Desk (NRC), "Request for Review of EMF-CC-074(P) Volume 4 Revision 0, *BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2*," NRC:00:047, November 24, 1999.

This letter formalizes a request made by Siemens Power Corporation at a meeting held in Rockville on March 2, 2000. The meeting was attended by representatives from Entergy, NRC, and SPC. SPC requests that the SER for the topical report submitted to the NRC by Reference 1 include a statement approving Enhanced Option 1-A (E1A) STAIF validation success criteria. These criteria were discussed with and provided to the NRC at the March 2 meeting.

The proposed E1A STAIF validation success criteria are:

1. That the computed global and regional decay ratios be used instead of the current FABLE/BYPASS boundary, which is based on the global and channel decay ratio map, and

2. Validation success values of 0.9 global and 0.8 regional decay ratios as determined by the STAIF computer code be used.

These criteria are justified because the improved computer code modeling produces less uncertainty in the results from STAIF and from its complementary, approved core simulator code, MICROBURN-B2. In addition, the use of global decay ratio versus regional decay ratio directly characterizes the modes of oscillation of actual cores rather than relying on an empirical correlation between global and channel decay ratios. These criteria have also been validated by the use of an expanded database for benchmarking STAIF. Pages 36 and 37 of the presentation material (see enclosed viewgraphs) graphically demonstrate how the proposed STAIF criteria preclude the instabilities and marginally stable conditions that were observed in the validation database. Page 38 summarizes the justification for using the STAIF proposed validation success criteria.

While the existing E1A monitored, restricted, and exclusion regions provide margin for plant startup and operating maneuvers, even limited expansion of those regions reduce operating flexibility. The application of the proposed STAIF criteria will limit the expansion of those regions, while allowing the operators to perform safe reactor maneuvers.

Siemens Power Corporation

2101 Horn Rapids Road
Richland, WA 99352

Tel: (509) 375-8100
Fax: (509) 375-8402

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The proposed validation success criteria for STAIF analysis limit the growth of the E1A regions which could result from compounding conservatisms and uncertainties due to current methodology approximations. The proposed criteria reduce the methodology uncertainty while preserving all of the defense-in-depth inherent in the current E1A solution.

Siemens Power Corporation considers some of the information contained in the enclosure to this letter to be proprietary. This information has been noted as such by enclosing it in brackets or italicized text. The affidavit provided with the original submittal of the reference topical satisfies the requirements of 10 CFR 2.790(b) to support the withholding of this information from public disclosure.

Very truly yours,

James F. Mallay, Director
Regulatory Affairs

/arn

Enclosures

cc: Mailed direct to Mr. N. Kalyanam
Mr. N. Kalyanam (w/Enclosures)
Dr. T. L. Huang (w/2 Enclosures)

Mailed direct to Document Control Desk
Mr. J. L. Wermiel
Project No. 702 (w/Enclosures)

MICROBURN-B2/STAIF

Stability Methodology and Application

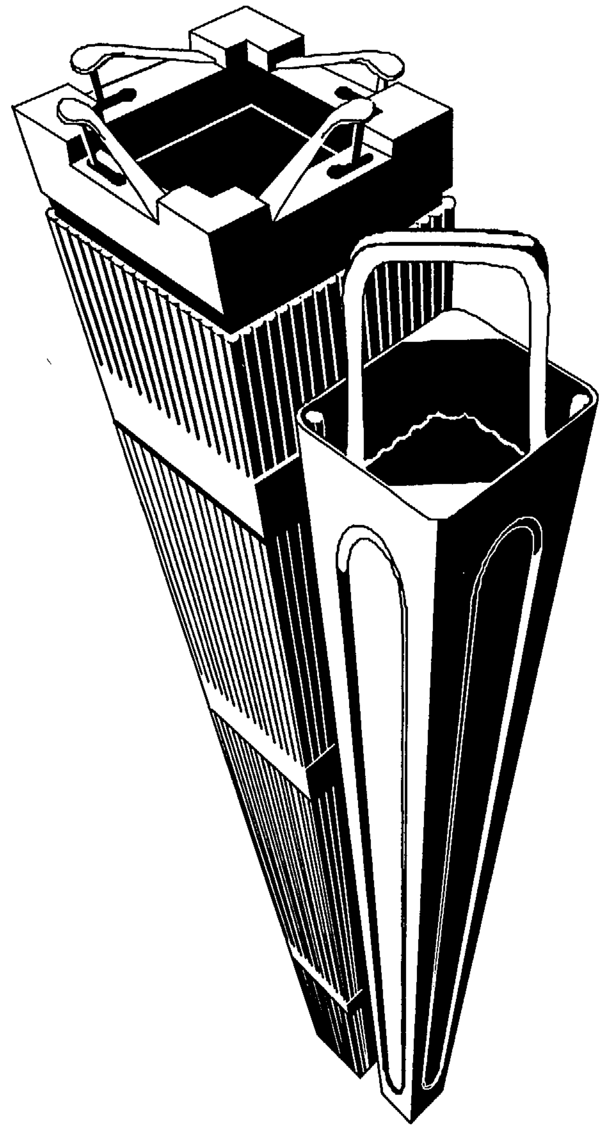
- AGENDA

- **Part I**
- Opening Remarks — Don Curet, Product Licensing
- MICROBURN-B2/STAIF STABILITY METHODOLOGY — Doug Pruitt, Safety Analysis Methods
- Presentation Summary — Entergy/NRC/SPC
- Break before **Part 2**

MICROBURN-B2/STAIF Stability Methodology

Presentation to

Nuclear Regulatory Commission
Rockville, Maryland
March 2, 2000



Douglas Pruitt
Safety Analysis Methods

Motivation for New STAIF Development

- STAIF SER (TER ORNL/NRC/LTR-94/07) treats the steady-state core simulator as an integral part of the stability methodology
  - New core simulator requires validation assessment as a minimum
- Hydraulic stability measurements conducted for the ATRIUM-10
  - Extends the validation database for the hydraulic models
- Additional stability measurements made since 1994 SER
  - Additional high decay ratio data (>0.6) for current fuel designs
- Additional Verification and Validation commitments to the NRC

Improved Models
MICROBURN-B2

- Submitted to the NRC in December 1998 and approved in October 1999
  - Additional nuclides tracked
  - Advanced NEM solution
  - New hydraulic correlations
  - Reactivity feedback from boiling in the core bypass region
  - Validation for increased cycle lengths, longer control blade sequences, and mixed oxide cores

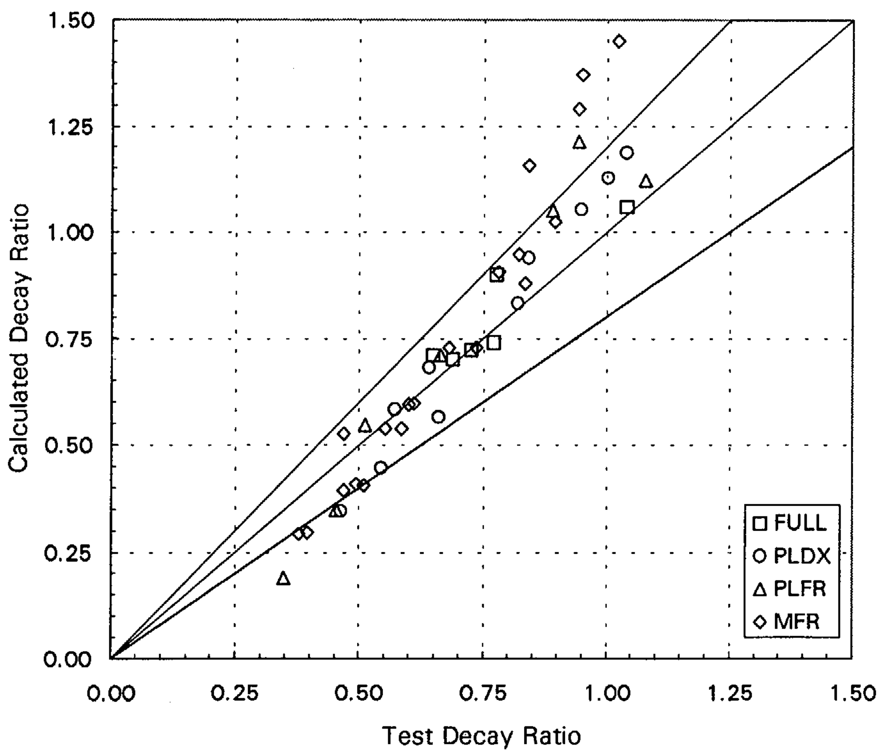
Improved Models
STAIF Hydraulics

- Minimize differences between the MICROBURN-B2 hydraulic correlations and those used in STAIF

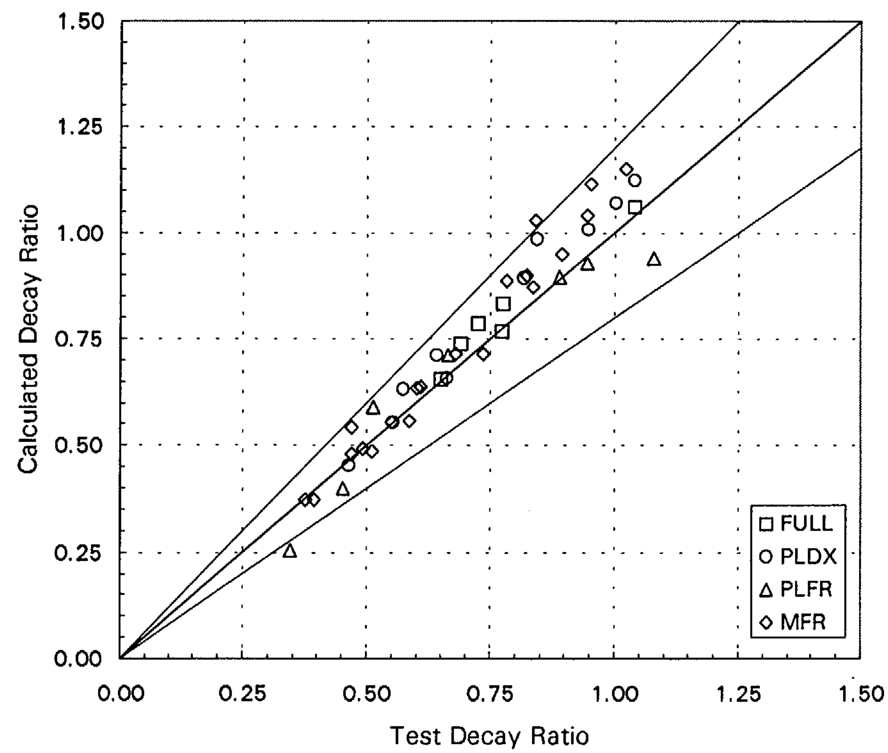
CORRELATION	MICROBURN-B2	STAIF
Void Fraction Correlation		
Two-Phase Friction Multiplier		
Two-Phase Local Loss Multiplier		
Single Phase Friction Factor		
Spatial Acceleration		
Subcooled Boiling Initiation		
Subcooled Boiling Energy Distribution		

Improved Models
STAIF Hydraulic Validation Comparison

- Improve Comparison to Data Measured in [ ]
  - Previous Validation
    - EMF-CC-074, Volume 2



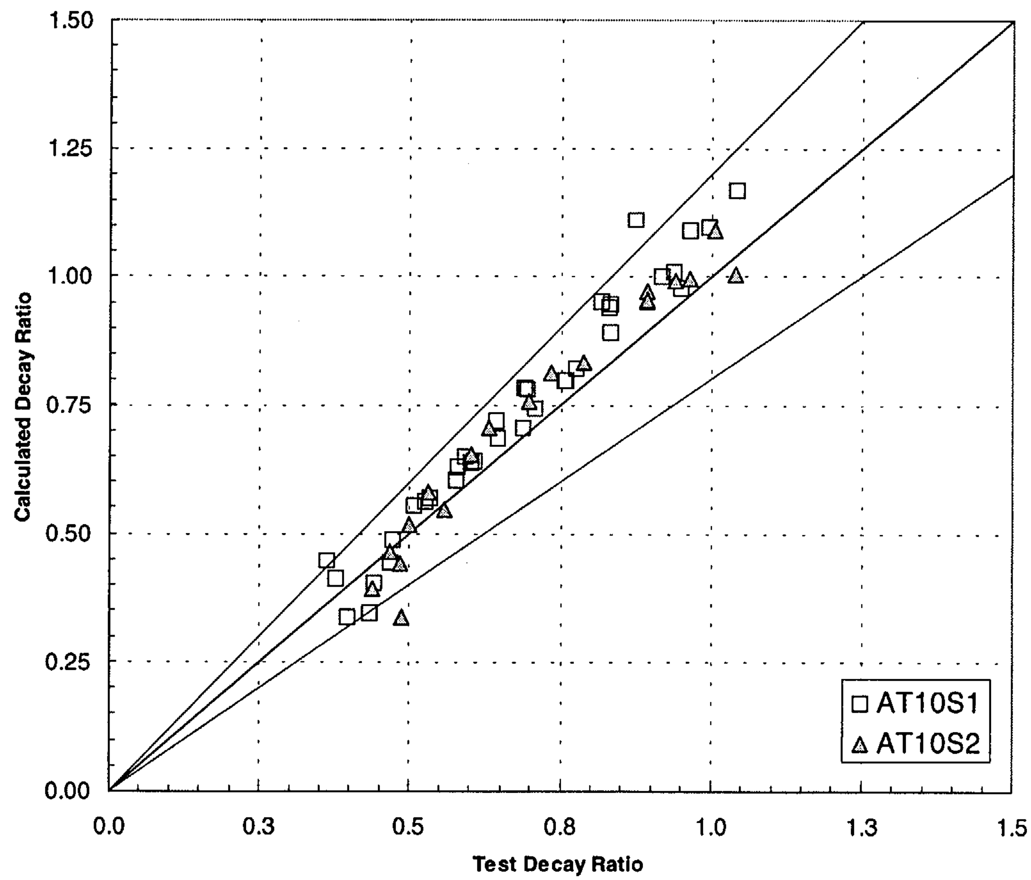
  - New Validation
    - EMF-CC-074, Volume 4



Improved Models
New STAIF Hydraulic Validation

- ATRIUM-10 Measurements in [ ]

- Part-Length Rods
- Natural Circulation
- Two Orifice Sizes
- Varied Conditions
  - Pressure
  - Subcooling
  - Power



Improved Models
Heat Conduction

- Fission energy deposition in pellets is now radially non-uniform to account for self-shielding. The radial distribution depends on pellet size and exposure.
- Actual uranium oxide density is used [
  ]
- The thermal conductivity of the fuel pellet in the previous model is a function of fuel temperature only. The new function depends also on pellet density, Gd content, and exposure.
- The pellet-clad gap conductance was input for each fuel type in the previous model. New model accounts for pin geometry, exposure, and power level. This allows effectively 3-D representation of the gap conductance. [
  .]

Improved Models

Example Gap Conductance for Fuel Designs

Improved Models

Gap Conductance Sensitivity to Initial Gap Size

Improved Models

Gap Conductance Sensitivity to Power Level

Improved Models

Gap Conductance Sensitivity to Fill Gas Pressure

Improved Models

Gap Conductance Sensitivity to UO_2 Density

Improved Models

Modal Kinetics

- Reactivity-to-power transfer function was derived using modal neutron kinetics starting from single group diffusion equation with 6 group delayed neutron representation. No other assumptions were needed.
- The n^{th} mode flux perturbation relative to the initial value for the fundamental mode is:

Improved Models
Modal Kinetics

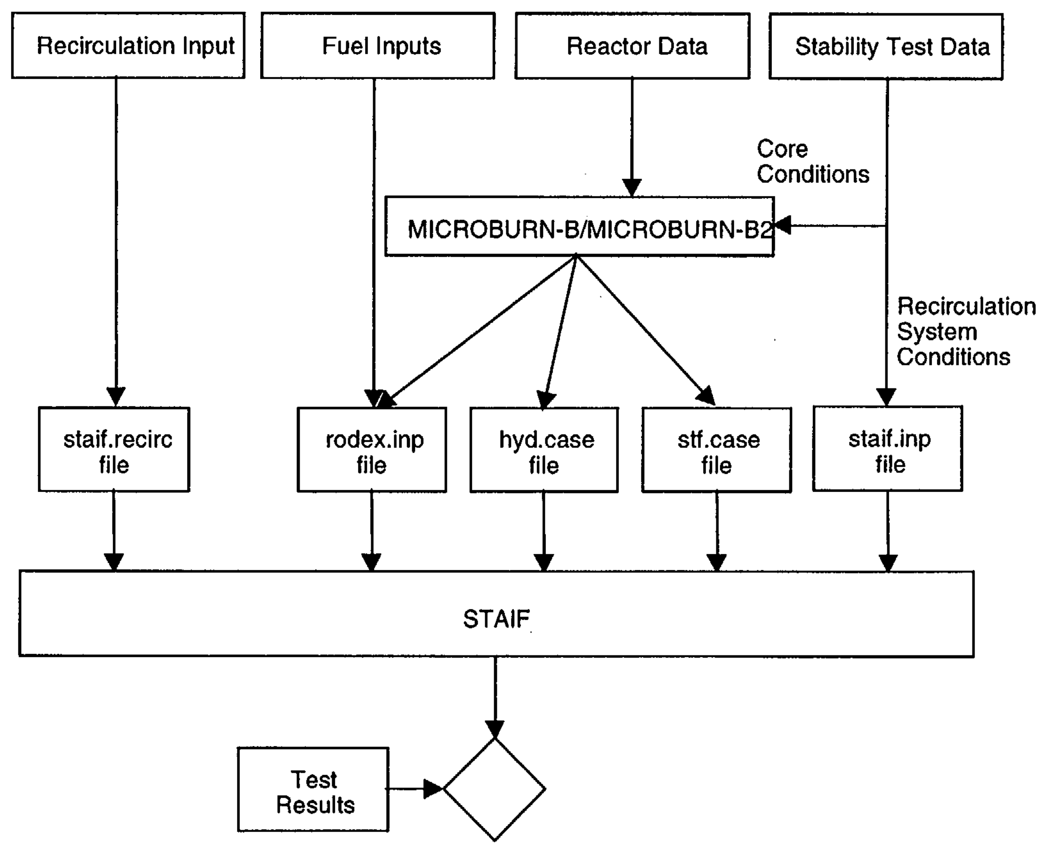
- Global Mode:
  - The original model is a 1-D nodal representation with invariant radial shape.
  - Comparison of the original model with the modal kinetics show similarity in all basic aspects including the weighting of cross sections and their perturbations.
  - The numerical results confirm the similarity.
  - The original model is kept for the global mode.

Improved Models

Modal Kinetics

Improved Models
STAIF Input Automation

- MB2STF functions incorporated into STAIF
  - Eliminates interface files
- SER channel grouping automated
- Fuel Gd concentrations and exposures automated
- Clad dimensions automated



Integral Validation

Reactor Validation Database

Integral Validation

STAIF Qualification with Reactor Data

MICROBURN-B2/STAIF Summary

The new stability analysis capabilities provide significant advances for best-estimate predictions.

- Steady-state simulator accuracy
- STAIF hydraulic correlation set
- Heat conduction model parameters
- Application of modal kinetics for the regional mode

The improvements have been validated.

- Expanded set of full-scale hydraulic tests
- Expanded set of reactor benchmarks that include current fuel and core designs

The new best-estimate stability methodology application to long-term stability solutions and the associated acceptance criteria will be discussed next...

MICROBURN-B2/STAIF

Stability Methodology and Application

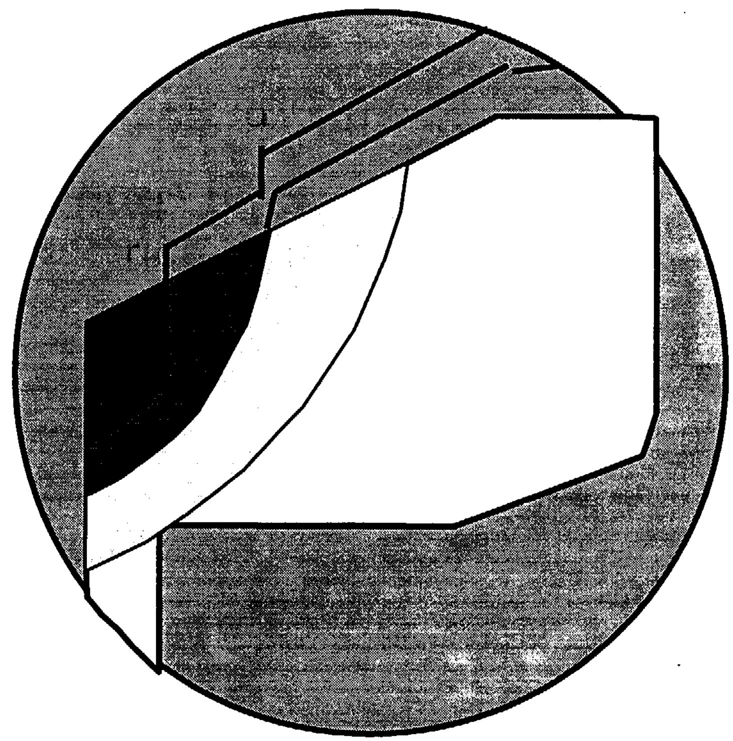
AGENDA

- **Part 2**

• Opening Remarks	Don Curet, Product Licensing
• STAIF APPLICATION to Enhanced Option I-A	Doug Pruitt Safety Analysis Methods
• Presentation Summary	Entergy/NRC/SPC
• Concluding Remarks	Don Curet

Enhanced Option I–A

STAIF Application To Core Stability Solution



Douglas Pruitt
Safety Analysis Methods

Initial Application

Enhanced I-A Overview

- Within the context of GDC-10 and 12, Enhanced I-A seeks to provide:
    - sufficient operating stability margin
    - flexibility for required reactor maneuvers
    - reduction of solution reload dependency
    - prevention of unnecessary challenges to safety systems

Initial Application

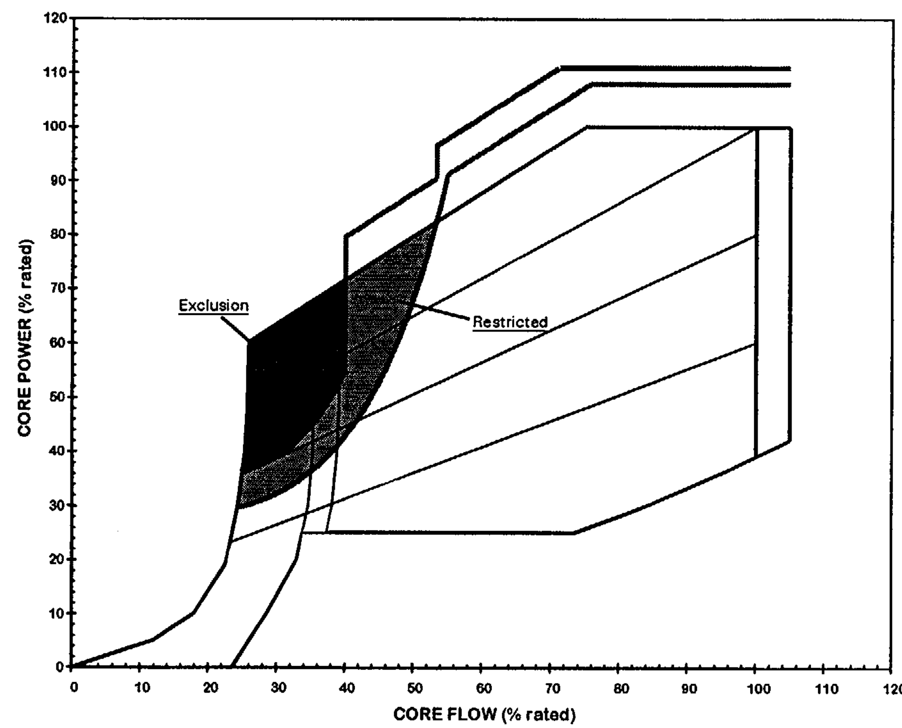
Enhanced I-A Overview

- In compliance with GDC-10 and 12, the balance is accomplished by progressively more restrictive operating requirements as susceptibility to instabilities increases
  - Automatic prevention where susceptibility is anticipated during normal operation and as a result of moderate frequency events
  - Prevention through a combination of automatic and manual actions and stability controls for regions where instabilities are anticipated without compensatory action
  - Protection through automatic and manual actions and automatic detection for regions where instabilities are not anticipated or are beyond the existing design bases of the reactor system.

Initial Application

Enhanced I-A Licensing Basis

- Exclusion Region
  - Prevented by automatic scram
- Restricted Region
  - Normal Operation
    - Operation in region avoided
    - Effectively protected by Rod Block
    - Increases excluded domain
  - Controlled Entry
    - FCBB Stability control required
    - Rod Block setup to allow entry
  - Uncontrolled Entry
    - LOFH, flow reduction
    - Instability not likely
    - Continued operation not allowed
- Remaining operating domain
    - Instability not anticipated



MCPR Safety Limit protection for anticipated events by instability prevention

Initial Application

Enhanced I-A Region Boundary Generation

- FABLE/BYPASS procedure defines the Exclusion Region boundary
  - FABLE/BYPASS received SER for Exclusion Region application
  - FABLE/BYPASS licensing methodology is overall conservative
- Exclusion Region is enhanced by adding a Restricted Region and associated stability controls
  - FABLE/BYPASS procedure expanded to define Restricted Region
  - Consistency with exclusion boundary analytical basis (core power distributions) is enforced by avoidance of the Restricted Region or imposition of stability controls prior to planned entry

Initial Application
Enhanced I-A Region Boundary Generation

- Decay Ratio Bias developed between standard cycle and a reference cycle with a best-estimate stability code
    - Captures change in stability characteristics for new fuel designs and fuel management strategies
    - Bias used to adjust FABLE/BYPASS standard cycle to generate conservative boundaries for the reference cycle

- Validation analysis require using a best-estimate code
    - Reasonably limiting, challenging conditions are prescribed by Enhanced I-A methodology
    - Confirms that the FABLE/BYPASS procedure provides region boundaries appropriate for the stability characteristics of actual core and fuel designs within the overall context of Enhanced I-A

Initial Application

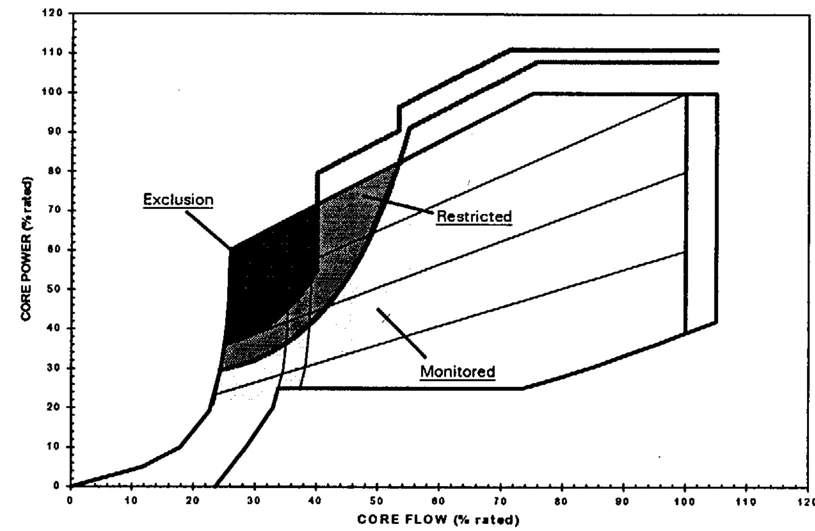
Enhanced I-A Defense-In-Depth

- Defense-in-depth features add diverse methods and systems for prevention of instabilities and protection from unanticipated and hypothetical precursors to reactor instability
  - Definition of Monitored Region where the reactor is hypothetically susceptible to instability
  - Operation within the defined regions requires an automatic detection system (PBDS) :
    - Reductions in stability margin (Hi DR alarm)
    - Onset of instabilities (Hi-Hi DR alarm).
  - APRM flow-biased control rod block instrumentation monitors the restricted region boundary and automatically alarms upon entry.
  - APRM flow-biased scram clamp above the restricted region
  - Automatic setdown of APRM scram and rod block trip reference setpoints
  - Manual Operator Actions

Initial Application

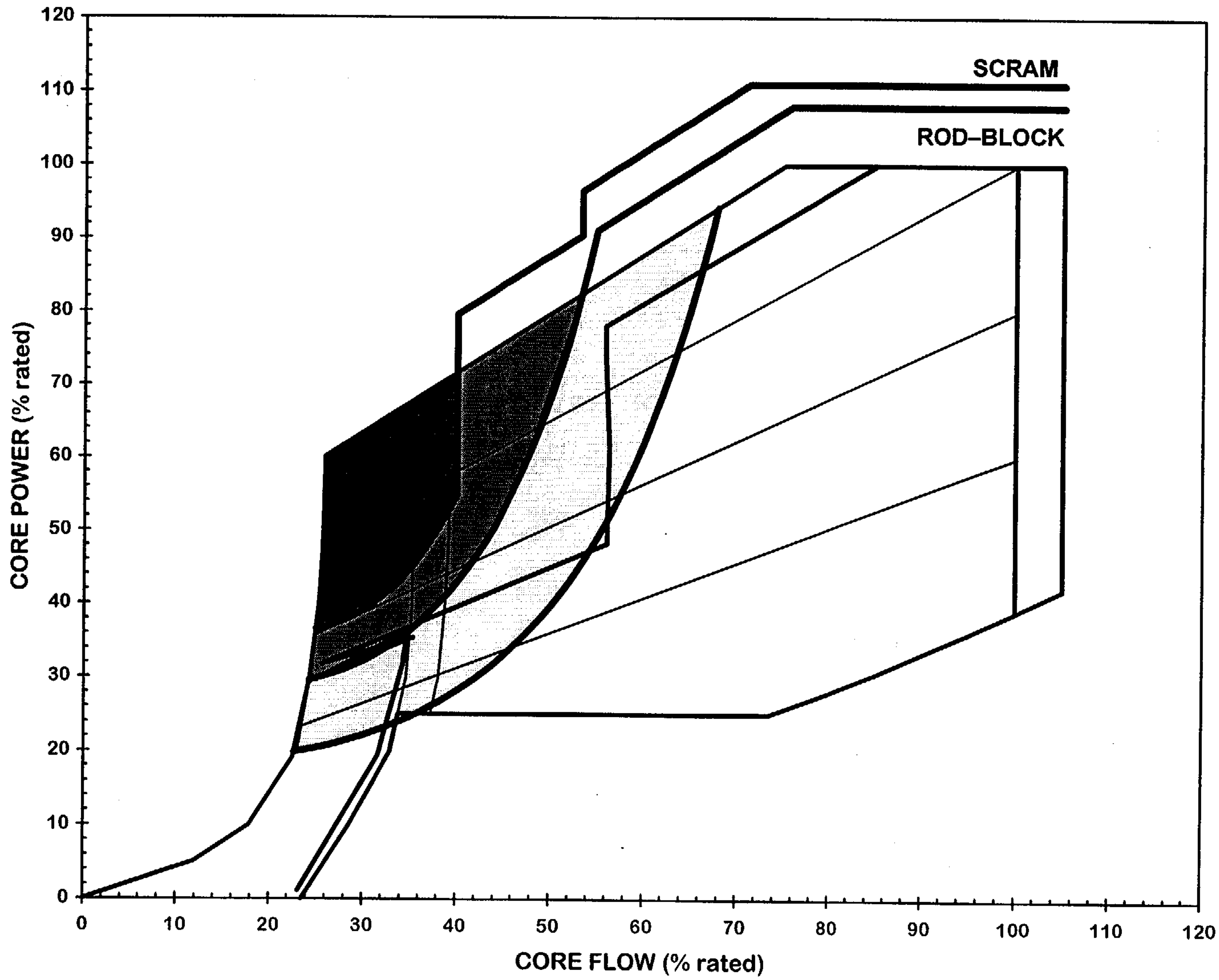
Enhanced I-A Overview

- Licensing Basis:
  - Flow-Biased Scram
  - Stability Controls
- Defense-in-Depth:
  - Rod Block Alarm
  - Period Based Detection / Alarm
  - Scram setpoint clamp above Restricted Region
  - Operator Actions



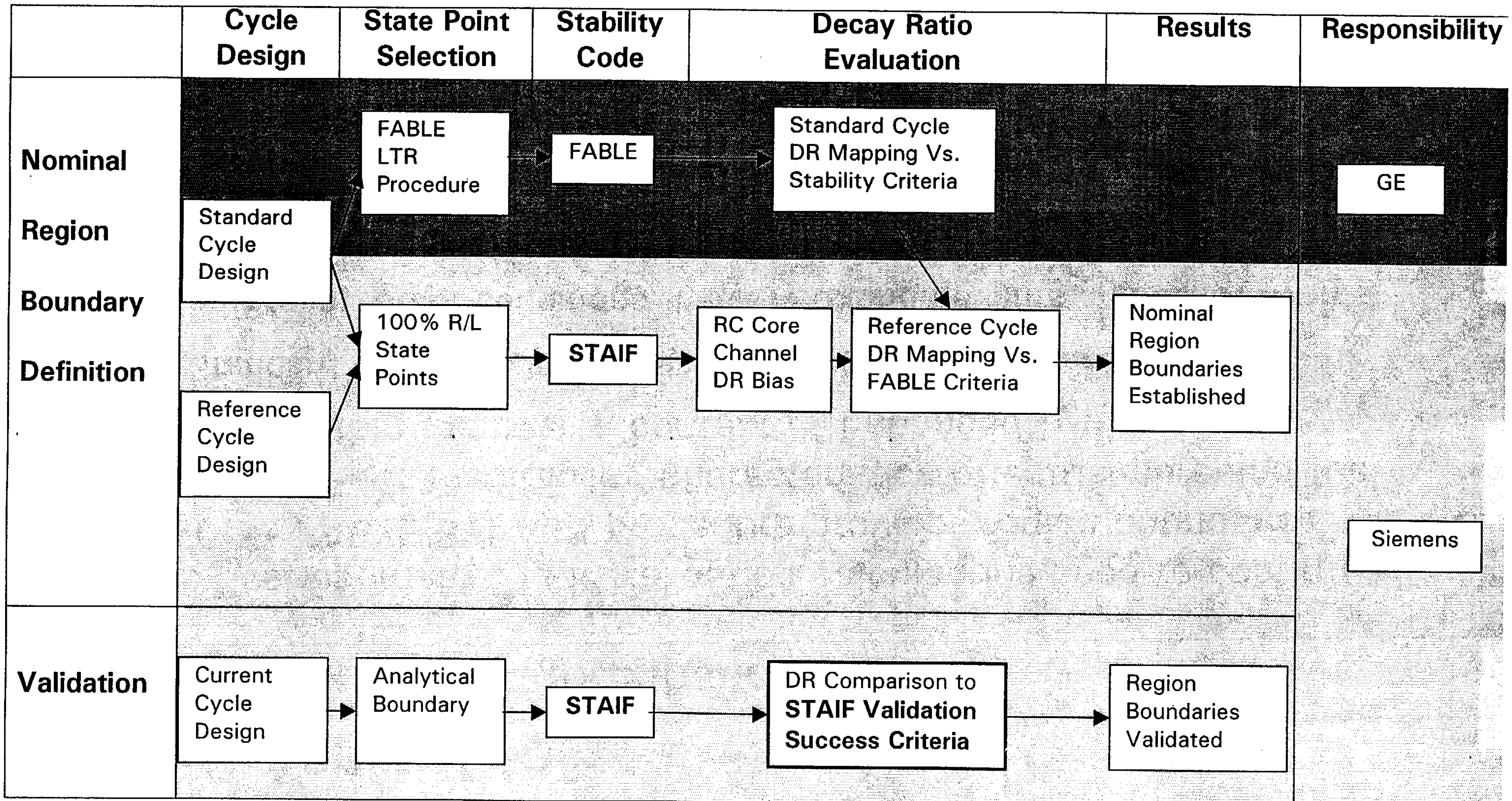
REGION	Exclusion	Restricted		Monitored
Type of Entry	Any	Uncontrolled	Controlled	Any
Licensing Basis Protection	Flow Biased SCRAM	N/A	FCBB Stability Control	N/A
Defense-in-Depth Conditions and Immediate Actions	N/A	- Rod Block Alarm EXIT - Hi-Hi Alarm - PBDS Inoperable SCRAM	- PBDS Inoperable - Transient in Region EXIT - Hi-Hi Alarm SCRAM	- PBDS Inoperable EXIT - Hi-Hi Alarm SCRAM

Normal APRM Flow-Biased Setpoints



Initial Application

STAIF Application to Enhanced I-A



Initial Application

STAIF Application to Enhanced I-A

- The best-estimate STAIF validation calculations need to confirm that the FABLE/BYPASS procedure provides region boundaries appropriate for the stability characteristics of actual core and fuel designs within the overall context of Enhanced I-A
  - Standard validation state-points are prescribed by methodology
    - Steady-State conditions, Flow Reduction events and LOFH events
    - Setpoint uncertainty is addressed by statepoint selection
  - Analytical boundaries are based on a 5% of rated reduction of the nominal restricted and exclusion region boundaries
- Options for the STAIF Enhanced I-A validation criteria can be evaluated with the benchmarks in EMF-CC-074(P), Volume 4
  - **Adoption of current FABLE region boundary generation criteria** or
  - **Development of fundamentally based validation criteria**

Initial Application

STAIF Enhanced I-A Validation Success Criteria

- Assessment of FABLE region boundary generation criteria against STAIF reactor benchmarks

Initial Application

STAIF Enhanced I-A Validation Success Criteria

- Channel/Global decay ratio map is a rough correlation for regional stability margin and the level of conservatism is uncertain
  - Channel/Global decay ratio map does not accurately capture the regional stability margin as a function of radial power distributions and core sizes
- The mean exclusion margin, average distance between the validation border and the calculated instabilities, is 0.04 for the three regional instabilities
- Higher degree of certainty can be obtained by using success criteria that are based solely on the Global and Regional decay ratios
  - Places the acceptance criteria directly on the reactor oscillation modes
  - Highlights changes in fuel management strategies that impact the preferred oscillation mode

Initial Application
STAIF Enhanced I-A Validation Success Criteria

- Assessment of STAIF Validation Success Criteria
  - $DR_G \leq 0.90$; $DR_R \leq 0.90$ provides a mean exclusion margin of 0.12 for the regional instabilities

Initial Application
STAIF Enhanced I-A Validation Success Criteria

- Assessment of STAIF Validation Success Criteria
  - $DR_G < 0.90$; $DR_R < 0.80$ provides a mean exclusion margin of 0.22 for the regional instabilities

Initial Application

STAIF Enhanced I-A Validation Success Criteria

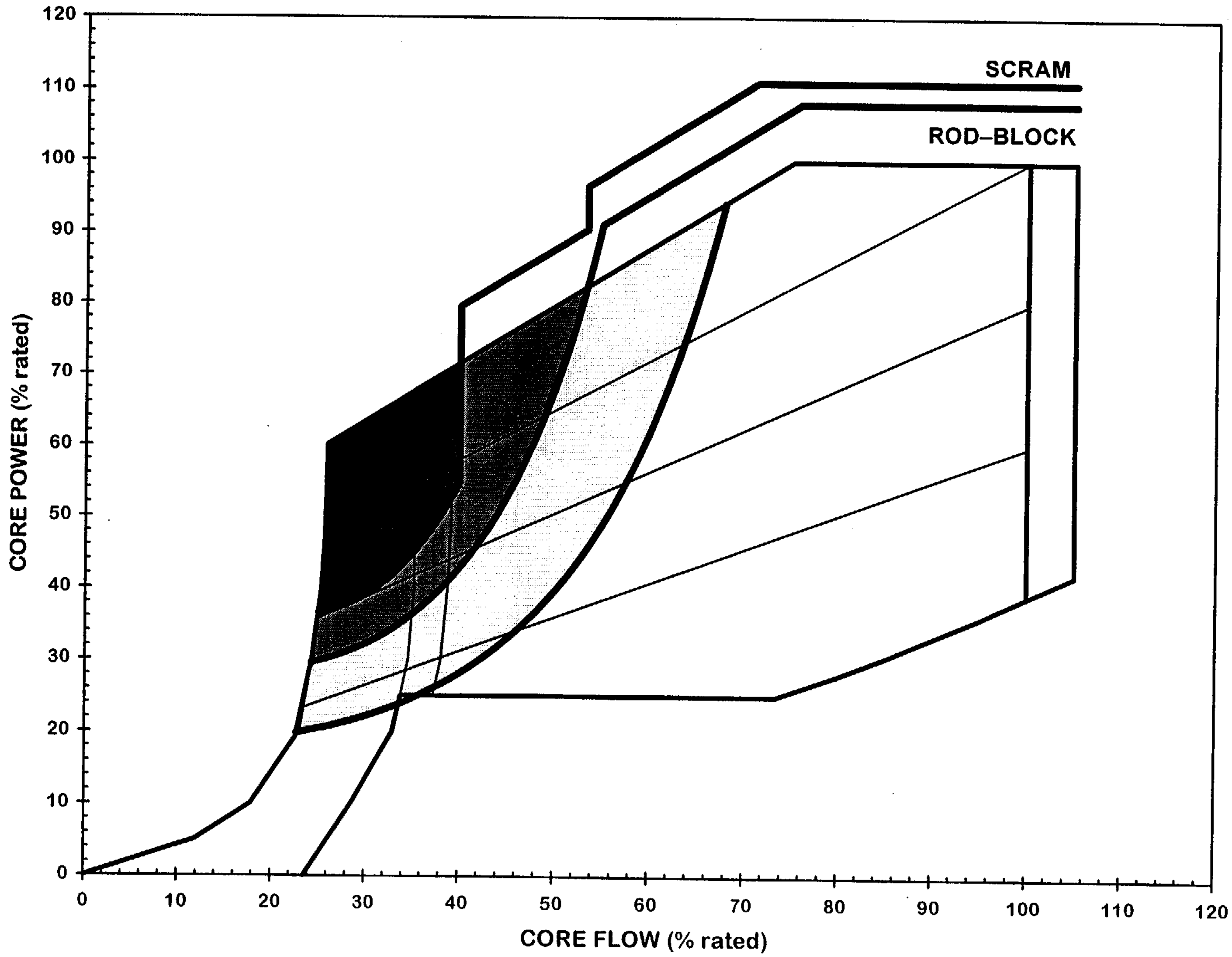
- Assessment of STAIF Validation Success Criteria for measured Decay Ratios > 0.8

Initial Application

Enhanced I-A Validation Summary

- The STAIF Validation Success Criteria (Global Decay Ratio ≤ 0.9 and Regional Decay Ratio ≤ 0.8) is appropriate for use with the Enhanced I-A solution
  - Effectively characterizes the stability performance of actual core and fuel designs by providing acceptance criteria directly on the modes of oscillation
  - Effectively precludes instabilities and marginally stable conditions observed in the validation database
  - Provides a best-estimate confirmation that the FABLE/BYPASS procedure provides region boundaries appropriate for the stability characteristics of an actual core design within the overall context of Enhanced I-A

Typical Enhanced I-A Power/Flow Map



Setup APRM Flow-Biased Setpoints