Implementing Documents

TDP-00049, Rev. 5, August 2003: Safety Limit Minimum Critical Power Ratio (SLMCPR) tdp 0049

AG-0006, Rev. 5, August 2003: Safety Limit Minimum Critical Power Ratio (SLMCPR) ag 0006

GESTAR Amend. 25: Cycle-Specific SLMCPR

Revision No.[a]	Amend. No.	GE Amend. Reference[b]	NRC Approval Reference[b]	Amendment Content
12			45	Superceded by Revision 13.
13		46	47	Cold water event determination.
14	25	48	49	Cycle-specific Safety Limit MCPR.
	26	50	51, 52	Administrative including approvals of Stability and ATWS, inclusion of MLHGR, classifying PRDF, implementing improved GE steady-state methods, et. al.

Amendment 25 References

48. Letter from R.J. Reda to Document Control Desk, *Proposed Amendment 25 to GE Licensing Topical Report NEDE-24011-P-A (GESTAR II) on Cycle-Specific Safety Limit MCPR, MFN-179-96, December 13, 1996.*

49. Letter from Frank Akstulewicz to Glen A. Watford, *Acceptance For Referencing of Licensing Topical Reports NEDC-32601P, Methodology And Uncertainties For Safety Limit MCPR Evaluations; NEDC-32694P, Power Distribution Uncertainties For Safety Limit MCPR Evaluation; and Amendment 25 to NEDE-24011-P-A On Cycle-Specific Safety Limit MCPR (TAC NOS. M97490, M99069 AND M97491), MFN-003-99, March 11, 1999.*

[[

Determine SLMCPR – Limiting Condition

[[

{3}]]

imagination at work

Determine SLMCPR – Monte Carlo

[[

{3}]]

Determine SLMCPR – Monte Carlo

[[

{3}]]

imagination at work

Determine SLMCPR – Monte Carlo

[[

{3}]]

imagination at work

Determine SLMCPR – Monte Carlo

[[

{3}]]

NEDC-32601P-A Table 2.1 Summary of SLMCPR Uncertainties

Uncertainty Parameter	GETAB Uncertainty ±σ (%)	Revised Uncertainty and Procedures ±σ (%)	Reference
Feedwater Flow System Overall Flow Uncertainty	1.76	[[(3)]]	Section 2.2
Feedwater Temperature Measurement	0.76	[[(3)]]	Section 2.3
Reactor Pressure Measurement	0.50	[[(3)]]	Section 2.4
Core Inlet Temperature	0.20	0.2	Section 2.5
Total Core Flow Measurement	2.5 (6.0 for Single Loop Operation)	2.5 (6.0 for Single Loop Operation)	Section 2.6
Channel Flow Area Variation	3.0	[[(3)]]	Section 2.7
Friction Factor Multiplier Uncertainty	10.0	[[(3)]]	Section 2.8
Channel Friction Factor Multiplier	5.0	5.0	Section 2.9

[[

{3}]]

Standard Power Distribution Uncertainties	GETAB NEDC-32601P-A	GETAB Revised Methodology NEDC-32601P-A	Revised Methodology Reduced Power NEDC-32694P-A
GEXL R-factor	1.6	[[{3}]]	[[{3}]]
Random effective TIP reading	1.2 (TLO) 2.85 (SLO)	1.2 (TLO) 2.85 (SLO)	1.2 (TLO) 2.85 (SLO)
Systematic effective TIP reading	8.6	[[{3}]]	[[{3}]]
Integrated effective TIP reading	N/A	[[{3}]]	[[{3}]]
Bundle power	N/A	[[{3}]]	[[{3}]]
Effective total bundle power uncertainty	4.3	4.3	[[{3}]]

Exceptions to Standard Power Distribution Uncertainties	GETAB NEDC-32601P-A	GETAB Revised Methodology NEDC-32601P-A	Revised Methodology Reduced Power NEDC-32694P-A
GEXL R-factor	[[{3}]]	[[{3}]]	[[{3}]]

Process Drivers

[[

{3}]]

Correlation of SLMCPRs using MIP and RIP Ratios

- *Empirical correlation has been used previously*
- *Theoretical-based correlation is now preferred*

[[

{3}]]

MCPR Importance Parameter (MIP)

[[

{3}]]

[[

{3}]]

Two Key Cycle-Specific Parameters

[[

{3}]]

[[

{3}]]

Conclusions

NRC approved process

Statistical model automated in GESAM code

Inputs controlled by TDP and AG

Customer inputs controlled by FRED

Automated plant/cycle specific inputs controlled by approved PANAC10 and PANAC11 codes

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Licensing Topical Report

General Electric Standard Application
for Reactor Fuel

AOO Transient Analysis

Fran Bolger, GE Nuclear
April 19-20, 2004

AOO Topics

- GESTAR II Requirements
- GESTAR II Limiting Events
- Reload Process for Transients
- Operating Flexibility Thermal Limits
- Transient Selection
- Mixed Fuel
- Technical Design Procedures

GESTAR II Requirements

Unacceptable Results for Incidents of Moderate Frequency (AOOs)

- (1) a release of radioactive material to the environs that exceeds the limits of 10CFR20;
- (2) a reactor operation induced fuel cladding failure;
- (3) nuclear system stresses in excess of that allowed for the transient classification by applicable industry codes; and
- (4) containment stresses in excess of that allowed for the AOO classification by applicable industry codes.
- Compliance to the above related fuel criteria (1) and (2) is conservatively demonstrated by conformance to the fuel design limits and by maintaining the MCPR above the Fuel Cladding Integrity Safety Limit MCPR

GESTAR II Limiting Events

AOOs most likely to limit operation because of MCPR considerations:

- generator load rejection without bypass or turbine trip without bypass;
- loss of feedwater heating or inadvertent HPCI startup;
- control rod withdrawal error;
- feedwater controller failure (maximum demand)

For reloads, the potentially limiting events are evaluated to determine the required operating limits and results provided in the SRLR

Input process with Utility (OPL-3) provides key plant data for transient analysis evaluation. Includes information important for limiting and non-limiting events

GESTAR II Limiting Events

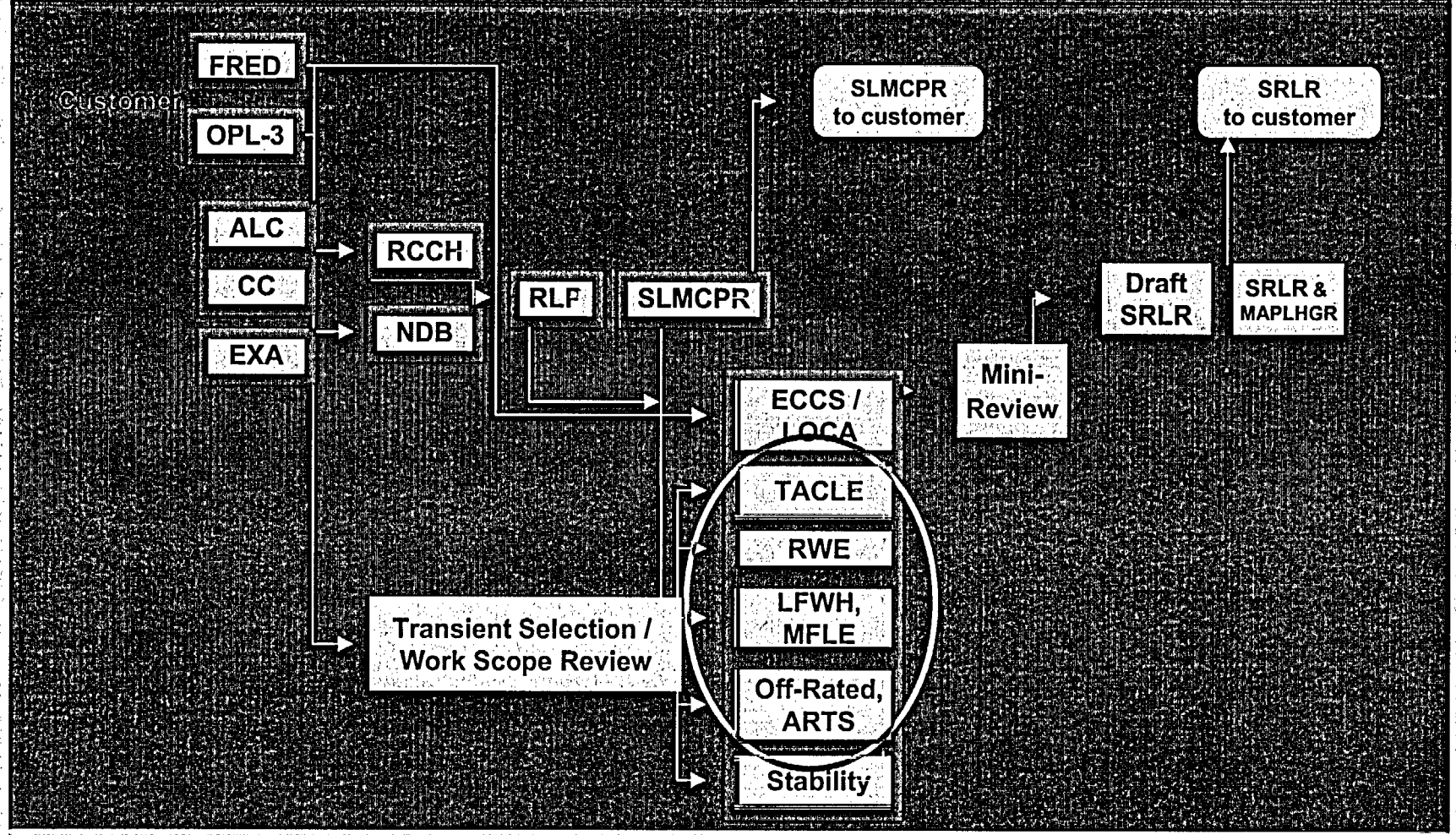
The description and frequency categorization of Significant AOOs and Accidents are provided in GESTAR II

The event descriptions discuss the starting conditions, key assumptions and operator actions following the event.

The methods used are referenced

Analysis Options (Flexibility Options) are dependent on the Plant Licensing Basis and are generally described in Section S.5

AOO Transient Licensing Process



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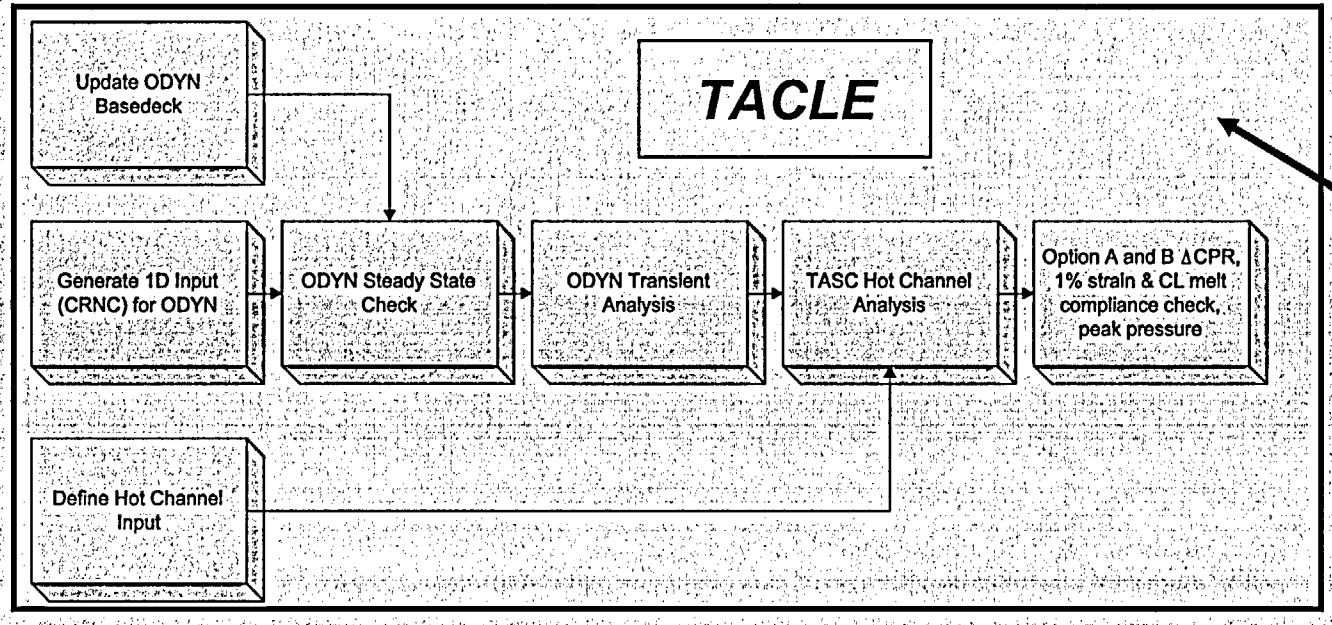
Fran Bolger
April 19-20, 2004
Imagination at work

Reload Pressurization Transients



This may be replaced by TRACG

Option A and B delta-CPR Based on Statistical Adders, GESTAR Section 4.3.1.2.6

For ODYN, Option B 95/95 ΔCPR is calculating using the model bias and uncertainty along with a response surface on ΔCPR/ICPR as a function of scram speed and core power. Calculated for BWR types and fuel product lines.

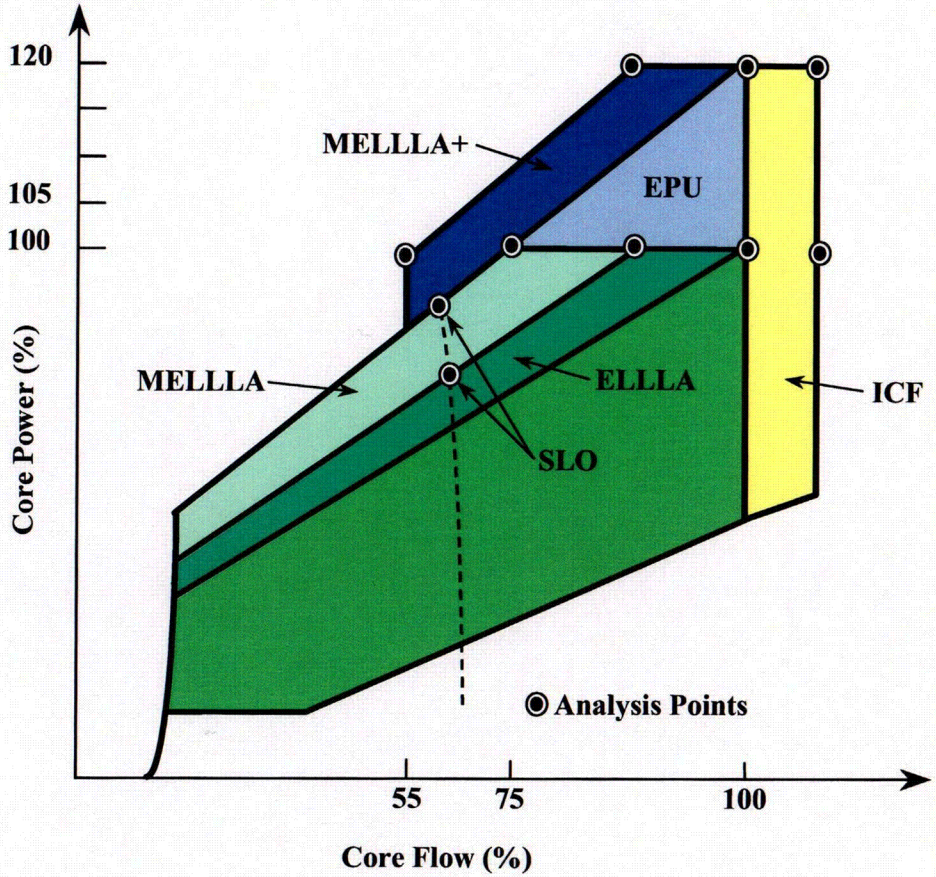
Consideration of Core Burn Strategies for AOOs

> From TDP-0029 tdp_0029

[[

{3}]]

Operating Flexibility Thermal Limits - Options



Available Options

- > ELLLA
- > MELLLA/MEOD
- > Increased Core Flow
- > Single Loop Operation
- > Feedwater Temperature Reduction
- > ARTS
- > Turbine Bypass Out of Service
- > Safety/Relief Valves Out of Service
- > Recirculation Pump Trip Out of Service
- > Main Steam Isolation Valves Out of Service

C01

GESTAR Rev 0 Operating Flexibility Thermal Limits

1978 SER

Plants had K(f) curves and Total Peaking Factor Setdown

8x8R Fuel

No Flow Domain Extension

Limits were all in Technical Specification

GESTAR Rev 5 Operating Flexibility Thermal Limits

1983 SER

BWR/6 added

GE provides demonstration analysis for K(f)

Event descriptions clarified

Margin Improvement Options introduced

> Staff notes that generic approval is outside the scope of GESTAR review

GESTAR Rev 5 – AOO Analysis Requirements

Load Line Limit

> "The consequences of AOOs are evaluated to determine if operating limit adjustments are necessary for operation in the extended operating range"

Increased Core Flow

> "The limiting AOOs that are analyzed at rated flow as part of a standard supplemental reload licensing report are reanalyzed for increased core flow operation"

Feedwater Temperature Reduction

> "The limiting AOOs are reanalyzed for operation at a reduced feedwater temperature"

GESTAR Amendment 13 Operating Flexibility Thermal Limits

1986 SER

ARTS and MEOD added to flexibility option

> Staff indicates that "separate approval must be obtained before these options can be used on a specific plant"

GESTAR Amendment 22 Operating Flexibility Thermal Limits

2.7 Operating Limit MCPR Licensing Evaluation

> "Plant Operating Limit MCPR is established by considering the limiting anticipated operational occurrences for each operating cycle."

> "For each new fuel design the applicability of generic MCPR analyses described in Section 4 (of GESTAR II) or in the country-specific supplement to this base document shall be confirmed for each operating cycle or a plant-specific analysis will be performed."

Analysis Requirements For Addition of Flexibility Option

GESTAR does REQUIRE determination of Operating Limit MCPR for all flexibility options

GESTAR does REQUIRE "confirmation" of generic MCPR limits.

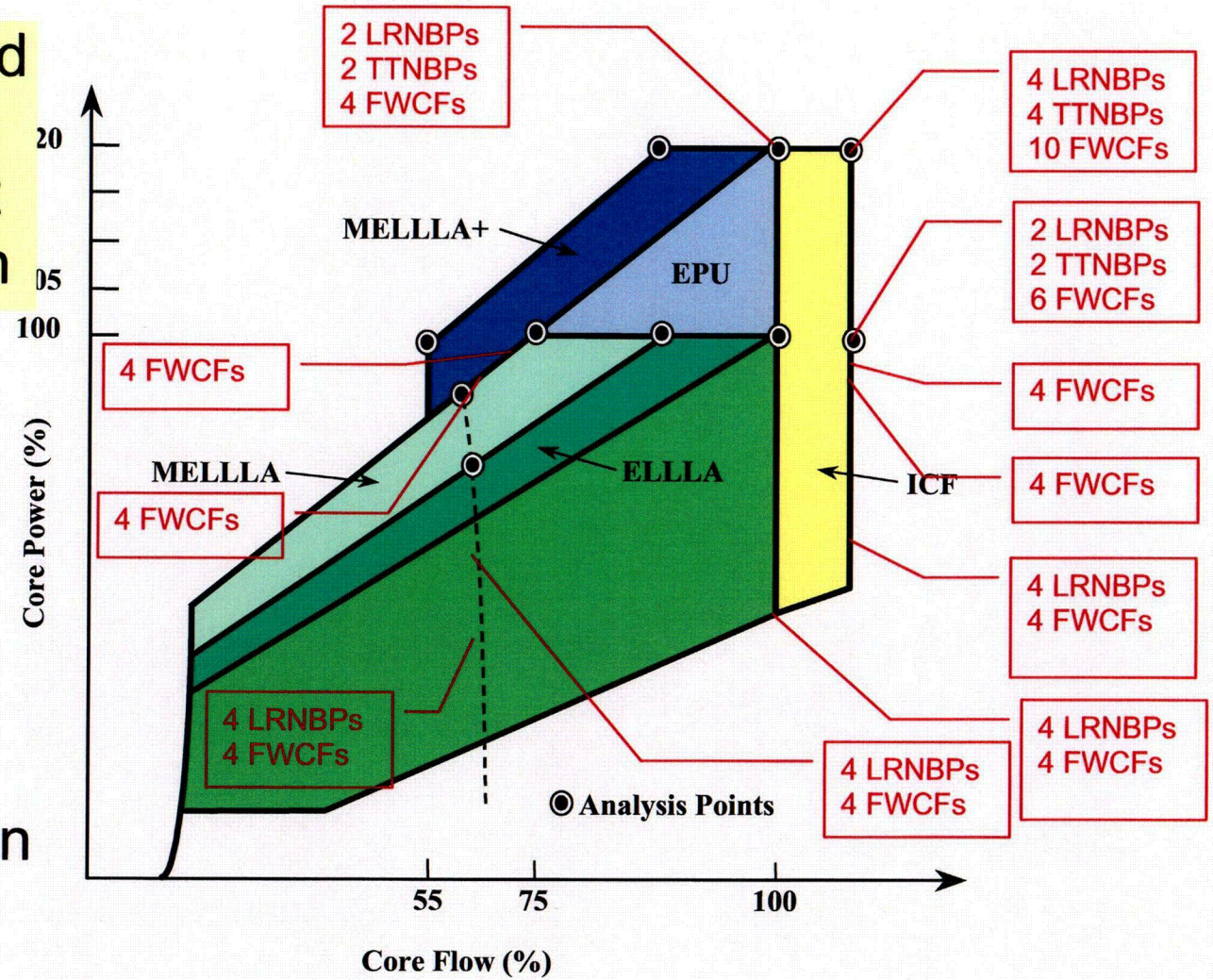
GESTAR does NOT "license" any flexibility options.

> Licensee may submit to the NRC as a License Amendment

OLMCPR and Generic MCPR Limit Confirmation

BWR/3

Pressurization Event Matrix



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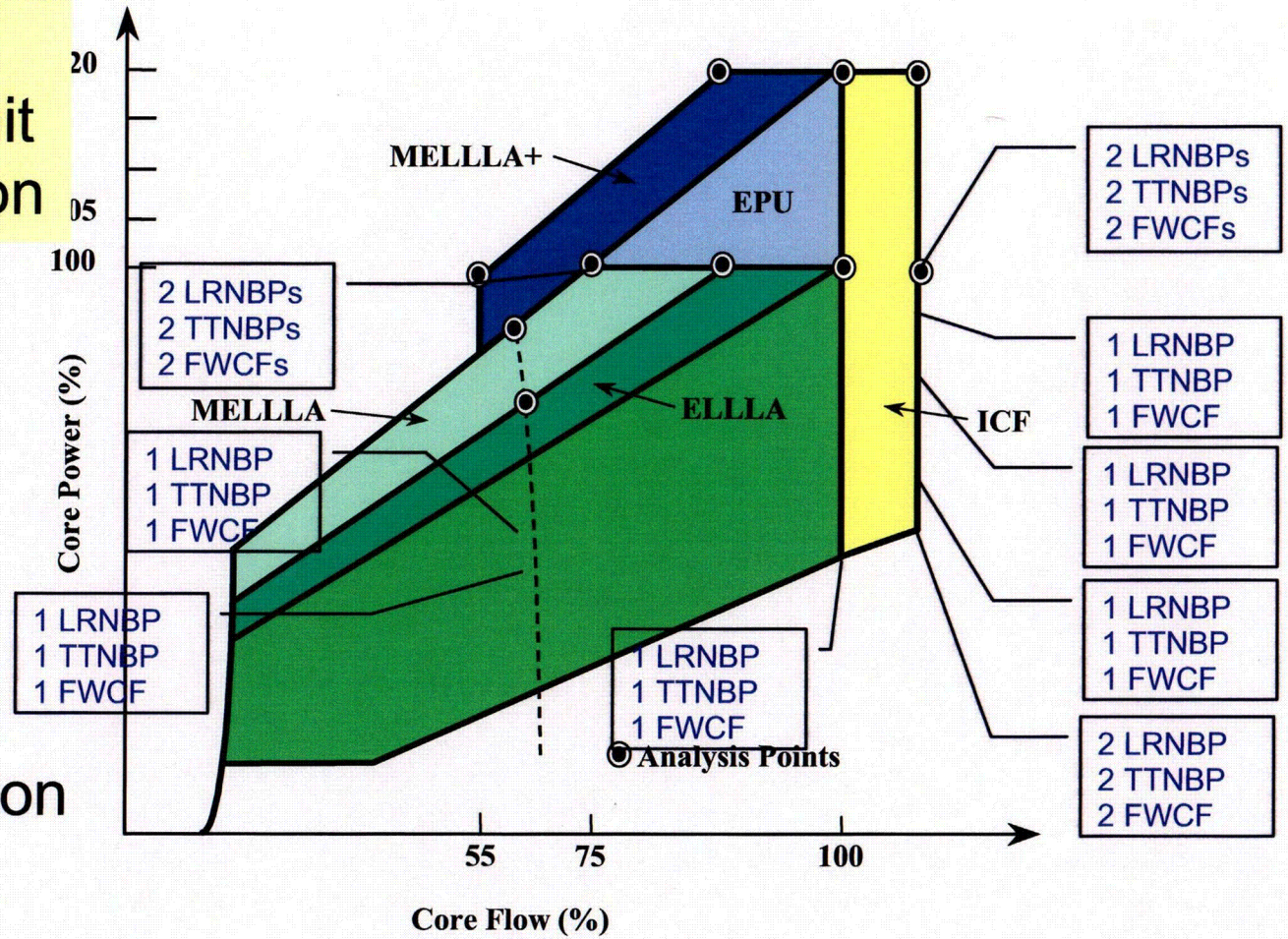
C02

OLMCPR and Generic MCPR Limit Confirmation

BWR/4 Plant A

Pressurization Event Matrix



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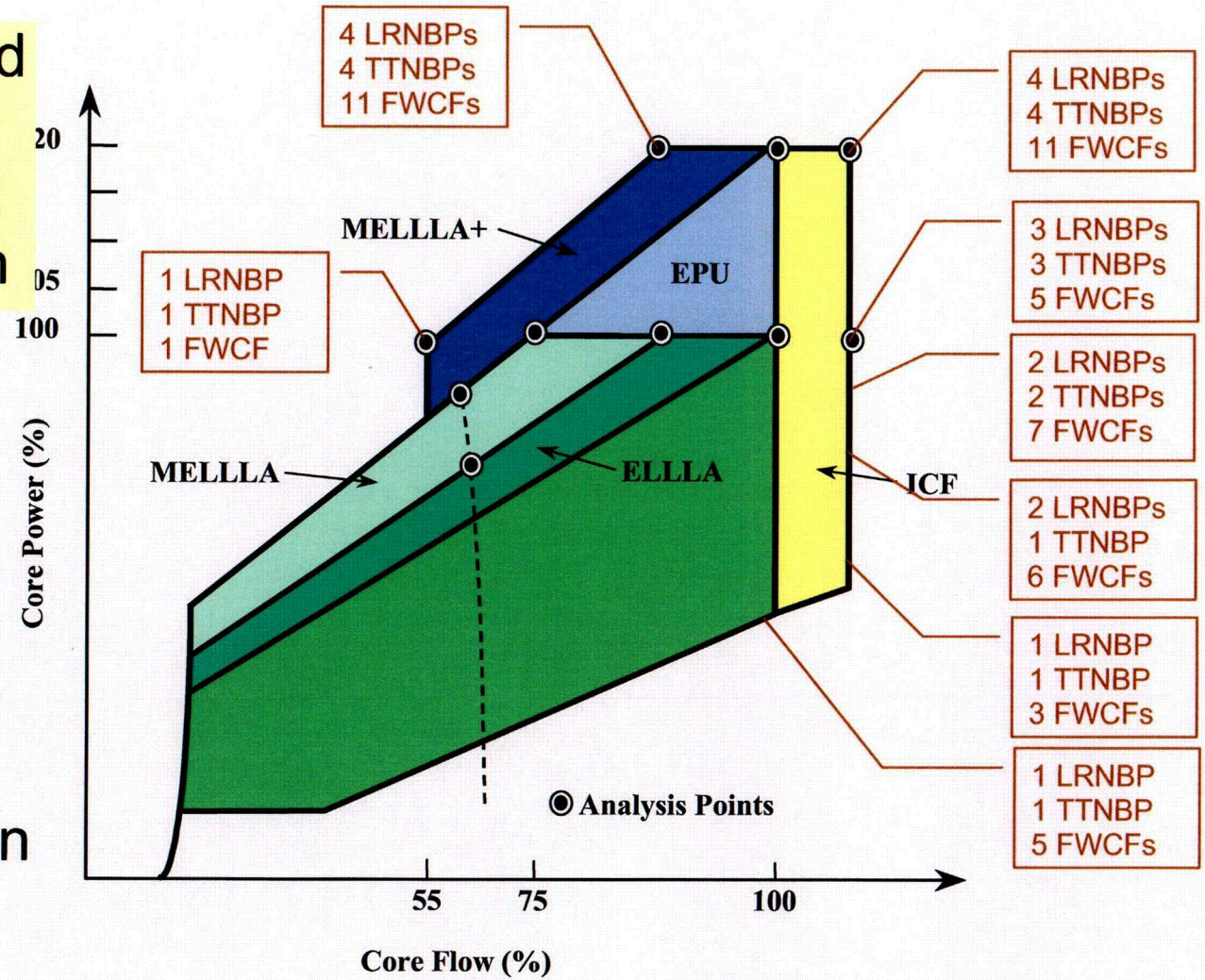
C03

OLMCPR and Generic MCPR Limit Confirmation

BWR/4 Plant B

Pressurization Event Matrix



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C04

Transient Selection

[[

{3}]]

Transient Selection

[[

{3}]]

Transient Selection

[[

{3}]]

Transient Selection

[[

{3}]]

Typical Pressurization Transient Selection Matrix

[[

{3}]]

Transient Selection Review

[[

{3}]]

Mixed Fuel Cores

Mixed Fuel (non-GNF) cores are handled no differently than GNF fueled cores for transient analysis

Process is data driven and needs:

Defined geometry and hydraulic characteristic

GEXL Correlation

Overpower Limits (MOPs and TOPs)

Mixed Fuel Cores

Once this data is defined:

Statistical Adders are developed for the fuel type / plant application

Rated and Offrated Limits are Calculated

Reload Licensing Report contain OLMCPR requirements for fuel type

Technical Design Procedures

The GESTAR and LTR requirements are implemented in TDPs. There are many related to transient analysis, including:

TDP-0024 Reload Licensing for Non-Standard Operation
TDP-0087 OPL - 3 Design Guide
TDP-0035 Rod Withdrawal Error
TDP-0029 Selection of Reactor States for Transient Analysis
TDP-0038 Mislocated Fuel Loading Error
TDP-0040 Reload Transient Analysis
TDP-0041 Generator Load Rejection
TDP-0042 Turbine Trip
TDP-0043 Main Steam Isolation Valve Closure Transients
TDP-0044 Loss of Feedwater Heating
TDP-0045 Feedwater Control Failure - Increasing Flow
TDP-0047 Pressure Regulator Downscale Failure
TDP-0051 REDYM & ODYNM Basedeck Input
TDP-0057 ODYN Statistical CPR Analysis
TDP-0145 Inadvertent High Pressure Coolant Injection Startup

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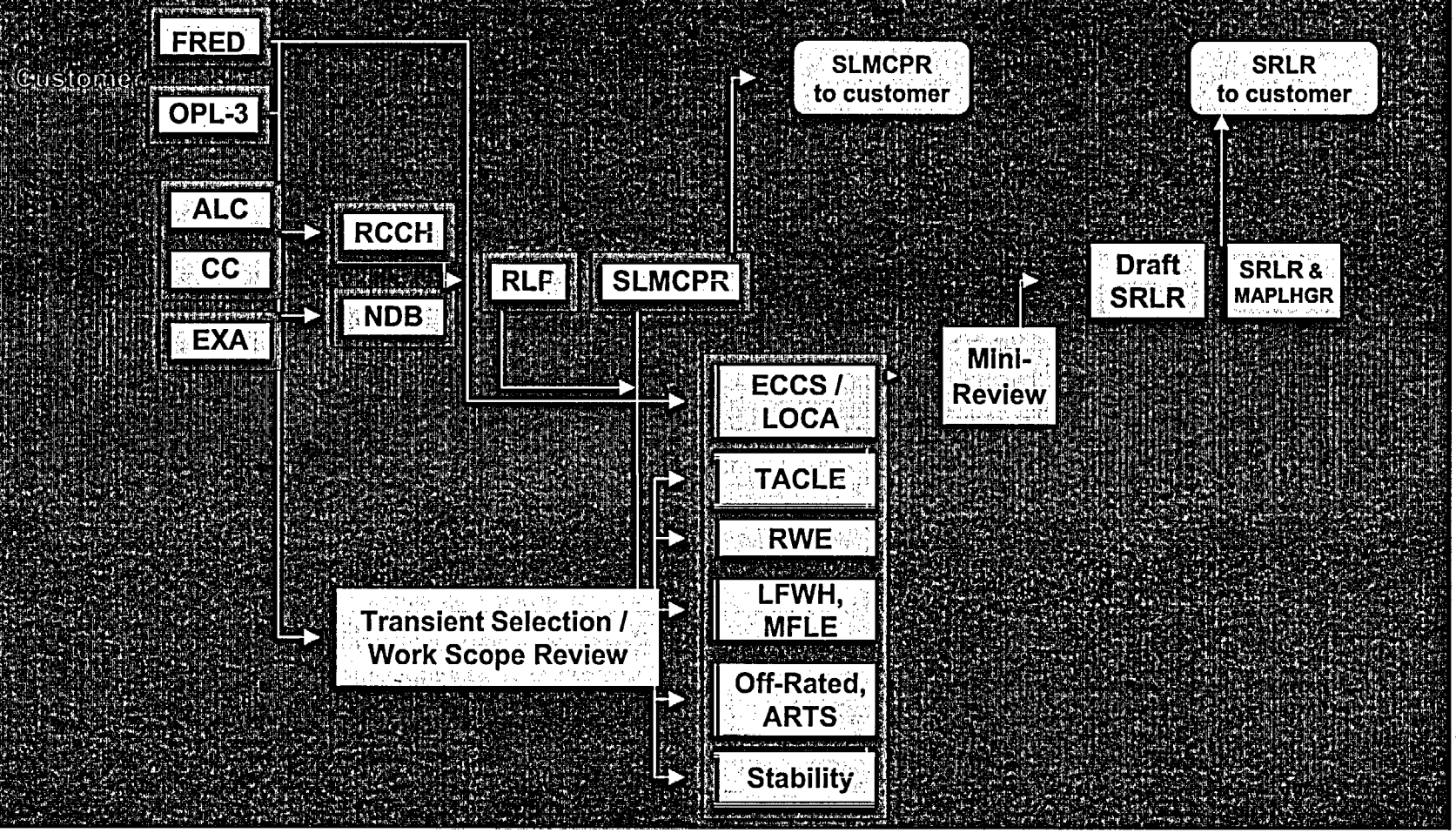
for Reactor Fuel

GESTAR II Review
LOCA / 10CFR50.46 Compliance

Wayne Marquino
April 19-20, 2004

Standard Licensing Process



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GESTAR Regulatory Requirements - LOCA

1.2.10 Loss–of–Coolant Accident Analysis Methods

> The criteria in 10CFR50.46 shall be met on plant–specific or bounding analyses.

> Plant MAPLHGR adjustment factors must be confirmed when a new fuel design is introduced.

4.2.2 Max. Average Planar Linear Heat Generation Rate (MAPLHGR)

> Models used given in Section 2. (S.2.2.3.2 describes SAFE and SAFER Application Methodology)

> Comply with 10CFR50 Appendix K limits

Loss-of-Coolant Accident (LOCA)

Design Basis Event

> Governed by 10 CFR 50.46, App. A & K of 10 CFR 50

> Potential restrictions if acceptance criteria not met

> Any reactor coolant pressure boundary pipe; Any size including double-ended rupture of largest pipe

> Include adverse effects of loss-of-offsite power

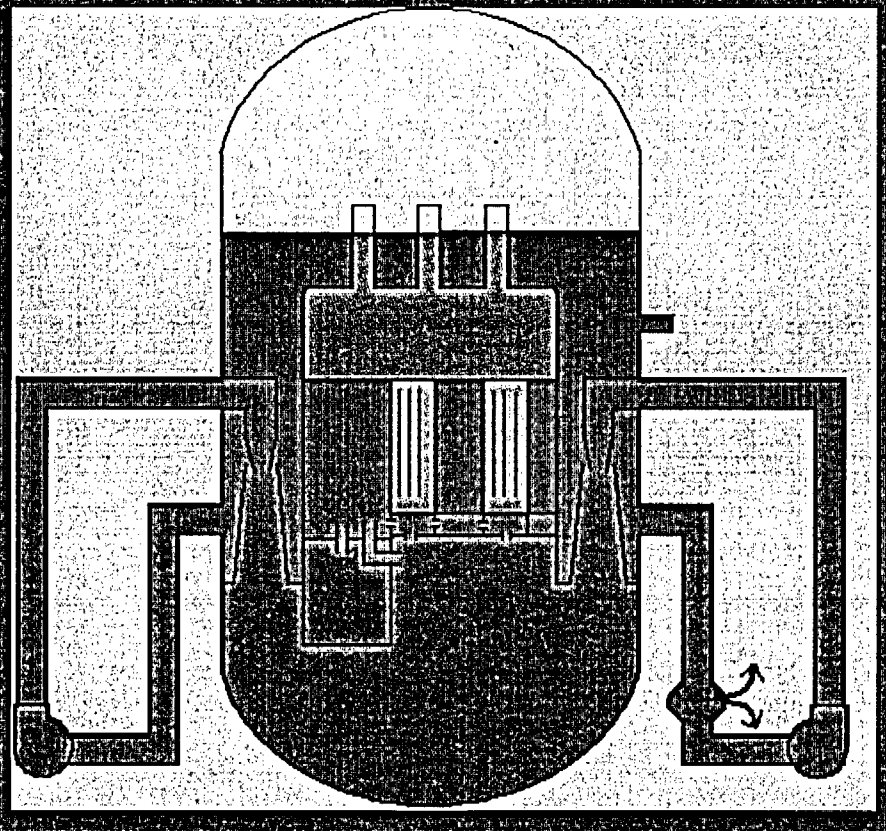
> Concurrent with single active failure

Protection systems function

> Scram (High DW pressure, L3 water level, high steam flow)

> ECCS trips (High DW pressure, low water level 2 or 1)

Initial Pipe Rupture



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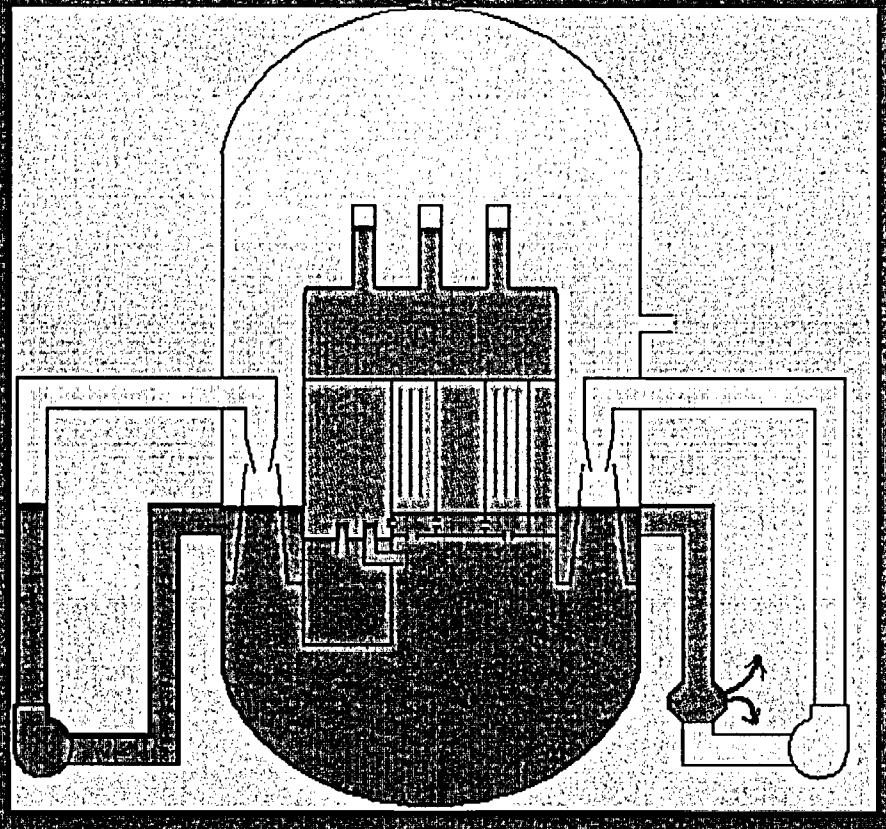
Suction Line Uncovery



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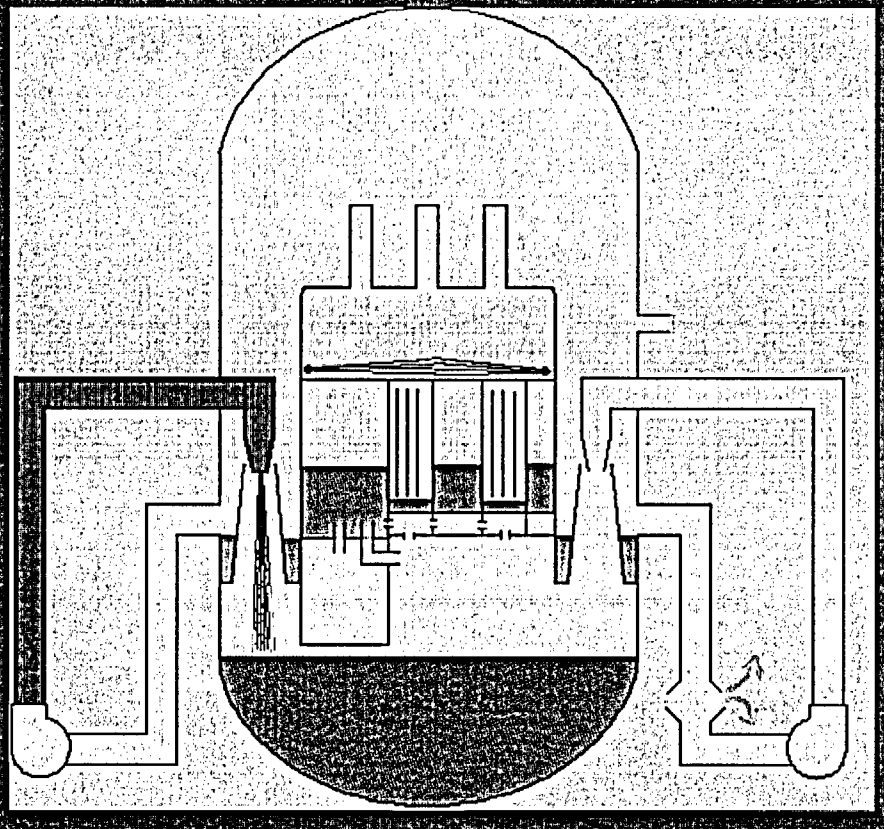
ECCS Initiation



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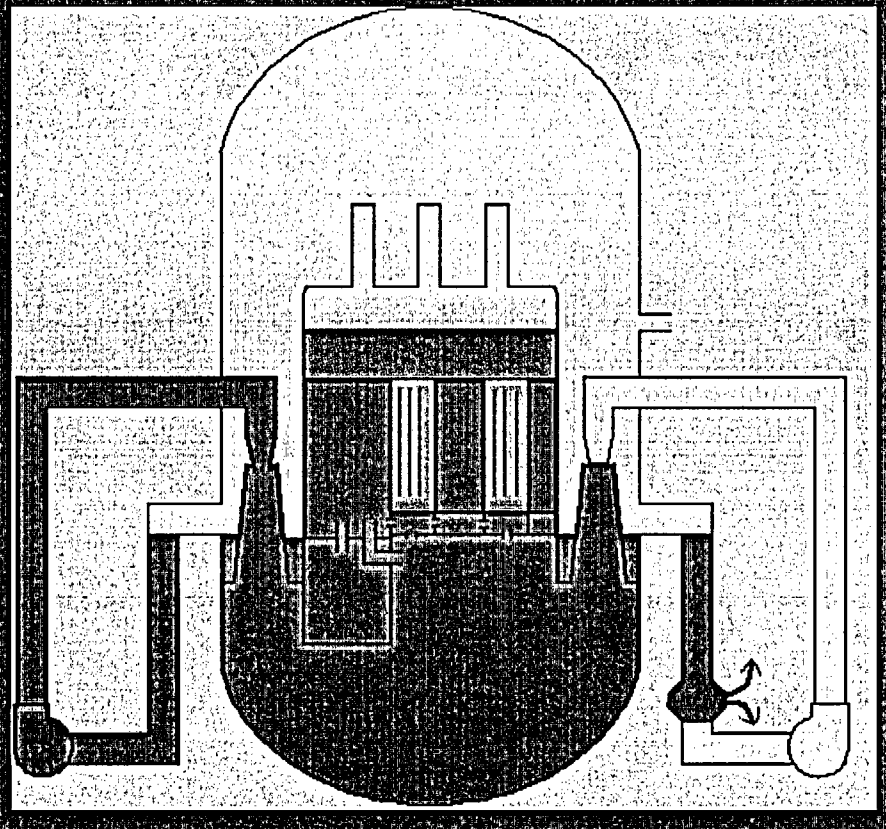
Core Reflood



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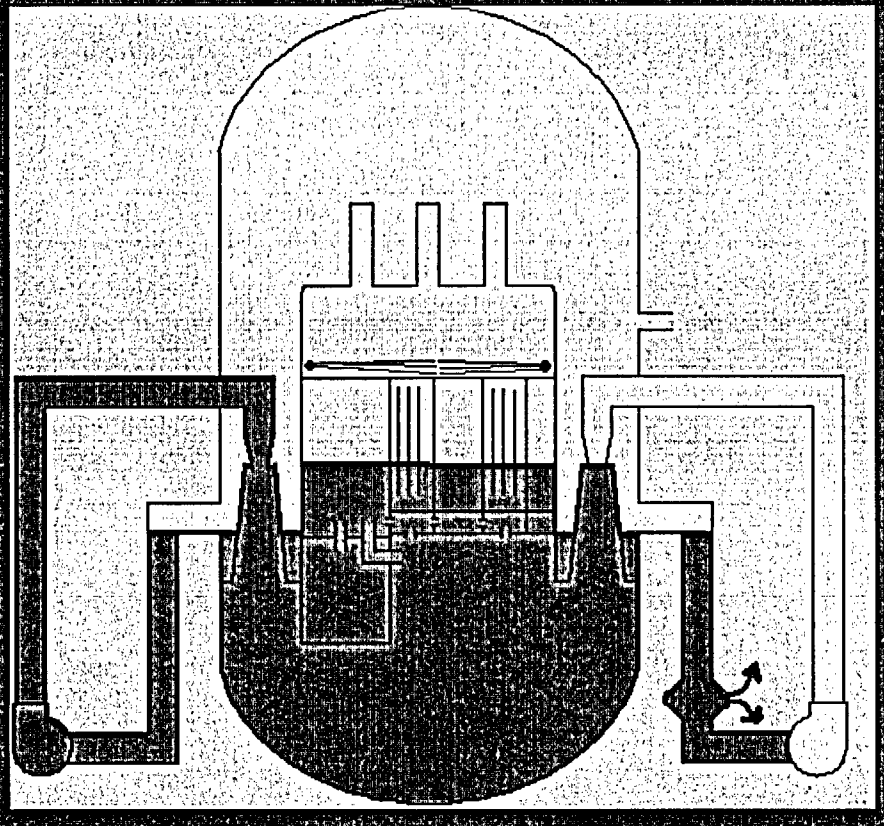
Long-Term Cooling



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Acceptance Criteria - 10 CFR 50.46

Peak Cladding Temperature < 2200°F

Peak Local Oxidation < 17%

Core-Wide Metal-Water Reaction < 1%

Coolable Geometry

Long Term Cooling Capability

SAFER Application Methodology

[[

{3}]]

SAFER/GESTR complies w/ Appendix K requirements and is approved by NRC

GESTAR Figure S–2: Loss–of–Coolant Accident Evaluation Model (Process Map)

[[

{3}]]

SAFER Analysis Inputs

OPL-4, ECCS Parameters (Customer Review)

[[

> {3}]]

> Plant Operating Conditions: Power, Flow, Pressure, Temp.

OPL-5, Single Failures/Systems remaining (Customer Review)

Fuel Inputs

Plant Modeling Inputs (geometry, heat slabs, etc.)

New Fuel Introduction

Perform subset of base analysis w/ both App K & Nominal assumptions:

[[

{3}]]

Power Uprate or Extended Power Uprate (EPU)

[[

{3}]]

Constant Pressure Power Uprate (CPPU)

[[

{3}]]

MELLLA plus

Determine PCT (nominal & Appendix K assumptions) at M+ core flow, and lower.

NRC RAI pending establishing Licensing Basis PCT from M+ results

Upper Bound PCT validation

A 95% statistical Upper Bound PCT was required per the SAFER/GESTR SER

> Purpose is to assure the Licensing Basis PCT is conservative

Confirmation that the generic UB PCT applied to a specific plant was required in the SER

[[

{3}]]

Recent NRC SER approved using these plant specific UB PCTs, and the magnitude of the PCT change to confirm the conservatism of the Licensing Basis PCT

[[

{3}]]

LOCA Reload Evaluation

[[

{3}]]

LOCA thermal limits

MCPR (Minimum Critical Power Ratio)

[[

{3}]]

LHGR (Linear Heat Generation Rate kw/ft)

[[{3}]]

MAPLHGR (Average Planar Linear Heat Generation Rate kw/ft)

[[

{3}]]

SLO (Single recirc. Loop Operation)

More rapid flow reduction: 1 loop stopped, break in other loop

"First peak" PCT higher

[[

{3}]]

Off rated Thermal Limits

[[

{3}]]

When they are considered in the LOCA analysis, the limits are checked to apply each reload.

LOCA Summary

LOCA Analysis demonstrates that 10CFR50.46 criteria are met (GESTAR 1.2.10 A)

SAFER/GESTR methodology is NRC reviewed & approved and meets Appendix K (GESTAR S.2.2.3.2)

Reload evaluation assures the previous analysis remains bounding, or provides a new analysis

MAPLHGRs are determined is plant is ECCS limited (GESTAR 1.210 B)

New Fuel Introduction provides plant specific analysis for a new fuel type.

Plant configuration changes also require plant specific analysis, e.g., EPU

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Stability Analysis

Fran Bolger, GE Nuclear
April 19-20, 2004

Topics

- GESTAR II Requirements
- GESTAR II Demonstration
- Reload Process for Stability
- Stability Options
- Mixed Fuel
- Technical Design Procedures

GESTAR II Amendment 22 Requirements

The new fuel design must meet either of the criteria described below:

1. The stability behavior, as indicated by core and limiting channel decay ratios, must equal to or better than a previously approved GE fuel design."

2. If the core and limiting channel decay ratios are not equal to or better than a previously approved GE fuel design, it must be demonstrated that there is no change to the exclusion zone.

   Note: exclusion regions are generated or validated every cycle for nearly every plant

GESTAR II Stability Analysis

NRC General Design Criteria:

–Reactor instability can be either *prevented*, or

–Reliably and readily, *detected and suppressed*

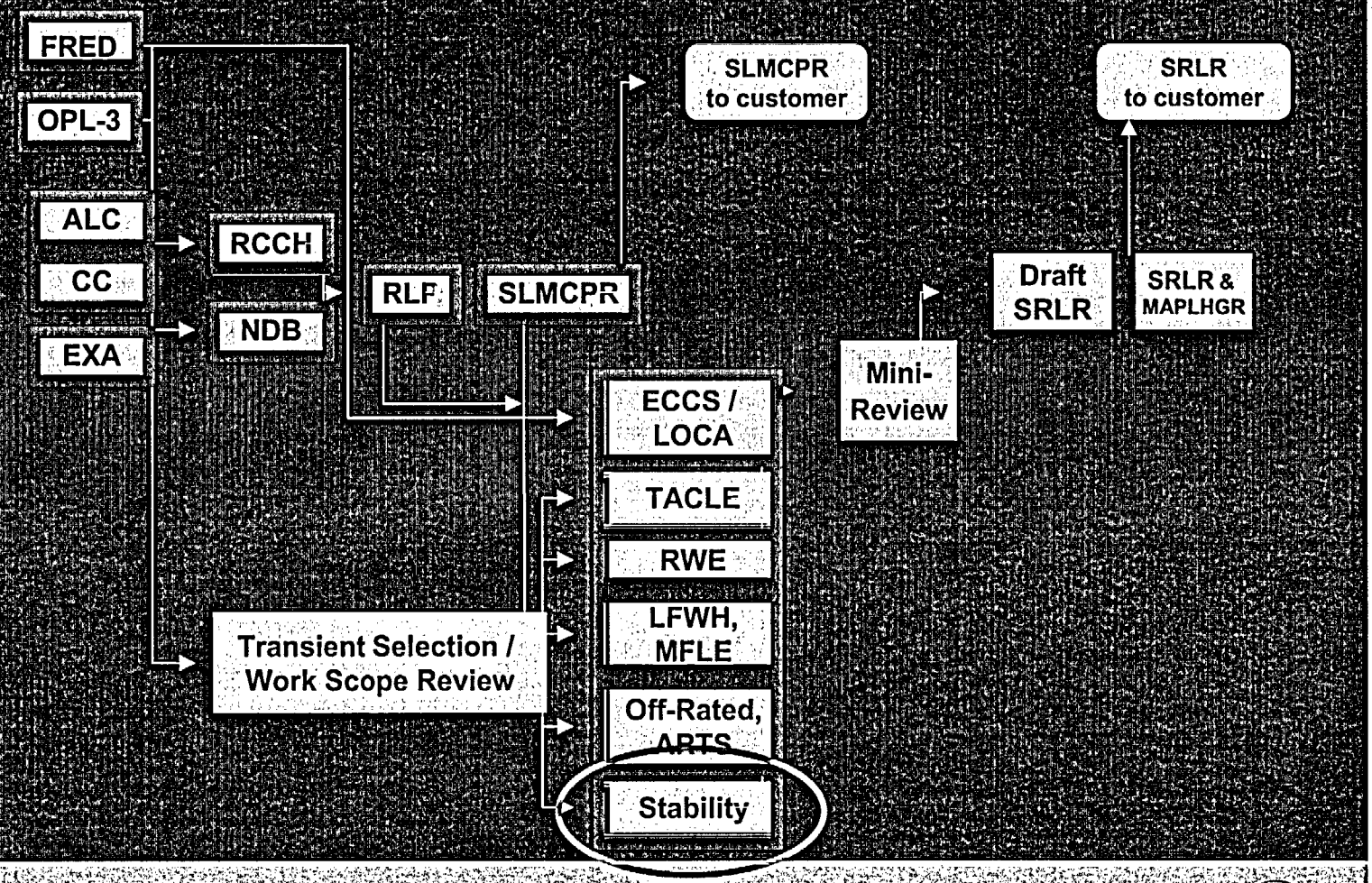
Criterion 10 (Reactor Design) requires that:

"The reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated occurrences."

Criterion 12 (Suppression of Reactor Power Oscillations) requires that:

"The reactor core and associated coolant, control, and protection systems shall be designed to assure that power oscillations which can result in conditions exceeding specified acceptable fuel design limits are not possible or can be reliably and readily detected and suppressed."

Stability Reload Licensing Process



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Fran Bolger
April 19-20, 2004

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Reload Process

Each US plant is required to implement one of the stability long-term solutions. The current long term stability options are:

1. Enhanced Option I-A
2. Option I-D
3. Option II
4. Option III

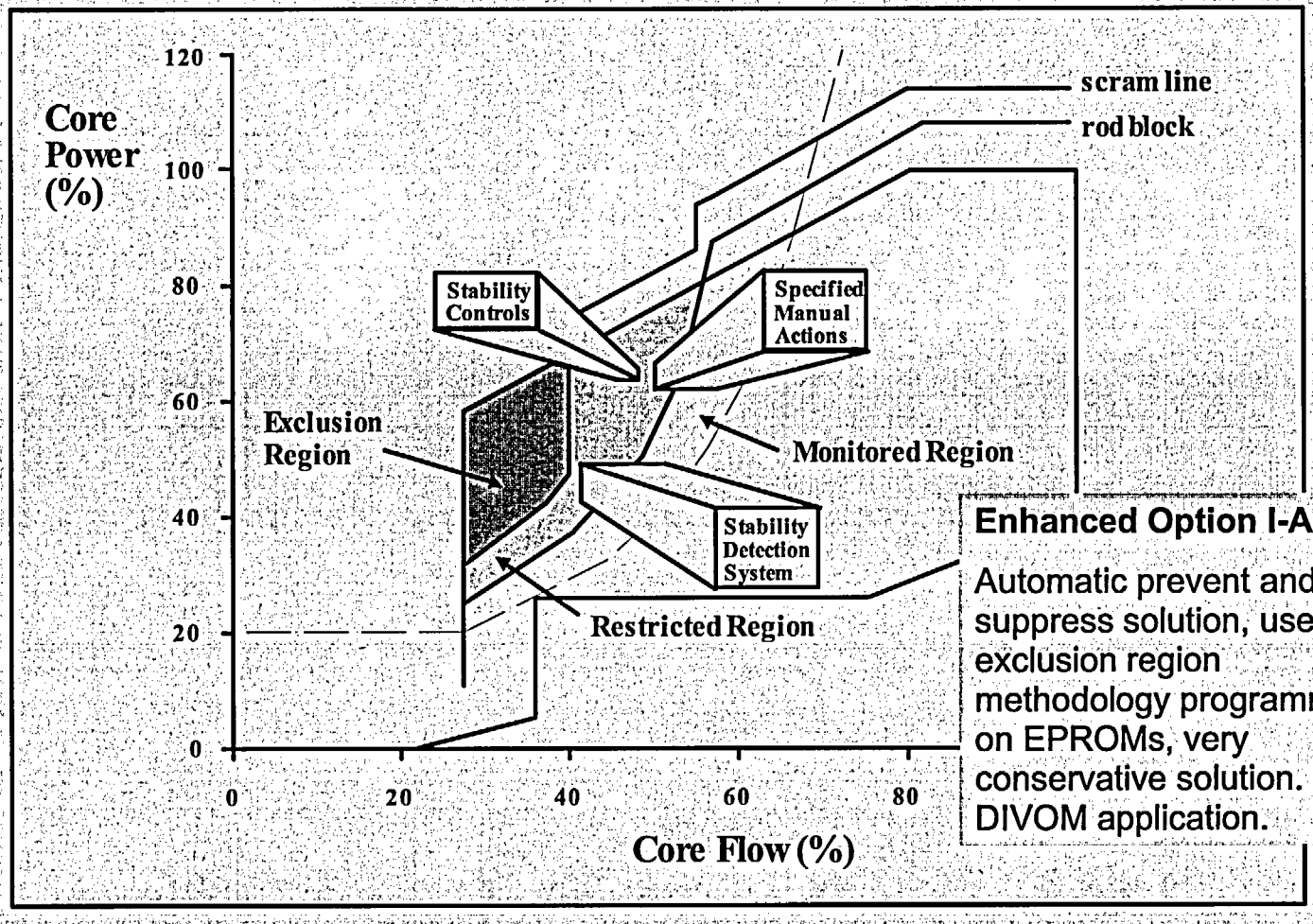
New stability solutions pending review and approval:

1. Detect and Suppress Solution – Confirmation Density (DSS-CD)
2. Detect and Suppress Solution – APRM Based (DSS-AB)

Backup stability solutions:

1. Interim Corrective Action (ICA) for Option III
2. Backup Stability Protection (BSP) for Option III
3. BSP for DSS-CD

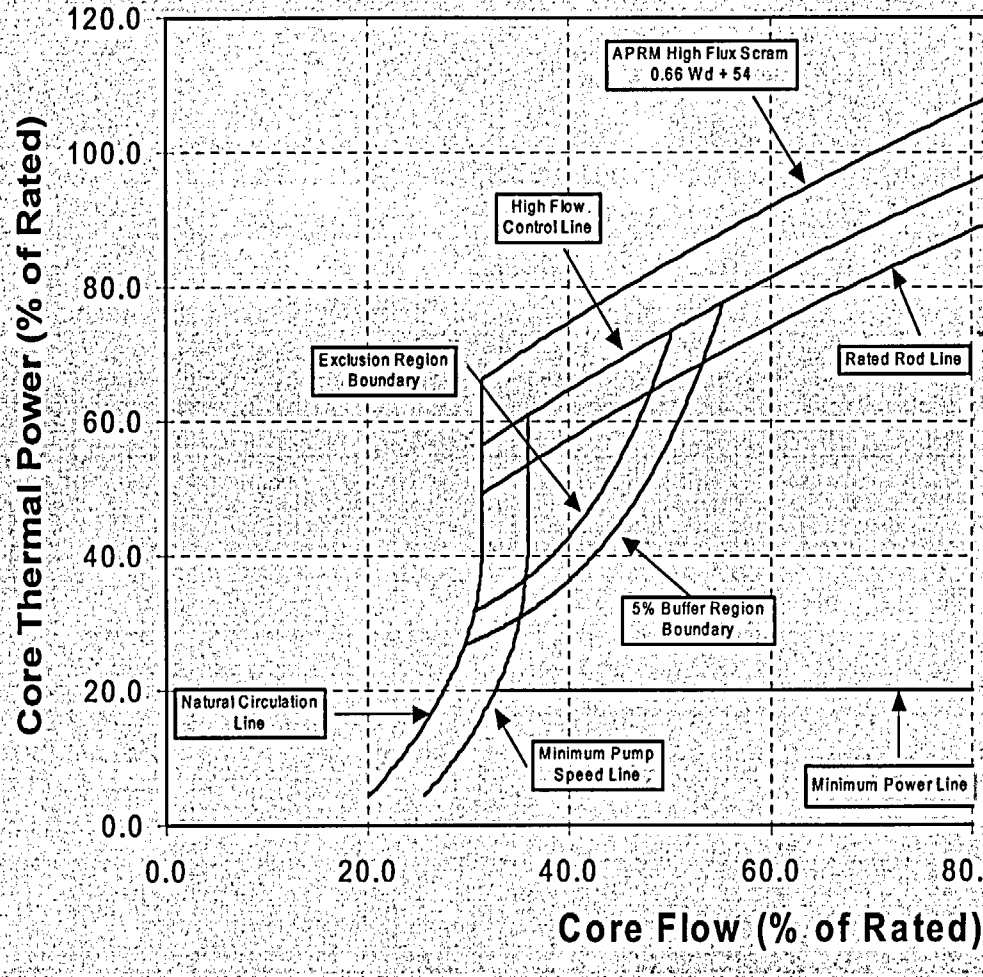
Enhanced Option 1A Stability



Enhanced Option I-A (E1A)

Automatic prevent and suppress solution, uses exclusion region methodology programmed on EPROMs, very conservative solution. No DIVOM application.

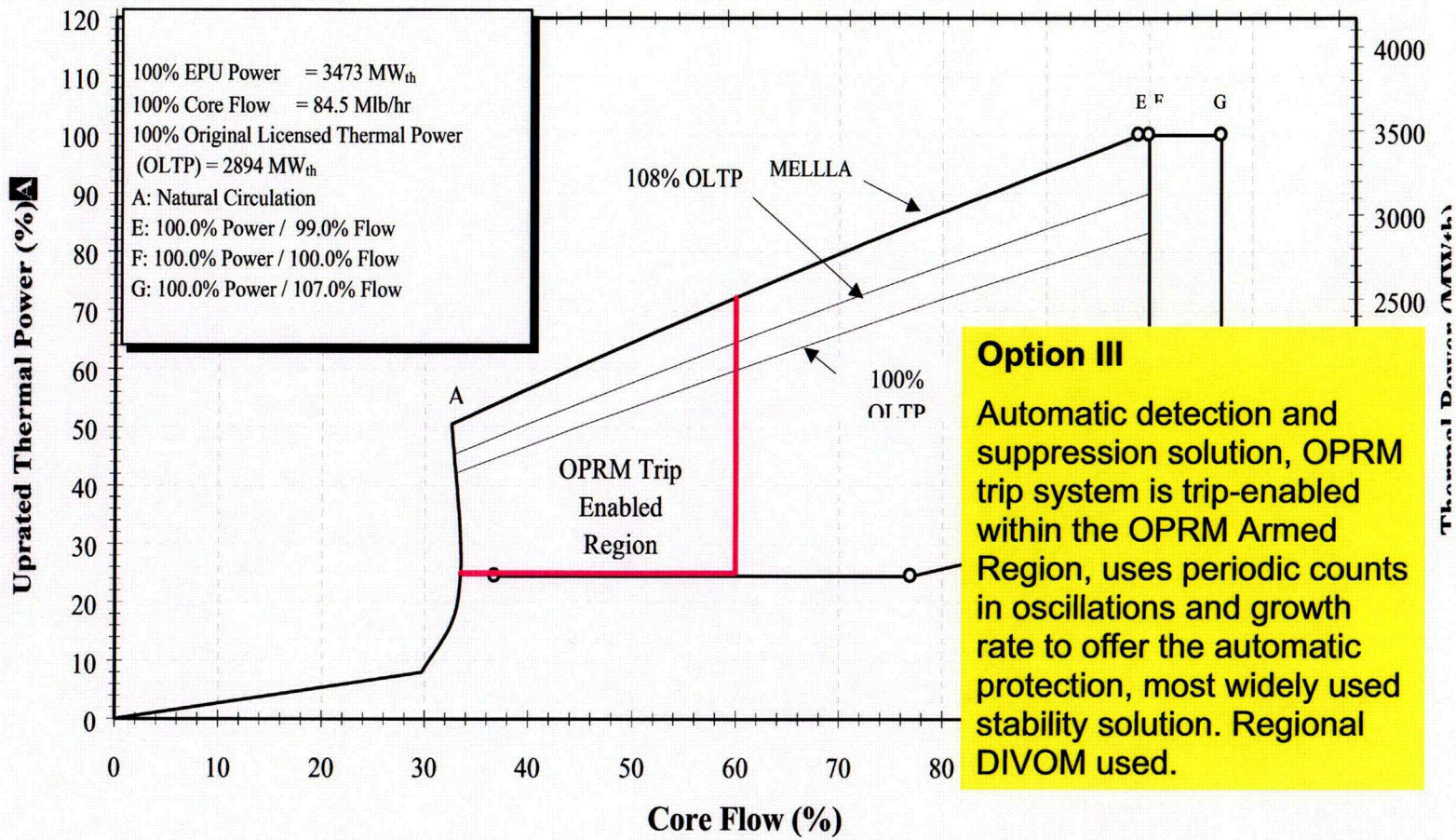
Option 1D Stability



Option I-D

Small sized plant, tight orifice, core-wide mode dominance over the regional mode oscillation, stability online monitor (SOLOMON) required, exclusion region based, depends on the APRM flux-scram line to offer the stability protection. Core-wide DIVOM used.

Option III Stability

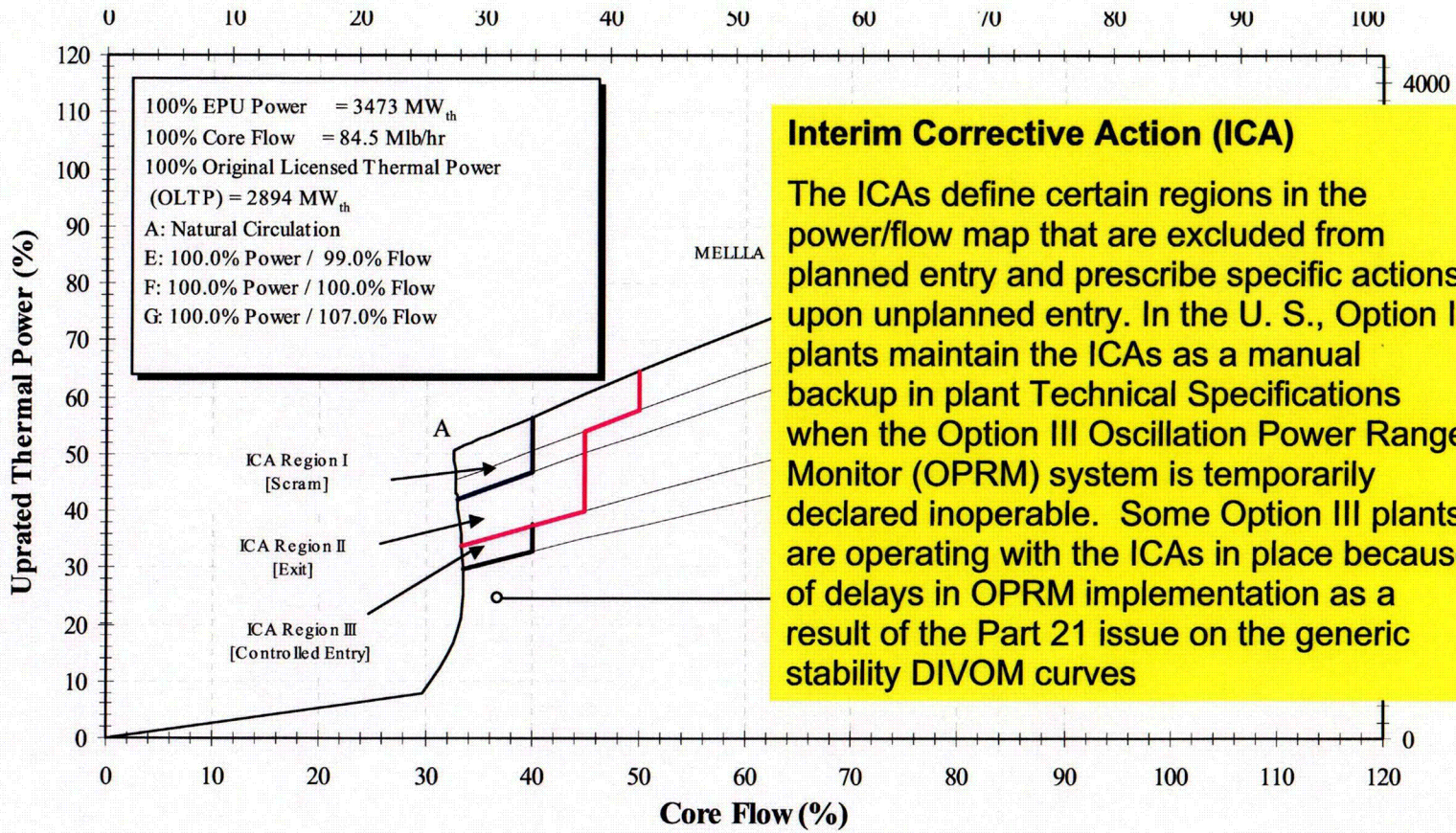


Option III

Automatic detection and suppression solution, OPRM trip system is trip-enabled within the OPRM Armed Region, uses periodic counts in oscillations and growth rate to offer the automatic protection, most widely used stability solution. Regional DIVOM used.

C05

ICA Stability



Interim Corrective Action (ICA)

The ICAs define certain regions in the power/flow map that are excluded from planned entry and prescribe specific actions upon unplanned entry. In the U. S., Option III plants maintain the ICAs as a manual backup in plant Technical Specifications when the Option III Oscillation Power Range Monitor (OPRM) system is temporarily declared inoperable. Some Option III plants are operating with the ICAs in place because of delays in OPRM implementation as a result of the Part 21 issue on the generic stability DIVOM curves

C06

Other Stability Options

Option II

Quadrant-based, BWR/2 only, can detect both core-wide and regional oscillations, depends on the APRM flux-scram line to offer the stability protection, exclusion region based. Regional DIVOM used.

BSP (Option III Backup)

Backup Stability Protection (BSP) may be used when the Option III OPRM system is temporarily inoperable, applicable up to and including EPU/MELLLA operation. The BSP regions are confirmed on a plant cycle specific basis to provide consistency with the LTS general requirement of long-term applicability.

Key Stability Licensing Documents

BWR Owners' Group Long-Term Stability Solution Licensing Methodology, NEDO-31960-A, November 1995.

BWR Owners' Group Long-Term Stability Solution Licensing Methodology (Supplement 1), NEDO-31960-A, Supplement 1, November 1995.

Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Application, NEDO–32465–A, August 1996.

BWROG-94079, "BWR Owner's Group Guidelines for Stability Interim Corrective Action," June 1994.

BWROG-02072, Review of BWR Owners' Group Guidelines for Stability Interim Corrective Action, November 20, 2002.

OG 02-0119-260, GE to BWR Owner's Group Detect and Suppress II Committee: "Backup Stability Protection (BSP) for Inoperable Option III Solution," July 17, 2002.

NEDC-33143P, General Electric Boiling Water Reactor Detect and Suppress Solution – APRM Based, April 2004 (pending NRC review).

NEDC-33075P, Rev. 4, General Electric Boiling Water Reactor Detect and Suppress Solution – Confirmation Density, March 2004 (under NRC review).

NEDC-32992P-A, ODYSY Application for Stability Licensing Calculations, July 2001.

NEDO-32339-P, Rev. 1, Reactor Stability Long-Term Solution: Enhanced Option I-A, June 1997.

Reload Stability Analysis

Option-specific stability requirements will require plant-specific evaluations as a result of using a new fuel design. For instance, the Option I-D solution requires an Exclusion Region to deter the inadvertent entry. The determination of this Exclusion Region depends to a large extent on the fuel type and fuel burnup. Hence, a new fuel introduction to an Option I-D plant may require a new Exclusion Region, which may be larger or smaller than the existing Exclusion Region.

Reload Stability Scope

	E1A	Option 1D	Option II	Option III	ICA	BSP
Detect and Suppress Adequacy Review		X	X	X		
Exclusion Region Calculation	X	X	X		X	X
SLMCPR Protection Check		X	X	X		
Trip Reference Functions	X					
Exclusion Regions Rescaling					X	
OPRM Armed Region				X		
Hot Channel Oscil. Magnitude (HCOM)		X	X	X		
TRACG Evaluation if Required		X	X	X		

Technical Design Procedures

The GESTAR and LTR requirements are implemented in TDPs. There are many related to stability analysis, including:

TDP-0097 Option I-D (FABLE-Based)

TDP-0127 Option I-D (ODYSY-Based)

TDP-0084 E1A Stability

TDP-0155 BSP/ICA Stability

TDP-0098 Option III Stability

TDP-0138 TRACG Stability Application

Mixed Fuel Cores

Stability analysis is either validated or performed for every reload. Hence all mixed fuel cores are covered.

Part 21 DIVOM Issue

GE issued Part 21 notifications 6/29/01 and 8/31/01:

- **Generic regional DIVOM curve non-conservative for high peak bundle powers in current core designs**
- **OPRM setpoints based on generic regional DIVOM may not provide SLMCPR protection for instability events**
- **Does <u>not</u> produce a significant safety hazard**
- **The BWROG with assistance from GE is currently developing a plant-specific DIVOM guideline for resolution of this Part 21 issue.**
- **All Option III plants have sent in commitment letters to the Staff for OPRM system arming. GE is currently helping utilities develop plant-specific DIVOM curve.**

GNF

Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

NEDE-24011-P-A-14-US
Class III
June 2000

Global Nuclear Fuels – Americas
Proprietary Information

Licensing Topical Report

General Electric Standard Application
for Reactor Fuel

GESTAR II As Loaded Core Confirmation

Jim Fawks, GNF
April 19-20, 2004

GESTAR II 3.4 Final Loading Pattern Comparison -TDP-0020 tdp_0020

- Various levels
  - Level 1
    - No impact on key parameters that affect the licensing calculations
  - Level 2
    - No impact on key parameters that affect the operating limits
  - Level 3
    - New licensing calculations and/or operating limits

GESTAR II 3.4 Final Loading Pattern Comparison -TDP-0020 tdp_0020

- Level 1
  - Identifies key parameters that affect the licensing calculations and their allowable variance
    - Key parameters
      - Bundle type/number/placement deviation criteria
      - Exposure deviation criteria

GESTAR II 3.4 Final Loading Pattern Comparison -TDP-0020 tdp 0020

- Level 2
  - Identifies key parameters that determine the operating limits and their allowable variance
    - Key parameters
      - Scram reactivity
      - Dynamic void coefficient
      - Peak fuel enthalpy during RDA
      - SDM
      - Change in critical power ratio due to a misloaded fuel assembly
      - Rod block monitor response to a rod withdrawal error
      - SLMCPR

Critical Power Monitoring

Presentation to NRC

April 2004

Critical Power Monitoring

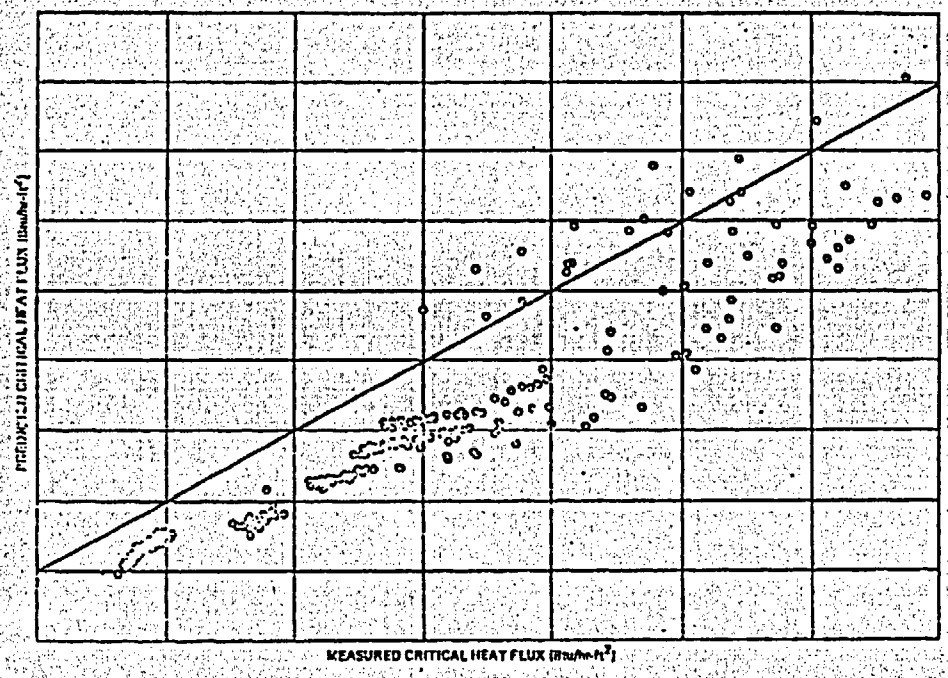
Limit Line Analysis

- Local condition critical heat flux correlation $\Phi_c = f(G, D, P, X)$
- Chosen to bound the data
- Janssen-Levi Limit Line (1962)
  - Based on single heated rod with uniform axial heat flux.
  - Did not simulate multi-rod data
- Hench-Levy Limit Line (1966)
  - Based on 2X2 and 3X3 multi-rod data
  - Did not simulate axial power shape effect

GEXL Boiling length Correlation

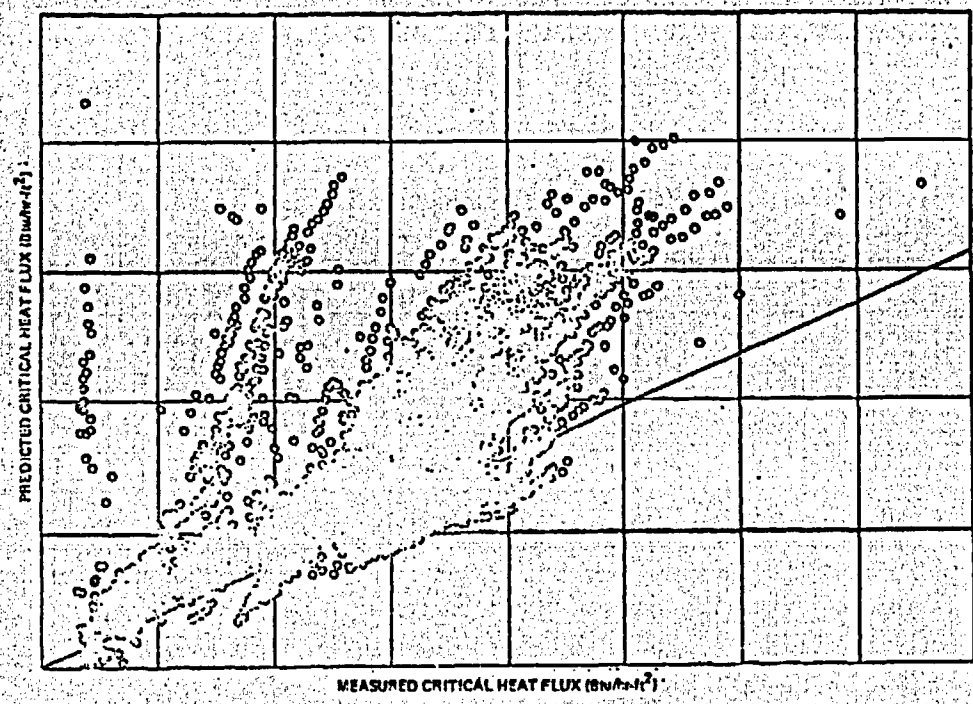
- Critical Quality versus Boiling Length Correlation $X_c = f(G, P, D, R, L_B, L_A)$
- GEXL approved with GETAB in 1974
  - Based on full-size multi-rod data with non-uniform radial and axial power shape
  - Best estimate correlation with a typical 3.5% uncertainty
  - Uncertainty accounted for in Safety Limit
  - GEXL+ approved with Amendment 15 to GESTAR II in 1988

Limit Line Critical Power Correlation (Hench-Levy) Uniform Axial and Uniform Radial heat flux



- Limit Line Correlation bounds most data with uniform heat flux
- Uncertainty covered through a conservative operating limit – Typical 1.9

Limit Line Critical Power Correlation (Hench-Levy)
Non-Uniform Axial and Radial Heat Flux



- Large errors in predicted critical heat flux

Limit Line versus GEXL

[[

{3}]]

- Greatly improved accuracy with GEXL correlation

GNF Proprietary Information

Summary

- Original Critical Power Based on Limit Line Local Conditions Correlation
  - Large errors in predicting power shape trends

- GEXL correlation based on Global Parameters
  - Radial power shape captured by R-factors
  - Axial power shape captured by boiling and annular lengths
  - Huge database > 20,000 data points, 7X7, 8X8, 9X9, 10X10
  - Small error [[{3}]]

Technical Design Procedure

LOCA INPUTS AND FUEL STORED ENERGY UNCERTAINTY ANALYSES

TEXICO/GEGAP/GESTR- History of Thermal/Mechanical (T/M) MODELS

Mark Colby

April 19-20, 2004

Topics

- Early Generation T/M Codes
- New Codes and Improvements
- History of Transition

imagination at work

Early Generation T/M Codes

GEGAP/TEXICO

GEGAP – stored energy and fission products/gap conductance inputs to LOCA analyses (CHASTE-SAFE/REFLOOD)

TEXICO – fuel rod thermal-mechanical design

New T/M Codes and Differences

Improvements in GESTR-MECHANICAL/GESTR-LOCA Compared to TEXICO/GEGAP

- Added Model for Pellet Constitutive Relationship
- Contact Component for Gap Conductance
- Added Gadolinia Dependence To Fuel Thermal Conductivity and Melting Temperature
- General Update of Material Properties
- Exposure/Temperature Dependent Fission Gas Model
- Expanded Qualification Data Set

History of Transition

GESTR submitted to the NRC in 1981 as next generation Code

- GESTR-LOCA Approved by the NRC in 1983 (Rubenstein September 26th, 1983)
- GE Procedure for Fuel Property and Performance Model Revision Approved in December 1984 (MFN-169-84)
- GESTR-MECHANICAL and Application Methodology Approved by NRC in 1985 (GESTAR Amendment 7 Revision 6, MFN-036-85)

Between 1981 and 1985 new fuel was designed to meet licensing limits with both old and new codes (GE6/7), all fuel after 1985 was designed with GESTR-MECHANICAL

The GEGAP Analysis was continued for sometime with CHASTE-SAFE/REFLOOD methodology as a result of commercial agreements