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ODYSY Application

Stability Licensing Calculations

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Topics

- Goals
- Introduction
- ODYSY Description
- ODYSY Procedure
- Application for Option I-D
- Application for New Fuel Design Licensing
- Application for Enhanced Option I-A
- Conclusions

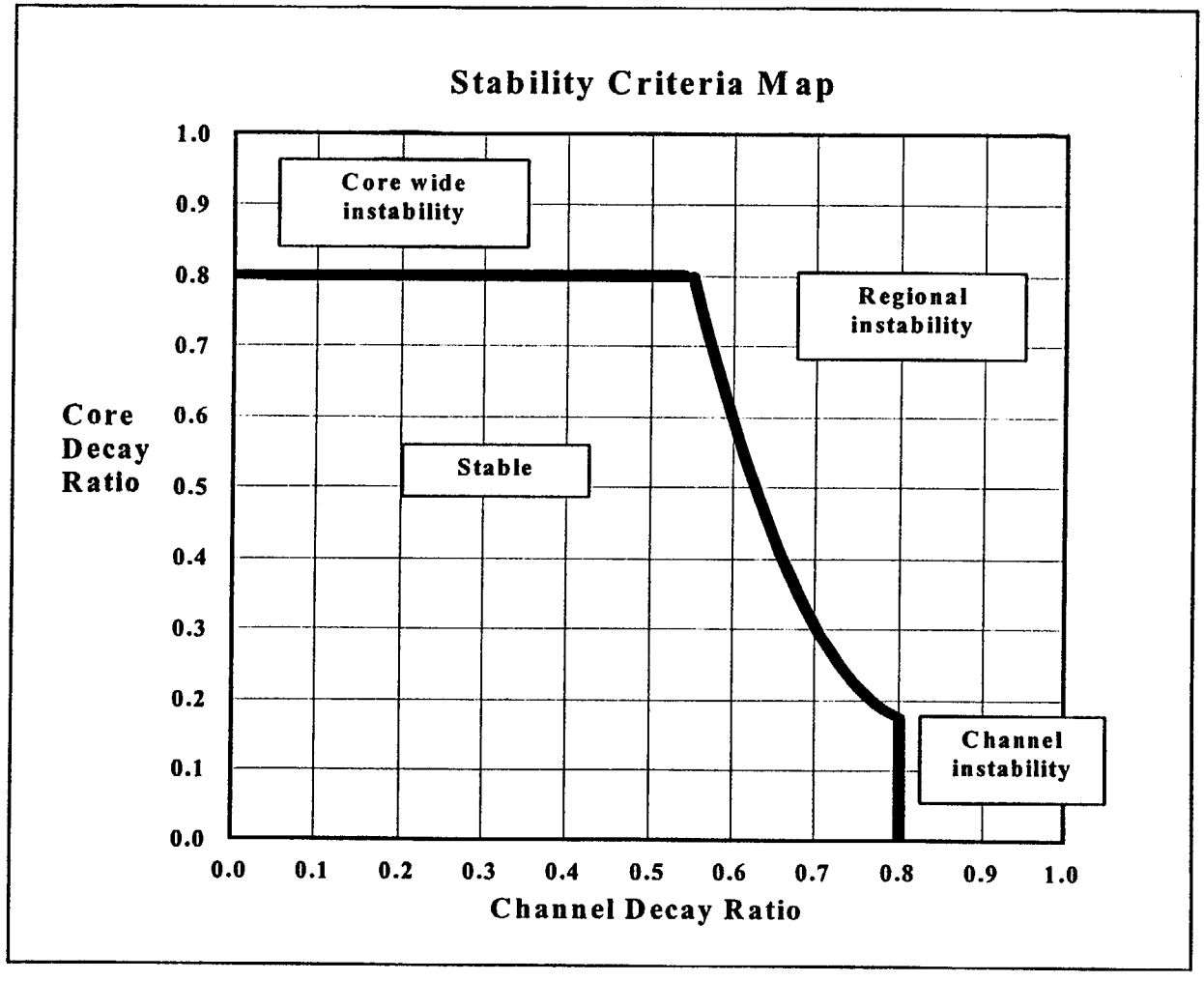
Goals

- **GENE Goals:**
  - **Replace FABLE with ODYSY for all stability licensing calculations**
  - **Establish an ODYSY application procedure**
- **Meeting Goals:**
  - **Obtain feedback from NRC**
    - **Proposed application procedure**
    - **Submittal plans**
    - **Expected review cycle**

Introduction

- Fuel vendor calculation models must include capability to evaluate coupled neutronic-thermal hydraulic stability
  - Development and implementation of stability solutions
  - Core reload licensing
  - New fuel design licensing
- Stability models calculate core and channel decay ratio
- Compare decay ratio to stability criteria map to confirm adequate stability margin

Introduction



Introduction

- Stability Models
  - Laplace transform of time domain equations to produce frequency domain model
    - FABLE is based on REDY
    - ODYSY is based on ODYN
  - ODYN is significant transient model improvement over REDY
    - Improved kinetics and axial geometry modeling
  - REDY use has been phased out – all transient calculations currently performed with ODYN
  - ODYSY provides a corresponding frequency domain model improvement over FABLE

Introduction

- Stability Models (continued)
  - Frequency domain codes require input from core simulator (PANACEA)
  - Significant core tracking improvements from PANAC10 to PANAC11
  - FABLE will not accept PANAC11 input
  - Must use ODYSY if use PANAC11 for core simulation
- NRC has approved procedure for FABLE
- Now establishing procedure for ODYSY

Introduction

- Current approvals, reference documents

FABLE	ODYSY
• Option I-D (and II) exclusion region • E1A standard cycle • New fuel licensing compliance with Amendment 22 of GESTAR II	• E1A region boundary generation and validation (except E1A standard cycle) • Also used: Option I-D Stability On-Line ODYSY Monitor (SOLOMON)
NEDO-31960-A, "BWR Owners' Group Long-Term Stability Solutions Licensing Methodology," November 1995	NEDC-32339P-A Supplement 1, "ODYSY Application to E1A," December 1996, and NEDC-32661P, "ODYSY Description and Qualification," October 1996

Introduction

- Propose to use ODYSY for all licensing applications
- Plan to submit licensing topical report to address new ODYSY applications
  - Option I-D (and II) exclusion region
  - E1A standard cycle
  - New fuel licensing

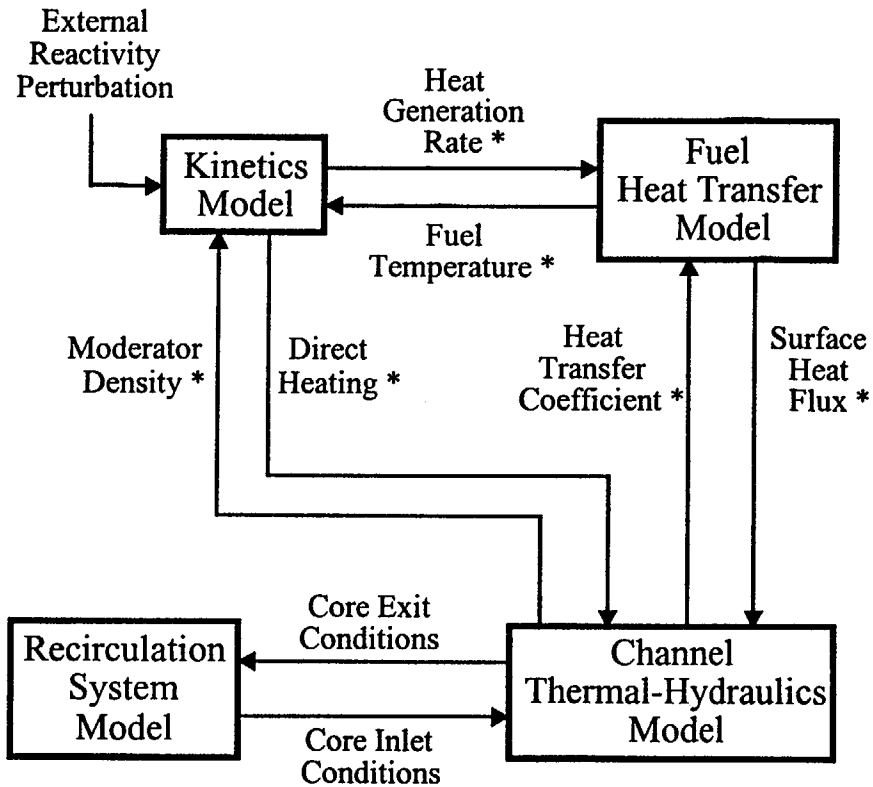
Model review is not required – model use already accepted - only requesting an application extension

Introduction

- ODYSY procedure needed to support lead plant EPU submittal
- ODYSY application schedule
  - Obtain NRC feedback today
  - Provide LTR for staff review September 2000
  - Requesting SER by March 2001
- Application review should be uncomplicated

ODYSY Description

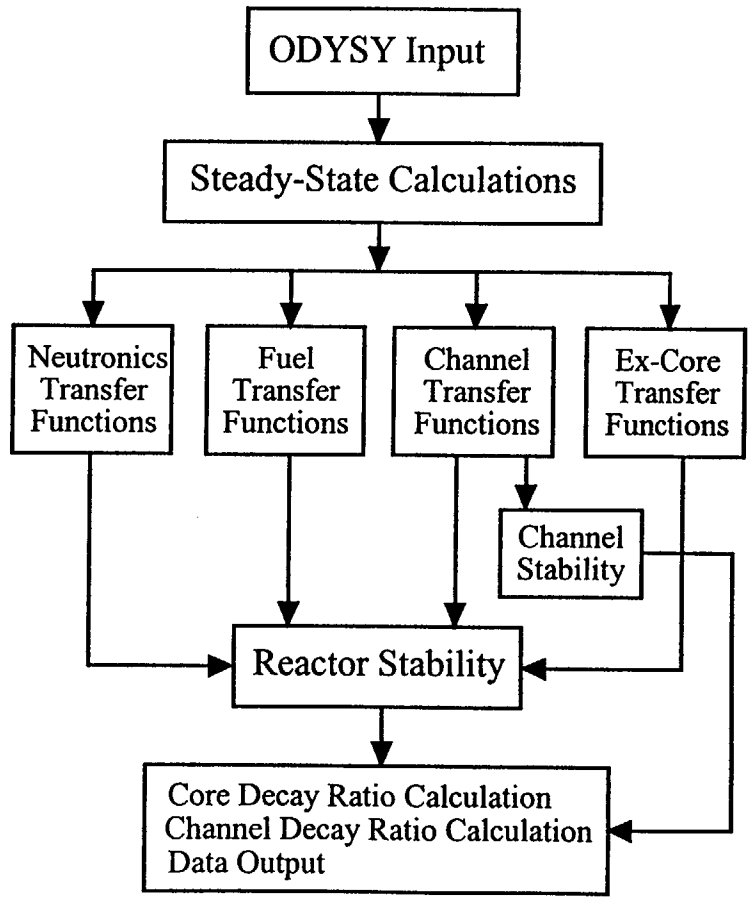
Structure of Models and Interconnections



* For each channel type and axial node

ODYSY Description

Programming Organization



ODYSY Description

Modeling	FABLE	ODYSY
Neutronics	• Point kinetics • Void feedback from flux squared weighting of nodal void reactivities	• 1-D kinetics with void and Doppler feedback • Parameters collapsed from 3-D PANACEA wrap-up
Thermal-Hydraulics	• Mixture equations with subcooled boiling • Bankoff slip correlation	• Drift flux formulation with subcooled voids • Consistent with other GE design methods
Ex-Core Hydraulics	• Numerical transfer function using gain and phase lags based on downcomer and recirc loop geometry	• Upper plenum, separator, downcomer, recirc loops, modeled as hydraulic regions
Fuel Heat Transfer	• Lumped parameter model for cladding, gap, and fuel • Constant gap conductance	• 1-D radial conduction model for cladding, gap, and fuel • Constant gap conductance
Axial Geometry	• Does not model axial geometric variation in advanced fuel designs	• Models axial geometric variation in advanced fuel designs
Core simulator	• Input from PANAC10 or earlier	• Input from PANAC11 or earlier

ODYSY Procedure

Application	FABLE Procedure	ODYSY Procedure
Region Boundary Generation	• Determine endpoint on NCL and HFCL • Draw boundary with generic shape function	• Same as FABLE procedure
Void Coefficient	• Void coefficient is most negative in cycle at rated power/flow point • Produces an exposure independent decay ratio calculation	• Void coefficient is dependent on exposure and power/flow condition • Produces an exposure dependent decay ratio calculation
Thermal-hydraulic data	• Standard values consistent with transient analysis	• Same as FABLE procedure
Core average axial power shape	• On NCL, overlay limiting off rated power/flow APS from EOC full power Haling depletion • On HFCL, overlay rated power/rated flow APS from EOC full power Haling depletion • Produces exposure independent APS	• On NCL, use off rated power/flow APS based on full power/rated flow Haling depletion • On HFCL, use off rated power/flow APS based on full power/minimum flow Haling depletion • Produces exposure dependent APS

ODYSY Procedure

Application	FABLE Procedure	ODYSY Procedure
Hot channel axial power shape	• Overlay conservative hot channel APS	• Same as FABLE procedure
Radial Power Distribution	• 8 or more channel groups used to model core	• 19 channel groups used to model core
Gap conductance	• 1.6 gap conductance multiplier on core average gap conductance	• No additional gap conductance multiplier
Spacer model	• Crudded spacer loss coefficients	• Clean spacer loss coefficients
ISCOR methodology	• "Method A" (old methodology)	• "Method B" (new methodology)
Empirical Output Adjustment	• Yes	• No
Conservative adder	• No	• Yes

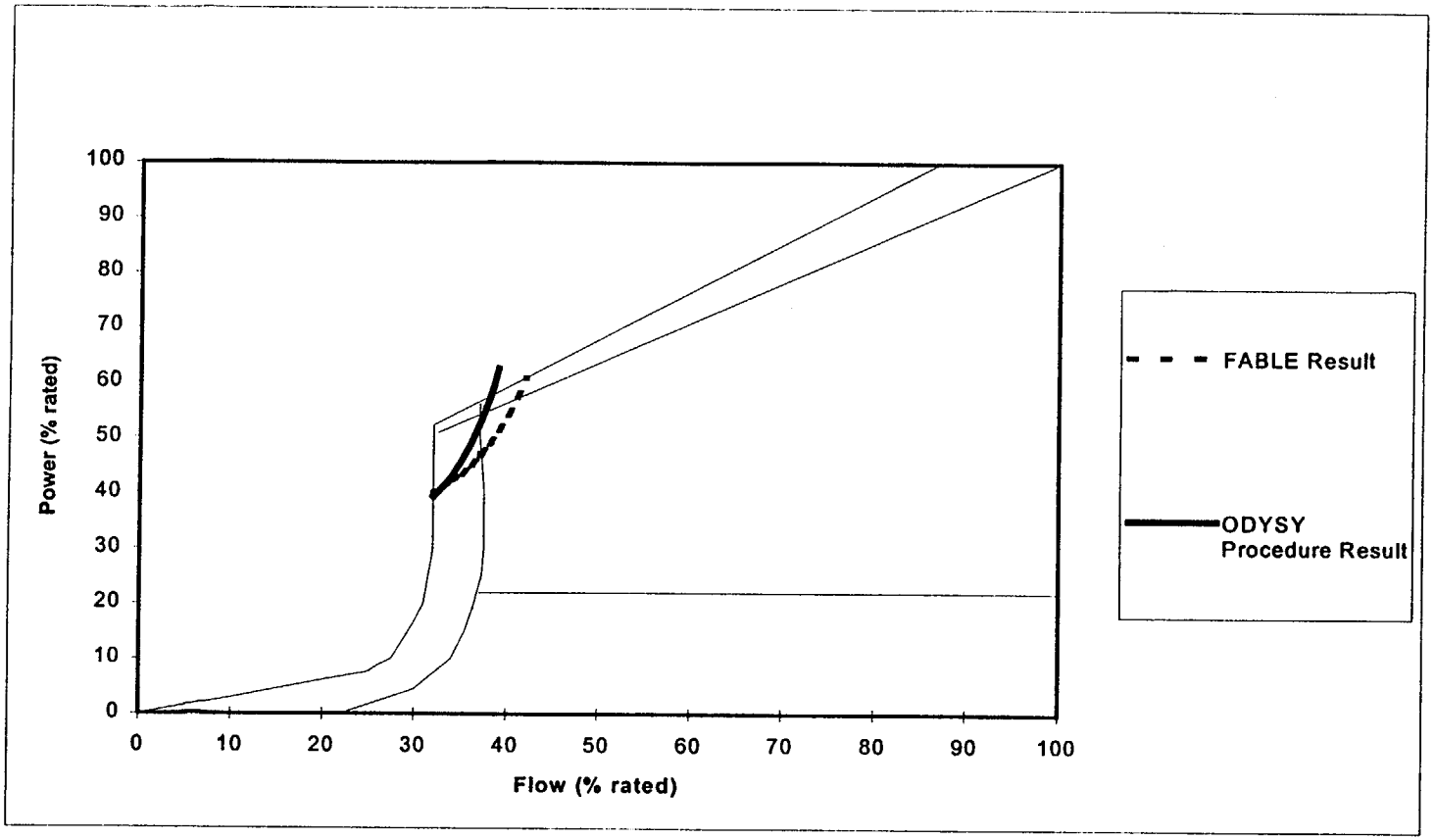
ODYSY Procedure

- **Summary:**
  - **Use standard ODYSY calculation capability**
  - **Perform best-estimate calculation**
  - **Produce exposure dependent result**
  - **Apply additional core decay ratio adder to limiting exposure result**
  - **Use approved stability criteria map to determine stability margin**
  - **Calculate exclusion region endpoints on NCL and HFCL**
  - **Use generic shape function to define region boundary**

Application for Option I-D

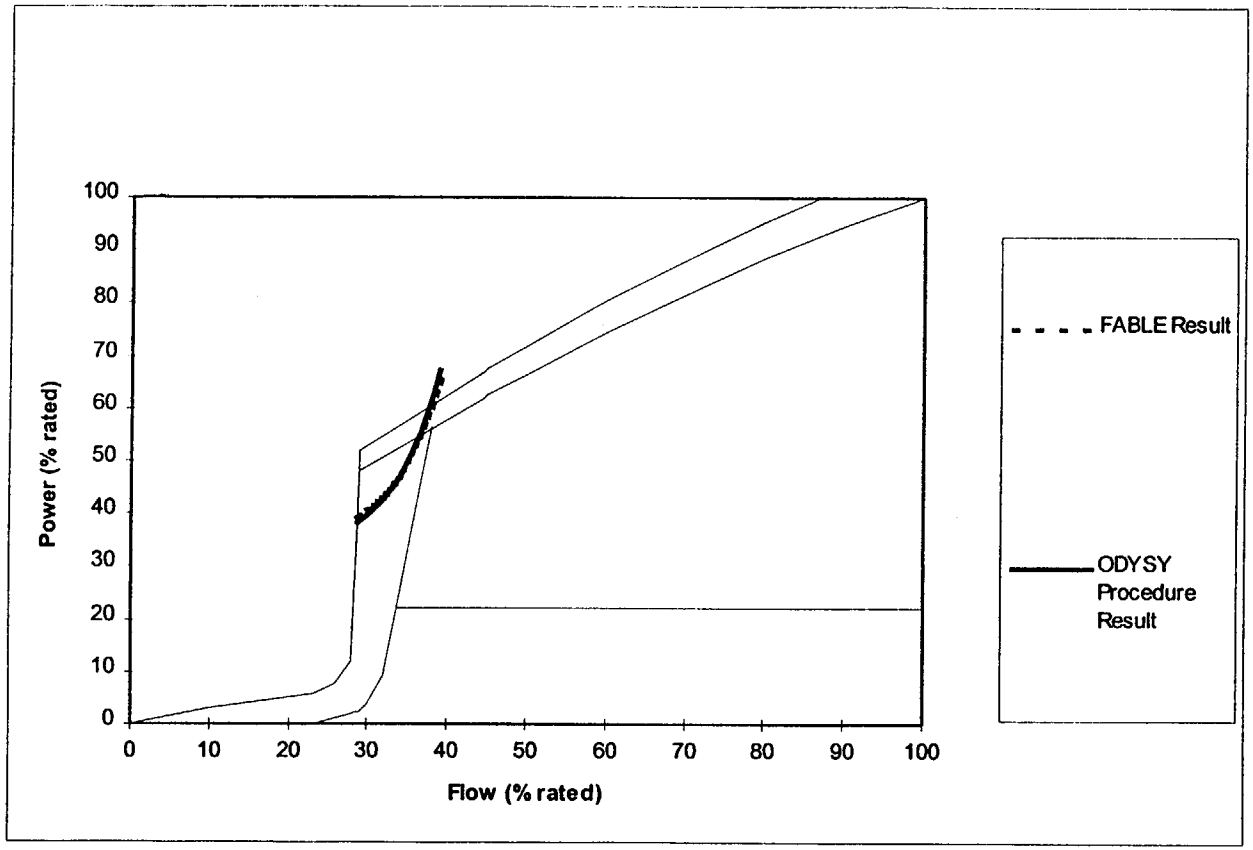
- Option I-D has an administratively controlled exclusion region
- Also has a buffer zone 5% in power and flow outside the exclusion region
- Exclusion region is reviewed for applicability or recalculated for each reload
- Sample calculations performed for three plants to compare FABLE and ODYSY application procedures

Application for Option I-D



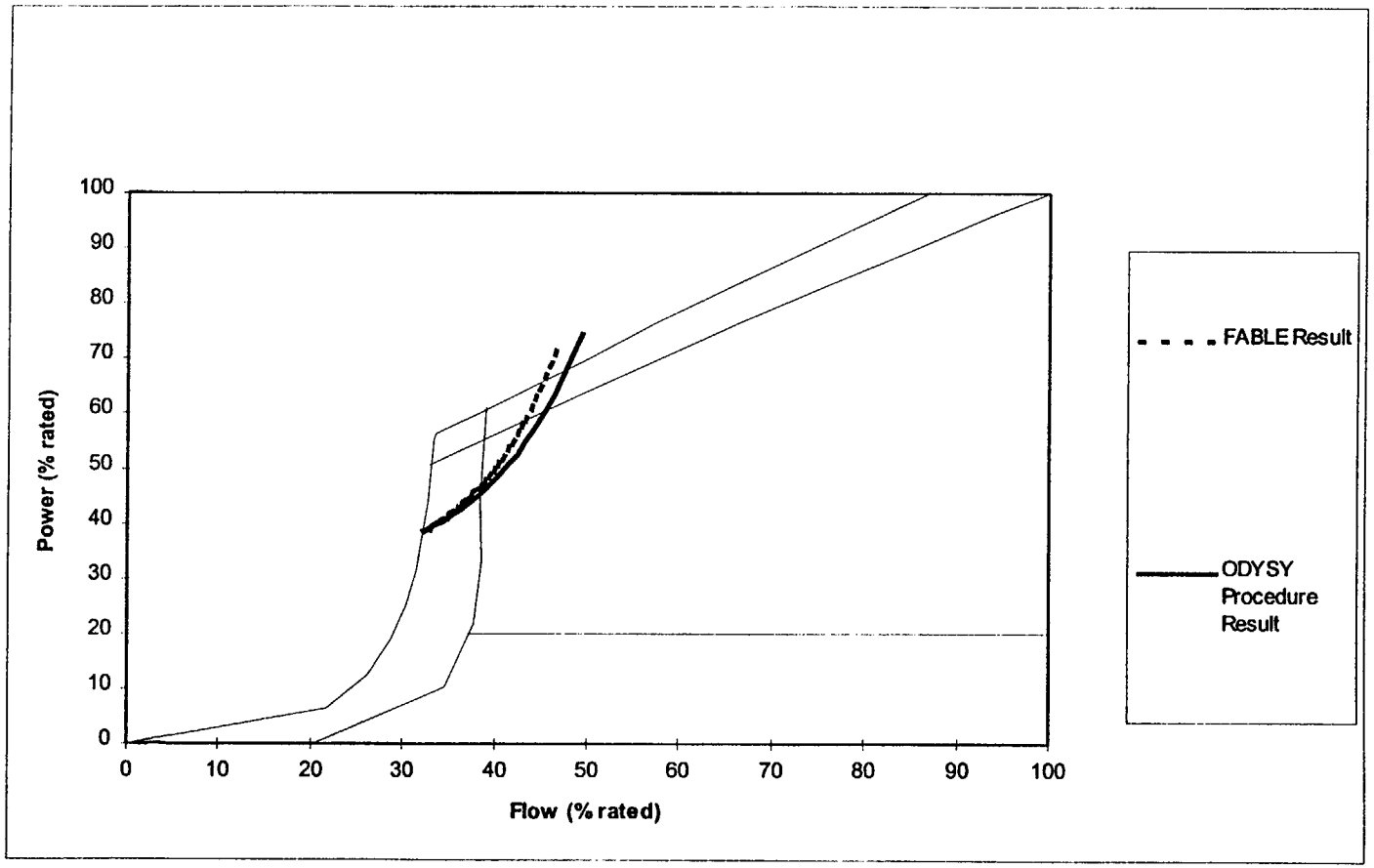
- **Plant 1 – Small improvement in region size**

Application for Option I-D



- **Plant 2 – Produces identical region size**

Application for Option I-D



- **Plant 3 – Small enlargement in size of region**

Application for Option I-D

- ODYSY procedure reproduces FABLE result on NCL within a small variation tolerance
- ODYSY procedure reproduces FABLE result on HFCL within a greater variation tolerance
  - Core is more highly voided on HFCL – improved accuracy in ODYSY due to modeling advanced fuel designs with axial geometry variation
  - Contributing factor:
    - larger flow change per DR change on the HFCL
    - than the power change per DR change on the NCL

ODYSY procedure is appropriately conservative for application to Option I-D exclusion region calculations

Application for New Fuel Licensing

- **Compliance requirement established in Amendment 22 to GESTAR II:**

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

or

Criterion #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 region."**

Application for New Fuel Licensing

- Reference fuel design is evaluated with exactly the same method and procedure as new fuel design
  - Produces a benchmark for comparison to new fuel design
- Comparison is performed for loose inlet and tight inlet orifice plant configurations
- Reference fuel design is P8X8R
- Demonstrate ODYSY procedure on a previously submitted new fuel design

Application for New Fuel Licensing

- FABLE based comparison between reference design and new fuel design:

Inlet Orifice	ΔDR = Reference Design – New Design	
	Core ΔDR	Channel ΔDR
Loose	0.02	0.09
Tight	0.02	0.06

- Concluded that new design bounded by reference design
  - Criterion #1 met
  - Exclusion region comparison not necessary

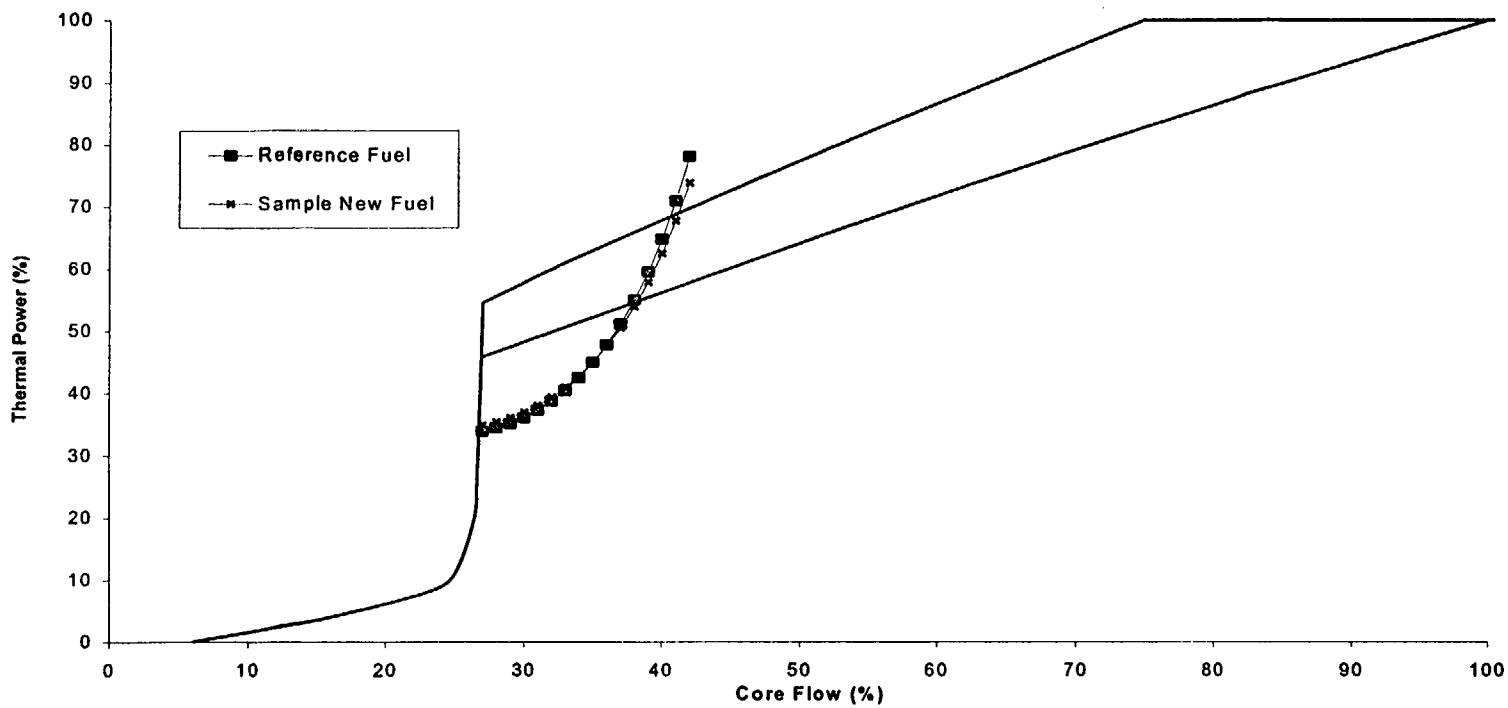
Application for New Fuel Licensing

- ODYSY procedure based comparison between reference design and new fuel design:

Inlet Orifice	ΔDR = Reference Design – New Design	
	Core ΔDR	Channel ΔDR
Loose	-0.05	0.04
Tight	0.03	0.09

- Tight orifice configuration: reference design bounds new design - Criterion #1 met
- Loose orifice configuration: new design not bounded by reference design - Exclusion region comparison necessary to show meet Criterion #2

Application for New Fuel Licensing



Exclusion Region Comparison

Application for New Fuel Licensing

- **Exclusion region calculation would have been required if used the ODYSY application procedure to license the example new fuel design**
- **Difference between example new fuel design and reference fuel design exclusion regions is small**
- **Would reach the same conclusion: example new fuel design is an acceptable fuel design under GESTAR II Amendment 22 stability criteria**

ODYSY procedure is appropriate for application to fuel licensing calculations

Application for E1A

- FABLE only used for "Standard Cycle" calculation
  - Remainder of E1A application uses ODYSY
- Standard Cycle procedure is identical to Option I-D
  - Uses 8x8 fuel design similar to P8X8R
  - Consists of decay ratio calculation at 4 points on the NCL and 4 points on the HFCL for a standard 8x8 fuel design
  - Similar to Amendment 22 decay ratio calculations
  - Expect same trends as shown above for Option 1-D

ODYSY procedure is appropriate for E1A Standard Cycle calculation

Conclusions

- **Proposed application procedure**
  - **Use standard ODYSY calculation capability**
  - **Perform exposure dependent calculation**
  - **Apply conservative core decay ratio adder**
- **Submittal plans**
  - **Obtain feedback today**
  - **Submit application report in September 2000**
- **Review cycle**
  - **Request NRC approval by March 2001 to support lead plant application**