Minimum Critical Volume

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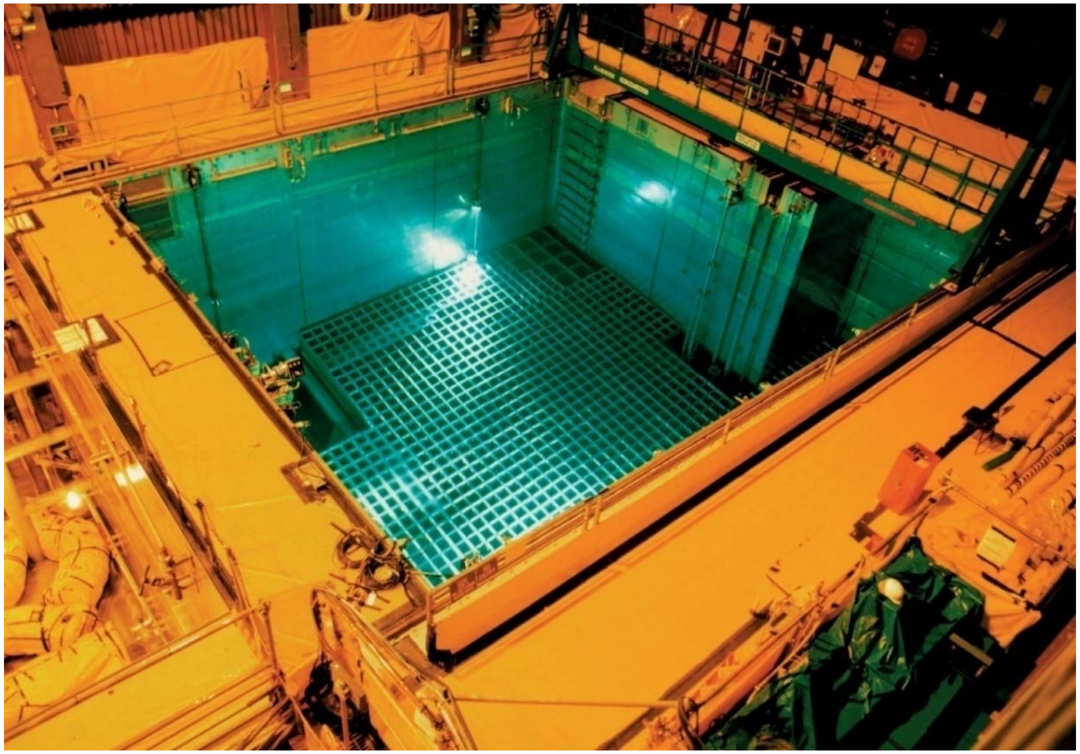
Overview

- Background
- ICE at Shika 1 June 18 1999
- Relation to SFP NCS
- Summary



Picture: Spent Fuel Pool

Background

- High capacity SFP storage designs
- Neutron absorber degradation
- More reactive fuel assemblies
  - Higher enrichment
  - Core design & operating parameters
- SFP NCS analyses & controls more complex
  - Analyses continue to take new approaches
  - More storage configurations
- SFPs have 100s or 1000s of control volumes

SFP NCS 'Conservatisms'

- Often cited SFP NCS Conservatisms
  - Neutron absorber B-10 modeled at SFP average, but not all are at average, i.e., some are above average.
  - Neutron absorber B-10 modeled at panel average degradation
  - Fuel assemblies modeled at limit, but not all are at the limit
    - Burnup
    - Peak Reactivity
    - Core Depletion Parameters
  - 10CFR50.68 says keff but we modeled kinf
    - kinf > keff
- How much conservatism is really there?

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ICE at Shika 1

- June 18 1999
  - Refueling outage
  - Preparations for a single rod scram test
  - Hydraulic control units were being isolated
  - Last 3 control rods unexpected partial withdrawal
  - Core became critical
  - Scram signal from intermediate range detectors
  - Accumulators were not charged
  - Shift manager directs workers to recover the HCUs
  - 15 minutes until the control rods insert and end the event
  - http://www.gengikyo.jp/english/shokai/070417E_Rinkai_Kaiseki.pdf

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Shika 1 ICE Core

- Control Rods
  - 89 Total
  - 3 Moved
- Displacement
  - A: 16 steps
  - B: 20 steps
  - C: 08 steps
  - The rest: 0
- Core periphery
  - Leakage

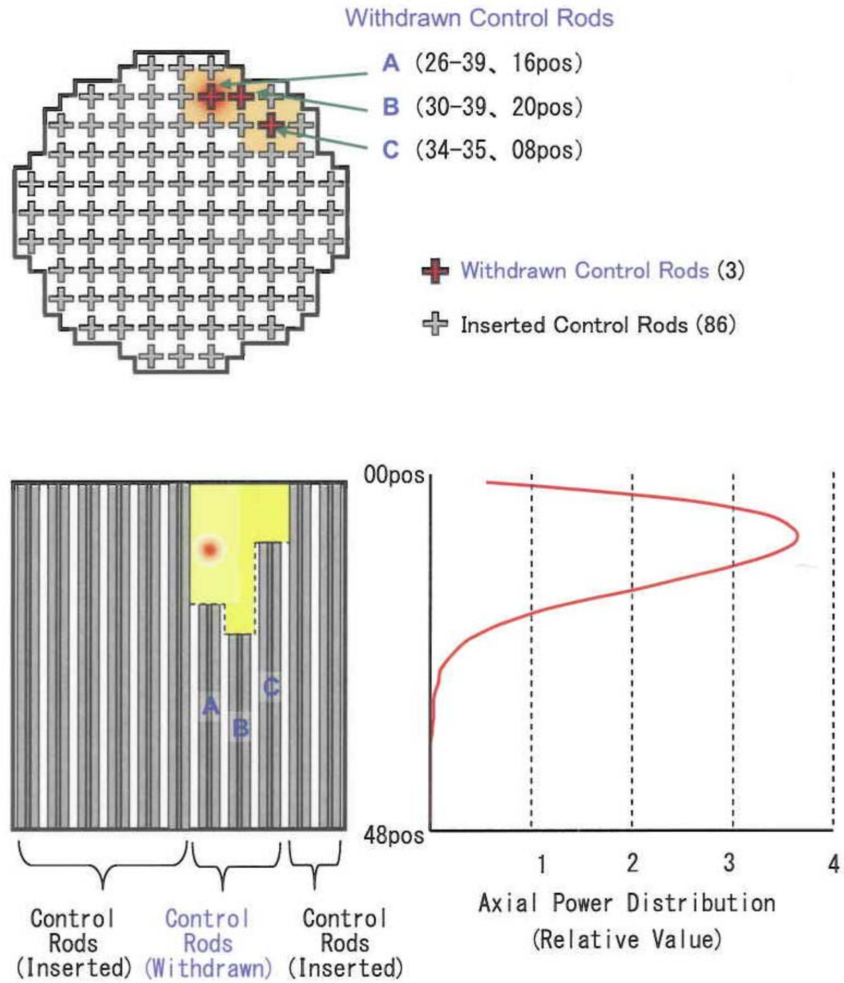

Figure 2 Power Distribution of the Core

Shika 1 ICE Power

- Prompt Critical
  - ≈ 240 MW
- Delayed Critical
  - ≈ 4 MW
  - 15 minutes
- Consequences
  - No Fuel Damage
  - Negligible worker dose
    - None in the shine

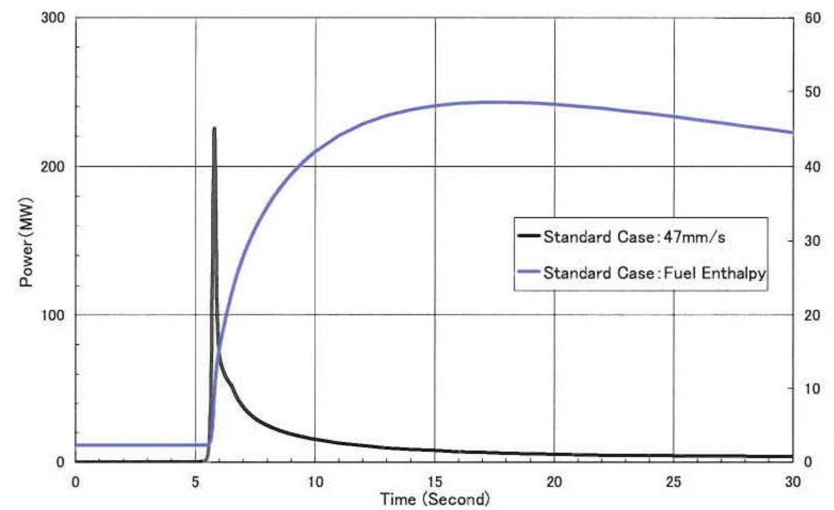

Figure 4-1 Trend of Power (Standard Case)

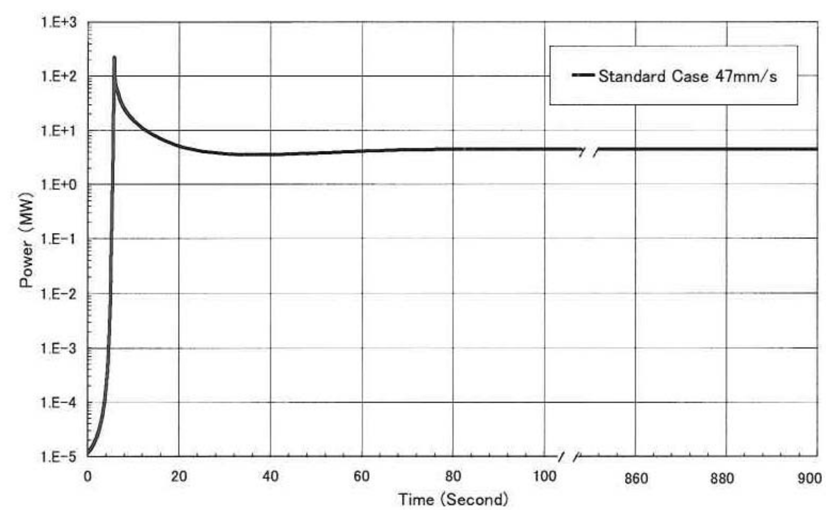

Figure 4-2 Trend of Power (Standard Case)

Lessons from Shika 1 ICE

- How does Shika 1 relate to SFP?
  - Can we model all CRs at an ‘average’ position?
    - Neutron absorber SFP panel average degradation
  - Can we model the individual CR position as an average?
    - Neutron absorber individual panel average degradation.
  - 86 CR are fully inserted
    - Doesn’t that provide ‘excess’ insertion above the limit?
  - This occurred on the periphery
    - What happened to the leakage?

Shika 1 CR Position

- 3 Rods
  - Total of 44 steps withdrawn
- 89 Total Rods
  - 4272 total steps
- Ave CR Position
  - 0.5 steps withdrawn
- Core average not a valid modeling assumption

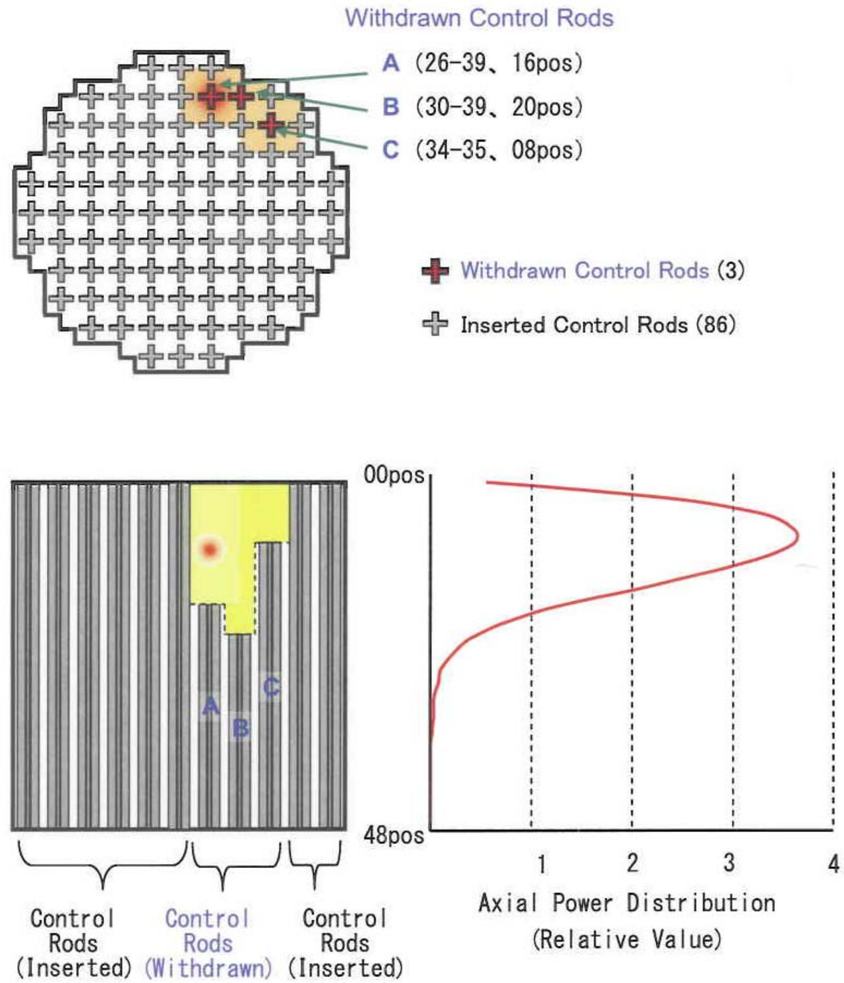

Figure 2 Power Distribution of the Core

Shika 1 CR 'Degradation'

- Rod A
  - 16 steps
  - 33.3% 'degraded"
- Rod B
  - 20 steps
  - 41.6% 'degraded"
- Rod C
  - 08 steps
  - 16.6% 'degraded"
- Individual CR average 'degradation' not a valid modeling assumption

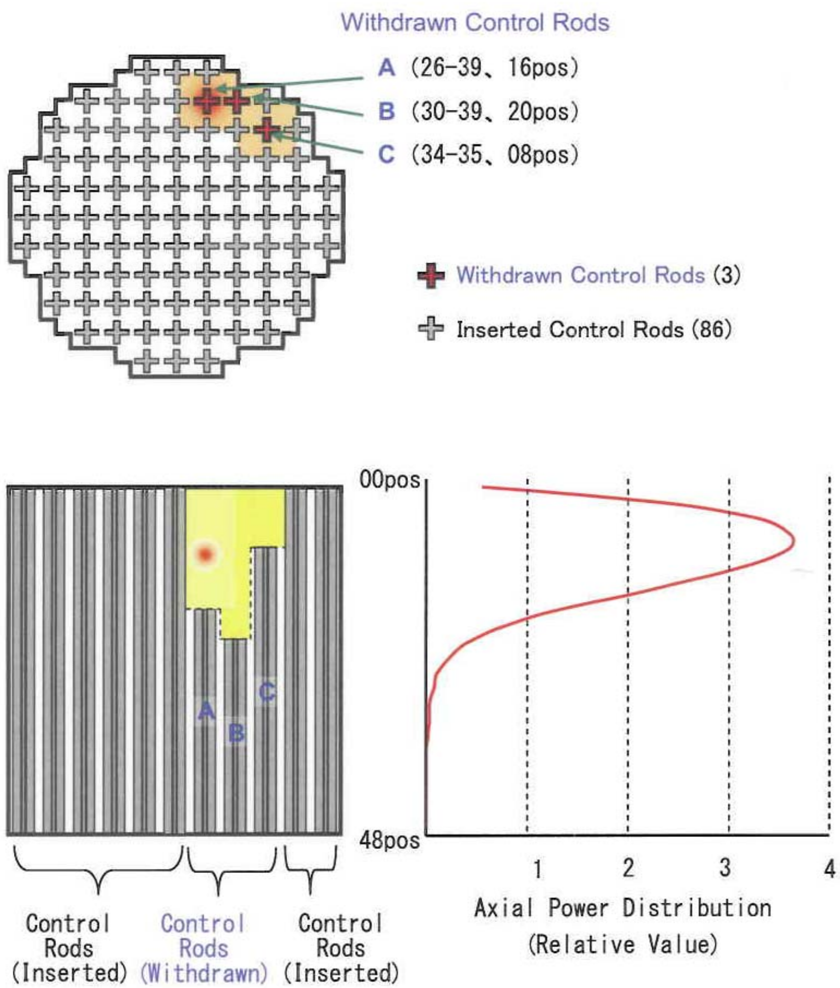

Figure 2 Power Distribution of the Core

Shika 1 CR Insertion

- 86 CR Fully Inserted
  - “Excess Insertion”
- CR “Excess Insertion” outside the affected volume did not stop the ICE

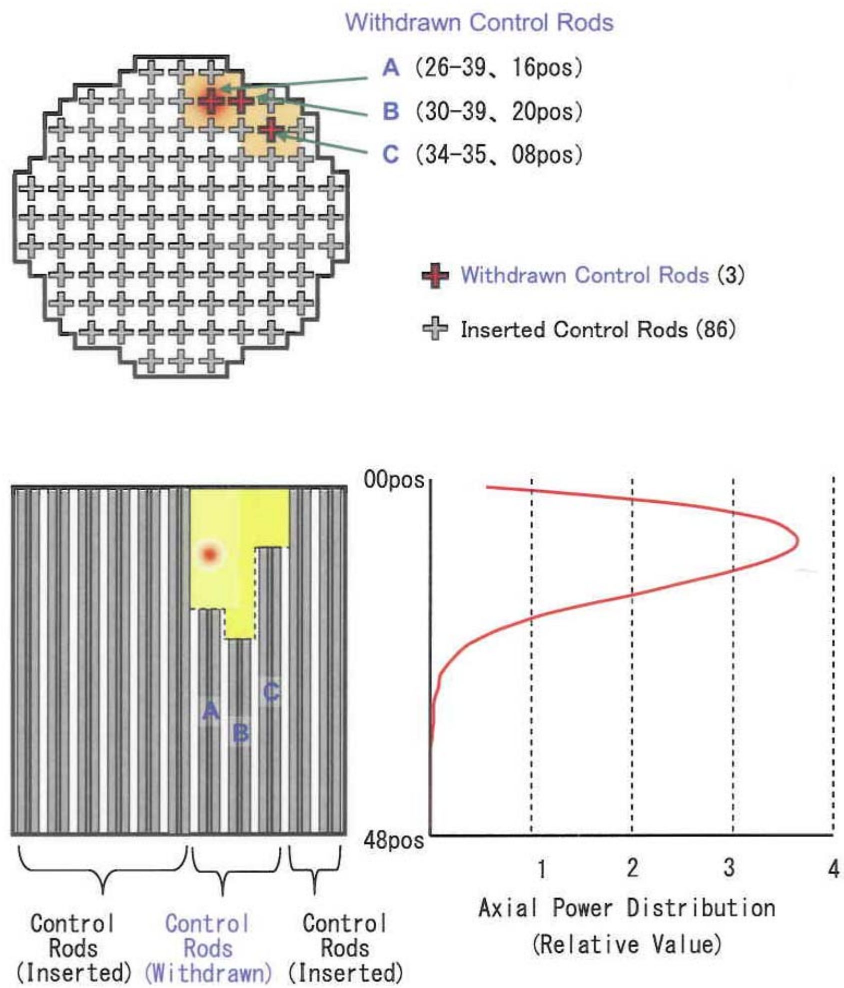

Figure 2 Power Distribution of the Core

Shika 1 Core Leakage

- Several FA on periphery
- Rod C not face adjacent with others
- Leakage not enough

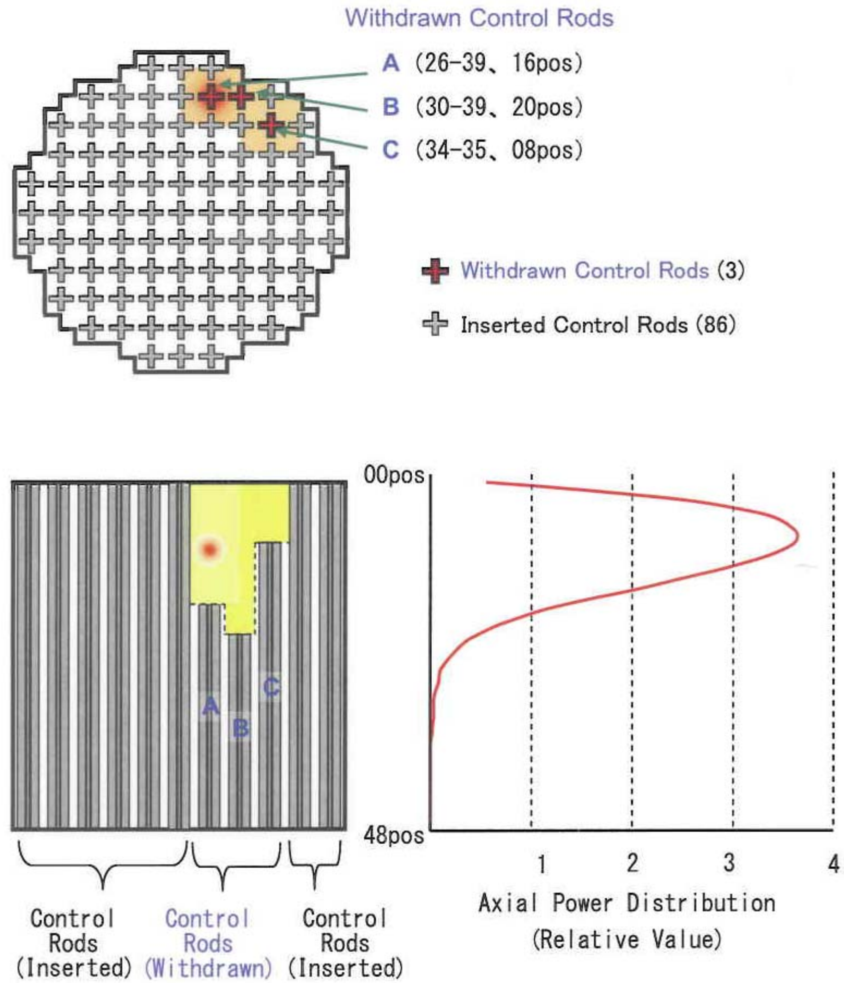

Figure 2 Power Distribution of the Core

Minimum Critical Volume

- Shika 1 ICE Summary
  - Affected volume > Minimum Critical Volume
  - Global or average parameters are not necessarily applicable to the minimum critical volume
  - Excess conservatism/margin outside the minimum critical volume doesn’t matter

SFP NCS ‘Conservatisms’

- Neutron absorber B-10 modeled at SFP average, but not all are at average, i.e., some are above average.
  - Is this applicable to the minimum critical volume?
- Neutron absorber B-10 modeled at panel average degradation
  - Are local effects being fully considered?
- Fuel assemblies modeled at limit, but not all are at the limit
  - Can the minimum critical volume be created?
- keff vs kinf
  - What is the leakage for the minimum critical volume
- How much conservatism is really there?

Summary

- What is your minimum critical volume?
- What is happening inside your minimum critical volume?

- http://www.gengikyo.jp/english/shokai/070417E_Rinkai_Kaiseki.pdf

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