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DOCUMENTS REVIEWED

- ANSI/ANS-19.6.1-2011 : reload startup physics test for pressurized water reactors
- STAR (Startup Test Activity Reduction) Program WCAP-16011-NP-A
- ICD Startup Report Evaluation Report for HB3&4, SK1&2, SW1&2
- Core Performance and Anomalous Data Resolution Training Materials (1997)
- Many Startup Test Report Summary (Downloaded by Google Search)

INTRODUCTION (1/2)

- Test Objectives
  - To determine if the measured reactor physics parameter is consistent with the design predicted value
  - May be used to establish appropriate operating limits or to determine compliance with appropriate Technical Specifications
  - Deviations would indicate a problem with either the as-built reload core or the design calculations
- Test Classification
  - FOAK (First of a Kind) vs Follow on Unit : Initial Core
    - ✓ Hanbit Unit 3, SK3
    - ✓ Hanbit Unit 4,5,6, Hanul 3,4,5,6, SK1,2, SW1,2, SK4,5,6
  - Initial Core vs Reload Core
  - Zero Power vs Power Ascension

INTRODUCTION (2/2)

❑ Test Criteria Bases

- Based on differences between calculations and measurements that would suggest a problem with the as-built core, the measurement, or the prediction (Something may be wrong)
- Not established by rigorous analysis of the test methods or design models
- The ideal criterion to be used is tight enough such that no design anomaly would go unnoticed but loose enough such that typical differences would not violate the criterion
- Be established assuming that known biases are accounted for in the predictions before comparisons are made

TEST OBJECTIVES & BASES (1/6)

❑ HZP CBC

- To confirm the reactivity balance
  - ✓ Tech. Spec. SR 3.1.3.1
- Measures the overall reactivity of the reactor and validates the accuracy of the predicted criticality calculations
- This verification ensures that predicted shutdown boron concentrations provide the necessary margin to criticality to meet operability requirements
  - ✓ Minimum Boron Concentration for SDM Requirement
- This test provides verification that soluble boron sources provide adequate negative reactivity as modeled in the accident analysis

TEST OBJECTIVES & BASES (2/6)

❑ Control rod worth

- To confirm the capability to shut down and control reactivity
- It demonstrates that the reactivity worth of the safety and regulating control rods is consistent with predictions
- This test provides a level of assurance that the fuel and core components are configured consistent with design assumptions
  - ✓ Predicted Power Distribution (peaking factors)
  - ✓ Core Loading (Assemblies and Inserts)
  - ✓ Control Rods Properly attached to drive line
- The total safety and regulating control rod worth verifies adequate shutdown margin capability
- Control rod group worths and shapes provide initial indication of an acceptable power distribution
- This test represents the only opportunity to verify that the rod worths are consistent with those assumed in the shutdown margin calculations and in the safety analysis for the core

TEST OBJECTIVES & BASES (3/6)

❑ ITC

- To confirm the reactivity control characteristic
- The test demonstrates that the reactivity response to temperature changes in the reactor core is consistent with design predictions
- To compare to Tech. Spec. Values at HZP
- Measured MTC = Measured ITC - Predicted FTC

❑ Flux Symmetry

- To confirm that the power distribution in the core is consistent with design predictions at low power
- This measurement may reveal core anomalies (e.g., dropped rods, detached rod fingers, fuel misloadings, flow anomalies, etc.)

TEST OBJECTIVES & BASES (4/6)

❑ Power Distribution

- To confirm that the power distribution is consistent with design predictions at low, intermediate, and high power levels
- The measurements verify that the power distribution is within its design and licensing bases, and they may identify any power distribution anomalies
- These measurements provide comprehensive assurance that the fuel and core components are configured consistent with design assumptions
- Level of confidence : Bank Worth (minimal), Flux Symmetry (Good), Direct Power Distribution (Best)
- A direct power distribution measurement is necessary before exceeding 50% of full power to provide a high level of confidence that unforeseen power distribution anomalies will not result in violations of design assumptions

TEST OBJECTIVES & BASES (5/6)

❑ Power Distribution

- Demonstrate that maximum power peaking factors are below TS limits
  - ✓ All WH plants have $F_{\Delta H}$ surveillance requirements
  - ✓ Some plants have FQ SR including OPR1000 & APR1400, others have Fxy SR to determine FQ acceptance
- Confirm the conservatism of measured Fxy is are below value installed in COLSS/CPC (OPR&APR)

❑ To verify that the core behavior is as designed and to verify adequacy of physics models used to generate safety analysis input

- Radial power distribution
- Axial Power Distribution (OPR&APR)
- Core Fxy, Fr, Fz, and Fq (OPR&APR)

TEST OBJECTIVES & BASES (6/6)

- HZP to HFP reactivity
  - To ensure the power defect is consistent with design predictions and operability requirements for shutdown margin
  - This test incorporates a number of reactivity effects : xenon, moderator temperature, fuel temperature, soluble boron worth

STAR PROGRAM (1/2)

- Startup Test Activity Reduction (STAR) : licensed in Feb. 2005
- STAR Program Tests
  - Eliminated from Generic Program
    - ✓ CEA Worth
    - ✓ ITC at HZP
    - ✓ MTC at HZP
  - Added to Generic Program
    - ✓ Alternate MTC Surveillance at HZP
    - ✓ ITC at Intermediate to HFP
    - ✓ Applicability requirements (core design, fabrication, refueling, startup testing, CEA lifetime)
  - Submit a summary report included
    - ✓ Identify the core design method used
    - ✓ Compare the measured and calculated values and the differences between these values to the corresponding core design method uncertainties and
    - ✓ Show compliance with the STAR applicability requirements

TEST CRITERIA (1/5)

❑ Review Criteria

- Based on differences between calculations and measurements
- Not based on the Safety Analysis
- Two-sided tolerances
- Be used to identify measurement or design errors
- Failure of any one test criterion does not necessarily warrant stopping the testing process or power ascension
- ANS WG believes that it is prudent to address these test criteria as part of a continuing evaluation of the design and measurement processes

TEST CRITERIA (2/5)

❑ Acceptance Criteria

- Those criteria that have a direct link to the Safety Analysis or are defined by Technical Specifications
- One-sided tolerances
- Be constructed from Safety Analysis or related assumptions
- Failure of these criteria should not prevent further testing at the current power plateau for supporting information
- Resolution of a failure is often performed under established procedures (e.g., Technical Specification action statements)
- The established procedures will typically stipulate the power ascension requirements

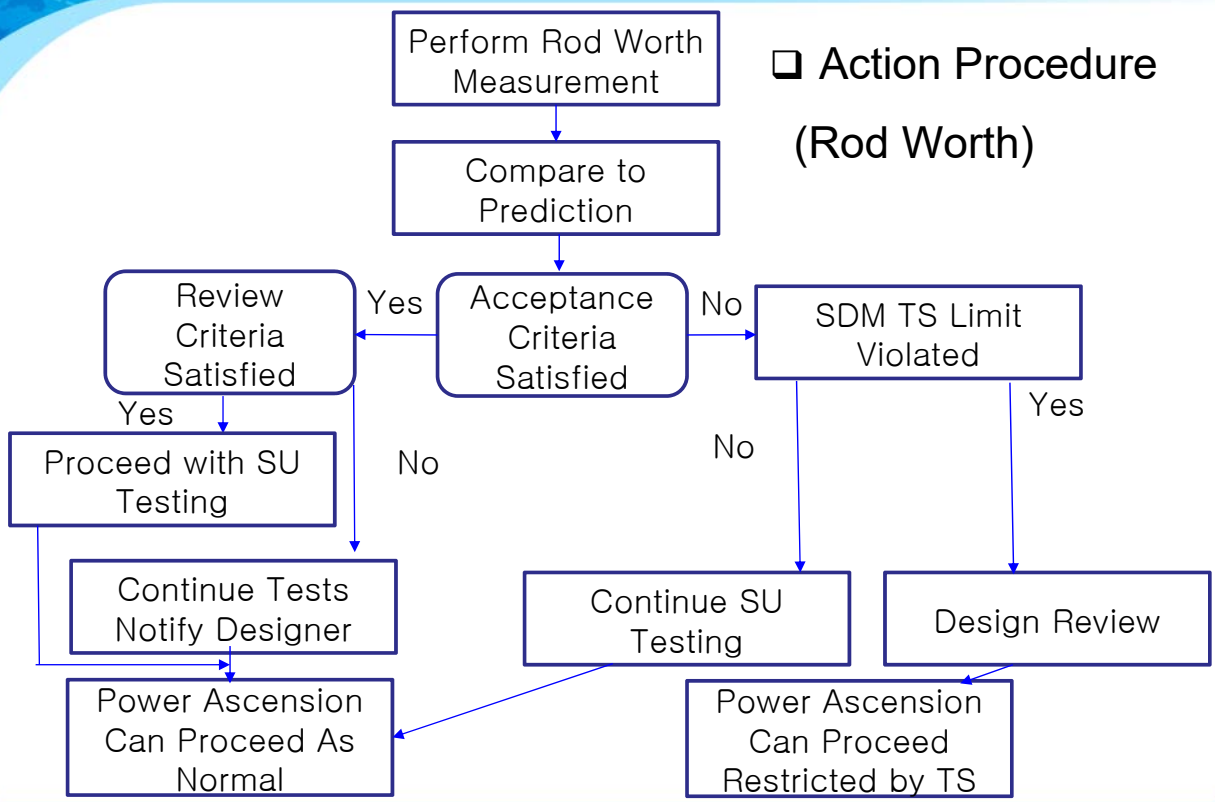
TEST CRITERIA (3/5)

❑ Reload Physics Test (WEC Recommendation)

Item	Review Criteria	Acceptance Criteria	Basis
ARO CBC	±500 pcm	±1000 pcm	SR 3.1.3.1
ITC	±3.6 pcm/ºC	MTC Tech. Spec. Limit	SR 3.1.4.1
Rod Swap Method	Ref. : ±10 % Test : 15% or 100 pcm Total RW : ±10 %	Ref. : ±15 % Test : 30% or 200 pcm Total RW : -10 %	WCAP, Available SDM
Sequential Dilution Method	15% or 100 pcm Total RW : ±10 %	Total RW : -10 %	
DRWM	15% or 100 pcm Total RW : ± 8 %	Total RW : -8 %	
Power Distribution	±0.1 RPD 5% RMS (Radial, Axial)	-	
Peaking Factor (Fxy,Fr,Fz,FQ)	10,10,10,10%	< COLSS/CPC Fxy, < Tech. Spec. FQ	CE Plants

TEST CRITERIA (4/5)

❑ Action Procedure (Rod Worth)



TEST CRITERIA (5/5)

❑ Reload Physics Test (Recommendation)

Item	Review Criteria (OPR,APR)	Review Criteria (WH)	Acceptance Criteria (OPR/APR, WH)
HZP/HFP CBC & HFP-HZP CBC	±500 pcm	Same	±1000 pcm
ITC	±3.6 pcm/ºC (or Code Unc. pcm/ºC)	±3.6 pcm/ºC	MTC Tech. Spec. Limit
Rod Swap Method	Ref. : ±10 % Test : 15% or 100 pcm Total RW : +10,-6.52 %	Ref. : ±10 % Test : 15% or 100 pcm Total RW : ±10 %	Ref. : ±15 % Test : 30% or 200 pcm Total RW : -6.52, 10 %
Sequential Dilution Method	15% or 100 pcm Total RW : +10,-6.52 %	15% or 100 pcm Total RW : ±10 %	Total RW : -6.52 % Total RW : -10 % (WH)
DCRM	15% or 100 pcm Total RW : +8,-6.52 %	15% or 100 pcm Total RW : ±8 %	Total RW : -6.52 % Total RW : -8 % (WH)
Power Distribution	±0.1 RPD 5% RMS (Radial, Axial)	±0.1 RPD 5% RMS (Radial)	-
Peaking Factor (Fxy,Fr,Fz,FQ)	10,10,10,10%	-	< COLSS/CPC Fxy, < Tech. Spec. FQ < Tech. Spec. FΔH,FQ

INITIAL CORE RESULTS ANALYSIS (1/6)

- ❑ Plants/Units : U5,6, SK1,2, SW1,2 Initial Core
- ❑ HZP Physics Test Item
  - ARO CBC
  - B-in CBC
  - ARO ITC
  - Individual Rod Worth
  - Total Rod Worth
  - Boron Worth
- ❑ Review of Measurement Data & Difference Between Prediction and Measurement Data

SUMMARY & DISCUSSION

- Clear Explanation of the purpose and bases of physics tests
- To be defined clearly two level criteria for the evaluation of the test results
  - Test (Review) Criteria
  - Acceptance Criteria
- The consensus on procedure and criteria are required through the continuous communication between vendor, utility and regulator