Nuclear Fuel Update

Palo Verde Nuclear Generating Station

March 7, 2001
Meeting with US NRC

March 9, 2000 Meeting

- Models & Methods Submittals
- OPTIN High Burnup Topical Update
- Fuel Clad Performance Strategy
- U2C9 Axial Offset Anomaly

Agenda Today

- U2 Fuel Failures Root Cause
- Clad Performance Strategy Update
- Implementation of CENTS code
- Dry Cask Storage Overview
- Transition to Westinghouse Fabrication

Unit 2 Fuel Failures

and

Root Cause Investigation

Locations Of Unit 2 Cycle 9 Failed Rods

					J441	J101	J443	J426	J109	J107	J110					
			J207	J420	K602	L107	L211	L203	L209	L114	K625	J121	J205			
		K615	L104	L215	L303	K105	K122	K308	K106	K114	L308	L202	L111	K613		
	J203	L106	K120	K109	K405	1F L521	L518	L507	L516	1F L502	K404	K127	K117	L102	J202	
	J115	L218	K108	K406	L418	K504	K606	K630	K631	K507	L413	K411	K121	L220	J429	
J112	K623	L304	K414	L412	K618	L524	K205	L528	K203	L519	K622	L407	K408	L307	K616	J403
J117	L116	K113	L513	K508	L526	K601	L409	K306	L408	K612	L508	K501	L503	K101	L112	J125
J106	L204	K119	L531	K632	K207	L420	K410	L415	K409	L402	K201	K605	L514	K107	L210	J448
J413	L214	K304	L530	K627	L525	K305	L419	H312	L411	K303	L501	K628	1F L532	K302	L213	J433
J447	L208	K123	L517	K608	K202	1F L401	K401	L405	K402	L416	K204	K610	L515	K116	L212	J119
J102	L110	K126	L527	K506	L529	K614	L410	K307	L403	K629	L506	K505	L505	K102	L108	J105
J442	K603	L302	K413	L404	K617	L520	K206	L511	K208	L523	K621	L406	K407	L305	K624	J113
	J405	L219	K124	K416	L417	K502	K626	K611	K609	K503	L414	K403	K110	L217	J118	
	J201	L101	K103	K111	K412	L504	3F L510	3F L512	L522	L509	K415	K128	K104	L109	J208	
		K604	L105	L216	L306	K118	K112	K301	K115	K125	L301	L201	L103	K607		
			J204	J120	K619	L115	L205	L206	L207	L113	K620	J417	J206			
					J123	J116	J114	J434	J446	J122	J410					

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L-1

Bases For Core Redesign

- Transportability
  - Discharged 20 (Inner Ring) Batch L5 Assemblies
- Spallation
  - Cleared Highest Duty Return Assembly (K406)
- L401 Re-Constituted/Re-Caged
- All Other Assemblies for C10 Cleared UT
- Re-Worked All Chapter 15 Events

Fuel Inspections Performed

- Westinghouse in October & December
- Assembly & Rod Visual Inspections
- Reconstitution w/Single Rod Examinations
- Eddy Current Testing
- Oxide+CRUD Thickness Measurements

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Summary of Fuel Inspections

- **Significant Tenacious Crud Deposits**
  - Crud observed in grid spans 7, 8 and 9 for both failed and sound, peripheral and interior rods
  - Peripheral rods on fresh against fresh faces most affected
  - Averaged thickness of Crud + oxide equal or slightly greater than previously measured for U2 & U3 rods
  - Localized spikes in Crud thickness
  - Greater surface area affected than previously observed
  - Clad anomalies coincide with local peaks of oxide + Crud

Summary of Fuel Inspections (cont.)

- Through Wall Penetrations in Crud Regions
  - Similarity suggests primary defect locations
  - Secondary hydriding observed in lower grid spans
- Incipient Failures Suspected
  - Anomalies with OD ECT indications have similar locations and characteristics to probable primary defect locations
- No Unusual Performance Characteristics Outside Areas with Tenacious Crud
- No Correlation with Fabrication Processes
- No Evidence of Debris Induced Wear

Unit 2 Cycle 9 Root Cause of Fuel Failure Investigation Team

Name	Root Cause Role	Home Organization
Tom Cannon	Investigation Director	APS – Palo Verde Reactor Engineering
Tom Matlock	Lead Investigator	APS – Palo Verde System Engineering
Kris Govertsen	Reactor Engineer	APS – Palo Verde Reactor Engineering
Jeff Schmidt	Core Design	APS – Palo Verde Nuclear Analysis
Mike Oren	Manufacturing	APS – Palo Verde Fuel Cycle Services
Joe Santi	Chemistry	APS – Palo Verde Chemistry
Steve Wagner	Significant Investigator	Westinghouse
Craig Clapper	Consultant	Performance Improvement International
George Smith	Metallurgy	Westinghouse
Mark Floyd	Metallurgy	Atomic Energy of Canada Limited
Richard Weader	Core Design	Duke Engineering & Services
Fred Smith	Core Design	Entergy
Zeses Karoutas	Core Design	Westinghouse
Balendra Sutharshan	Core Design	Westinghouse
J. Badri Narayan	Manufacturing	Westinghouse
David Smith	Performance Monitoring	Entergy
Jeff Deshon	Chemistry	EPRI

Root Cause Hypothesis

- "Loss of AOA" Lead to Power Increase Concentrated in Limited Number of Rods
  - January 2000 shutdown flushed boron out of Crud at time of moderate steaming
  - AOA induced axial burnup re-distribution lead to increased reactivity in top of core later in cycle
  - Assembly design & fuel management lead to concentration of power in peripheral rods
- Some Form of Crud-Enhanced Corrosion
  - "Dryout" leading to high temperatures/accelerated corrosion
  - Corrosion from concentration of unknown chemical species

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Remaining Issues

- Exact Failure Mechanism Not Confirmed
  - Additional fuel exams planned
  - Is "AOA Crud" different than earlier Crud?
- Interior Rod in P2L401 Not Explained
  - Similar Crud observations on/around failed rod
  - Interior Crud distribution may be atypical
- Issue Report & Continue with Actions

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Further Investigations Planned

- May Fuel Inspection
  - P2K410 (2 cycle high duty, previously measured)
  - Crud grinding, collection & oxide measurement
  - Assembly bow measurements
- Ship Crud Sample & Fuel Rods to Chalk River
  - Incipient and failed rods for hot cell exams
- Continue High Duty Clad Model Development
  - APS Lukic model, Westinghouse BOB code and 9-pin high duty model

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Compensatory Actions

- Prior to Unit 2 Cycle 10 Outage
  - Reduced number of fresh-to-fresh interfaces
  - Reduced steaming rates
  - Evaluated RCS pH from 6.9 to 7.1
- After Unit 2 Cycle 9 Fuel Failures
  - Premature discharge of 20 P2L5xx assemblies and re-design cycle 10 for lower steaming
  - Second, larger reduction in steaming rates for subsequent cores

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Proposed Corrective Actions

- Crud Carryover Reduction
- Evaluate Additional Chemistry Changes
- Advanced Cladding Program
- Establish Steaming Rate Threshold
- Evaluate Additional Core Design Changes
- Benchmark New High Duty Models

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Clad Performance Strategy

Update for 2000 Activities

Fuel Clad Strategy

- Data Collection
- RCS Chemistry
- Steaming Rates & Core Design
- Higher Order Modeling
- Fuel Assembly Cleaning
- Advanced Clad Alloys

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Data Collection

- Oxide + Crud Axial Profile Measurements
  - P3J321 (2nd cycle of measurements)
  - U2 inspections to support root cause investigation
  - P2K410 (postponed to May 2001)
- Onset of Spallation on Peripheral Rod
  - P3J321 (at < 100 microns)
- Chalk River Results
  - "Benign" nickel ferrite

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Chemistry

- Add Lithium Prior to Hydrogen During Startups
- Evaluating Additional RCS Cleaning at EOC Shutdown
- U2C10 Primary Chemistry Change
  - Increase BOC pH (6.9 $\Rightarrow$ 7.1)
  - Increase Max Lithium (3.0 $\Rightarrow$ 3.5 ppm)
- “Sticky” Resin for Nickel Clean-up

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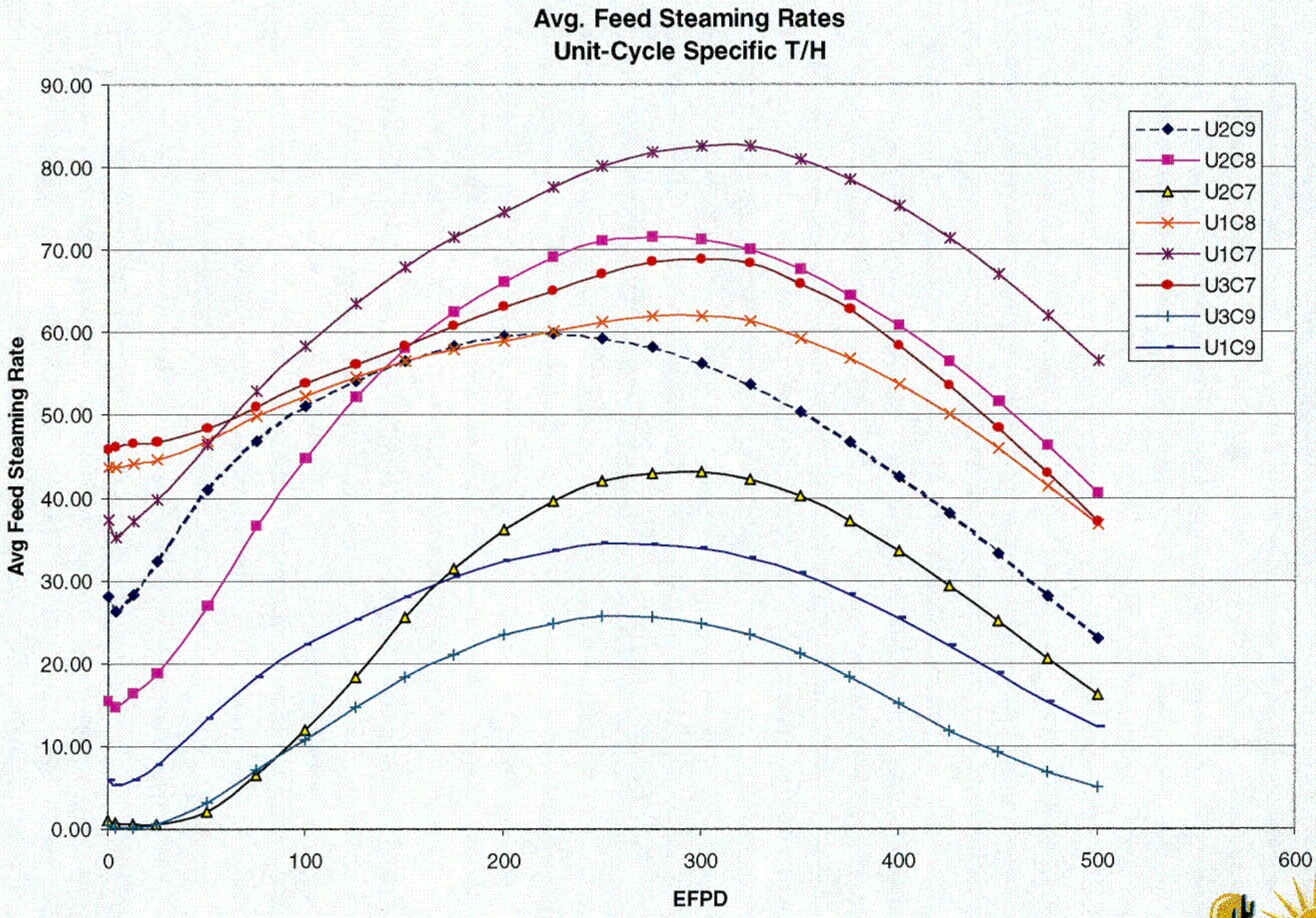
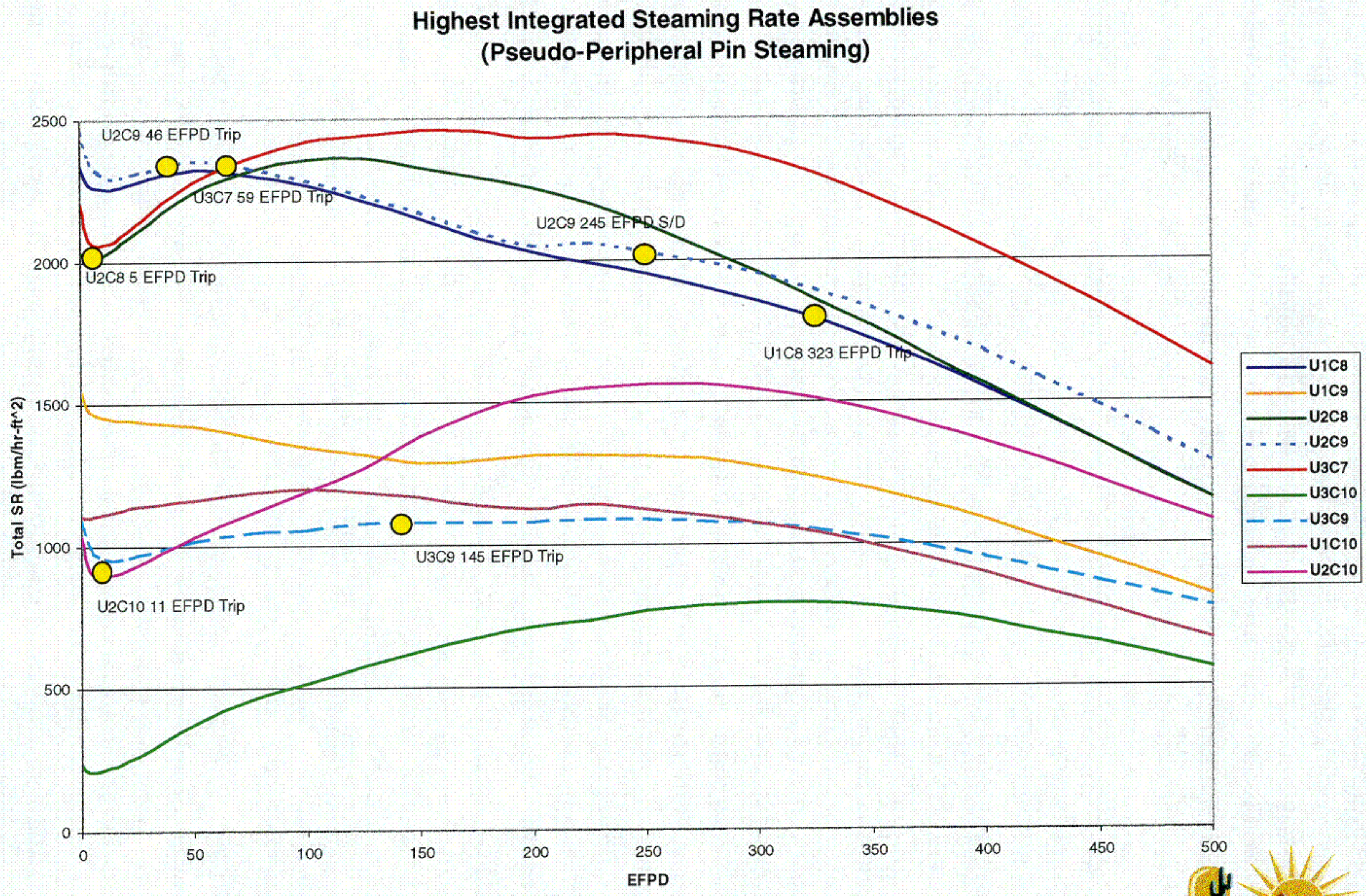
Steaming Rate Calculations

- Adapted TxU code to Palo Verde
- Based on Thom Correlation
- Assembly Average Calculation
  - Under-estimates PV high risk rods
- Modified to Model "Pseudo" Peripheral Rod
- Working to Determine Threshold from U3C9


Avg. Feed Steaming Rates
Unit-Cycle Specific T/H
Avg Feed Steaming Rate
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
EFPD
U2C9
U2C8
U2C7
U1C8
U1C7
U3C7
U3C9
U1C9

c-2


Highest Integrated Steaming Rate Assemblies
(Pseudo-Peripheral Pin Steaming)
Total SR (lbm/hr-ft^2)
EFPD
U2C9 46 EFPD Trip
U3C7 59 EFPD Trip
U2C9 245 EFPD S/D
U2C8 5 EFPD Trip
U1C8 323 EFPD Trip
U3C9 145 EFPD Trip
U2C10 11 EFPD Trip
U1C8
U1C9
U2C8
U2C9
U3C7
U3C10
U3C9
U1C10
U2C10

C-3

Core Design

- Original U2C10 and U1C10 De-tuned after AOA
  - 4 extra assemblies and more erbium BA
  - Very low assembly steaming rates
- Re-design U2C10 Further De-tuned (Shorter Cycle)
- U3C10 Design after Fuel Failure & U3C9 (mild) AOA
  - More fuel and even lower peaking
  - Very low pseudo-peripheral pin steaming rates
- U2C11 Design Begins April 2001
  - Continue low pseudo-peripheral pin steaming rates
  - Design cycles 11 & 12 (uprate) simultaneously

Higher Order Modeling

- Limited Calculations with W BOB code
- Purchased W High Duty Fuel Model Effort
  - 9-pin thermal hydraulics
  - Enhanced oxide buildup, local steaming rate and fuel duty index correlation to spallation
- APS Lukic Correlation Very Promising
  - Predicts detailed local oxide and Crud buildup
  - Developed from P2K410 & P3J321 high duty data

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Fuel Assembly Cleaning

- Negotiation Ongoing for EPRI/Dominion/ Centec Ultrasonic Cleaning System
- Desired Implementation Fall 2001 in U3
- Goal is All Units and All Burned Assemblies Returning to Next Cycle

Advanced Clad Alloys

- Zirlo
  - Possible implementation in U2C11, Spring 2002
  - Part of U2 power uprate clad corrosion strategy
- Alloy A
  - Promising performance in previous LTA
  - Planned 4th cycle full LTA for U3C10, Fall 2001

CENTS System Code

Implementation Plan

CENTS Implementation Plan

- CENTS Generically Approved
- Tech Spec Change - COLR Reference Update
- Implementation for U2C11 (4/02 Startup)
- Generic Letter 83-11 Suppl 1 Program
  - Benchmark
  - Training (formal & OJT)
  - Design Control Program Enhancements
  - 90 day notice

CENTS For CEA Ejection

- History of CEA Ejection Methodology

CENPD-190	CEFLASH/STRIKIN
CESSAR	CESEC/STRIKIN
CENPD-282	CENTS/STRIKIN

- RAI for Events Not Presented
  - NSSS response bounded by CEA Withdrawal
  - Referenced CENPD-190 without clarification
- SER Excludes Use for CEA Ejection
  - SER references CENPD-190 for methodology

CENTS For CEA Ejection

- Intent of Topical -
  CENTS Acceptable for NSSS Response
  - SER states CEAW NSSS response bounds event class
  - Validation Benchmark provided in Tech Spec letter
  - SGR/Uprate submittal
  - Continue CENPD-190 Use of STRIKIN for Consequence Calculation

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Dry Cask Storage

Plan Overview

Spent Fuel Pool Capacity

- Loss of full core offload reserve
- Unit 1 Spring 2004
- Unit 2 Fall 2003
- Unit 3 Fall 2004
- Possible pool capacity expansion if needed

Project Schedule

- ISFSI Design complete 3/31/01
- ISFSI Construction starts 9/1/01
- ISFSI Construction complete 3/31/02
- First Canister delivery 1/15/02
- Concrete Cask fabrication 3/31/02
- Dry runs 8/1/02
- Load First system 11/4/02

Heavy Loads

- Inside Fuel Building
  - Crane strategy
- Movement of Casks to ISFSI
  - Rail car and transporter
- NUREG 0612 & NRC B. 96-02 evaluation
- 50.59 evaluation

Licensing Actions

- Part 50 OL/Tech Spec Changes
  - Fuel movement applicability
  - Heavy load movement
  - Submittal 9/1/01, approval 6/1/02
- Security plan changes
  - 73.55 (c)(5) lighting deviation
  - submittal 8/1/01, approval 5/1/02

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Transition to Westinghouse Fuel Fabrication

Hematite - Columbia Transition

- Hematite, MO operations to Columbia, SC
- Maintain Component Production in Windsor
- Minimize (and manage) changes
  - Powder production process
  - Pellet drying process
  - End cap welding process
- Westinghouse Transition Plan
  - End Production at Hematite 2Q 2001
  - Increased Security and Oversight
  - PV3M Last Fuel Batch Assembled at Hematite

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