UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

February 11, 1992

Docket Nos. 50-528, 50-529
and 50-530

LICENSEE: Arizona Public Service Company

FACILITY: Palo Verde Nuclear Generating Station

SUBJECT: SUMMARY OF MEETING HELD ON FEBRUARY 5, 1992, REGARDING THE 5-YEAR FUEL ENHANCEMENT PROGRAM AND OTHER FUEL-RELATED ISSUES

On February 5, 1992, the NRC staff met with representatives of Arizona Public Service Company (APS) in which the licensee presented its 5-year fuel enhancement program and other fuel-related issues. The meeting was held pursuant to notice issued on January 28, 1992. A list of attendees is shown in Enclosure 1. Copies on nonproprietary viewgraphs are shown in Enclosure 2.

The 5-year fuel enhancement program consists of the following elements:

1. Fuel assembly design improvements.
2. Fuel pellet design improvements.
3. The use of erbium as a distributed burnable poison.
4. Axial blankets.
5. Increased burnup and enrichment limits.
6. Advanced alloy program, corrosion resistant cladding.

Details of these enhancements are contained the viewgraphs in Enclosure 2.

Other fuel-related issues are the reload technology transfer program wherein APS personnel have acquired the training and skills to perform reload evaluations, including Chapter 15 transient and accident analyses; an upcoming Core Operating Limit Report amendment request (per Generic Letter 88-16); and four core analysis method improvements contained in the Unit 1, Cycle 4 reload analysis which is currently under review.

The NRC staff requested that APS give NRC a one-year notice of intent to submit an application for the use of erbium, and a minimum time of six months for review.

Regarding the technology transfer program, the NRC staff stated that we would like to review this program in more detail than was presented at the meeting. A generic letter has been issued on this subject (Generic Letter 83-11, "Licensee Qualification for Performing Safety Analyses in Support of Licensing Actions," February 8, 1983). The material contained in APS' Reload Capability Report appeared to contain the type of information that NRC will need for its review.

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Enclosures:
As stated

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See next page

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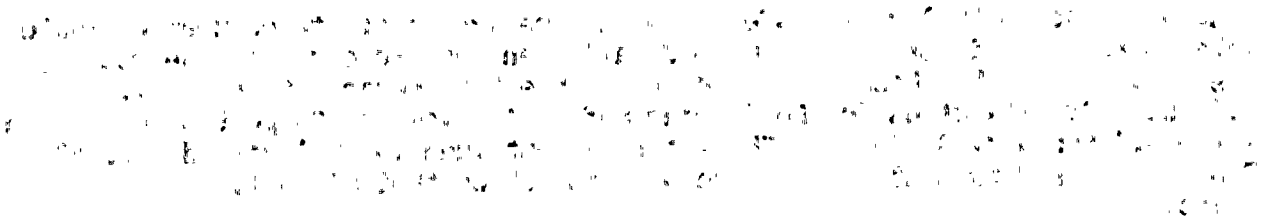

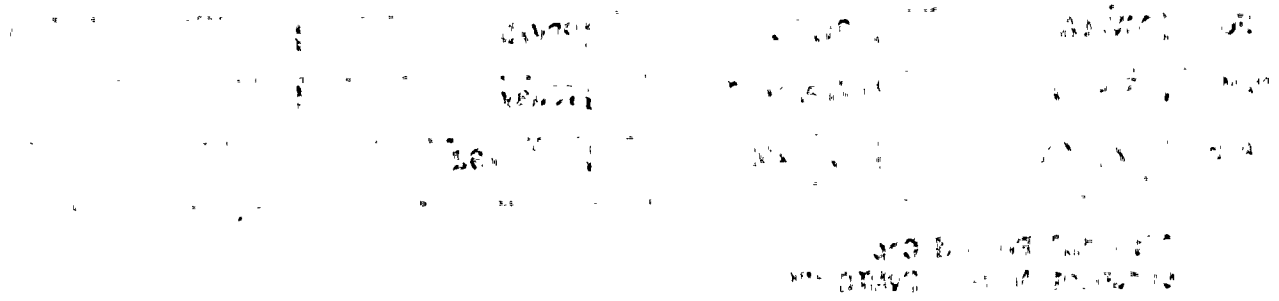

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APS/NRC Meeting

Enclosure 1

1-5-92

Name	Affiliation
Charles Trammell	NRC, PD5
Catherine Thompson	NRC, PD5
Paul Crawley	APS Mgr, Nuc. Fuel
Nancy Turley	APS - Senior Licensing Engr
MICHAEL POWELL	APS - MANAGER, NUCLEAR LICENSING
BOB BANDERA	APS - SUPVSR, NUCLEAR ANALYSIS
Stephen Troisi	APS - Supv. Safety Analysis
Douglas E. Sipes	ABB CE - Asst. Fuel Proj. Mgr, (APS)
STEVEN TOELLE	ABB CE - MANAGER, NUCLEAR LICENSING
Larry Corsetti	ABB-CE Mgr. Materials Developme.
P. Rotondo	ABB CE Mgr. Fuel Mech. Design
Jeff Brown	ABB-CE Supv., Nuclear Analysis
Ed Kendrick	NRC SRXB
Larry PHILLIPS	NRC/NRR/DST/SRXB
Shih-Liang Wu	NRR/SRXB
Tony Attard	NRR/SRXB

Palo Verde Nuclear Generating Station

5-Year Fuel Enhancement Program And Other Fuel-Related Issues

Presented to
Nuclear Regulatory Commission
February 5, 1992

Enclosure 2

Agenda

I. 5-Year Fuel Enhancement Program:

- A. Introduction
- B. Fuel Assembly Design Improvement Program
- C. Fuel Pellet Design Improvements
- D. ERBIA Burnable Absorber Program
- E. Axial Blankets
- F. Increased Burnup and Enrichment Limits
- G. Advanced Alloy Program/Corrosion Resistant Cladding
- H. Integrated Schedule for Program Implementation

II. Other Fuel-Related Issues:

- A. Reload Technology Transfer
- B. Fuel Analysis Capability
- C. Core Operating Limit Report Submittal (G.L. 88-16)
- D. Unit 1, Cycle 4, and Unit 2, Cycle 4 Methods Improvements

Purpose

- To provide the NRC with the current APS plan and schedule for the implementation of fuel design enhancements

- To provide the NRC with a status of current APS fuel related programs

Fuel-1

I.
5-Year Fuel Enhancement Program

- **Improve fuel cycle economics while maintaining margin of safety:**
  - Improve utilization of fuel resources
  - Achieve higher burnups with fewer fuel assemblies
  - Increase enrichment limit
  - Maintain flexible operation at full power with more thermal margin thereby offsetting higher power peaking
  - Utilize Erbium to achieve thermal margin & MTC goals
  - Improve clad to achieve higher burnups

Fuel-1A

IB.
Fuel Assembly Design Improvement Program

Fuel-1B

Fuel Assembly Design Improvement Program

Fuel assembly design improvements:

- Guardian Grid will reduce debris failures
- Self-locking plenum spring will increase free volume in fuel rod

Fuel-101

Guardian Grid Design

Characteristics:

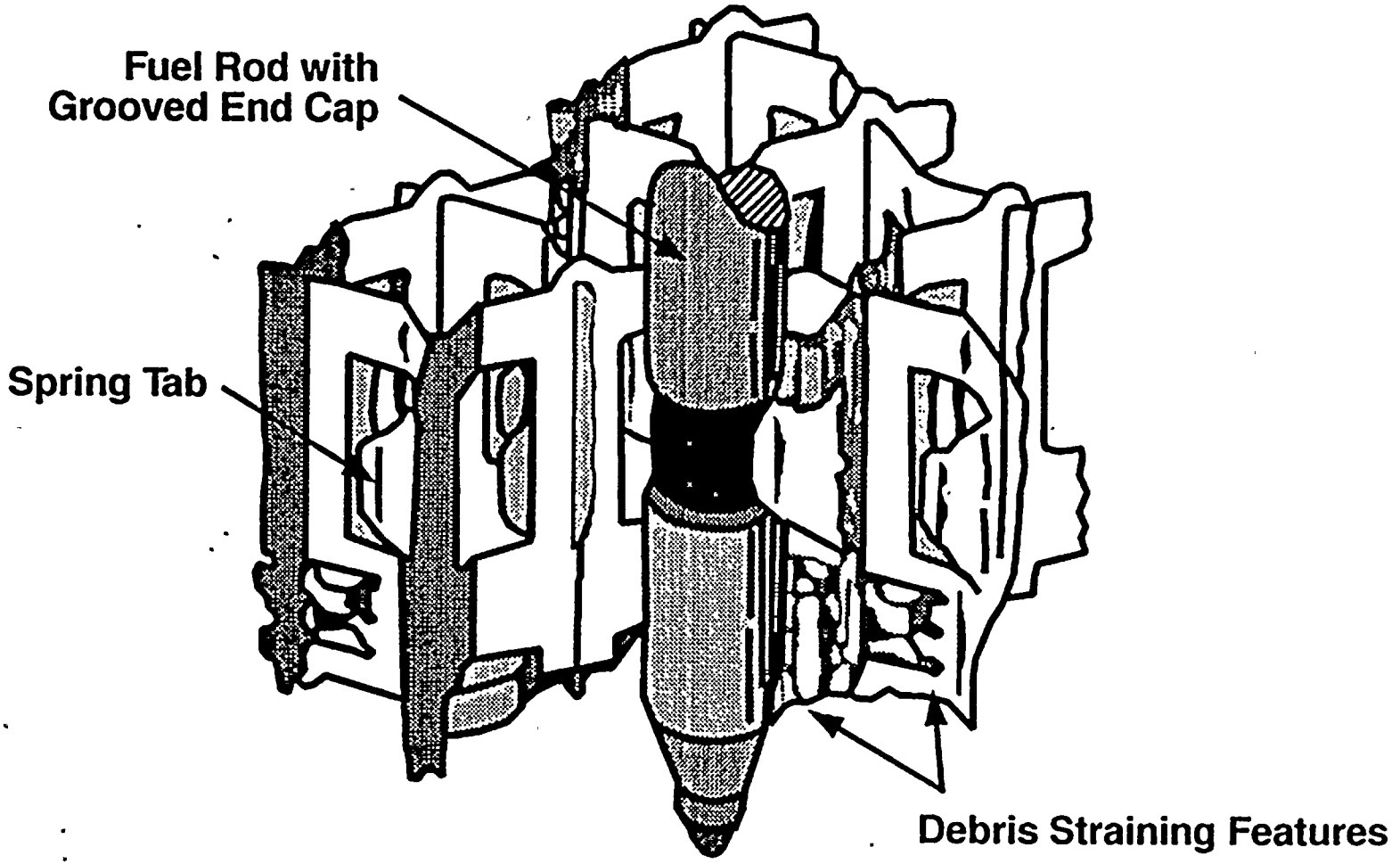
- Filtering features added to Inconel bottom grid
- Grid lowered and fuel rods retained in down position
- Greater than 90% filtering effectiveness

Benefits:

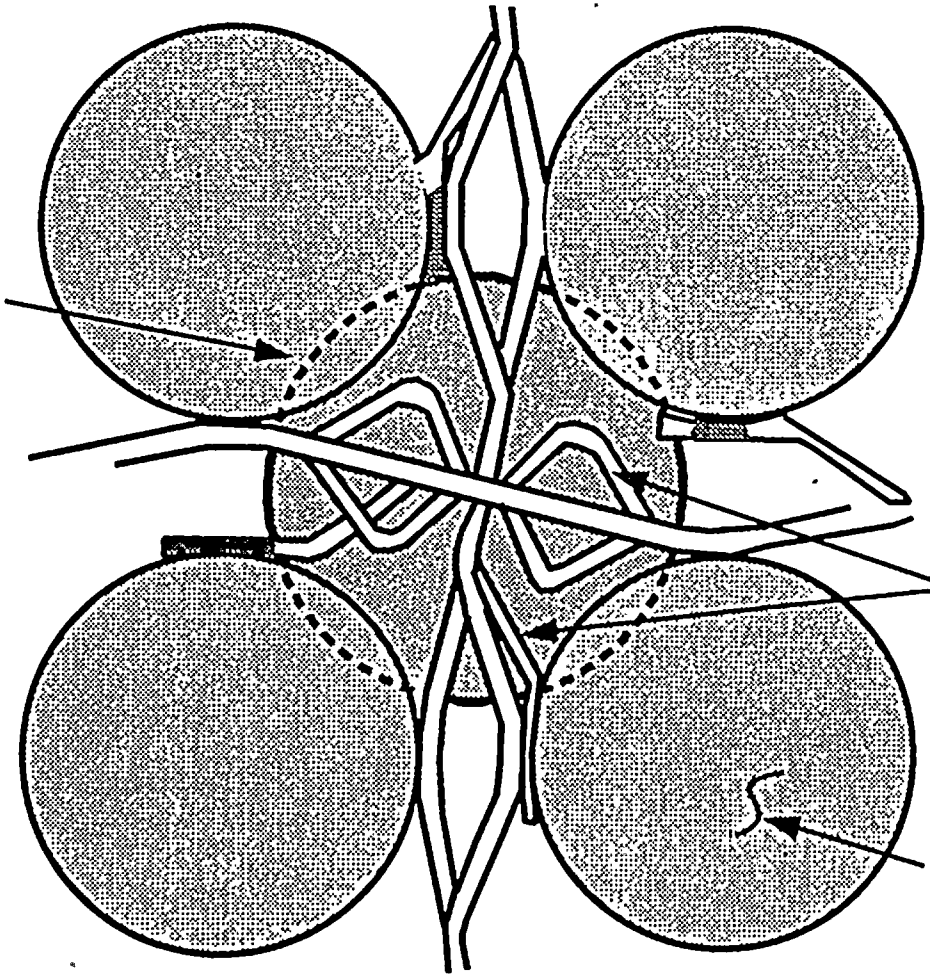
- Move cladding away from highest wear positions
- Provide a debris filter and trap

Fuel-1B2

Isometric View of Guardian™ Grid
(Conceptual Drawing)



Guardian™ Design Showing Debris Straining Features
(Conceptual Drawing)



Guard-1

Guardian Grid 16x16 Design

Objectives:

- Dramatically reduce susceptability to debris-induced failures
- Maintain or improve fuel assembly pressure drop
- Maintain reconstitutable feature
- Maintain fuel rod performance capability
- Maintain mechanical integrity

Status:

- Supplied in 1991 for 14x14 plants
- Currently under development for ABB-CE 16x16

Fuel-1B4

Self Locking Plenum Spring Design

Design Characteristics:

- Short fuel rod plenum spring
- Accomodates differential thermal expansion and radiation-induced dimensional changes between the pellet column and cladding tube

Benefits:

- Significant reduction in spring volume

Status:

- Feasibility study complete
- Manufacturing qualification to be completed in 1992

Fuel-185

IC.
Fuel Pellet
Design Improvements

Fuel-1C

Fuel Pellet Design Improvements

Characteristics:

- Modified dish and chamfer
- Increased density
- Slightly larger diameter

Benefits:

- Increased fuel loading improves fuel costs
- Susceptibility to densification during irradiation is minimized

Fuel-1C1

Fuel Pellet Design Improvements

Status:

- APS will authorize fuel design improvements in near future

Implementation:

- No regulatory/licensing/analysis concerns identified
- Subject design changes can be implemented under 10 CFR 50.59 without resulting in an unreviewed safety question
- May be implemented at any time
- UFSAR changes will be made as required
- Design changes will be documented in future Reload Analysis Reports

Fuel-1C2

ID.
Erbia Burnable Absorber Program

Fuel-1D

Erbia Burnable Absorber Program

Application:

- Integral with the UO_2
- Low concentration; typically 1.5 wt%
- In typically 20% of reload fuel pins

Erbium Characteristics:

- Rare earth similar to gadolinium
- Er_2O_3 is compatible with UO_2 and with Zr
- Thermal conductivity/melting point impact on UO_2 similar to that of Gd
- Neutron cross-sections much lower than Gd, similar to boron

Fuel-1D1

Erbia Burnable Absorber Program

Benefits:

- Increased thermal margin:
  - Eliminates displacement of fuel
  - Reduces local peaking
- Improved fuel cycle economics
- Improved MTC and power distribution control for low leakage, extended cycles

Consequences:

- Small impact on thermal conductivity and UO_2 melting point
  - No reduction in enrichment required

Fuel-1D2

Erbia Burnable Absorber Program

Status:

- Material Property Evaluation complete
- Critical experiments at RPI test reactor show excellent agreement with predictions
- Lead Fuel Assembly Program currently in progress at SONGS-2 and Calvert Cliffs-2

Fuel-103

Erbia-Urania Development Program

- Pellets were successfully fabricated for lead fuel assemblies using standard methods
- The effect of Erbia additions on melting point and thermal conductivity was consistent with expectations:
  - Negligible effect on melting point
  - Small effect on thermal conductivity consistent with available data on Gadolinia-Urania
- Other pellet characteristics including density, Erbia homogeneity, etc, were satisfactory and consistent with Gadolinia experience

Fuel-1D4

Erbium Lead Test Assemblies

- Calvert Cliffs (Unit 2 Cycle 9) - 4 assemblies:
  - Startup achieved May 1991
  - Burnup is now approximately 6.8 GWD/MT
  - Preliminary core follow looks good
- San Onofre (Unit 2 Cycle 6) - 4 assemblies:
  - Startup achieved November 1991
  - Burnup is now approximately 1.9 GWD/MT
  - Will provide direct comparison with B_4C - Al_2O_3

Fuel-1D6

IE.
Axial Blankets

Fuel-1E

Axial Blankets Application

- Essentially a low axial leakage fuel management (axial leakage reduced by factor of 2 to 3)
- Natural uranium pellets loaded into top and bottom of fuel rod
- Approximately 20 cm blanket (10% core volume)
- Amount and axial placement of burnable absorbers may be modified from non-blanket designs

Fuel-1E1

Axial Blankets
Status/Schedule

- Proven fuel design technology (PWRs and BWRs)
- No regulatory/licensing/analysis concerns identified
- May be implemented at any time sufficient thermal margin is available to accomodate increased axial peaking

Fuel-1E2

Axial Blankets
Benefits

- Lower average feed enrichment
- Reduced fuel costs
- Effectively shorter core improves axial stability

Fuel-1E3

Axial Blankets

Consequences

- Increases axial peaking
- Small impact on MTC
- Small impact on CEA trip reactivity insertion curve
- Minimal effect on planar radial peaking (Fxy)
- Minimal effect on CEA worths

Fuel-1E4

IF.

Increase Fuel Burnup and Enrichment Limits

Fuel-1F

Increase Fuel Burnup and Enrichment Limit

Status:

- Docketed methodology supports peak rod average burnups to 52 GWD/MT
- PVNGS currently licensed for maximum enrichment of 4.05 wt% U-235

Benefit:

- Increased limits provide greater fuel management flexibility resulting in reduced fuel costs

Fuel-1F1

Spent Fuel Pool Expansion In Conjunction With Increased Enrichment Limit

- Current spent fuel pool, new fuel pit, and fuel handling equipment criticality analysis:
  - 4.3 wt% with fuel stored in checkboard array
  - 4.0 wt% with fuel stored in high density mode with poison inserts
- Pool capacity for fuel stored in checkerboard array will be met in 1994/1995
- Alternatives currently under consideration for expanding capacity:
  - Credit boron
  - Take credit for burned fuel and license regions
  - Poison inserts
- Licensing changes will be submitted to the NRC

Fuel-1F2

High Burnup Fuel Performance

- Performance areas addressed by ABB-CE Material Evaluation Programs include:
  - Corrosion
  - Mechanical properties
  - Dimensional stability
  - Fuel performance:
    - Swelling
    - Gas release
  - PCI
- The ABB-CE database addresses these concerns to:
  - Peak-rod average burnups of 63 GWD/MT
  - Peak-assembly average burnups of 57 GWD/MT
  - Fast fluences of 13×10^{21} n/cm^2 (E > 0.821 MeV)
- For high temperature plants like Palo Verde, clad corrosion continues to be a controlling issue for high burnup operation

Fuel-1F3

Dimensional Stability

- **Related performance areas include:**
  - Fuel rod and assembly growth
  - Fuel rod cladding creep
  - Fuel rod channel closure
- **Data sources:**
  - Ongoing surveillance programs on commercial power reactor fuel
  - Ongoing test reactor programs
  - Palo Verde Unit 1
- **No unforeseen or abrupt changes in fuel rod or assembly dimensional stability have been observed after extended burnup operation**
- **No mechanical limitations on current & future PVNGS designs in achieving burnups up to 60 GWD/MT have been identified to date**

Fuel-1F4

UO_2 Fuel Performance

- Programs and data sources on fission gas release and fuel swelling behavior include:
  - Fuel performance surveillance programs
  - Halden (from early 1970s)
  - NFIR
  - Ramp test programs
- Results have been used to establish fission gas release and fuel swelling models to support design and licensing to pressures greater than RCS system pressure
- No limitations on UO_2 fuel performance identified up to 60 GWD/MT

Fuel-1FS

Pellet-Cladding Interaction

- PCI has not been a problem for modern PWR fuel
- Programs include ramp tests:
  - CE/KWU/DOE Ramp Test Program at Petten
  - Super ramp and super ramp extension
  - Over ramp
- Supplemental information from Halden Reactor Base Program
- Program includes a wide range of variables: fuel pellet/rod design characteristics, Burnups, and power histories
- Results have been used to establish failure thresholds, as well as provide additional benchmark data for development of fuel performance models for fission gas release, and fuel swelling behavior
- Operating guidelines have been effective in preventing PCI failures in modern PWRs
- PCI will not be a problem for Palo Verde to achieve burnups to 60 GWD/MT

Fuel-1F6

Summary

- Increased enrichments and burnups are planned to provide fuel management design flexibility for purposes of producing improved fuel cycle economics
- Burnups to 60 GWD/MT have been achieved with no decrease in fuel reliability
- Power reactor LFA programs and test reactor experiments have provided information necessary to develop fuel performance models for high burnup application
- High burnup design methodology has been approved by the NRC and is being employed in current reload fuel batches in other ABB-CE plants to rod average burnups of 60 GWD/MT
- Corrosion and its related effects remain an important issue for PVNGS

Fuel-1F7

1G.
Advanced Alloy Program/Corrosion Resistant Cladding

Fuel 1G

Advanced Alloy Program

Status:

- Zr-4 clad corrosion recognized as fuel rod life limit in high temperature plants like Palo Verde
- APS currently measures clad film oxide thickness in PVNGS Unit 1 at the end of each cycle
- APS currently utilizes Zr-4 clad with controlled chemistry and optimized annealing process
- Tech Spec changes were submitted to the NRC on 12/20/91, which will allow up to 80 fuel rods in two assemblies to be irradiated in Unit 3, Cycles 4, 5, and 6
  - Assemblies contain rods with chemistry variants outside of Zr-4 ASTM specification

Fuel-1Q1

Reactor Coolant Temperature Comparison
Zircaloy Corrosion Ranking

Plant	Inlet Temp. (°F)	Outlet Temp. (°F)
Goesgen	555	615
Ringhals - 2	546	611
North Anna - 1	556	620
Grohnde	556	615
EDF 1300 MWe	559	625
Palo Verde - 1, 2 & 3	565	621
EDF 900 MWe	548	613
Ringhals - 3 and 4	543	613
ANO - 2	555	613
SONGS - 2 and 3	553	611
Maine Yankee	552	602
Calvert Cliffs - 1 and 2	548	599
Fort Calhoun	543	599
St. Lucie - 2	549	600

FUEL1Q2

Status of Advanced Alloy Demonstration Program

- Tube fabrication completed
- Mechanical properties meet Zr-4 requirements
- Activities related to fuel rod fabrication are in progress
- Safety Evaluation Report submitted to NRC
- Insertion of demonstration assemblies targeted for Palo Verde Unit 3 Cycle 4 November 1992 startup

Fuel-105

Corrosion Demonstration Program at Palo Verde Unit 3 on Alternate Cladding Variants

- Plan to irradiate several cladding variants for three cycles at Palo Verde Unit 3 beginning with Cycle 4:
  - Zr-4 compositional variations beyond ASTM specification limits
  - Alternate Zr-based alloys

Fuel1Q8

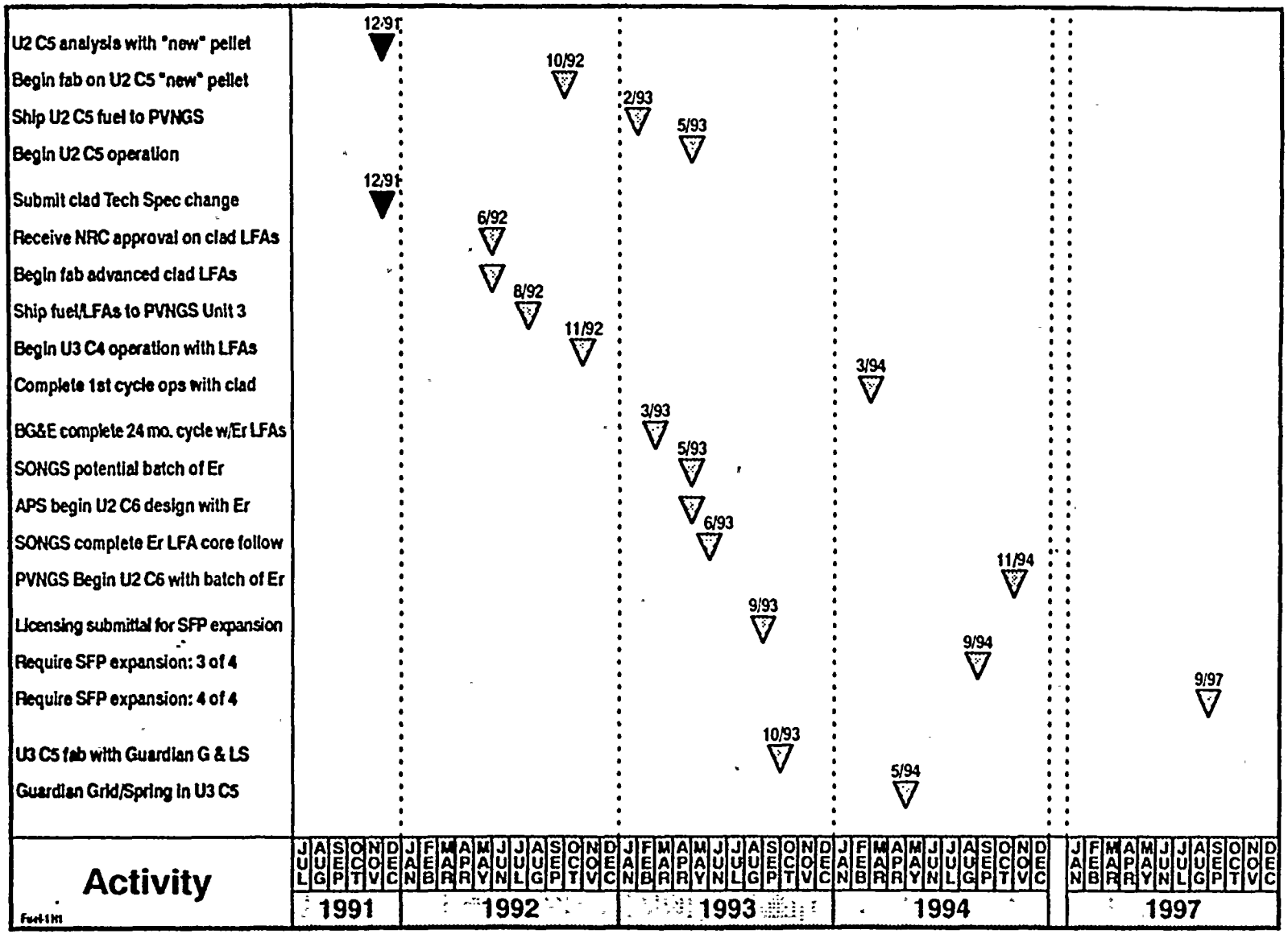
IH.
Integrated Schedule For Program Implementation

Fuel-1H

Summary

- 5-Year Fuel Enhancement Program:
  - Fuel Assembly Design Improvement Program
  - Fuel Pellet Design Improvements
  - ERBIA Burnable Absorber Program
  - Axial Blankets
  - Increased Burnup and Enrichment Limits
  - Advanced Alloy Program/Corrosion Resistant Cladding

Preliminary Integrated Schedule For Fuel Enhancement Implementation



II. Other Fuel Related Issues

- APS has completed Reload Technology Transfer with ABB-CE
- APS staff has demonstrated capability to utilize ABB-CE methods to perform reload and plant support functions
- Technical specification changes will be submitted to NRC in near future which will remove cycle-specific data from technical specifications for inclusion in a unit/cycle specific Core Operating Limit Report
- Discuss physics methods improvements submitted to the NRC in December 1991

Fuel-2

IIA.
Reload
Technology Transfer

Fuel-2A

Reload Technology Program

Objectives:

- Acquire qualified methods for specific events analyses
- Qualify engineering staff
- Acquire qualified computer codes

How:

- ABB-CE/APS Reload Technology Transfer Program

Fuel-2A1

Reload Technology Transfer Program Overview

Option in 1986 APS - CE Fuel Fabrication Contract

Scope:

- Reload engineering technology obtained:
  - Physics Analysis
  - Fuel Performance
  - Core Thermal Hydraulics
  - Non-LOCA Transient Analysis
  - COLSS/CPC Analysis
- Reload engineering technology excluded:
  - LOCA Analysis
  - Fuel Mechanical Design
  - Fuel Fabrication
  - Reload Software Generation

Fuel-2A2

Reload Technology Transfer Program Overview

Option in 1986 APS - CE Fuel Fabrication Contract

Program:

- Three Phases:
  - ✓ Classroom lecture
  - ✓ On the job training (OJT)
  - ✓ Independent analysis

Goal:

- Acquire and maintain reload technology capability
- Provide improved plant support
- Develop "partnership" with ABB-CE
- Develop capability to utilize alternate fuel vendor

Fuel-2A3

Summary of Independent Analysis

Objective:

- To demonstrate that APS has been adequately trained in ABB-CE Reload Engineering Methods
  - APS engineers perform independent reload analysis
  - ABB-CE independent review and approval of all calculations/results and Reload Capability Report (i.e. Topical Report)
  - Submittal of Reload Capability Report or other documentation to NRC for approval as required

Criteria:

- Results of APS analysis were equivalent to ABB-CE findings

Fuel 2A4

Reload Technology Transfer

Status:

- Reload Capability Report is currently in review by ABB-CE
- Upon final approval by ABB-CE, APS will discuss with NRC to determine required level of review/ approval by the NRC
- Schedule and level of review will be determined by option(s) selected for utilization of capability:
  - Plant support
  - Unit/cycle-specific reload analysis
  - "Partnership" with ABB-CE

Fuel-2A5

IIB.
APS Fuel
Analysis Capability

Fuel-28

APS Fuel Analysis Capability

- **Benefits of APS fuel analysis capability:**
  - Optimized plant operating space
  - In-house control of reload analysis design basis
  - Improved plant engineering support
  - Increased plant "ownership"
  - Improved technical audit capability
  - Potential "partnership" with ABB-CE

Fuel-201

Optimized Plant Operating Space

- Palo Verde specific in-house designs with operating space optimized for Palo Verde's unique needs
- Enhanced direct interface between analysis engineer and operations
- Improved thermal margin
- Fuel vendors may strive for the "bounded" reload design that can encompass several utility issues

Fuel 2B2

Enhanced Engineering, Licensing and Operations Support

- Direct and rapid response to plant issues
- Comprehensive understanding of the design and licensing basis of the plant
- Increased ability to independently complete safety significant documents:
  - JCOs
  - 10 CFR 50.59s
  - Nuclear Safety Assessments
  - Technical Specifications

Fuel 2B3

Plant "Ownership" Increased

- Cannot "own" the plant unless design/analysis basis from which it was built is understood
- Reduced reliance on vendors
- Reduced impact of the vendor becoming non-viable
- Ability to perform in-house reloads ensures utility maintains "ownership" of the plant

Fuel-284

Improved Technical Audit Capability

- APS Nuclear Fuel Management Department (NFM) is responsible (design authority) for review and approval of all fuel vendor documentation for changes
- As design authority for fuel-related products, APS NFM Department must fully understand and concur with all fuel-related changes proposed by the fuel vendor
  - Superficial review is not acceptable considering safety significance of transmitted material
  - Independent technical review is possible only if engineers have extensive training on fuel vendors methods and codes
- Strong technical review will help to identify and minimize errors

Fuel-2B5

ABB-CE/APS Partnership

- Current degree of "partnership" currently exists:
  - *Reload fuel management development*
  - *Plant support analysis verification and review*
  - *Loan APS engineers to ABB-CE for peak reload analysis and plant support efforts*
- ABB-CE and APS are working to formalize "partnership" to integrate resources into planned and emergent workloads

Fuel-2B4

Development of ABB-CE/APS Partnership

- 1986 CE Reload Fuel contract is currently under renegotiation
- ABB-CE and APS are working to formalize a "partnership"
- Resource Sharing:
  - Increase pool of trained engineering resources available to meet peak demands
  - Improve utilization of ABB-CE and APS engineering staff
  - Provide continued on the job training and relevant work experience for APS and ABB-CE engineering staff
- APS maintains fuel analysis capability consistent with ABB-CE

Fuel-287

IIC.
Core Operating Limit Report Submittal (G.L. 88-16)

Fuel-2C

Core Operating Limit Report (COLR) Submittal (G.L. 88-16)

- APS will submit technical specification changes for the removal of cycle-specific data from technical specifications in the near future:
  - COLR was developed for currently operating/upcoming cycles. (Unit 1 Cycle 4, Unit 2 Cycle 4, & Unit 3 Cycle 3)
  - Submittal is in accordance with Generic Letter 88-16 and similar to those previously submitted on other dockets
- Implementation is in accordance with G.L. 88-16. An implementation plan for defining details outside the scope of G.L. 88-16 is under development
  - Controlling document
  - Review and approval of COLR
  - Placement in Control Room

Fuel-2C1

IID.
Unit 1 Cycle 4, and
Unit 2 Cycle 4
Methods Improvements

Fuel-20

Benefits of APS Fuel Program

- Maintain current margin of safety
- Improve fuel reliability
- Increase core design flexibility
- Increase plant "ownership" and improve technical oversight
- Improve fuel cycle economics

Benefits