UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 29, 2001

LICENSEE: Tennessee Valley Authority (TVA)

FACILITY: Browns Ferry, Units 2 and 3, Sequoyah Nuclear Plant, Units 1 and 2

SUBJECT: SUMMARY - JANUARY 11, 2001, MEETING WITH TVA RE: STATUS OF THE USE OF EXCESS DOE REACTOR FUEL IN TVA-OWNED PLANTS

On January 11, 2001, representatives of the Tennessee Valley Authority (TVA), the licensee for the Browns Ferry and Sequoyah Nuclear Plants, met in a public meeting with members of the U.S. Nuclear Regulatory Commission (NRC) staff at NRC Headquarters in Rockville, Maryland. TVA requested this meeting to brief the staff regarding current status of their long-range plan for using excess Department of Energy (DOE) reactor fuel (containing highly enriched uranium (HEU)) in TVA-owned plants. This meeting was a follow up to three prior meetings on the same subject held on August 20, 1997, March 5, 1998, and July 8, 1998. A list of attendees is given in Enclosure 1. The handout provided by TVA during the meeting is included as Enclosure 2.

Background

In 1994, DOE announced that it was looking for possible solutions for disposal of surplus uranium at Savannah River because the federal government decided that it no longer needed about 174 metric tons of HEU. This uranium was once used to fuel the now-closed Savannah River reactors, which produced tritium and plutonium for the nuclear weapons program (the subject HEU material was reactor fuel, not byproduct material). TVA was the only party to respond with a proposal to use this material (May 1994). Their proposal was to purify the material (much of which was scraps), dilute (or "downblend") it to an enrichment level suitable for commercial reactor fuel, and use it as fuel for the two TVA-owned Sequoyah commercial nuclear power plants. Thus, DOE and TVA began negotiations for a long-range program to utilize this excess DOE nuclear material as Sequoyah fuel.

The NRC staff (Office of Nuclear Material Safety and Safeguards (NMSS) Division of Fuel Cycle Safety) met with TVA, Siemens Power Corporation, and Nuclear Fuel Services (NFS) on August 20, 1997, in a public meeting, to discuss this project. During this meeting, the staff was informed that, in March 1995, President Clinton had declared 200 metric tons of HEU held by DOE as surplus to the needs of the U.S. Thirty to 40 tons of this material was determined to be usable in commercial reactors after some processing (because it was not commercial-grade uranium and was highly enriched). In April 1996, the USEC [United States Enrichment Corporation] Privatization Act provided for the transfer of "off-specification" uranium from DOE to TVA. In January 1997, TVA and DOE entered into a Memorandum of Understanding to use this "off-spec" uranium in TVA reactors.

A second public meeting was held on March 5, 1998, between the NRC staff (this time involving the Office if Nuclear Reactor Regulation, NMSS, and the Office of General Counsel) TVA, DOE, Oak Ridge, and Framatome-Cogema Fuels (FCF), Inc. (the selected fuel vendor at that time). The purpose of the second meeting was to review the detailed HEU re-use program including installation of four lead test assemblies (LTAs) in the Sequoyah Unit 2 core in the spring of

1999 (Phase 1) and insertion of a full 84-assembly production core reload in 2001 (Phase 2). The LTAs involved downblending (diluting) 107 kilograms of HEU and the full-production cores will utilize (recover) up to 40 metric tons of HEU.

A third public meeting was held on July 8, 1998, between the NRC staff, TVA, and FCF, dealing primarily with the LTAs. Chemical concentrations and activities of the actual LTA material were reviewed and compared with the standard commercial nuclear fuel specifications. Core performance monitoring plans to assess behavior of the installed LTAs were also reviewed.

During the January 11, 2001, meeting, TVA stated that 33 metric tons would be used for fuel in their reactors. The uranium is in the form of uranyl nitrate and uranium metal and contains uranium (U)-234 and U-236 from previous neutron irradiation as nuclear fuel.

Discussion

TVA submitted a topical report (prepared by FCF) for insertion of the LTAs into the Sequoyah Unit 2 Cycle 10 core reload on August 7, 1998. The NRC staff reviewed the report and notified TVA of its approval by letter dated February 18, 1999. TVA also submitted a request on August 27, 1998, to amend the Sequoyah Unit 2 Operating License to allow insertion of the LTAs, referencing the topical report. The amendment involved adding one sentence to the reactor core fuel assembly description of the Sequoyah Technical Specifications, specifically authorizing insertion of the LTAs as described in the topical report. A license amendment was required for installation of the LTAs partly because of the high concentration of U-234 and U-236 in the downblended material (U-234 and U-236 are fission products from previous irradiation as Savannah River fuel). The NRC approved the requested license amendment on April 12, 1999 (Amendment No. 234).

During the Cycle 9 refueling outage at Sequoyah Unit 2 (April 18 - May 11, 1999), the four LTAs were installed in the Unit 2 reactor core. Reactor startup and low-power physics testing following the outage indicated that the LTAs performed as expected, including power distribution and critical boron concentration. However, early in the operating cycle, TVA noted that reactor coolant dose equivalent iodine-131 levels were higher than expected, indicating the possibility of one or more leaking fuel rods. During the October 2000 refueling outage, TVA determined that one fuel rod in one of the four LTAs was leaking (one rod out of a total of 1056 rods). TVA made the decision to remove all four LTAs from the core. Fuel leakage was also found in several Westinghouse fuel rods that were scheduled to be removed anyway because they had completed their third cycle.

TVA, FCF, and Siemens performed independent evaluations of the failed LTA fuel rod and concluded that the cause of the failure was either a manufacturing defect or debris and was not caused by HEU-derived uranium (see Enclosure 2). This failure has no programmatic effect on the plans to use DOE HEU material for fueling one or more TVA reactors. TVA plans to re-insert the three "sound" LTAs in Sequoyah Unit 1 during the Fall 2001 refueling outage.

TVA management plans to seek approval of the TVA Board of Directors in February 2001 to proceed with a full core reload for Browns Ferry starting in 2005. Although the original plan was to use the HEU-derived material to fuel the Sequoyah reactors, it is now probable that Sequoyah will be involved in tritium production for DOE and intermingling tritium production and

HEU fueling at the same reactor site is prohibited by Federal policy. Thus, TVA is proposing to use the downblended HEU fuel in the Browns Ferry reactors instead of the Sequoyah reactors.

A representative of Siemens Power Corporation presented a discussion of the approach to use downblended HEU as fuel at Browns Ferry. Fuel pellets would be fabricated to the same specifications as utilized for standard commercial-grade uranium. The only difference would be the U-234 and U-236 isotopic content. Siemens has delivered significant quantities of "reprocessed" uranium fuel for 10 reactors in European countries (Germany, Sweden, and Switzerland) since 1983. No operational problems have been reported related to off-spec uranium fuel materials in the U.S. or Europe. Siemens stated that the Sequoyah LTA experience is valid for evaluating all key issues for use of downblended HEU in a boiling water reactor, such as Browns Ferry. Therefore, TVA has proposed that no LTAs would be inserted in the Browns Ferry reactors prior to a full core reload. The NRC staff challenged the lack of a Browns Ferry LTA program prior to production loading. TVA stated that no new information would be yielded by such a program. The staff countered by stating that, if that be the case, TVA's amendment request for the Browns Ferry HEU production core must be "robust" and include as much information as is available regarding the European experience with reprocessed uranium cores. The staff also advised that a convincing case must also be made to demonstrate why the Sequoyah LTA program yielded sufficient information for use of HEU material at Browns Ferry, because Sequoyah is a pressurized water reactor, not a boiling water reactor.

The staff, noting that problems have arisen during licensing actions involving increased fuel burn-up levels, advised TVA that it should review the Regulations (Part 51, "S-Tables") to assure that no unforseen environmentally-related legal issues might arise in the course of future licensing actions involving use of HEU fuel.

The NRC staff had no other significant questions or comments and expressed appreciation for a timely and informative presentation. TVA suggested another meeting within 6 months after approval of the next phase of the HEU program by the TVA Board of Directors.

Ronald W. Hernan

Ronald W. Hernan, Senior Project Manager, Section 2
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-260, 50-296, 50-327, and 50-328

Enclosures: 1. Attendance List
2. TVA Handout

cc w/enclosures: See next page

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/RA/

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cc w/enclosures: See next page
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Tennessee Valley Authority

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Tennessee Valley Authority

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NRC/TVA MEETING ON USE OF EXCESS DOE HEU FOR TVA REACTOR FUEL

THURSDAY, JANUARY 11, 2001

ATTENDEES

Name	Affiliation
Ronald Hernan	NRC
Gary Janosko	NRC
Rich Correia	NRC
Stacy Rosenberg	NRC
John Lehning	NRC
Muffet Chatterton	NRC
Howard Richings	NRC
Larry Kopp	NRC
Sherwin Turk	NRC
Bill Long	NRC
Ralph Shell	TVA
Jeanette Pablo	TVA
T. A. Keys	TVA
Jim Robert	TVA
Dean Tousley	DOE
Bill Wallach	McGraw-Hill
Frank Peters	NFS
Pat Koppel	NFS
Charlie Holman	Siemens
Norman Garner	Siemens
L. W. Newman	Framatome
John Willse	Framatome

ENCLOSURE 1

Highly Enriched Uranium Program

Lead Use Assembly Evaluation

NRC/TVA/FCF/SPC/NFS Meeting
Washington, DC
January 11, 2001

ENCLOSURE 2

Background

- TVA briefed NRC in March 1998 on HEU Program
  - Use 33 MT of surplus HEU from DOE as source of fuel
  - HEU-derived fuel higher than ASTM specs for U-234 & U-236
  - First phase was a limited demonstration at Sequoyah

- Four LUAs loaded into Sequoyah Unit 2 Cycle 10
  - Fabricated by Framatome using pellets manufactured by Siemens from LEU produced by NFS from HEU
  - Cycle startup in May 1999
  - Early indications of fuel failure

- Two leakers identified by sipping during the refueling outage
  - One Westinghouse reinsert assembly and one LUA
  - Additional inspections performed by Framatome to evaluate failure
  - Independent assessment of LUA failure by Stoller

Stoller Assessment of LUA Failure

- No evidence that failure caused by HEU-derived uranium
- Fuel rod growth indicates severe secondary hydriding
- Likely cause of failure either a manufacturing defect or debris

HEU PROGRAM PLANS

- Reinsert 3 sound LUAs in Sequoyah
  - Use in Unit 1 in Fall 2001 refueling
  - Irradiate to end of life

- Request TVA Board approval of HEU Program in 2/01
  - Start work 3/01
  - Brief NRC on licensing actions within six months
  - Use HEU-derived reloads in Browns Ferry starting in 2005

FRAMATOME ANP

BHEU LUA Failed Rod Evaluation

Comparison of BHEU with Virgin and Rep-U

Fragema Experience with Rep-U

BHEU LUA Measured vs Predicted Power

Summary & Conclusions

FRAMATOME ANP

HEU vs. Standard UO2 Pellet As-Built Characteristics					
Pellet Attribute	**Specification Limit**	**Lot numbers**			
		HEU Lot #	HEU Lot #	HEU Lot #	Standard
Chemical Impurities		669-01X	669-02X	669-01X1	Lot #557-01D
Total Impurities	1500 ppm	561	515	557	335
Aluminum	250 ppm	175	168	170	107
Silicon	250 ppm	32	22	21	<20
Iron	500 ppm	199	163	189	29
Thorium	10 ppm	1	1	1	<1
Fluorine	15 ppm	< 1	< 1	< 1	<1
Carbon	50 ppm	< 5	< 5	< 5	<5
Nitrogen	25 ppm	< 5	< 5	< 5	<5
Chlorine	25 ppm	< 2	< 2	< 2	3
Total EBC	4.0 ppm B	1.8	1.8	1.8	2.0
Stoichiometry					
Oxygen-to-uranium ratio	UTL (95/95) ≤ 2.02	2.00	2.01	2.01	2.00
	$X_i \geq 1.99$	2.00	2.00	2.00	2.00
		2.00	2.00	2.00	2.00
		2.00	2.00	2.00	2.00
Hydrogen Content	UTL (95/95) ≤ 1.0 ppm	0.48	0.10	0.10	0.10
Sorbed Gas	UCL (95) ≤ 0.01 cc/gm	0.010	0.009	0.009	Qual only
	UTL (95/95) ≤ 0.02 cc/gm	0.013	0.009	0.009	"

FRAMATOME ANP

Enrichment	Average ± 0.03 w/o nominal value				
	4.34 ± 0.03 (HEU)	4.340	4.345	4.339	
	4.30 ± 0.03 (Std)				4.304
	Individual ± 0.04 w/o nominal value				
	4.34 ± 0.04 (HEU)	4.339	4.346	4.337	
		4.341	4.344	4.341	
	4.30 ± 0.04 (Std)				4.305
					4.303
Total U Content	$X_i \geq 87.7$ w/o	88.082	88.085	88.079	88.113
		88.084	88.088	88.083	88.115
		88.079	88.091	88.083	88.115
Total Isotopic	^{238}U (Report value only)	94.733	94.632	94.733	95.647
	^{236}U	0.862	0.956	0.863	0.009
	^{234}U	0.064	0.067	0.064	0.039

FRAMATOME

BHEU vs Rep-U Isotopics

U Isotopics	Rep-U	As-built BHEU LUA	C996
U-235, wt%	4.383	4.341	5.0
U-232, ppb	9	<2	<50
U-234, wt%	0.065	0.065	<1.4
U-236, wt%	0.95	0.894	0.025<x<0.05*

* No actual upper limit - additional measurements required

Note: Information in column 2 is taken from 1996 presentation to TVA by FCF.

FRAMATOME ANP

Fragema Experience with Rep-U

- Rep-U usage began in 1987
- As of 12/2000, irradiation experience is 171,058 fuel rods (722 assemblies) for up to five cycles
  - Two leaking fuel rods
  - One occurred in its third cycle and was caused by debris
  - One occurred in its second cycle, cause is unknown, reloaded for a third cycle
- Defect Rate for Rep-U not counting debris: 1/171,058 rods, which is comparable to virgin U failure rate
- Rep-U impurities, within specification, have no demonstrated impact on failure rate or gravity

FRAMATOME ANP

HEU LTA Manufacturing

1) DOE provided the HEU material

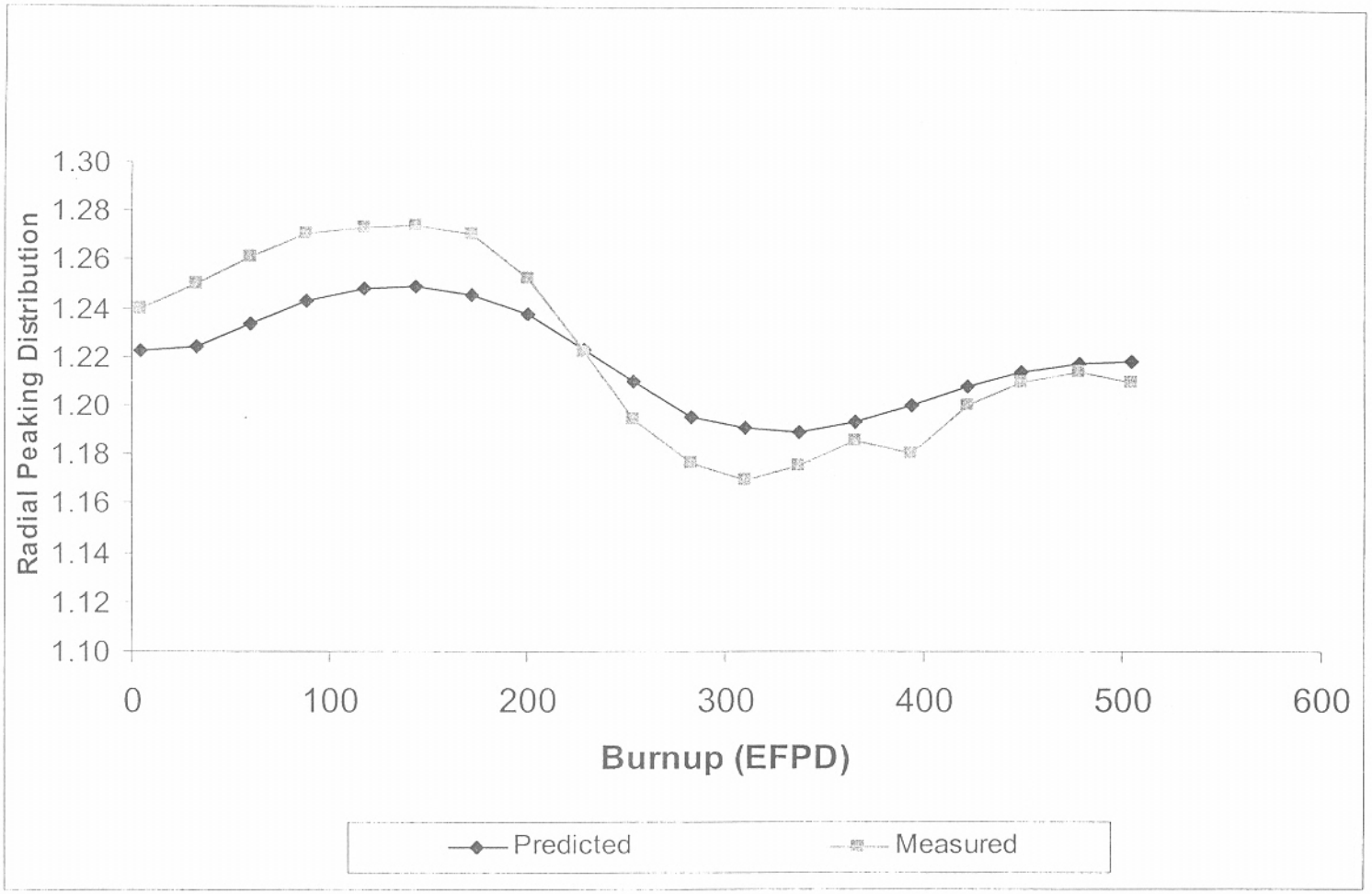
2) NFS performed solvent extraction & blend-down
   - o Used established technology
   - o Met specifications

3) SPC fabricated fuel pellets
   - o Same process and specifications as virgin U pellets, except for U-234 and U-236 quantities
   - o Met specifications

4) FRA-ANP manufactured the fuel rods & assemblies
   - o Same process and specifications as virgin U assemblies
   - o Met specifications; no deviations identified

FRAMATOME ANP

BHEU Assembly RPD Comparison
Sequoyah 2 Cycle 10



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FRAMATOME ANP

Summary & Conclusions

- One failed fuel rod was found in one of the four LUAs
- Coolant chemistry indicated a failure occurred at about 7 EFPDs
- Manufacturing processes were the same as for assemblies using virgin U
- No deviations were identified for the fuel pellets and fuel rods during the manufacturing process
- The in-core performance of the LUAs matched well with code predictions
- BHEU and Rep-U have the same U constituents and behavioral characteristics
- Impurity specifications for virgin U were imposed and all were met
- BHEU meeting specifications has no known or expected performance issues

Failed Fuel Rod Examination

Identification Of The Failure

Visual Examinations Performed

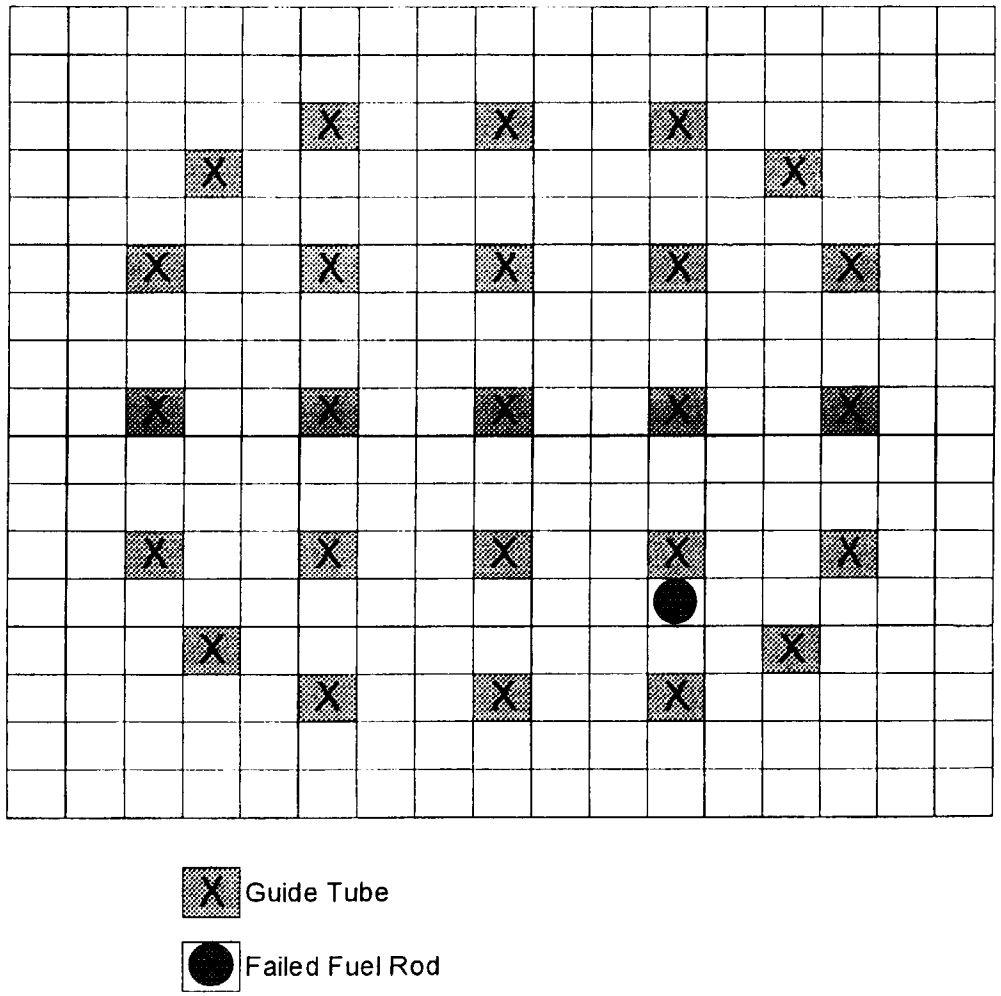
Framatome Failure History

Conclusions

Failed Fuel Rod Inspection

- Failure may have occurred at about 7 EFPD
- Failed assemblies identified by sipping
  - 1 LUA fuel assembly
  - 1 Third burned fuel assembly supplied by other vendor
- Failed fuel rod identified by UT
  - 1 rod failed in LUA assembly
  - Other LUAs were defect free
  - Other failed assembly contained several failures

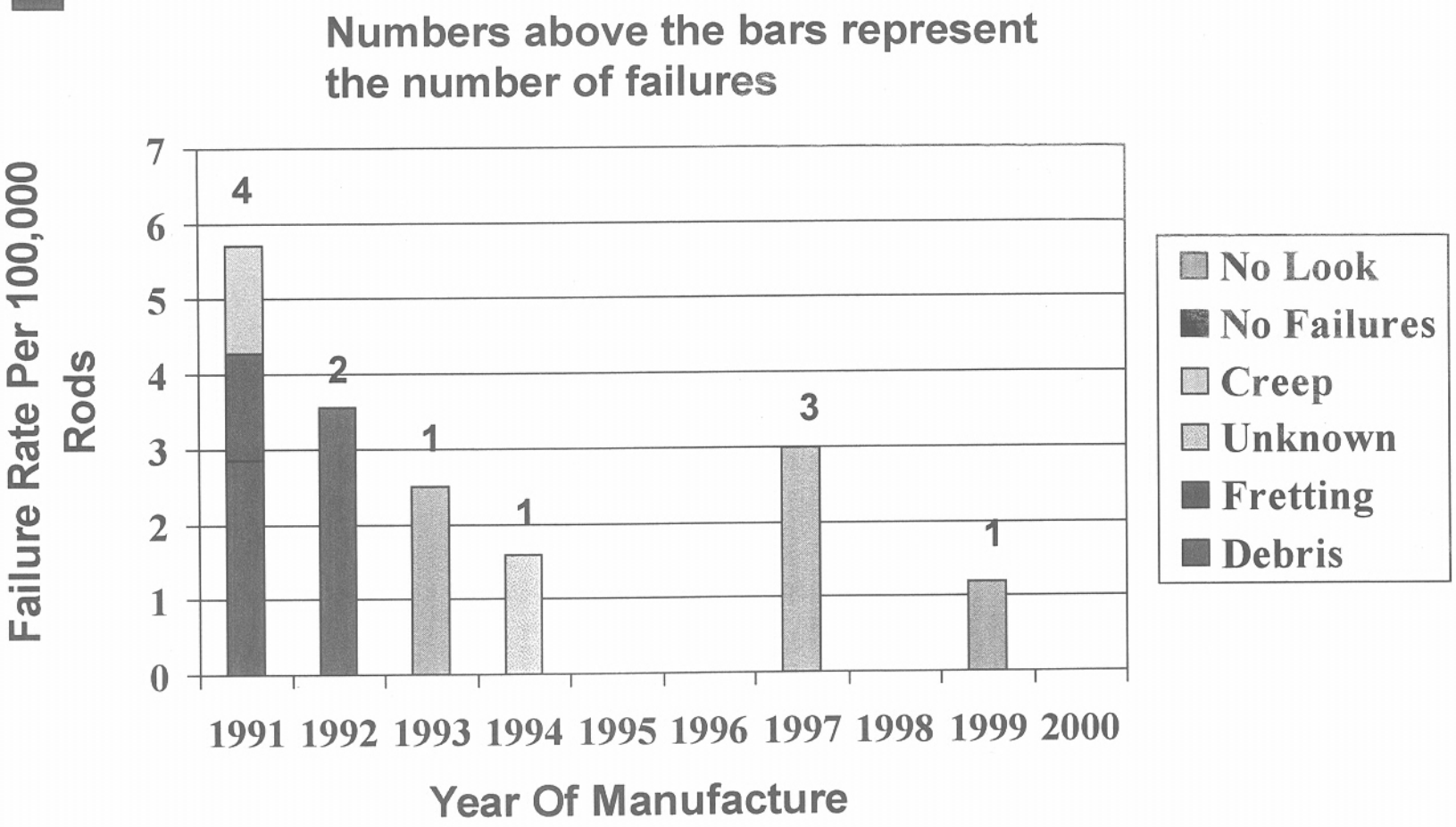
Failed Fuel Rod Location



Visual Examination

- Fuel assembly looks normal
- No debris observed in this assembly
- Failed fuel rod has grown 0.25 to 0.50 inches
- No visible defects

Failure Rate For Mark-BW Fuel By Year Of Manufacture



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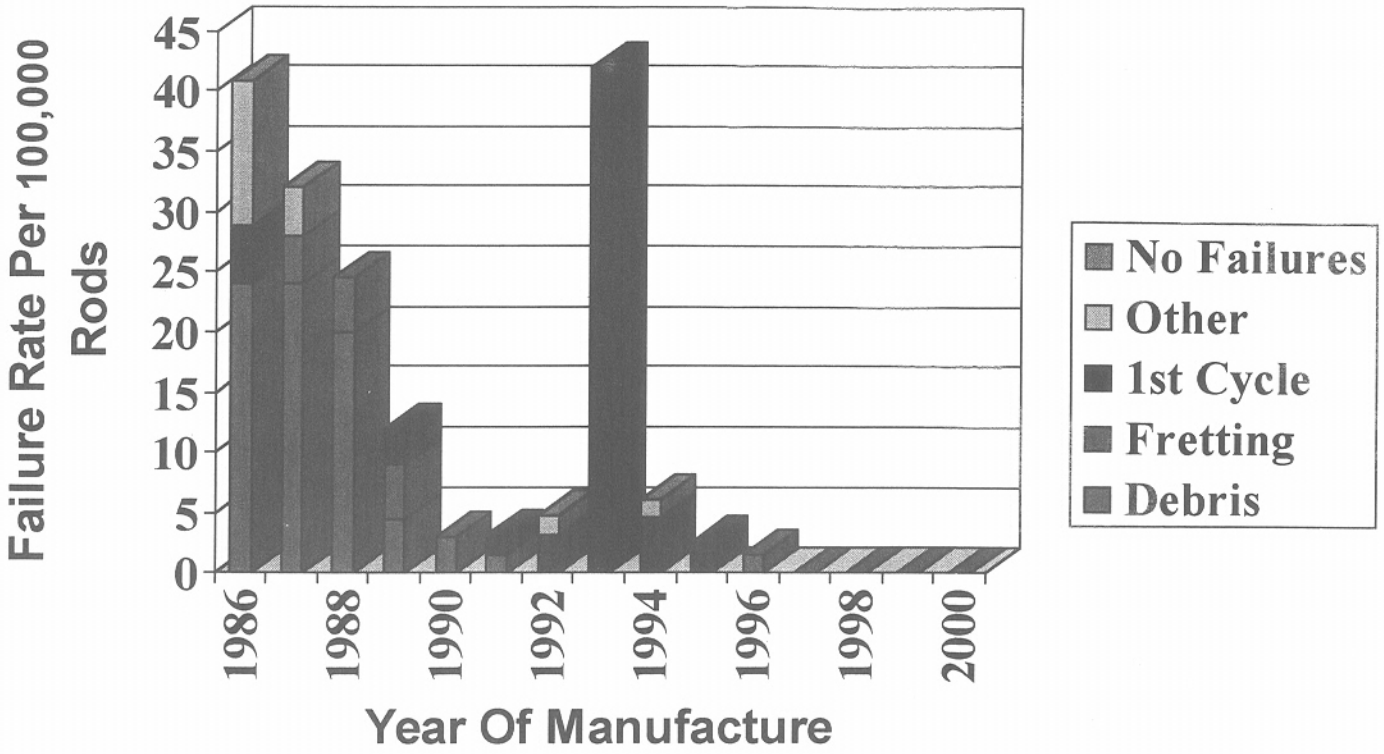
Failure Rate For Mark-B Fuel By Year Of Manufacture



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Conclusions

- Failure mechanism could not be determined from visual examinations performed
- There is no indication that this was an abnormal failure
- Most likely failure mechanisms - debris or spacer grid fretting, improper weld, or surface contamination
- Approximately ten percent of failed fuel rods separate during removal from the fuel assembly
- If the fuel rod is removed from the fuel assembly there is only about a fifty percent probability that the failure mechanism can be identified

SIEMENS

TVA/NRC Meeting, January 11, 2001
Highly Enriched Uranium Program

Blended Highly Enriched Uranium (BHEU)
Fuel for TVA Browns Ferry

Approach for Use at Browns Ferry

Performance Considerations

Experience

Conclusions

SIEMENS

Use of Off-Spec BHEU for Reload Fuel Assemblies at Browns Ferry

- Cycle design studies have shown significant quantities of off-spec BHEU can be efficiently utilized at Browns Ferry
- Reloads would be fabricated utilizing SPC's approved ATRIUM-10 fuel design
- Pellets would be fabricated to the same specifications, except for isotopic content, as utilized for standard commercial grade uranium
- Nuclear analyses would be performed with SPC's recently approved CASMO-4/MICROBURN-B2 advanced core simulator methodology

SIEMENS

Off-Spec BHEU
Thermal-Mechanical Performance

- The BHEU differs from commercial grade uranium primarily in the U234 and U236 isotopes.
- Elevated levels of U234 and U236 in BHEU do not affect the thermal-mechanical behavior of the fuel pellets
- Elevated levels of U234 and U236 do not lead to increased production of gaseous fission products

The approved generic ATRIUM-10 mechanical design analyses are bounding for assemblies with off-spec BHEU

SIEMENS

Off-Spec BHEU
Nuclear Performance

- Elevated U234 and U236 levels depress the reactivity of BHEU material relative to commercial grade material of equal U235 enrichment
- Behavior of U234 and U236 under irradiation is well understood
- SPC CASMO/MICROBURN methodology explicitly models and tracks U234 and U236 isotopes for accurate prediction of reactivity characteristics of fuel

SPC's approved CASMO-4/MICROBURN-B2 methodology is valid for use in analyzing off-spec BHEU within the limitations specified in the topical report

SIEMENS

Off-Spec Uranium SPC/Siemens Experience

- SPC has delivered fuel containing U236 levels up to 2.3 times the ASTM limit for 6 BWRs and 4 PWRs in the US since 1993
- Siemens has delivered significant quantities of reprocessed uranium (REPU) fuel with U236 levels up to 18.4 times the ASTM limit for 10 reactors in Europe since 1983
  - Approved for use in reload quantities by regulatory authorities in Germany, Sweden, and Switzerland

No operational problems related to off-spec uranium fuel materials have been encountered in the US and Europe

SIEMENS

Off-Spec BHEU Fuel for Browns Ferry Applicability of Sequoyah LUA Experience

- SPC fabrication of pellets for the Sequoyah LUAs demonstrated ability to produce pellets to the same specifications as used for commercial grade pellets
- Close agreement of measured vs. predicted power of Sequoyah LUAs confirms the accuracy of CASMO based methods for analyzing BHEU fuel with elevated levels of U234 and U236

Sequoyah LUA experience is valid for evaluating all key issues for use of off-spec BHEU in a BWR