GE Nuclear Energy

General Electric Company
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U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Mail Station P1-137
Washington, D.C. 20555

Attention: M.W. Hodges, Chief
Reactor Systems Branch

Gentlemen:

SUBJECT: Experience With BWR Fuel Through December 1987

Attached is a copy of the GE report providing an update of GE's experience with BWR fuel through December 1987. It is being sent to you at your request for use in the preparati n of your annual fuel performance report.

Please contact me if you have any questions.

J.S. Charnley
Fuel Licensing Manager

Attachment

cc: L.S. Gifford
S. Wu (NRC)

GENERAL ELECTRIC COMPANY PROPRIETARY INFORMATION

NUCLEAR FUEL & ENGINEERING SERVICES DEPARTMENT
San Jose, California

RECEIVED
OCT 10 1988
J. S. CHARNLEY

September 26, 19878

cc: JA Baumgartner
GAP GA Potts

To: J. S. Charnley
M/C 687

Subject: EXPERIENCE WITH BWR FUEL THROUGH DECEMBER 1987

Attached is the annual update of the subject report for transmittal to the NRC. If you have any questions or comments, please contact the undersigned.

L. P. Harding
Fuel Rod Thermal &
Mechanical Analysis
M/C 155, Ext. 5-6580

Approved:
R. A. Proebstle, Manager
Fuel Engineering

Attachment

EXPERIENCE WITH BWR FUEL

THROUGH DECEMBER 1987

I. Introduction

This information report provides an updated review of General Electric experience with production and developmental BWR Zircaloy-clad UO_2 fuel rods through December 1987. This experience includes successful commercial reactor operation of fuel bundles to greater than 45,000 MWd/MTU bundle average exposure (approximately 60,000 MWd/MTU peak pellet exposure).

The performance of General Electric 8X8 fuel types continues to be highly successful as demonstrated by a 1987 fuel rod reliability rate of greater than 99.99%.

II. General Electric BWR Fuel Experience Base

As of December 31, 1987, over 3.3 million General Electric 8X8 fuel type production Zircaloy-clad UO_2 fuel rods were in, or had completed, operation in commercial BWRs. Figure 1 shows cumulative 8X8 fuel rods loaded as a function of calendar year. As of December 31, 1987, over 1.5 million General Electric fuel rods were in operation. Figure 2 illustrates General Electric's core loadings by fuel type as a function of calendar year. As of December 31, 1987, General Electric had loaded approximately 700,000 pellet-cladding interaction (PCI) resistant barrier fuel rods in commercial BWR's. The General Electric fuel manufacturing facility in Wilmington, North Carolina, is producing 100% of its 1988 load as barrier fuel, demonstrating the overall customer acceptance of this fuel design.

III. Generic Concerns

Early General Electric fuel operating experience identified fuel performance problems that have been subsequently corrected through evolutionary design, manufacturing, and operating improvements. These earlier problems are not affecting fuel performance at this time. Pellet-cladding interaction (PCI) and crud-induced localized corrosion (CILC) are the only cladding perforation mechanisms which have affected fuel performance in recent periods. As described below, product improvements have been developed that will essentially eliminate these two fuel rod failure mechanisms.

A. Pellet-Cladding Interaction

Light Water Reactor (LWR) nuclear fuel is susceptible to fuel rod cladding perforation, commonly called pellet-cladding interaction (PCI) failure, when subjected to fast power increases at moderate to high exposures. Operational procedures (PCIOMRs), which involve slow approaches to power, have essentially eliminated PCI failures in LWRs, but at the cost of reactor capacity factor losses. Zirconium barrier fuel was invented by General Electric as a material solution to the PCI failure problem. Extensive test reactor and laboratory tests along with successful in-core power ramp demonstrations in the Quad Cities Unit 2 power reactor have shown that Zr-barrier fuel is convincingly failure resistant. Barrier fuel was commercially introduced by General Electric in 1983. The Zr-barrier fuel commercial experience further confirms the effectiveness of this fuel design concept, with not a single PCI-induced Zr-barrier fuel rod failure in greater than 300,000 barrier fuel rods completing at least one reactor cycle of operation.

B. Crud-Induced Localized Corrosion

In 1979, an unexpected low-level failure mechanism of localized fuel rod cladding corrosion was revealed in some BWRs. Poolside examination of the failed fuel rods revealed plant corrosion product (crud) scale deposits with high copper concentrations. The nature of the failures led to identification of special conditions of environment, operational history, and material-susceptibility that must occur simultaneously to cause failure. These crud-induced localized corrosion (CILC) failures have been limited to plants with copper alloy condenser tubes and filter demineralizer condensate cleanup systems.

Fuel examinations, surveillance, and extensive research have led to a practical understanding of, and solution to, this mechanism. A reproducible out-of-reactor test for measuring the susceptibility of Zircaloy to in-reactor nodular corrosion was developed by General Electric and correlated to in-reactor performance (Reference 1). This test confirmed a previously undetected variability in the susceptibility of Zircaloy to in-reactor nodular corrosion. This test has been patented and made available to the industry on a non-profit basis through the ASTM.

A new manufacturing process was developed that improves the corrosion resistance of the incoming material produced by the Zircaloy vendors to yield material which is more resistant to in-reactor nodular corrosion. This process has been implemented in the production of all General Electric fuel to provide a high degree of assurance that adequate corrosion resistant properties are achieved.

IV. In-Reactor Surveillance Programs and Summary of Surveillance Results

One of the most important aspects of the General Electric fuel design process is the in-reactor performance monitoring of a design before and after its introduction. In keeping with the General Electric philosophy of test-before-use, lead test assemblies (LTA's) containing selected key design features are used to demonstrate the satisfactory performance of these features and to provide lead experience for future production fuel. The fuel surveillance program adopted by General Electric and accepted by the NRC is described in References 2 through 5.

A summary of General Electric's lead test assembly surveillance program is contained in Table 1. Examination results are provided below:

A. Barrier Fuel Program

The goal of this program was the demonstration of a PCI-resistant fuel under conditions which would provide statistically significant results. The PCI-resistant fuel features the barrier concept to protect the fuel cladding from failure caused by PCI. The barrier fuel program consisted of lead test assemblies, loaded into Quad Cities-1 in 1979 at the beginning of cycle 5, and a demonstration reload of 144 bundles with Zr-lined cladding placed into the core at Quad Cities-2 at the beginning of cycle 6.

The barrier LTA's at Quad Cities-1 have undergone four poolside examinations to date, consisting of visual inspections and nondestructive testing of selected fuel rods. These examinations, have revealed that the bundles and individual fuel rods exhibited charac-

teristics typical of normal operation. Two LTA's completed a fifth cycle of operation in September 1987.

The Quad Cities-2 barrier fuel program was designed to subject the barrier cladding fuel to significant power increases in order to demonstrate the PCI resistance of barrier fuel. Two power increase demonstrations have been performed; the first in 1983 at the end of Cycle 6 and the second in 1985 at the end of Cycle 7. Sixteen barrier bundles were involved in each demonstration. During the following plant outage, all demonstration barrier bundles were evaluated by vacuum offgas sipping and determined to be sound. Subsequent to the power increase demonstrations, all PCIOMR operating restrictions were removed from the barrier fuel bundles in the core. Plant offgas surveillance indicates that all fuel bundles in the core continue to operate reliably.

B. Improved Design Feature Lead Test Assemblies

Several Lead Test Assemblies have been designed and placed in operation for the purpose of obtaining experience and performance data on new product design features. These LTAs have undergone extensive pre-irradiation characterization, with plans for interim poolside examinations. These Improved Design Feature LTAs include:

1. 1981 Lead Test Assemblies

Eight LTAs were loaded into Browns Ferry-3 in 1982 at the beginning of Cycle 5. A poolside examination, after the first cycle of operation in 1984, showed that the LTAs exhibited characteristics typical of normal operation.

2. 1983 Lead Test Assemblies

Four LTAs were loaded into Peach Bottom-3 in 1983 at the beginning of Cycle 6. The first poolside examination of these bundles was completed in August 1985, after one cycle of operation, and showed characteristics typical of normal operation. The LTAs completed their second cycle of operation in 1987 and were again visually examined in November 1987 and showed characteristics typical of two cycles of normal operation.

3. 1984 Lead Test Assemblies

Five LTAs were loaded into Duane Arnold in 1985 at the beginning of Cycle 8. The first poolside examination of these bundles was completed in April 1987, after one cycle of operation, and showed characteristics typical of normal operation. The next poolside examination is scheduled in 1988 after the second cycle of operation.

4. 1987 Lead Test Assemblies

Four LTAs were loaded into Hatch-1 in 1987 at the beginning of Cycle 11. The first poolside examination of these bundles is scheduled in 1988 after the first cycle of operation.

V. Conclusions

General Electric has developed a substantial fuel experience base that, coupled with an aggressive fuel surveillance program, has provided significant feedback on statistically significant numbers of fuel rods with regard to the performance effectiveness of design, operational and manufacturing changes. It is concluded that the experience gained with General Electric production and developmental fuel continues to demonstrate the high reliability of the General Electric designed BWR fuel.

VI. References

1. B. Cheng, H. A. Levin, R. B. Adamson, M. O. Marlowe, V. L. Monroe, "Development of a Sensitive and Reproducible Steam Test for Zircaloy Nodular Corrosion", ASTM 7th International Conference on Zirconium in the Nuclear Industry, Strasbourg, France, June 24-27, 1985.

2. J. S. Charnley (GE) to C. H. Berlinger (NRC), "Post Irradiation Fuel Surveillance Program", November 23, 1983.

3. J. S. Charnley (GE) to L. S. Rubenstein (NRC), "Fuel Sruveillance Program", February 29, 1985.

4. J. S. Charnley (GE) to L. S. Rubenstein (NRC), "Additional Details Regarding Fuel Surveillance Program", May 25, 1984.

5. L. S. Rubenstein (NRC) to R. L. Gridley (GE), "Acceptance of GE Proposed Fuel Surveillance Program", June 27, 1984.

Table 1

Summary of Ongoing Lead Test Assembly Surveillance Programs

Program	Reactor	Number of Bundles	Number of Completed Cycles of Operation	Bundle Average Exposure At Last Outage (GWd/MTU)	Objectives
Barrier LTA's	Quad Cities-1	2	5	43	Barrier Cladding
1981 LTA's	Browns Ferry-3	8	1	12	Improved design features
1983 LTA's	Peach Bottom-3	4	2	24	Improved design features
1984 LTA's	Duane Arnold	5	1	15	Improved design features
1987 LTA's	Hatch-1	4	-	--	Lead Use GE8X8NB

Figure 1

GE 8X8 BWR Fuel Rod Experience

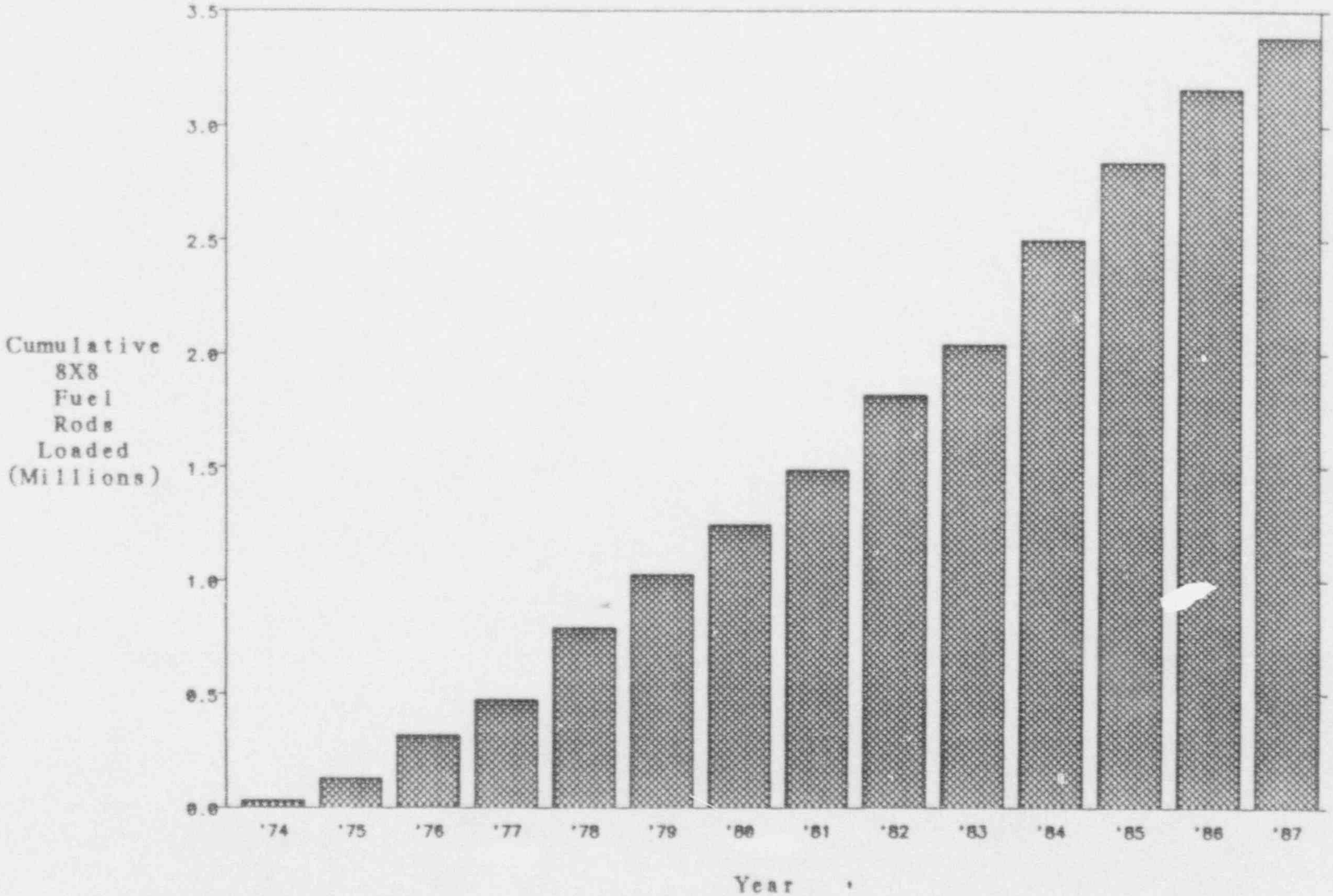

Figure 2

GE BWR Fuel Rods in Operation