Westinghouse Proprietary Class 3

WCAP-11930

SAFETY EVALUATION
ZIRCONIUM BASE ADVANCED CLADDING MATERIALS
USAGE IN NORTH ANNA UNIT 1
DEMONSTRATION FUEL ASSEMBLIES

J. Skaritka, Editor

August 1988

APPROVED: ______________________
E. H. Novendstern, Manager

Westinghouse Electric Corporation
Commercial Nuclear Fuel Division
P. O. Box 3912
Pittsburgh, Pennsylvania 15230

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SAFETY EVALUATION

Zirconium Base Advanced Cladding Materials Usage in North Anna Unit 1 Demonstration Fuel Assemblies

Introduction

Virginia Electric and Power Company is currently irradiating two demonstration fuel assemblies in North Anna Unit 1 containing fuel rods clad with an advanced zirconium base alloy. This alloy cladding is expected to have superior corrosion resistance compared to conventional Zircaloy-4 cladding. Developing advanced cladding materials with improved corrosion resistance is important because corrosion is one of the most limiting parameter with regard to achieving extended burnups. The advanced alloy cladding can achieve region average burnups exceeding [ ]+ MWD/MTU while maintaining clad (a,b,c) integrity. A license condition approval for the use of this advanced alloy cladding in the two demonstration fuel assemblies was given in an USNRC letter of May 13, 1987.

To enhance the understanding of the effects of small variations in alloy composition on in-pile corrosion and creep performance and to obtain a more comprehensive data base, it is proposed to irradiate fuel rods clad with additional advanced zirconium base alloys which differ slightly in composition from Zircaloy-4 and the advanced cladding currently being irradiated in the North Anna demonstration fuel assemblies. The chemical compositions of these advanced alloys are similar to Zircaloy-4 and the advanced alloy currently being irradiated. It is proposed that fuel rods clad with these advanced alloys be irradiated in North Anna 1 beginning with Cycle 8. They would be inserted in the demonstration fuel assemblies in place of irradiated rods which would be removed.

The fuel assemblies have removable top nozzles which allow access to all fuel rods for inspection. The fuel rods, as other fuel rods in the core with advanced alloy cladding, will contain nominally 95% dense UO_2 pellets, will have the same fuel rod dimensions, will have Zircaloy-4 end plugs, and will be pressurized with helium.

PROPOSED LICENSE CHANGE

The North Anna Unit 1 Technical Specification Section 5.3.1 describes the reactor core as consisting of assemblies containing 264 fuel rods clad with Zircaloy-4. In order to allow the use of more than one advanced zirconium based alloy cladding, it is proposed deleting the following condition for the North Anna Unit 1 license:

> "Virginia Electric and Power Company may use two (2) fuel assemblies containing fuel rods clad with advanced zirconium base alloy cladding material as described in the licensee's submittal dated 02-20-87.",

and replacing this current license condition with the following:

> "Virginia Electric and Power Company may use two (2) fuel assemblies containing fuel rods clad with advanced zirconium base alloy cladding materials as described in the licensee's submittals dated 02-20-87 and 09-__-88."

EVALUATION

Chemical/Mechanical Properties

The chemical compositions of the additional advanced alloys are very similar to the current approved advanced alloy and Zircaloy-4 as shown in Table 1. Based on these compositions, it is predicted that the physical properties of the additional advanced alloys fall within the range of the properties of the approved Zircaloy-4 and advanced alloy clad material used in the demonstration fuel assemblies. All fuel rod design bases are met by the demonstration fuel assemblies containing the additional advanced alloys.

The corrosion behavior of one of the advanced alloys versus Zircaloy-4 is shown in Figures 1 and 2. This alloy has an appreciably better out-of-pile corrosion behavior than Zircaloy-4 at all four test temperatures. When comparing the chemical compositions of the alloys in Table 1, it is expected that the additional alloys will have similar rrosion behaviors.

<u>Cladding Behavior Under LOCA Conditions</u>

The key aspects of cladding materials behavior which affect fuel performance during LOCA are high temperature metal-water reaction kinetics and clad ballooning. The following discussion presents a comparison of the expected behavior of advanced zirconium base alloys with that of Zircaloy-4.

The high temperature metal-water reaction rates for Zircaloy-4 were reported
by Cathcart[1]. [ ]+[2] reported similar reaction rates for (a,b,c)
Zircaloy-4, Zircaloy-2, [ ]+. Both of these investigations show (a,b,c)
reaction rates less than those predicted by the Baker-Just correlation which
was adopted for LOCA modeling by the NRC. Since the advanced alloys are
[ ]+ they are (a,b,c)
expected to have similar high temperature metal-water reaction kinetics and
thus, have reaction rates less than those predicted by the Baker-Just
correlation.

[ ]+[3] compares the high temperature strain behavior of Zircaloy-4 [(a,b,c)
]+. These studies found that [ ]+ is stronger than (a,b,c)
Zircaloy-4 in both the alpha and beta phases but is weaker in the intermediate
two phase region. For the [ ]+ alloy, the two phase region begins at (a,b,c)
about [ ]+ and ends about [ ]+. For Zircaloy-4, the corresponding (a,b,c)
temperatures are about 820C and 950C. For the advanced alloys, the
temperatures are estimated to be intermediate to those of Zr-4 and
[ ]+ (a,b,c)

The attached Figure 3 shows the expected strain vs. temperature for Zircaloy-4 and [ ]+ heated at a rate of 25°C/sec, replotted from Reference 3. (a,b,c)
Also shown in the figure is the estimated curve for one of the advanced alloys [

.]+. The conclusion drawn from the figure is that the (a,b,c)
strain behavior of the advanced alloys will be very similar to that of Zircaloy-4.

EVALUATION CONCLUSIONS

The use of two demonstration fuel assemblies with fuel rods clad with a zirconium base alloy will not result in any new accident, since the two demonstration fuel assemblies and their fuel rods will satisfy the same design bases (References 4 and 5) used for other assemblies in the fuel region.

For each reload core until discharge, the demonstration fuel assemblies will be specifically evaluated using standard nuclear design methods (Reference 6) and approved fuel rod design methods(7). The existing reload design and safety analysis limits will apply. This will include consideration in the core physics analysis of peaking factors and core average linear heat rate effects. Therefore, there will be no reduction in safety margin.

Based on the preceding information, Virginia Electric and Power Company concludes that the performance of fuel rods clad with advanced zirconium base alloys during a LOCA event will be bounded by the performance previously calculated for other incore fuel rods clad with Zircaloy-4, which was based on accepted ECCS evaluation models. Further, we conclude that the use of fuel rods cladded with the additional advanced alloys in the two North Anna Unit 1 demonstration assemblies would conform to all the current fuel design bases, would not change the existing reload design and safety analysis limits, and satisfies the guidelines stated in Reference 8 for lead test assemblies.

REFERENCES

1. Cathcart, J. V., et al, "Zirconium Metal-Water Oxidation Kinetics IV. Reaction Rate Studies" ORNL/NUREG-17, Oak Ridge National Laboratory, August 1977.

2. [(a,b,c)

]+

3. [(a,b,c)

]+

4. Davidson, S. L., Iorii, J. A., "Reference Core Design Report - 17x17 Optimized Fuel Assembly," WCAP-9500-A, Volume 2, May 1982.

5. Letter from T. M. Anderson (Westinghouse) to J. R. Miller, Chief (NRC), NS-TMA-2366, Answer to Question 231.2 (4.2.1), dated January 1, 1981.

6. VEP-FRD-42 Revision 1-A, "Reload Nuclear Design Methodology," September 1986.

7. Kersting, P. J., "Extended Burnup Evaluation of Westinghouse Fuel," WCAP-10125-P-A, December 1985.

8. "Safety Evaluation by the Office of Nuclear Regulation Related to Amendment No. 94 Facility Operating License No. NPF-4 Virginia Electric and Power Company Old Dominion Electric Cooperative North Anna Power Station, Unit No. 1 Docket No. 50-338" dated May 13, 1987.

TABLE 1

CHEMICAL COMPOSITION OF ADVANCED ZIRCONIUM BASE ALLOYS

Comparisons with Zircaloy-4

	Zircaloy-4	Approved Advanced Alloy	Additional Advanced Alloys (a,b,c)
Sn (%)	1.2 - 1.7		
Fe (%)	0.18 - .24		
Cr (%)	.07 - .13		
Nb (%)	---		
Zr (%)	Balance	Balance	Balance

UNREVIEWED SAFETY QUESTION EVALUATION

The use of the two fuel demonstration assemblies containing rods with additional advanced cladding materials in North Anna Unit 1 has been determined not to result in an unreviewed safety question as defined in 10 CFR 50.59. The basis for this determination is as follows:

1) The probability of occurrence or the consequences of an accident or malfunction of equipment important to safety previously evaluated in the safety analyses is not increased. The demonstration fuel assemblies with zirconium base alloy clad fuel rods meet the same fuel assembly and rod design bases as other fuel assemblies in the fuel region. In addition, the 10CFR50.46 criteria remain applicable to the zirconium base alloy clad fuel rods. Therefore, the use of these demonstration fuel assemblies will not result in a change to existing reload design and safety analysis limits, and the consequences of an accident are not increased.

2) The possibility for an accident or malfunction of a different type than any evaluated in the safety analyses is not created since the demonstration fuel assemblies satisfy the current design bases. In addition, the use of the demonstration fuel assemblies does not involve any alterations to plant equipment or procedures which would introduce any new or unique operational modes or accident precursors.

3) The margin of safety as defined in the basis for any technical specification is not reduced since the demonstration fuel assemblies do not change the existing reload design and safety analysis limits. In addition, the 10CFR50.46 criteria remain applicable to the zirconium base alloy clad fuel rods. Therefore, the current UFSAR analyses remain bounding and there is no reduction in the margin of safety.

10 CFR 50.92 SIGNIFICANT HAZARDS CONSIDERATION ANALYSIS

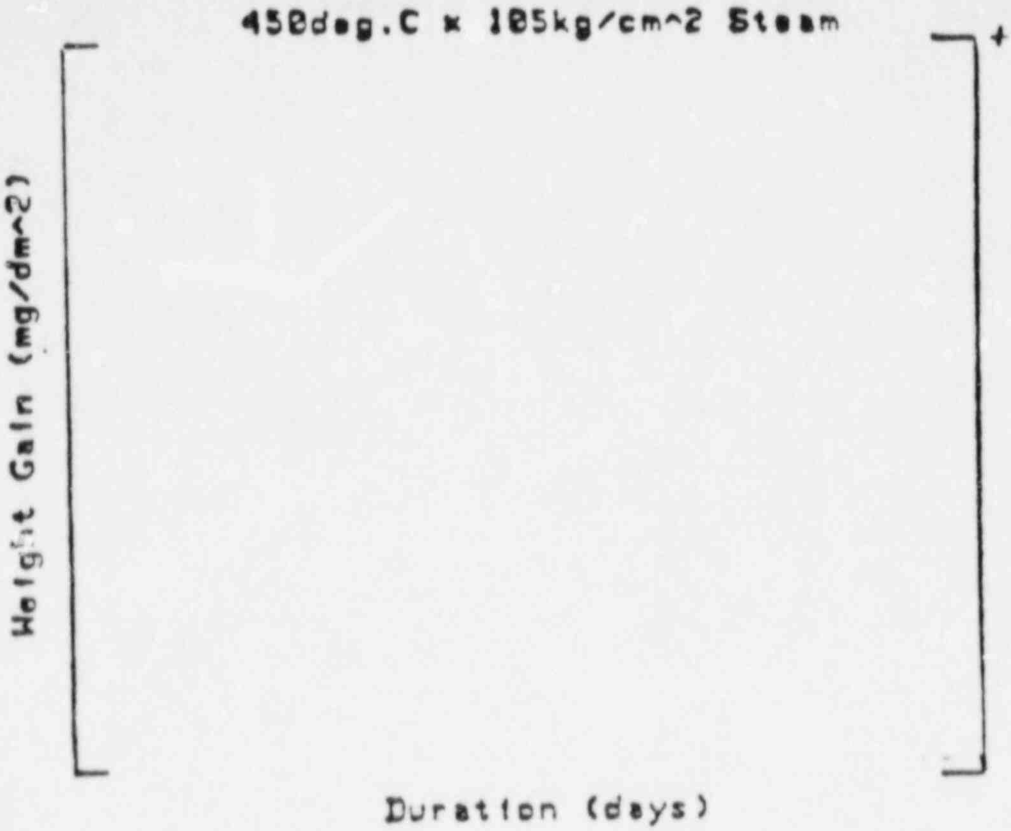
It has also been determined that the proposed change does not involve a significant hazards consideration as defined in 10 CFR 50.92.

Specifically, the change does not:

1) Involve a significant increase in the probability or consequence of any accident or malfunction of equipment important to safety previously evaluated in the safety analyses. The fuel assemblies with zirconium base alloy clad fuel rods meet the same fuel assembly and rod design bases as other fuel assemblies in the fuel region. In addition, the 10CFR50.46 criteria remain applicable to the zirconium base alloy clad fuel rods. Therefore, the use of these fuel assemblies will not result in a change to existing reload design and safety analysis limits, and the consequences of an accident are not increased.

2) Create the possibility of a new or different type of accident than previously evaluated since the fuel assemblies satisfy the current design bases. In addition, use of the assemblies does not involve any alterations to plant equipment or procedures which would introduce any new or unique operational modes or accident precursors.

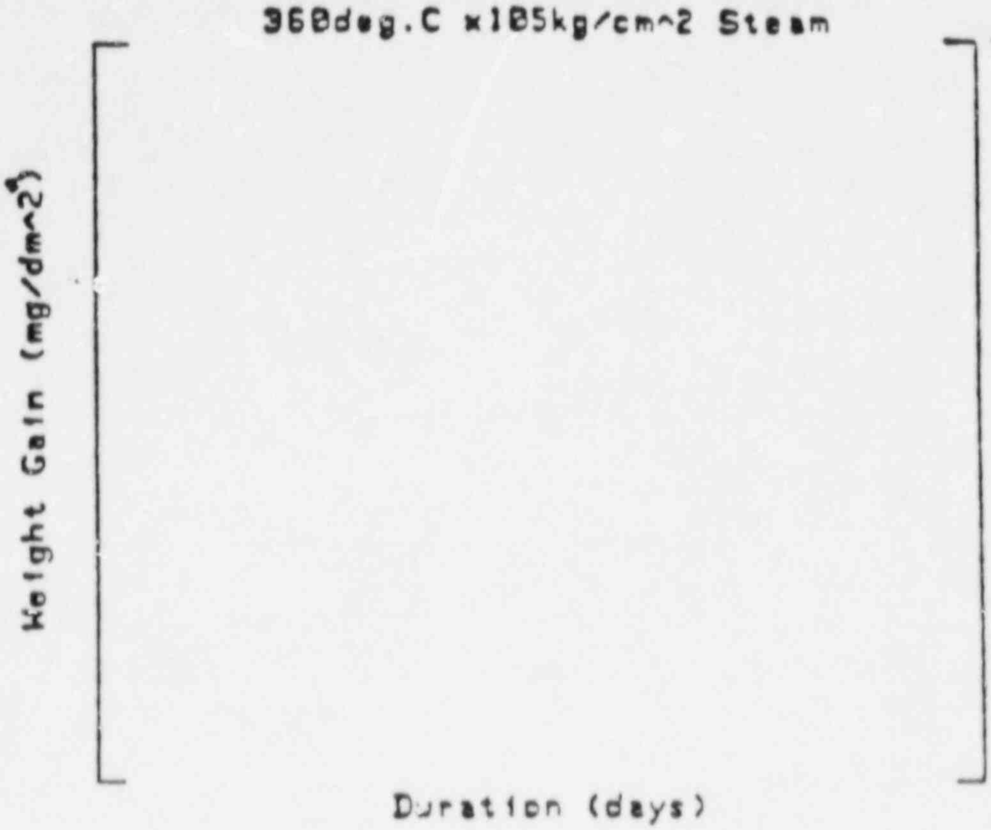
3) Involve a significant reduction in the margin of safety. The fuel assemblies do not change the existing reload design and safety analysis limits. In addition, the 10CFR50.46 criteria remain applicable to the zirconium base alloy clad fuel rods. Therefore, the current USFAR analyses remain bounding and there is no reduction in the margin of safety.



(a,b,c)

(a,b,c)

FIGURE 1: CORROSION TEST RESULTS ON Zr ALLOY TUBING



(a,b,c)

(a,b,c)

FIGURE 2: CORROSION TEST RESULTS ON Zr ALLOY TUBING

+(a,c)

Max Diametral Strain %

Temperature °C

FIGURE 3. DIAMETRAL EXPANSION OF Zr CLADDING ALLOY TUBING AS A FUNCTION OF TEMPERATURE