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Proposed Peach Bottom Atomic Power Station Unit 2 Alternate Absorber Control Blade Test Program

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1. INTRODUCTION

It is proposed that an Alternate Absorber Control Blade Test Program be conducted at the Peach Bottom Atomic Power Station Unit 2 during fuel Cycle 5, (Reload 4), and Cycle 6 (Reload 5). The purpose of this test program is to obtain data on the performance of hafnium in a Boiling Water Reactor (BWR) environment. The primary parameters of interest are: (1) the corrosion rate, and (2) radiation growth. This series of tests is part of an improvement program to extend the useful operating life of BWR control blades.

2. TEST PROGRAM DESCRIPTION

The Alternate Absorber Control Blade Test Program consists of the following major activities.

Two standard control blades in the reactor core will be replaced with test control blades. The test control blades contain three solid hafnium rods in each wing (Figure 3-1), which replace three standard boron carbide (B_4C) absorber rods.

The test control blade will be operated as a normal control blade during reactor operation.

After one fuel cycle, one of the control blades will be removed from service for destructive examination and replaced by a standard B_4C control blade. The second test control blade will be removed after two fuel cycles and replaced by a standard B_4C control blade.

The irradiated hafnium rods will be shipped to a hot cell for examination and data collection.

The performance of this test program at Peach Bottom 2 is desirable because of the high power density in the core, and the control cell core mode of operation. This mode of operation allows the maximum control blade burnup in the shortest period of time, since the control blades would almost continuously be in a high radiation field. This is expected to maximize the radiation growth of the hafnium absorber rods.

The particular core locations in the Peach Bottom 2 reactor core which would be most desirable for the test control blade are: 22-31, 38-31, 30-23, or 30-39. These are expected to be the locations of highest control blade exposure in the core. However, other high control blade exposure locations in the core are also acceptable.

3. TEST CONTROL BLADE

The test control blade is a standard control blade which has been modified as described below.

Each test control blade contains twelve (12) solid hafnium rods (three per wing), and seventy-two (72) stainless steel tubes containing boron carbide (B_4C), as shown in Figure 3-1. The solid hafnium rods are the test material. The hafnium rods are positioned in the wings to obtain maximum data on irradiation growth due to fast neutron fluence. The test control blade mechanical design is the same as the standard B_4C control blade currently in use.

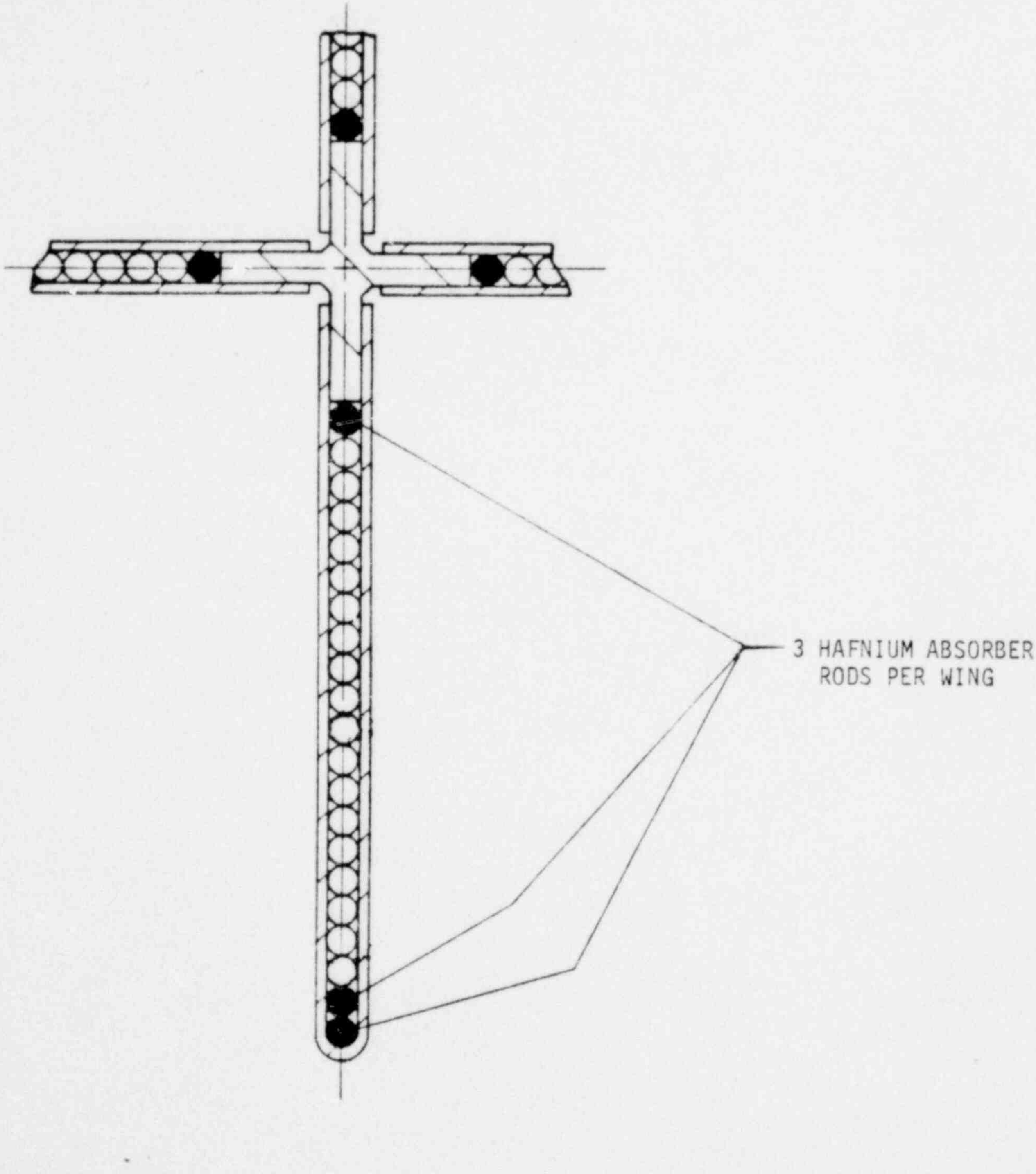


Figure 3-1. Location of Hafnium Absorber Rods

4. HAFNIUM ABSORBER RODS

Hafnium is a well known neutron absorbing material which has a long nuclear lifetime due to the characteristics of its neutron absorption products which decay into other high cross-section hafnium absorber isotopes. Most of the reactor experience with hafnium is in naval pressurized water reactors, where hafnium has been used extensively as the control blade material. It has also been used in the Shippingport Atomic Power Station pressurized water reactor.

4.1 Corrosion Resistance

Almost all data available on hafnium corrosion in a reactor environment is under pressurized water conditions. Bare hafnium control blades were used in the Experimental Boiling Water Reactor (EBWR), but no quantitative data on corrosion is readily available for these control blades.

Data on the corrosion of hafnium are presented in References 1 through 4. Tables 4-1 and 4-2 present data from Reference 1 on the corrosion of hafnium of various chemical compositions. Figure 4-1 provides a graphical representation of the data in Table 4-2. The data in Figure 4-1 show that hafnium has very good corrosion resistance. The minimal corrosion which occurs under such conditions has made detailed measurements difficult. The data show that the oxide layer formed is only 1×10^{-6} inch thick after 200 days in water at 540°F. In addition, after approximately 30 days at 540°F, the rate of oxide layer growth becomes small, and remains relatively constant with time.

Table 4-3 (from Reference 2) shows the superior corrosion resistance of hafnium compared to Zircaloy 2 at various temperatures in water and in steam. Figure 4-2, from the same reference, shows the effect of the nitrogen content in hafnium on its corrosion resistance in 680°F water and 750°F steam. The average nitrogen content of the hafnium to be used for the absorber rods in the test program at Peach Bottom is 26 ppm (Table 4-4), which is equal to the lowest value of nitrogen shown in the curves.

Figure 4-3 (from Reference 3) shows data reported by the Bettis Atomic Power Laboratory on the corrosion of hafnium at different temperatures in water and in steam. Table 4-5 (from Reference 4) gives irradiated corrosion data from the Shippingport Reactor.

While almost no quantitative data is available on hafnium under boiling water reactor conditions, it is expected that corrosion in a boiling water environment, even if significantly greater than under pressurized water reactor conditions, will be minimal, and fully acceptable. Corrosion of the hafnium rods to be used in the test program is expected to be low, particularly in view of the low average nitrogen content (26 ppm). However, one of the objectives of the test program is to quantitatively determine the actual corrosion rate under boiling water reactor operating conditions.

4.2 Radiation Growth

Detailed radiation growth data for hafnium is not available except in nuclear naval reactor programs. The radiation growth of hafnium is expected to be less than that of Zircaloy. One of the objectives of the test program is to quantitatively determine the radiation growth of the hafnium absorber rods under boiling water reactor operating conditions.

4.3 Nuclear Characteristics

Data on the nuclear characteristics of hafnium are available, including cross-section data. Hafnium cross-section data will be available in the ENDF/B-V library system maintained by the Brookhaven National

Laboratory. Formal documentation of the ENDF/B-V data, which update the previous ENDF/B-IV data (Reference 5), will not be released until work on all of the libraries is completed. However, General Electric has the incomplete ENDF/B-V libraries, which include the completed cross-section data on the hafnium isotopes.

Using the hafnium data, the reactivity worth of an unirradiated test control blade was determined to be equivalent to a standard unirradiated B_4C control blade. Since the test control blades are designed to the same end of life criteria as the standard B_4C control blade, there will be no change in the shutdown margin calculations, scram reactivity, and transient analyses during the test program. Evaluations have been performed to assess the impact of control blade depletion on ΔCPR. These evaluations demonstrate that over the control blade lifetime limit of 10% change in relative control blade worth, the ΔCPR results remain unchanged. Also, since the worth of the test control blades are equivalent to the worth of the standard B_4C control blade, the control rod drop accident and rod withdrawal error evaluations are not impacted.

TABLE 4-1

CHEMICAL ANALYSIS OF HAFNIUM

%		PPM							
Hf	Zr	W	Fe	Si	Cu	Ti	Al	N_2	U
Bal.	1.1	100	190 83*	35	10	8	25	-	-
(95.3) min	(4.5) max	(150) max	(500) max	-	(100) max	(100) max	(100) max	(100) max	(200) max

* Wet chemical analysis

() Values in parentheses represent the military specifications for reactor grade hafnium

TABLE 4-2

CORROSION OF HAFNIUM (REFERENCE 1)

DAYS -- Mg/Dm^2

	No.	7	14	28	42	46	70	84	98	112	140	163	168	191	196
540°F Water	1	1.4	2.0	1.7	1.7	2.0	2.6	-	2.3	2.8	2.3	2.0		2.8	
	5	1.1	1.7	2.3	2.3	1.7	2.3	-	2.6	2.3	2.3	2.3		2.8	
	9	0.9	1.4	1.7	1.4	1.7	1.1	-	2.3	2.0	2.3	1.7		2.8	
	11	0.6	1.4	1.4	1.1	1.2	0.9	-	1.7	0.9	1.1	1.1		2.0	
	Avg.	1.0	1.6	1.8	1.6	1.6	1.7	-	2.2	2.0	2.0	1.8		2.6	
680°F Water	2	2.8	4.0	4.8	4.8	5.1	5.7	-	6.8	7.7	6.5		6.8		8.3
	6	2.3	3.7	4.6	4.9	4.6	5.4	-	5.7	6.8	6.0		6.8		8.0
	7	2.8	3.4	4.3	4.9	4.8	5.4	-	6.3	7.4	6.3		6.8		8.0
	12	2.0	3.4	4.3	4.0	4.3	4.6	-	5.4	6.8	6.0		6.0		7.4
	Avg.	2.5	3.6	4.5	4.7	4.7	5.3	-	6.1	7.2	6.2		6.6		7.9
750°F Steam	3	4.5	7.7	13.1	14.5	17.4	20.8	26.5	30.8						
	4	4.8	8.5	12.8	14.2	16.4	19.8	25.5	29.8						
	8	3.7	7.7	12.8	13.9	16.7	20.1	26.1	30.9						
	10	3.1	7.1	11.4	11.9	14.5	17.9	24.7	29.0						
	Avg.	4.0	7.8	12.5	13.6	16.3	19.7	25.7	30.1						

TABLE 4-3

CORROSION OF HAFNIUM* (REFERENCE 2)

(Weight Increase in Mg/Dm^2)

TIME (DAYS)	600°F WATER		680°F WATER		750°F STEAM	
	HF	ZR-2	HF	ZR-2	HF	ZR-2
44	5	14	6-9	27	4-7	48
195	6	21	7-9	65	7	210
234	-	23	-	100	9	300

* Crystal Bar

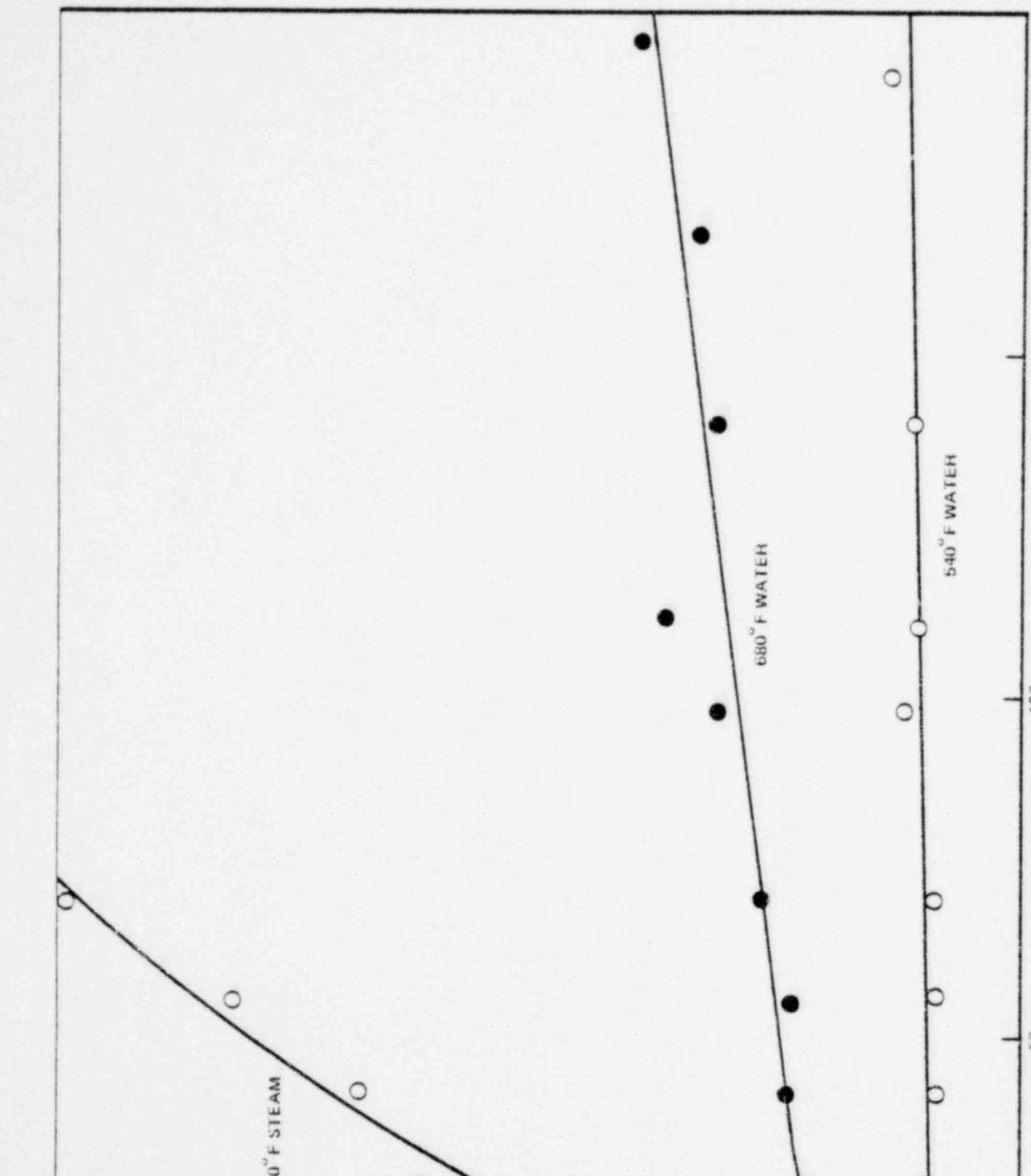
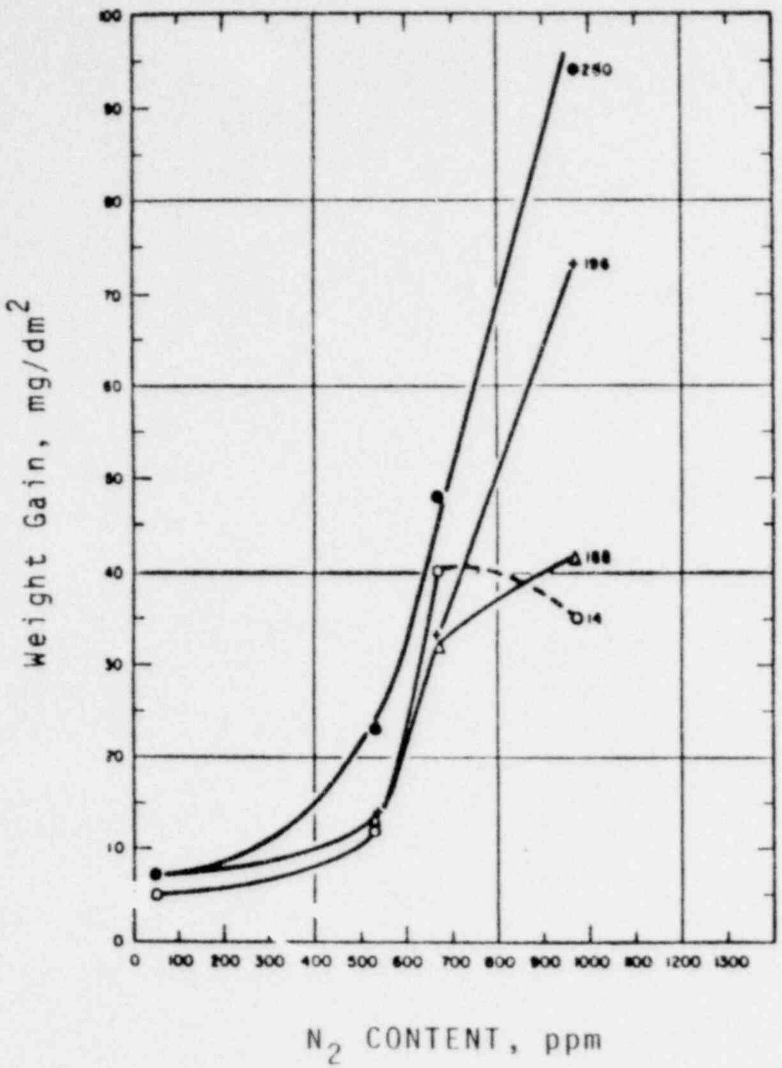
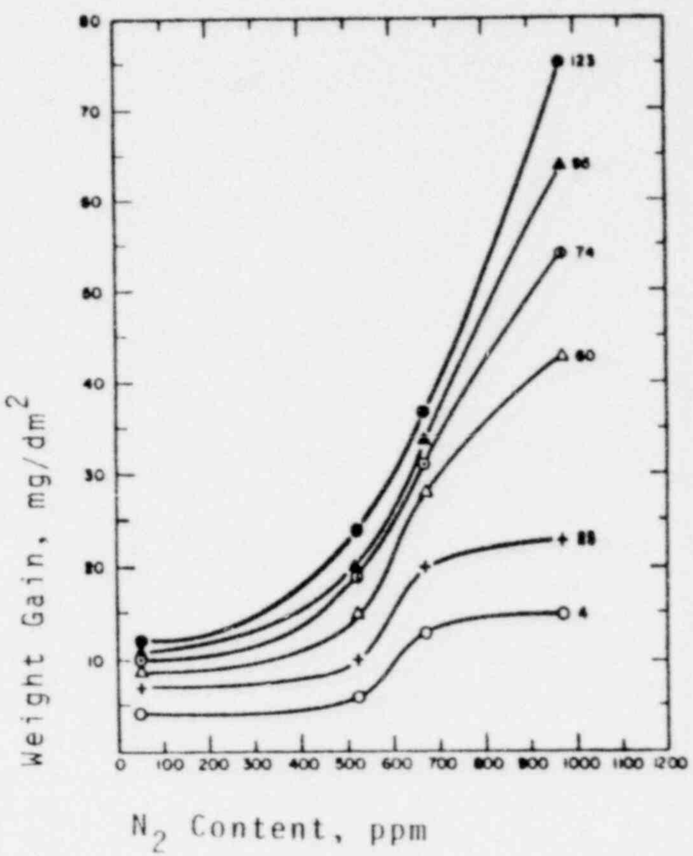


Figure 4-1. Corrosion of Hafnium (Reference 1)



Weight Gain vs. Nitrogen Content for Hafnium in 680°F Water at Saturation Pressure. Numbers on Curves Refer to Exposure Time in Days.



Weight Gain vs. Nitrogen Content for Hafnium in 750°F Steam at 1,500 psi. Numbers on Curves Refer to Exposure Time in Days.

Figure 4-2. Effect of Nitrogen Content on Corrosion of Hafnium

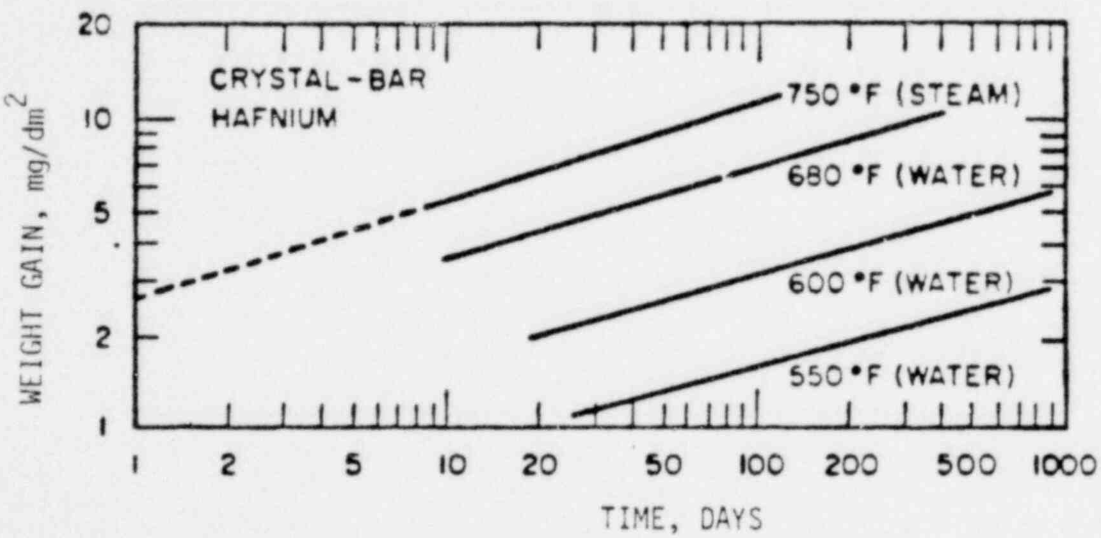


Figure 4-3. Corrosion of Hafnium (Reference 3)

5. SAFETY EVALUATION

The results of the safety analysis presented in the Peach Bottom 2, Reload 4, licensing amendment submittal (Reference 6) are unchanged by the use of the test control blade in the Reload 4 core during Cycle 5 operation.

As previously mentioned in Section 4.3, the worth of test control blades are equivalent to the original worth of the standard B_4C blades being replaced. Therefore, the control rod drop accident, and the rod withdrawal error event results previously reported for the Reload 4 core (Reference 6) are unchanged with the test control blades in the Reload 4 core.

Hafnium is heavier than B_4C. This results in a 16 lbm. increase in the total test control blade weight. The effect of this increased weight compared to a standard B_4C blade is a slight increase in scram time. The calculated increase in scram time of the test control rod for 5%, 20%, 50%, and 90% insertion is given in Table 5-1. The effect of the slight increase in the scram times for two test control blades on the core average scram times employed in the Reload 4 licensing amendment submittal (Reference 6) is negligible. Evaluations demonstrate that the critical power ratio (ΔCPR) results for all of the abnormal operational transients reported in the Reload 4 licensing amendment submittal are unchanged.

The proposed test program could be implemented under the provisions of 10CFR50.59, except that a change to the Technical Specifications is required. This is discussed in Section 6. However, the other requirements of 10CFR50.59 are satisfied by the proposed test program, as discussed below.

The first requirement of 10CFR50.59 is that a proposed change in a facility, or the operating procedures, shall not increase the probability of occurrence or the consequences of an accident or malfunction of equipment important to safety. The proposed test program meets this requirement, since it has been shown above that the Reload 4 safety analysis (Reference 6) is not affected by operation with the test control blades.

The second requirement of 10CFR50.59 is that the possibility of an accident or a malfunction of a different type than any evaluated previously in the safety analysis report shall not be created. This requirement is also satisfied for the proposed test program, since the test control blade mechanical design is the same as the standard B_4C blade and the nuclear design is equivalent.

The third requirement of 10CFR50.59 is that the margin of safety as defined in the basis for any technical specification is not reduced. This requirement is also satisfied. The operating limits defined in the Reload 4 licensing amendment submittal (Reference 6) are unaffected by the use of the test control blade. The shutdown margin and control rod drop accident results are also unaffected. Therefore, the margins of safety as defined in the basis for the Technical Specifications are not reduced by the test control blades.

However, changes can only be implemented under 10CFR50.59 if, in addition to satisfying the above requirements, no changes to the Technical Specifications are required. The proposed test program does require a change to the Peach Bottom 2 Technical Specifications, as discussed in Section 6.

The effect of the hafnium test control blades on reload analyses is generic in nature and the foregoing safety evaluation applies equally to operation with the test blades during the test program period (i.e., Cycle 5 and 6).

TABLE 5-1

TEST CONTROL BLADE SCRAM TIME INCREASE

% INSERTION	SCRAM TIME INCREASE (SEC)
5	0.005
20	0.009
50	0.018
90	0.03

6. PROPOSED TECHNICAL SPECIFICATION CHANGE

To conduct the proposed test program a temporary change must be made in Section 5.2 of the Peach Bottom 2 Technical Specifications.

Specification 5.2.B currently limits the control material to boron carbide powder. The specification should be modified to read as follows:

> The reactor core shall contain 185 cruciform-shaped control rods. The control material shall be boron carbide powder (B_4C) compacted to approximately 70% of the theoretical density or hafnium metal.

It is proposed that this specification be changed, as shown, to permit operation with two control blades (the test control blades) containing up to 12 solid hafnium absorber rods each in place of a corresponding number of B_4C absorber rods. The test control blades will replace two standard control blades in the core.

7. REFERENCES

1) B.E. Dearing and A.M. Andrako, "Corrosion Behavior of Hafnium in Aqueous Media as a Function of Temperature", KAPL-M-BED-3 August, 1961.

2) D.E. Thomas and E.T. Hayes, "The Metallurgy of Hafnium", Naval Reactors, Division of Reactor Development, AEC.

3) "A Compilation of the Properties of Hafnium", Bettis Atomic Power Laboratory, WAPD-TM-528.

4) G.J. Salvaggio, "Hafnium Control Rod Behavior in the Shippingport Pressurized Water Reactor", Nuclear Applications, Vol. 5, July, 1968.

5) "Data Formats and Procedures for the Evaluated Nuclear Data File, ENDF", BNL-NCS-50496 (ENDF 102), TID-4500, October 1974.

6) Supplemental Reload Licensing Submittal For Peach Bottom Atomic Power Station Unit 2 Reload No. 4, NEDO-24237, January 1980.