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WHC-SD-GN-DP-20002
Revision 0

**DATA PACKAGE ADDENDUM
FOR COBRA-1A2 LIFE EXTENSION TO 400 EFPD**

August 1994

Prepared for:

Westinghouse Hanford Company
P.O. Box 1970
Richland, Washington 99352

DATA PACKAGE ADDENDUM
FOR COBRA-1A2 LIFE EXTENSION TO 400 EFPD

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DATA PACKAGE ADDENDUM FOR COBRA-1A2 LIFE EXTENSION TO 400 EFPD

1.0 INTRODUCTION

The COBRA-1A experiment was originally designed for irradiations up to 350 effective full power days (EFPD) in EBR-II. Three of the seven B7A test capsules were discharged after 88.6 EFPD (COBRA-1A1; EBR-II designation X516), while the remaining four capsules continued to be irradiated to a goal exposure of 300 EFPD (COBRA-1A2; EBR-II designation X516A). However, it was recently decided that COBRA-1A2 was to remain in the reactor during Run 170, giving a nominal end-of-life (EOL) exposure of 375 EFPD. Since the revised test exposure exceeds the design basis given in supporting analyses, amended analyses are provided herein, giving the technical bases for the extended irradiation.

The COBRA-1A design description is given in Reference 1. Supporting analyses, including safety analyses, are given in References 2, 3 and 4. These analyses are generally based on a EBR-II irradiation of 350 EFPD; however, in many cases more bounding life assumptions were employed. Analyses given herein supersede associated analyses given in the references.

2.0 DESIGN CONDITIONS AND ASSUMPTIONS

The COBRA-1A2 test is assumed to be irradiated to a goal exposure of up to 400 EFPD. With a peak fast neutron flux of 2.4×10^{15} n/cm²/s, an EOL fast fluence of 8.29×10^{22} n/cm² is accumulated at 400 EFPD. Design transients are assumed to be the same (characteristic and frequency) as that given in previous safety analyses (References 3 and 4). Changes in steady-state characteristics, related to increased exposure, are to be used in any updated evaluations.

3.0 SAFETY/STRUCTURAL ANALYSIS

The effect of additional exposure on the COBRA-1A2 test is to potentially alter steady-state and related transient performance related to additional irradiation swelling and creep, increased gas generation and associated pressures, and changes in material properties.

3.1 Irradiation Swelling and Creep Effects

Of the four B7A capsules that will continue the irradiation to the experiment EOL, three are weeper capsules (B388-B390). The temperatures of these weeper capsules and capsule inserts (subcapsules and baskets) are approximately at the temperature of the coolant, or 400°C. The majority of

the subcapsules and baskets within the weeper capsules are made of 20%CW 316 SS, the same material as the B7A capsules. Therefore, these stainless steel components will thermally expand and swell roughly the same amount. Consequently they should retain approximately the same thermal and structural conditions as at beginning of life. Furthermore, for 20%CW 316 SS irradiated at 400°C to a fast fluence of 8.29×10^{22} , the predicted volumetric swelling is 0.80% (Reference 5), a relatively small amount.

As for the two TZM subcapsules within these weeper capsules, (B09 and C03, which are not at the core mid-plane), the predicted swelling is less than 0.3% volumetric (Reference 2, Section 7.3, and Reference 6). Hence, irradiations swelling will cause the annular gap to slightly increase, and assure the absence of interference and associated loading.

The gas filled B7A capsule, B391, contains two TZM sealed subcapsules (D03 and D05) and one stainless steel basket (D04) in the core region. The D03 TZM subcapsule has a wall temperature of 400°C, and hence, should not be a concern (see above). The D05 subcapsule operates with a wall temperature of 800°C. At this temperature, the D05 capsule can be expected to swell no more than 3.0% volumetric (Reference 2, Section 7.3, Reference 6), while the 316 SS B7A capsule swells 0.80% volumetric. Hence, the annular gap will decrease. Based on the conservative TZM swelling assumption, the annular gap will decrease as determined below:

OD TZM subcapsule = 0.7173 in, ID B7A SS capsule = 0.75 in

cold annular gap = $0.75 - 0.7173 = 0.0327$ in

swelling change in TZM subcapsule = $(.03/3)(0.7173) = 0.0072$ in

swelling change in SS B7A capsule = $(.008/3)(0.75) = 0.002$ in

therefore, the gap will close by $0.0072 - 0.002 = 0.0052$ in

the EOL cold gap is $0.0327 - 0.0052 = 0.0275$ in

At temperature this gap opens by an additional 0.003 in (References 1,2)

As there is clearance between the capsule and subcapsule, potential problems due to interference are not expected. However the reduction in gap will cause a change in the heat transfer characteristics, and hence the subcapsule temperature. As a rough estimate of the subcapsule temperature change, conservatively neglect thermal radiation and surface boundary film effects. The EOL gap is 84% of the of the as-built conditions. Therefore, the temperature drop across the gas gap can be directly ratioed:

$$\Delta T = (400)(.84) = 336^{\circ}\text{C}; \text{ and } T_{\text{subcap}} = 400 + 336 = 736^{\circ}\text{C}$$

References 1 and 2 address irradiation creep in both B7A capsules and susceptible subcapsules. The analysis showed negligible creep and associated deformations. The additional proposed irradiation (14%) will not change this conclusion.

3.2 Gas Generation Effects

Two subcapsules (C03 and D05) contain beryllium which produces helium during irradiation, which in turn causes a pressure build-up within the subcapsules. This has been conservatively addressed in References 2, 3 and 4, and found to be acceptable at 350 EFPD. At 400 EFPD, additional gas generation and associated pressure increases are calculated below (see Reference 2, Section 6):

As the pressure within the subcapsule, P , is proportional to the number of moles, T , of helium generated, the following relationship gives the ratio of pressure at 400/350 EFPD:

As $P \propto T \propto 1 - e^{-\phi\sigma t}$; where $\phi\sigma = 1.792 \times 10^{-5} \text{ days}^{-1}$, and t is time in EFPD

so that:

$$P_{400}/P_{350} = [1 - e^{-(.00001792)(400)}] / [1 - e^{-(.00001792)(350)}] = 1.142$$

The gas pressure can be expected to be 14.2% higher at 400 EFPD than it is at 350 EFPD.

The EBR-II user guide limits plenum pressures to 1800 psi for stored volumes up to 10 cc. Reference 3 identified subcapsule C03 at an upper-bound¹ internal pressure of 414 psia. A 14.2% increase gives a pressure of 473 psia, which is below the allowable limit.

Reference 2 sites the maximum upper-bound steady-state EOL gas pressure differential as 392 and 325 psid for subcapsules C03 and D05 respectively. The added 50 EFPD irradiation can be expected to increase the upper-bound pressure differential to 447 and 371 psid in these 400°C TZM subcapsules. As the allowable internal pressure differential has been determined to be 938 psid (Reference 2, section 7.1), more than sufficient margin exist for the continued irradiation.

For the worst case transient, i.e., the anticipated loss of flow scenario, the pressure in the C03 and D05 subcapsules has been shown to

¹ upper-bound pressure is based on the assumption of 100% gas release. Data (Reference 2, Section 6.2) shows that only 5% of the helium generated will be released from the beryllium specimens

increase by 8.3% (Reference 3) due to increase in coolant temperature. For this condition, the CO3 pressure would increase to 484 psid. The allowable pressure differential at these conditions (455°C) is approximately 920 psid.

Another concern related to gas pressure build-up is potential gas leakage from subcapsule D03 into the B7A capsule, the primary barrier. This is addressed in Reference 2, Section 7.3, which predicted a maximum pressure of 8.76 atm. Increasing this pressure by 14.2%, to 10.0 atm, still provides adequate margin from the 18.6 atm allowable limit.

3.3 Material Properties Effects

The reference analyses evaluated both unirradiated and EOL irradiated material properties for both the TZM and 20%CW SS material. Both of these materials exhibit fluence hardening characteristic at the temperature of interest. Additional irradiation would only strengthen the respective materials if they had not reached the saturation condition. Structural evaluation was based on using the minimum allowable, based on either ductile, brittle, or stress-rupture failure criteria. Hence, any additional loss of ductility due to additional irradiation (not expected) was implicitly addressed.

4.0 CONCLUSIONS

The additional 50 EFPD irradiation of the COBRA-1A2 experiment to 400 EFPD is shown acceptable by the analyses, given herein. Safety and structural performance of this experiment are little changed from that of 350 EFPD, and are well within their acceptance criteria.

The additional irradiation, however, could affect the irradiation temperature of the D05 subcapsule. This capsule is design to run at 800°C. Assuming worst case differential irradiation swelling (large uncertainty) analysis shows that this subcapsule can be at a temperature as low as 736°C.

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