



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
WASHINGTON, D. C. 20555

March 6, 1997

MEMORANDUM TO: ACRS and Staff

MEMORANDUM #: AWC-106.97-DRAFT

FROM: August W. Cronenberg

SUBJECT: Safety Issues Concerning Tritium Production in  
Commercial LWRs

Summary: Per request by Dana Powers, I have summarized here observations from a "quick-look" assessment of potential safety concerns related to tritium ( $H_3$ ) production in commercial LWRs, with emphasis on materials interactions and oxidation behavior under design basis and severe accident conditions. Questions related to the regulatory framework and appropriate CFR regulations that might ultimately govern licensing requirements are not considered.

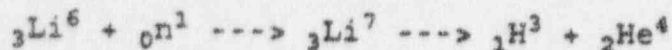
From an examination of phase-diagram information and chemical reaction energetics, it can be inferred that the  $Li-AlO_2$  targets clad in a stainless-steel/Zircaloy composite present no increased degradation potential than that for typical PWR Zircaloy-clad  $Al_2O_3-B_4C$  burnable poison rods. Binary phase diagrams for Fe-Zr and FeO-ZrO<sub>2</sub> indicate eutectics at 1220 K for the Fe-Zr system and 1640 K for FeO-ZrO<sub>2</sub>. Since the  $Li-AlO_2$  target design entails concentric layers of stainless-steel and Zircaloy, eutectic melting can be expected for either metallic or oxidic conditions. However, similar eutectic assembly degradation can be expected at the stainless-steel spider/Zircaloy end-plug junction for typical PWR burnable poison rods, and indeed was observed for the TMI-2 burnable poison assemblies.

A comparison of simple parabolic kinetics for Zircaloy-steam and steel-steam reactions indicates both a higher reaction heat and faster kinetics for the Zircaloy-steam reaction than for steel. Thus, oxidation associated degradation of typical Zry-clad PWR poison assemblies is predicted to be greater than that for the stainless-steel clad target rods. These observations thus indicate no increased overall degradation for target rods than that for standard burnable poison rods. This reasoning is corroborated by TMI-2 findings, where the extent of degradation of Zircaloy-clad burnable poison rods was observed to be greater than that of the stainless-steel clad Ag-In-Cd control rods.

Although no "show stopper" problems related to use of  $Li-AlO_2$ /Zry-SS-clad targets in commercial LWRs is evident from the limited assessment provided here, a comprehensive examination of all aspects of safety will be required for licensing of reload cores containing  $Li-AlO_2$  targets.

## 1. BACKGROUND

The U.S. Department of Energy (DOE) is currently pursuing three options to assure continued tritium production capability for DOD (Department of Defense). Under consideration are the accelerator production of tritium option, tritium ( $H^3$ ) production in the Fast Flux Test Facility (FFTF), as well as  $H^3$  generation from irradiation of Lithium-bearing targets in a commercial LWR. In prior decades  $H^3$  was produced at the Savannah River Site (SRS), using heavy-water moderator/coolant reactor technology with an Al/U-alloy lead fuel design and Li-Al alloy targets for tritium generation. In the early 1990s, DOE made the decision to forgo restart of the Savannah River reactors, and to rely on a different technology for tritium production. For LWRs the basic process is the same as used that using the SRS heavy-water technology, that is:



$${}_1\text{H}^3 \text{ (1/2-life) } = 12.3 \text{ yrs}$$

DOD needs for fissionable tritium ( ${}_1\text{H}^3$ ) relate to weapons stockpile replenishment, due to its relatively short 1/2-life of ~12.3 years. To secure irradiation services from an existing commercial LWRs, will require NRC approval and certification. DOE has tasked the Pacific Northwest Laboratory (PNL) to assess the qualification process for NRC approval, where Li-Al alloy targets would replace  $\text{Al}_2\text{O}_3\text{-B}_4\text{C}$  burnable poison rods presently used in many commercial PWR cores.

For present discussions and comparative remarks, we shall assume basic Westinghouse 4-loop PWR design conditions. The following section briefly reviews the proposed design of the Li-Al alloy targets that would replace  $\text{Al}_2\text{O}_3\text{-B}_4\text{C}$  burnable poison rods, followed by a brief discussion of material, core physics, and safety issues that may need to be considered in the licensing of such technology. First however, I present my own thoughts on weapons  $H^3$  production in commercial LWRs.

## 2. PROPOSED Li-AlO<sub>2</sub> TARGET DESIGN for LWR APPLICATIONS

The overall approach is to replace several Westinghouse type  $\text{Al}_2\text{O}_3\text{-B}_4\text{C}$  burnable poison rods with Li-AlO<sub>2</sub> target rods for  $H^3$  production. All Westinghouse fuel assemblies employ the same basic mechanical design, using a 17x17 array and differ only with respect to the types of control, burnable poison, or instrument tubes that are part of each fuel assembly. Figure 1 illustrates the basic features of a typical fuel assembly.

The fuel rods are connected to stainless-steel upper and lower end fittings, while the movable burnable poison rods in the assembly are bolt attached to a stainless-steel spider-like structure which is shown in more detail in Figure 2. Of interest here is differences between the  $\text{Al}_2\text{O}_3\text{-B}_4\text{C}$  burnable poison rods that are normally contained within a licensed PWR core, which are to be replaced by Li-Al alloy targets for tritium production.

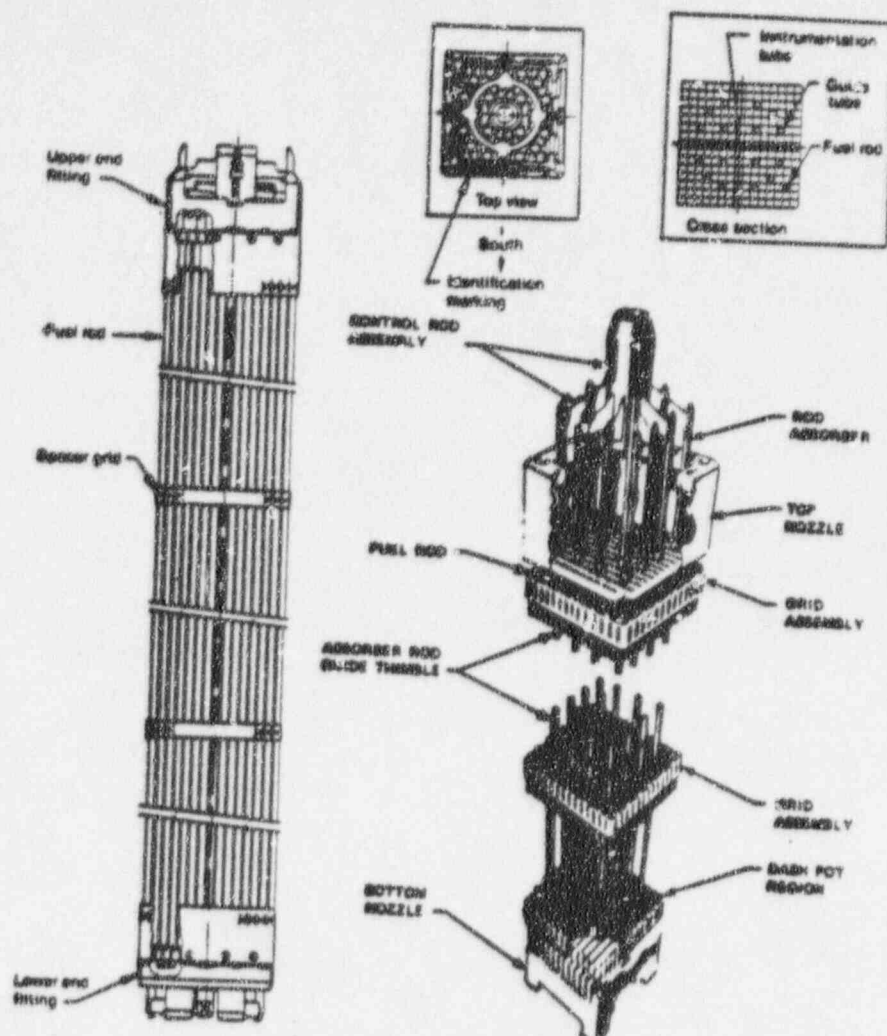


Figure 1. Illustration of a typical PWR fuel assembly incorporating a spider-like absorber assembly with control rods that move within guide tubes (thimbles).

Most of the burnable poison rods in a typical Westinghouse-PWR are a  $B_4C$  compound dispersed in a ceramic  $Al_2O_3$  pellet material, which are clad with Zircaloy and attached to a stainless-steel spider element. Motion of the  $Al_2O_3$  pellet stack is restrained by a hold-down spring, while the ends of the Zircaloy cladding tubes are closed by welded Zircaloy plugs. For Westinghouse PWR designs, there are 16 burnable poison rods in each fuel assembly, which fit inside 16 Zircaloy guide tubes (thimbles), which provide an envelope which directs the movement of the rods. The tubes ends are open to coolant flow at the top and bottom, but the amount of flow is small compared to a fuel rod channel.

The  $Li-AlO_2$  target design is shown in Figure 3, with similar dimensional characteristics as the  $Al_2O_3-B_4C/Zry$ -clad burnable poison rods. However, the  $Li-AlO_2$  target has a concentric/layered design. The  $Li-AlO_2$  target is annular in form and is encased on both its inner and outer surfaces with a nickel-plated Zircaloy barrier material. The  $Zry-AlO_2-Zry$  annular composite is then clad with stainless-steel to provide structural strength. To prevent diffusion of hydrogen from the target, the inner surface of the cladding is coated with a

permeation resistant aluminized barrier. The irradiation design for the reference target is 550 effective full-power days, for one fuel cycle.

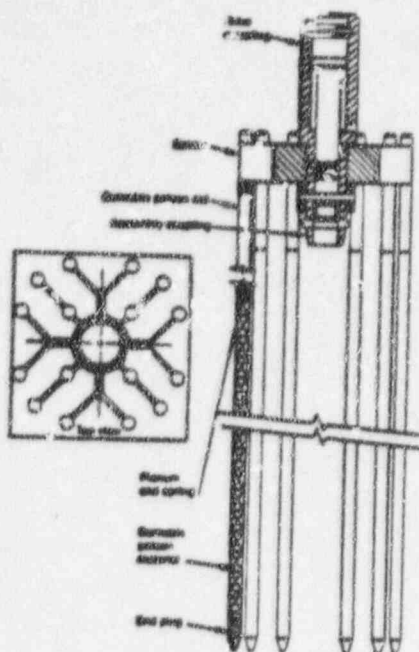


Figure 2. Typical Westinghouse PWR spider-like absorber assembly with 16 rods that move within guide tubes (thimbles).

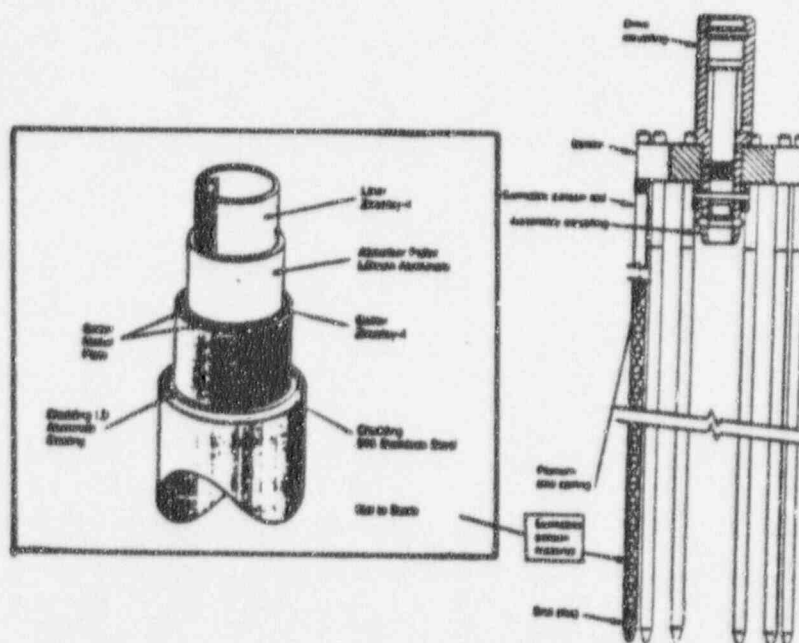


Figure 3. Illustration of proposed concentric-annular Li-AlO<sub>2</sub> target design for tritium production in commercial LWRs.

### 3. SAFETY ISSUES for Li-AlO<sub>2</sub> TARGETS in COMMERCIAL LWRS

Table 1 presents prototypic material and dimensional data for the proposed tritium target rods and standard Westinghouse burnable poison rods. Also included is data for Ag-In-Cd type control rods used in some PWRs (e.g. TMI-2). As indicated, dimensional characteristics are essentially the same, though differences exist with regards to materials. Although a Zircaloy/stainless-steel composite is proposed as the cladding for the Li-AlO<sub>2</sub> absorber rods, as opposed to Zry-4 cladding for standard PWR Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C burnable poison rods, stainless steel is also the cladding for a number of licensed PWR reactors that use Ag-In-Cd type control rods.

Table 1. Comparison of Li-AlO<sub>2</sub> Target Rods with Full-length Burnable Poison (Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C/Zr-clad) and Ag-In-Cd Type Control Rods.

Parameter	Al-Li Target	Burnable Poison	Control Rod
Absorber Material	Li-AlO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub> -B <sub>4</sub> C	Ag-In-Cd
Overall Length	~ 152 in	152 in	152 in
Absorber Length	~ 134 in	142 in	142 in
Rod Weight (1 rod)	2.26 lb	1.9 lb	~ 6 lb
Rods/assembly	16	16	16
Absorber Clad OD	0.381 in	0.381	0.381
Absorber Cladding	SS-316	Zircaloy-4	SS-304
Barrier Material	Ni-Zry	----	----
Guide Tube Thimbles	Zircaloy-4	Zircaloy-4	Zircaloy-4

A preliminary examination of some of the licensing and safety issues associated with the use of Li-AlO<sub>2</sub> target material in a commercial PWR is presented in a recent PNL report [1]. The PNL report argues that the testing of the tritium production can be done by a commercial licensee under a 10CFR50.59 process. A recent memo by Powers [2] however suggests that the 10CFR50.59 process may not apply because of a number of unreviewed safety questions associated with material interactions during design basis accident conditions, as well as changes in core neutronics associated with replacement of Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C/Zr-clad rods with Li-6 enriched Li-AlO<sub>2</sub>/SS-clad rods, where the full extent of differences in core response for rod drop accidents has not been assessed. Additional concerns of Powers [2] include:

- lack of a comprehensive assessment of material interactions and overall target assembly performance under design basis accident conditions
- the safety implications of steam reactions with stainless-steel,
- the safety implications of exothermic inter-metallic reactions of Al with stainless-steel components (Fe, Cr, Ni)
- adequate understanding of the potential for exothermic inter-metallic reactions of Zr with Ni

- potential interactions of a Zr-Ni eutectics with Li-AlO<sub>2</sub> alloy
- potential problems associated with cracking in the Li-AlO<sub>2</sub> alloy due to power cycling and shutdown transients.
- lack of substantiated target vibrational analysis to preclude fretting of the Li-AlO<sub>2</sub> targets
- stress corrosion cracking of assemblies and release of tritium to the coolant, may be issue requiring in-core detection for H3

In view of these concerns and safety questions, Dr. Powers has expressed the view [2] that NRC approval of a commercial PWR core reload, replacing Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C burnable poison rod with Li-AlO<sub>2</sub>/SS-clad target rods, cannot be done under a 10CFR50.59 process. Powers [2] argues that the safety analysis will have to be far more comprehensive and persuasive than that provided in the subject PNL report [1].

Although no attempt is made here to address all of the above indicated safety concerns, the following information is considered useful in providing some physical basis to assess target material behavior under operational and design basis accident conditions. Areas of primary investigation discussed here, relate to material interactions and oxidation behavior under off-normal/high-temperature (LOCA) and core uncover conditions.

#### 4. MATERIAL-INTERACTION & SAFETY CONSIDERATIONS

To assess potential chemical and metallurgical processes that may influence target behavior under accident conditions, information is presented comparing thermophysical property and phase-diagram information for the Li-AlO<sub>2</sub>/SS-Zry composite target rods as opposed to the Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C/Zry-clad burnable poison rods. Heavy reliance is made on prior investigations [3-6] related to material interactions noted from post-accident examination of the TMI-2 core debris, since the TMI-2 core incorporated Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C/Zry-clad burnable rods.

##### 4.1 Comparison of Thermal/Physical Properties

Most of the burnable poison material in the TMI-2 core was Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C pellets which were clad in Zircaloy-4. About 1.4 wt-% of the TMI-2 pressed and sintered burnable poison pellet is B<sub>4</sub>C. The theoretical density of burnable poison pellets is about 248 lb/ft<sup>3</sup> (3.97 g/cm<sup>3</sup>). The melting point of the Al<sub>2</sub>O<sub>3</sub> + B<sub>4</sub>C mixture is about 3700°F (2310 K), while the heat of fusion can be approximated as that of Al<sub>2</sub>O<sub>3</sub> is 46 Btu/lb (25.5 cal/g).

Figure 4 shows the thermal conductivity, specific heat, and thermal expansion properties of Al<sub>2</sub>O<sub>3</sub> and B<sub>4</sub>C [9] as a function of temperature. As indicated, the thermal conductivity of Al<sub>2</sub>O<sub>3</sub> + B<sub>4</sub>C decreases with increasing temperature, although it is somewhat higher than that of UO<sub>2</sub>.

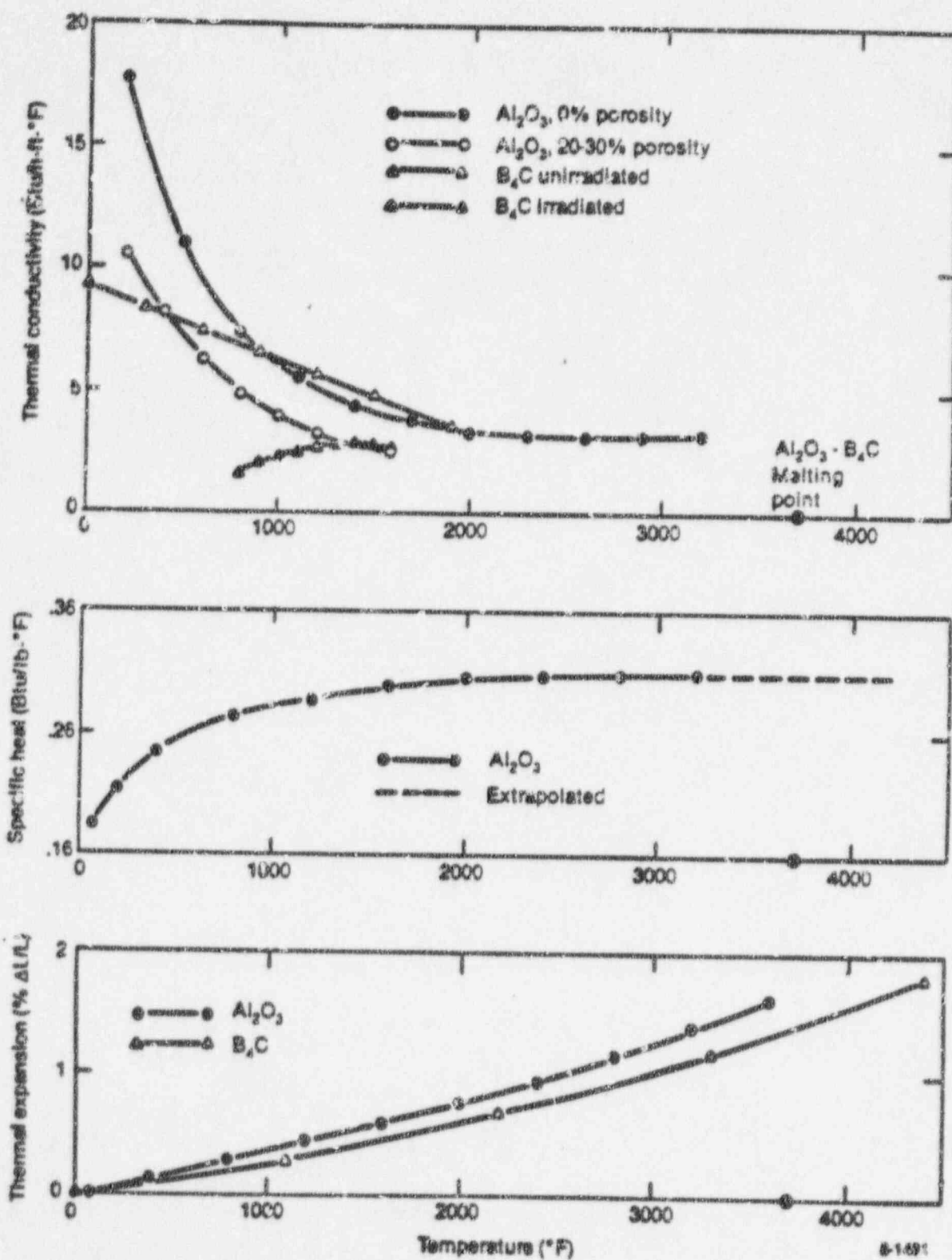


Figure 4. Temperature dependent thermophysical properties of  $\text{Al}_2\text{O}_3$  and  $\text{B}_4\text{C}$  [3].

As previously indicated the Li-AlO<sub>2</sub> target (see Figure 3) has a concentric/layered design where the stainless-steel cladding is lined on its inside surface with a Zircaloy-Ni barrier material, so that the Zr-Fe binary phase diagram is of interest. As shown in Figure 5, the spider/end-plug junction of standard PWR burnable poison assemblies consist of a Zircaloy end-plug attached to the stainless-steel spider. Thus the Zr-Fe binary phase diagram is likewise of interest and is also presented in Figure 5. This phase diagram indicates a eutectic at 1577 K for 0.088 atom percent (a/o) Zr and another eutectic at 1220 K for 0.76 a/o Zr. Thus at temperature above about 1600 K, eutectic associated degradation of both PWR burnable poison and Li-AlO<sub>2</sub> target rods can be expected.

Figure 6 presents the binary phase diagram for the FeO-ZrO<sub>2</sub> system [2], indicating a eutectic at about 1370°C (1643 K) for 5 w/o ZrO<sub>2</sub>. Therefore, whether in a metallic or oxide state, Zr-Fe eutectic interaction can be expected during severe core damage conditions for either Zircaloy-clad Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C burnable poison or Li-AlO<sub>2</sub>/SS-Zry target assemblies. Such Zr-Fe eutectic interaction was indeed observed from examination of the TMI-2 core [3,5-6].

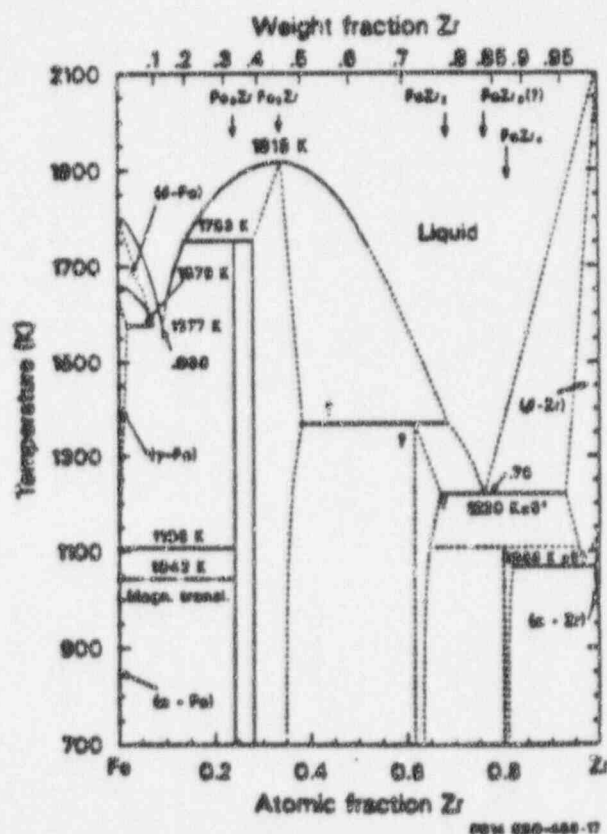
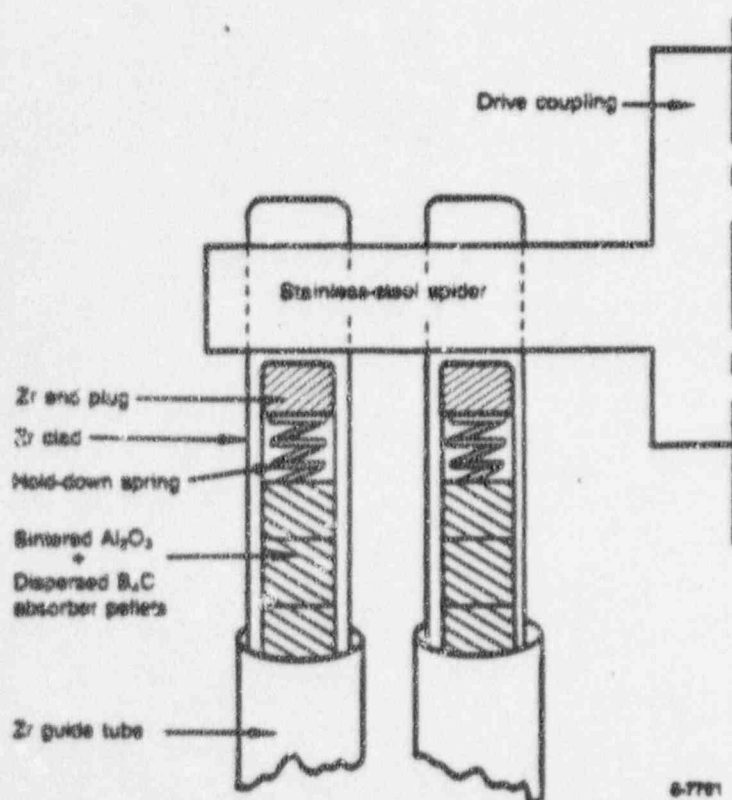


Figure 5. Illustration of the material composition of a Al<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C burnable poison assembly at the upper-end fitting [3], and the Fe-Zr binary phase diagram [2].

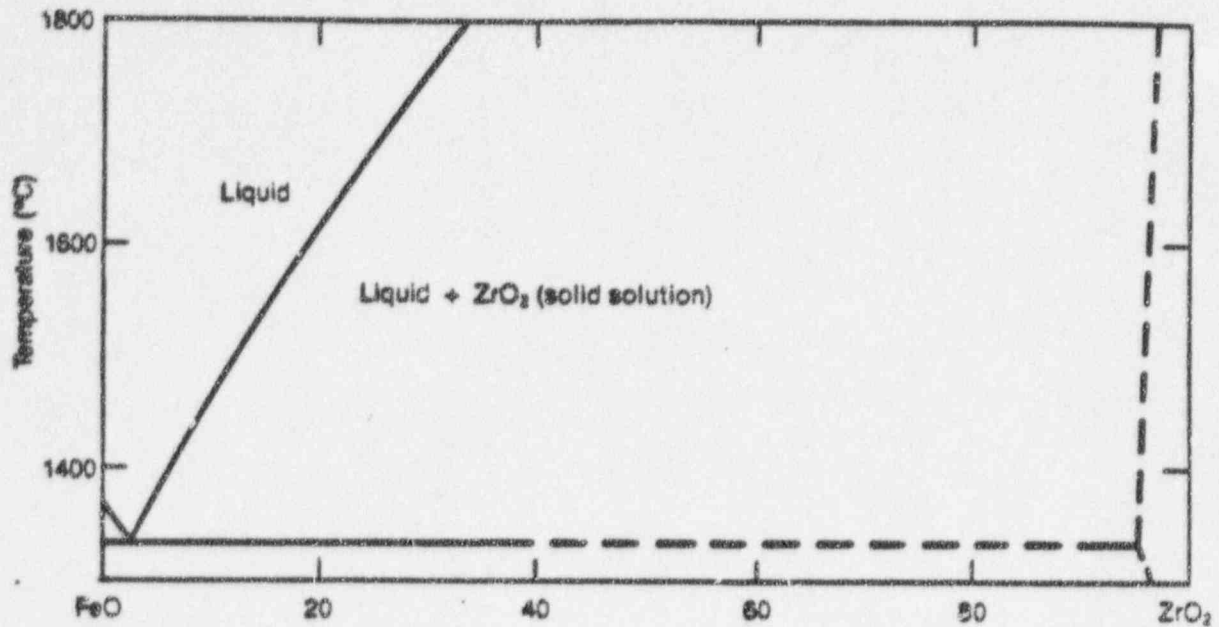


Figure 6. Binary phase diagram for the FeO-ZrO<sub>2</sub> system.

#### Al<sub>2</sub>O<sub>3</sub>-Zr(O) System

Since the Al<sub>2</sub>O<sub>3</sub> + B<sub>4</sub>C absorber material is contained within Zircaloy cladding, the phase diagrams of interest are for the Al<sub>2</sub>O<sub>3</sub>-Zr and Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub> systems. These binary phase systems are not available in the common literature, so that one can not definitively judge the potential for eutectic melting of such materials. However, the fact that the melting point of Al<sub>2</sub>O<sub>3</sub> (2310 K) is significantly higher than its metal (Al = 933 K), and that both Zr and ZrO<sub>2</sub> have relatively high melting points (Zr = 2125 K, ZrO<sub>2</sub> = 2950 K), indicates that the Al<sub>2</sub>O<sub>3</sub>-Zr or Al<sub>2</sub>O<sub>3</sub>-ZrO<sub>2</sub> systems, probably would not form eutectics melts at temperatures lower than that for the Fe-Zr system (eutectic melt at 1220 K). Thus, the most likely mode of eutectic melt failure is via Fe-Zr (spider/end-plug) interaction, rather than Al<sub>2</sub>O<sub>3</sub>-pellet/Zr-cladding interaction.

## 4.2 Exothermic Reactions

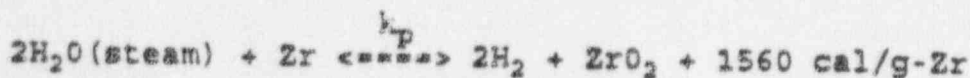
In addition to phase-diagram considerations and the attendant potential for formation of low melting point eutectics, high-temperature exothermic reactions may also increase structural degradation of the burnable poison and target assemblies. Although the potential exists for numerous chemical reactions between core constituents, reactions that are significant contributors to core degradation are essentially limited to mechanisms in which one of the reactants is in the gas phase, for example steam-metal reactions. Solid-solid or liquid-solid reactions are considered of secondary importance, because the kinetics of such ion-exchange reactions are largely dictated by reactant diffusivities for the condensed phase), which are much lower than that for the gas phase. Thus, the relevant exothermic reactions of interest for absorber rod degradation are essentially limited to steam-metal (i.e., gas-solid) rather than absorber-cladding (i.e. solid-solid) reactions.

Zircaloy cladding, stainless steel, and  $\text{UO}_2$  fuel exhibit some tendency to react with steam [11-17]. From a core degradation standpoint, Zircaloy and stainless-steel reactions with steam are of primary importance, because of their relatively high reaction heats and fast reaction kinetics. With respect to the actual absorber materials, the burnable poison pellets ( $\text{B}_4\text{C}$  dispersed in ceramic-like  $\text{Al}_2\text{O}_3$ ) would not be expected to experience significant oxidation by steam, since  $\text{Al}_2\text{O}_3$  is itself a stable oxide. Therefore, the primary chemical reactions of interest center on the steam induced oxidation reactions of Zircaloy and stainless steel. The principal thermodynamics properties for these reactions are summarized in Table 2. As indicated, the heat of reaction for Zircaloy is about 2-1/2 times greater than that of stainless steel, at the respective melt temperatures.

Table 2. Thermodynamic Properties of Zircaloy and Stainless Steel Reaction with Steam

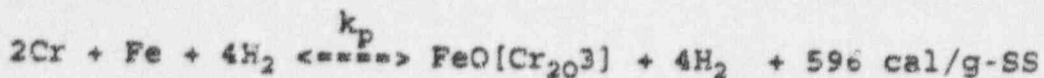
Reactant (liquid)	Melt Temperature (K)	Principal Oxides Formed	Heat of Reaction	
			with Oxygen (cal/g)	with Steam (cal/g)
Zircaloy	2125	$\text{ZrO}_2$	-2,883	-1560
Stain-steel	1640	$\text{FeO}, \text{Cr}_2\text{O}_3$	-1,098	-596

For Zircaloy, the governing stoichiometric reaction can be expressed as:



where  $k_p$  is the reaction rate constant. For each mole of Zircaloy oxidized, two moles of hydrogen are generated and a significant amount of reaction heat is released.

For stainless steel, the reactions are more complex, since a number of the constituents of the alloy material can oxidize. Stainless steel-304 contains about 70 w/o iron, 18 w/o chromium, 8 w/o nickel, and lower fractions of other elements. Stainless steel-316 contains about 2 w/o more of nickel and 2 w/o less of chromium. For present purposes, the chemical reaction suggested by Baker [11-13] can be used to approximate the reaction of stainless steel (SS) with steam:



The ratios for various equilibria are shown in Figure 7. The figure indicates that chromium would tend to react when in the presence of a large excess of hydrogen to form  $\text{Cr}_2\text{O}_3$ . However, the exceptional stability of the  $\text{FeO}-\text{Cr}_2\text{O}_3$  oxide compound, suggests that it would be the likely product in a hydrogen-rich atmosphere because of the higher weight percent of iron in the steel alloy as compared to chromium. However, the remainder of the iron should form  $\text{FeO}$  only when the local steam to hydrogen ratio is greater than about 0.5.

Any comparison of the overall impact of oxidation on structural degradation, involves not only a comparison of reaction heats but also speed at which such reactions occur, that is, reaction kinetics. For intact geometry, the oxidation reactions of metal structures in a steam environment can be approximated based by parabolic kinetics [10], where the mass of metal reacted per unit surface area ( $W$ ) is proportional to the square root of time, i.e.

$$W = (k_p t)^{0.5}$$

where  $t$  is time in seconds and  $k_p$  is the parabolic rate constant ( $\text{mg-Zr reacted}/\text{cm}^2)^2/\text{s}$ . Such parabolic kinetics are governed by the oxygen diffusional characteristics in the metal, so that the rate constant  $k_p$  (analogous to the diffusion coefficient) can be expressed in terms of the temperature-dependent diffusional properties of the oxide surface layer. The temperature dependence of  $k_p$  can be described by the Arrhenius equation of the form:

$$k_p = A \exp(-Q/RT)$$

where  $A$  is a scaling constant,  $Q$  is the activation energy,  $R$  is the universal gas constant, and  $T$  is the absolute temperature.

Table 3 presents the principal expressions developed for  $k_p$  for Zircaloy and stainless steel, where results are compared at the common temperatures of 1200 K and 1600 K. As indicated, the Zircaloy-steam reaction exhibits faster overall kinetics than stainless steel at equivalent temperatures. The fact that burnable poison rods are clad in Zircaloy, which is more reactive with steam than stainless-steel clad rods assembly, indicates standard burnable poison assemblies would experience a higher degree of oxidation and structural degradation when exposed to high-temperature steam.

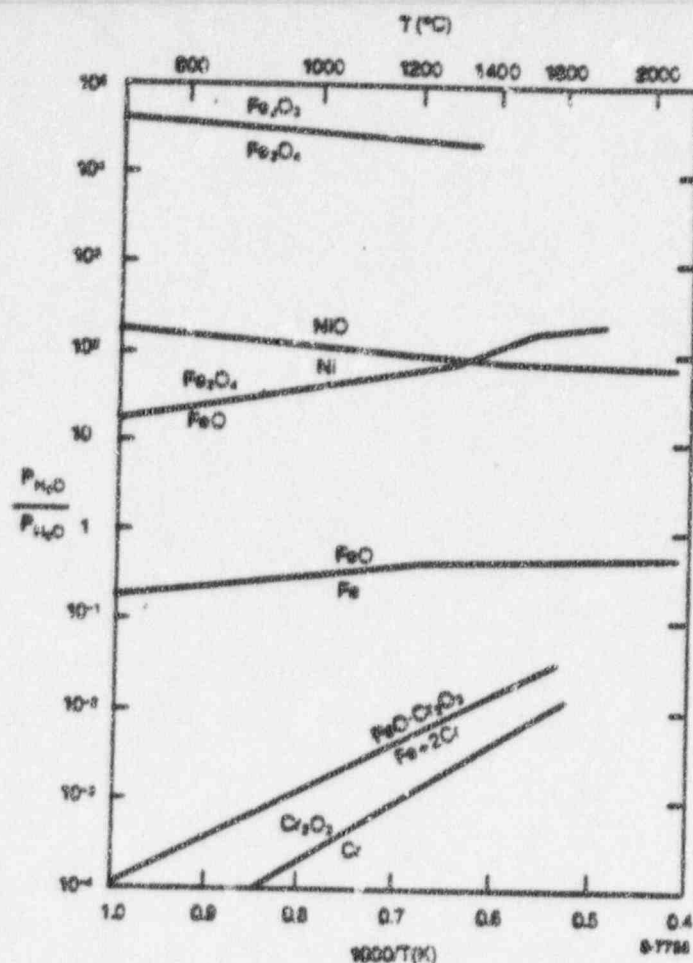


Figure 7. Thermochemical equilibria data for oxides of stainless-steel constituents.

Table 3. Arrhenius Correlations for the Parabolic Rate Constant  
Zircaloy/Steam:

$k_p$ [(mg-Zr reacted/cm <sup>2</sup> ) <sup>2</sup> /s]	Temperature, K	Reference
$2.94E+6 [\exp(-39,940/RT)]$	$T < 1800$	Cathcart-Pawel
$8.79E+5 [\exp(-33,000/RT)]$	$T > 1650$	Urbanic-Heidrick
$33.3E+6 [\exp(-45,500/RT)]$	$T > 1500$	Baker-Just (*)
$26.8E+7 [\exp(-52,350/RT)]$	$T > 1770$	Prater-Courtright

Stainless Steel/Steam:

$k_p$ [(mg-Zr reacted/cm <sup>2</sup> ) <sup>2</sup> /s]	Temperature, K	Reference
$2.4E+12 [\exp(-84,300/RT)]$	$1273 < T < 1650$	White
$3.0E+07 [\exp(-50,000/RT)]$	$1200 < T < 1700$	Baker (*)

#### Results:

Parabolic Rate Constant in Steam	$k_p$ at 1200 K (mg-metal reacted/cm <sup>2</sup> ) <sup>2</sup>	$k_p$ at 1600 K (mg-metal reacted/cm <sup>2</sup> ) <sup>2</sup>
Zircaloy	0.172	20.3
Stainless-Steel	0.023	4.43

$R = 1.987$  cal/g-mole K

\* = Reaction Rate Constant ( $k_p$ ) used here

## 5. INSIGHTS ON TRITIUM PRODUCTION USING Li-AL<sub>2</sub>O<sub>3</sub> RODS in LWRs

Based on a limited examination of phase-diagram information and chemical reaction energetics, it can be inferred that for design basis and severe accidents, Li-AL<sub>2</sub>O<sub>3</sub>/SS-Zry-clad targets present no increased degradation potential under steam-oxidation conditions than that for typical Zircaloy-clad AL<sub>2</sub>O<sub>3</sub>-B<sub>4</sub>C burnable poison rods. It is noted that the binary phase diagrams for the Fe-Zr and FeO-ZrO<sub>2</sub> systems indicate low melting point eutectics. For the Fe-Zr system, a eutectic as low as 1220 K can occur, while for the oxide FeO-ZrO<sub>2</sub> system a eutectic is indicated at about 1640 K. At the stainless-steel spider/Zircaloy end-plug junction of burnable poison assemblies, eutectic melt failure can be expected at the temperatures indicated. Similar behavior would be expected for the Zircaloy/Stainless-steel concentric target cladding.

A comparison of the Zircaloy-steam oxidation reactions for standard PWR burnable poison rods (with Zircaloy cladding) and tritium production target rods (stainless-steel cladding) assemblies, indicates both a higher reaction heat and faster kinetics for the Zircaloy-steam reaction versus the steel-steam reaction. Thus, steam-induced oxidation of the Zircaloy clad poison assemblies can be expected to be greater for typical PWR burnable poison rods than for the stainless-steel clad target rods. These observations thus indicate no increased overall degradation for target rods than would occur for standard burnable poison rods; rather Zircaloy-clad burnable poison rods indicate greater degradation potential. This reasoning is corroborated by TMI-2 findings, where the extent of degradation of Zircaloy-clad burnable poison rods was observed to be greater than that of the stainless-steel clad Ag-In-Cd control rods [3].

Although the limited comparison here does not indicate any "show stopper" problems related to use of Li-AL<sub>2</sub>O<sub>3</sub>/Zry-SS-clad targets, other considerations may be noteworthy. Though the use of commercial LWRs to produce tritium for fusion weapons replenishment may be the most cost efficient of the three options proposed, particularly when compared against the spallation/accelerator option (several billions of dollars in research/development/construction costs), I would nevertheless expect that use of commercial LWRs for this purpose to draw extensive negative public reaction.

Recent surveys appear to indicate a slow but steady increase in public acceptance of nuclear power, following low-points after the TMI-2 and Chernobyl accidents. I believe the nuclear power industry would be well advised to weigh heavily public opinion in this case, and may best forgo any short-term gains related to weapons tritium production. As in the past, the production of weapons material I believe is best accomplished at a dedicated government facility, where the best approach appears to lie with the FFTF option. If indeed the government-owned FFTF option should prevail, as a reactor facility, FFTF conversion/restart would most likely be subject to NRC jurisdiction, as this agency moves to oversight of the DOE complex.

## 6. REFERENCES

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