

2-3 Evaluation of the Environmental Release of Radionuclide Material in a SA — Accident Analysis Considering Oxidation of BWR Control Material —

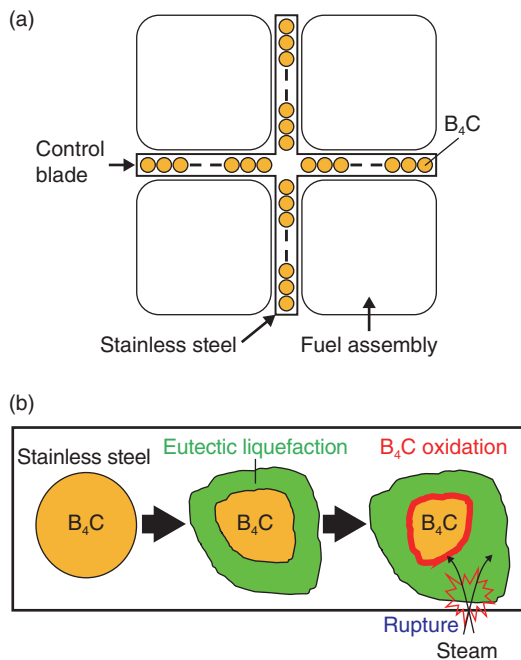
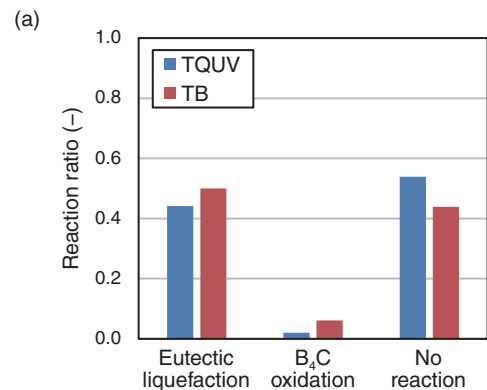


Fig.2-9 Melt progression of BWR control blade

(a) BWR control blade is made of boron carbide (B₄C) and stainless steel; (b) Oxidation of B₄C starts after the surrounding steel of the control blade is damaged by the progress of eutectic liquefaction.

For the purpose of obtaining technical knowledge to support nuclear safety regulations, research on source term evaluation, which focuses on the chemical reaction of fission products (FP) such as iodine and cesium, were carried out. Boron carbide (B₄C) was used as a neutron-absorbing material in a boiling water reactor (BWR) (Fig.2-9(a)), and boron species, which were produced from the reaction of B₄C oxidation, would affect the chemical reactions of FPs in the reactor coolant system (RCS) (Fig.2-9(b)). The interaction between the B₄C and the surrounding steel caused their liquefaction at a temperature lower than the melting point of either material. The reaction rate of B₄C oxidation was decreased by promoting eutectic liquefaction, which led to a decrease in the reaction area between the B₄C and steam. An integrated severe accident (SA) analysis code is needed to simulate these complex behaviors. The models for the eutectic interaction of B₄C with steel and B₄C oxidation were incorporated into the THALES2 code and applied to the source term analyses for a BWR with Mark-I-type containment. Two SA sequences



(b)

	Product material by B ₄ C oxidation (mol)				
	B ₂ O ₃	CO	CO ₂	CH ₄	H ₂
TQUV* ¹	77.6	1.5	37.3	2.1×10 ⁻¹⁵	331
TB* ²	2140	273	797	2.0×10 ⁻¹³	8353

*¹TQUV : Accident of loss of core coolant injection

*²TB : Accident of station blackout

Fig.2-10 (a) Fraction of B₄C oxidation and (b) amount of products material

The models for B₄C/steel eutectic liquefaction and B₄C oxidation were developed and incorporated into the THALES2 code. In our analysis, core melt progression affected the behavior of B₄C oxidation. In particular, the fraction of B₄C oxidation was decreased in the TQUV sequence, in which the core damage progressed under the steam starvation condition.

with drywell failure by overpressure initiated by a loss of core coolant injection (TQUV sequence) and long-term station blackout (TB sequence) with and without a steam starvation condition in the core, respectively, were selected as representative accident sequences. Approximately half of the B₄C was predicted to melt in the analyses for the TQUV and TB sequences, as shown in Fig.2-10. On the other hand, a remarkable difference was found for the fraction of the B₄C oxidation between the two sequences. The B₄C oxidation was limited for the TQUV sequence under the steam starvation condition in the RCS due to the activation of reactor depressurization. Additionally, the oxidation of B₄C leads to the production of carbon dioxide (CO₂), which could greatly influence the pH of the water pool in the containment and the subsequent formation of volatile iodine species. Further studies are necessary for the FP chemistry in the RCS, taking into account the influence on pH variation and iodine chemistry in the water pool, to improve the predictability of the source term.

Reference

Ishikawa, J. et al., Source Term Analysis Considering B₄C/Steel Interaction and Oxidation during Severe Accidents, Proceedings of the 25th International Conference on Nuclear Engineering (ICONE25), Shanghai, China, 2017, ICONE25-67858, 7p.