SAFETY MARGINS FOR SODIUM

BONDED CARBIDE FUEL

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Presented at

AMERICAN NUCLEAR SOCIETY
ANNUAL WINTER MEETING
WASHINGTON, D. C.

October 27 - November 1, 1974

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Unvented sodium bonded fuel has the potential for sudden bond loss and, consequently, sudden fuel temperature increase. This is a potential new mechanism for local fuel failure propagation. The high thermal conductivity of carbide compared to oxide has lead to speculation that vapor explosions may be more probable with carbide and that higher energy yields might be obtained from molten fuel/coolant interactions. This paper is focused on the sodium bond behavior and the effects of fuel coolant interactions (FCI) in carbide fuel assemblies.

The state-of-the art has been reviewed including carbide TREAT experiments, and bond loss experiments. New calculations have been performed⁽¹⁾ using SOCOOL II (FCI), NABOND (loss of bond code), and the Fauske criterion. It is concluded that loss-of-bond will cause fuel redistribution within the fuel pin but fuel will not breach the clad. The upper limit for FCI work energy yields for the carbide fuel are approximately the same as for oxide fuel based on a modified Hicks-Menzies type analysis. Carbide fuel does not satisfy Fauske's criterion for vapor explosions except under severe hypothetical multiple faulted accident conditions.

The NABOND code was used to analyze the loss-of-bond transient by quickly removing the bond while holding the power and coolant flow constant. The results showed that for a fresh pin, the fuel will melt, flow against the clad and resolidify. The sudden loss-of-bond transient takes about 20 seconds during which only a part of the pin is molten at any one time. During the transient the maximum temperature of the fuel in the axial center of the pin is 2580°C. The

highest clad temperature occurs when the fuel slumps against the clad near the top of the core and is 828°C, well below melting. The analysis of fuel pins with high burnup showed that they will not melt. The presence of fission gases and fuel swelling should further reduce the amount of fuel melting. Consequently, the effect of an occasional loss-of-bond will be confined to the affected fuel pin and no significant hazard would result.

Fuel-coolant-interaction analysis indicates that the chance of a vapor explosion with molten carbide and sodium is extremely small. If fuel melting occurs when sodium temperatures are normal, vapor explosions cannot happen because the fuel would have to be above its boiling point to satisfy the Fauske temperature criteria for spontaneous nucleation.⁽²⁾ This means that the single faulted loss-of-bond or local blockage events cannot lead to a vapor explosion. At the fuel melting temperature, the fuel-coolant interface temperature is very similar to the oxide interface temperature and about 700°C below the spontaneous nucleation temperature. The sodium must be near its boiling point and the fuel must be 500° to 1000°C above its melting point for the spontaneous nucleation temperature to be reached when sudden contact occurs. Such conditions are only possible during hypothetical, multiple faulted reactor accidents. Even then, the presence of large amounts of fission gas which are released when the fuel melts should prevent a vapor explosion.

Upper-limit work-energy yields were calculated for sodium contact with molten oxide and carbide fuels using the SOCOOL II code.⁽³⁾ Temperatures, properties and geometry were varied and the results showed greater dependency on assumptions than the fuel material. In all cases the carbide/sodium work-energy yields were very similar to oxide/sodium yields. The similar energy yields for the two fuels are

caused by the smaller heat capacity and lower temperatures of the carbide fuel offsetting the effect of its higher thermal conductivity.

The results of this analysis indicate that the safety margins for sodium bonded carbide fuel are satisfactory. During bond loss, large temperature margins exist between the peak clad temperature and the temperatures required for clad failure. Sufficient margins exist between fuel/sodium temperatures and the spontaneous nucleation temperature to make vapor explosions unlikely.

REFERENCES

1. J. A. Vitti, et al., "Preliminary Assessment of Proof Testing LMFBR Carbide Fuel Subassemblies in the FTR Driver Positions," CEND-370 (to be published under AEC Contract No. AT (11-1)-2426).
2. H. K. Fauske, "Some Aspects of Liquid - Liquid Heat Transfer and Explosive Boiling," Proc. ANL Conference on Fast Reactor Safety, April 1974, Beverly Hills, California.
3. A. Padilla, Jr., "Mechanical Work Energy for Sodium - Fuel Thermal Interaction," HEDL-TME-71-94, (June 1971).

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