volume. The volume of the noncondensable gases in a single fuel pin is about 20 cm^3. The pin internal pressure may be between 1 and 60 atm. Therefore, the existence of a thin layer of gas at the condensing surfaces in the fuel/sodium interaction region is a distinct possibility.

From the above considerations, we conclude that in the analysis of the consequences of releasing small amounts of molten fuel to the coolant in liquid-metal fast breeder reactors, it is necessary that the effects of noncondensable gases be considered.

Debaprasad Majumdar
Mujid S. Kazimi

Brookhaven National Laboratory
Upton, New York 11973

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Reply to "Comments on Fuel-Pin-Failure Propagation"

The effect of noncondensables has been shown in a recent paper by Theofanous and Fauske[1] to seriously retard the condensation process, in the case the bulk concentration of noncondensables is assumed to remain constant with time. A simple extension of this analysis, accounting for depletion of noncondensables as additional vapor is produced and new condensing surface area is uncovered, indicates that in the case of fresh fuel (this is the case treated in the fuel failure propagation paper[2]) the presence of bond gases has little effect upon the rate of vapor bubble growth. In fact, the value of 1.5 cal/(sec cm^2 °C) used for the condensing coefficient may be on the low side. It is important to recognize that in the present application the condensing surface area is rapidly varying with time, and that the small amounts of noncondensables present initially (at time equals zero the fuel is assumed fully fragmented) is rapidly being depleted as a result of being absorbed on surface areas created early in the bubble lifetime. The condensing analysis presented by Majumdar and Kazimi[3] would not appear to be applicable in this case since their treatment assumes a uniform layer of noncondensables adhering to the total available condensing surface.

In the case of highly irradiated fuel, the release of molten fuel is likely to be preceded by fission gas release as indicated by Majumdar and Kazimi. The question in this case is not the potential for large pressure generation and bulk flow starvation, but rather the potential for creating a blockage (as a result of freezing and plugging) or for adding to the blockage that may have caused the fuel release in the first place; i.e., *blockage propagation* rather than *rapid* fuel failure propagation is the main concern in this case. In the concluding remarks of my paper, it was stated that the magnitudes of the pressure generation and the void growth appear insufficient to cause *rapid* failure propagation. It should be added that slow propagation (blockage propagation) cannot be ruled out at this time. However, note that detection by means of fission product monitoring systems is possible even for a single failed fuel pin, within a time period of tens of seconds. It is, therefore, important to clearly distinguish, on the one extreme, rapid pin-to-pin failure propagation, postulated to take place on a time scale too short to enable detection of the phenomenon and shutdown of the reactor prior to involvement of the entire subassembly, and, on the other extreme, self-limiting and/or slow failure propagation (blockage propagation), occurring on a time scale long enough to allow ample time for detection and corrective action if necessary. Major safety testing needs in the area of fuel pin failure propagation, therefore, appear to be the study of long term behavior following molten fuel release (both fresh and old fuel), including measurements of the rate of blockage propagation if it should occur and the related signals associated with fuel sweepout (delayed neutron detection) and boiling noise. Both out-of-pile and in-pile experiments are in progress to provide information in the above areas.

H. K. Fauske

Argonne National Laboratory
9700 S. Cass Avenue
Argonne, Illinois 60439

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[2] H. K. FAUSKE, *Nucl. Sci. Eng.*, **54**, 10 (1974).
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The Influence of Neutron Poisons on High-Concentration Plutonium Solutions

The criticality of plutonium nitrate solutions poisoned by borosilicate glass raschig rings was discussed by Lloyd et al.[1] I wish to comment on one of their conclusions which could have dangerous consequences if applied to a typical process plant situation and could result in a nuclearly unsafe condition. They state on p. 133 of Ref. 1 that: ". . . the calculations indicate that (the reactivity effect of) neutron poisoning is nil in the high, 391-g Pu/liter, concentration solution. The small reactivity effects . . . observed in this relatively undermoderated system appear to be entirely due to the density reduction caused by the rings displacing solution." These statements are true because of the small size of the experimental vessel used. Assuming their validity for larger vessels could lead a design agency to reduce costs by substituting a less expensive material for the boron-loaded glass. Their sole criterion would be that 19.27% of the tank's volume be consumed by the substitute material, as was the case in Ref. 1.

The vessel used by Lloyd et al. measured only 61 cm in diameter, and the critical 391-g Pu/liter solution height was 25.5 cm when 0.5 wt% boron-loaded rings occupied 19.27% of the volume. Using the KENO (Ref. 2) code and GAMTEC-II (Ref. 3) cross sections, they calculated k_{eff} = 1.012 ± 0.006, treating the raschig rings as parallel vertical tubes displacing the same solution as rings. Their conclusion apparently is based on the result of a second calculation in which the geometry and materials used in the first were retained except that the borosilicate glass material was replaced by a void. This result (k_{eff} = 1.010 ± 0.006) was not significantly different from the calculation including ring material and, hence, their conclusion.

At Rocky Flats, similar experiments involving heterogeneous poisoning of uranyl nitrate solutions have been performed.[4-6] The most recent experiment measured

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[2] G. E. WHITESIDES and N. F. CROSS, "KENO, A Multigroup Monte Carlo Criticality Program," CTC-5, Computing Technology Center, Union Carbide Corp., Nuclear Division (1969).
[3] L. L. CARTER, C. R. RICHEY, and C. E. HUGHEY, "GAMTEC-II—A Code for Generating Consistent Multigroup Constants Utilized in Diffusion and Transport Theory Calculations," BNWL-35, Battelle-Pacific Northwest Laboratories (1965).