LETTERS TO THE EDITOR

COMMENTS ON "EVALUATION OF VOLATILE AND GASEOUS FISSION PRODUCT BEHAVIOR IN WATER REACTOR FUEL UNDER NORMAL AND SEVERE CORE ACCIDENT CONDITIONS"

In the paper by Rest,[1] the words "diffusion" and "diffusion coefficient" are used to evaluate the behavior of noble gas bubbles, iodine, cesium, CsI, etc., in irradiated nuclear fuel.

Since formation of compounds and gas bubbles implies precipitation from super-saturated solutions, and since precipitates of gas bubbles and molybdenum-ruthenium "ingots" and cesium iodide have been identified in or on irradiated UO_2, it is clear that irradiated UO_2 is multiphase.[2-4] The thermodynamic principles associated with the phase rule tell us that there are negligible macroscopic chemical activity gradients associated with the elements in multiphase systems at equilibrium. Since diffusion is usually driven by activity gradients, it appears that the author may not have selected a physically realistic mechanism for the migration of fission product precipitates within and out of UO_2 at temperatures above 1500 K.

Let's get our homework done without requiring another Three Mile Island Unit 2 (TMI-2). It may be helpful to estimate the quantities and, hence, provide an indication of the maximum possible concentration gradients of ^{131}I and ^{133}Xe in a typical power reactor core at full power. About 20 millimicrograms (nanograms) of each of these radioactive fission products were present in the entire TMI-2 core at the time of the accident. About 10% of the ^{133}Xe was released from the containment and ~40% of the ^{131}I was released to the coolant. The model presented is not consistent with these data at any temperature. It predicts just the opposite behavior of these isotopes.

Radioisotopes are frequently employed as "tracers" in "carrier" media in which they may be moved about, not by diffusion, but by gravitational forces, convection, or mechanical forces that move the carrier.[5] Perhaps our understanding of fission product transport *in* and *out* of UO_2 needs to be reoriented along these lines.

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March 17, 1983

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REPLY TO "COMMENTS ON 'EVALUATION OF VOLATILE AND GASEOUS FISSION PRODUCT BEHAVIOR IN WATER REACTOR FUEL UNDER NORMAL AND SEVERE CORE ACCIDENT CONDITIONS' "

Chubb's[1] contention that fission product transport in solid UO_2 fuel is controlled "by gravitational forces, convection, or mechanical forces" and "*not* by diffusion" is counter to observation[2-6] and theory.[2,7-9] Chubb is mistaken about the fundamental processes of fission product transport in solid UO_2 fuel. Clearly, gravitational forces are much too weak to affect the migration of precipitates through a solid crystal lattice. Convection applies to the transference of heat by the circulation or movement of the heated parts of a liquid or gas and *not* to the migration of precipitates in a solid. If by mechanical forces Chubb is referring to the effect of stress gradients on precipitate motion, then these effects have been considered in the development of FASTGRASS: Stress gradient effects were found to be much weaker than temperature gradient related processes. Chubb's hypothesis that diffusion is not "a physically realistic mechanism for the migration of fission product precipitates within UO_2" because "there are negligible macroscopic chemical activity gradients associated

with the elements in multiphase systems at equilibrium" is erroneous: The UO_2 fuel was *not* in thermodynamic equilibrium during the accident at TMI-2!

Indeed, in that diffusional processes are considered to be key factors affecting fission product behavior (gaseous as well as volatile), the FASTGRASS diffusive flow model has been improved along the lines suggested by Matthews and Wood.[10] A paper describing this model as well as other improvements (e.g., modeling intergranular bubble behavior with lenticular bubbles instead of spherical) and an extensive comparison of FASTGRASS predictions with experimental results will be available in the near future.

Fission product release from Three Mile Island Unit 2 (TMI-2) is estimated to be ~70% for the noble gases and ~50% for both iodine and cesium.[11] Figure 4 of Ref. 11 shows that FASTGRASS predicts that this magnitude of release is possible from low-burnup solid fuel under "TMI-2-type" heating conditions.

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COMMENTS ON "A COMPARISON OF GADOLINIA AND BORON FOR BURNABLE POISON APPLICATIONS IN PRESSURIZED WATER REACTORS"

The paper by Goldstein and Strasser[1] concerning the use of gadolinium in pressurized water reactors (PWRs) inexplicably omits three seminal references. The first[2] made the important observation that, for the 3 to 4 wt% Gd_2O_3 range, a one-for-one replacement of burnable ^{10}B elements by Gd_2O_3/UO_2 elements need not have major effects on power distributions and cycle lengths for first cycles.

The second[3] analytically presented the effects of axial zoning of Gd_2O_3 in PWRs for the first time in the open literature and suggested generic techniques for power shaping by means of such axial zoning.

The third reference[4] discussed the reduction of moderator coefficient in PWR first cycles by development of a unique hybrid (Gd_2O_3 and ^{10}B) design, the purpose being the solution of the anticipated-transient-without-scram problem.

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April 28, 1983

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