LETTERS TO THE EDITOR

Regarding "Elastic-Plastic Thermal Stresses in Tubes Subjected to Uniform Heat Generation Evaluation of Experimental Results Obtained Using Graphite Tubes"*

The author has analyzed the case of a cylindrical tube with uniform internal heat generation, with the heat removed symmetrically from the exterior cylindrical surface, and with the axial thermal expansion of the tube completely suppressed. The latter condition is indicated by the author's assumption in his second paragraph that there is no axial strain and is confirmed by Fig. 6 which shows axial compressive stresses over the entire cross section of the tube. In view of the obvious desirability of allowing freedom for axial expansion, the author should have explained why he assumed that axial expansion was suppressed. If a reactor were designed with axial thermal expansion of the fuel elements suppressed, buckling of the fuel elements might be a serious problem, and upon reduction of the heat generation, there might be either a problem of fracture due to tensile stresses caused by suppression of axial thermal shrinkage or a problem associated with shortening of the fuel elements as a result of prior axial plastic compression. This shortening might allow vibration under the action of forces exerted by the reactor coolant.

The writer finds it surprising that the author did not reveal until his penultimate paragraph that the tests which he correlated with his theoretical analysis involved axial restraint which was not complete but which was "believed to be small." The fundamental difference between theoretical and test conditions eliminates all reason for existence of a correlation, and this apparently explains the gross disagreement between theory and experiment indicated by Fig. 2.

It appears reasonable to conclude that the failures which were encountered in the tests were caused by tensile stresses and strains in the graphite near the cooled surface. Fracture in a body subjected to a single application of nonuniform temperature would not occur simply as a consequence of the body developing plastic strains throughout most or even all of its volume. Fracture would be initiated only because local strains produced by thermal differential expansions are sufficiently high that they cannot be accommodated by plastic flow and elastic deformation without elevation of stresses to levels sufficient to cause fracture.

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* By T. Kammash, *Nuclear Sci. and Eng.* **7**, 425–434 (1960).

Rebuttal

Mr. Miller's explanation of the failure of the tubes is simply a restatement of the general theory of failure. In effect, it states that fracture occurs when the stresses in the material exceed a certain level. I agree wholeheartedly.

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Slowing-Down Time of Neutrons in Water

The slowing-down time, t_s, of high-energy neutrons to the cadmium cutoff energy in a moderator having $1/v$ absorption may be obtained from a measurement of the cadmium ratio with a thin $1/v$ detector. For $1/v$ epicadmium and thermal absorption, the probability of neutron capture is independent of velocity and is given by

$$-dN/N = dt/\tau_{th}$$

where τ_{th} is the mean thermal lifetime. This becomes after integration

$$N/N_0 = e^{-t/\tau_{th}} \tag{1}$$

Let $Q = N_0/\tau_{th}$ be the number of case histories of neutrons investigated during a time interval. At mean time, t_s, after source emission, a neutron is slowed to the thermal region. Because of $1/v$ epicadmium absorption, N_{th}/τ_{th} will be the reduced number of neutrons slowed below the cadmium cutoff energy. At $t = t_s$, $N/N_0 = N_{th}/N_0$ and Eq. (1) becomes

$$N_{th}/N_0 = e^{-t_s/\tau_{th}} \tag{2}$$

If a source of emission rate Q is present in the medium, $Q = N_0/\tau_{th}$ where N_0/τ_{th} is the neutron absorption rate in the medium. N_0 is the equilibrium number of neutrons present in the medium at any instant, and N_{th} and N_{Cd} are the thermal and epicadmium numbers, respectively. Equation (2) may be rewritten as

$$N_{Cd}/N_0 = 1 - e^{-t_s/\tau_{th}} \tag{3}$$

The activities with and without cadmium of the $1/v$ detector will be proportional to the corresponding neutron densities

$$\begin{aligned} A_{Cd}/A_0 &= 1 - e^{-t_s/\tau_{th}} \\ &= t_s/\tau_{th} \quad \text{for} \quad t_s/\tau_{th} \ll 1 \end{aligned} \tag{4}$$

Walker (*1*) has measured the ratio of epicadmium-to-bare capture, $\int_0^\infty A_{Cd}r^2\,dr / \int_0^\infty A_0 r^2\,dr$ with a small BF_3 detector