LETTERS TO THE EDITOR

RESOLUTION CRITERION FOR FUEL MOTION DETECTION

We seek a criterion for the resolution required to interpret fuel motion effects in large in-pile tests of liquid-metal fast breeder reactor (LMFBR) fuel bundles. Current experiments involved a field of view encompassing only a few pins, and it is natural to specify solely the spatial resolution. When large numbers of pins are involved, such a criterion loses meaning. It may be too precise for some regions and too weak for others in the same experiment.

The tack we take is to estimate the worth of a representative fuel displacement. A resolution criterion in terms of g-cm can then be related directly to the error in reactivity effect when the experimental observations are extrapolated to whole-core accident analysis. This is also the proper measure of resolution for an imaging system. A resolution of 1 g-cm is the ability to detect the displacement of 1 g of fuel through 1 cm. To determine the resolving power needed, we have to estimate the average worth gradient of fuel in a large LMFBR.

The average worth gradient can be estimated by approximating the flux as $1 - (r/R)^2$, where R is the radius of an equivalent spherical core, by designating the worth per unit volume as the flux squared, and by assuming a uniform fuel density.

Straightforward integration then yields the worth gradient at $r = 0.5\,R$:

$$(\overline{\Delta k}/k)/\text{g-cm} \simeq 10/Mc^{4/3} \quad ,$$

where Mc is the critical mass in grams. A mass of 10^7 g yields

$$\overline{\Delta k}/k \simeq 5 \times 10^{-9}/\text{g-cm} \quad .$$

If we recall that a dollar of reactivity is $\sim 3 \times 10^{-9}$ $\Delta k/k$, we get the resolution needed to yield a 1-dollar accuracy, A, from

$$3 \times 10^{-4} = A \times 5 \times 10^{-9}$$

or

$$A = 0.6 \times 10^5 \text{ g-cm} \quad .$$

Higher precision is usually needed. If motion within a subassembly is to be measured that when extrapolated to a whole core would equal 1 dollar, A = 600 g-cm; an accuracy of 10 cents then corresponds to A = 60 g-cm.

In any specific situation, the resolution can be related to a visual field. For example, if a vector detector views a major diameter of a large subassembly, the fuel density per unit height will be ~40 g-cm. A spatial resolution of 1.5 cm^2 then yields A = 60 g-cm. Detectors viewing fewer pins would have correspondingly coarser spatial resolution.

On a visual field basis we would estimate 1000 vector detectors being needed for a precision of 10 cents, but, on a fuel displacement basis, we estimate that about half that number would be needed with varying spatial resolution.

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