

LETTERS TO THE EDITOR



RULE OF THUMB FOR FAST FLUX IRRADIATIONS

Dear Sir:

The growing need for irradiation of large samples in fast neutron fluxes has prompted intensive review of the use of thermal test reactors for such irradiations. A typical result of such a review was presented by Wood *et al.*¹ The main problem is that of obtaining a neutron flux characteristic of an LMFBR in the irradiation volume when the incident flux is highly thermalized. The solution presented in Ref. 1 is to use a carefully designed filter, together with enrichment variation in the sample, to produce the desired spectrum. The power density in the sample is then limited to "about one-half that in EBR-II." It is natural to try to exceed this limitation by combining the filter with a flux converter. We propose here some simple rules of thumb to estimate the magnitudes of the power densities in the irradiation volume and the accompanying flux converter and filter assembly. Estimates thus obtained should be useful in screening various candidates for irradiation testing.

Assume that the flux converter and filter is black to thermal neutrons and that each incident thermal neutron yields ϵ virgin neutrons. Further, assume that the converter-filter thickness, Δ , is small compared to the test zone radius, r . Assume that the power density in the test volume is flat and that the material has an effective multiplication M . Let S be the total source in the test zone.

Then the power in the test zone is proportional to MS , and the power in the flux converter and filter is proportional to $2S$. The latter, in turn, is (nearly) proportional to $2\pi r J \epsilon$, where J is the incoming current. But by diffusion theory and the assumption of blackness the current is related to the (thermal) flux at the outer surface of the converter by $J = \phi/2$. ϕ is not quite the average thermal flux in the reactor; it differs from the average flux by a flux depression factor, as well as any local factors applicable to the particular location of the test zone in the reactor. Such factors are lumped into the efficiency, ϵ . Recalling that the average power density in the test reactor core is just $\Sigma_f \phi$, where Σ_f is the core fission cross section, we can now compute the power densities in the irradiation volume and flux filter converter, neglecting neutron and gamma heating.

The power density in the test volume, P_f , is given by:

$$P_f = MS/\pi r^2$$

but

$$S = \pi r J \epsilon = \pi r \phi \epsilon / 2 ,$$

whence

$$P_f = M\phi\epsilon/2r .$$

Introducing the test reactor average power density, P_r , we have:

$$P_r = \Sigma_f \phi$$

and

$$P_f/P_r = M\epsilon/2r\Sigma_f .$$

Similarly the ratio of the power density in the flux converter-filter, P_c to P_r , is given approximately by:

$$P_c/P_r = \epsilon/2\Delta\Sigma_f .$$

Some typical values of the parameters in an ETR type environment are

$$M = 1, \quad \Sigma_f \approx 0.06/\text{cm} ,$$

whence

$$P_f/P_r \approx 8\epsilon/r ,$$

where r is the radius of the test volume in centimeters. ϵ is the ratio of source neutrons produced in the flux converter filter to the number of thermal neutrons absorbed in the converter (including flux perturbation effects) and varies typically^a from 0.05 (no converter) to 0.5. In larger test zones, $M \geq 1$. In application where P_f and P_c are limiting factors, their ratio is also important:

$$P_f/P_c = M \Delta/r .$$

If, for example, one wished to have a test volume of radius ~ 2 cm with a power density of 1 MW/l in a test reactor with an average power density of 500 kW/l, one finds $\epsilon = 0.5$, a very high value that is probably difficult to achieve.

In setting forth these relationships we have not explored the practical difficulties of making flux converter filters. These difficulties, such as those described by Wood *et al.*,¹ may force effective compromises in design. For example, the filter in Ref. 1 is not thin with respect to the test volume, and there is still a small epithermal neutron component to the filtered flux; this may require large enrichment variations in the irradiated samples. Nevertheless, the filter of Ref. 1 has an apparent $\epsilon \approx 0.2$.

One conclusion that can be quickly reached is that irradiation of large samples (e.g., complete fuel subas-

^aIn principal, higher values of ϵ ($\leq \eta \approx 2$) can be achieved, but in practical applications this is rarely done.

semblies) is most readily done in dilute thermal reactors such as graphite-uranium systems, where Σ_f is small. One proposal made along these lines was the "Briseis" concept.² However, the total power in such cases tends to be large, and it may be advantageous to consider designs not requiring a flux converter filter, i.e., a fast test reactor.

Charles N. Kelber

Argonne National Laboratory
Argonne, Illinois 60439

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REFERENCES

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2. A. DESCAMPS, E. FOSSOUL, N. MEYVAERT, M. STIEVENART, G. TAVERNIER, and J. VANDIEVAT, "Briseis: Transient Reactor for Fast Reactor Fuel Testing," *Proc. Conf. on Breeding, Economics and Safety in Large Fast Power Reactors, Oct. 7-10, 1963*, ANL-6792, pp. 113-122, Argonne National Laboratory (1963).

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HANDLING PuO₂ OUTSIDE GLOVEBOXES

Dear Sir:

We had the problem of loading a (Pu,U)O₂ specimen into a capsule for an in-pile experiment.¹ The assembly techniques for the 20-ft-long insert used in the experiment were developed over a period of years and involve delicate hand operations on a bench assembly located in a noncontamination area. We did not wish to attempt to assemble a 20-ft-long rig in a glovebox or to change our successful assembly techniques.

An alternative method was to apply a temporary coating on the (Pu,U)O₂ specimen so that it could be handled without spreading plutonium contamination. Naphthalene was selected for the coating material because it has a low melting point (80°C), forms a hard coating, is relatively non-toxic, yet can be vaporized without leaving a residue.

The (Pu,U)O₂ specimen consisted of two pellets, each 0.54-cm o.d., 0.58-cm long, with a 0.127-cm-diam axial hole. The pellets were placed in a glovebox and slid into a tungsten holder that had been machined into a hollow cylinder, 0.60-cm i.d. and ~2.2-cm long, with one end open and the other closed. A drill rod was placed into the axial hole of the pellets so as to leave a hollow space for subsequently receiving a thermocouple. Molten naphthalene was poured into the tungsten holder,

covering the specimen and filling the holder, which was then removed from the glovebox by the usual plastic-bagging method.

The contaminated glovebox had contributed some activity to the naphthalene coating, so the specimen was removed from the bags in a relatively clean hood (used for handling toxic materials) and re-dipped in a series of four clean naphthalene baths. This resulted in a very slightly contaminated outer coating with the contamination firmly fixed. The dipped specimen was stored in a closed bottle containing naphthalene crystals to prevent the coating from evaporating before installation in the capsule.

The specimen was loaded into the capsule using the usual techniques. A portable hood and constant monitoring were employed, but only surgical gloves and lab coats were used for personnel protection. The central rod was extracted from the capsule by twisting until the naphthalene bond broke. Surprisingly, this operation released no contamination.

After the capsule was assembled, a weld was made within one inch of the coated specimen. The naphthalene was prevented from melting by cooling the capsule between short weld periods. The welding required a continuous purge of argon over the interior of the assembly, and there was some concern that this might cause loose contamination to be carried out into the room. However, no release was detected.

After the welding was completed, the assembly was evacuated and the capsule warmed to ~80°C. The warming and pumping was continued overnight; bench tests had shown this to be more than sufficient time to ensure evaporation of the naphthalene. A filter was placed in the pump line to detect any plutonium released during the evaporation of the naphthalene.

Through the entire operation, no detectable contamination was found on any of the equipment, the handling gloves, or the tools. Air monitors detected no activity, although they were placed very close to all operations. All smears and filter readings had zero count level.

The ease of applying and removing naphthalene suggests that it might serve as a protective coating for many types of specimens, especially those of a friable nature, during handling and storing.

R. M. Carroll
H. E. Robertson

Reactor Chemistry Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

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REFERENCE

1. R. M. CARROLL and P. E. REAGAN, "Techniques for In-Pile Measurement of Fission-Gas Release," *Nucl. Sci. Eng.*, 21, 141 (1965).

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