CONF-860906--3

MASTER

The submitted manuscript has been authored by a contractor of the U. S. Government under contract No. W-31-109-ENG-38. Accordingly, the U. S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U. S. Government purposes.

LOCAL HETEROGENEITY EFFECTS ON SMALL-SAMPLE WORTHS

R. W. Schaefer

CONF-860906--3

DE86 006448

Argonne National Laboratory
P. O. Box 2528
Idaho Falls, Idaho 83403-2528

Submitted to:

Topical Meeting on Advances in Reactor Physics and Safety
September 17-19, 1986

Work supported by the U. S. Department of Energy,
Nuclear Energy Programs under contract W-31-109-Eng-38.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

jsw

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Local Heterogeneity Effects on Small-Sample Worths

R. W. Schaefer

One of the parameters usually measured in a fast reactor critical assembly is the reactivity associated with inserting a small sample of a material into the core (sample worth). Local heterogeneities introduced by the worth measurement techniques can have a significant effect on the sample worth. Unfortunately, the capability is lacking to model some of the heterogeneity effects associated with the experimental technique traditionally used at ANL (the radial tube technique). It has been suggested that these effects could account for a large portion of what remains of the longstanding central worth discrepancy.[1] The purpose of this paper is to describe a large body of experimental data - most of which has never been reported - that shows the effect of radial tube-related local heterogeneities.

In the radial tube technique, samples are inserted into the core through a steel tube. The tube and sample capsule constitute steel not in the normal core unit cell (steel hardware effect). Core material must be displaced to make room for the tube. This is done either by using "tunnel" plates or by creating a slot along one matrix row. In either case a cavity and neutron streaming path are created (cavity and streaming effects). The slot is usually created at the matrix interface, where there is extra steel and a ~1 mm-wide planar gap (matrix interface effect). The sample typically is a cylinder or annulus that is inserted perpendicular to the plate unit cell loading and spans the cell (orientation effect). Its size is such that self shielding or self multiplication effects are often several percent (sample size effect).

There have been numerous experiments over the past 15 years to quantify these local heterogeneity effects associated the radial tube technique. The idea behind these experiments is to change or eliminate one or more of the local heterogeneities normally present with the radial tube technique and measure the effect on sample worth.

In many cases it was necessary to apply calculated adjustment factors that put the different measurements of a material's worth on a common basis. There is ample evidence that adjustments are quite accurate for modest differences in position within the core and for differences in position within the unit cell. The available evidence suggests that adjustments for different sample size effects are accurate to about 1%[1,2], but the possibility of poorer accuracy exists.

Experimental results from seven critical assemblies are collected here. Each assembly provided a different global environment (core composition and geometry, neutron spectrum, etc.) The particular radial tube-related heterogeneity effects measured and the approach for doing so varied with assembly. The conditions for each assembly (and the date of the experiments) were as follows:

- ZPPR-2[3] (1970). This was a mixed Pu-U oxide fuel, homogeneous LMFBR design with two enrichment zones. An indication of the combined effect of cavity, streaming and matrix interface was obtained by comparing the two ways of inserting the radial tube into the core.
- U/Fe[1] (ZPR-9/34, 1979). The uranium/iron benchmark core was composed almost entirely of highly enriched uranium fuel and iron moderator. The neutron spectrum was roughly comparable to that of an LMFBR. A radial tube measurement of ^{235}U worth was compared with a ^{235}U worth measurement that introduced minimal local heterogeneities.
- ZPR-9/35 (1980). The experiments took place in a central zone containing a uranium oxide LMFBR composition. Using a drawer oscillator[1], each of the radial-tube-related local heterogeneities

was simulated and the effect on sample worth measured. Some representative results are given here.

- o U9[1] (ZPR-9/36, 1980). The core was nearly all uranium (9% ^{235}U) and had a hard, narrow neutron spectrum. The effect of neutron streaming along the tube path was determined for this small radius core.

- o ZPPR-12[1] (1982). The small homogeneous core had a high enrichment Pu-U oxide LMFBR composition. The worth of fissile plate samples having sample size, cavity and in-cell orientation comparable to those in radial tube measurements were compared against the average worth from a large set of measurements having either small or accurately calculable local heterogeneities ("clean" measurements). The spread about the average for the set was included as an uncertainty in the comparison.

- o ZPPR-13[4] (1982-1984). This was a large, mixed Pu-U oxide-fueled, radially heterogeneous assembly. The experiments were done in three configurations. In two of these, the region of the fuel ring where the measurements were done, had the same unit cell as in ZPPR-12. In the third configuration, this region was a zone with uranium oxide fuel. Most of the kinds of experiments done in ZPPR-12 were performed here. In addition radial tube measurements and simulations of tube measurements with the drawer oscillator were done. The average of radial tube and tube-like results was compared against the average from the "clean" measurements.

- o ZPPR-15A (1985). This was a mixed Pu-U metal fuel homogeneous design. Again the average of radial tube and tube-like results was compared with the average of "clean" results.

Table I is a summary of results from the many dozens of measurements. The quantity displayed is the percentage difference in sample worth that is attributable to one or more of the local heterogeneity effects associated with the radial tube technique. In some cases the measured difference is smaller than the uncertainty, meaning there is a 1σ probability that the effects are not larger than the uncertainty. The effects that potentially are responsible for the measured difference are identified by an "X" in the appropriate column.

There appear to be few simple generalizations; the magnitude of the effects varies with assembly, sample type and fuel type. The effects are not always insignificant yet they are not understood sufficiently that their magnitude can be anticipated reliably. On the other hand, they are almost never so large that their neglect could be termed intolerable. Some observations that can be made are:

- o The combined effect of the neglected heterogeneities on fissile worth ranges from less than 1% up to 6%. (The 11% value from ZPPR-12 is an anomoly; even with the same unit cell, experiments in ZPPR-13 found the effect to be much smaller.)

- o The effect on fissile worth depends on the core fuel. (This is not really understood but may be related to differences in adjoint spectrum.)

- o With ^{235}U fuel, the effect on fissile and absorber worths is generally small, about 2% or less.

- o With ^{239}Pu fuel, the effect on fissile worth ranges from < 2% to 6% (excluding ZPPR-12).

- o For ^{238}U and for samples that are principally scatterers, the effect on worths is larger. It could be 5 to 10%, even with ^{235}U fuel.

- o Neutron streaming along the tube path is a large effect only when the core radius is small.

References

1. K. S. Smith and R. W. Schaefer, "Recent Developments in the Small-Sample Reactivity Discrepancy," Nucl. Sci. Eng., 87, 314 (1984).

2. P. J. Collins and R. G. Palmer, "Calculated Size Effects for Reactivity Perturbation Samples in ZPPR," ANL-7910, p. 247, Argonne National Laboratory (1971).

3. R. E. Kaiser and R. J. Norris, Critical Mass Evaluation in ZPPR Assembly 2, a Demonstration Reactor Benchmark Assembly, ANL-7710, p.140, Argonne National Laboratory (1971).

4. H. F. McFarlane et al., "Experimental Studies of Radially-Heterogeneous LMFBR Critical Assemblies at ZPPR," Nucl. Sci. Eng., 87,204 (1984).

TABLE I. Effect of Radial Tube-Related Heterogeneities on Sample Worths

Assembly	Fuel	Sample	Unaccounted-for Sample Worth Difference (%)	Phenomena Potentially Responsible: Sample Size	Matrix Interface	Steel Hardware	Cavity/ Orientation	Streaming
ZPPR-2	^{239}Pu	^{239}Pu	-2.5 ± 1.0		X		X	X
		^{241}Pu	-5.4 ± 1.0		X		X	X
		^{235}U	-3.0 ± 1.0		X		X	X
		^{238}U	7.4 ± 2.0		X		X	X
		^{10}B	-0.6 ± 1.0		X		X	X
ZPR-9/35	^{235}U	^{235}U	-0.3 ± 0.7	X	X	X	X	X
		^{238}U	-10.8 ± 3.1			X	X	X
		^{6}Li	-1.3 ± 0.6		X	X		X
		C	3.0 ± 6.1		X	X		X
		Steel	5.3 ± 4.0		X	X	X	X
U/Fe	^{235}U	^{235}U	-2.3 ± 1.4	X		X	X	X
U9	^{235}U	^{235}U	4.0 ± 1.0					X
ZPPR-12	^{239}Pu	^{239}Pu	11.0 ± 1.4	X			X	
		^{235}U	4.2 ± 0.9	X			X	
ZPPR-13A	^{239}Pu	^{235}U	6.0 ± 1.8	X		X	X	
ZPPR-13C	^{239}Pu	^{239}Pu	2.8 ± 2.6	X			X	
		^{235}U	3.1 ± 1.6	X		X	X	
ZPPR-13C	^{235}U	^{239}Pu	0.4 ± 2.3	X			X	
		^{235}U	0.2 ± 1.9	X		X	X	
ZPPR-15A	^{239}Pu	^{239}Pu	0.3 ± 1.2	X		X	X	X
		^{235}U	2.0 ± 0.7	X		X	X	X
		^{238}U	-0.1 ± 2.3	X		X	X	X
		^{10}B	1.2 ± 1.1	X		X	X	X
		Steel	0.2 ± 7.6	X		X	X	X