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E. I. du Pont de Nemours and Co.
Savannah River Laboratory
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SECTION I

PHYSICS EXPERIMENTS WITH FUEL ASSEMBLIES SIMULATING BURNED-UP FUEL

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INTRODUCTION

Experiments have been performed in the Process Development Pile (PDP) and the Subcritical Experiment (SE) at the Savannah River Laboratory (SRL) to investigate the physics behavior of burned-up fuel in the CANDU and similar heavy-water power reactors. These experiments used specially fabricated fuel assemblies containing plutonium and uranium in approximately the isotopic compositions expected for fuel irradiated to 5000 MWD/ton. Separate sets of fuel assemblies also varied the total plutonium content and the isotopic fraction of ^{240}Pu.

SUMMARY

Activations of Lu-Mn foils in the natural UO_2 and the mockup burned-up fuel clusters were used to determine "spectral indices" for the hardening of the thermal neutron flux in the fuel clusters. Comparison with calculations by the HAMMER code showed qualitative agreement with the experiments, but the code tended to overestimate the flux hardening.

DISCUSSION

Spectrum Index in 19-Rod Clusters

The energy spectrum for the thermal neutrons inside a reactor fuel assembly is considerably altered from the neutron energy spectrum in the moderator because of energy selective neutron absorption by the fuel atoms within the fuel assembly. Normal "1/v-law" absorbers give rise to the conventional "spectrum hardening." The plutonium-bearing fuel clusters give more complicated spectrum shifts resulting from the added selective absorption by the strong ^{239}Pu resonance at 0.297 ev. A knowledge of the thermal neutron spectra is in these clusters of particular interest because the neutron reaction rate in plutonium relative to the other isotopes is quite sensitive to the spectrum shift. An integral, or energy-average, measurement of the shift may readily be obtained by comparing activations in pairs of foil materials with different energy-dependent cross sections. Foil pairs used in the present experiment were Lu-Mn and ^{239}Pu-^{235}U. Typical results from Lu-Mn are presented in this report.

Both cadmium-covered and bare foils were placed throughout typical fuel cells in the Subcritical Experiment (SE) and activated. For each foil the ratios of the induced subcadmium activities of ^{177}Lu to Mn were then normalized to the corresponding ratio for foils in a fully thermalized flux (the SP thermal column) to obtain the spectrum index $g^{Lu}/g^{1/v}$ plotted in Figures 1 and 2. The measured indices were also compared to cross section ratios derived directly from the THERMOS portion of the HAMMER code, which has been used to calculate the energy spectra in these lattices. The relation is

$$\left[g^{Lu}/g^{1/v}\right]_{\text{Expt}} \longrightarrow \left[\sigma^{Lu}/\sigma^{1/v}\right]^{\text{cell}}_{\text{HAMMER}} \Big/ \left[\sigma^{Lu}/\sigma^{1/v}\right]^{\text{thermal}}_{\text{HAMMER}}$$

where the cell cross sections, σ^{Lu} and $\sigma^{1/v}$, are HAMMER flux averaged by region within the cell and the Maxwellian energy averaged thermal values are 3080.6 barns for Lu and 0.886 barn for a 1/v-law detector such as manganese.

The comparison of experiment to HAMMER calculations is shown in Figure 1 for natural uranium and in Figure 2 for Pu-bearing rods. All experiments were made with 19-rod clusters (0.597-inch rod pitch) at a 9.33-inch triangular lattice pitch in D_2O. These clusters were surrounded by 3.020-inch-ID aluminum housings which contained the various coolants D_2O, air, or HB-40. Scattering kernels, which predict diffusion and energy exchange properties of the moderator in the HAMMER calculations, were the Honeck-Nelkin kernel for D in D_2O and the Ardente-Nelkin kernel for H. The theory properly predicts the qualitative relation of the air-to-D_2O-to-organic profiles, but overestimates the magnitude of the spectrum shift for both fuel types. Also the computations correctly predict the lower indices measured for the Pu-bearing rods compared to the natural uranium. The difference is ascribable to resonance shielding of the lutecium foils by plutonium rather than to a true spectrum shift of the equilibrium distribution. Studies are being made to determine to what extent the systematic discrepancies are due to inadequacies of the physics approximations used in the HAMMER code and to what extent they are due to inadequacies of the concentric ring model used to reduce the cluster to one-dimensional geometry for the calculations.

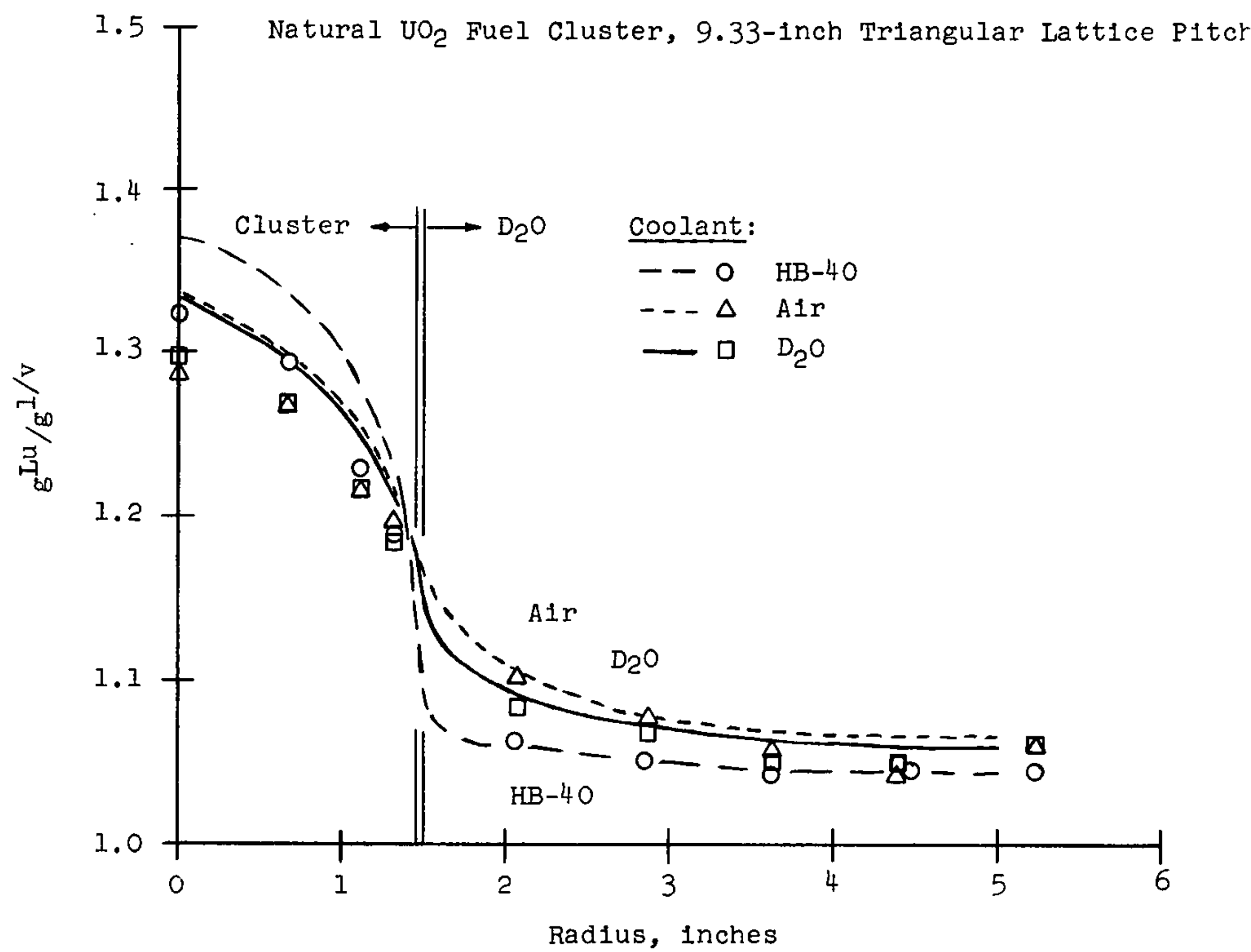

Figure 1 - Neutron Temperature Index in Lattices of 19-Rod Clusters of Natural Uranium Oxide, Experiment and THERMOS Computations

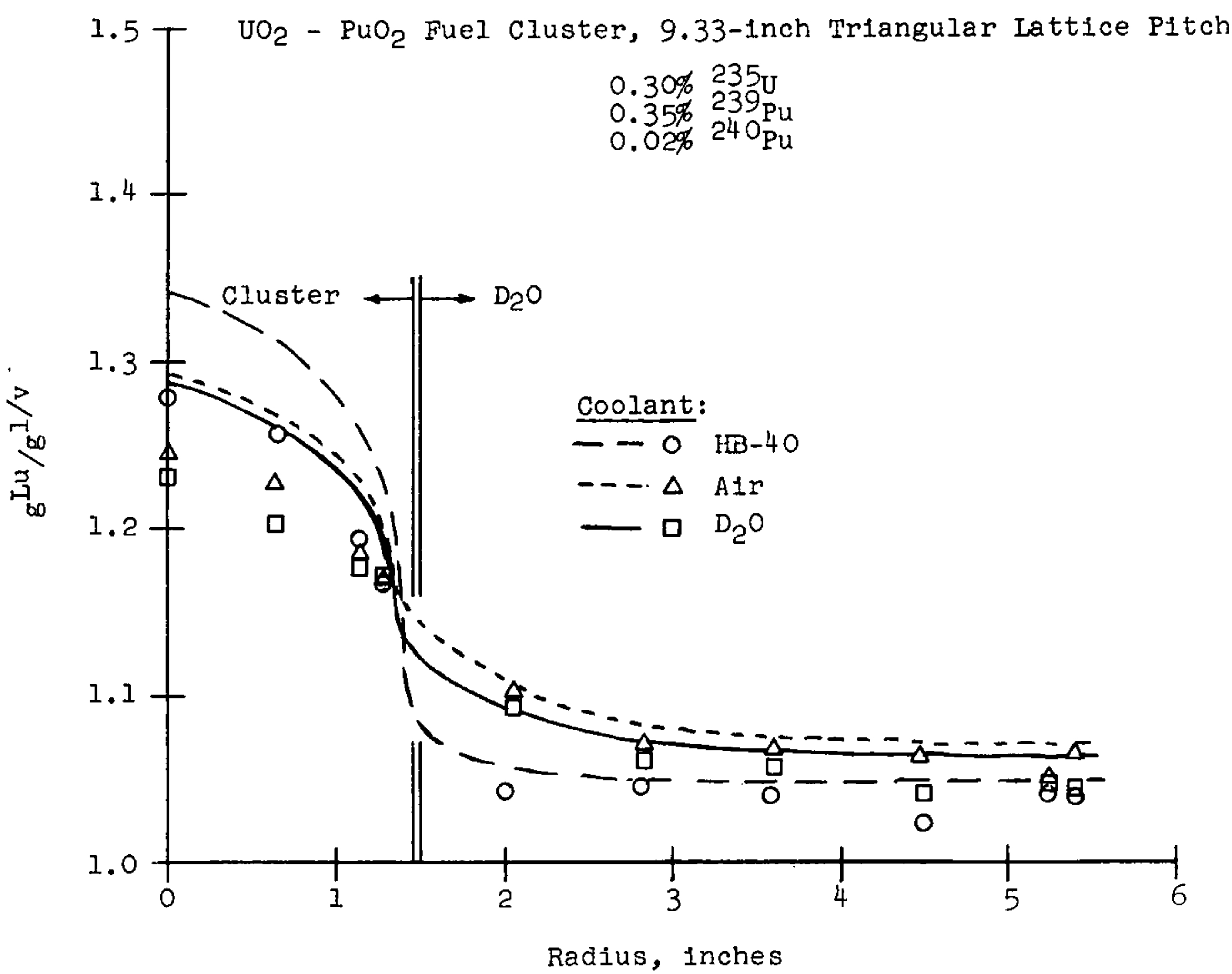

Figure 2 - Neutron Temperature Index in Lattices of 19-Rod Clusters of Pu-Bearing Uranium Oxide, Experiment and THERMOS Computations

SECTION II

AECL IN-CORE FLUX MONITORS

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An irradiation test of in-core flux monitors is being made in one of the Savannah River Plant reactors to determine the life characteristics of a selection of flux detectors and of the mineral insulation used in their construction. Self-powered flux detectors are relatively new; therefore, confidence in their use hinges to a great extent on proven performance at large integrated exposures. The chief points of interest are 1) integrity of the conductors and sheath during life, 2) life of insulation, and 3) sensitivity. The higher flux density available at SRP (vis-à-vis Chalk River) will shorten the irradiation time for a given exposure and should also show whether or not any new high intensity effects appear.

Fabrication and installation of the detector rod in the reactor has been completed and testing is in progress. There were no special tests in October. The data being collected will be reported in a separate topical report at the conclusion of the tests.

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