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1-3: JP Derouin (RL-AEC)

March 29, 1967

U. S. Atomic Energy Commission
Richland Operations Office
Richland, Washington

Attention: Mr. J. P. Derouin
Classification Officer

Gentlemen:

CLASSIFICATION - GUIDANCE FOR SPECIALTY IRRADIATIONS

- References: 1. My letter to you, same subject, DUN-2119, dated February 17, 1967.
2. H. E. Ransom's draft of revised guide topics for specialty irradiations, dated March 24, 1967.

Reference 2, which is intended to replace Subsection 304 in the proposed rearrangement of Section 300, seems to incorporate very well the agreements reached in our several discussions of the approach described in Reference 1. This approach recognizes that flux tailoring techniques may be used to enhance localized flux for specialty irradiation purposes, and proposes that (on a limited volume basis) we be at liberty to disclose test specimen and assembly fluxes up to 2×10^{14} neutrons/cm²-sec.

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U. S. Atomic Energy Commission -2-

March 29, 1967

As agreed in our March 22 meeting, Mr. Fullmer has prepared a brief technical description of reactor flux tailoring--the key to this proposal. His explanation is included with this letter as an unclassified attachment. It will be seen that these techniques are capable of making the requested specialty irradiation flux available in a DUN-operated reactor restricted to the unclassified average flux of 1×10^{13} .

Our few suggestions for further refinement of the topics contained in Reference 2 are relatively minor and have been marked on the copy being returned to you. It is understood that you plan to recommend this revised Subsection 304 to the Division of Classification for approval. If there is anything further that we can do to expedite action on this request, please let us know.

Very truly yours,

DOUGLAS UNITED NUCLEAR, INC.

T. W. Hauff
Specialist - Classification
& Administration

TWH:mhm

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FLUX TAILORING
FOR SPECIALTY IRRADIATIONS

INTRODUCTION

The purpose of this memorandum is to describe the concepts for accomplishing localized tailoring of thermal neutron flux. The application of fuel displacement and enrichment techniques in lattice cells surrounding a test facility may accelerate sample irradiation rates by an order of magnitude or more above those in the normal reactor environment. Thus, test irradiation conditions may be established by such flux tailoring techniques which are not indicative of the specific flux and power conditions characteristic of the reactor loading as a whole.

FLUX MODERATION BUILDUP

If a neutron source, such as polonium beryllium, with its α -n reaction, is placed in a moderating medium, it will be observed that the peak flux of thermal neutrons is not at the source itself but rather some distance away. The reason for this effect is that the thermal neutrons are "born" from the original fast neutrons which travel, on the average, this observed distance before becoming fully moderated.

In addition to this increase in thermal neutron flux with initial distance due to moderation, there is an absorption effect in a heterogeneous lattice which appears additive to the moderation effect. The fuel columns are strong absorbers of thermal neutrons whereas the moderator is not. Hence, the thermal neutrons are not only "born" mostly in the moderator, but they are absorbed most strongly, or "die," in the fuel column. Thus the thermal neutron flux in the moderator is higher than that in the fuel of the same lattice; a factor of two or more difference in average thermal neutron flux between the two locations is not unexpected in a heterogeneous thermal reactor.

A slight local rearrangement of the heterogeneous lattice may be made to exploit the moderation effect. By replacing fuel with non-neutron-absorbing, and preferably neutron-moderating, material in a local region of the reactor, some of the neutrons otherwise captured at resonance energies plus some of the others previously captured in the fuel thus have a longer lifetime before capture, and effectively result in a local buildup in thermal neutron population. This modification is referred to as a "flux trap," a technique with the potential for increasing local thermal flux by a significant fraction.

LOCAL ENRICHMENT

If fissionable atoms are added to the fuel in a small region of the reactor which previously maintained an exact balance between neutron capture and neutron formation from fissions, that region will begin to generate a surplus of neutrons. Two effects result: the local flux level increases, and a flux

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gradient is formed between the enriched locale and the less reactive parts of the reactor. The buildup and gradient effects may be visualized as similar to the peaking and outward flow of an active volcano.

The degree of peaking and the steepness of flux gradients within the reactor are directly dependent upon the amount and type of enrichment used. A high-flux peak of twice normal flux level could be created with modest effort utilizing uranium enriched in U-235. An increase of ten times normal flux level could be created with enriched uranium with the gradient covering a greater portion of the reactor; if pure U-235, U-233 or plutonium were used as the driver fuel, however, a steep gradient could be created and only a small portion of the reactor lattice would need to be involved to create an equivalent peaking effect. A feel for the steepness of flux tailoring capabilities as a function of enrichment may be obtained from the comparison of "critical slab" dimensions given below. A critical slab is the thickness necessary to cause a given type of loading to go critical, assuming the dimensions in the plane of the slab to be infinite; the flux would go from zero at each face of the slab to a cosine peak at its center, or half-thickness.

<u>Fuel Loading in Graphite Lattice</u>	<u>Approximate Half-Thickness of Critical Slab</u>
Natural Uranium (0.7% U-235)	10 lattice units
Low Enrichment (1% U-235)	5 lattice units
High Enrichment (2-100% U-235)	2-3 lattice units

The creation of high flux locations in the reactor involves some other considerations. Specific power levels in a few columns would be appreciably higher than would be characteristic in the major portion of the reactor. Additional neutron absorbers at the edge of the gradient region are required to compensate the additional reactivity and to tailor the flux appropriately for maintaining normal flux levels and gradients in the remaining majority of the reactor lattice. Reactor temperature coefficients of reactivity and reactor safety and operational control effects must also be considered. Although the principles of flux enhancement and attenuation are straightforward, the specific techniques utilized to maintain optimum reactor operating conditions may be quite sophisticated.

IN CONCLUSION

It is possible, through well established flux tailoring techniques to attain localized flux levels for specialty irradiations an order of magnitude or more beyond the levels characteristic of the normal reactor environment. Standard techniques are available for attenuating the thermal neutron flux as a means of varying sample exposure downward.