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SUBJECT: PARTIALLY ENRICHED U^{235} FOR USE AS FUEL IN OFF-SITE REACTORS

TO: S. R. Sapirie

FROM: C. E. Larson

CLASSIFICATION CANCELLED
DATE 10-17-62
Edgar J. Murphy
CO-ORDINATING ORGANIZATION DIRECTOR
OAK RIDGE NATIONAL LABORATORY
AUTHORITY DELEGATED BY AEC 9-10-57

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Date: 8-16-16

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"This document consists of 5 pages.
No. 11 of 16 copies, Series A"

August 10, 1953

U. S. Atomic Energy Commission
P. O. Box E
Oak Ridge, Tennessee

Attention: Mr. Kenneth Kasschau

Subject: PARTIALLY ENRICHED U^{235} FOR USE AS FUEL IN OFF-SITE REACTORS

Gentlemen:

This is in reply to the memorandum of July 21, 1953, from R. W. Cook to S. R. Sapirie, requesting opinions on several questions involved in substituting uranium of low enrichment for the highly enriched material now used in the active lattice of the reactor in the Bulk Shielding Facility. The numbered paragraphs below correspond to the numbered paragraphs in Mr. Cook's memorandum.

1. According to the K-25 people it is feasible to draw UF_6 from the process stream at practically any enrichment. This procedure is somewhat less costly than diluting the highly enriched end-product with natural uranium.

   As far as obtaining material of low enrichment is concerned, there is no reason to standardize on some particular enrichment since all enrichments can be obtained with equal facility.

2. This question, which has to do with reprocessing, will be answered by the Arco people.

3. Calculations of the critical mass of a number of water-reflected active lattices of two sizes (15" x 15" x 24" and 24" x 24" x 24") have been made. Critical masses increased by about 20% to allow for burnup and beam holes are shown as a function of the degree of enrichment on Figure I. If a BeO reflector is provided on four sides of the lattice, the uranium requirement is reduced by about 20%. This will cause the curve for the 25 element lattice to intersect the "permitted by AEC formula" curve at an enrichment between 20 and 30%.

   In addition to nuclear considerations there are several constraints which limit the active lattice design if MTR type fuel elements are

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used. The fuel plates cannot be more than 100 mils thick, and with 20 mils of cladding the aluminum-uranium core thickness is limited to 60 mils. Using powder metallurgy techniques, the ORNL Metallurgy Division believes it can make satisfactory fuel plates containing cores with a weight percentage of uranium as high as 40% and a density of 3.7 grams per cc. To supply adequate cooling surface the lattice should contain at least 125 plates or, with a 25 element lattice, five plates per element. On the other hand, the cooling channels should not be less than 125 mils thick and this forbids more than 13 or 14 plates per element. This in turn determines the maximum amount of uranium which the lattice can contain.

Any reactor of this type should be designed to have as few fuel plates as possible in order to reduce the Al/water ratio and the critical mass.

4. The chief effect of partial enrichment, versus 93% enrichment, is to increase the U^{235} requirement. At moderate enrichments the effect is not large, but at low enrichments the resonance escape probability is noticeably decreased and the uranium requirement goes up very rapidly.

5. We have not calculated critical masses for homogeneous (water boiler) reactors using light water and uranyl sulphate. The increase in U^{235} requirement with decrease in enrichment will be small until the enrichment falls to perhaps 20%. The limiting factor probably will be the solubility of uranyl sulphate in water at room temperature. Solubility is sufficient so that the H/U ratio can be made as low as 12.

   Even with the more concentrated solution, corrosion should not be troublesome at temperatures below 100° C.

6. MTR fuel plates contain a core of aluminum-uranium alloy. The reject rate goes up rapidly when the weight percentage of uranium in this alloy exceeds 22%. This percentage is far below that necessary to fabricate satisfactory fuel elements from material of low enrichment. However, as mentioned before, the ORNL Metallurgy Division has produced sintered cores, employing powdered metallurgy techniques, with uranium weight percentages as high as 40%. These cores have not yet been fabricated into a fuel element or tested in a reactor. All the calculations for the accompanying curves assumed this fuel plate design with 40% weight of uranium in the core.

   Before the lattice described in this report is made available to schools two experiments should be performed.

   a. A fuel element should be fabricated from sintered core plates and placed in the MTR or LITR until 10 to 15% burnup is achieved. Then an examination should be made to determine whether or not there has been any deformation, whether the bond between the core and the cladding is intact, etc.

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b. A critical experiment should be performed to confirm the calculations of the critical mass and to establish the value of the boron shim safety rods.

The cost of each of these experiments is estimated to be between $10,000 and $25,000.

In addition, in order to keep the U^{235} requirements below that given by the formula $M = 1/C^{0.7}$ kg. it will be necessary for the AEC to furnish the school with sufficient hot-pressed BeO to form a reflector on four sides of the active lattice. About 500 pounds of BeO will suffice. This reactor should be as satisfactory for research purposes as the one in the Bulk Shielding Facility.

Besides the calculations covering the aluminum-water lattices, some calculations were made to determine critical masses of this type of reactor with stainless steel fuel plates. The reason is the following: one member of the Reactor Safeguard Committee states that in his opinion there is sufficient probability of an explosive reaction between (molten) aluminum and water in a reactor employing aluminum alloy fuel elements to justify an exclusion area calculated on the same basis as that for any experimental reactor. Clearly if the Safeguard Committee agrees that such a hazard is present, no college administration can afford to make such a facility available to its faculty and students. It has been suggested that stainless steel fuel plates would remove this hazard.

A BeO reflected active lattice was designed with the following characteristics and the critical mass calculated:

Active lattice 12" x 15" x 24" (20 elements)

Five fuel plates per element

Core of fuel plates 50% by volume UO_2 and 50% Fe or stainless steel

Cladding 5 mils stainless steel

Enrichment = 20%

BeO reflector on four sides which requires about 500 pounds of BeO

Critical mass + 20% = 4.3 kg. of U^{235}.

The critical mass is somewhat greater than that allowed by the AEC formula, but it may be that the formula can be modified at 20% enrichment to permit this design.

The same two experiments should be completed before the design is released.

1. An element should be fabricated and tested in the MTR or LITR.

2. The critical mass should be confirmed by experiment.

The ORNL Metallurgy Division has had some experience in making fuel plates with cores containing as much as 50% volume of UO_2. They have never fabricated a fuel element from such plates, and the procedure will in all probability be different from that now employed in MTR fuel element production. We estimate that development work, including fabrication and testing of a stainless steel fuel element, may cost as much as $80,000. Twenty additional elements will probably cost $1000 each, exclusive of uranium costs, although a firm estimate cannot be given until the first one is completed.

Very truly yours,

OAK RIDGE NATIONAL LABORATORY

for C. E. Larson
Director

WMBreazeale/ebr

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FIGURE 2

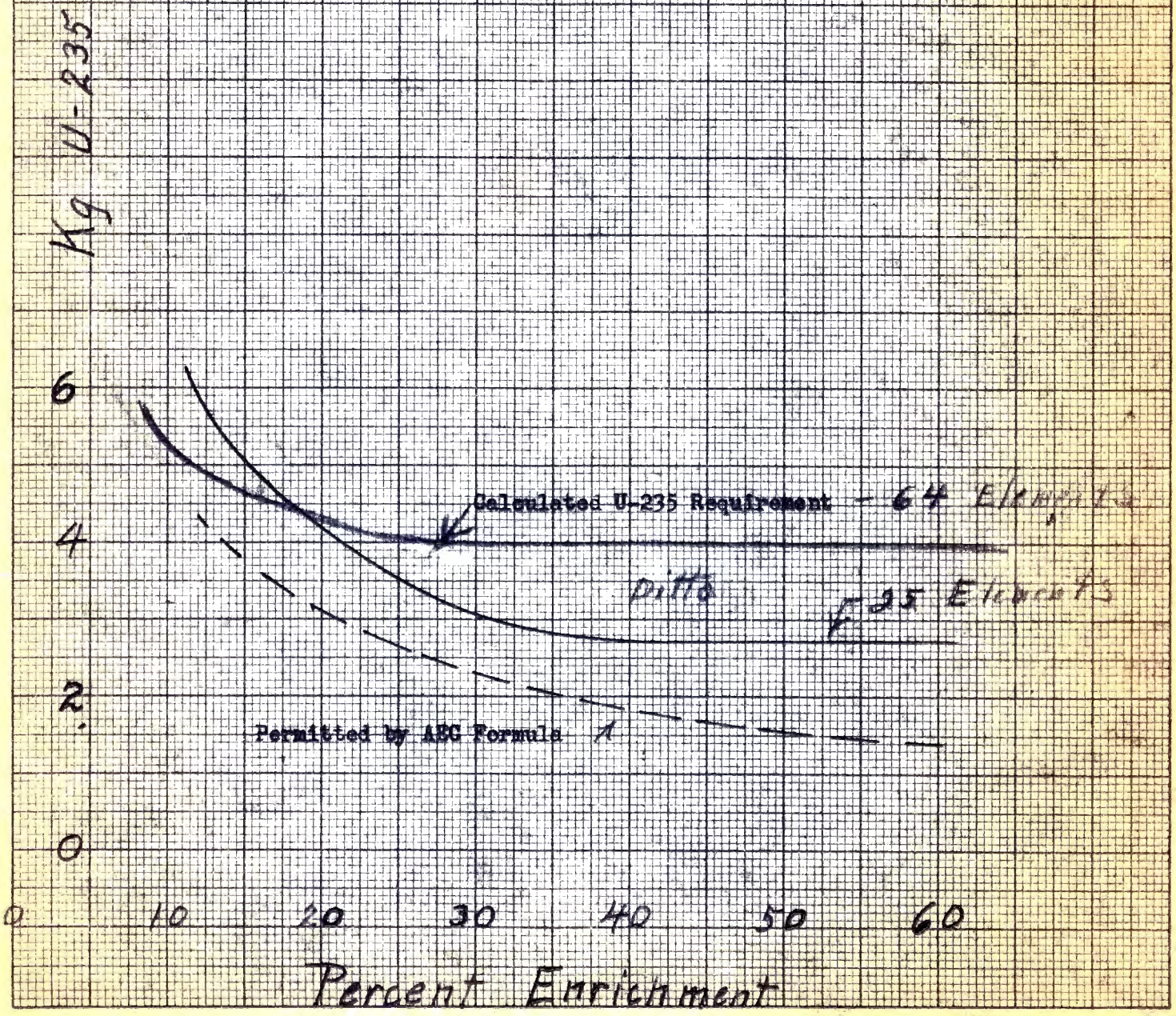
U-235 Requirement vs Percent Enrichment

for Water Reflected Lattices

Calculated Under Following Conditions:

25 Fuel Elements. Lattice 15"x15"x24".
64 Fuel Elements. Lattice 24"x24"x24"
Fuel Plates with Sintered Cores - Cores
40 weight percent uranium

Al/Water ratio constant above 35 % enrichment.



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