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Subject Category: REACTORS-POWER

REACTOR RESEARCH REPORT
PRELIMINARY STUDY OF SYSTEMS
UTILIZING LOW ENRICHMENT FUELS

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SUMMARY AND RECOMMENDATIONS

To-date practically all reactors have used either fully enriched or natural uranium fuels. In anticipation of the restriction of fuels to ones of low enrichment, this preliminary study was made to determine the effects on costs, operation, and design.

It appears that research reactors, of the "swimming pool" and "water boiler" types can be built, using fuels of 20% enrichment, with only minor modifications in the core and auxiliary systems.

The cost of 20% enrichment uranium is essentially the same as that for highly enriched uranium. The use of low enrichment fuel is justified solely by the fact that the fuel of low enrichment does not have weapons value.

The cost of the basic components of a research reactor using low enrichment fuel will probably be not more than 20% higher than the cost of a similar flux level reactor using highly enriched fuel.

Detailed calculations and designs are required to determine the effects of low enrichment on specific reactor systems. It is recommended that these calculations and designs be made in order to have available working drawings of research reactor systems suitable for both foreign and domestic use. Such a study can be divided into two principle phases: the nuclear physics and layout work costing approximately \$18,000; and the design and detailing work costing approximately \$59,200.

In order to expedite completion of this study we have quoted freely from consultants reports and statements, and from AEC Laboratory reports, memorandums, and statements.

REACTOR RESEARCH REPORT
E.R. #6810 - AMF GR. -2-54
PRELIMINARY STUDY OF LOW ENRICHMENT SYSTEMS

I. INTRODUCTION

Interest in the design of research reactors using fuels in which the U-235 enrichment is only ten to twenty-five times that of the U-235 content in natural uranium (7-20%) is prompted by the possibility that the U. S. Government will adopt a policy of supplying friendly countries with low enrichment fuel for use in such reactors. Research reactors in this country, to-date, use fuels enriched to 93%.

Although many foreign countries possess sufficient natural uranium and heavy water (D_2O) or graphite to build a natural uranium reactor, there will still be great interest in low enrichment systems. A natural uranium system (0.7% U-235) is an expensive source of neutrons because the active lattice is so large. The flux density is low in relation to the power.

The large lattice requires larger shielding, a larger cooling system, better moderator, more controls, and generally more and larger auxiliaries.

The heavy water-natural uranium reactor and controls at Kjeller, Norway, cost \$2,107,000 not including the uranium, and nearly 5000 pounds of this metal are required. The peak neutron flux at 100 KW power level is 3×10^{11} n/cm²/sec., less than one third of the swimming pool type reactor at a corresponding power.

In recent years the requests to the AEC for domestic off-site (by "off-site" is meant outside of AEC reservations) research reactors have increased beyond all expectations. The original AEC ruling was that not more than one kilogram of highly enriched fuel would be permitted at any off-site installation. As yet this ruling has not been rescinded (although Pennsylvania has received assurance that fuel would be made available to them, 3 kg.). With the increase in requests for fuel it is entirely possible, and very likely that the AEC will limit the release of highly enriched fuel for off-site reactors and supply only partially enriched fuels.

It is because of these two opinions that AMF has undertaken the investigation of research reactors utilizing low enrichment fuels (5-20%). This cursory investigation encompasses the effects on:

- (a) core size
- (b) critical mass
- (c) operation
- (d) control
- (e) cost

This investigation has shown the need to alter the program of the AMF Atomic Energy Department such that complete designs of two basic research reactor systems utilizing low enrichment fuels, swimming pool and water-boiler, can be available by August 1955. It is felt

that these designs will be more readily marketable than those of highly enriched systems, especially abroad.

To gather information for this report information has been extracted from past AMF studies, visits, and reports as described in Appendix A.

II. THE PROBLEM

A. General. Since highly enriched uranium has been readily available for reactors until now, only limited experimental data is available for low enrichment systems, however some paper studies have been undertaken. The only experimental data available is that derived from the operating experience of the initial Los Alamos water-boilers, LOPO and HYPO, which operated with fuels enriched to 14% and the critical experiments conducted at Oak Ridge by C. K. Beck and then A. D. Callihan. A discussion of the effect on reactor parameters will follow.

The studies to date have shown that fuel enrichments of 20% will give acceptable core sizes and fuel inventories. Therefore, this report is directed toward showing the feasibility of research reactors using this low enrichment fuel of 20%.

Contrary to common belief the cost of fuel enriched to 20% will be very little changed from that of fuel enriched to 93%. For example, if 93% fuel costs \$20/gm, then 20% fuel costs about \$18.75/gm. The only real advantage is as stated before, larger amounts may be stored at an off-site location, or sent out of the country.

B. Effect on Core Parameters. Studies have been made to determine the effect of enrichment on the core parameters of some existing reactors. For this study, the reactors under consideration and described below were the MTR, BSF, Los Alamos "Water-Boiler", and the CP-5. Since only research reactors were considered, two core parameters were kept constant - the neutron flux density and the overall dimensions of the fuel element.

The critical masses as a function of enrichment are given in Figure 2.

1. MTR (Materials Testing Reactor). In order to keep the U-235/Al ratio and the critical mass of a lower enrichment reactor as small as possible, the sintered UO_2 -Al fuel elements should be used in preference to the U-Al alloy type of elements now in the MTR. The core of the sintered elements can contain as much as 50% UO_2 by weight. Calculations for the U-Al alloy fuel plate core give critical masses which are considerably larger than those for the UO_2 -Al elements.

The calculations were made for the sintered elements containing the maximum allowable U; the cladding, spacing between plates and the over-all dimensions of the element were kept fixed to present MTR specifications. The thermal neutron flux was set equal to the MTR flux by keeping the amount of U-235 per unit area of fuel plate the same as for the MTR and allowing the thickness of the core of the fuel plate to vary inversely with the fuel enrichment. Small differences in the critical mass can be obtained by changing the amount of U-235 per unit area of fuel plate. These calculations are, however, preliminary and we have not attempted to optimize the variables.

The critical masses were calculated for a 30-cm Be + 2% H_2O reflector and for 18% excess reactivity. The results are summarized in Table 1.

In the MTR there are 23 fuel elements containing an average of 187 gms U-235/element which gives an average thermal flux in the core of 1.4×10^{14} n/cm²-sec. at 28 Mw. As the enrichment is lowered, the power must, of course, be increased to keep the same flux as shown in Table 1. The results show that fuel enrichments much below 20% lead to rather large critical masses and correspondingly large total powers if one wishes to maintain the high neutron flux of the MTR.

As seen in Table 1, the use of 20% enriched fuel has increased the critical mass by 2.3 kg and has increased the core dimensions from approximately 12" x 16" to something slightly

TABLE 1

Enrichment (%)	Core Thickness of fuel plate (inches)	Number of Plates per Fuel Element	$\frac{V_{Al}}{V_{H_2O}}$	Thermal Utilization	Resonance Escape Probability	k_{∞}	Critical Mass of U-235 (kg)	Total Power (Mw)	No. of Elements
10.4	.03972	17	.714	.7681	.933	1.498	23	151	138
20.6	.01998	19	.549	.7926	.959	1.589	6.0	45	37
35.6	.01159	20	.480	.7996	.973	1.626	4.8	31	24
MTR (93.5%)	.0200	19	.583	.8040	1.000	1.680	4.3	28	23

greater than $18'' \times 18''$. The power level has increased more than 1.5 times the power at full enrichment.

2. BSF (Bulk Shielding Facility - "swimming pool" type reactor). The fuel element specifications are the same as those for the MTR type reactor. The excess reactivity requirement, however, is only 5%, resulting in a somewhat lower critical mass. The reflector is 15 cm of Be surrounded by water.

The critical mass for the swimming pool at full enrichment is about 3 kg, which gives an average thermal flux of 0.7×10^{12} n/cm²-sec at 100 kw power. The total powers required to give the same flux for the lower enrichment fuels and critical masses are given in Table 2.

TABLE 2

Enrichment	Critical mass of U-235 plus 5% Δk	Total power (kw)
10	8.4 kg.	280
20	4.2 kg.	140
30	3.4 kg.	113
93.5%	3 kg.	100

With 20% enrichment it can be seen that a satisfactory system can be built with a lattice pattern $15'' \times 15''$ which is only slightly larger than the $12'' \times 12''$ pattern for fully enriched fuel. The power level of 140 kw (an increase in the power, at full enrichment of 40 kw) can still be dissipated by natural convection.

In general, as the enrichment is made less, a large part of the increase in critical mass is due to the increase in aluminum necessary to carry the uranium. Each additional cubic centimeter (cc) of uranium requires that about 14 cc of aluminum be added. The thermal cross section of U-238 is not large, approximately 2.8 barns, and the resonant escape probability becomes significantly less than unity at very low enrichments. A table calculated from the relation given above and illustrating this last point follows:

Percent Enrichment	Resonant Escape Probability
40%	98%
30%	97%
20%	96%
10%	93%
5%	90%

The fact that the captures in aluminum are important in increasing the critical mass illustrates the desirability of further metallurgical work aimed at reducing the amount of alloying metal necessary to fabricate a successful fuel element. Such development is not needed if highly enriched material is available, since the amount of alloying metal is determined by structural and heat transfer requirements. For instance, in the MTR fuel elements the uranium concentration is only about half the 22% which has been shown to be practical.

The only major drawback to the heterogeneous systems described is the fuel element problem. An element using these uranium to aluminum ratios has not yet been built. Using powder metallurgy techniques, the Metallurgy Department at ORNL feels confident that elements using these high densities of uranium can be fabricated satisfactorily. ORNL feels confident that plates can be fabricated that contain 50% uranium by weight and there is a possibility that as much as 70% by weight will give a satisfactory plate. The Sylvania Electric

Company has done considerable work in powder metallurgy techniques of fuel fabrication and have already manufactured plates, containing 35% uranium by weight. They are now investigating the desirability of manufacturing plates with the higher weight ratios.

3. Water Boiler Type (Los Alamos Water Boiler Reactor). The critical mass of the water boiler increases much less with decreasing U-enrichment than does the critical mass of the MTR, this is because no alloying metal is required. Some of E. Greuling's calculations for the minimum mass of U-235 as a function of U enrichment, total U concentrations, powers for a thermal flux of 10^{12} n/cm²-sec., and power densities are given in Table 3.

TABLE 3

Enrichment (%)	U-235 (kg)	Diameter (cm)	U conc. (gms/l)	Total power (KW) (Ave. thermal flux of 10^{12} n/cm ² -sec)	Power Density (kw/l)
5	2.90	50	890	138	2.1
10	1.75	38	610	83	2.0
20	1.30	31	420	62	4.0
93.5	0.98	24	145	47	6.5

A detailed discussion of the CP-5 or D₂O moderated systems is omitted since the cost of the heavy water cannot be justified as long as some enrichment is provided. Beside reduction in cost, a light water moderated research reactor has several advantages; the active lattice is smaller (see Fig. 3); and the ratio of fast flux to thermal flux is much higher. This last consideration is most important if the reactor is to be used as a source of neutrons for radiation damage and solid state physics experiments. It was these last two considerations that led to the changing of the original design of the Clinton high-flux pile from a heavy water moderated reactor to a light water moderated one, the present MTR.

Neutron flux is the primary product of a research reactor. Figure 4 illustrates the cost of neutrons plotted against the amount of U-235 for these typical research reactors.

All the foregoing figures for heterogeneous type reactors have been based on aluminum elements. If stainless steel clad fuel elements are deemed necessary, the fuel loadings will more than double, affecting element plate size and core dimensions.

C. Effect on Controls. The change to lower enrichments in no way changes the general design criterion. The only appreciable modification will be in the size and number of the shim-safety rods. The control effect is a ratio of volumes with effectiveness of the rod limited by the migration length of the neutrons. Therefore, a point will be reached where an increase in the effective diameter of the original rods will no longer give required control and another rod or rods must be added.

To determine exact requirements, detailed core analysis must be made for the specific systems under consideration.

For example in a "Swimming Pool" type system with a U-235 element assembly, rough calculations indicate that four shim-safety rods, instead of three for the high enrichment reactor, will suffice if a cruciform design is employed. The cruciform rods are six inches on a side and consist of a $\frac{3}{8}$ " sheet of boral clad in cadmium foil and aluminum. The regulating rod can be similar to the present design and operate inside or between special fuel elements as in the present "swimming pool" design. The spacing of the holes in the bottom grid will need to be modified to provide space to accommodate the absorbing rods. A suggested loading pattern is shown in Figure 5.

The nuclear characteristics of the reactor are not changed greatly by the substitution of fuel with low enrichment for high. The neutron generation time is shortened slightly, for the

assembly under consideration possibly by ten or fifteen percent, and as a result the reactor will rise on a slightly faster period for a given step increase in reactivity above prompt critical. Thus, if the highly enriched lattice could withstand a step change of 3% without damage, the lattice with low enrichment might be damaged if the step exceeded 2.7%.

Changes in other characteristics include a small increase in the temperature co-efficient and a slight modification of the neutron spectrum. Neither of these will have any effect on the use of the reactor. Additional equipment required, beside the fourth shim-safety rod, includes one more safety amplifier, rod actuator and magnet, indicators and miscellaneous limit switches.

D. Effect on Auxiliaries. Through special attention to the detailed design of the core system, the auxiliary systems should remain essentially unchanged.

In the "swimming pool" system as described in the preceding section, for example, the shim safety rods should not cost more than those now in use (approximately \$600 each) and the total additional equipment cost caused by the substitution of fuel of low enrichment should not exceed \$15,000. For flux densities of 10^{12} n/cm²/sec. convective cooling is sufficient to prevent boiling although the power level is 1.4 times that of a high enrichment fuel system.

In the "water boiler type" there are other problems involved. In homogeneous systems, even at the lowest power levels, external cooling systems are required. Figure 6 shows a typical cooling system for a water boiler installation. The operation of the system is restricted to a limited temperature range and power level. Corrosion and precipitation problems, which are a function of the operating conditions, are encountered in these systems.

Unaware of the precipitation at low temperatures and high power at the North Carolina State College, the reactor was operated at low temperature. When higher level operation was attempted within a very few hours all the uranium precipitated out and the system shut down. Hot water was pumped into the cooling system in order to dissolve the uranium peroxide and get the system operating again. After one month, all of the uranium is not yet back into solution.

It is felt that the lower enrichment will have little effect on the size and operation of the recombiner now used at N. C. State, although the pumping capacity through the recombiner may have to be increased to keep the concentration of hydrogen below 4%. Concentrations exceeding 4% of hydrogen in the system are explosive. The present recombiner catalyst beds are of sufficient sizes to accommodate the requirements of the increased flow. At power levels above 40 kw a catalyst of copper salts can probably be added to the reactor solution to inhibit dissociation, or the bubble formation will produce erratic operation. The increased amount of fission products can be taken off satisfactorily but provisions will have to be made for increased capacity in the fission product hold-up tanks and stack.

The increase in control effect demanded by the increase in core volume can be met by the addition of another shim-safety rod.

As stated previously, exact detailed effects can only be calculated for specific systems.

III. DESIGN CONCEPTS

From all studies conducted to-date it appears that the only reactor systems applicable to industrial and university type research are the "swimming pool" and "water boiler" types. As a result, further discussion will be confined to systems of these types.

Studies have also shown that minimum acceptable flux densities are in the 10^{12} n/cm²/sec. range. With low enrichment systems flux densities of 10^{13} n/cm²/sec. increase system requirements and costs.

AMF in the past has developed design concepts of "swimming pool" type systems for various purposes. These concepts are still valid with low enrichment fuels.

Figure 7 shows a model of the AMF unitized research reactor. This concept just as it stands can be operated with 20% enriched fuel. Its unitized design permits the grid plate to accept the additional 14 fuel elements required and its mounting plate and control system

permit the addition of the unitized control mechanisms, rods, and control stations with no modifications whatsoever.

Figure 8 shows a concept designed for Wright Air Development Center. This design features a fixed core with an integral hot cell for large irradiations. The same core components as shown in Figure 7 can be used.

Typical of water boiler systems are those at Los Alamos and North Carolina State College. Figure 9 shows a cutaway view of the North Carolina State College "water boiler". The gas evacuation line can be seen at the top left of the safety envelope but the recombiner, gaseous fission product holdup tanks, and stack have been omitted from the picture. Beam tubes opening into combination locked plugs can be seen protruding radially from the stainless steel core cylinder. The core vessel is approximately 11" in diameter and 11" high. For 20% enrichment fuel this core cylinder would probably be 14" in diameter.

Figure 10 shows a view of same installation looking at the steel shield door of the thermal column. The shield is octagonal in shape, 18' across flats.

Figure 11 shows a simplified elevation section of the HYPO at Los Alamos. This also omits all views of the gas handling equipment. The core vessel differs from that at North Carolina in that it is a 12" diameter stainless steel sphere. This system has operated at a fuel enrichment of 14% while the North Carolina system has fuel of 93% enrichment.

The critical masses considered in this report are based on reflector arrangements common to the particular type of reactor. Our design studies will show the effect of several different reflectors for the two types in order to optimize the design for a particular application. Rough calculations indicate that if an efficient solid reflector (Be, BeO, or graphite) is used instead of a light water reflector, the critical mass is reduced, or, alternately, the enrichment with the same size lattice can be lowered.

The shield designs described are by no means optimum. Detail design will help to establish shields to meet present and future needs. Water shields will be investigated for the water boiler as well as the swimming pool type systems since water does provide a convenient "self-sealing" feature which makes for extreme flexibility.

Test and experimental facilities will of necessity be designed separately since these will vary with the purpose of the installation.

Building designs cannot be made in advance since requirements are determined largely by the site and by specifications as set down by the Committee on Reactor Safeguards or a similar safety committee.

IV. PROGRAM

The program contemplated for Research Reactors utilizing low enrichment fuel will be such that detailed designs will be completed by August 1955 for both a "swimming pool" research reactor and a "water boiler" research reactor utilizing 20% enriched uranium fuel. These designs will include:

1. core
2. core support
3. control mechanisms
4. control console
5. instrumentation
6. auxiliaries as required for the particular reactor type
 - (a) component mountings
 - (b) recombiner
 - (c) gas hold-up
 - (d) cooling arrangement
 - (e) stack
7. typical research reactor arrangements employing the above

This will be accomplished by dividing the program into phases as follows:

1. Nuclear Physics
 - (a) to be accomplished with the aid of consultants
2. Conceptual designs and final layouts
 - (a) previous AMF studies will be modified by the results obtained under 1
 - (b) all new requirements determined by personal contacts will be incorporated
3. Component layout
 - (a) as far as is possible components will be designed to be applicable to both systems using the AMF unitized concepts.
4. Detailing

V. COSTS

All costs are based upon:

1. Nuclear physics to be completed by consultants by January 31, 1955.
2. Project Engineer to start November 1, 1954.
3. Design layouts to start December 1, 1954.
4. All details to start March 1, 1955.
5. Prototype tests of research reactor control mechanism complete by May 1, 1955.
6. Any fuel-sample fabrication and testing required starts January 1, 1955 and is completed by July 1, 1955.

The detailed costs and program will have to be reestimated after the completion of the nuclear physics phase on January 31, 1955. Preliminary layouts will have been completed by that time.

A. Manpower. The following chart shows the manpower allocation required at AMF to carry out the joint design program for "water boiler" and "swimming pool" reactor types covered in Design Concept Section III. Because of the many common components and the demand for these two types, we feel that both design concepts should be carried on concurrently. A saving of approximately 20% in consulting and 20% in design can be made if only one type is designed.

B. Jury Rig.

1. Model of water boiler to give space relationship	\$ 6000.
2. Jury rigs required for these designs are presently planned under AMF research reactor component development programs	--
	<u>\$ 6000.</u>

C. Fuel Elements.

1. Sylvania has successfully experimented with plates of low enrichment but has not as yet produced plates with the concentrations required as shown by this study. However, it is assumed that the AEC or Sylvania will pay for the necessary development and no fuel development costs have been included here.

D. In-Pile Tests.

1. No estimate can be made of any in-pile or loop tests until the nuclear physics portion of the program has been completed. If AEC accepts this program, joint programs will probably be carried out with them.

E. Consultants.

1. Nuclear calculations of core parameters to establish:

- (a) critical size
- (b) critical mass
- (c) optimum concentration
- (d) optimum geometry
- (e) control criteria

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		1954				1955							
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.		
Consultants (See Section V-D for costs)		x-----x										x-----x	
<hr/>													
Engineering													
1-Project Engineer	x-----											-----x	
1-Development Engineer	x-----											-----x	
1-Controls Engineer	x-----											-----x	
1/2 time	1/2 time												
TOTALS		1	2	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2	2-1/2		
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Design													
1-Mechanical Designer	x-----											-----x	
1-Mechanical Designer	x-----											-----x	
1-Electrical Designer	x-----											-----x	
1-Mechanical Detailer	x-----											-----x	
1-Mechanical Detailer	x-----											-----x	
1-Electrical Detailer	x-----											-----x	
TOTALS		2	2	2	3	6	6	6	5	3	3		

(f) data on effects of catalysts, temperatures, bubble formation, etc.
60 man days at \$60/day \$3600.

2. Review completed designs

5 man days \$ 300.
\$3900.

F. Costs Summary.

1. To complete nuclear physics and preliminary layouts Jan. 31, 1955

Engineering - 5-1/2 man months at \$1500 -

Design - 4 man months at \$1400. -

Travel -

\$8250.
5600.
600.

Sub Total \$14,450.

Consultants

3600.

Total \$18,050.

2. To complete design and detailing, prepare report and component cost analysis - Aug. 1, 1955

Engineering - 15 man months at \$1560.

Design - 3 man months at \$1400.

-23 man months at \$1200.

- 3 man months at \$1400.

Travel

\$22,500.

4,200.

27,000.

4,200.

1,000.

Sub Total \$58,900.

Consultants

300.

Total \$59,200.

Project Total \$77,250.

3. If construction of a model of the "water boiler" type (similar to one of "Unitized Swimming Pool" type) is deemed advisable, \$6000 should be added to project total.

MASS OF U²³⁵
VERSUS
ENRICHMENT
FOR VARIOUS SYSTEMS

FIG. 2

FIG. 3

FIG. 4

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SHIM SAFETY RODS

REGULATING ROD

Active Lattice 5 elements X
5 elements.
Light water reflector on all
sides.
Pos. 3 through 7 for variation
in loading.

ACTIVE LATTICE

TYPICAL FUEL LOADING FOR
FOR "SWIMMING POOL" TYPE REACTOR
UTILIZING 20% ENRICHMENT FUEL

FIG. 5

WATER COOLING SYSTEM

FIG. 6

Fig. 7 Model of AMF "Unitized" Swimming Pool Research Reactor.

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PLAN VIEW

VIEW "A-A"

END ELEVATION

SIDE ELEVATION

Fig. 8 Swimming Pool Design Concept for Wright Air Development Center.

RALEIGH REACTOR

NORTH CAROLINA STATE COLLEGE

Fig. 9 Raleigh Reactor - Cutaway View.

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Fig. 10 Raleigh Reactor - View of Shield.

SECTION THROUGH HYPO (SIMPLIFIED)

Fig. 11 Los Alamos Water Boiler - Side Elevation.

APPENDIX A

I. REFERENCES

- (a) "Summary of Low-Enrichment Research Reactor Calculations" dated September 23, 1954 by M. C. Edlund (Confidential) AMF File 2695-016-04.
- (b) "Research Reactor Using Material of Low Enrichment" dated October 18, 1954 by W. M. Breazeale (Secret) AMF File 2695-016-04.
- (c) AECD-3065 "High Power Water Boiler" dated September 19, 1945 Los Alamos Scientific Laboratory.
- (d) "Technical and Cost Data for Reactor Design" by J. A. Lane Nucleonics April 1954.
- (e) "AMF Research Reactor Facility" E.R. 5511 dated April 30, 1945.
- (f) "Proposal for Investigation of Research Reactor to Fulfill Requirements of the Wright Air Development Center", dated November 1953, AMF J.O. 78262.
- (g) "Technical Discussion For a Research Reactor, prepared for the University of California at Los Angeles", dated July 1954, AMF J.O. 78569.

II. INFORMATIONAL VISITS

<u>Person Visited</u>	<u>Place & Time</u>	<u>Subject</u>
J. A. Lane	ORNL 10-20-54	Fuel costs; effects of low enrichment on homogeneous systems operation.
M. C. Edlund	ORNL 10-20-54 ORNL 10-20-54	Critical masses and control for low enrichment systems.
A. D. Callihan	ORNL 10-21-54	Critical Experiments on low enriched systems
C. K. Beck	Raleigh 10-22-54	Effects of low enrichment on water boiler components; consulting requirements.
A. Menius	Raleigh 10-22-54	Effects of low enrichment on water boiler controls, components and operation.
L. D. P. King	Los Alamos 11-53	Requirements of water boiler, systems for high flux operation
T. Journey C. Zabel	Los Alamos 11-53 Los Alamos 11-53	Comparisons of reactor systems for high flux operation.

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II. INFORMATIONAL VISITS (Continued)

<u>Person Visited</u>	<u>Place & Time</u>	<u>Subject</u>
W. M. Breazeale	Greenwich 9-54	Comparison of reactors for convenient research; costs of systems.
W. M. Breazeale	Greenwich 10-29-54	Review of preliminary AMF report on low enrichment research reactors.

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