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PROPOSAL TO INCLUDE BLANKET LOADINGS IN OUR PLANT IMPROVEMENT PROGRAM

L. W. Lang

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November 18, 1960

O. C. Schroeder
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PROPOSAL TO INCLUDE BLANKET LOADINGS
IN OUR PLANT IMPROVEMENT PROGRAM

INTRODUCTION

Test metal was irradiated to simulate a "blanket" loading and striped E-N load under PT-IP-255-A-9-FP. The product analysis has now been obtained on the test material. The interpretation of this data and plant direction that might follow is considered in this document.

SUMMARY AND CONCLUSIONS

Conversion ratios calculated from this irradiated test material indicate gains in the order of five percent are possible with a blanket loading. In such a loading, highly enriched lithium-aluminum target elements are charged in the outer lattice unit tubes. Pile reactivity is restored by charging several lattice units of slightly enriched U in adjacent tube columns.

Characterizing H-Pile from the fringe segment tested: Seventeen percent of the pile power would be secured from changing natural U columns to slightly enriched U columns to support the blanket. The equivalent production obtained from these columns would be 1.11 grams/MWD (.34 Pu g atom equivalents of tritium and .77 grams of Pu/MWL) as compared to .818 g/MWD that would accrue to normal U irradiation. The conversion ratio data is summarized in Table No. 1. The values are stated slightly differently in Table No. 2. Although additional analyses are planned for E-metal columns, there are no further analyses scheduled for lithium-aluminum extraction. The final concluded ratios would not be expected to be lower than .717 for the Pu part of the conversion, the value used in the Accountability references. Thus, the final indicated pile gain after adjustment for additional tests might be as low as four percent from the blanket, a number that would more that adequately justify use of blanket loadings.

On the basis of the enrichment required at H-Pile, the amount of enrichment required for blanket loading of all reactors might be 1,000 tons of E-metal per year. HAP0 total tonnage would be near Fernald and Redox capacities. Adaptation of the C-Pile overboring program with blanket loadings at all piles would probably exceed these capacities.

TABLE NO. 1

INDICATED AND PREDICTED CONVERSION RATIO GAINS
FROM H-PILE TEST -- ALL EXPOSURES 740 MWD/T

	<u>Natural U Irradiation⁽²⁾</u> <u>(Typical Old Pile)</u>		<u>Natural U Irradiation⁽²⁾</u> <u>(H-Pile)</u>		<u>Predicted Conversions⁽¹⁾</u> <u>(Old Pile Blanket)</u>		<u>Analytical Results⁽³⁾</u> <u>(Old Pile Blanket)</u>	
	<u>% of</u> <u>Pile Power</u>	<u>Conv.</u> <u>Ratio x</u> <u>Percent</u> <u>(g/MWD)</u>	<u>% of</u> <u>Pile Power</u>	<u>C</u> <u>Conv.</u> <u>Ratio x</u> <u>Percent</u>	<u>% of</u> <u>Pile Power</u>	<u>Conv.</u> <u>Ratio x</u> <u>Percent</u>	<u>% of</u> <u>Pile Power</u>	<u>Conv.</u> <u>Ratio x</u> <u>Percent</u>
Natural U	94.9	.790	86.2	.717	65.9	.548	68.6	.571
Enriched U - Pu	5.1	.036	13.8	.101	34.1	.257	31.4	.242
T ₂	---	---	---	---	---	.070	---	.059
TOTAL CONV.(g/MWD)		.826		.818		.875*		.872
Indicated Conversion Ratio Gain								5.4%
Indicated CR Gain (If Accountability numbers low)								4.7%
Required Investment in Enrichment					29.0%		17.6%	
Gain from Reduced Neutron Leakage						.010		.020

(1) HW-62462, "Production Economics Associated with a Supported Blanket Load," Lang, L. W., 10-15-59.

(2) Conversion ratios from HW-50300-B: .832 g/MWD Nat U at 740 MWD/T, .712 g/MWD Enriched U at 740 MWD/T -

(3) HW-66775, "E-N Load Conversion Ratio Measured Tritium Values," Nechodom, W. S., 10-7-60.

*It should be pointed out that although the predicted values of Reference No. 1 agree quite closely with the analytical results, higher conversion ratios were assumed for enriched uranium than are now used in the Accountability Reference. Thus, the predicted percentage gain was not as large as now calculated.

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TABLE NO. 2

ITEMIZED CONVERSION RATIOS AT 740 MWD/T

	FROM ACCOUNTABILITY REFERENCE (4)		FROM PROPOSAL DOCUMENT (5)		FROM ANALYSIS	
	Partial	Total	Partial	Total	Partial	Total
	<u>Conversions</u>	<u>Conversions</u>	<u>Conversions</u>	<u>Conversions</u>	<u>Conversions</u>	<u>Conversions</u>
<u>Natural Uranium at H-Pile</u>						
Natural U - 86.2%	.717		.717			
Enriched U - 13.8%	<u>.098</u>		<u>.104</u>			
		.815 (Pile)		.821 (Pile)		
<u>Striped E-N Load</u>						
Pu from Enriched U			.756		.771	
Tritium from Enriched U			<u>.203</u>		<u>.235</u>	
				.959 (Core only)		1.005 (Core only)
<u>Blanket Loadings</u>						
Enriched U to Support			29.0%		17.6%	
Pu from Enriched U			.756*		.771*	
Tritium from Enriched U			.203*		.235*	
Tritium from Reduced Leakage			<u>.034*</u>		<u>.103*</u>	
				0.994 (Based Upon 29.0% Increased Enrichment)		1.109 (Based Upon 17.0% Increased Enrichment)
<u>E-N with Blanket</u>						
From E-N Core			$\frac{\text{Pu}}{.432}$	$\frac{\text{T}_2}{.116}$	$\frac{\text{Pu}}{.524}$	$\frac{\text{T}_2}{.181}$
From Normal Enrichment for Reactivity			.104		.098	
From Blanket	<u>.219</u>	<u>.068</u>			<u>.135</u>	<u>.059</u>
				.939		.997

*Striped conversion ratios are assumed to here apply for the added enrichment.
The balance of observed tritium credited to neutrons formerly lost to leakage.

(4) HW-50300-B, "IPD Plutonium Conversion Tables," Hoba, D. W.

(5) HW-62462, Ibid.

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RECOMMENDATIONS

On the basis of these favorable data, we should probably include blanket loading as part of our plant improvement program. By including the blanket load as recognized HAPO direction, we may be able to accelerate capital procurement for expanding E-metal capacities in the Fuel Chain and at CPD.

Although little direct capital would be required for IPD to implement blanket loadings, the contemplated fuel arrangement with blanket might affect other portions of the Reactor Improvement Program.

DISCUSSION

The test results, as given in Tables No. 1 and 2, are favorable and represent a greater gain per added E-metal than postulated in the blanket loading proposal document.⁽⁶⁾

The analytical data clarifies some points but brings up other theoretical considerations that will ultimately have to be investigated before conversion ratios can be stated with any degree of finality. It should be remembered that the extraction data is being applied to obtain the conversions in the striped portion of an E-N load, as well as the conversion from a blanket load. The degree of assurance is different for blanket load conversions than for the striped core since the blanket gains are principally from tritium, whereas the striped core-loading is more sensitive to Pu production in the slightly enriched U.

Test results:

- (1) The tritium extraction data is firm. The method of extrapolation, however, can be questioned. The tritium analyses were made at Savannah River. Extracted helium and tritium gases from irradiation furnish a check on the analytical results of the analysis. The tritium values were related to adjacent tube column power generation, which were in turn calculated as percent of pile power. Thus, the tritium yield per pile MWD results. The results, as stated in terms of grams per MWD added enrichment, may be more accurate than g atom equivalents of tritium per pile MWD. For pile values, the results are dependent upon extrapolating the fringe unit to a complete reactor. When the tritium is related to supporting enrichment, however, the measure should be quite accurate since the amount of tritium and the amount of added enrichment is known.

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(6) HW-62462, Ibid.

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Since the gains from the blanket loading conversion are 80 percent, based upon tritium analysis, there can be little doubt of the favorable production economics associated with this type of loading.

- (2) The Pu side of the conversion is somewhat in doubt. The extraction data used in determining the Pu side of the conversion was from a striped enrichment column surrounded by other striped columns. The results were .771 g of Pu/column MWD at 740 MWD/T, and the tritium analysis was .234 Pu equivalents/MWD. For comparative purposes, the Accountability Reference gives .717 g Pu/MWD at 740 MWD/T from E-metal columns currently being used for enrichment.

Points that need clarification are:

- a) Does this analysis apply to all columns of charged enrichment whether interspersed with lithium-aluminum targets or not?
- b) Does this high Pu conversion ratio depend upon surrounding E-metal columns?
- c) Would these ratios hold for the lattice unit of enriched U directly adjacent to the lithium blanket? Adjacent to a natural U core?
- d) Was the reactivity perfectly matched in the striped central column analyzed?

Related points of interest to present enrichment columns are:

- a) Are the lower yields being used by the Accountability Reference correct?
- b) If the answer to (a) is affirmative, do the surrounding natural U columns have incrementally higher conversion ratio yields that would account for the difference between yields obtained in this test and the Accountability Reference?
- c) What is the conversion ratio of the natural U column next to the shield?

Obviously, some of these points of question will require considerable time to answer. The higher Pu conversions should be verified by further CPD analyses within the next few months. However, the tubes originally designed to get interface data (enriched columns adjacent to lithium target elements and adjacent to natural U) were lost and control tubes will have to be irradiated for ultimate analysis if this information is to be obtained. Such tubes can (and should) be ultimately secured from our E-N demonstration load.

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The extraction of full-length E-columns will give further data on surrounded columns to confirm or adjust the data now in hand. With this additional data, the major production parameters should be fairly well established. Although interface effects are important to ultimate analysis and possibly to present irradiations, these effects may cancel out in making comparative economic analyses between an E-N load and a natural U load. The outer fringe tube of a natural U load, for instance, will be comparable to the E-metal tube adjacent to the blanket.

The irradiated E-N columns under the production were shortened to avoid tube limits. It is possible that the lengths of lithium to uranium were not exactly reactivity matched. Slight mis-matching would probably not be detected in the few tubes irradiated. If the length of lithium to uranium ratio were slightly low, ultimate conversion ratios would be higher; or alternatively, if the ratio were high, final conversions would be slightly lower. This point will be somewhat clarified, also, in the full-pile demonstration.

Summing up:

- (1) Certain areas of clarification are needed on the Pu conversions to be expected from an E-N load.
- (2) It is difficult to visualize present values from limited analysis being changed by further analyses to the extent that the final numbers would be less than that used in proposal documents. This is especially true of the gains from the blanket loading since these gains are largely from the tritium side of the conversion ratio.

Process Considerations

A gain of roughly five percent in conversion ratio is indicated with blanket loadings. The five percent gain in conversion ratio must be matched against possible process losses. In a highly flattened pile, the central tube powers will have to be increased to restore pile power. An increase of as much as eight percent might be required. Although some water may be diverted to the central zone tubes, it will probably not be possible to hold central tube outlet temperatures at their present level and still maintain reactor power level. If an eight percent loss were sustained (and this appears completely unrealistic) break-even economics would exist.

If Pu-239 and tritium isotopes were our irradiation products rather than total Pu, the increased conversion from the blanket load would be roughly one percent higher than that indicated.

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If the blanket program is adopted, it will be necessary to effect changes in the Feed Materials Plant and in our own Chemical Processing Department. At the Feed Materials Plant, increased E-metal capacity will probably be ultimately required whether we proceed with blanket and overbore cases or not since Savannah River is also considering the use of slightly enriched uranium loadings. By rough estimate, capital expenditure in the order of four million dollars might be required for facilities to process the required additional enriched U.

The HAPO Chemical Processing Department will have to make Purex plant changes to accommodate separation of depleted .94 percent material. Part of the capital cost of Purex change-over, however, would be regained by the reduced operating costs of Purex over Redox. Nevertheless, the brunt of the capital expenditures would probably have to be considered attributable to overbore and blanket cases, and thus included in any project proposal.

Although no direct capital expenditures are indicated from blanket loading, as far as IPD is concerned, the consideration of such a program would probably affect other plant improvement programs. Since negligible power generation would exist in lithium used for blanket elements, the fringe tubes would not normally be replaced with zirconium or overbored. Since they would be charged only once every twelve to eighteen months, the effect of having non-standard metal in them would not be great as far as over-all reactor efficiency. Incremental capital savings of roughly \$150,000 per pile could be made by eliminating the fringe tubes from a zirconium replacement program. If they were omitted from an overbore program, this might amount to as much as \$500,000 reduced capital expenditure per reactor.

Although the blanket loading may not be quite as attractive for overbore cases, as for present fuel sizes, its incentive should still be substantial. We can consider the benefits from blanket loadings due to three effects:

- (1) Conversion of neutrons into useful product that were formerly lost to leakage.
- (2) Improved thermal utilization.
- (3) Reduced product burn-out.

The leakage term is the sum of fast and thermal neutron leakage. Overboring may reduce thermal leakage but will not affect the fast leakage term, which may in actuality be slightly increased. Thus, the potential gain from a blanket loading will only be slightly reduced from this effect. Percentage increases in conversion, by blanket loading, will not be as large from improved thermal utilization and reduced product burn-out factors if considered

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with over-size elements. Thus, the percentage gain in blanket loading for overbore reactors may be 60 percent that of indicated gains from reactors with present fuel size. Such a gain would still be worth-while, but this gain has to be considered within a constant reactor power reference. In short, the gains from blanket loading appear attractive for overbore reactors but this application should be studied further.

Immediate implementation of blanket loading could be considered for reactors as they change out to bumper or self-supported fuels. The K-Reactors would be particularly attractive for such loading since overboring is not presently being considered and substantial amounts of E-metal are currently being used to support the reactor reactivity. If only the K-Reactors were considered, sufficient E-metal could probably be made available to implement the program without capital expenditure. Redox capacity under these circumstances would not be exceeded until after NPR start-up.

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