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October 6, 1960

J. H. Brown, Manager
Process and Reactor Development Subsection

C PILE MARK I OVERBORE FUEL ELEMENT DESIGN

INTRODUCTION

It is necessary to provide the option of using either aluminum or zirconium tubes in the C pile 20-tube overbore test. A bumper-type fuel element has been designed to fit a fixed ribbed aluminum tube size; zirconium tube dimensions were then determined which will provide the same flow and pressure drop when the fuel element is changed from bumper type or self-supported without changing other fuel dimensions.

RESULTS AND DISCUSSIONS

Results of this design study are reported in Tables I and II.

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TABLE I

FUEL ELEMENT AND TUBE DIMENSIONS

	<u>3 Bumper Fuel in Al. Tube</u>		<u>4 Bumper Fuel in Al. Tube</u>	
	<u>Hot</u>	<u>Cold</u>	<u>Hot</u>	<u>Cold</u>
Aluminum Tube OD*	2.317	2.315	2.317	2.315
" " ID*	2.157	2.155	2.157	2.155
Fuel Element OD	2.009	1.991	2.006	1.988
Uranium ID	1.901	1.883	1.898	1.880
Uranium ID	.455	.452	.455	.452
Fuel Element ID	.342	.339	.342	.339
Zirconium Tube OD	2.238	2.237	2.237	2.236
" " ID	2.148	2.147	2.147	2.146

* Assumed fixed in this study

TABLE II

OTHER ENGINEERING AND PHYSICS RESULTS

	<u>3 Bumper Fuel in Al. Tube</u>		<u>4 Bumper Fuel in Al. Tube</u>	
	<u>Al Tube</u>	<u>Zr Tube</u>	<u>Al Tube</u>	<u>Zr Tube</u>
Conversion Ratio, (gms Pu/MWD)*	0.997	0.996	0.996	0.995
25 Burnout (gms/ton)	797.0	797.0	797.0	797.0
Discharge Enrichment (% 25)	0.624	0.624	0.624	0.624
Equil. k_{ex} (full pile, mk)	- 12.1	- 4.5	- 12.2	- 4.6
Poison Effect of 20 tubes (mk)	.4	.3	.4	.3
Required Supporting 35 Pc E Cols	6	4	6	4
Maximum Uranium Temp., °C	320	320	320	320
Calculated Jacket Conversion Rates (Mils/Mo.)	1.4	1.4	1.4	1.4
Elastic Stresses'				
Inner radius (psi)	68,000	68,000	68,000	68,000
Outer radius (psi)	70,000	70,000	70,000	70,000

*Based on natural uranium. Actual full pile conversion would be lower due to enrichment required.

ASSUMPTIONS

Active zone pressure drop was assumed to be 270 psi for conservatism in case fitting redesign does not provide the expected active zone ΔP of 295 psi. Flow = 50.6 gpm; This is current control zone tube flow.

Feed enrichment = natural uranium

Fuel element length = 8.865 (Net), 32 slugs per column.

Fuel element supports:

Bumper fuel = 3 or 4 on each end of slug, 3/16" wide, suitcase handle design

SSFE = 4 on each end, 3/16" wide, suitcase handle design.

Tube power = 1222 kw (assumed for design purposes only - See discussion)

Goal exposure - 800 MWD/T.

Aluminum Tube Ribs: For fuel element design purposes the rib height was assumed to center the fuel element, and to calculate pressure drops the ribs were smeared around the inner circumference of the tube.

DISCUSSION

The "Flex I" 709 program of R. J. Shields was used to perform all engineering and physics calculations except the relative tube power calculations which used the "IDIOT" program of C. R. Richey. The general approach used was to arbitrarily choose a fuel element OD in a ribbed aluminum tube, then design the fuel element for equal corrosion rates in each flow passage and determine flow rates and other parameters. The fuel element was then changed from bumper to self supported without changing other dimensions and a series of cases run with smooth bore zirconium tubes of various ID's. By merely plotting parameters of interest, a zirconium tube was found which would give the same flow and temperature distribution as the original aluminum tube. The set was then repeated for various fuel element OD's in order to bracket the desired final result. Cross-plotting then determined a combination of fuel element and zirconium tube dimensions which would provide the desired flow rate, temperature rise, and pressure drop. Detailed results are presented in Tables I and II.

The assumption was made that only natural uranium would be used in the 20-tube overbore test. Previous calculations indicate that either uniform enrichment or 20 to 30 percent E metal (plus the equivalent of an E metal ring) will be required in the fully overbored reactor. Fuel element design will vary as a function of enrichment level, so that the current dimensions apply only to the 20-tube test or the natural uranium portion of a full reactor load.

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A value of $1.5 + .08$ was calculated for the relative tube power in an overbored tube surrounded by normal C pile lattices. If located in the central zone, this tube power will be too high because of tube outlet temperature considerations. The tube power can be reduced by:

- (1) Short-charging. This is undesirable because the test will not closely represent final conditions. Specific powers and corrosion rates will be excessive.
- (2) Using partially depleted uranium. In addition to cost considerations, it would not be possible to obtain representative conversion ratio data, the heat split to the flow channels will differ from natural uranium because of a different flux distribution in the slug, and the slug would therefore have to be redesigned.
- (3) Locate the test tubes in fringe locations. No significant objections are apparent in this approach. It is probable that only one given lattice distance from the pile edge will be satisfactory, so that the 20 tubes cannot be "blocked" together. A possible disadvantage is that any conversion ratio information obtained from the test will be clouded by the fact that the test facility is surrounded by foreign lattices.

Reactor Physics
Research and Engineering
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