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FROM: L. BERNATH

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HEAT TRANSFER BURNOUT OF MARK VIII FUEL

Name Title Date
2/5/89

INTRODUCTION

Mark VIII fuel is to be charged into the Savannah River reactors beginning with the L-3 cycle on September 5, 1956. The flow characteristics of this charge are summarized in DPSP-56-770, L-3 Charge Specifications, J. M. Boswell to F. H. Endorf, July 12, 1956.

To pilot the high sheath temperatures and heat fluxes to be encountered, Test Authorization 1-430 (July 18, 1956) proposes that twelve special Mark VIII quatrefoils be irradiated in the flat zone of R-reactor. During these pilot irradiations, R-reactor will contain natural uranium elements, either Mark I or VII, and it will follow an ascending power schedule.

The special Mark VIII quatrefoils are to contain six fuel slugs of 7.5% U-235 in each column whereas the normal Mark VIII fuel column is to contain nine fuel slugs of 5% U-235. Thus, the pilot fuel slugs are to experience very high heat fluxes ($\sim 1,000,000$ Pcu/hr-ft²) and sheath temperatures ($\sim 180^\circ\text{C}$). Such operating conditions are unprecedented in nuclear reactors although they have frequently been encountered in experiments simulating fuel element operation by electrical resistance heating. While the effects of a high sheath temperature can be determined by piloting, the heat fluxes may be high enough

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to cause burnout (melting of the fuel) with no prior warning, since the phenomenon is much different from corrosion. Furthermore, the consequences of burnout are considered serious and may be dangerous.

SUMMARY

The operating conditions to which the special Mark VIII quatrefoils will be exposed during the proposed pilotting program have been compared with the conditions required to cause burnout, using an established method* of calculating these conditions. The results of this comparison permit the following conclusions to be drawn:

- 1) With normal flow of coolant through the special elements, the heat flux to be encountered in the R-8 cycle (1400 MW) will be 70% of that required to cause burnout (30% margin from burnout).
- 2) With a reduction of coolant flow to 82% of normal through one tube of a special element, burnout of that fuel column is possible in the R-8 cycle.
- 3) In the R-6 cycle (1280 MW), the margin from burnout in the special Mark VIII quatrefoils is 42% with full flow and 20% with the above reduced coolant flow.

A similar comparison of operating conditions predicted for the L-3 cycle (full Mark VIII charge) shows that, even at the highest power level (1250 MW), the margin from burnout is greater than 55% with normal flow and 40% with reduced flow.

RECOMMENDATIONS

It is recommended that -

- 1) the pilot irradiations be approved through the R-6 cycle, and
- 2) the L-3 fuel charge be permitted to attain the proposed power level of 1250 MW, other (than burnout) power limitations permitting.

DISCUSSION

Operation of fuel slugs at high heat fluxes and sheath temperatures has been simulated in the experimental work

* DP-121, "Heat Transfer as Limited by Fuel Element Burnout", L. Bernath, June 1955.

conducted at Columbia University. Based on the Columbia data, a correlation was developed that permits prediction of the heat transfer conditions that cause burnout. Data, taken after the correlation was presented, have shown it to predict burnout conditions conservatively (15-20%).

This method of prediction was applied to determine whether the operating conditions proposed for the special Mark VIII quatrefoils and for the L-3 charge were safe from burnout. The table below presents the results of these calculations.

COMPARISON OF OPERATING AND BURNOUT CONDITIONS

Fuel Elements	Reactor Charge	Reactor Power-MW	Channel Flow-%	Heat Flux ⁽¹⁾ Pcu/hr-ft ² x 10 ⁻³		Ratio of Operating to Burnout Heat Flux
				Operating	Burnout	
Special Mk. VIII	R-8	1400	100	945 ⁽²⁾	1,350	0.700
" " "	"	"	82	945 ⁽²⁾	948	0.997
" " "	R-6	1280	100	862 ⁽²⁾	1,488	0.580
" " "	"	"	82	862 ⁽²⁾	1,073	0.803
Mark VIII	L-3	1000	Zone 2	519 ⁽³⁾	1,720	0.301
"	"	"	" 3	425 ⁽³⁾	1,350	0.315
"	"	"	" 4	270 ⁽³⁾	864	0.313
"	"	1250	" 2	649 ⁽³⁾	1,610	0.403
"	"	"	" 3	531 ⁽³⁾	1,250	0.425
"	"	"	" 4	338 ⁽³⁾	796	0.425

- (1) This heat flux is the value along the fuel column where burnout is most likely to occur.
- (2) Based on a $q_{max}/q_{av.}$ of 1.30 and a rooftop ratio of 1.0.
- (3) Based on chopped cosine, $q_{max}/q_{av.}$ of 1.328.

The results above indicate that all but the special fuel elements in the R-8 cycle are safe from burnout. The conservatism (mentioned earlier) in the burnout prediction may make the margin of safety even larger, but it is not sound practice to consider this as an added safety factor.

With pilot irradiations through the R-6 cycle, shown to be safe in the table above, operating conditions comparable to the L-3 cycle at 1600 MW will have been piloted. On this basis it is reasonable to leave the special assemblies out of the R-7 and R-8 cycles. Before piloting at higher powers additional experiments are advisable.

The 82% of normal channel flow used in the above corresponds to a quatrefoil flow of 95.5% of normal. A signal of this magnitude is adequate to fire the Very Low Flow alarm of the flow monitor reliably. Therefore, the VLF alarm will protect against both burnout and flow instability in all but the R-7 and R-8 cycle irradiations.

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