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August 11, 1959

RUPTURE POTENTIAL AND AXIAL POWER DISTRIBUTION

INTRODUCTION

This report gives results of a study of the effect of changes in axial power distribution on rupture potential. Possible interrelationships between this effect and the effects of other reactor variables were investigated.

SUMMARY

The rupture potential of a charge increases greatly if the power distribution is peaked very much above that obtained from a cosine flux distribution. The rupture potential is further increased if the peak is downstream of the center of the charge but reduced if the peak is upstream. This relationship is shown in Figure 1. The effect of power distortion is independent of tube power and coolant flow rate, but increases with inlet temperature. This temperature dependence is shown in Figure 2.

DISCUSSION

A basic rupture rate equation was developed from rupture information on solid slugs⁽¹⁾:

$$RR = aP^b M^c T^d$$

where RR = rupture rate, ruptures/tube irradiated.

P = tube power, kilowatts.

M = tube exposure, MWD/T.

T = tube outlet temperature, °C.

a, b, c, d = constants.

The I & E side failure rate predicted from this equation does not differ significantly from that observed in the reactors⁽²⁾. This equation has been used as the basis for developing a method of calculating rupture potentials on a slug-by-slug basis⁽³⁾. The slug-by-slug method has been programmed on the IBM 709 and calculations have been made over a wide range of reactor conditions.

- (1) HW-55377, RR Bloomstrand and WI Neef, "Analyses and Correlations of HAPO Rupture Experience with Natural Uranium Material," 4/23/58 (Secret).
- (2) HW-58416 RD, JL Jaech, "Comparing Observed Rupture Rates of I & E Fuel Elements with Predicted Rates," 12/5/58 (Secret Rough Draft).
- (3) Unpublished, RR Bloomstrand and WI Neef, "A Slug-by-Slug Method of Calculating Rupture Potential."

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In the discussion below, the terms, flux distribution and power distribution, are considered synonymous and are both used to indicate power distribution.

In order to define peaking, let us compare two charges which contain the same number of the same type of fuel element and operate at the same tube power. One charge has a cosine flux distribution and the other does not. If the maximum powered slug of the cosine charge is called P_o and the maximum powered slug of the other charge is called P_i , the per cent peaking, or depeaking, is defined by the ratio:

$$\frac{P_i - P_o}{P_o}(100).$$

This is the term used as an abscissa in Figures 1 and 2.

A preliminary report of some calculations of flux distortions and rupture potential which were done by hand has been published⁽⁴⁾. The interrelated effects on rupture potential of flux distortion and tube power, flow rate and inlet temperature have since been calculated on the 709. Thirty-one theoretical flux distributions⁽⁵⁾ were used in the calculations. As previously reported, flux distortion has a severe effect on the calculated tube rupture potential. Flux distortion is found to have no inter-dependence with coolant flow rate nor tube power. However, increasing inlet temperature reduces slightly the effect of flux distortion. This reduction is so small that the data for a median inlet, say 10°C, can be used and the inter-relationship of flux distortion and inlet temperature can be neglected. (See Figures 1 and 2).

These calculations were performed for thirty-two piece charges of O-II-N I & E slugs. The effect shown in Figures 1 and 2 would be the same for longer charges except that the displacement of the peak from center must be multiplied by the ratio of charge lengths. Thus a thirty-eight piece charge peaked six slugs from the center would have the same effect shown as that for a thirty-two piece charge peaked five slugs from center, i.e. $(6)\left(\frac{32}{38}\right) = 5$. All this applies to nominal eight-inch pieces

only. Charges composed of different length slugs must be converted to the same length charge with an equivalent number of nominal eight-inch pieces before Figure 1 will be applicable. Because very little of the rupture potential of a full length charge is contributed by the slugs on the ends, the relationship shown applies to any charge that includes at least the central seventy-five per cent or more of the full length.

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(4) RR Bloomstrand, "Effect of Peaking and Skewing on Rupture Potential (Uncl.) 3/12/59. I suggest that, in order to avoid confusion, Bloomstrand's preliminary report be destroyed.

(5) HW-56522, DE Goins and DE Clark, "Slug Factors for Various Flux Distributions," (Secret) 9/5/58.

FIGURE 1

Effect of Flux Distortion on Rupture Potential

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FIGURE 2

Effect of Flux Distortion on Rupture Potential

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