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LOCAL CONTROL STRENGTH CHANGE DUE TO OVERBORING

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LOCAL CONTROL STRENGTH CHANGE DUE TO OVERBORING

INTRODUCTION

The possibility of overboring in existing Hanford reactors to increase slug size has been suggested as a means of increasing production. The effect on control system strength of such a modification is, of course, one of the factors which must be considered. This report presents the results of a study requested by the Reactor Physics Unit of the local buckling of control rods as a function of the migration area.

The migration area varies for different lattice make-ups, but due to the complexity, calculation of T and L^2 for changes in slug and hole size was not done here; instead, the range of values given by the "Giant" Program/1/ was assumed.

The method of calculation is given by J. A. Wheeler in N-2292 Control Theory, and consists of solving a modified one-group buckling equation.

SUMMARY

For the maximum change in diffusion length, the results shown on graphs 1, 2, and 3 indicate a 20 per cent reduction in δB_c LOCAL for K piles and a 30 per cent reduction at all the old piles for the range of fuel element diameters considered. A decrease in local strength is only one of the factors indicative of control adequacy; control requirements due to temperature coefficient and water loss effects will also change

/1/ Personal communication - W. S. Nechodom, 10-14-59 - Results of the "Giant" Program.

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in the overbored loadings, and the geometrical pattern of a given system is also a significant factor in determining overall control capacity. The latter two factors were not considered in this study.

DISCUSSION

(1) Assumptions

A range of the square of the diffusion length from 250 cm² to 125 cm² at K reactors was given by the "Giant" Program. (This program also indicated a variation of five to ten cm² in Fermi Age over the proposed maximum overboring range, which would cause a variation of δB_0 LOCAL vs. τ/L^2 of less than one per cent. This change is less than the accuracy of the individual points on the graph, and consequently can be ignored. For illustration purposes, a curve for the change in τ of 50 cm² was also plotted.)

No values for L^2 and τ were given for B, C, D, DR, F, and H piles, so the number given for L in "Pile Physics Manual," HW-46000 I were assumed, and a variation proportional to the one given for K piles was devised. (See Table II.)

(2) Data and Sources

TABLE I

From Nucleonics, DATA SHEET Number 23

<u>Material</u>	<u>L, Diffusion Length</u>
Carbon	54.5 cm
Carbon Dioxide	2.8×10^5 cm
Helium	199.1 cm
Uranium	1.37 cm

TABLE II

<u>Reactor</u>	<u>Fermi Age</u>	<u>Variation in L^2</u>
KE, KW	350 and 400 cm ²	*250 cm ² to 125 cm ²
B,C,D,DR,F,H	350 and 400 cm ²	**310 cm ² to 175 cm ²

* See Reference 1

** Assumed range from given present value.

(3) Calculational Details

The migration area M is given by: $M^2 = L^2 + \tau$, where L is the diffusion length in centimeters and τ the Fermi Age in centimeters squared.

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Removal of graphite and replacement with the reactor atmosphere results in a larger diffusion length. Subsequent increase in uranium (e.g., a larger slug) then lowers the diffusion length. The effective diffusion length after over-boring depends upon proportionate amounts of slug size increased and carbon increased. Values of L for several materials of interest are given in Table I above.

The equation derived by J. A. Wheeler/2/ for calculating local control strength is:

$$N_o(b r_{eff}) - \frac{N_1(bR)}{J_1(bR)} J_o(b r_{eff}) = \tau/L^2 \left[i H_o^{(1)}(i \sqrt{\tau^{-1} + L^{-2}} r_{eff}) - \frac{H_1^{(1)}(i \sqrt{\tau^{-1} + L^{-2}} R)}{-i J_1(i \sqrt{\tau^{-1} + L^{-2}} R)} J_o(i \sqrt{\tau^{-1} + L^{-2}} r_{eff}) \right]$$

When r_{eff} is small:

$$i H_o^{(1)}(i \sqrt{\tau^{-1} + L^{-2}} r_{eff}) \gg \frac{H_1^{(1)}(i \sqrt{\tau^{-1} + L^{-2}} R)}{-i J_1(i \sqrt{\tau^{-1} + L^{-2}} R)} J_o(i \sqrt{\tau^{-1} + L^{-2}} r_{eff})$$

Then the equation becomes:

$$N_o(b r_{eff}) - \frac{N_1(bR)}{J_1(bR)} J_o(b r_{eff}) = \tau/L^2 \left[i H_o^{(1)}(i \sqrt{\tau^{-1} + L^{-2}} r_{eff}) \right]$$

and also noting that for small argument,

$$N_o(b r_{eff}) = \frac{2}{\pi} \ln(b r_{eff})$$

The effective radius R_{eff} is defined by:

$$r_{eff} = r_1 \exp \left\{ - \frac{4 \lambda}{3 r_o} \right\}, \text{ for a circular control rod}$$

$$r_{eff} = r_1 \exp \left\{ - \frac{8 \pi \lambda}{3 S} \right\}, \text{ for an odd shaped rod.}$$

Where: r_1 = inside diameter of the hole.

r_o = outside diameter of the control rod.

λ = mean-free path = 2.7 cm.

S = perimeter of the control rod.

(Fast flux corrections are given by D. E. Simpson and G. R. Parkos.)

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Still considering C Reactor

where $\tau = 350 \text{ cm}^2$ and $L^2 = 310 \text{ cm}^2$, a solution for $\delta B_c \text{ LOCAL}$ is to be found by iteration.

If $\delta B_c \text{ LOCAL}$ is (fortuitously) set equal to $72.4 \text{ } \mu\text{b}$, then

$$b = 8.51 \times 10^{-3} \text{ cm}^{-1}$$

$$b_{\text{eff}} = 0.0269; \text{ bR} = 0.692 \sqrt{\tau^{-1} + L^{-2}} \quad r_{\text{eff}} = -0.247$$

$$N_0(b_{\text{eff}}) = N_0(0.0269) \approx \frac{2}{\pi} \ln(0.0269) = (0.637)(-3.616) = -2.303$$

$$N_1(bR) = N_1(0.692) = -1.114$$

$$J_1(bR) = J_1(0.692) = +0.3257$$

$$J_0(b_{\text{eff}}) = J_0(0.0269) = +0.9998$$

$$iH_0^{(1)}(i\sqrt{\tau^{-1} + L^{-2}} r_{\text{eff}}) = iH_0^{(1)}(i 0.247) = 0.989$$

$$\tau/L^2 = 1.129$$

$$N_0(b_{\text{eff}}) - \frac{N_1(bR)}{J_1(bR)} J_0(b_{\text{eff}}) = -2.303 - \left[\frac{-1.114}{0.3257} \right] (0.9998) = 1.117$$

$$\tau/L^2 \left[iH_0^{(1)}(i\sqrt{\tau^{-1} + L^{-2}} r_{\text{eff}}) \right] = (1.129)(0.989) = 1.117$$

The equality indicates that $\delta B_c \text{ LOCAL} = 72.4 \text{ } \mu\text{b}$ is a solution.

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Local Buckling of Control Rods

GRAPH 1 - C, H PILES
LOCAL CONTROL STRENGTH AS A
FUNCTION OF r/L

C, Local Age, in cm^2/l^2 , (distortion length) 2 , in cm^2

Graph 1
C, H Piles

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Local Buckling of Control Rods in the

LOCAL BUCKLING STRENGTH AS A
FUNCTION OF T/T_c^2

T_c Critical Temperature, in $^\circ\text{C}$; T/T_c^2 , (diffusion length) 2 , in cm^2

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