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INTRODUCTION

The three alterations listed below have an effect on the parameters used in Total Control Calculations for C Reactor:

1. Conversion to smaller diameter and shorter vertical safety rods in six outer control channels.
2. Installation of forty-four overbored tubes with short fuel charges in the flat zone and an associated increase in spike enrichment.
3. Centralization of the enrichment ring into a three-lattice unit width in place of three and one-half lattice units previously in use.

New parameters are derived in this document for future total control calculations.

DISCUSSION

A. Effects of Installing "B" Type Vertical Safety Rods

Due to rod sticking problems, smaller diameter vertical safety rods were required in several VSR channels. Therefore "B" type flexible rods were installed where necessary. The basic differences between the "C" and "B" type safety rods are listed in Table I.

TABLE I: VERTICAL ROD DIMENSIONS

Rod Type	Rod Entry Length	Diameter	Local Control Strength
B	979.81 cm	5.70 cm	-98 pb
C	1049.69 cm	7.57 cm	-120 pb

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Figure 1 illustrates the specific VSR channels which now contain the "B" type safety rods. The rods are also depicted in their geometric relationship to the square pile dimensions of total control theory.

The difference in the local control strength of the two VSR's results in a reduction in the average strength of the complete system. An accurate calculation of this decrease based on the area of control and geometric position of each channel within square pile geometries, is practically impossible.

A reasonable and conservative estimate of the reduced local control strength with the "B" type VSR's in service has been conservatively set at 100 μ b in zone two (the enriched fueled zone) and 120 μ b in zone one (the flat zone) and center B section. The control strength in the center section is assumed to be unaffected by the "B" type VSR's.

By applying the whole effect of the "B" type VSR's to the outer enriched fuel region, poison requirements will increase by approximately ten per cent during Ball 3X lockout periods. This additional poison will be required in the outer enrichment ring where it will be most effective because of both the higher relative flux and the lower local rod shadowing of the "B" type rods.

The "B" type VSR's require a second compensation because of their reduced length. The tips of the "B" type VSR's when fully inserted are approximately 3-1/2 lattice units shorter than the "C" type rods, whereas control calculations are based on the assumption that all rods are of equal length. Therefore, when VSR's are depended upon for total control, four splines (two per side) should be inserted in the bottom E-ring as close as possible to those fuel columns passing through the safety channels

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Figure 1

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containing "B" type control rods. Specifically, these would be channels 55 through 63 inclusive, and 84 through 92 inclusive. These splines would be required only when VSR's were in service, the Ball 3X channels locked out, and the reactor had been down for some time; the excess xenon concentration between shutdown and 35 hours downtime would be an adequate substitute for these four splines.

The insertion of the splines will effectively reduce the average buckling in those zones normally shadowed by "C" type safety rods. The requirement is based on the average buckling of the tubes in an area 3.5 lattice units high and nine lattice units wide on each side of the reactor under the "B" type rod tips.

B. Effect of Overbored Channels in the Flat Zone

Forty-four process tube channels in C Pile were overbored and are presently being used to test prototype fuel elements. Although these channels have no direct effect on total control requirements, the fact that they contain short fuel charges which must be compensated by enriched fuel during equilibrium operation does adversely affect the control system strength.

Actually there are two reactivity effects which can be considered: (1) the negative reactivity of the water on each end of the short over-bored fuel column which must be compensated by enrichment and which gains reactivity upon water loss and therefore must be compensated by adequate controls, and (2) the negative reactivity effect of the over-bored fuel charges themselves (in comparison to a current natural uranium fuel element) which must also be compensated by enriched fuel (but does not increase total control requirements for the reasons stated below).

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Because the overbored fuel elements do not become more reactive in a dry lattice, and the reactivity increase of enriched fuel due to water loss is practically the same as that of natural uranium,¹ the enriched fuel directly compensating the overbored fuel elements can be treated as natural uranium fueled tubes when calculating total control requirements.

Twelve full-length E columns will effectively compensate the reactivity change due to forty-four overbored channels containing 32-piece full-length fuel charges.² The forty-four channels in C Reactor contain 18 pieces of fuel in comparison to a 32-piece full column charge, so that flux squared weighting calculations reduce the effective number of compensated E columns to a total of nine.

In effect, this says that nine enriched fuel columns, adjacent to the overbored lattice are compensated by the reactivity effect of the overbored fuel elements and may be treated as natural uranium fuel charges when calculating total control requirements. However, the reactivity effect of all other enrichment columns required for compensating the overbore columns, namely for the water in the ends of the short charges, must be included in total control requirements.

C. Effect of Reducing the Width of the Enrichment Ring to Three Lattice Units

Supplementary control requirements are based on the increased density of the enriched fuel in the E-ring; the C enrichment ring pattern corresponds more closely to a 3 LU width than the 3.5 LU width previously assumed.

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1. HW-68250, "Total Control Aspects of Fringe Poison Loadings," by A. D. Vaughn, January 26, 1961.
 2. Personal notes, R. H. Meichle.

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Figure 2

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Although changes in poison requirements are minor, total control parameters should represent the actual fuel geometry of the pile as accurately as possible.

Graphs of the critical buckling based on the new dimensions in Figure 2 should be used for future total control calculations.

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