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TITLE

FINAL REPORT, PT IP-535-C:
TEST OF SMALLER VSR'S IN DR REACTOR

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FINAL REPORT, PT IP-535-C: TEST OF SMALLER VSR'S IN DR REACTOR

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INTRODUCTION

Because of rod-sticking problems at DR Reactor a knuckle rod of B Reactor design was installed in vertical safety channel number 28. The substitute VSR, which has a smaller diameter than the original DR rod, has been tested for its operational feasibility including both drop time and reactivity effect. Although the reactivity effect of the rod cannot be measured precisely in an irradiated fuel loading, a reasonable estimate was possible by comparison of the reactivity transient caused by insertion of the specific B-type rod after it was scrammed into the pile. This transient was then compared to similar transients caused by the insertion of a normal vertical safety rod in an adjacent channel. This document lists the indicated relative control strength of the rod as an empirical basis for future safety calculations.

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SUMMARY

The results of the individual VSR comparison test indicate that the B-type knuckle rod in DR Reactor is approximately 80 per cent as strong as a normal DR vertical safety rod if used individually in an equivalent flux distribution and location. These results make it reasonable to conservatively assume that the local control strength of the B-type knuckle rod is 98 μb for application to nuclear safety calculations.

DISCUSSION

1. Description Of The Test

PT IP-435-C/1/ was performed at DR Reactor with the hope of demonstrating that a B-type knuckle rod is as strong in DR Reactor as expected (i.e., approximately 80 per cent of the strength of the normal DR vertical safety rod). Specifically, the test consisted of the rod-drop technique of measuring the flux decay after several individual vertical rod scrams. The subcritical monitors were used to provide data for the individual rod measurements.

2. Results Of The Test

Although it is impossible to derive exact rod worths from a rod-drop test of this type, a reasonable comparison can usually be obtained. The comparison of the specific reactivity transient compensating effect of the B-type knuckle rod with the transient compensating effect of a normal DR vertical safety rod in an adjacent safety channel is illustrated in Table 1

Table 1

Relative Strength of Two Different Vertical Safety Rods
Measured in Comparable Safety Channels

Rod Channel	Rod Type	Relative Rod Worth Based On Transient Compensating Ability
28	B-Type Knuckle Rod	1.00
22	Normal DR VSR	1.20
26	Normal DR VSR	1.21

Prior to this test a rod comparison test/2/ was performed at D and DR Reactors in order to estimate the shadowing effect of the residual balls in the graphite stack following the July, 1961, ball drop at DR Reactor. During the earlier test a normal DR vertical safety rod was in use in channel number 28 and it so happened that this rod was tested as part of the comparison of individual rods at D and DR Reactors This data is listed in Table 2 and illustrates the relative differences in transient-compensating ability between

/1/ HW-75203, Production Test IP-535-C, Test of Smaller VSR's in DR Reactor, A D. Vaughn, October 9, 1963
/2/ HW-75407, Final Report PT IP-447-C, Rod Drop Transient Comparison, D and DR Reactors - Redefinition of DR Vertical Safety System Strength, A.D Vaughn, October 10, 1962

a normal DR safety rod as measured in safety channel number 28 and a similar VSR measured in adjacent channels during the same test.

Table 2

Relative Strength of Normal Vertical Safety Rods Measured in Adjacent Channels

Rod Channel	Rod Type	Relative Rod Worth Based On Transient Compensating Ability
28	Normal DR VSR	1.00
23	" " "	0.95
22	" " "	0.96

The relative reactivity effect of a B-type knuckle rod in channel 28 compared to a normal DR-type safety rod in the same channel is listed in Table 3. This value has been estimated by comparing the relative differences listed in Tables 1 and 2.

Table 3

Relative Worth of B-Type Knuckle Rod In Channel 28 In Comparison to Normal DR Safety Rod In Same Channel

Rod Channel	Rod Type	Relative Rod Worth Based On Transient Compensating Ability
28	B-Type Knuckle Rod	0.80
28	Normal DR Safety Rod	1.00

3 Results of Theoretical Analysis of Local Control Strength

A theoretical analysis of the B-type rod in a DR safety channel gives a calculated value of 130 μb for the local control strength.[3] This is 80 per cent of the strength calculated for the normal DR safety rod in the same channel. These calculations are based on an equation derived by J. A. Wheeler.[4] The values derived from this equation are relative and should be supported by experimental measurements.

4 Conclusions

Based on the results of the comparison test as well as the theoretical analysis, it is reasonable to use smaller vertical safety rods in DR Reactor provided a corresponding adjustment is made in the calculated control strength of the VSR system.

/3/ Local control strength is defined as the reduction in lattice material buckling (within the area occupied by the control array) resulting from insertion of the control.

/4/ N-2292 - Principles of Nuclear Power - Chapter 22: Control, P. 77

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The local control strength of the DR vertical rods used in total control calculations has been 120 μb based on a conservative extrapolation of startup test results at C Reactor The local control strength of the B-type vertical rods used in safety calculations has been 98 μb based on B startup tests. Since the measured values in this report are reasonably close to the values currently in use, the local control strength of the B-type rods in DR Reactor will be assumed to be 98 μb. There has been essentially no reduction in blackness and control area in going from the rigid B VSR's to the B knuckle-rods.

The control strength will be adjusted by assuming that any weaker rods will be partially shadowed by adjacent safety channels with stronger rods Therefore any B-type rod in a 3x3 array of rods will reduce the strength of the array by 2.5 μb (i.e. $\frac{8 \times 120\ \mu b}{9} + \frac{1 \times 98\ \mu b}{9} = 117.5\ \mu b$). In this case a local control strength of 120 μb was assumed for the stronger control and 98 μb for the weaker control The system strength used in safety calculations must be the strength of the weakest 3x3 array of rods. The bases for control system strength assumptions have been developed in greater detail in reference 5. The result of having four B-type knuckle rods in DR Reactor will increase their supplementary control requirements during extended outages with Ball 3X lockbars in place by approximately eight splines based on the current fuel loading.

A. D. Vaughn
Process Physics Studies
Operational Physics Sub-Section
Research and Engineering Section

AD Vaughn:gs

Concurrence for use of results and conclusions in the document for total control administration:

H C Fullmer
Manager, Operational Physics
Research and Engineering Section

P Nelson
Supervisor, Reactor Physics
Process and Reactor Development
Research and Engineering Section

/5/ HW-68940 - Recommended Limits During Safety Control Malfunction Within Total Standards, A D Vaughn, March 22, 1961

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