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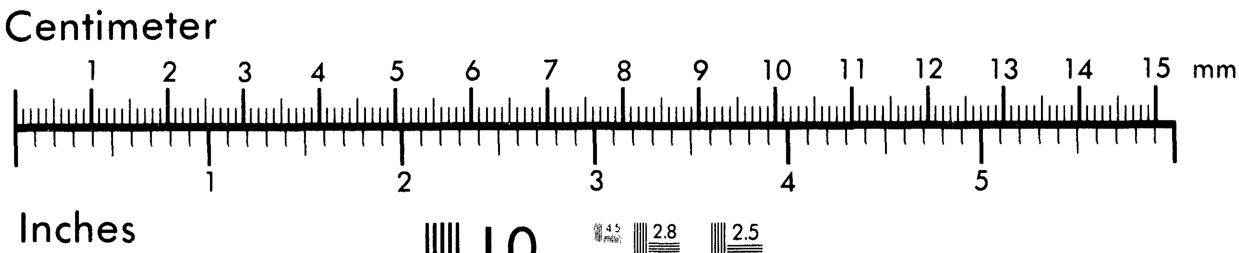

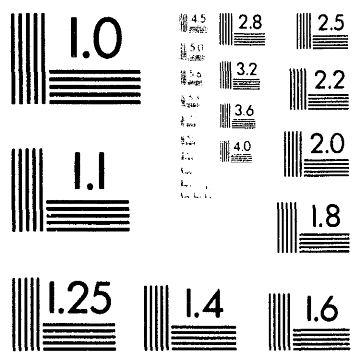

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RELATIVE BALL 3X-VSR REACTIVITY STRENGTH - DR REACTOR - INTERIM REPORT OF PT-IP-126-C

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RELATIVE BALL 3X-VSR REACTIVITY STRENGTH - DR REACTOR
INTERIM REPORT OF PT-IP-126-C

INTRODUCTION

Prior to this experiment, no measurements of Ball 3X effectiveness had been performed for any of the older 2004-tube Hanford piles, and calculations concerning total control requirements were made assuming the vertical safety system strength equal to the strength of the B, D, F vertical safety rods. With current and projected enrichment loadings, the vertical control system was calculated to be inadequate to satisfy the total control criteria at all times, resulting in the necessity to provide supplementary control in the form of horizontal rods or temporary process tube poison. Because of the larger ball channels at DR, the Ball 3X system is stronger than at the other 29-VSR piles. Therefore, the potential relaxation of total control limits was greater for DR should an experiment show the Ball 3X strength to be significantly greater than the B, D, F VSR strength.

PT-IP-126-C authorized an experiment to determine the Ball 3X effectiveness at DR Pile by measurement of the relative strength of a VSR and a column of 3X balls in the same channel /1/. The experiment was performed in March, 1958, and on the strength of favorable results a supplement to the PT was prepared to authorize the same test at one

/1/ HW-53523, "PT-IP-126-C, Comparison of Ball 3X Column and VSR Reactivity Effects," D. E. Simpson, November 8, 1957.

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INTRODUCTION (Continued)

of the other 29-VSR piles. This supplement has not been approved; therefore, the results of the DR test are being reported separately in this document.

Currently total control calculations are based on the DR individual Ball 3X channel strength as observed in this test for DR, H, and C piles, and on the B pile VSR strength for B, D, and F piles.

SUMMARY

The relative strengths of the original DR polyethylene-moderated VSR, a Ball 3X channel, and a new boron-graphite filled VSR were measured by measuring rising periods with and without the individual controls inserted. The results are given below:

Control Element	Relative Strength
Old VSR	1.00
Ball 3X	1.06
New VSR	0.88

On the basis of these results, total control calculations for DR, H, and C piles are made using 127 μb as the effective buckling reduction over the region of control due to insertion of the Ball 3X system; the value used for the B pile VSR is 93 μb.

Theoretical calculations, combined with a comparison of calculated and experimental VSR-Ball 3X strength ratios at DR, indicate that the B, D, F pile Ball 3X strength is probably about 26 per cent stronger than the VSR. Allowing a 10 per cent safety factor, this yields an equivalent buckling reduction of 105 μb. The increased control strength, if confirmed experimentally, would permit addition of 15-25 near-side E columns without raising the current supplementary disaster control requirement.

DISCUSSION

I. Test Procedure and Results

The experiment was performed at DR pile on March 13, 1958, following an extended outage. At the start of the test the regular pile P.C. was in operation providing an indication of the subcritical flux, and a special P.C. installed for the test was operating with somewhat lower sensitivity. The pile had been shut down approximately 73 hours. All VSR's were pulled, and HCR's were withdrawn until a period of about 58 seconds was measured. A second period of about 35 seconds was then measured with a different HCR configuration. An attempt was made to measure a rising period with the second HCR configuration and with VSR No. 26 inserted, but the pile was subcritical; HCR's were further withdrawn until a rising period of 136 seconds was observed, and then a period of 20 seconds was measured with the new HCR configuration and with all VSR's out. Following this measurement, rising periods were obtained with the same HCR configuration, first with VSR No. 14 inserted and then with all VSR's out but channel No. 26 filled with 3X balls of a nominal 70 per cent boron-steel, 30 per cent steel mixture.*

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* D. L. Hirschel determined the ball mixture of a sample of 432 balls from channel No. 26 to be 68.3 per cent boron-steel, 31.7 per cent steel.

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DISCUSSION (Continued)

I. Test Procedure and Results (Cont'd)

After removal of the balls from channel 26 and completion of other outage work, including replacement of the polyethylene-moderated VSR No. 26 with a new boron-graphite filled rod, rising periods were measured with the same HCR configuration previously used, first with all VSR's out, second with VSR No. 26 inserted, and third with VSR No. 14 inserted. Measurements on these same VSR's were also obtained with a new HCR configuration. To determine the magnitude of the xenon-decay reactivity transient, periods were measured at the beginning and end of the series with a repeated HCR configuration. Four periods were measured with two HCR configurations early in the first period group, but a repeat measurement later in the series to determine a better value for the xenon transient was not obtained. The xenon transient during the first group of periods was, therefore, calculated from the transient measured during the second group of periods; iodine decay into xenon was negligible and, therefore, was not considered.

Rising period data obtained from the pile P.C. were somewhat more difficult to analyze than the special P.C. data because of the frequent range changing required with the pile P.C. Data from both instruments were analyzed independently with approximately the same results; values reported below were obtained from the special P.C. data which are considered slightly more reliable.

Table I below lists the period measurements obtained, Table II contains the measured absolute and relative control strengths, and Table III lists the HCR configurations employed during the test.

TABLE I

REACTIVITY DATA

Period No.	HCR Conf. No.	Vertical Control	Time	Period Sec.	Period mk.	Xenon mk.
Group I						
1	1	--	0850-1/2	57.7	.997	
2	2	--	0858-1/2	35.0	1.397	
3	1	--	0903-1/2	52.5	1.066	
4	2	--	0913-1/2	34.0	1.423	
5	5	VSR 26 (old)	0932	136.5	.513	1.447
6	5	--	0941	20.3	1.934	1.431
7	5	VSR 14	0947	61.3	.955	1.420
8	5	Balls 26	0957	149	.477	1.402
Group II						
9	6	--	2249-1/4	76.5	.811	.533
10	2	--	2257-1/4	70.8	.859	.527
11	5	--	2307-1/4	31.5	1.492	.520
12	7	--	2318-1/2	22.7	1.815	.513
13	7	VSR 14	2327	43.3	1.216	.507
14	7	VSR 26 (new)	2336-3/4	53.3	1.055	.501
15	5	VSR 26 (new)	2343-1/2	108.8	.617	.497
16	5	VSR 14	2349-1/2	78.3	.797	.493
17	2	--	2356	66.7	.898	.489
18	2	--	0003-1/2	66.5	.900	.484

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DISCUSSION (Continued)

TABLE II

VERTICAL CONTROL ELEMENT STRENGTH

Control Element	Period Group	HCR Configuration	Strength (mk)
VSR 26 (old)	I	5	1.405
VSR 14	I	5	.990
Balls 26	I	5	1.486
VSR 26 (new)	II	7	.772
VSR 26 (new)	II	5	.898
VSR 14	II	7	.605
VSR 14	II	5	.722

Controls	Period Group	HCR Configuration	Strength Ratio
Balls 26 / VSR 26 (old)	I	5	1.058
VSR 26 (Old) / VSR 14	I	5	1.419
VSR 26 (new) / VSR 14	II	7	1.276
VSR 26 (new) / VSR 14	II	5	1.244
VSR 26 (new) / VSR 26 (old)	II / I	7 / 5	.899
VSR 26 (new) / VSR 26 (old)	II / I	5 / 5	.877

The absolute VSR strength (of No. 14 rod) is different in groups I and II because of temporary poison additions in the interval between the groups which altered the flux distribution somewhat. Similarly the strength of the VSR's in Group II differs between the measurements made with HCR configuration 5 and those made with configuration 7 because of flux distribution effects. For this reason the value of 0.877 for the ratio of new to old VSR strength is the more accurate value since HCR configuration 5 was used in all period measurements taken to obtain this ratio. The charging of temporary poison columns should have had no appreciable effect upon this ratio since the nearly full length poison columns do not greatly alter the front-to-rear flux distribution, and VSR's 26 and 14 are in the same front-to-rear line.

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DISCUSSION (Continued)

TABLE III

HCR CONFIGURATIONS

Configuration Number	HCR Positions (Inches Out)								
	A	2	B	4	5	6	7	8	9
1	Out	115	300	300	Out	In	Out	115	300
2	"	"	Out	"	"	100	"	"	Out
3	"	"	"	"	"	165	"	"	"
4	"	"	"	"	"	220	"	"	"
5	"	"	"	"	"	280	"	"	"
6	"	"	"	Out	"	40	"	"	"
7	"	"	"	"	"	Out	"	"	"

II. Interpretation of The Results

The strength of a single H pile VSR (identical to the original DR VSR's) was measured in a small loading during the initial startup experiments. Neglecting the flux depression in the neighborhood of the rod, C. L. Miller calculated the equivalent material buckling reduction in a region of 24 square lattice units cross-sectional area to be 133 µb. The analytical method was the same one used to determine the K pile control element strengths used in criticality calculations with multiple control element patterns. Therefore, for DR (and H) pile the local control effectiveness applicable for total control criticality calculations is:

DR (and H) Control	Local Δ Buckling
Ball 3X	141 µb
Original VSR	133 µb
New VSR	117 µb

Based on K pile test results, these values should be reduced about ten per cent to provide "always safe" results. The C pile Ball 3X channels are the same size as those at DR and H; therefore, the same Ball 3X strength applies for C pile. The VSR's at C should be about the same strength as the new DR and H rods.

The method of analysis used to obtain the local rod strength quoted above gives values which are certainly less than would be obtained with an exact analysis; however, exact values could be approached only with a rather sophisticated and difficult calculation. This is not of particular concern at present since the values from the original analysis must be used in total control calculations by current methods.

Approximate theoretical local control strengths can be calculated without too much difficulty; the theoretical ratios of the strengths of the different control types may appropriately be compared with the experimental ratios. This gives some idea of the error one might expect in estimating the strength of the B, D, and F pile Ball 3X systems with respect to the measured VSR strength. The following theoretical values have been calculated for DR pile controls.

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DISCUSSION (Continued)

II. Interpretation of the Results (Cont'd)

DR Control	Local △ Buckling (Theoretical)	Relative Strength
Ball 3X	174 µb	1.14
Original VSR	152 µb	1.00
New VSR	135 µb	.89

The strength of the original VSR is the most uncertain since the effect of the polyethylene moderator is particularly hard to evaluate. Therefore, the most meaningful ratio for comparison with the experimental results is that of the Ball 3X to the new VSR; the experimental ratio was 1.20, whereas the theoretical calculation yields a ratio of 1.28.

The local effect of the B pile VSR's was determined experimentally, by the same analytical method as that used for the H rod, to be 93 ub. Theoretical calculations of the rod and Ball 3X strengths give:

B,D,F Control	Local △ Buckling	Relative △ Buckling
VSR	113 µb	1.00
Ball 3X	153 µb	1.35

If the theoretical calculations over-estimate the ratio of Ball 3X to VSR strength by as much as the difference between the experimental and theoretical ratios of DR Ball 3X and the new VSR strengths, a Ball 3X channel at B, D, and F is probably about 26 per cent stronger than the VSR. If this relationship were confirmed experimentally, the control system strength assumed for B, D, F total control calculations could be increased accordingly. This would result in the reduction of supplementary disaster control requirements for a given enrichment loading by roughly 8-10 µb or alternatively the addition of some 15-20 near-side E columns for the same supplementary control requirement.

DE Simpson
Operational Physics Sub-Section
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

DE Simpson:mwe

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