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REACTIVITY AND EFFICIENCY TRENDS VS.
OPERATING TRENDS FOR B, D, DR, AND F REACTORS
1956 THROUGH 1960

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REACTIVITY AND EFFICIENCY TRENDS VS. OPERATING TRENDS
FOR B, D, DR, AND F REACTORS - 1956 THROUGH 1960

MASTER

INTRODUCTION

Changes in operation and corresponding changes in the reactivity status of Hanford reactors are the result of a continuing effort to improve operating efficiency. Trends data related to these changes in operation and reactivity have been published previously for the periods from 1955 through 1959. The purpose of this report is to include trends data for 1960. All included data were selected from the sources listed as reference on page 54.

Bar graphs in the first part of the report show yearly averages of selected data, and the line graphs in the second part show the interrelationship of some of the yearly averages depicted in the first part. The tables in Appendix I show maximum, average, and minimum values. This document presents trends data for B, D, DR, and F reactors, while a second document, HW-72856, presents trends data for C, H, KE, and KW reactors.

Notice that all reactivity values are listed in the unit per cent exc

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HW-72855
Page 2

SUMMARY AND CONCLUSIONS

The graphs show that the general trends in operating and reactivity variables leveled off some in 1960 thus tending to make reactivity predictions more straightforward; increases in power level, not shown on the graphs, did continue to complicate predictions. Prediction accuracy has been maintained due primarily to advancements in defining pertinent variables and use of modified calculational techniques.

Startup efficiency and flattening efficiency, in the form of nonequilibrium losses and equilibrium losses, respectively, show considerable improvement in this report. Splines were put into use at B and F reactors during 1960. More efficient use of splines, gained through experience in 1961, and the addition of spline usage at DR reactor by mid-1961 should lead to improved startup and flattening efficiency, thereby further reducing non-equilibrium and equilibrium losses.

Data within show that there is a slight improvement in the accuracy of startup predictions during 1960; however, the uncertainties of graphite temperature and uranium metal temperature coefficients still exist. Work continues on these items, and as time goes on, should show a trend toward the improvement of startup predictions.

DISCUSSIONS

The Shutdown Data Sheets, authored by the area physicists for the respective reactors, are essentially a running account of reactor startups, shutdowns, and associated reactivity conditions and were therefore the main source of data for this report. New methods of calculating some of the reactivity and operating variables have changed the average values of the respective variables significantly in some cases. However, these are noted and explained in the descriptive discussion accompanying each graph.

The line graphs showing the relationships between potential gains, effective central tubes and nonequilibrium losses are included for the first time this year.

The graphs and tables in this report present summaries of information used in making criticality predictions and operational efficiency studies and for historical purposes. The data are not absolutely accurate but for the purpose here intended are quite adequate.

The graphs are presented in the order given on the following page. References, Appendix and Tables follow the graphs.

E. R. Perl

Pile Physics Unit
Operational Physics Sub-Section
Research and Engineering Section
IRRADIATION PROCESSING DEPARTMENT

ER Perl:gs

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HW-72055
Page 3

TABLE OF CONTENTS

Part I

	<u>Page Number</u>
I. <u>OPERATING TRENDS</u>	
I-A Uranium Discharge Size	4
I-B Uranium Exposure Level	6
I-C Effective Full Power Days	8
I-D Duration of Operating Period	10
I-E Duration of Outage Period	12
I-F Total Outage Time	14
I-G Number of Outages	16
I-H Average ECT	18
I-I Number of Scrams	20
I-J Average Scram Recovery time	22
II. <u>TRENDS IN REACTIVITY VARIABLES</u>	
II-A Reactivity in Control Rods	24
II-B Reactivity from Temperature Coefficients	26
II-C Reactivity Absorbed by Flattening	28
II-D Fringe Poison Columns	30
II-E Fringe Poison Compensation	32
II-F Enrichment Reactivity	34
II-G Enrichment Discharged	36
III. <u>STARTUP CRITICAL PREDICTION TRENDS</u>	
III-A Startup Pile Periods	38
III-B Average Prediction Error	40
III-C Speed of Prediction Error	42
IV. <u>OPERATING EFFICIENCY TRENDS</u>	
IV-A Nonequilibrium Losses per Startup	44
IV-B Potential Equilibrium Gains	46

Part II

I. <u>LINE GRAPHS</u>	
B Reactor	49
D Reactor	50
IR Reactor	51
F Reactor	52
Summary of Eight Reactors	53

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Page 9

FIGURE I-A - AVERAGE PER CENT OF PILE DISCHARGED EACH OUTAGE

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FIGURE I-B - AVERAGE EXPOSURE OF DISCHARGED URANIUM

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FIGURE I - C - EFFECTIVE FULL POWER DAYS IN YEAR (SEE TEXT FOR DEFINITION)

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Days

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FIGURE I-D - AVERAGE NUMBER OF DAYS OPERATED BETWEEN OUTAGES

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Page 13

FIGURE I-E - AVERAGE OUTAGE DURATION

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Page 15

FIGURE I-F - TOTAL TIME DOWN (NOT INCLUDING SCRAMS AND POISON DISCHARGE OUTAGES)

*Nonequilibrium Losses

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Page 11

FIGURE I-G - NUMBER OF OUTAGES MORE THAN TEN HOURS DURATION

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FIGURE I-H - AVERAGE EFFECTIVE CENTRAL TUBES

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FIGURE I-I - NUMBER OF SCRAMS PER YEAR

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II. TRENDS IN REACTIVITY VARIABLES

This group of graphs shows the reactivity contributions of relevant variables, and also presents quantitative values of selected variables associated with the reactivity of a reactor.

II-A. Reactivity in Control Rods

Data in Figure II-A show the average reactivity, in percent excess k , held in horizontal control rods just before shutdown. These data are based on the results of rod calibration tests. The most recent rod calibration test for 9-rod piles was conducted at IR pile in 1956, and this test showed that the rods were stronger - that is, absorbed more reactivity than earlier tests indicated.

The large increase in values for 1957 reflects a re-evaluation of rod strength on the basis of the calibration test in 1956. To be consistent with the results of the 1956 calibration test, the reactivity values for 1956 would need to be increased by about 50 per cent.

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Page 29

Data Prior to 1957 is not corrected for new calibration. Correction is on the order of 50%.

FIGURE II-A - AVERAGE REACTIVITY HELD IN RODS AT SHUTDOWN

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FIGURE II-B - AVERAGE VALUE OF REACTIVITY FROM OVER-ALL TEMPERATURE COEFFICIENT

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FIGURE 17- C AVERAGE REACTIVITY ABSORBED BY FLATTENING AND OTHER NON-URANIUM COLUMNS IN PILE

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Fringe Poison Charged in F Pile on 12-8-59.

FIGURE II-D - AVERAGE NUMBER OF FRINGE POISON COLUMNS

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Page 33

FIGURE II-E - AVERAGE NUMBER OF "E" ENRICHMENT COLUMNS
FOR FRINGE POISON COMPENSATION

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HW-72855
Page 35

FIGURE II-F - AVERAGE ENRICHMENT REACTIVITY
EXCLUDING FRINGE POISON COMPENSATION

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HW-72855
Page 37

FIGURE II-G - TOTAL NUMBER OF ENRICHMENT COLUMNS DISCHARGED EACH YEAR

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Per Cent Excess

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FIGURE III-A - AVERAGE COLD STARTUP RISING PERIOD

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Per cent excess k

FIGURE III-B - ARITHMETIC AVERAGE OF PREDICTION ERRORS

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Page 43

FIGURE III-C - ROOT MEAN SQUARE VALUE OF PREDICTION ERROR

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Page 45

FIGURE IV-A - AVERAGE NONEQUILIBRIUM LOSS PER STARTUP

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HW-72855
Page 47

FIGURE IV-B - AVERAGE POTENTIAL EQUILIBRIUM GAIN PER OPERATING PERIOD

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PART II

LINE GRAPHS

The first four of the following five figures depict the inter-relationship between theoretical potential gains, gains by control zones, monthly average effective central tubes, and nonequilibrium loss averages by month.* The 1959 and 1960 averages for effective central tubes and nonequilibrium losses for the respective reactors are shown at the left of each graph.

The fifth figure shows the over-all average values for all eight reactors. The values for KE and KW reactors for these averages were counted twice since their production is nearly double that of each of the other six reactors. The over-all 1959 and 1960 averages for ECT and NEL are shown at the left of the graph.

*For further explanation of values, refer to the respective bar graph explanatory notes in Part I.

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B REACTOR

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HW-72855
Page 50

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HW-72855
Page 51

DECLASSIFIED

HW-72855
Page 52

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Average of Theoretical Potential Gains

Average of Gains

% Equilibrium Power Level

14
12
10
8
6
4
2
0

84
83
82
81
80
79
78
77
76
75
74

$$\frac{2 \text{ Avg Ect} \times 100}{18464} = \%$$

1960 Avg

1959 Avg

1.2
1.0
0.8
0.6
0.4
0.2
0

Equilibrium Days

1959 Avg

1960 Avg

Average Nonequilibrium Losses

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REFERENCES

All references for data applicable to the year prior to 1960 are listed on page 48 of HW-64931. The 1960 data was obtained from the following shutdown data sheets for each reactor: B - HW-62998; D - HW-63001; IR - HW-63002; F - HW-63003.

1. HW-63753B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, January, 1960
2. HW-64122B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, February, 1960
3. HW-64555B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, March, 1960
4. HW-65013B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, April, 1960
5. HW-65527B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, May, 1960
6. HW-65924B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, June, 1960
7. HW-66296B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, July, 1960
8. HW-66685B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, August, 1960
9. HW-66970B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, September, 1960
10. HW-67286B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, October, 1960
11. HW-67681B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, November, 1960
12. HW-68039B - "Monthly Record Report, Irradiation Processing Department, Research and Engineering," O. H. Greager, December, 1960

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HW-72855
Page 55

APPENDIX I

List of long outages not included in other listings.

B FILE

All outages listed for B File prior to 1960 are listed on page 49 of HW-64931.

January, 1960	74 hours	for rupture and maintenance
February, 1960	62.5 hours	for rupture and maintenance
February, 1960	73.9 hours	for rupture and maintenance
March, 1960	74.9 hours	for water leak and maintenance
April, 1960	125.3 hours	for tube replacement and ball 3X modification
April, 1960	73.5 hours	for rupture and maintenance
September, 1960	179 hours	for reactor maintenance
October, 1960	76.8 hours	for water leak and maintenance
December, 1960	65.4 hours	for rupture and maintenance

D FILE

All outages listed for D File on pages 49 and 50 of HW-64931.

January, 1960	118 hours	for maintenance and tube replacement
February, 1960	66 hours	for trip-out test, tube replacement and maintenance
March, 1960	85.5 hours	tube replacement and maintenance
April, 1960	60.13 hours	water leak and maintenance
May, 1960	64.2 hours	rupture and maintenance
July, 1960	135.7 hours	reactor maintenance
September, 1960	157.7 hours	reactor maintenance
October, 1960	60.9 hours	reactor maintenance
November, 1960	60.2 hours	rupture and maintenance

IR FILE

All outages listed for IR File on pages 50 and 51 of HW-64931.

February, 1960	130.6 hours	block discharge and maintenance
May, 1960	96.4 hours	tube replacement and maintenance
September, 1960	85.3 hours	reactor maintenance
October, 1960	142.3 hours	reactor maintenance

F FILE

All outages listed for F File on pages 51 and 52 of HW-64931.

January, 1960	115.5 hours	install crossheader differential pressure gages and maintenance
February, 1960	135.2 hours	tube replacement and maintenance
February, 1960	80.7 hours	tube replacement and maintenance
March, 1960	83.65 hours	tube replacement and maintenance
July, 1960	179.4 hours	reactor maintenance
August, 1960	68.4 hours	reactor maintenance

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HW-72855
Page 56

APPENDIX I (Continued)

F FILE (Continued)

September, 1960	94.6 hours	reactor maintenance
October, 1960	158.2 hours	reactor maintenance
November, 1960	71.9 hours	water leak and maintenance

Refer to HW-64931, pages 53, 54, and 55 for data for the years 1955, 1956, 1957, 1958, and 1959 of Maximum, Average, Minimum Values. Following is the maximum, average, minimum values for 1960.

TABLE OF MAXIMUM - AVERAGE - MINIMUM VALUES

CALENDAR YEAR REACTOR		1960			
		B	D	DR	F
Uranium Discharge Size in Per Cent of Pile	Max.	29.2	----	----	----
	Avg.	15	17	72.9	17.8
	Min.	0.68	----	----	----
Uranium Exposure Level in Megawatt Days Per Ton	Max.	713	763	750	677
	Avg.	680	720	640	650
	Min.	604	639	641	477
Effective Full Power	Days	271	284	278	269
Duration of Operating Period in Days	Max.	19	28	27	28
	Avg.	10.2	12	9.9	10.9
	Min.	1.0	0.7	1.0	1.0
Duration of Outage in Hours	Max.	59.8	56.4	45.3	55.6
	Avg.	42	39	39	38.5
	Min.	20.0	31.7	32.4	23.2
Total Outage Time	Days	70	62	63	70
Number of Outages		30	26	30	27
Reactivity in Control Rods in Per Cent Excess k	Max.	0.421	0.602	0.60	0.896
	Avg.	0.81	0.84	0.87	0.78
	Min.	0.954	1.206	1.506	0.525
Reactivity from Temp. Coefficients in Per Cent Excess k	Max.	1.25	1.97	1.86	1.52
	Avg.	1.47	1.56	1.54	1.33
	Min.	1.60	1.36	1.27	0.79
Flattening Reactivity in Per Cent Excess k	Max.	1.11	1.15	1.93	1.10
	Avg.	.79	.83	1.10	.75
	Min.	.42	.57	.97	.71

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HW-72855
Page 57

TABLE OF MAXIMUM - AVERAGE - MINIMUM VALUES
(Continued)

CALENDAR YEAR REACTOR		1960			
		B	D	DR	F
Enrichment Reactivity in Per Cent excess k	Max.	1.10	.95	1.69	.83
	Avg.	.91	.78	1.29	.66
	Min.	.69	.65	.65	.65
Pile Period at Startup in Per Cent Excess k	Max.	.125	.150	.150	.134
	Avg.	.072	.067	.060	.063
	Min.	.015	.024	.015	~ 0
Prediction (+/-) Error in Per Cent Excess k	Max.	160/190	154/379	245/576	374/296
	Avg.	-.017	.0012	-.0046	-.042
	Min.	0	~ 0	-.009	.009
RMS Prediction Error		.094	.067	.088	.146
Nonequilibrium Losses in Equivalent Equilibrium Days	Max.	.963	.736	1.65	1.27
	Avg.	.48	.39	.52	.67
	Min.	.301	.028	.135	.126
Equilibrium Gains in Per Cent of Equilibrium Power Level	Max.	$\frac{TH^*}{ZONE} \frac{11.1}{4.5}$	$\frac{9.4}{3.3}$	$\frac{12}{2.9}$	$\frac{11.7}{4.1}$
	Avg.	$\frac{TH}{ZONE} \frac{8}{2.5}$	$\frac{7.5}{2.0}$	$\frac{8}{2.9}$	$\frac{10}{3}$
	Min.	$\frac{TH}{ZONE} \frac{6.2}{1.8}$	$\frac{6.3}{1.2}$	$\frac{6.5}{2.0}$	$\frac{9.0}{1.9}$

*TH - Theoretical gains
ZONE - Zone gains

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