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TRENDS FOR B, D, DR, AND F REACTORS - 1955
THROUGH 1959

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by

J.P. Owsley

April 29, 1960

REACTIVITY AND EFFICIENCY TRENDS VS. OPERATING TRENDS FOR B, D, DR, AND F REACTORS - 1955 THROUGH 1959

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 1950 through 1958. (1) The purpose of this report is to include trends data for 1959. All included data were selected from the sources listed as references on page 48.

Bar graphs in the first part of the report show yearly averages of selected data, and tables in the last part of the report show maximum, average, and minimum values. This document presents trends data for B, D, DR, and F Reactors, while a second document, HW-64932, presents the trends data for C, H, KE, and KW Reactors.

Data included in past years which have not been included in this report are trends in pile power level at shutdown omitted due to a security status change regarding power levels, and number of temporary poison columns per startup omitted due to virtual elimination of temporary poison startups at B, D, DR, and F Reactors; added were potential non-equilibrium gains and potential equilibrium gains.

Notice that all reactivity values are listed in the unit per cent excess k.

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SUMMARY AND CONCLUSIONS

The graphs show that the general trend in operating and reactivity variables is continuing in directions tending to make reactivity predictions more difficult, and it appears that this trend will continue for some time. Despite the tendency of the trend above, prediction accuracy has maintained or improved upon past performance levels, due primarily to advancements in defining pertinent variables.

Startup efficiency and flattening efficiency in the form of non-equilibrium losses and equilibrium losses, respectively, are expected to show considerable improvement in the next trends report according to data for late 1959 and early 1960. Poison spline use for supplementary control at startup and for equilibrium flattening at D pile has significantly reduced both non-equilibrium and equilibrium losses particularly during late 1959 and early 1960. As more experience in poison spline usage is gained, the non-equilibrium and equilibrium losses should decrease more, or in other words, the startup efficiency and flattening efficiency should be improved at those piles where splines are used.

Observation shows that while knowledge of and experience with reactivity variables have developed over the years, there are still uncertainties about certain of the reactivity associated variables. Among these are the graphite temperature and uranium metal temperature coefficients both of which have a significant effect on reactivity calculations. The study on the graphite temperature coefficient started in 1959 is continuing and results are expected in 1960. Metal temperature coefficient data are being collected whenever reactor operating status is favorable. More accuracy in the temperature coefficients would be congruent with the trend to improved startup reactivity predictions.

DISCUSSION

The Shutdown Data Sheets, (2-5) authored by the area physicists for the respective reactors, are essentially a running account of reactor startups, shutdowns, and the 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.

Temporary poison startups were virtually eliminated in 1959 because of the greater efficiency attainable with Poison Column Control Facility at the B, D, DR, and F piles. Poison splines were also used for startups at D pile. Loss of production due to non-equilibrium operation and potential equilibrium gains from increased flattening efficiency are two items included in the trends reports 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 by no means absolute values 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.

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Operational Physics Sub-Section
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I. OPERATING TRENDS

These first ten graphs show variations in selected operating variables which directly or indirectly affect reactivity predictions and efficiency while operating.

I-A. Uranium Discharge Size

Figure I-A shows the average per cent of the pile discharged per outage based on flux-squared reactivity weighting. Outages where no discharge was taken or where the size of the discharge was negligible were not considered in determining the averages given here. Note that reactivity weighted percentages are presented rather than the weight or number of tubes per outage; however, the values are very close to but slightly higher than weight or number of tubes per outage.

Longer operating periods increase the per cent of the uranium reaching goal exposure and, therefore, the size of the discharge increases accordingly. It is significant that the discharge size has generally increased despite a marked increase in goal exposure which tends to reduce the effects of higher power levels and longer operating periods.

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

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I-B. Uranium Exposure Level

The exposure level of discharged fuel is primarily a function of the established goals. For 1955 through 1958 the data shown are for natural uranium only, while for 1959 exposure levels of enriched uranium were included with the natural uranium exposure levels to determine the average. The higher exposure with the I & E fuel element, used as the primary production fuel element in 1959, has reduced the operating reactivity loss associated with the transition from solid to I & E elements.

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FIGURE I-B - AVERAGE EXPOSURE OF DISCHARGED URANIUM

I-C. Effective Full-Power Days

The value of effective full-power days for 1955 and 1956 is defined as annual pile production divided by the average pile power level at shutdown. For 1957 through 1959, the value was re-defined as total number of days operated minus the annual non-equilibrium loss in equivalent equilibrium days. (The actual non-equilibrium losses are shown in Figure I-F.) The 1959 value for F Pile reflects 18 days of operation at about half normal power level as the result of excessive water in the moderator.

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

I-D. Duration of Operating Period

This graph shows the average number of days of operation between outages for the respective reactors. The increase in 1959 is the result of longer operating periods which were made possible at least partly by high goal exposures and decreases in ruptures and spurious scrams. Notice that the marked reversal in the trend occurred concurrently with the full-pile loading of I & E fuel elements.

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

I-E. Duration of Outage

Figure I-E shows the average duration of outages in hours. The average does not include scrams, poison push outages, and the extended outages listed in Appendix I.

Although the "minimum" down time has lengthened as a result of higher pile power levels and there were fewer outages in 1959 (see Figure I-G) the average outage time has not increased comparably.

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FIGURE I-E - AVERAGE OUTAGE DURATION

I-F. Total Outage Time

Figure I-F shows the total number of days down for the year. This includes the long outages in Appendix I, but does not include the time down for scrams or temporary poison discharges.

Non-equilibrium losses in equivalent equilibrium days are shown at the top of each bar graph for 1957 through 1959. The sum of outage time, non-equilibrium losses, and effective full power days (see Figure I-C) should be approximately equal to the number of days in the year. Since outage time for scrams and poison discharges was not included, the summation will be slightly less than the number of days in the year.

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* Non-Equilibrium Losses

← Outage Time

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

I-G. Number of Outages

The number of outages shown in Figure I-G is restricted to all outages of ten or more hours duration in order to exclude scrams and temporary poison outages. The term "scrams" is used here to refer only to those outages where a recovery is made in less than ten hours.

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

I-H. Average ECT

ECT (Effective Central Tubes) is defined as follows:

$$\text{ECT} = \frac{\text{Total Reactor Power in Megawatts}}{\text{Average Maximum Tube Power in Megawatts*}}$$

* for the ten most productive tubes in the reactor.

Values shown in Figure I-H for 1955 to 1958 are arithmetic averages of data presented in monthly Reactivity Balance Reports.(6) Values for 1959 are arithmetic averages of data included in Pile Physics Monthly Reports. Data from the Reactivity Balance Reports are best values for a given date, whereas data from the Pile Physics Monthly Reports are monthly average values for normal equilibrium operation. To give a more exact comparison the annual averages from the Pile Physics Monthly Reports for the past three years are presented below:

<u>Reactor</u>	<u>1957</u>	<u>1958</u>	<u>1959</u>
B	1360	1435	1435
D	1390	1440	1475
DR	1470	1490	1500
F	1365	1435	1445

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FIGURE I-H - AVERAGE EFFECTIVE CENTRAL TUBES

I-I. Number of Scrams

Figure I-I shows the total number of scrams per year, whether recoveries were made or not. Available scram recovery time has decreased while operational difficulty following a scram recovery has increased as the result of higher pile power levels. Therefore, the reduction in number of scrams for the past two years is particularly important to the maintenance of high operating efficiency.

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FIGURE I-I - NUMBER OF SCRAMS PER YEAR

I-J. Average Scram Recovery Time

Scram recovery time in this report refers to that amount of time after a scram within which a recovery can be successfully accomplished before the pile goes subcritical. The general decrease in available scram recovery time has resulted from increased pile power levels. The marked increase for DR in 1959 is attributed to increased goal exposure, a higher base reactivity at DR (compared to the other three reactors in this report), and increased enrichment to improve efficiency and extend the flattened zone - these effects outweighed the loss of scram recovery time due to increased pile power levels.

The average values shown in the graphs were calculated from data submitted by the area physicists in their respective monthly reports.

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Data not readily available prior to 1957

FIGURE I-J - AVERAGE SCRAM RECOVERY TIME

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 per cent 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 DR 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 1955 and 1956 would need to be increased by about 50 per cent.

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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

II-B. Reactivity from Temperature Coefficients

Figure II-B shows the average reactivity contribution from the over-all effect of metal and graphite heating. The over-all reactivity of the temperature coefficients is obtained by algebraically summing a negative metal temperature effect and a positive graphite temperature effect of a reactor just before shutdown. The relatively higher values for 1959 are the result of higher pile power levels, higher uranium fuel exposures for the pile, and the smaller negative uranium temperature coefficient of I & E fuel elements compared to solid fuel elements.

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FIGURE II-B - AVERAGE VALUE OF REACTIVITY FROM OVERALL
TEMPERATURE COEFFICIENT

II-C. Reactivity Absorbed by Flattening

Figure II-C shows average effective reactivity absorbed by non-power tubes in the respective reactors. Fringe poison tubes for shield protection were not included here; all other non-power tubes were included.

The indicated increase in flattening for 1959 is the result of the need for more flattening flexibility to absorb the long term reactivity gain which accompanies long periods of operation at higher pile power levels. This flattening is generally in the form of lead-cadmium in the PCCF. At D pile poison splines are also included. Special irradiations tubes and tubes out of service pending replacement absorbed a portion of the reactivity.

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FIGURE II- C - AVERAGE REACTIVITY ABSORBED BY FLATTENING AND OTHER
NON-URANIUM COLUMNS IN FILE

II-D. Fringe Poison

Biological shield damage has increased with higher pile power levels. Therefore, fringe poison columns were charged at those reactors where shield damage was greatest in order to reduce shield temperatures and prolong the life of the shield. Figure II-D shows the average number of fringe poison columns used for shield protection. The value for F pile shows the number of fringe poison columns charged on 12-8-59. This is the first use of fringe poison at F pile. D pile has not charged fringe poison yet.

Enrichment columns were also charged near the fringe poison to compensate for the reactivity loss caused by the poison. (See Figure II-E.)

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

FIGURE II-D - AVERAGE NUMBER OF FRINGE POISON COLUMNS

II-E. Fringe Poison Compensation

Figure II-E shows the average number of enrichment columns charged to compensate for reactivity losses caused by the fringe poison. (See II-D.)

The value for F pile shows the number of columns in the initial charging of fringe poison and compensating enrichment on 12-8-59. D pile has not charged fringe poison for shield protection and, therefore, has no compensating enrichment charged.

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Charged in F Pile on 12-8-59

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

II-F. Enrichment Reactivity

Figure II-F shows the average monthly reactivity inventory of enriched uranium from the time enrichment charging began at the 9-rod piles. Additional pile reactivity became necessary in 1957 to compensate for reactivity losses associated with increases in pile power levels and decreased uranium fuel exposures following CG-558 water plant modification. The need for additional reactivity was increased when I & E fuel elements were charged in 1958. Practically all of the additional reactivity was supplied by enriched natural uranium (E). Some came from a few columns of U-235 aluminum alloy (C) which has currently been replaced with "E" material.

The large inventory of enrichment at D pile was necessary to compensate for boron-steel balls left in the pile after the May, 1957, Ball 3X trip.

The one-group diffusion theory as described in HW-60439 (9) was used to evaluate enrichment reactivity for the last half of 1959. The flux-squared weighting method was used previously, and is still applicable for small changes in reactivity. For the relatively moderate enrichment at these four reactors the two methods yield nearly identical results.

Note: This graph does not include enrichment charged for fringe poison compensation (see Figure II-E).

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

II-G. Enrichment Discharged

This figure shows the total number of enrichment columns discharged per year since they were first charged in 1957. A few "C" columns were discharged in 1957 and 1958, but since they were so few compared to the number of "E" columns and were no longer in use after 1958, they were included in the totals instead of being shown separated from "E" columns as in past trends reports. Reactivity-wise, a "C" column is equivalent to three "E" columns.

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

III. STARTUP CRITICAL PREDICTION TRENDS

The graphs in this section, except for Figure III-A, show the trend in criticality prediction accuracy. Predictions are based on the ability to calculate the reactivity of the pile when startups are being attempted. Reactivity calculating methods are included in the discussion for III-B.

III-A. Startup Pile Periods

Figure III-A shows the average magnitude of reported startup periods in reactivity units of per cent excess k.

It is desirable to maintain a reasonably slow rising period for cold startups and, therefore, the average value of the rising periods should not be increasing or decreasing as pile power level, exposure, outage time or any other related factor varies. Prediction accuracy and instrument sensitivity are two main factors which provide greatest assurance of starting up on a reasonable rising period; improvements in both have permitted less conservative rod withdrawal procedures. This combined with subcritical monitoring should tend to show a continued trend to leveling out of the average startup period.

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FIGURE III-A - AVERAGE COLD STARTUP RISING PERIOD

III-B. Average Prediction Error

Startup reactivity can be calculated either as a difference between the hot operating reactivity preceding shutdown and the cold reactivity after shutdown or as the change in cold reactivity from startup to startup. Calculated differences by the first method are large and highly sensitive to exposure, whereas the calculated changes by the second method are relatively small and independent of exposure. Therefore, since the dependence on exposure (with its associated inherent uncertainties) is essentially eliminated from the calculation, the results by the second method should be more reliable. This method has been used during part of 1959 and the results are reflected in Figures III-B and III-C.

Figure III-B shows the arithmetic average of prediction errors that were reported in the Shutdown Data Sheets (2-5). Large negative errors caused by excessive water in the pile from tube leaks were not included in the average since it is virtually impossible to evaluate in advance the reactivity loss caused by the water.

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FIGURE III-B - ARITHMETIC AVERAGE OF PREDICTION ERRORS

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III-C. Spread of Prediction Error

This graph shows the scatter of prediction errors about zero. The values were determined by the root mean square method which is as follows:

$$\text{Root Mean Square} = \sqrt{\frac{\sum_{i=1}^{i=N} E_i^2}{N}}$$

where E is the magnitude of the prediction error and N = total number of predictions made.

Large negative errors caused by excessive water in the moderator by leaking process tubes were not included in the averages.

The RMS for F pile reflects one large conservative (negative) error caused by mis-reading a table. If this were excluded the RMS would be approximately 0.112 per cent excess k, instead of 0.156 per cent as shown.

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

IV. OPERATING EFFICIENCY TRENDS

The graphs in this section indicate the trend of startup efficiency and flattening efficiency as shown by non-equilibrium losses and potential equilibrium gains, respectively. These data were not routinely collected until late 1956 and, therefore, are not shown for 1955 and 1956.

IV-A. Non-Equilibrium Losses Per Startup

Non-equilibrium losses can be simply defined as the number of days of full production lost because the pile could not be started immediately up to full power level. Thus one day of non-equilibrium loss as defined here is equivalent in production lost to one full day of shutdown time.

The increase in non-equilibrium losses for 1959 is the result of higher pile power levels and longer periods of transient operation before reaching an equilibrium level. Supplementary control in the form of poison splines at D pile and PCCF at all four 9-rod piles has been utilized since late 1959 to decrease the non-equilibrium losses. Late 1959 and early 1960 trends are toward decreased losses.

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FIGURE IV-A - AVERAGE NON-EQUILIBRIUM LOSS PER STARTUP

IV-B. Potential Equilibrium Gains

The data in Figure IV-B are based on analyses of temperature maps where a flattened zone is assumed for the respective reactor and the difference between the observed flattening and theoretical flattening is called the potential equilibrium gains. In other words, it is the gain in power level which could be achieved with perfect flattening flexibility in the central zone. Reactivity changes can adjust the relative level of fairly small groups of tubes in respect to other groups of tubes, but still have little effect on the relative difference in powers between tubes within one to three lattice units of each other. This theory was applied in the analysis of temperature maps to find the potential gains.

The average results from temperature map analyses were found to be low in comparison to more exact analyses of tube power data. Future potential equilibrium gains will be based on analysis of tube power distribution.

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

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APPENDIX I

List of long outages not included in other listings.

B FILE

February, 1955	107 hours	for cushion chamber repairs
July, 1955	617 hours	to replace HCR's
November, 1955	167 hours	to install television
January, 1956	203 hours	for reactor maintenance
February, 1956	246 hours	for reactor maintenance
March, 1956	143 hours	for reactor maintenance
March, 1956	98 hours	for reactor maintenance
June, 1956	137 hours	for tube replacement
August, 1956	136 hours	for tube replacement
September-December, 1956	77.3 days	for CG-558 water plant expansion
February, 1957	155 hours	for tube replacement
March, 1957	259 hours	for Ball 3X recovery
May, 1957	162 hours	for tube replacement
June, 1957	259 hours	for tube replacement
August, 1957	123 hours	for tube replacement
September, 1957	127 hours	for tube replacement
January, 1958	134 hours	for tube replacement
January-February, 1958	112 hours	for tube replacement
March, 1958	104 hours	for tube replacement
May, 1958	134 hours	for tube replacement
August, 1958	73 hours	for rupture and maintenance
September, 1958	165 hours	for tube replacement
November, 1958	62 hours	for leak testing
December, 1958	60 hours	for leak testing
January, 1959	222 hours	for tube replacement and reactor maintenance
January, 1959	108 hours	for tube replacement and reactor maintenance
February, 1959	75 hours	for reactor maintenance
May, 1959	157 hours	for tube replacement and reactor maintenance
August, 1959	90 hours	for project work
August, 1959	78 hours	for project work
September, 1959	122 hours	for reactor maintenance and removal of rubber particles from front-face piping.
October, 1959	118 hours	for tube replacement and reactor maintenance
November, 1959	94 hours	for removal of a stuck charge
December, 1959	103 hours	for tube replacement and reactor maintenance

D FILE

June, 1955	517 hours	to replace HCR's
September 1955	146 hours	for tube replacement
October, 1955	483 hours	for tube replacement

APPENDIX I (Continued)D PILE (Continued)

December, 1955	561 hours	for chute linear replacement and gamma monitor installation
January, 1956	173 hours	for tube replacement
February, 1956	189 and 148 hours	for tube replacement
March, 1956	166 hours	for tube replacement
April, 1956	176 hours	for tube replacement
May, 1956	155 and 160 hours	for electrical maintenance and tube replacement
July, 1956	227 hours	for tupture removal and tube replacement
August, 1956	184 hours	for tube replacement
November, 1956	172 hours	for tube replacement
January, 1957	83 hours	for maintenance
February-March, 1957	1152 hours	for CG-558 water plant expansion
May, 1957	223 hours	for Ball 3X recovery
June, 1957	99 hours	for tube replacement
July, 1957	75 hours	for tube replacement
September, 1957	93 hours	for tube replacement
November, 1957	110 hours	for tube replacement
December, 1957	85 hours	for scheduled outage and leak testing
January, 1958	93 hours	for tube replacement
March, 1958	109 hours	for tube replacement
June, 1958	71 hours	for tube replacement
July, 1958	116 hours	for tube replacement and maintenance
September, 1958	111 hours	for tube replacement
January, 1959	102 hours	for tube replacement, reactor maintenance, and rear cross-header decontamination
March, 1959	119 hours	for tube replacement and reactor maintenance
June, 1959	139 hours	for slug removal from rear and miscellaneous reactor maintenance
August, 1959	96 hours	for tube replacement and reactor maintenance
October, 1959	71 hours	for rupture removal and decontamination of rear face
November, 1959	72 hours	for tube replacement
	66 hours	for tube replacement

DR PILE

April, 1955	393 hours	for HCR replacement
September-October, 1955	240 hours	for ball valve and gamma monitor installation
February, 1956	78.9 hours	for PT-605-A rod calibration
May, 1956	65.5 hours	for tube replacement
January-February, 1957	1173 hours	for CG-558 water plant expansion
June, 1957	100.5 hours	for tube replacement
July, 1957	89.3 hours	for tube replacement

APPENDIX I (Continued)

DR FILE (Continued)

September, 1957	92.2 hours	for rupture and tube replacement
October, 1957	120.5 hours	for rupture and tube replacement
December, 1957	110.4 hours	for rupture and tube replacement
	110.2 hours	for ruptures and discharge of rupture-prone material
February, 1958	118 hours	for tube replacement
March, 1958	89 hours	for tube replacement
April, 1958	150 hours	for tube replacement
May, 1958	95 hours	for tube replacement
July, 1958	179 hours	for tube replacement
July-August, 1958	174 hours	for tube replacement
September, 1958	80 hours	for water leak and maintenance
October, 1958	225 hours	for tube replacement
November, 1958	267 hours	for tube replacement
December, 1958	85 hours	for tube replacement
January, 1959	158 hours	for tube replacement and reactor maintenance
March, 1959	97 hours	for reactor maintenance
April, 1959	97 hours	for removal of stuck charges and maintenance work
May-June, 1959	173 hours	for tube replacement, reactor maintenance, and project work
July, 1959	96 hours	for tube replacement, reactor maintenance, and project work
August, 1959	76 hours	for reactor maintenance
October, 1959	106 hours	for tube replacement and reactor maintenance
December, 1959	98 hours	for tube replacement and reactor maintenance
	51 hours	for miscellaneous reactor maintenance

F FILE

February, 1955	608 hours	for HCR replacement
June, 1955	308 hours	to recover balls from 3X chambers
September, 1955	288 hours	for tube replacement
October, 1955	313 hours	for tube replacement
November, 1955	307 hours	for tube replacement
January, 1956	96 and 167 hours	for rupture removal, leak test, and tube replacement
February, 1956	206 hours	for tube replacement
March, 1956	171 and 192 hours	for tube replacement
April, 1956	179 hours	for tube replacement
May, 1956	195 hours	for tube replacement
June, 1956	195 hours	for tube replacement
July, 1956	216 hours	for tube replacement
August, 1956	165 hours	for tube replacement
September, 1956	196 hours	for tube replacement
October, 1956	178 hours	for tube replacement
December, 1956	169 hours	for tube replacement

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APPENDIX I (Continued)

F PILE (Continued)

January, 1957	182 hours	for tube replacement
April-May, 1957	1269 hours	for CG-558 water plant expansion
August, 1957	86 hours	for tube replacement
September, 1957	90 hours	for tube replacement
October, 1957	127 hours	for tube replacement
	71 hours	for rupture and leak testing
November, 1957	78 hours	for leak testing
December, 1957	116 hours	for tube replacement
	26 hours	for rupture and tube replacement
January, 1958	106 hours	for tube replacement
March, 1958	172 hours	for tube replacement and leak testing
		for tube replacement
April, 1958	116 hours	for tube replacement
May, 1958	88 hours	for tube replacement
June, 1958	98 hours	for tube replacement
July, 1958	66 hours	for tube replacement
August, 1958	90 hours	for tube replacement
October, 1958	138 hours	for tube replacement
November, 1958	56 hours	for leak testing
January, 1959	127 hours	for tube replacement and reactor maintenance
		for tube replacement and reactor maintenance
March, 1959	153 hours	for leak testing, tube replacement, and reactor maintenance
	106 hours	for leak testing and reactor maintenance
April, 1959	96 hours	for tube replacement and reactor maintenance
May, 1959	125 hours	for leak testing, tube replacement, and removal of a stuck charge
May-June, 1959	196 hours	for leak testing and reactor maintenance
June, 1959	83 hours	for tube replacement and reactor maintenance
July, 1959	145 hours	for leak testing and tube replacement
September, 1959	106 hours	for tube replacement and reactor maintenance
October, 1959	123 hours	for tube replacement and reactor maintenance
December, 1959	102 hours	for tube replacement and reactor maintenance

APPENDIX II - TABLE OF MAXIMUM - AVERAGE - MINIMUM VALUES

CALENDAR YEAR REACTOR		1955				1956				
		B	D	DR	F	B	D	DR	F	
I. Operating Trends	Uranium Discharge	Max.	26.0	38.2	25.0	44.3	23.9	31.7	26.7	20.1
	Size in Per Cent	Avg.	9.5	10.9	8.8	5.6	13.8	11.2	10.9	10.9
	of the Pile	Min.	1.0	1.0	0.6	0.7	3.2	3.4	1.8	1.4
	Uranium Exposure	Max.	900	1050	900	900	800	800	875	768
	Level in Megawatt	Avg.	578	512	590	228	734	611	574	519
	Days per Ton	Min.	200	248	205	200	522	234	202	219
	Effective Full Power Days(1)		267	205	287	209	209	237	297	202
	Duration of Oper-	Max.	27.4	14.7	31.9	33.1	32.0	34.0	38.3	33.0
	ating Period	Avg.	14.0	6.0	12.9	6.2	11.6	7.5	8.3	7.9
	in Days	Min.	6.3	0.5	0.9	0.4	1.3	0.1	1.0	0.1
Duration of Outage in Hours (2)	Max.	85.0	103.3	70.0	170	88.4	75.0	66.2	77.0	
	Avg.	49.5	46.9	39.3	55.1	38.7	39.3	35.6	47.1	
	Min.	26.9	16.0	23.6	13.2	21.5	21.8	19.0	23.4	
Total Outage Time (3)			74.3	136	62.4	143	140.0	110.6	47.5	133.6
Number of Outages (3)			20	37	24	34	21	33	34	27
II. Trends in Re- activity Variables	Reactivity in	Max.	.550	.532	.690	.825	.590	.728	.780	.808
	Control Rods in	Avg.	.455	.285	.492	.490	.498	.512	.578	.625
	Per Cent Excess k	Min.	.315	.250	.332	.370	.462	.332	.315	.445
	Reactivity From Temp.	Max.	1.022	1.280	1.275	1.372	.902	1.232	1.180	1.465
	Coefficients in	Avg.	.810	1.125	1.068	.988	.832	1.042	.952	1.088
	Per Cent Excess k	Min.	.678	.950	.625	.700	.668	.852	.588	.890
	Flattening Reactivity	Max.	1.185	.915	1.278	.880	1.292	.952	1.155	1.028
	in Per Cent	Avg.	.992	.792	.950	.702	1.030	.695	.795	.745
	Excess k	Min.	.860	.595	.528	.530	.878	.460	.422	.522
III. Critical Pred. Trends	Pile Period	Max.	.212	.158	.200	.168	.108	.135	.115	.158
	at Startup in	Avg.	.125	.090	.070	.110	.072	.078	.052	.085
	Per Cent Excess k	Min.	.050	.038	0	.048	.038	.025	.025	.035
	Prediction (+/-)	Max.	.168/.432	.212/.198	.500/.242	.148/.222	.170/.285	.222/.290	.138/.225	.190/.148
	Error in	Avg.	-.048	.015	-.070	-.062	-.075	-.040	-.045	-.008
	Per Cent Excess k	Min.	-.015	.002	0	-.012	-.015	-.002	.008	.010
	RMS Prediction Error		.158	.120	.222	.165	.102	.115	.092	.072

(1) See page 8 for definition.

(2) These values do not include outages listed in Appendix I.

(3) These values include outages in Appendix I but do not include outage time for temporary poison discharging or scram times where recoveries were made.

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APPENDIX II - TABLE OF MAXIMUM - AVERAGE - MINIMUM VALUES (Cont'd)

CALENDAR YEAR REACTOR		1957				1958			
		B	D	DR	F	B	D	DR	F
Uranium Discharge	Max.	29.0	32.3	29.0	26.7	36.0	35.0	33.3	41.0
Size in Per Cent	Avg.	12.8	16.2	11.5	14.6	11.9	17.9	9.9	20.0
of Pile	Min.	2.7	3.2	2.8	5.0	2.0	3.0	1.0	3.6
Uranium Exposure	Max.	538	628	568	643	613	774	535	517
Level in Megawatt	Avg.	459	517	481	480	477	520	431	483
Days per Ton	Min.	211	375	276	242	395	239	283	350
Effective Full Power Days (1)		274	263	258	242	292	311	282	301
Duration of	Max.	20.6	22	21	22.5	21.2	35.3	22.9	31.7
Operating Period	Avg.	7.3	10	7	8.7	8.1	14.4	6.1	13.4
in Days	Min.	0.2	0.1	0.2	0.1	0.3	1.0	0.2	0.3
Duration of	Max.	67.2	63.6	71.3	78.0	53.1	59.3	67.2	52.1
Outage	Avg.	33.1	37.7	35.2	43.4	34.5	44.0	37.8	40.8
in Hours (2)	Min.	13.0	13.7	13.0	19.2	20.9	25.9	15.4	28.4
Total Outage Time (3)		86.5	108	117.4	119.6	75.8	49.9	101.4	55.9
Number of Outages (3)		37	26	36	28	36	21	42	20
Reactivity in	Max.	1.305	1.175	1.012	1.338	.968	.988	.888	.955
Control Rods in	Avg.	.880	.808	.860	.895	.830	.842	.750	.828
Per Cent Excess k	Min.	.630	.650	.742	.682	.695	.665	.618	.525
Reactivity from Temp.	Max.	1.808	1.532	1.572	1.495	1.510	1.972	1.298	1.480
Coefficients in	Avg.	1.408	1.240	1.332	1.200	1.220	1.382	1.130	1.335
Per Cent Excess k	Min.	.888	.638	1.002	.192	.912	.925	.898	1.120
Flattening Reactivity	Max.	1.000	1.082	.885	1.750	1.008	.900	1.075	1.032
in Per Cent	Avg.	.690	.720	.678	.798	.785	.632	.745	.808
Excess k	Min.	.300	.450	.510	.540	.620	.338	.580	.642
Pile Period at	Max.	.132	.085	.150	.122	.125	.122	.120	.092
Startup in Per Cent	Avg.	.075	.048	.050	.072	.072	.060	.045	.052
Excess k	Min.	.042	0	.005	.025	.030	.025	.010	.025
Prediction (+/-)	Max.	.382/.270	.180/.278	.430/.450	.322/.330	.310/.275	.318/.175	.368/.175	.175/.125
Error in Per Cent	Avg.	.090	.040	.070	-.01	.005	.100	0	.032
Excess k	Min.	0	0	-.012	0	.002	.015	0	0
RMS Prediction Error		.158	.105	.202	.128	.145	.152	.180	.088
Non-Equilibrium	Max.	1.93	1.30	1.0	1.31	.82	.84	.72	.68
Losses in (5)	Avg.	.53	.54	.42	.52	.34	.42	.39	.37
Equivalent	Min.	.04	.08	.03	.06	.03	.02	.01	.02
Days	Total	21.73	15.0	15.3	14.1	16.8	17.4	17.4	10.4
Equilibrium Gains	Max.	6.35	2.03	2.27	4.04	1.90	1.10	1.80	1.60
in Per Cent of (6)	Avg.	1.67	.75	.62	1.97	.71	.46	.60	.78
Equil. Pwr. Level	Min.	0	0	0	.42	0	0	.30	.30

(1) See page 8 for definition.

(2) These values do not include outages listed in Appendix I.

(3) These values include outages in Appendix I but do not include outage time for temporary poison discharging or scram times where recoveries were made.

(5) Defined on page 44.

(6) Defined on page 46.

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APPENDIX II

TABLE OF MAXIMUM - AVERAGE - MINIMUM VALUES
(Continued)

CALENDAR YEAR			1959			
REACTOR			B	D	DR	F
I. Operating Trends	Uranium Discharge	Max.	44.5	35.9	40.8	46.7
	Size in Per Cent	Avg.	13.5	18.6	16.3	19.1
	of Pile	Min.	2.1	1.7	1.3	.9
	Uranium Exposure	Max.	752	852	836	880
	Level in Megawatt	Avg.	689	705	693	676
	Days per Ton	Min.	590	488	477	372
	Effective Full Power Days (1)		279	298	290	252
	Duration of	Max.	36.0	38.9	36.5	50.5
	Operating Period	Avg.	12.5	16.0	16.4	15.3
	in Days	Min.	0.6	2.5	3.9	1.0
II. Trends in Reactivity Variables	Duration	Max.	52.8	61.4	44.4	67.5
	of Outage	Avg.	38.8	43.3	38.6	45.1
	in Hours (2)	Min.	25.9	32.0	30.7	29.8
	Total Outage Time (3)		71.2	51.1	55.8	73.6
	Number of Outages (3)		24	20	19	20
	Reactivity in	Max.	.888	.912	.980	.942
	Control Rods in	Avg.	.790	.832	.830	.742
	Per Cent Excess k	Min.	.610	.718	.692	.590
	Reactivity from	Max.	1.818	1.885	1.870	2.198
	Temperature Coefficients	Avg.	1.545	1.598	1.595	1.610
III. Critical Trends	in Per Cent Excess k	Min.	1.340	1.310	1.422	.955
	Flattening Reactivity	Max.	1.165	1.418	1.240	1.152
	in Per Cent	Avg.	.848	.755	1.058	.838
	Excess k	Min.	.600	.350	.898	.640
	Enrichment Reactivity	Max.	.530	.715	.778	.688
	in Per Cent (4)	Avg.	.385	.612	.520	.455
	Excess k	Min.	.225	.482	.385	.398
	Pile Period at	Max.	.162	.158	.225	.110
	Startup in Per Cent	Avg.	.058	.057	.078	.060
	Excess k	Min.	.015	.018	.022	.028
IV. Efficiency Trends	Prediction (+/-)	Max.	.102/.302	.130/.205	.132/.135	.350/.348
	Error in	Avg.	-.058	.004	.014	.019
	Per Cent Excess k	Min.	-.008	0	.002	.005
	RMS Prediction Error		.118	.071	.074	.157
	Non-Equilibrium	Max.	1.16	1.03	2.29	1.60
	Losses in (5)	Avg.	.55	.62	.67	.73
	Equivalent	Min.	.07	.12	.37	.41
	Equilibrium Days	Total	13.7	15.6	16.1	22.9
	Equilibrium Gains in	Max.	1.8	1.8	0.6	2.8
	Per Cent of (6)	Avg.	0.7	0.8	0.4	1.1
Equilibrium Power Level	Min.	0.2	0.2	0	0.5	

(1) See page 8 for definition.

(2) These values do not include outages listed in Appendix I.

(3) These values include outages in Appendix I but do not include outage time for temporary poison discharging or scram times where recoveries were made.

(4) Does not include enrichment for fringe poison compensation

(5) Defined on page 44.

(6) Defined on page 46.

DATE

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8/9/94

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