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DOCUMENT NO. HW-24848

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FILE DESIGNATION

SUBJECT OR TITLE

Recommended C Pile Power Level Limits

TO

G. E. McCullough

FROM

L. H. McEwen - L. W. Lang

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This document consists of 19 pages. Copy No. 25 of 26 copies. Series A.

RECOMMENDED C PILE POWER LEVEL LIMITS

PURPOSE

The purpose of this document is to summarize the existing or contemplated limits of C Pile power level and to recommend the rates of increase of power toward these limits during initial operation. In this report pile power level and limits are expressed in terms of tube power only.

SUMMARY

1. During initial operation it is assumed that C Pilo will operate with 100 per cent CO₂ gas atmosphere, 440 psig riser pressure, and approximately 72,000 gpm water flow.

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2. Current plans call for enrichment sufficient to provide 300 added inhours of reactivity. This enrichment will permit operation with approximately 1350 effective central tubes within 2 to 3 months after start-up, after first passing through a reactivity minimum of 1235 effective tubes approximately 2 to 4 weeks after start-up caused by samarium build-up.
3. No appreciable risks should be encountered at operation with maximum tube powers of 425 kw provided ample time is allowed between power increases to verify that no unusual conditions have arisen.
4. Operation at tube powers above 425 kw per tube results in radiation fields greater than any which have been experienced in the past except during infrequent periods of transient operation. Higher radiation fields may conceivably alter the relationship between factors now thought to govern slug corrosion, distortion, and failure. Because of these risks, powers above 425 kw per tube should be raised stepwise with provisions made for monitoring corrosion rates and metal condition between increases in power.
5. The maximum power to be attained will be that resulting from the minimum limit as outlined below. The minimum limit, as shown, appears to be the ruptured slug limit. While this limit is the most realistic which can be computed at this time, it may be unduly conservative since it is based on experience with metal manufactured at least six months ago, and assumes that the enlarged annulus will not affect the ratio of stuck ruptured slugs to total ruptured slugs. Granting that it will be exceedingly difficult to predict the benefits to be derived from the above mentioned effects, it is perhaps not proper to place undue emphasis on this limit at the present time. It will be necessary to revise the limit periodically in the light of the most recent experience prior to C Pile start-up and to re-examine the limit periodically as operation continues.

Tube Power Limits at C Pile

<u>Limit Designation</u>	<u>Allowable Tube Power</u>	<u>Basis</u>
Vapor Binding	340 kw	440 psig riser pressure
Graphite Temperature	1200 + kw	410°C maximum temperature, no fringe enrichment, adjustment of gas atmosphere between 100 per cent CO ₂ and 100 per cent He allowable
Slug Corrosion	700 kw	85°C allowable maximum tube cooling water outlet temperature (currently in use at existing piles)
Slug Core Temperature	700 to 900 kw	550°C maximum allowable slug core temperature to prevent phase transformation
Ruptured Slug Rate	480 kw	Point where production gains from increasing tube power are equal to production losses due to increased number of ruptured slugs brought on by increasing tube power

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DETAILS AND DISCUSSION

Initial Operation

Recommendations have been made to operate C Pile with a riser pressure of 440 psig and a resulting water flow rate of 72,000 gpm. While such riser pressure and water flow rates do not appear to be necessary when maximum tube powers are below 700 kw, they have been recommended to provide extra cooling for the fuel pieces. It is thought that this may lower the ruptured slug incidence rate.

From the standpoint of graphite thermal conductivity change and physical expansion it is desirable to maintain C Pile graphite at maximum allowable temperatures. For this reason, until experience indicates the tube powers at which helium is required to keep graphite temperatures below 410°C, a 100 per cent CO₂ atmosphere is desirable.

Enrichment and Reactivity

Differing enrichment programs for C Pile are under study. The program which seems most firm is one for which materials have been ordered. Under this plan the enrichment will consist of approximately 10 Kg of U-235 in the form of Uranium-Aluminum alloy pieces (4.125 per cent Uranium which is 93 per cent U-235). This will be distributed in approximately 30 tubes on a radius of 14 lattice units and should contribute approximately 300 inhours of reactivity.

It is expected that the cold clean reactivity, with 300 inhours of enrichment as described above, will vary as shown on the graph on page 10. This graph was extrapolated from H and DR data.

The approximate number of effective central tubes will reach a low of 1235 at the first reactivity minimum and a high of 1415 at the first reactivity maximum and will thereafter oscillate about a value of 1400 (1350 - 1450). While it is understood that proposals to modify the reactivity fluctuations are under study, these have not been taken into consideration in predicting reactivity values. Similarly, while it is understood that the desirability of even greater enrichment is being considered, it is assumed that only 300 inhours of enrichment will be provided continuously.

Operation at Tube Powers below 425 kw

H Pile has operated with maximum tube powers of 425 kw over extended periods with no unusual effects, hence it appears that C Pile can be taken to comparable tube powers without excessive risk. This is contingent on close monitoring during power increases to the 425 kw per tube level to make sure that non-cumulative factors such as shield temperatures do not exceed specifications or prove to be limiting. Power increases above tube powers of 200 kw should be at rates of perhaps 75 kw per week, thus allowing ample time for equipment verification and study of other effects after each 75 kw increase in maximum tube power.

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Operation at Tube Powers above 425 kw

Operation at maximum tube powers in excess of 425 kw brings about radiation fields in the central core of C Pile which will exceed those experienced in the past during normal operation. It appears doubtful that higher radiation fields could appreciably affect the graphite, rods, or tubes in an unforeseen manner. Moreover, during recoveries from emergency outages, maximum tube powers markedly in excess of 425 kw have existed for short periods without causing any particular troubles.

Prolonged operation at tube powers greater than 425 kw may act in a cumulative manner so as to bring about unforeseen difficulties. Increased radiation fields may alter the relationship between the variables now thought to control slug corrosion and will certainly bring about increased temperatures and temperature gradients in the fuel pieces. How this will affect slug distortion and slug failure rates cannot be predicted with accuracy.

Should these factors be seriously aggravated by tube power increases, it is conceivable that operation at some high power may result in spoiling the metal, and perhaps some tubes, in the central core. To minimize these risks a policy of intermittent power raises with frequent metal monitoring would appear justified. Metal monitoring cannot be expected to shed light on slug failure rates but should provide insurance against gross slug distortion and corrosion occurring before preventive action can be taken. Since less is known about the effects of tube power on slug distortion than on slug corrosion, this, presumably, is the larger risk of the two.

H Pile power, as indicated by the pile power meter, typically runs as much as 5 per cent above the power indicated at DR Pile. After applying a positive correction of 5 per cent to H Pile power due to inaccurate water flow measurement, and ignoring the differences in pile reactivity which may exist from time to time, it appears that the maximum tube powers at H Pile have frequently been 40 kw above DR Pile values. Apparently no gross differences in metal distortion or slug rupture phenomena exist between DR and H Piles. Increasing maximum tube powers in increments of 75 kw above powers of 425 kw is therefore not an unreasonable increase of the range of extrapolation existing in the past. If the maximum tube power will be limited to values below 500 kw, increasing tube powers above 425 kw in increments of 75 kw becomes of no significance.

Time allowed between power increases should be sufficient to permit observation of the effects of the latest power before increasing power again. Because slug corrosion and distortion are cumulative effects, it is felt that pilot discharges of approximately 10 tubes at monthly intervals are extremely desirable. These will permit observation of cumulative deleterious effects in sufficient time to forestall power increases beyond safe values. Only by waiting at least one month between power increases can the effects of power on slug distortion and corrosion be determined. Using these techniques, the likelihood of spoilage of core metal due to warpage and corrosion will be minimized.

Vapor Binding Limits

The technical basis for such limits is well known and need not be discussed here. C Pile pumping equipment and piping is capable of maintaining riser pressures of

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525 psig. Initial operation at a riser pressure of 440 psig has been recommended and will result in an allowable tube power of 840 kw. The relationship between allowable tube powers and riser pressures are as follows:

<u>Riser Pressure</u>	<u>Allowable Tube Power</u>
300 psig	550 kw
350	650
400	750
450	850
500	950
525	1000

Graphite Temperature Limits

It is planned that graphite temperature limits will remain at 410°C for all cases where more than 10 per cent CO₂ exists in the pile atmosphere. Pile atmosphere composition will be manipulated by adjusting its helium content to maintain approximately 410°C maximum graphite temperature. Precise graphite temperature - tube power relationships cannot be predicted at this time owing to uncertainties as to oversized tubes, sag of tubes between points of support and thermal conductivity of the graphite. Engineering approximations have been made, and while perhaps 15 per cent in error, result in the following relationships:

<u>Power per Tube</u>	<u>Per Cent CO₂ in Pile Gas to Give 410°C Maximum Graphite Temperature</u>
450 kw	100 per cent
600	75
800	50
1000	33
1250	20

These values, extrapolated from electrical analog results, have been checked against H Pile experience at 100 per cent CO₂ and were found to be reasonable.

From this it appears likely that unless extensive enrichment is used near the fringe regions of the pile, tube powers exceeding 1200 kw can be allowed. It should be noted that when maximum tube powers are below 450 kw the gas atmosphere should be 100 per cent CO₂.

Slug Corrosion Limits

It is difficult to predict what limits will be in effect at C Pile since slug corrosion limits are now in process of change.

The water to be used at C Pile will be coagulated with alum but at present it is not certain whether sodium dichromate will be used as an additive. This decision awaits the results of in-pile tests which seek to determine how eliminating

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sodium dichromate from alum coagulated water affects slug corrosion rates. It seems reasonable to assume that the water treatment finally chosen for C Pile will give corrosion rates equal to or less than the corrosion rates experienced with the ferric sulfate coagulated, sodium dichromate free water now in use at B, D, DR, and H Piles.

Maximum allowable tube cooling water outlet temperatures of 85°C are now permitted with the water in use at existing piles. Assuming this to hold true at C Pile, and using the individual tube water flow rates expected from a riser pressure of 440 psig (total pile flow of 72,000 gpm) the maximum allowable tube power, during summer water conditions, will be approximately 700 kw. The expected tube power-water flow relationships at C Pile appear such that fringe tubes will have lower outlet temperatures than central tubes. These relationships are illustrated below:

Orifice Zone	Approximate Water Flow Rate per Tube at 440 psig Riser Pressure	Tube Power Required to Give 85°C Outlet Temperature *	Tube Power Expected during Equilibrium Operation when Central Tube is at 700 kw
1	41.6 gpm	711 kw	700 kw
2	37.2	636	574
3	29.4	503	462
4	22.6	389	322
5	18.1	310	238

* Based on 20°C inlet water temperature

The ratio of fringe tube power to central tube power will be markedly altered if extensive enrichment is used.

Slug Core Temperature Limits

It is believed necessary that the uranium in the fuel slugs must be maintained in the alpha crystal phase. At 660°C, alpha uranium becomes transformed into beta uranium. To prevent this occurrence, a limit of 550°C has been placed on the fuel slug core temperature.

Uncertainties exist as to the thickness and thermal conductivity of the film which will coat the slugs and the effect of irradiation on the thermal conductivity of uranium metal. Since slug core temperatures depend on these factors, there exists an uncertainty as to tube powers which can be allowed. The range of likely values is indicated below:

Case	Allowed Tube Power	Basis for Allowed Power
I	900 kw	<ol style="list-style-type: none"> 100°C slug surface temperature. 20°C inlet water, 95°C outlet water. Film equivalent to 5 psig pressure drop in standard annulus at 20.4 gpm.

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<u>Case</u>	<u>Allowed Tube Power</u>	<u>Basis for Allowed Power</u>
I	900 kw	<ol style="list-style-type: none"> 4. Film conductivity estimated from (a) experimental data, (b) CMX data, and (c) computations by W. K. Woods and S. S. Jones. 5. Thermal conductivity of uranium from Kumiansky. Assumed no change in thermal conductivity due to irradiation.
II	800 kw	Same as Case I except assuming film twice as thick and with $1/2$ the film thermal conductivity.
III	800 kw	Same as Case I except assuming thermal conductivity of irradiated uranium to be 10 per cent less than virgin uranium.
IV	700 kw	Cases II and III combined.

The exact value for this limit will be determined when data concerning film thickness and conductivity become available.

Ruptured Slug Limit

An analysis of expected ruptured slug incidence rates at C Pile has been prepared by L. W. Lang and appears as an appendix to this report. From the ruptured slug incidence rates forecast on the basis of H Pile experience with Group 8 Metal and trends indicated by B, D, DR, and F Pile experience with Group 7 Metal, it appears that maximum tube powers exceeding 480 kw (corresponding to pile power level of 650 MW with 1350 effective tubes) may not be economical. The predictions indicate that tube powers in excess of 480 kw bring about a number of ruptured slugs sufficient to counterbalance the production gained by the increase in tube power.

The assumptions used in forecasting the ruptured slug incidence rates are clearly stated and, in general, assume that no gain will result from (1) improved metal produced prior to C Pile start-up, (2) increased water flow through the process tubes, and (3) larger annulus size. The extent of the reduction in the ruptured slug incidence rate which may result from the above three factors is difficult to estimate, and it is even conceivable that the ruptured slug rate at C Pile could be aggravated by increased water flow and annulus size.

Ruptured slug incidence rates appear to increase markedly with tube exposure and lowering the goal exposure from 600 MWD/T should result in lower ruptured slug incidence rates. Whether it is desirable to do so depends on such factors as (1) metal availability, (2) urgency of demand for product, (3) metal caming capacity,

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and (4) costs of preparing and recycling metal. A study should be initiated to determine whether or not it is sound practice to increase the production rate at C Pile at the expense of higher metal throughput.

CONCLUSIONS

1. Assuming 300 inhours of enrichment will be provided, sufficient reactivity will be available after 2 to 3 months of operation to permit operation with between 1750 and 1450 effective central tubes.
2. After shakedown and verification of the reliability of equipment, maximum tube power should be increased to 425 kw.
3. Subject to verification after each power increase that non-cumulative effects depending on power level are not limiting, and providing that limiting powers are materially in excess of 500 kw per tube, power should be increased beyond 425 kw per tube in increments of 75 kw per tube.
4. At least one month should elapse between each incremental increase in power. After each month of operation at powers in excess of 425 kw per tube, approximately 10 tubes should be discharged to permit monitoring of slug distortion and corrosion.
5. Power should be increased in such a manner until the lowest limiting power is reached. It appears likely that ruptured slug incidence rates will determine the lowest limiting power. Where ruptured slug incidence rates are concerned, the limiting power is that power where the predicted production losses due to ruptured slugs equal the gain in production resulting from increasing power. The ability to predict with precision the ruptured slug incidence rates at C Pile is limited. Present calculations based on extrapolations of relationships not yet verified at high levels, indicate that the optimum maximum tube power would approximate 480 kw per tube. Predictions of the expected ruptured slug incidence rate at C Pile should be continually revised in the light of latest available experience.
6. A study should be initiated to determine the advisability of the discharging of the central core of C Pile at exposures less than 600 MWD/T in order to lessen the ruptured slug incidence rate and thus permit an increase in allowable tube power.

SOURCES OF INFORMATION

This report was compiled from information made available by other members of the Pile Technology Unit. Sources of information are indicated below:

Information

Source

Vapor Binding Limits

R. G. Vandervater

EW-24273, "C Pile Recommended Flow-Pressure Characteristic Curve and Orifice Pattern",
H. G. Spencer to G. E. McCullough, 4-29-52.

Slug Core
Temperature Limits

H. H. Greenfield

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Information

Source

Graphite Temperature
Limits

L. P. Bupp
M. Altman

HDC-2157, "An Analysis of the Suitability of
Various Coring Patterns for Inclusion in C
Reactor", G. M. Roy and R. K. Andersen,
4-13-51.

Slug Corrosion Limits

R. J. Shields
R. G. Vandewater

HW-24273, "C Pile Recommended Flow-Pressure
Characteristic Curve and Orifice Pattern",
H. G. Spencer to G. E. McCullough, 4-29-52.

Reactivity and
Enrichment

R. O. Brugge
G. C. Fullmer

L. H. McEwen

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ENGINEERING DEPARTMENT

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P. H. Leimker

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ESTIMATED C PILE COLD CLEAN REACTIVITY

(Assumes 300 inhours of enrichment)

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APPENDIX

C PILE POWER LIMITATIONS DUE TO RUPTURE RATES

INTRODUCTION

Any prediction of rupture rates for C Pile will be limited in accuracy since the data on which it must be based are not directly applicable to C Pile operation. The largest volume of slug rupture data is that obtained from Group 7 Metal, but C Pile will be loaded with material of later manufacture which has been demonstrated to be less prone to rupture.¹ Any application of past data to predict future rates will be further limited by increased water flows, and the effect of changed water treatments. Since H Pile has operated at higher powers than the other piles, and with slightly increased water flows, its operating experience should be indicative of what may occur at C Pile. Because of the H-10 loading, however, rupture data from H Pile obtained prior to September 1, 1951 cannot be used for comparative purposes. Thus the largest bulk of data is from B, D, DR, and F Piles, and trends must be established from their rupture experience. These trends must be extrapolated to C Pile at different proposed power levels. The predicted ruptured slug incidence rate at C Pile is, then, based on Group 7 trends and brought up-to-date for the improved metal by the rupture experience at H Pile for Group 8 Metal.

RECOMMENDATIONS

A conservative interpretation of rupture experience to date indicates that the break-even point for production gains due to increased power and predicted production losses due to ruptures appears to be near 650 MW or about 480 KW per tube for C Pile. Further analysis of rupture experience with material more nearly like that which will be charged into C Pile may lead to a revision of the prediction before pile start-up. Four to five months of C Pile operation should furnish adequate rupture rate data to permit a realistic power limit to be ultimately established.

DISCUSSION

Rupture Rate versus Tube Power

The overall rupture rate increases with tube power. The data for Group 7 Metal are plotted in Figure 1. The rupture rate is also shown for cap failures and uranium cleavage failures. The data are plotted using over-lapping tube power ranges, and the curves are a visual approximation of the best straight line connecting the points. The uranium cleavage failures show a more pronounced increase with tube power than do the cap failures.

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1. HW-24247, "Comparison of Rupture Rates in Group 7 and Group 8 Material", L. W. Lang to File, 4-23-52.

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Figure No. 1

Rupture Rate, R/N , vs. Tube Power

1632 Tubes from Central Orifice Zones B, D, F, DR

1517 Fringe Tubes from B, D, F. Ruptures from

April 1, 1951 To March 31, 1952

All Tubes Based on Nov. 1951 Tube Power Distribution

Group 7 Metal

* R = No. Ruptures N = No. Tubes Discharged

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In Figure 3 the rupture rate is plotted against actual slug power for those ruptures where this information was available. The cleavage failures show a more pronounced increase with slug power, whereas the cap failures demonstrate a rupture rate decrease at maximum power.

Rupture Rate for H Pile

There have been nine ruptures in H Pile Group 8 Metal out of 700 tubes discharged or near 600 MWD/T. If the ruptures had been predicted on the basis of Figure 2 for Group 7 Metal with no improvement factor, 52 ruptures would have been expected. Group 8 Metal rupture experience for H Pile shows roughly an improvement factor of six over the Group 7 Metal. Thus, if the rates indicated in Figure 2 were divided by a factor of six, the rupture rates would be applicable to H Pile.

Type of Rupture

Since the amount of down-time required to remove a cap failure from a pile is much less than that required for other ruptures, the type of rupture that occurs will be the determining factor on how many failures can be tolerated.

Although the majority of failures in B, D, F, and DR Piles have been cap failures, this type failure can generally be pushed from the process tube and does not necessitate the pile being down for an extended period of time. The uranium cleavage failure, however, often is stuck in the process tube and cannot be removed in time for the pile to recover. The non-classified type of rupture also averages considerably more down-time than that required for cap failures.

Of particular interest, and bearing on the question of how many ruptures can be tolerated, are side failures that have happened at H Pile in which the process tubes have been penetrated and a water leak resulted. This type of failure has occurred in higher power tubes and resulted in large losses of production.

In Figure 2 the rupture rate of Group 7 Metal is plotted versus tube power for the uranium cleavage type failures, cap failures, and total failures. If these rates are extrapolated for the higher anticipated powers of C Pile, it is evident that the cleavage type failure extrapolates to a higher rupture rate than the cap failures at increased tube powers. The quality of the uranium rods, and rigorous inspection of machined pieces, however, may eliminate many of these failures.

The type of failures expected may be further indicated by comparing the type of rupture that has occurred in H to those that have occurred in other piles. Table II shows this listing.

C Pile Predicted Tube Power Distribution

Tube power distributions projected for C Pile are based on a distribution for H Pile at 550 KW power level. The predicted tube powers are secured by increasing

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Figure No. 2

Rupture Rate, R/N , vs. Tube Power

Tube and Ruptures same as Figure No. 1
Extrapolation Indicated by Dotted Line
Group 7 Metal

* R = No. Ruptures

N = No. Tubes Discharged

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Figure No. 3

Rupture Rate, R/N , vs. Slug Power

1632 Tubes .240, .285 Orifice Zones B, D, F, and DR
Group 7 Metal Charged after January 1, 1951
1517 Fringe Tubes Considered B, D, F for Group 7
Ruptures Occurring from May 1, 1951 to April 30, 1952
* R = No. Ruptures
N = No. Slugs Charged

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tube powers by the same percentage as pile powers are increased. The predicted number of tubes in each power grouping are shown in Table I.

Production Losses

Whether a larger process tube annulus would appreciably change the ratio of stuck ruptures to those that can be pushed is largely conjecture and is not used as a basis for proceeding to higher levels.

Each stuck rupture is credited with 36 hours of lost production. Twelve hours of useful down-time are deducted from the 36 hours for the first three stuck slugs occurring in a given month since this much time would normally be used for charge, discharge, and maintenance. Ruptures that can be pushed in scram recovery time are credited with two hours of lost production.

Metal Quality

The only proven appraisal of metal quality as to rupture resistance has been actual in-pile experience. There is roughly, an eight month time lag between date of metal manufacture and pile discharge. The metal destined for charging in C Pile may have been improved, but such improvement is not evident at this time, and cannot be used as a basis for proceeding to higher levels.

Extrapolation to C Pile

In Figure 2, the Group 7 rupture rate experience is plotted on semi-logarithmic paper, and a slope established which is then extended to the tube power ranges expected for C Pile. The exponential increase in rupture rate with tube power thus assumed is felt to be a conservative interpretation of these data. If the rupture rates thus established are corrected in light of H Pile experience, and applied to the predicted tube power distribution for C Pile, the number of ruptures to be expected at various power levels are obtained, as shown on Figure 4. The loss in production to be expected from these ruptures can be estimated, and the net production plotted as a function of pile power.

SUMMARY

The power limit of 650 MW (480 KW/tube) is based on a predicted rupture rate of five tubes per month after the initial build-up of tube exposures, and that three of these ruptures will be stuck.

The predicted rupture rate is based on the following assumptions:

1. Rupture rates increase exponentially with tube power.
2. This exponential increase can be applied to the improved metal that will be used in C Pile by using the slope of the exponential curve for Group 7 Metal but decreasing the rupture rate by a factor secured from the rupture experience of H Pile.
3. More than 50 per cent of the ruptures will be stuck.
4. The increased tube diameters for C Pile will not appreciably change the ratio of stuck ruptures to those that can be pushed.

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5. No further improvement in the metal will be made between now and the charging of C Pile.

The optimum power is obtained from Figure 4 using the following operating assumptions:

1. Thirty-six hours production are required per month for charging and maintenance of the pile.
2. Thirty-six hours of production are lost for each stuck rupture, but 12 hours of this time per rupture for the first three ruptures in a month can be used for normal maintenance and charging.
3. Two hours production are lost for each rupture that can be pushed from the process tube.

It is felt that re-examination of subsequent Group 8 rupture rate experience prior to C Pile start-up should permit a more precise estimate of the local power limit for C Pile. Maximum net production should be possible after initial operation of C Pile has established the rupture rates directly.

LW Lang

PILE TECHNOLOGY UNIT
ENGINEERING DEPARTMENT

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P. Pfeiffer

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Figure No. 4

Plot of Predicted Gross Production,
Net Production, and Production Losses
from Ruptures for C - Reactor at
Different Power Levels

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TABLE I

PREDICTED TUBE POWER DISTRIBUTION FOR C FILE

<u>Tube Powers</u>	<u>No. Tubes 555 MW</u>	<u>No. Tubes 600 MW</u>	<u>No. Tubes 650 MW</u>	<u>No. Tubes 700 MW</u>
80-99	25	16	10	6
100-119	45	39	17	13
120-139	50	48	35	25
140-159	60	58	38	33
160-179	70	57	45	37
180-199	90	65	53	43
200-219	100	72	79	53
220-239	100	92	84	73
240-259	100	93	86	78
260-279	100	99	92	85
280-299	100	92	91	85
300-319	100	91	84	83
320-339	110	92	84	78
340-359	180	97	84	77
360-379	340	143	88	78
380-399	340	246	112	79
400-419	50	313	175	91
420-439		214	249	124
440-459		33	252	168
460-479			173	230
480-499			29	241
500-519				154
520-539				26
TOTALS	1960	1960	1960	1960

TABLE II

TYPE OF RUPTURE AND DOWN-TIME REQUIRED FOR GROUP 8 METAL

	<u>B. D. F. DR Piles</u>		<u>H Pile</u>	
	<u>No. Ruptures</u>	<u>Down-Time</u>	<u>No. Ruptures</u>	<u>Down-Time</u>
Cap Failures	14	16 of 32	3	5 out of 9
Uranium Cleavage	11	Required	1	Required
Side Failures	3	Extended	2	Extended
Non-Classified	4	Down-Time	3	Down-Time

DECLASSIFIED

**DATE
FILMED
1/10/93**