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HANFORD TECHNICAL RECORD

100 AREA PROCESS IMPROVEMENT PROGRAM FOR THE PERIOD NOVEMBER, 1954 THROUGH APRIL, 1955

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November 19, 1954

100 AREA PROCESS IMPROVEMENT PROGRAM FOR THE PERIOD NOVEMBER, 1954 THROUGH APRIL, 1955

INTRODUCTION

This is the second of a series of documents issued quarterly. The documents present, for critical examination by management and for the information of related groups, that portion of the future 100 Area technical program which relates directly and more or less immediately to the Technical-Manufacturing efforts to increase both power levels and production. An attempt is made to describe and justify the key production tests planned for the following six month period. Only those tests necessary for the relief of technical and process limitations and vital to the slug improvement program are included. Best estimates of changes in current Process Specifications during the ensuing six months are also given. To further longer range planning, power level forecasts based on foreseeable changes of technical limits and scheduled physical changes of the water plants and reactors are extended several years into the future.

Prior to the issuance of each program document, responsible field personnel in 100 Area Technical and Manufacuring review and approve the program portion of the contents. Signature approval is also requested of the Manager, Manufacturing and the Manager, Technology. This management approval will signify that those 100 Area production tests

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specifically identified in the program for the coming six months period may be authorized and approved by the Manager, Reactor and the Manager, Pile Technology even though the tests may permit operation outside of process limits. Any exception to this authorization is specifically signified in the body of the report. For slug evaluation tests, the signature of the Manager, Fuel Technology, will also be required.

SUMMARY AND FORECAST

Figures are attached which plot a month-by-month estimate of the maximum possible equilibrium power levels for each reactor through December 1947. The limits which restrict the power level are shown, and each is discussed briefly.

The table on the following page summarizes the power levels shown in the Figures. Columns headed "Maximum" give the maximum power levels that could exist under the following conditions: (1), power levels are limited by 105°C tube outlet temperatures until December 1, 1954; (2), power levels are limited by 95°C bulk outlet temperatures after December 1, 1954 except for the C Pile; (3), power levels at C are limited by 115°C tube outlet temperatures after December 1, 1954. Discussion in the body of the document presents the basis for these assumptions. Columns headed "Act." give realistic estimates of the maximum power levels that could exist when all the limitations to power levels are in effect. The realistic estimates and the figures are also based on conditions as follows:

1. In line with metal availability and 200 Area capacity, the B, D, DR, F, and H Reactors are operated at 900 MWD exposure. The C Reactor is operated at 200 MWD/T exposure. The first loading of the K Reactors is discharged at 900 MWD/T.* As this load is discharged, cored slugs (See 2 below) are charged. The power level is raised as allowed by the ruptured slug limit for solid slugs as they are discharged from the higher powered regions. The goal exposure for the cored slugs is lowered as the power level increases so that the solid slugs in the fringe continue to be limiting until they are all discharged or until a 95 C bulk outlet temperature becomes nominally limiting. It is believed that more than enough uranium will be available to allow operation of the plant in the manner described. If an excess occurs before cored slugs become available for the old reactors, the goal exposure at these reactors could be lowered somewhat to allow increase of their power levels. However, for the table, the conservative assumption has been made that the uranium supply will just equal the consumption under the proposed exposure schedule.

2. Cored slugs, which are assumed to have a rupture rate a factor of 100 below that of 19-M material, become available for charging according to the following schedule:

Time	No. of 8" Slugs/Month	Description of Preceding Interval
Dec. 54	1000	
Mar. 55	6000	Gradual Change
Apr. 55	20000	Step
Aug. 55	50000	Gradual Change
Jan. 56	50000	No Change
Feb. 56	Entire Production excluding C Reactor Consumption	

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*From the present information regarding K Pile start-up, it is likely that the power levels will be higher and the goal exposures lower than those presented in this document. Subsedocuments in this series should allow more realistic forecasts for K after initial performanc is determined. (Added 12-10-54.)

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TABULAR SUMMARY OF MAXIMUM EQUILIBRIUM POWER LEVELS

	B		C		D		DR		F		H		KW**		KE**	
	Act.	Max.	Act.	Max.	Act.	Max.	Act.	Max.	Act.	Max.	Act.	Max.	Act.	Max.	Act.	Max.
1954																
Nov.	910	980	1630	1630	900	900	760	880	910	940	960	960				
Dec.	910	1060	1750	1850	910	1130	780	940	910	990	980	1140				
1955																
Mar.	910	1130	1850	1940	1030*	1190	780	1170	910	1070	980	1310	1620	3260	1620	3260
Sept.	910	960	1610	1770	910	1030	910	1000	910	920	980	1130	1860	2800	1620	2800
1956																
Mar.	910	1130	1850	1940	910	1190	910	1170	910	1070	1040	1310	3500	3840	3050	3840
Sept.	910	960	1720	1720	1000	1030	1000	1000	920	920	1110	1130	3300	3300	3300	3300
1957																
Mar.	1550	1650	1850	1940	1550	1650	1500	1650	1070	1070	1340	1340	3500	3840	3500	3840
Sept.	1420	1420	1720	1720	1420	1420	1420	1420	1060	1060	1220	1220	3300	3300	3300	3300

*Exposure reduced for production test 105-546-E on as many tubes as is necessary.

** (Added 12-10-54)
From the present information regarding K Pile start-up, it is likely that the power levels will be higher and the goal exposures lower than those presented in this document. Subsequent documents in this series should allow more realistic forecasts for K after initial performance is determined.

[redacted]

Since little production would be gained, incentive to operate the C Reactor with cored slugs is small. The ruptured slug limit is adjusted according to predicted performance of cored slugs. The cored slugs are used first in the K Reactors where the most can be gained, and are used next at the H Reactor.

3. The schedule for the venturi outages, Project CG-558, and the reactor flow rates achieved is that shown in the section titled "Reactor Flow Rates".

4. The riser pressure at the K Reactors is raised in January of 1956 to obtain a flow rate of 165,000 gpm.

5. Enrichment is added as necessary to maintain the following numbers of effective tubes.

Time	B, D, F	DR	H	C	KW,KE
With J Load		1200			
Pre CG-558	1350	1350			
Post CG-558	1450	1450			
Always			1450	1540	2400

6. It is assumed that action is taken, when necessary, to ensure that the tube boiling limit is always above some other limitation.

REACTOR FLOW RATES

Tube power levels attainable under all limits except the slug rupture limit increase almost directly as tube flow rates can be increased. The best way for the available water to be distributed between the tubes is a function of the nominal and transient tube power distribution and of the characteristics of the active operating limits. There are now two separate programs for increasing reactor flow rates. These are the Venturi program and Project CG-558. The purposes of the Venturi program are (1) to increase the reactor flow rates to a maximum capacity of the presently installed pumping equipment and (2) to distribute this water in the best manner. Project CG-558 will increase reactor flow rates to the expected capacity of the filtration equipment except at F and H, where small increases are planned.

The following table shows expected flow rates after the two programs and presents best estimates of outage dates. Dates are also shown for HSR thimble removal and rod replacement outages, and for the adjusting of Panellit gages at the K Reactors for maximum flow rates.

Reactor	B	C	D	DR	F	H	KE	KW
Flow								
Present	--	--	48,000	43,000	--	52,000	--	--
Venturi	48,000	88,000	51,000	50,000	46,000	56,000	140,000	140,000
CG-558	71,000	--	71,000	71,000	52,000	61,000	--	--
Panellit Adj.	--	--	--	--	--	--	165,000	165,000
Outage Schedule								
Venturi	--	--	Dec. '54	Feb. '55	--	Mar. '55	--	--
HSR replacement	Mar. '55	--	Feb. '55	Feb. '55	Apr. '55	Mar. '55	--	--
CG-558	Sept '56	--	Jan. '57	Nov. '56	May '57	Mar. '57	--	--
Panellit Adj.	--	--	--				Jan. '56	Jan. '56

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GRAPHITE LIMITS

The present graphite limits are based on considerations of pile life and production rates. Two phenomena must be considered in controlling operating variables. Graphite burnout or transport rates become worse with increased temperature while the pile distortion rate is aggravated by low temperature operation. The maximum temperature to which the graphite stack can be raised has been set at what is currently thought to be the optimum value to allow maximum production and a controlled allowable reaction of the graphite with the pile atmosphere. The gas composition, namely the allowable percentage of helium, has been chosen on a sliding scale to permit optimum heat generation in the graphite consistent with permissible distortion trends. These values have been set at 500 C maximum at all reactors and up to 40 per cent helium at B, D, F, Reactors and 50 per cent at H and DR Reactors. Because of the coring pattern at C and K Reactors which is designed to compensate for effects of graphite growth, no maximum percentage helium has been set. At the present time both graphite stack distortion and burnout are routinely monitored.

To relax the existing graphite limits, full-reactor tests are needed and at the present time, four have been planned. They are (1) a burnout test at the C Reactor, (2) a test of the effect of helium on distortion at the D Reactor, (3) an expansion-annealing-cycle test at the B Reactor, and (4) an inert atmosphere test at the F Reactor. The tests at the B and D Reactors require high reactor and tube power levels. To attain these levels, the low inlet water temperature of Winter and Spring is required, and the D Reactor must be reorificed. By ~~mid-Summer~~ Fall of 1955, enough additional information will have been developed from these tests to allow formulation of graphite limits high enough to permit full utilization of the water to be supplied by Project CG-558. The graphite limits as shown in the attached graphs are specifically based on the successful completion of the burnout test at C Pile and the distortion test at D Pile.

Planned Production Tests (See Section on Production Tests, pp.10)

1. Burnout Test - C Reactor
2. The Effect of Helium on Distortion - D Reactor
3. Expansion-Annealing-Cycle - B Reactor
4. Inert Atmosphere - F Reactor

BOILING LIMITS

Individual Tube Limits - The restrictions which this limit places on the power levels have not been included in the figures because steps can and will be taken, when necessary, to raise the limit above others. Based on data from the tube boiling mock-up, this limit has recently been raised. It now restricted the allowable temperature rise across a tube such that should the tube flow rate drop, the Panellit gage trip would initiate an automatic shutdown before unstable boiling starts in the tube. Previously, the saturation temperature in the rear crossheader was used as the point of transition to unstable tube boiling. With the new limit, the magnitude of the allowable temperature rise depends on the following:

1. The rear header pressure. A higher rear header pressure gives a higher allowable temperature rise.

2. The sensitivity of the Panellit pressure to changes in tube flow rate. This in turn depends on the relationship of the Panellit pressure to the front and rear header pressures, which is again dependent on the characteristics of the installed orifice or venturi.

3. The proximity of the high and low pressure trips to the Panellit pressure. Trips set closer to the Panellit pressure give a higher limit.

4. The normal tube flow rate. Tubes with higher flow rates can operate stably at higher temperatures.

5. The type of screen in front of the orifice or venturi. If (1) a large-meshed cone-screen or cross-wire-type screen is provided, (2) the Panellit trip range is held to less than 60 psi, (3) cross header low-pressure trips are put into operation, and (4) the low pressure trip is kept above 75 psig, the limitation of the temperature rise by the proximity of the low pressure trip is eliminated.

A number of things can be done to increase the allowable temperature rise. Orifices can be placed at the ends of the upper rear crossheaders to increase their operating pressure. The Panellit trips can be maintained close to the Panellit pressures by some system of dial flagging plus frequent monitoring. These two actions will probably be sufficient to keep the boiling limit above the slug rupture limit. Large mesh screens can be installed. Installation is planned at D, DR and H for the venturi outages. With these screens in place, the high trips may be lowered and maintained close to the Panellit pressure, and the safety factor presently used to conteract screen plugging can be eliminated. As a result of the planned alterations of the tube corrosion limit, the re-orificing of the venturi outages will be such as to cause the fringe tubes to operate considerably cooler than the central tubes. This will have the effect of increasing the boiling limit, because the upper fringe tubes have the lowest boiling limits. Although it will probably not be necessary before Project CG-558, all Panellit pressures can be lowered, provided large-mesh screens are installed, by proper design of the orifices and venturies. This will increase the Panellit pressure sensitivity in relation to the high trip, and so increase the allowable temperature. Also some refinement and increase of the limit is expected to result from further experimentation with the tube boiling mock-up.

Rear Piping Limit - If the bulk water temperature in the rear piping exceeds the saturation temperature at atmospheric pressure, two phase flow will result which could reduce tube flows. Reduced tube flows would cause higher temperature which would cause more vaporization and still less flow. Mechanical damage from vibration could also result. Such unstable conditions are to be avoided. The conditions under which this instability results are unknown at the present time, but a bulk outlet temperature of at least 95 C can be tolerated. The present 92 C bulk water limit is very conservative and revision to 95 C by December 1, 1954, is planned.

Specific Tube Power Limit - Increases in specific tube power have been made cautiously under production test conditions and the slug end cap temperature limit has been increased stepwise and finally removed entirely. No harmful end cap corrosion phenomena were observed. Experience indicated, however, as discussed under Slug Rupture Limits, that extended operation of present slugs at high levels and concentrations was not practical. It is believed that no other specific tube power limit exists below a 120 C outlet temperature.

It was formerly believed that slug core temperature could not be allowed to exceed the β allotropic transformation temperature of 661 C. For recent test irradiations of enriched uranium slugs, calculations have shown that core temperatures above 660 C should have existed. Examination of the irradiated slugs did not evince damage by

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allotropic transformation. Consequently, it is believed that a limitation based on this transformation may not be necessary, but that operation of solid slugs above this temperature may result in an increased rupture rate. It is probable that cored slugs would be less seriously affected by the transformation. Internally-externally cooled slugs, now being developed, should operate at such a low temperature that transformation would not be a problem.

REACTIVITY AND ENRICHMENT LIMITS

The feasibility of fringe tube enrichment at B, D, DR, and F Reactors is now undergoing study. The degree of enrichment allowable while maintaining adequate safety margins will be determined upon the conclusion of PT 105-554-A and the completion of calculations. It is expected that the tests and the analysis of the data will be completed by January 1955. For the purposes of forecasting, it has been assumed that sufficient enrichment is allowed to utilize the full water plant capacity at a bulk water temperature of 95 C. One effect of enrichment is to increase the number of effective tubes. The number of effective tubes is defined as the reactor power level divided by power output of the maximum tube. Present values of 1350 are increased to 1450 after Project CG-558.

SLUG RUPTURE LIMITS

Slug rupture frequency affects the power level only because it is believed that by restricting the maximum level, the efficiency of operation will be higher and thereby the production maximized. The mechanisms of rupture and/or conditions leading to rupture are open to conjecture. However, from rupture rate data, a correlation of cleavage-type rupture rate, tube exposure, and tube power has been developed, and a specification has been written which attempts to limit the tube power for each goal exposure to a value resulting in near maximum production.

To take advantage of the extra water which will be made available by Project CG-558, a considerable improvement in slug quality is needed. An apparent alternative, reduction of the goal exposure, is not possible because sufficient uranium and 200 Area capacity will not be available. Slug improvement before that time would allow power increases, especially at the K Reactors. Many production tests are planned to test new and modified slugs, and it is certain that greatly improved slugs will be available in quantity by then. Results obtained from the irradiation of a few solid and cored enriched uranium slugs show the cored slugs to have greatly improved resistance to cleavage. The cored slug cleavage rupture rate appeared to be lower by a factor considerably over 100.

A graph on the next page shows the relationships of slug quality, power level, goal exposure, uranium throughput, and production for the K Reactors. The graph is based on the incurrence of five cleavage type ruptures per month, 2400 effective power tubes, a charging rate of twelve tubes per hour and a reasonable allowance for charging during rupture downtime. The extreme effect of slug quality on all other factors should be particularly noted. When slug quality is increased, power level, exposure, and production can all go up and, at the same time, throughput can be decreased. The rapid increase in throughput as exposure is decreased is evident. Because uranium supply and 200 Area capacity limit throughput, slug quality is a primary limit to increased exposure and therefore production.

For the power level forecasts, cored slugs have a cleavage rupture rate 100 times less than eight inch 19-M slugs have been assumed to be available on a schedule believed to be achievable.

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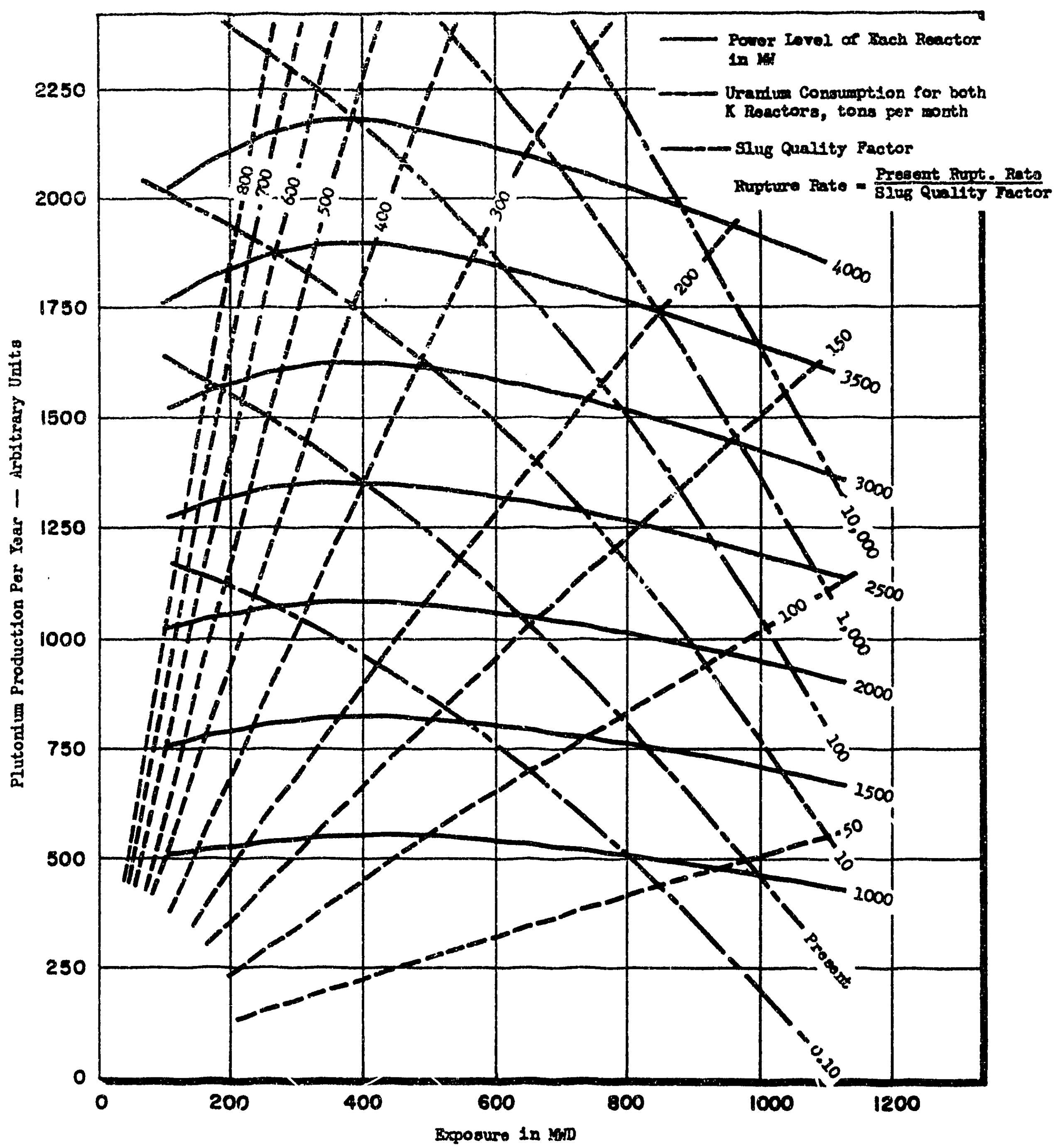

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Planned Production Tests (See Section on Production Tests pp. 12)

1. Cored Slugs
2. Unbonded and Mechanically Bonded Slugs
3. Alloyed Slug Cores
4. Internally and Externally Cooled Slugs
5. Insulated Slugs
6. Basic Slug Behavior Information

SLUG CORROSION LIMIT

The slug corrosion limit is based on the results of many in-pile slug corrosion tests and upon a maximum allowable uniform penetration of the can wall of ten mils. From the data, development of a correlation of slug power, calculated slug surface temperature, and slug corrosion rate has been possible. Using this correlation, the tube power, expressed by tube outlet water temperature and flow rate, and the goal exposure define the corrosion limit.

It is expected that the slugs can be improved in their resistance to corrosion at or before the time their resistance to slug rupture is improved. Thicker can walls can be provided, particularly by new canning processes. Low pH water is expected to decrease slug corrosion rates. The forecast assumes that with the advent of cored slugs, slug corrosion limits at 900 MWD/T exposure will be raised above a tube outlet temperature equivalent to the 95 C bulk outlet temperature limit. Before the advent of cored slugs, slug corrosion will not be limiting except at the C Reactor because at the goal exposures predicted for operation, slug rupture limits are lower. However, slug corrosion limits for the predicted exposure have been put on the figures for all Reactors until the time cored slugs are changed, to show the relationship of this limit to the others. After the charging of cored slugs, the limit is, as previously stated, assumed to be above the 95 C bulk outlet temperature limit, but is not shown because its position above the 95 C limit is uncertain at the present time.

Planned Production Tests

1. Improved Water Quality
2. High Temperature Slug Corrosion
3. Zirconium Tests

TUBE CORROSION LIMIT

The current process tube corrosion limit is a tube outlet temperature of 105 C. A new tube operating at this limit is estimated to have an average outlet temperature near 95 C and a minimum expected life of four years. The estimate is based on measurements on tubes that have been removed from the reactors and on the results of laboratory corrosion tests. The corrosion rate doubles for every ten degrees increase in temperature.

To give the minimum total corrosion rate in all the tubes of the reactor, the water must be distributed among the tubes so that tubes with lower power levels have lower outlet temperature than higher powered tubes. However, requirements of limits other than tube corrosion may necessitate a water distribution not giving the minimum corrosion rate. For any given water distribution, i.e., "orificing", and for a given nominal tube power distribution, increasing the maximum outlet temperature increases the reactor power level almost directly but also increases the overall tube corrosion rate. Considering a long operating period, increases in the tube corrosion rate increase the number of process tubes which must be replaced per unit time. This not only costs money but also reduces reactor operation time. Thus, for a maximum tube outlet temperature proceeding from a low to a high value, production per unit time passes through a maximum and unit cost of this production passes through a minimum. The outlet temperature for maximum production is higher than is the temperature for minimum unit cost. It is believed that the optimum outlet temperature limit should be that which produces the minimum unit cost. Because of the variables which determine this optimum temperature, its value will be slightly different for different reactors. It has not been accurately determined at the present time but is expected to be near 115 C at the DR and H Reactors after the venturi program reorificing, and near this value at the K Reactor if 2400 effective power tubes exist as predicted. At the C Reactor, the optimum temperature is probably a little higher, and at the B and F Reactors, perhaps a little lower than 115 C. For the forecast graphs, it has been assumed that after December 1, 1954, the revised bulk outlet temperature limit of 95 C, presently 92 C, will be limiting except at the C Reactor, where a 115 C maximum tube temperature is used.

Increases in the tube corrosion limit beyond the presently calculated values near 115 C may result from increased information on high temperature tube corrosion, success of low pH water, use of different material for tubes and slugs, and management decision that more production would be desirable even at increased unit costs, should this limit based on minimum unit cost become restrictive.

Planned Production Tests

1. Improved Water Quality
2. High Temperature Tube Corrosion
3. Zirconium Tests

PLANNED KEY PRODUCTION TESTS

1. Full-Reactor Burnout Test

This test, which was originally planned for the H Reactor, has been shifted to the C Reactor. This shift was necessitated by the continued delay of the thimble-removal-rod-conversion program. The objective of the test is to investigate the effect of higher graphite temperatures on the burnout rates. The test would authorize the operation of the C Reactor at a maximum graphite temperature of 550 C with limits relaxed to 600 C within one lattice unit of the J-Q columns and to 650 C within a 13 tube diamond array of J-Q columns centered on tube 2785-C. These temperatures would be attained by reducing the concentration of helium in the reactor atmosphere.

If this test were run it is not clear whether goal exposures would have to be reduced to maintain product purity (n/g/s) within specifications. Theoretical considerations, based on expected Pu-240 increase with increased neutron temperature, indicate that a lowering of the present exposure goal from 205 MWD/T would be necessary for the duration of the test. Preliminary, sketchy, experimental information indicates that this conclusion may not be confirmed. A thorough study of product purity, reactivity gains, flattening enrichment changes, exposure and expected graphite temperatures is being made. Since there is presently some doubt as to the feasibility of doing this test at C Pile, for purposes of program planning it is not included for authorization in this document. If the above studies are favorable, the production test will be circulated separately for full management approval.

2. The Effect of Helium on Distortion

The full reactor test of the effect of helium on distortion at the D Reactor is designed to find the upper limit of helium concentration at a 450 - 500 C maximum graphite temperature. Should 550 C be too high a temperature for continued operation, it is important to determine the maximum amount of helium that can be used at 500 C. Increased helium concentration increases the gas heat conductivity thus permitting higher power levels at any particular maximum graphite temperature. However, increased helium concentrations will lower the graphite temperatures in the fringe regions even at higher powers thus tending to aggravate distortion. It is the fringe distortion that will be monitored closely in this test.

D Reactor operation is planned from December through April at 500 C maximum graphite temperature and 60 per cent helium. A constant tube power of about 750 KW is scheduled resulting in a pile power level of approximately 1025 MW, or 100 MW above the level to which the pile would otherwise be limited by graphite temperatures. In the event that the above power level is not sufficient to produce the desired test conditions, tube powers may be increased to 830 KW/tube and a corresponding power level of 1120 MW. This higher power level would have to be obtained by increased outlet water temperatures. In order not to exceed slug corrosion and rupture limits, metal exposures would be adjusted. To compensate for reactivity losses resulting from the decrease in average graphite temperature, approximately 20 "C" enrichment tubes are expected to be required.

3. Expansion-Annealing-Cycle

The successful operation of the cycling experiment at the B Reactor would provide a solution to any graphite problems that might result from Project CG-558 conditions in the event that continuous operation at high temperature and high helium concentrations is not feasible. Should this be the case, it might be necessary to operate during the winter at a helium concentration too high to prevent all graphite distortion. When lower power levels resulting from the higher inlet water temperature of the Summer exist, it would be possible to decrease the helium concentration, raise the average graphite temperature, and anneal the distortion.

The cycling test at the B Reactor would involve the expansion and subsequent annealing of the graphite stack to determine the feasibility of this method of distortion control. The Reactor would be operated at about 750 KW/tube or a power level of approximately 1020 MW from December through April. This represents no power change from present graphite limits. Operation would be at constant power level, and the helium concentration would be varied to change the graphite temperature thus causing expansion or annealing conditions. These would be a 400 C maximum temperature and 70 per cent helium for expansion and a 500 - 550 C maximum temperature with 25 - 0 per cent helium for contraction. Twenty or thirty tubes of enrichment may be required during the low temperature phase.

4. Inert Atmosphere

It is anticipated that sufficient data will be available by December, 1954, from the present and planned single-tube in-pile tests investigating the effects of two inert gas systems, (1) He-CO_2 - CO and (2) HE-N_2, to permit a full reactor test of one of these systems starting in January, 1955. The goal of these tests is the elimination of graphite burnout by removing the cause of oxidation, carbon dioxide, or by inhibiting the oxidation reaction with carbon monoxide. The elimination of burnout would allow the elimination of all graphite damage limits. The full-reactor test, to be done in the F Reactor, will continue through May. Enrichment may be necessary, particularly if more than a small percentage of nitrogen is used.

Slug Improvement Tests

1. Cored Slugs

It is generally agreed from in-pile results and other testing that coring represents a significant improvement in slug quality. Cored slugs manufactured by drilling solid rods have been included in several production tests to compare effects of canning on irradiation performance. Extruded cored slugs are being evaluated to determine whether extruding hollow rods or drilling solid rods is more desirable. All tests involving cored slugs will probably be charged by December 1, except the "to rupture" test of extruded cored slugs which will be charged in January, 1955.

2. Unbonded and Mechanically Bonded Slugs

Splitting of the uranium core causes failure of a slug because water enters through the resulting tear in the aluminum jacket. Splitting of the uranium core would be less serious if it were not always accompanied by tearing of the aluminum jacket. If there were no bonding between the slug and the can, it might be possible for the core to split and merely deform the ductile aluminum can without tearing it. Ruptures might then be indicated by a steady rise in Panellit pressure and discharged before they were sufficiently serious to be "stuck".

The mechanically bonded slug is a design intermediate between the bonded and the unbonded slug and embodies some features of both. The uranium core is electrolytically etched to produce a roughened surface. When the aluminum can is sized on the uranium core, some aluminum flows into the roughened uranium surface.

For unbonded and mechanically bonded slugs, two types of can closures may be used. They are the standard fusion weld and the point pressure weld. In the pressure weld, the can is forced to flow under pressure until a cold weld is formed. No braze line exists for preferential corrosion attack.

Although a few unbonded and mechanically bonded slugs have been charged, the bulk will be charged in October and November.

3. Alloyed Slug Cores

Elimination of core splitting may be possible by alloying certain materials with uranium. Silicon, chromium, and titanium are being investigated as alloying agents. The first silicon alloy slugs (extruded solid core) are ready for charging, and extruded cored slugs should be available for charging in December. Titanium increases the ductility of uranium but it has a relatively high neutron cross section. Contingent upon further evaluation, uranium-titanium alloy slugs may be canned and available for charging in December.

4. Internally and Externally Cooled Slugs

Fuel elements with internal and external cooling may demonstrate improvement over the external cooled cored slug by further reduction of stresses. The internally and externally cooled slugs represent a substantial percentage of present fuel element development effort and should be available for charging in November.

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5. Insulated Slugs

The ductility of uranium increases with temperature up to about 200 C. Slug operation at relatively high temperature may result in increased ductility and decreased uranium cleavage failures. This will be attempted by using low-boron glass thread as an insulating material. Some insulated slugs should be available for chargirg early in November.

6. Basic Slug Behavior Information

Necessary for any firm explanation of the mechanism of slug failures are basic slug temperature data during exposure. The data will be obtained by exposing thermocouple slugs. It is planned to make especially careful preparation so that no slug failures are caused by the construction of the thermocouple slug, and for the same reason the exposures will be limited. Thermocouple slugs are planned to determine axial temperatures in natural and enriched uranium slugs and slug surface and end cap temperatures in natural uranium pieces. The thermocouple slug to measure surface temperatures is ready for charging.

Pile Safety and Control Production Tests

1. Improved Instrumentation

Improved pile instrumentation is now in the development stage and it is planned to install and test improved systems as the development efforts are completed. Either process tube or test hole facilities will be utilized. It is expected that in-pile testing will be initiated shortly and may extend over the next two years as performance, stability, and system life are evaluated. Major objectives of the program are:

1. To provide sub-critical pile monitoring
2. To provide monitoring of low level rate-of-power-increase
3. To provide improved ionization chambers for the present high level and octant monitoring systems
4. To provide automatic outlet temperature monitoring on one tube in each block of nine

2. Determination of Tube Flow Requirements During Shutdown

It is necessary to redetermine the tube flow requirements during shutdowns for charges that have been operating at the recent high levels. The natural uranium thermocouple slugs installed in the piles under separate Production Tests will be used to determine more accurately the cooling requirements during shutdown periods. Water flow to individual tubes and headers will be reduced for various periods of time, and slug temperature rise data will be obtained. The results of this test will lead to more efficient shutdown operations and will greatly assist in determining emergency cooling requirements.

3. Poison Spline Supplementary Control

A poison spline method of introducing additional poison to a pile during operation is being developed. The design of the system is such that extreme flexibility of tube location is possible; the normal uranium charge need not be disturbed, and no rear-face operations are required. A production test should be written by February, 1955.

4. BF_3 Supplementary Control System

Out-of-pile testing of BF_3 gas for use as a supplementary control medium has indicated its feasibility. Further test work will be conducted and remote operating equipment assembled for an in-pile test. A production test should be written within six months.

Basic Physics Information

1. U-235 Conversion

Required for a better understanding of reactor operation is additional information from the direct measurement of the U-235 conversion ratio. A major uncertainty in the design of reactor loadings has been the efficiency with which U-235 is converted to a desired product. Techniques for directly determining these efficiencies of conversion have been developed and demonstrated in Test Pile work to date; it is now planned to irradiate specially designated natural uranium slugs containing neutron detectors in a 105 Reactor to determine the efficiency of converting U-235 to plutonium so as to obtain a comparison between the results of a direct measurement and the 100-200 Area assay as determined from metal exposure and 200 Area product recovery. This work will then form a basis for an absolute determination of conversion efficiency at the K Reactors which will be done during KW startup.

A special loading is required for a single centrally located process tube. The required exposure is very low -- of the order of 500 KW - minutes. The measurements should be initiated about the first of December, 1954. The precise number of short irradiations required is not known; however, it is expected to be of the order of three which will be spaced at intervals of at least two weeks.

Reduction in Cost of Raw Material

1. Segmental Discharge

Segmental discharging of process tube loads permits a more even distribution of product concentration in individual pieces. The uranium throughput is thus reduced and for 200 MWD/T product significant cost savings appear possible. Equipment is being developed to effect segmental discharge by the tube flushing method. Several devices are being designed to perform the necessary operations, and after laboratory testing will require production testing.

New Products

1. U-233 Production

While a 410 tube irradiation of conventional thorium slugs alternated with J slugs is underway, other types of slugs appear to have cost or conversion advantages. Accordingly, small scale irradiations of J-thoria loadings and of a compound slug containing thoria pellets in a J matrix are planned.

2. Mixed Enriched Uranium

A method alternative to manufacturing U-233 by alternating uranium-aluminum alloy and thorium pieces (J-Q charge) would be the substitution of enriched uranium as a fuel

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element. Preliminary calculations show such an irradiation to be very attractive economically if the enriched uranium can withstand a sufficiently high exposure. A method of manufacturing high and low g/T Pu by enriched uranium and depleted uranium is also being considered.

It is expected that the experimental quantities of enriched uranium will be obtained for verification of physical constants, isotope ratios, and yields.

Improved Water Quality; Slug and Tube Corrosion

1. Improved Water Quality

Current process water quality production tests include the study of reduced dichromate concentration (0.5 ppm) in one-half of D Pile and lower pH (7.3) in one-half of F Pile. It is planned to initiate at F Pile a test of process water at pH 7.3 and 0.5 ppm dichromate. This test is scheduled to begin about November 1, 1954. Subsequently, the pH will be reduced to 7.0 on the side of F Pile now operating at 7.3. This test is scheduled to begin in January, 1955. All proposed tests are piloted by in-pile experiments conducted at the 105-D Flow Laboratory.

2. High Temperature Slug and Tube Corrosion

Increased operating temperatures on individual tubes up to an outlet temperature of 120 C are being investigated. Methods of alleviating localized corrosion on slug jackets are being studied at current and proposed operating temperatures.

3. Zirconium Tests

A test of regular slugs in zirconium tubes is planned. Both slug and tube corrosion data will be obtained. Also, some zirconium clad slugs will be irradiated in aluminum tubes to obtain corrosion and rupture rate data on the slugs. The latter test is scheduled to start immediately.

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Date Issued 12-14-54

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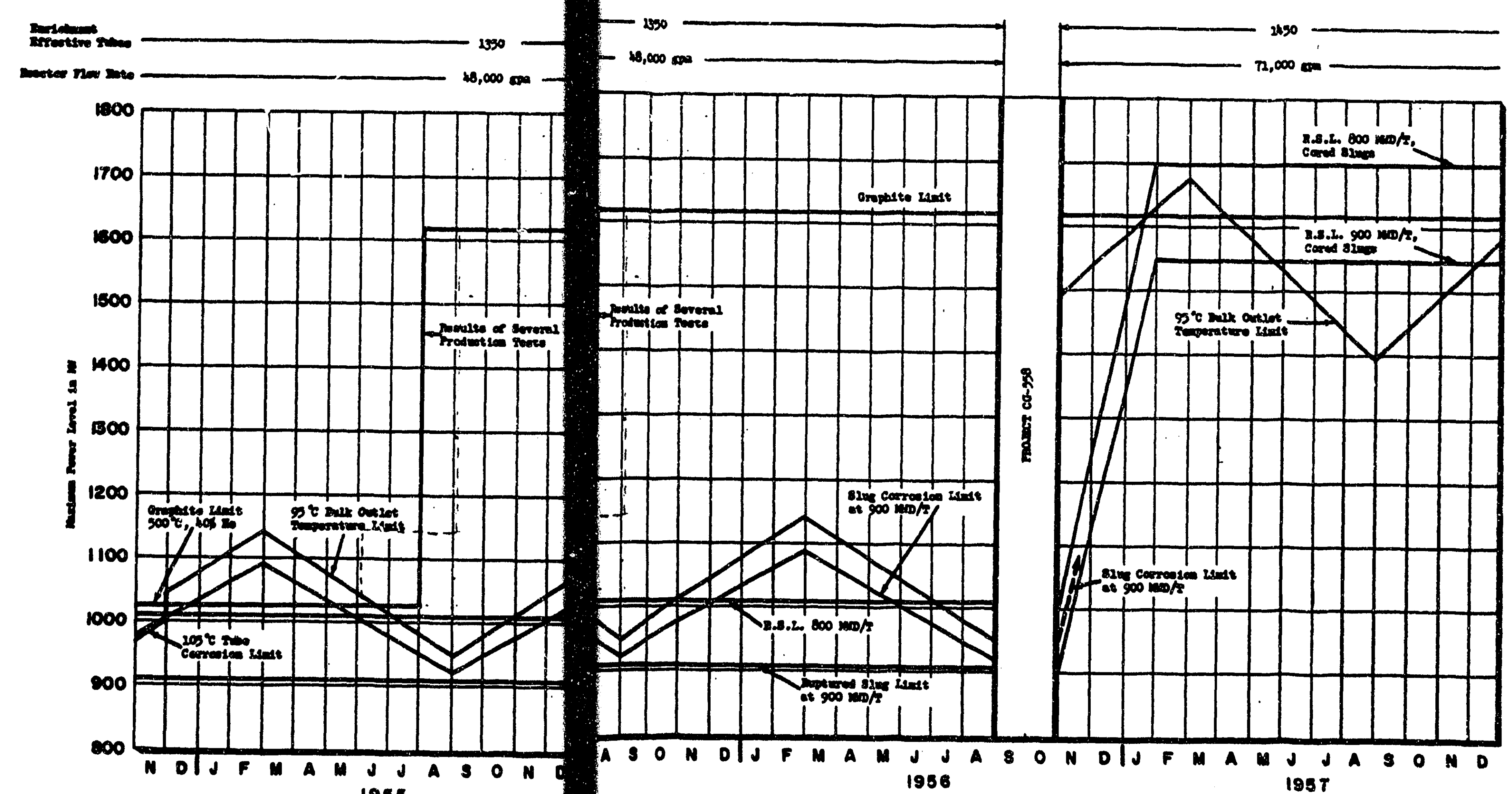

B REACTOR LIMITS

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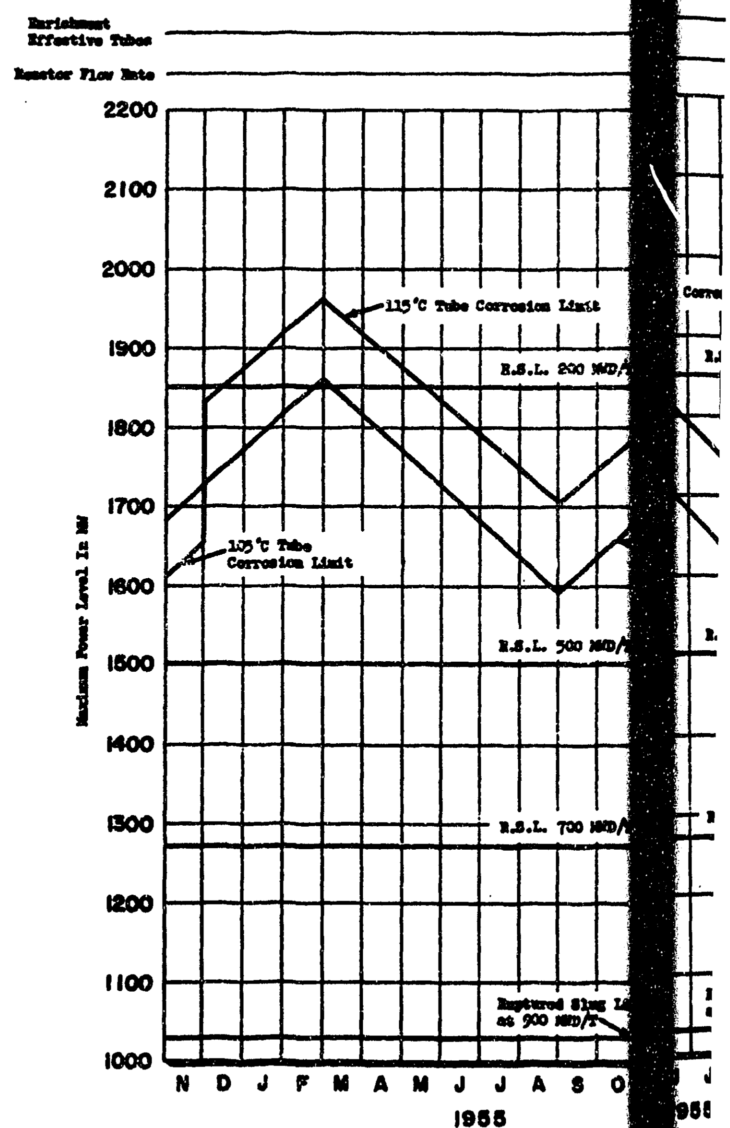
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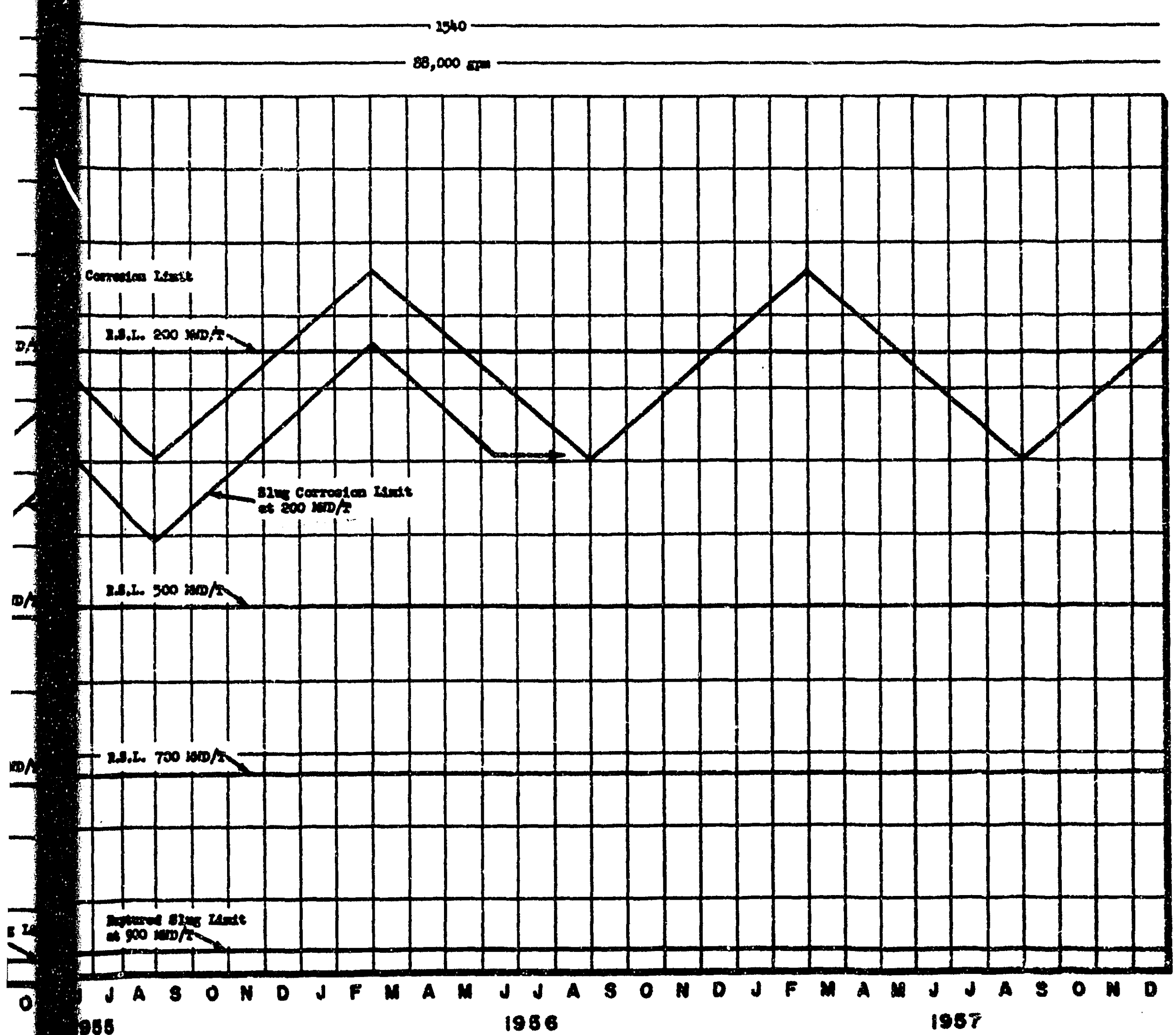

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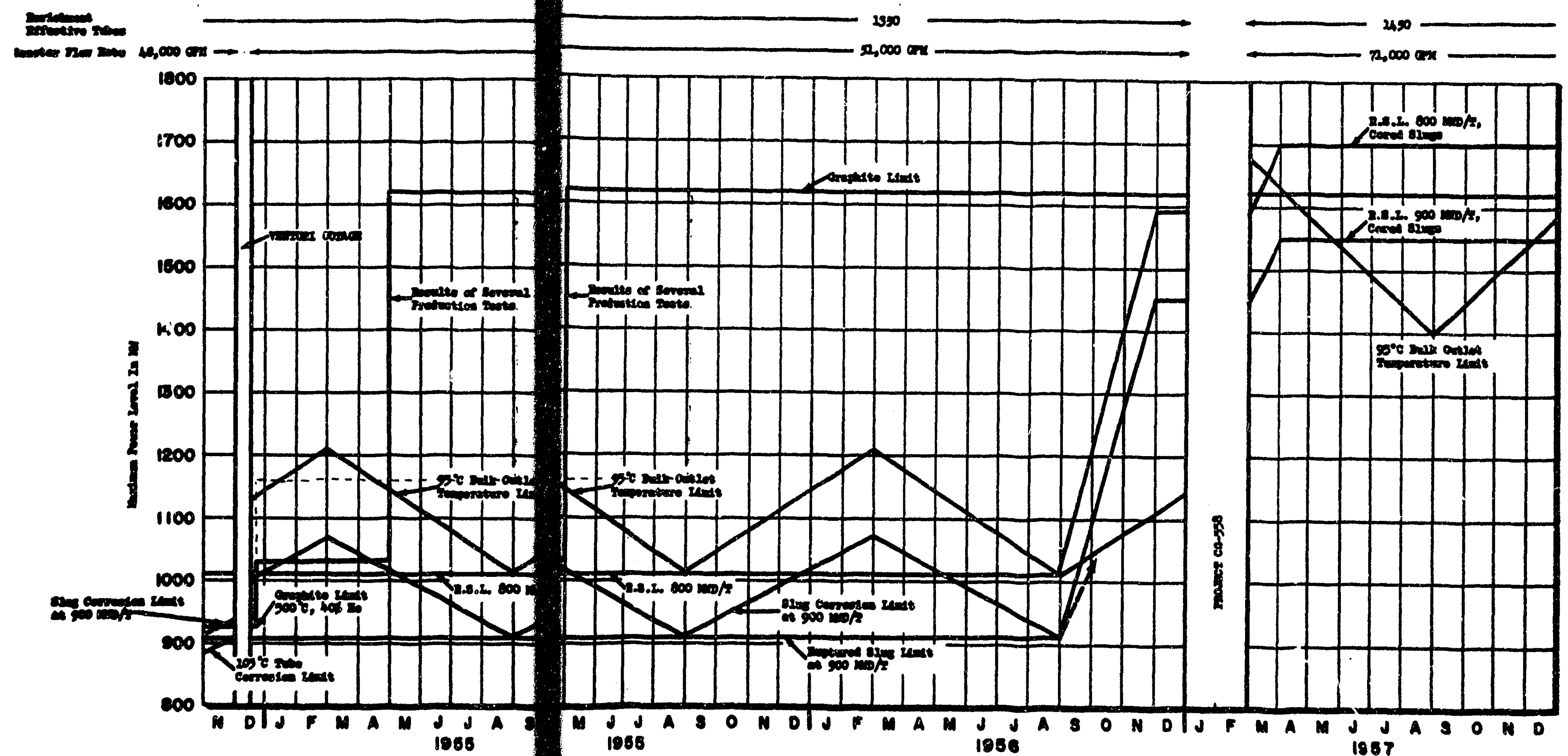

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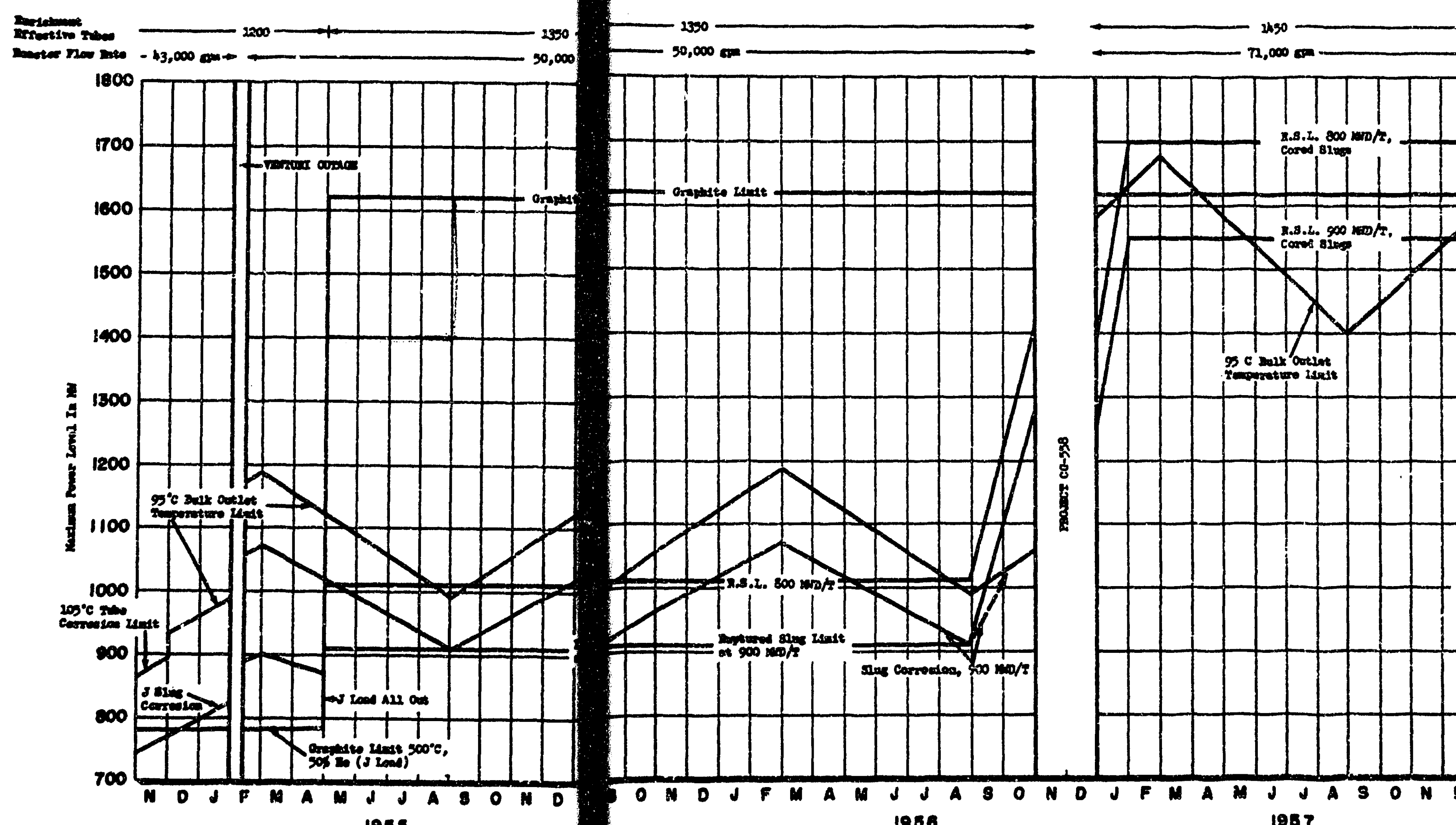

DR REACTOR LIMITS

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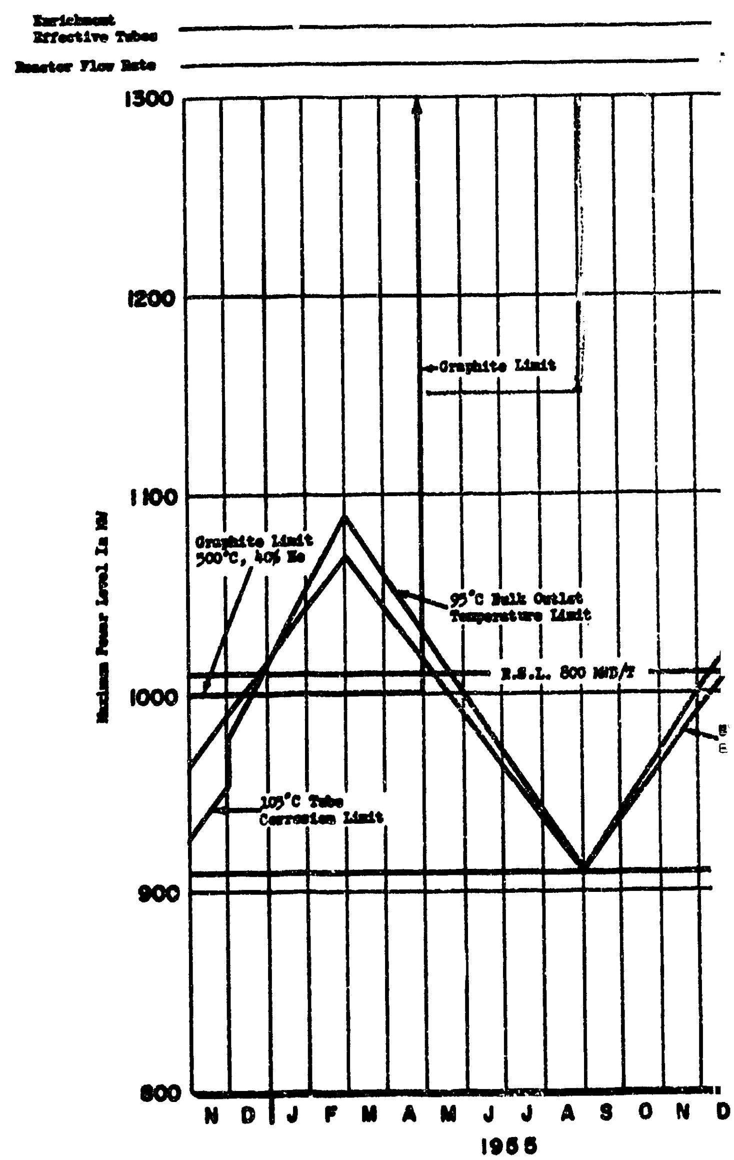

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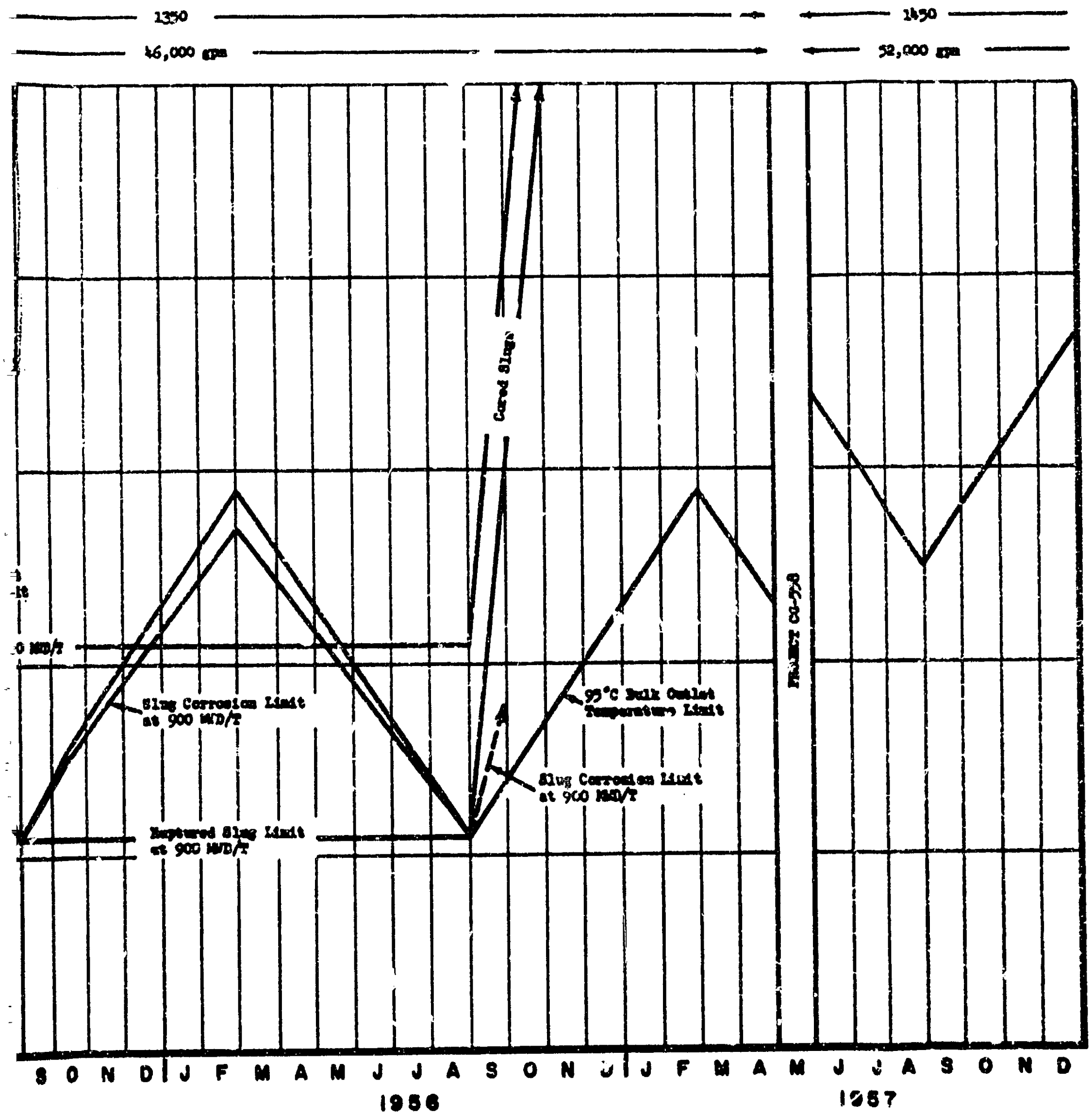

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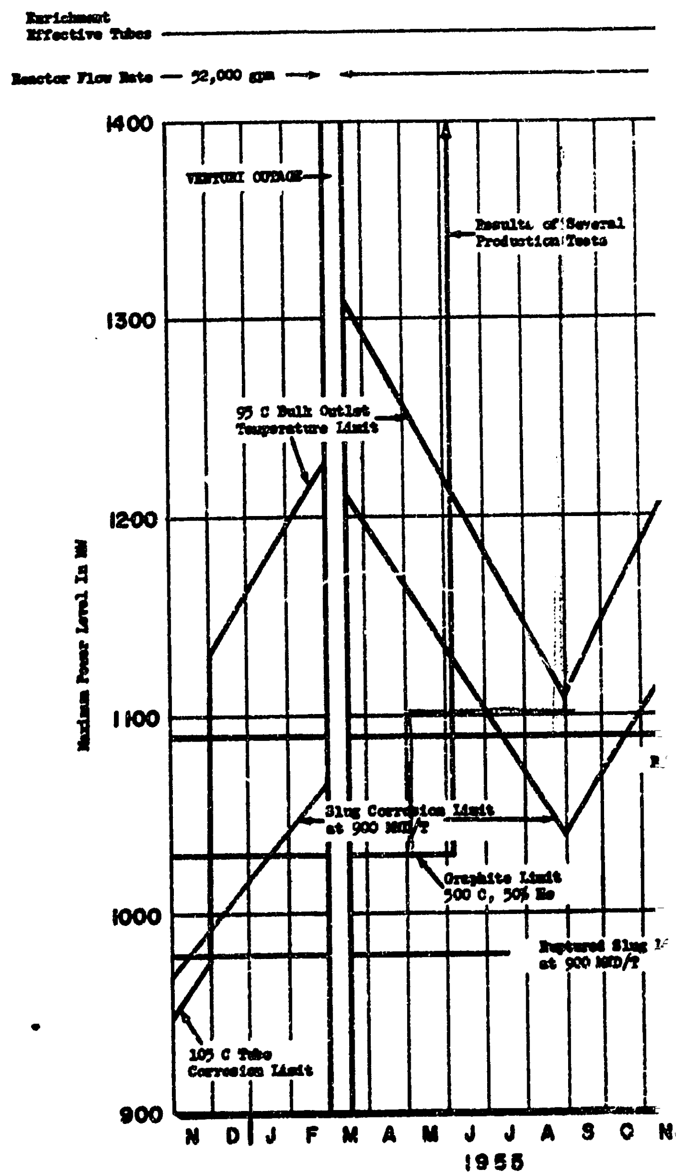

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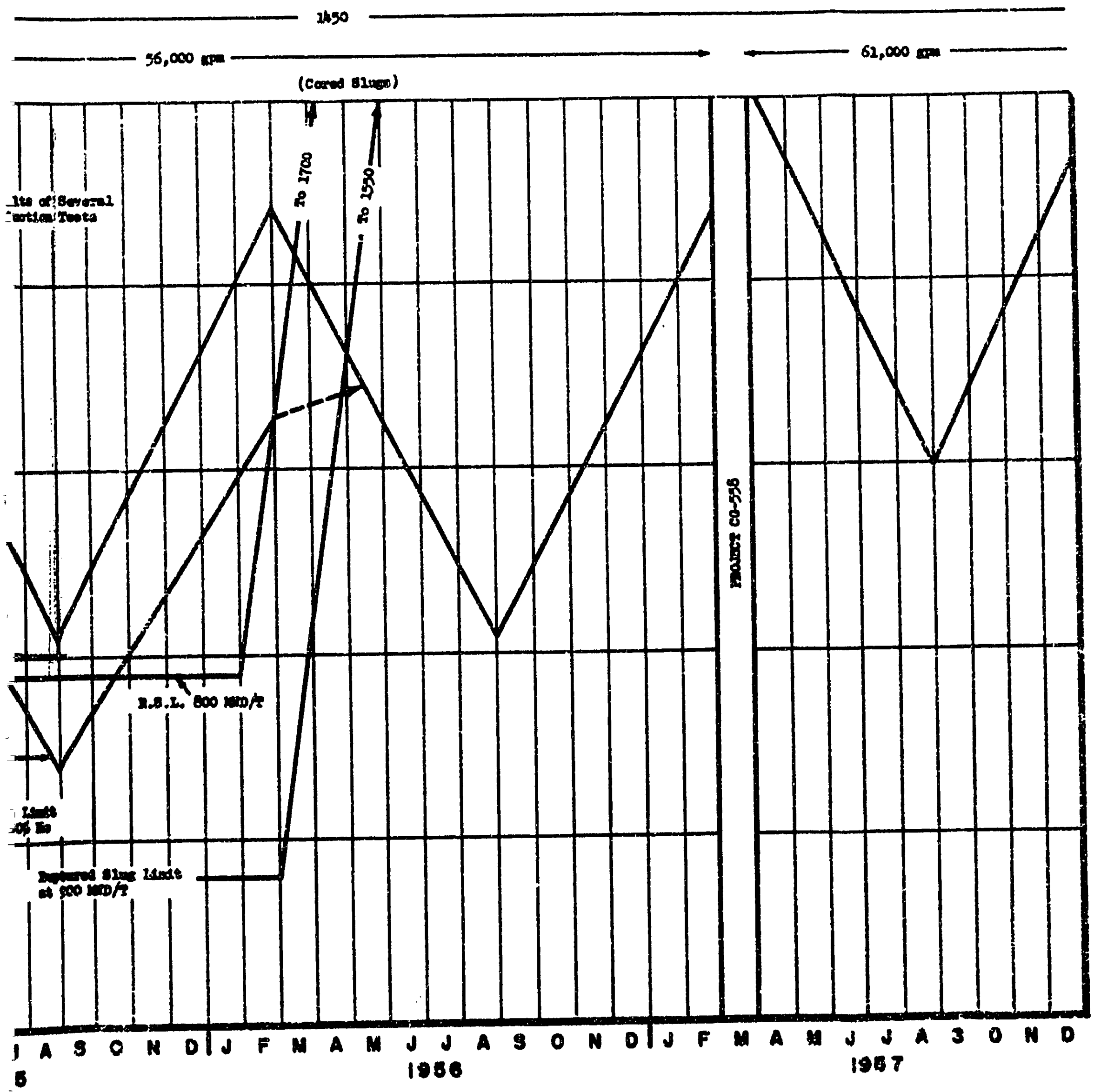

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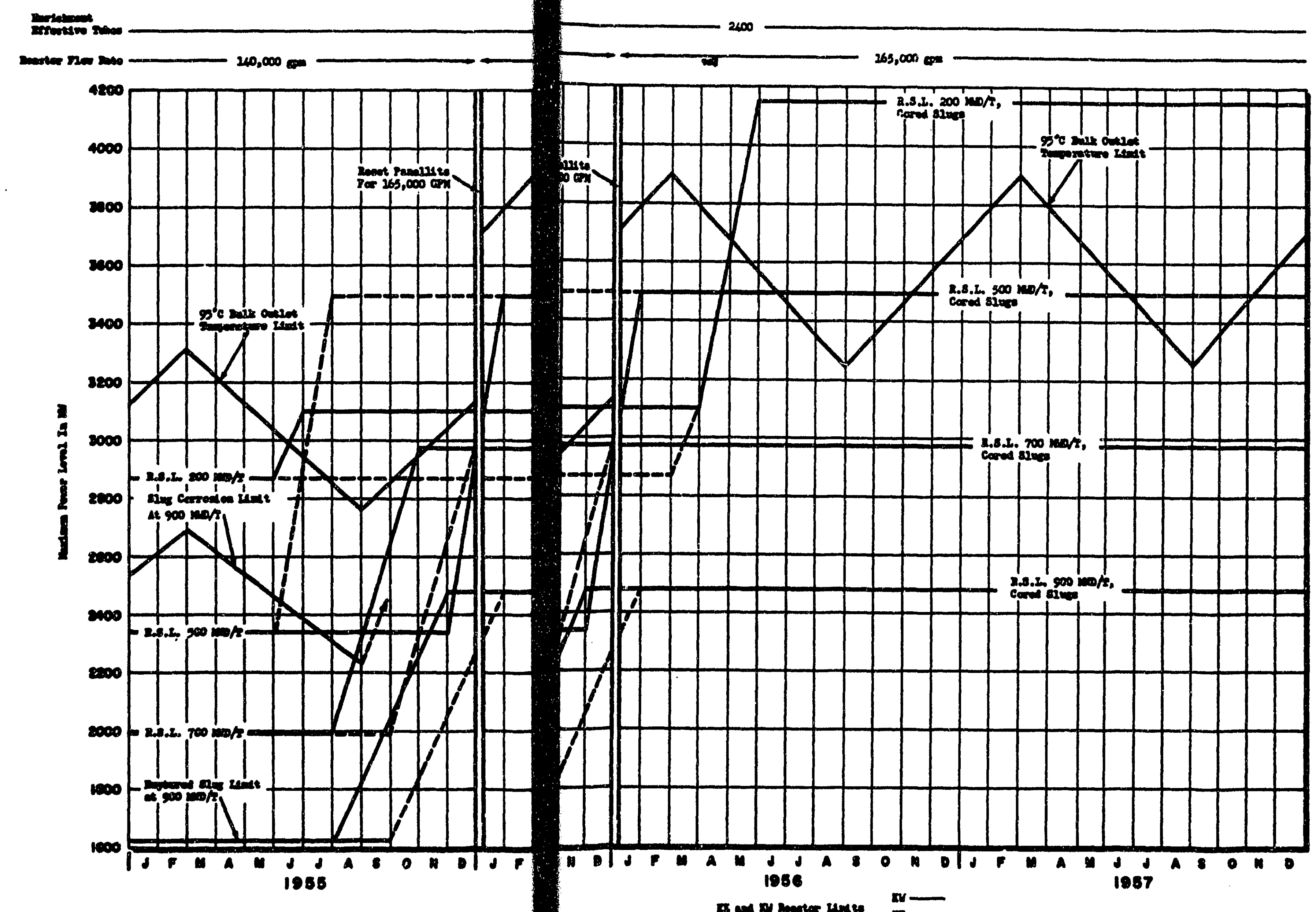

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