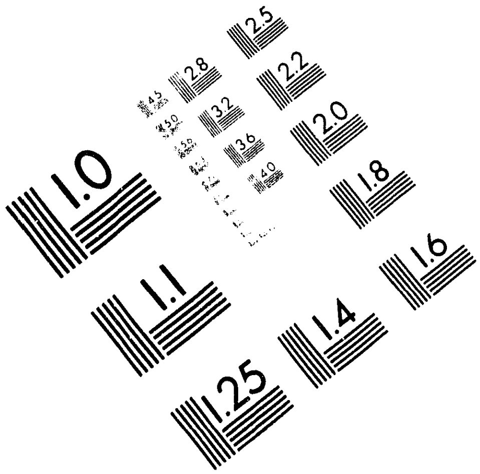

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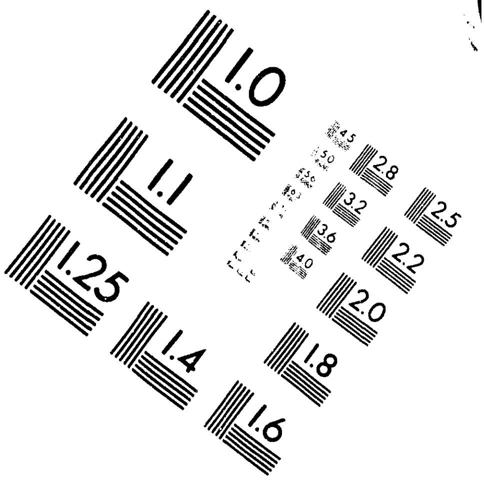

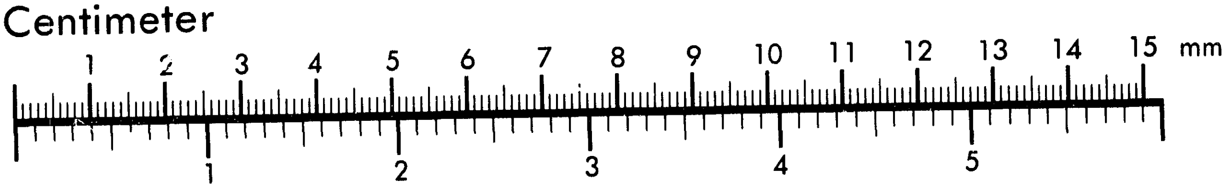

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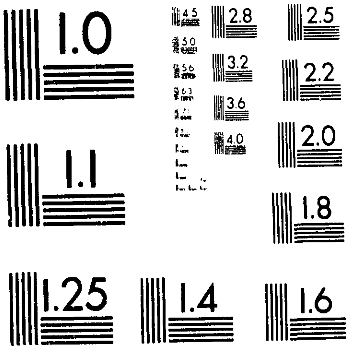

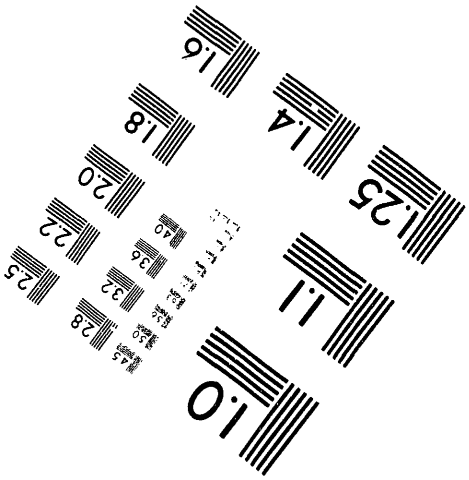

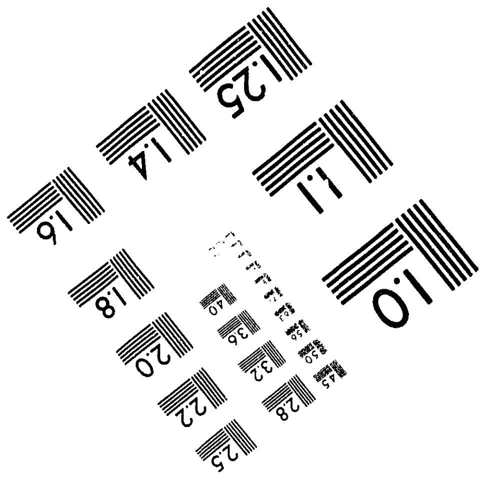

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GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION — RICHLAND, WASHINGTON

DOCUMENT NO.
HW-34324 -DEL

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TITLE
PRODUCTION TEST 105-548-E
C PILE GRAPHITE BURNOUT EXPERIMENT

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PRODUCTION TEST 105-548-E
C PILE GRAPHITE BURNOUT EXPERIMENT

by

D. H. Curtiss

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PRODUCTION TEST 105-548-E
C PILE GRAPHITE BURNOUT EXPERIMENT

OBJECT

The object of the production test is to obtain full pile high temperature graphite burnout data. In addition, the test will supply valuable data on the postulated influence of neutron temperature on plutonium purity.

This test was outlined in the 100 Areas technical program agreed upon by the Engineering and Manufacturing Departments(1), but was not authorized thereby.

BASIS

The maximum temperature at which piles may be run continuously without suffering excessive rates of graphite burnout is as yet not known. In order to achieve the power levels established as goals of the 100 Areas technical program(1), it will be necessary to operate the piles at or near 600 C, even with a high concentration of helium in the gas atmosphere.(2) The following table summarizes production losses and resulting costs for several cases in which graphite temperature limits pile power levels after completion of Project CG-558. These estimates are based on modifications of predictions published by Fletcher.(3)

Graphite Temperature, °C	600	650	550	550	550	550	500
Helium, Per cent	90	60	90	80	70	60	60
Tube Power, KW	1200	1200	1100	1050	1010	980	850
Pile Power loss, MW (1450 effective tubes)	Goal Power after CG-558		145	218	275	320	510
Production loss MWD/mo (25 operating days/mo	----	----	3620	5450	6880	8000	12,750

[redacted]

Prior to completion of this project, H Pile will be limited by graphite temperature for as much as ten months per year, at an average loss of [redacted] per month. In order to avoid such production losses after completion of Project CG-558, it must be shown in advance how a full pile can be operated at higher graphite temperatures.

---

(1) Reinker, P. H. and Bupp, L. P., "100 Area Process Improvement Program for the Period November 1954 through April 1955," HW-33842, 11-19-54

(2) Fox, J. C., "Graphite Experimental Program for Water Plant Expansion Project," HW-32925, 9-1-54

(3) Fletcher, J. F., "Graphite Temperature Predictions," HW-31125, 3-12-54.

[redacted]

Preliminary experiments which have been run both in the laboratory(4,5) and in the piles (6,7,8,9,10,11) indicate that a full pile test at 600 C graphite temperature is now feasible and would not result in excessive graphite burnout. At the present time, it is possible to do the test only at C Pile for reasons discussed in detail elsewhere.(12)

Operation of C Pile at a significantly higher temperature presents the first opportunity to verify the existence and extent of the postulated effect of thermal neutron temperature on plutonium purity. (13) Prior empirical evidence of this phenomenon is not conclusive. Since it will be necessary to raise graphite temperatures in the future, it is also necessary to determine the magnitude of the neutron temperature effect, and how it will affect the low concentration production program. Future low concentration metal can then be scheduled at the pile(s) which can produce it most economically at optimum exposures, temperatures, and power levels, with minimum adverse effect on the graphite structure. Theoretical calculations predict a 100 C increase in maximum graphite temperature might require as much as a 8 per cent reduction in exposure. At the present production rate, this would represent a monthly cost of approximately The temperature effect can be investigated concurrently with the graphite burnout test at less expense by taking advantage of the margin of conservatism in present goal exposures. The Pile Physics Unit recommends that goal exposure during the test period be reduced from 210 MWD/T to 200 MWD/T.(15) If plutonium purity specifications are changed from 20 n/gs to 25 n/gs, recommended goal exposure will be 250 MWD/T during the test. This conservative approach would require approximately 37.5 additional tons of uranium during the five month test period, at a total cost of Additional pile reactivity contributed by the higher graphite temperature would reduce the need for enriched metal, at a savings of approximately $100,000. Net cost of a five-month test is about $260,000, which is not excessive when compared to the potential savings to be realized should the test produce favorable results.

---

(4) Woodley, R. E., "Promotion of Chemical Reaction in Gas-Graphite Systems by Gamma Radiation," HW-31939, 5-24-54

(5) Spalaris, C. N., "The Role of Surface Area in the Kinetics of Oxidation of Graphite," HW-31928, 5-24-54

(6) Lovett, D. B., "High Temperature Graphite Burnout Experiment, PT 105-514-E," HW-26187, 1-15-53

(7) Woodley, R. E., "Final Report on PT 105-391-P, 105-435-P, and 105-514-E, Supplement A," HW-26320, 7-1-52

(8) Whatley, A. T. and Lovett, D. B., "PT 105-530-E, Full Pile Burnout Experiment," HW-29201, 9-1-53.

(9) Lovett, D. B., "PT 105-536-E, High Temperature Graphite Burnout," HW-30615, 1-22-54.

(10) Woodley, R. E., "PT 105-532-E, Graphite Monitoring Program," HW-29739, 10-23-53

(11) Woodley, R. E., "PT 105-532-E, Supplement A, Graphite Monitoring Program," HW-30571, 1-4-54

(12) Curtiss, D. H., "Review of Feasibility of Full Pile High Temperature Graphite Burnout Test," HW-34325, 1-5-55

(13) Heineman, R. E., "The Dependence of Pu-240 Content of Pile Produced Plutonium on Neutron Temperature," HW-32933, 9-2-54

month con
uranium represents the net cost to Hanford (Raw material cost plus canning less allowance for material recovered from UO_3 Plant).

(15) Fullmer, G. C. to Curtiss, D. H., "Recommended Low G/T Goal During High-Temperature Graphite Test," HW-34266, 1-4-54

[redacted]

[redacted]

PROCEDURE

The helium concentration of the pile atmosphere at C will be reduced and graphite temperatures increased until the maximum graphite temperature is 600 C. (except as noted later) The concentration of the helium will be adjusted to maintain the maximum graphite temperature at this value during operation. Duration of the test will be five months.

The pile shall be operated so as to bring the graphite temperature to 600 C as soon after startup as is practical from a control standpoint, and maintain it there during equilibrium operation. Temperature distribution shall be as uniform throughout the stack as possible, similar to the map shown in Figure 1. For the purpose of this test, it is imperative that heat cycles be avoided during "equilibrium" operation. Although the increased graphite temperatures will provide additional reactivity during the test, it will be necessary to hold sufficient reactivity in the control rods to assure that heat cycles do not occur, or can be satisfactorily controlled. To estimate the magnitude of the reactivity during equilibrium operation prior to the starting date of the test, helium concentration may be varied ±20% for a two day period.
If the 600 C temperature cannot be attained by removal of all the helium from the pile, power levels may be increased by allowing the outlet water temperature to increase to 105 C, as authorized by Process Specifications on tube corrosion and "trip before instability".(17)

Monitoring of graphite burnout will be accomplished in three phases as follows:

1. Full Sized Bars

   Prior to the initiation of this increased temperature test, eight graphite bars 4" x 4" x 12" will be installed in the D test hole. These bars will be cut from known material, tested and weighed prior to charging. At the completion of this test, these bars will be removed by the established procedure and again tested and weighed. From these data, information concerning the oxidation rate under actual high temperature pile operating conditions can be determined.

2. Process Channel Samples

   Graphite samples (1.125 inches in diameter and 4 inches long) will be installed in two empty process channels to provide prompt checks upon the rate of oxidation. These samples will be discharged periodically to insure that excessive rates of oxidation are not being encountered. The charge and

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(17) "Process Specification 15:01," and Process Specification 11:00," HW-27632, Rev. 9-30-54

[redacted]

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discharge of these samples and carriers will follow the procedures outlined in PT-105-532-E, PT-105-536-E, and PT-105-536-E, Supplement A (9, 10, 11, 18) One channel (1960-C) is presently used for this purpose.

3. Diamond Cluster Around 2773-C, J-Q Loading

Because of the tube block thermocouple arrangement peculiar to 2773-C, a diamond cluster of enriched columns will be established adjacent to this channel similar to a previous loading near 2785-C under PT-105-536-E(19) (2785-C cannot be used now since the adjacent tubes are occupied by PT-105-578-A metal). Eleven adjacent tubes will be loaded with J-Q columns under PT-105-579-A (18); tube numbers and charging order are given in Appendix B. Since these must be charged prior to initiating this test, the discharge of metal presently in these tubes at less than goal exposure is hereby authorized. Goal exposure for the J-Q columns will be established by Production Scheduling, but shall be a minimum of 5 months (unless a rupture occurs) or a maximum of 200 MWD/T.

While these columns are in the pile, 2773-C will be a test channel for PT-105-536-E. Perforated gun barrels will be installed in both front and rear of this channel and gas flow measured, as was done in 2785-C for PT-105-536-B. Samples will be charged into 2773C as specified in PT-105-536-E (9) and its Supplement A.(19) Similar samples will be placed in a "Follower Furnace" outside the pile which will maintain the out-pile samples at the sample temperature, gas composition, and gas flow as the in-pile samples. A connection to the pile gas inlet and outlet lines will be necessary to provide this atmosphere. TC-59-G-1 will be disconnected from the panel and its leads extended to the follower furnace to provide the control signal.

4. Monitoring of CO Content of Pile Gas System

C Pile is already equipped with an elaborate gas analysis system. This will be supplemented with periodic mass spectrographic analysis of gas samples withdrawn from the system. These analysis will be observed for significant increases of CO concentration.

5. Vertical Height Traverses

Vertical height traverses on tube 4674-C will be made at the initiation and completion of this test in addition to the three month interval required by Process Standards to ascertain if the rate of shrinkage of the central regions is temperature dependent.

6. Graphite Temperature Data

Temperature of selected graphite thermocouples near the graphite samples will be recorded daily by Operations on a data sheet provided by Technical.

Careful control of the pile atmosphere pressure must be maintained to prevent the inadvertent pile inhalation of air. Graphite at these temperatures reacts rapidly with the oxygen in air and the results of the experiment would be exaggerated by air leakage into the pile.

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(18) Brugge, R. O., "Production Test 105-579-A, Revised, Quantity Irradiation of J-Q Columns", HW-33170, 9-28-54.

(19) Lovett, D. B., "Higher Temperature Graphite Burnout, PT-105-536-E, Supplement A," HW-32871, 9-29-54.

(20) Galligan, W. L., "Interpretation of Graphite Temperature Limit Adjacent to Enriched Loadings", HW-33195, 9-29-54

(21) Bupp L. P., "Trip Report, AEC Technical Co[redacted]n Program on Graphite-Gas Reactions" HW-32505, 7-21-54

STARTING DATE

This test shall be placed into effect in the first part of 1955, and will continue for five months, unless cancelled (see "Hazards").

AREA

C Pile has been chosen for reasons presented elsewhere.(12)

DEVIATIONS FROM PROCESS SPECIFICATION

Process Specification 41.00, "Temperature of Graphite Moderator"

The maximum graphite temperature will be increased from 500 C to 600 C during the test except in the following locations:

a. Within the diamond cluster of J-Q tubes surrounding channel 2773, maximum permissible graphite temperature is 750 C, during the test period; 580 C following the test while the J-Q columns are still in the pile.

b. Within one lattice unit of a J-Q or J-N tube, maximum permissible graphite temperature is 640 C. The interpretation of this limit has previously been clarified.(20)

This relaxation is also permitted for a two day period prior to the test for the purpose of estimating reactivity effects.

Process Specification 31.00, "Composition of the Reactor Gas"

The minimum helium concentration of 0 per cent at all temperatures below 600 C is authorized. For a two day period prior to the test, helium concentration may be varied ±20% from that permitted by this specification for the purpose of estimating reactivity effects.

The remainder of the specifications are unchanged.

ADHERENCES TO PROCESS SPECIFICATIONS

Of particular importance during the term of this test is adherence to the following process specification:

Process Specification 32.00 "Pressure and Flow of Reactor Gas"

At no time during the operation of the pile shall the pile gas system pressure fall below that of the local atmosphere pressure immediately adjacent to the gas system. Care must be exercised to insure that regions of local high gas velocity and consequently lowered pressure do not exist as such conditions might aspirate air into the pile gas system.

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COSTS

Reactivity - Reactivity gains due to temperature increase.

Shutdown Time - Tube removal and replacement — 1 channel x 6 hr/channel = 6 hrs. (one channel is already reserved for this purpose under PT-105-532-E)

[redacted]

Gun barrel removal and replacement — 3 hrs. x 2 = 6 hrs.

Vertical height traverses — 2 tubes x 1 hr/tube = 2 hrs.

Sample removal and replacement — 6 charges x 1 hr/charge = 6 hrs.

Cost Code - 5730-253.62

HAZARDS

Burnout of Pile Graphite

The results of PT 105-536-E(18) have shown that the oxidation rate is probably not greater than three per cent per 1000 days at temperatures between 550 and 620 C with 40 ± 5 per cent helium in pile gas. Laboratory data obtained by the British show thermal oxidation rates of 0.69%/1000 days at 600 C and 21%/1000 days at 700 C for virgin graphite and carbon dioxide.(21) Laboratory data obtained at Hanford on reaction rates of irradiated graphite with carbon dioxide show weight losses of 1.57%/1000 days at 600 C and 33%/1000 days at 700 C. On the basis of these data it is not expected that five months of operation of C Pile at these temperatures would produce a burnout to exceed 1/2 per cent. If extreme oxidation rates are noted in the process channel samples (2 above) after the first month, then the test can be cancelled before severe harm is done to the pile. In view of the importance of the information potential from this experiment, it is felt that the risks are justified.

Isotopic Plutonium Purity

The increased graphite temperature may measurably increase the Pu^{240} concentration in the Pu^{239}; however, as discussed under the Justification section above, the total exposure will be reduced to counteract the maximum anticipated effect. In the extremely unlikely event that the Pu^{240} concentration is greater than limits, this material may be alloyed with "below-limit" material to produce an acceptable product.

RESPONSIBILITY

The Operations Sub-Section of Manufacturing Department will be responsible for the operation safety and production continuity of the pile. They will also be responsible for the scheduling of the shutdown work.

Pile Graphite Studies will be responsible for the charging and discharging of samples, operation of the "Follower Furnace", collection and interpretation of the data, and interpretation of provisions of this production test.

Pile Physics Unit will be responsible for collection and interpretation of data on plutonium purity as a function of exposure and "neutron temperature".

Technical representatives for this test will be J. C. Fox and D. B. Lovett.

Process Sub-Section will be responsible for the collection and interpretation of data on the graphite reactivity coefficient prior to starting the test.

D H Curtiss

[redacted]

Head, Pile Graphite Studies
Pile Technology Section
ENGINEERING DEPARTMENT

DH Curtiss:msj

[redacted]

APPENDIX A

TIME	ACTION
Pre test operation	1. Change gas composition 20% and estimate reactivity effect 2. Analyze temperature distribution. 3. Study gas composition. 4. Patch up as many leaks as possible. 5. String 59-G-1 extension to follower furnace.
Pre test shutdown	1. Remove 1 process tube and gun barrels 2. Install samples. 3. Charge J-Q into 2773 Diamond. 4. Charge 2773 Samples. 5. Install follower furnace. 6. Install blocks in D test hole.
First operating period	1. Decrease helium to achieve 600 C maximum. a. Collect gas composition data. b. Collect temperature data.
First Shutdown	Discharge and recharge one set of samples from process channel.
Subsequent Operating Periods	600 C Operation - collect temperature data.
Second Shutdown	Depending on results on first samples perhaps discharge and recharge other channel samples.
Last shutdown (late June)	1. Discharge test hole blocks. 2. Discharge channel samples. 3. Retube process channels. 4. Discharge 2773 samples and recharge PT 105-536-E.
Next Operating Period	Operate on Process Specifications.

[redacted]

APPENDIX B

Tube No.	Present Contents	J-Q Charging Pattern
2573-C	HM	A
2672-C	JQ	A
2673-C	HM	B
2674-C	JQ	A
2771-C	HM	A
2772-C	HM	B
2773-C	HM	Empty Channel
2774-C	HM	B
2775-C	HM	A
2873-C	PT-539-E	B
2874-C	JQ	A
2973-C	HM	A

Charging Pattern for J-Q Tubes:

Rear ——— Front
A. 15 - 8" Perfs Q-J-Q-J-Q ——————————— J-Q

Total 19 Q, 18 J

Tubes - 2573, 2672, 2674, 2771, 2775, 2874, 2973

Rear ——— Front
B. 14 - 8" Perfs U-J-Q-J-Q ——————————— J-Q

Total 1 U, 18 Q, 18 J

Tubes - 2673, 2772, 2774, 2873

APPROVALS

L P Bupp

L. P. Bupp
Manager, Pile Materials Sub-Section
ENGINEERING DEPARTMENT

P. H. Reinker

P. H. Reinker
Manager, Pile Engineering Sub-Section
ENGINEERING DEPARTMENT

OC Schroeder

O. C. Schroeder
Process Superintendent
REACTOR SECTION

RO Mehann

R. O. Mehann
Production Superintendent - Operations
REACTOR SECTION

J. H. Warren

J. H. Warren
Manager - Reactor Section
MANUFACTURING DEPARTMENT

O. H. Greager

O. H. Greager
Manager, Pile Technology
ENGINEERING DEPARTMENT

J E Maider

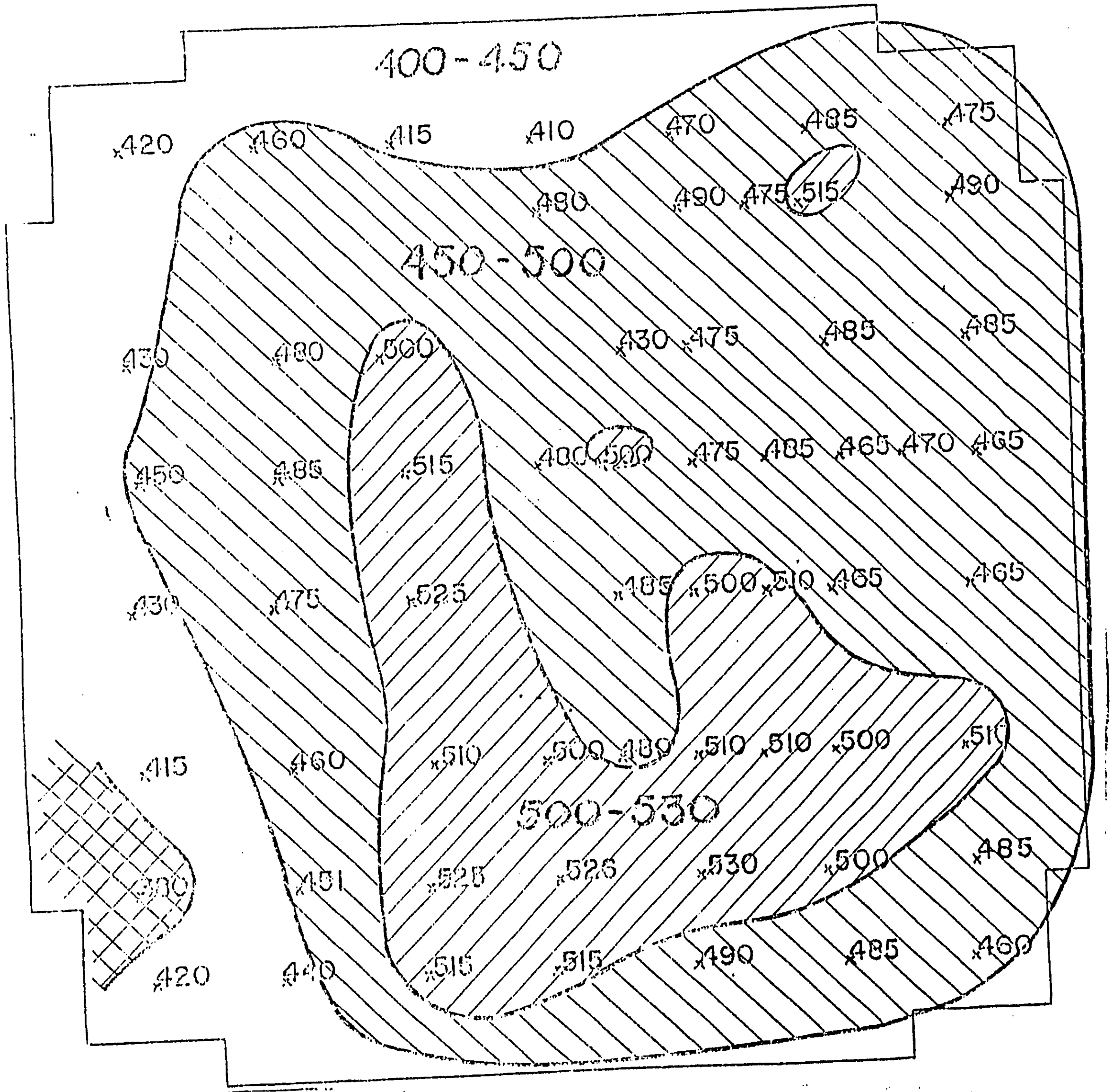
J. E. Maider
Manager - MANUFACTURING DEPARTMENT

Donald G. Sturges

D. G. Sturges, Chief
Operations Division
Hanford Operations Office, USAEC

Date of Issue____________________

DH Curtiss:msj



Gas Composition: 40 % He

Level: 1355

This Represents About The Best Equilibrium Graphite Temperature Distribution During September, Except For The Following 15' Couples Which Are Above Graphite Temperature Limits: 1067, 1567, 1582, 1591, 2282.

Figure I

Equilibrium Graphite Temperature Map 105-C September 22, 1954

(Thermocouples 15 ft. From Front, Closest To Center Line)

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END