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TEMPERATURES

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TEMPERATURES

J. R. Larson

January 13, 1961

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C REACTOR OVERBORE GRAPHITE
TEMPERATURES

INTRODUCTION

A study is presently being made considering overboring the C Reactor for a larger process tube. This overboring* would eliminate the existing coring pattern; and, therefore, change the temperature distribution in the moderating graphite. This report presents work done to determine the new temperature distribution, and, thereby, check how well the distribution would conform to requirements and current practice.

SUMMARY AND CONCLUSIONS

The temperature distribution in the graphite was determined by a series of digital computer program runs. Variables considered were heat generation rate, coolant temperature, geometry of the gap surrounding the process tube, and composition of the gaseous pile atmosphere.

The maximum center temperature of the graphite pile will fall within the limits specified with a pile atmosphere of 80% helium. This temperature may be easily controlled by varying the composition of the carbon dioxide helium atmosphere.

The entire front face and much of the rear face will run below a temperature of 200°C. Current practice in operating reactors and the NPR design is to maintain a temperature above this level to reduce the rate of graphite expansion. This practice would require additional coring during the C-Reactor retubing process. The problem of low temperature graphite growth should be examined to determine if the potential for growth and stack damage warrants the additional cost of coring.

A plot of required coring for the front and rear reactor faces is presented in the appendix.

DISCUSSION

The overbore concept studied consists of a 2.264 inch outside diameter zircaloy process tube with a 55 mil wall. This tube contains the fuel and water coolant. The tube rests on the graphite moderator in a hole bored 30 mils larger than the tube.

The only major specified operating criteria for the C-Reactor is a range for the maximum center graphite temperature. This range varies with the reactor gas

* Used herein, boring means a straight through cut of constant diameter, and coring means counterboring or a cut of larger diameter than the initial bore and limited in length.

atmosphere composition,¹ and varies from 475-560°C for 60% mole fraction helium gas atmosphere to 475-650°C for a 100% helium atmosphere. The minimum temperature of the range is set to reduce graphite growth and the maximum is set to inhibit burnout.

Other considerations tend to limit the minimum operating graphite temperature. Irradiated graphite grows considerably below a temperature of 200°C. Also, the graphite crystal lattice stores the energy resulting from irradiation damage. This stored energy can be released at a later time if the graphite temperature is raised rapidly above the threshold level. This release could cause local overheating and a reactivity increase. Mainly because of the growth problem, minimum temperature limits have been set for the NPR.

As the lattice of the C Reactor is not symmetric, the temperature distribution can best be obtained by dividing the lattice into nodes and using relaxation heat transfer methods. A digital computer program previously developed by F. J. Mollerus, Jr. was utilized to accomplish the iterations quickly and accurately. The nodal arrangement and basic dimensions of the lattice are shown in Appendix A.

Thermal conductivities of the helium-carbon dioxide pile atmosphere were taken from work of Davidson² and graphite thermal conductivity was previously used in a C Reactor study.³ All conductivities used were a function of temperature. The local heat generation rate in the graphite was assumed to be a constant 5% of the total generated power at any location. The total heat generation rates assumed were as follows:

Reactor center	85 KW/ft
Center of fringe	35 KW/ft
Fringe of faces	8 KW/ft
Center of faces	20 KW/ft

The coolant temperatures assumed were as follows:

Front face	12°C
Reactor Center	50°C
Rear face	104°C

A slight variation in center and rear face temperatures due to tube position was neglected.

The specified range for the hottest graphite is easily obtained by varying the pile atmosphere composition. An atmosphere of 100% helium will yield a maximum temperature of 470°C increasing to 527°C with 20% carbon dioxide added to the atmosphere. This is shown in Appendix B. The variation in temperature with node position is shown in Appendix A for the reactor center with a 80% helium atmosphere.

¹ HW-46000 B, "Process Standards Reactor, November 1956," Revised.

² HW-28766, "Calculated Thermal Conductivities of He-CO₂, He-Ne, and He-N₂ Mixtures," J. M. Davidson, July 20, 1953.

³ HW-65814, "Technical Aspects of 105-C Conversion to Zircaloy-2 Process Tubes and Self-supported Fuel Elements," C. A. Mansium and D. D. Stepnewski.

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The extreme front face graphite fringe will run cold, however, and cannot be raised sufficiently by varying the pile atmosphere composition. The temperatures would be 88°C with 100% helium and 111°C with 60% helium. The maximum front face temperature would be 178°C . The rear face would run some $50-60^{\circ}\text{C}$ higher.

If these low fringe temperatures are not neglected, coring both faces or a combination of variable size boring and coring is necessary. To core the front face only, the fringe tubes must be bored 200 mils larger to raise the rear face fringe graphite above 200°C . This method was not pursued further. The effect of variable size boring in front face temperatures is shown in Appendix C.

The coring required can be determined from Appendixes D and E, which give average graphite temperature as a function of core size and heat generated for the front and rear faces. To illustrate, the vertical lines give a possible coring pattern. The sharp discontinuity in the curves at the left side of the graph is caused by an abrupt change from an annular gas layer around the process tube to physical contact with the graphite occurring with the standard bore. The depth of coring required was not determined.

Results from the computer program are tabulated in Appendix F.

If larger bore sizes were to be considered, the effect of the gun barrel assembly and the process tube flexure or sag on the gap geometry should be determined. The gun barrel supports the tube in a position centered in the bore. The amount of tube sag determines when the tube actually comes in contact with the graphite. The gun barrels are located outside the graphite reflector some four feet from the active core. The data collected in this report assumed contact along the entire active core. This may not be the case for the larger bore sizes.

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APPENDIX

- A. Lattice Nodal Arrangement and Temperature Distribution at the Reactor Center.
- B. Maximum Graphite Temperature vs. Pile Atmosphere Composition.
- C. Front Face Temperatures vs. Bore Size.
- D. Front Face Temperature vs. Core Size.
- E. Rear Face Temperature vs. Core Size.
- F. Tabulated Results.

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APPENDIX A

Lattice Nodal Arrangement and Temperature Distribution at Reactor Center

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APPENDIX C

Front Face Temperature vs. Bore Size

Sink Temperature - 12°C
Pile Atmosphere - 80% Helium

Overbore - Mils
(Bore size means diameter of straight through cut.)

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APPENDIX D

Front Face Temperature vs. Core Size

Sink Temperature - 120°C
Pile Atmosphere - 80% Helium

Coring Pattern

Geometry

Kw/ft

Standard Bore + 200 Mil Core
Standard Bore + 100 Mil Core
Standard Bore + 40 Mil Core

(Core size means additional counter boring above the initial bore.)

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APPENDIX E

Rear Face Temperature vs. Core Size

Conditions:

Sink Temperature - 104°C
Pile Atmosphere - 80% Helium

(Core size means additional counter boring above the initial bore.)

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APPENDIX F

Tabulated Results

Case No.	Gap Geometry(1)	Position(2)	Heat Generation KW/ft	Mole Fraction Helium %	Average Node Temperature °C	Maximum Node Temperature °C
1	A	Center	85	100	407	470
2	A	Center	85	80	461	527
3	A	Front Face	8	100	88	
4	A	Front Face	8	80	99	
5	A	Front Face	8	60	111	
6	B	Front Face	8	80	153	
7	B	Front Face	12	80	202	
8	A	Front Face	16	80	155	
9	C	Front Face	8	80	173	
10	C	Center Fringe	35	80	518	540
11	B	Center Fringe	35	80	455	481
13	A	Rear Face	8	80	159	
14	A	Center Fringe	35	80	267	302
15	B	Rear Face	8	80	207	
16	F	Front Face	8	80	222	
17	F	Front Face	12	80	300	
118	E	Front Face	12	80	218	
119	E	Front Face	16	80	269	
20	E	Front Face	8	80	163	
21	D	Front Face	12	80	178	
22	D	Front Face	16	80	217	
23	D	Front Face	20	80	254	
24	A	Front Face	20	80	178	
25	E	Rear Face	8	80	223	
26	E	Rear Face	12	80	274	
27	D	Rear Face	8	80	196	
28	D	Rear Face	12	80	236	
29	D	Rear Face	16	80	272	
30	A	Rear Face	12	80	183	
31	A	Rear Face	16	80	205	

(1) Gap Geometry

- A. Standard 30 mil overbore
- B. 200 mil overbore
- C. 360 mil overbore
- D. Standard overbore plus 40 mil coring
- E. Standard overbore plus 100 mil coring
- F. Standard overbore plus 200 mil coring

(2) Coolant Temperature

Front face, 12°C; Center, 50°C; Rear face, 104°C