UNCLASSIFIED

BNL 255

Radiation Effects on Reactor Materials

EVALUATION OF BNL PILE GRAPHITE

October 5, 1953

Price \$ 0.25

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

Written By:

W.L. Kosiba
D.H. Gurinsky
G.J. Dienes

Work Done By:

Stored Energy - W.L. Kosiba
Physical Growth - E.E. Walsh
X-Ray - O.F. Kammerer, J. Sadofsky

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

CLASSIFICATION CANCELLED

DATE FEB 13 1957 *md*

For The Atomic Energy Commission

H.F. Cance
Chief, Declassification Branch

BROOKHAVEN NATIONAL LABORATORY
Upton, N. Y.

UNCLASSIFIED

~~SECRET~~

~~CONFIDENTIAL~~

ABSTRACT

The graphite in the Brookhaven reactor was evaluated with respect to the following properties:

- 1) stored energy,
- 2) physical growth, and
- 3) c-axis change.

As a result of these studies, it is believed that:

- 1) The temperature of the graphite in the BNL pile may be raised to 250°C or even 400°C without an excessive temperature excursion.
- 2) The low temperature stored energy in the BNL pile graphite may be safely released.
- 3) Some growth recovery should be expected.
- 4) It is desirable to anneal the BNL pile.

~~SECRET~~

~~SECRET~~

~~CONFIDENTIAL~~

EVALUATION OF BNL PILE GRAPHITE

Introduction

The studies on BNL pile graphite prior to this investigation were in the nature of monitoring rather than serious evaluation. The change in dimensions of the pile has been followed by the Operations Division under the direction of R.W. Powell. The growth in the BNL pile at the present time is not a serious concern but is already sufficient to distort the alignment of some of the openings through the graphite structure. It is estimated that within a few years operational difficulties may be experienced if the current rate of growth continues.

The information obtained from the British (BNL Log No. C-6851) strongly suggested that the BNL pile could be safely annealed. In order to determine the desirability and feasibility of such a large scale experiment an evaluation of the Brookhaven pile graphite was undertaken. The program consisted of three parts:

- 1) stored energy measurements,
- 2) physical growth measurements, and
- 3) x-ray c-axis measurements.

The stored energy measurements were undertaken to determine the necessity for a planned release of this energy. The physical growth and x-ray c-axis measurements were undertaken to determine whether recovery of some of the growth and a change in growth rate accompanied an energy release.

Stored Energy Measurements

Apparatus

A brass cylinder, 29-1/2 in. long and 4 in. ID with one end closed, was wrapped with a heating coil. This served as the furnace. An iron constantan thermocouple was attached at the midpoint of the brass cylinder. Asbestos was wrapped around the furnace as outside insulation and santocel was used as the insulation inside the furnace. The graphite sample with an iron constantan thermocouple in it was imbedded in the santocel at the midpoint of the furnace. A Loudon controller was used to control the temperature of the furnace. Two identical pieces of apparatus were constructed for more efficient collection of data. (See Figure 1.)

Figure 1. Furnace used for studying release of stored energy.

Method of Measurement

Release experiments were run at both 200 and 400°C. The brass cylinder was raised to 200°C or 400°C (depending on the run) as rapidly as possible. This took from 10 to 15 min for the 200°C runs and about 35 min for the run at 400°C. The temperature of the wall was then

~~SECRET~~

Figure 2. Maximum temperatures in energy release experiment as a function of flux and position. BNL Log No. D-2473.

~~SECRET~~

~~CONFIDENTIAL~~

Figure 7. BNL Log No. D-2451.

Figure 8. BNL Log No. D-2471.

Figure 9. BNL Log No. D-2453.

Figure 10. BNL Log No. D-2444.

~~SECRET~~

~~SECRET~~

Table I						
Stored Energy in Various BNL Graphite Samples						
Data from figure	Furnace temp. °C	Max. temp. reached by irradiated sample	Mass of sample (g)	Total energy released (cal)	Energy released (cal/g)	
3	200	282	13.5428	726.52	53.6	
4	200	265	33.2048	1580.59	47.6	
5	200	234	25.1070	626.35	24.9	
6	200	218	8.6330	203.90	23.6	
7	400.5	400.5	24.8995	1094.90	43.9	

by Hanford for stored energy from 0° to 250°C is approximately 25 cal/g. This value should be compared to that calculated from Figure 4 which is for a central core sample. The stored energy calculated for this run on a central core sample is 47 cal/g. (See Table I). This apparent difference obtained by the two methods for measuring energy storage may be explained in one of two ways - the samples run by Hanford were different from the sample used in run 4 or the two methods give different results. The former explanation is the more likely one since other central core samples, which were run in this laboratory, gave rise to lower maximum temperatures, i.e. lower energy releases, which compare favorably with the results obtained by Hanford.

The stored energy may be roughly calculated by obtaining the product of the temperature rise, i.e. the difference between the break away temperature and the maximum temperature attained, and the average specific heat of graphite, .25 to .30 cal/g/°C. The sharper the peak for the maximum temperature the better the approximation. Values calculated in this manner agree reasonably well with those calculated by Chernick but are apt to be lower. For example, in Figure 4 the temperature difference is about 135°C, thus the energy released is approximately 40 cal/g, whereas the value obtained by Chernick is 47 cal/g. It appears that maximum temperature attained is a reasonable measure of energy release.

Discussion of Results

In the section on method of measurement it was pointed out that these release experiments as conducted could be considered essentially adiabatic. The question of whether the experiments were designed to give the maximum temperature attainable under any set of conditions as a result of the energy release must be considered. From the shape of the curves obtained this question can be answered in the affirmative. However if the experiments were truly adiabatic the maximum temperature reached would be higher than that actually attained. The reason for not attaining the higher temperature in the actual experiments is due to the heat loss to the insulator. This however does not affect the calculation on the energy storage. The more exact calculation of stored energy does take this loss into account.

The shape of the curve is to some extent dependent on the size of the specimen in that a larger specimen is actually run under more adiabatic conditions. From the experiment on the large specimen (Figure 12) it is seen that the shape of the curve is changed in the region beyond the temperature maximum: the curve does not turn down as quickly in the large specimen as in the small one. The experiments as run should be comparable to an actual energy release in the pile because in all probability the release will occur in individual blocks rather than from the unit as a whole.

The results obtained in this study show the direct relationship between energy stored in the pile graphite and the temperature of the pile graphite (therefore the

~~SECRET~~

~~SECRET~~

Figure 14 (Left). Percent growth/1000 Mwd/ct of interlayer (Newson) graphite as a function of temperature. BNL Log No. D-2482.

Figure 15 (Right). Percent growth/1000 Mwd/ct of interlayer (Newson) graphite as a function of temperature. BNL Log No. D-2483.

four were chosen after the original measurements were made; one specimen was heat-treated at 250°C for 1 hr in a vacuum furnace and the other at 400°C to determine the recovery of growth at these temperatures. The vacuum in all cases was less than 5 μ . Figure 13 shows the layout of the specimens in the Newson hole containers. Table II shows the samples that were used at the 250°C and 400°C anneals.

Figure 16 shows the growth and the recovery of a composite of specimens annealed at 250°C. The results of the 400°C heat treatment are shown in Figure 17. Recovery ranging from 24 percent to 36 percent was noted as a result of the 400°C heat treatment. In general the amount of recovery depended on the amount of growth. Table III is a summary of the data presented in Figures 14 through 17.

Figure 16 (Left). Comparison of composite curves of growth and recovery as a function of temperature of exposure. BNL Log No. D-2489.

Figure 17 (Right). Comparison of composite curves of growth and recovery as a function of temperature of exposure. BNL Log No. D-2490.

~~SECRET~~

~~SECRET~~

Table IV						
c-Axis Growth and Recovery Data; specimens from north half of pile.						
Channel	Inches from gap	c-Axis after irradiation	c-Axis after anneal	% Recovery due to anneal **	Exposure Mwd/ct	Expansion 1000 Mwd/ct
B-10-2	32	6.824	6.816	8	326.	4.6
	25-3/4	6.842	6.836	5.1	329.	5.3
	17	6.87	6.864	4.1	327.	6.6
	8	6.902	6.858	24.7	322.	8.2
B-4-4	50	6.78	6.768	21.4	468.	1.8
	36	6.82	6.802	18.8	488.	2.9
	14	6.912	6.868	23.4	491.	5.7
	4	6.93	6.884	22.3	481.	6.4
B-2-7	34	6.828	6.830	----	457.	3.4
	15	6.9	6.876	13.6	459.	5.7
A-1-2	45	6.788	6.788	----	532.	1.8
	36	6.822	6.818	4.08	543.	2.7
	13	6.888	6.872	9.8	545.	4.5
	7	6.902	6.860	23.6	538.	4.9
B-0-4-1/2*	60	6.747	6.746	----	308.	1.3
	36	6.778	6.778	----	342.	2.4
	24	6.801	6.794	9.1	347.	3.3
	12	6.827	6.814	12.6	341.	4.4
	0	6.842	6.826	13.6	337.	5.1
Calculation based on c-axis = 6.724 (uncorrected for penetration of beam) for non-irradiated graphite.						
*Newson hole samples.						
**Annealed in stored energy apparatus with furnace wall temperature at 200°C.						

Table V						
c-Axis Growth and Recovery Data; specimens from south half of pile.						
Channel	Inches from gap	c-Axis before anneal	c-Axis after anneal	% Recovery due to anneal**	Exposure Mwd/ct	Exposure 1000 Mwd/ct
B-10-2	17-5/8	6.882	6.852	19	328.	7.2
	9-5/8	6.900	6.86	22.7	325.	8.1
B-2-7	33	6.842	6.826	13.5	459.	3.8
	26	6.86	6.844	11.8	463.	4.4
	16	6.886	6.864	13.6	460.	5.2
	6-1/2	6.914	6.894	10.5	453.	6.2
B-4-4	47	6.782	6.782	----	474.	1.8
	36	6.814	6.802	13.33	490.	2.7
	17	6.902	6.866	20.2	493.	5.4
	8	6.95	6.892	25.7	486.	6.9
A-1-2	43	6.832	6.824	7.4	550.	2.9
	32	6.850	6.846	3.2	565.	3.3
	15	6.940	6.924	7.4	564.	5.7
	6	6.958	6.910	20.5	554.	6.3
B-0-4-1/2*	60	6.74	6.742	----	308.	0.88
	36	6.76	6.76	----	342.	1.6
	12	6.832	6.820	11.0	341.	4.7
	0	6.846	6.826	16.4	337.	5.3
*Newson hole samples.						
**Annealed in stored energy apparatus with furnace wall temperature at 200°C.						

~~SECRET~~

~~SECRET~~

- c) Some growth recovery should be expected although the amount of recovery is hard to predict for a complex graphite structure, such as the reactor, from the study of individual pieces of graphite.
- d) It seems desirable to anneal the BNL pile graphite.

Acknowledgements

The authors wish to acknowledge the assistance of B. Turovlin for some preliminary work on stored energy, and of I. Kaplan for many helpful discussions. Thanks are due to R.W. Powell not only for devising and obtaining the cored channel specimens but also for consideration given to the many requests made of him.

Addendum

Since the main body of this report was written, the BNL reactor was annealed during the week of October 19, 1953. The temperature of the pile was increased at a rate of approximately 10°C/hr until parts of the pile reached 300°C . The pile was then allowed to cool of its own accord (i.e., no air was passed through it) for about 12 hr. The cooling was then accelerated by passing air through it.

During the annealing there were no drastic increases in the temperature rate; changes in the shape of the temperature curve were noticed but these changes were slight. Thus, as was expected from the way the anneal was conducted, the energy release occurred very closely in an isothermal manner.

Measurements were made to determine the recovery of the growth of graphite at the gap. The greatest recovery measured was .096 in. which is about a 23 percent recovery of the actual growth of the structure. The average recovery was about .077 in.

Post-anneal studies are being conducted. A full account of the results obtained will be issued as a supplement to this report.

~~SECRET~~