AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301-587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

**Cover Sheet for a Hanford
Historical Document
Released for Public Availability**

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

MAY 04 1994

OSTI

DISCLAIMER

This is a historical document that is being released for public availability. This was made from the best available copy. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DECLASSIFIED

HW-76060

DATA

January 2, 1963

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

[X] RESTRICTED AREA
THIS DOCUMENT CONTAINS RESTRICTED DATA AS
DEFINED IN THE ATOMIC ENERGY ACT OF 1954.
TRANSMITTAL OF THIS DISCLOSURE OF ITS
CONTENTS IN ANY MANNER TO AN UNAUTHORIZED
PERSON IS PROHIBITED.

TITLE

CONTRACTION OF GRAPHITE: A COMPARISON OF LABORATORY AND PRODUCTION REACTOR DATA - PART II - KE AND KW REACTORS

☐ OTHER OFFICIAL CLASSIFIED INFORMATION
THIS MATERIAL CONTAINS INFORMATION AFFECTING
THE NATIONAL DEFENSE OF THE UNITED STATES
WITHIN THE MEANING OF THE ESPIONAGE LAWS,
TITLE 18, U. S. C., SECS. 793 AND 794, THE TRANS-
MISSION OR REVELATION OF WHICH IN ANY MANNER
TO AN UNAUTHORIZED PERSON IS PROHIBITED BY
LAW.

AUTHOR

R. C. Giberzon

and

W. C. Morgan.

~~CIRCULAR FILE COPY~~

RECEIVED 300 AREA

FEB 14 1963

RETURN TO

TECHNICAL INFORMATION FILES

THIS DOCUMENT IS NOT TO BE LEFT UNATTENDED OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS TO IT. WHEN IN USE, IT MUST BE KEPT IN AN APPROVED LOCKED CUSTODY WITHIN AN APPROVED GUARDIAN AREA. WHILE IN YOUR POSSESSION AND UNTIL YOU HAVE OBTAINED A SIGNED RELEASE FROM CLASSIFIED FILES, IT IS YOUR RESPONSIBILITY TO PROTECT AND ITS CONTENTS WITHIN THE LIMITS OF THE PROJECT AND PREVENT ANY UNAUTHORIZED PERSONS FROM TRANSMITTAL TO, AND STORAGE AT YOUR PLACE OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE DUPLICATED. IF ADDITIONAL COPIES ARE REQUIRED, OBTAIN THEM FROM THE RELATED ISSUING OFFICE. ALL PERSONS READING THIS DOCUMENT ARE REQUESTED TO SIGN IN THE SPACE PROVIDED BELOW.

[illegible]

DECLASSIFIED

~~DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED~~

(CLASSIFICATION)

DECLASSIFIED

-1-

HW-76060

This document classified
ORIGINAL SIGNED BY
by R. E. NIGHTINGALE

This document consists of

19 pages. [REDACTED]
[REDACTED]
1-2-63

CONTRACTION OF GRAPHITE: A COMPARISON OF LABORATORY
AND PRODUCTION REACTOR DATA
PART II - KE AND KW REACTORS

R. C. Giberson and W. C. Morgan

DISTRIBUTION

1. F. W. Albaugh	15. W. C. Morgan
2. T. W. Ambrose	16. R. Neidner
3. R. W. Benoliel	17. R. E. Nightingale
4. C. E. Bowers	18. R. W. Reid
5. R. A. Chitwood	19. A. Russell
6. D. H. Curtiss	20. R. E. Trumble
7. J. M. Davidson	21. F. W. Van Wormer
8. A. E. DeMers	22. E. E. Voiland
9. R. C. Giberson	23. E. M. Woodruff
10. S. M. Graves	24. H. H. Yoshikawa
11. O. H. Greager	25. 300 Files
12. L. L. Grumme	26. Record Center
13. J. W. Helm	27-29. Extra
14. J. L. Jackson	

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of WA Snyder

CG-PR-2 3-16-94

By J. E. Savelly 4-16-94

Verified By Gerri Mally,
4-18-94.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

-2-

HW-76060

CONTRACTION OF GRAPHITE: A COMPARISON OF LABORATORY AND PRODUCTION
REACTOR DATA - PART II - KE AND KW REACTORS

INTRODUCTION

Part I¹ of this two-part report presented a comparison of the irradiation-induced contraction rates obtained on standard-size graphite samples and the apparent moderator contraction rates of H, DR and C Reactors. The distortion trends of the top center of the graphite stacks, from which the apparent moderator contraction rates were derived, were presented as a function of cumulative power generation since start-up for each of the six older Hanford reactors.

Since KE and KW Reactors are of identical construction, different in many details from the six older reactors, and have been operated under similar conditions, the data from KE and KW are treated as if from one reactor. As in Part I, contraction rates apply to measurements made transverse to the extrusion axis of the bars. As used in this report, the depression rates refer to the rate of reduction in height of the top center of the reactor moderators. This depression rate is the net effect of contraction and expansion of the graphite bars. The depression rate is used to calculate the contraction rate of the individual bars. The contraction rates derived from the reactor data are compared with contraction rates of small samples of the same graphite (TSGBF) as was used in the core of the K Reactors.

DECLASSIFIED

-3-

HW-76060

SUMMARY

The net moderator depression of the K Reactors is obtained as a linear function of the total reactor power generation. When the calculated contraction rates of the moderator bars are expressed as a function of fast-neutron exposure, the rates of the reactor moderator bars are found to be about 2.5 times the rate of standard-size (0.43 in. diameter by 4 in.) graphite samples. The data support previous results which indicate that the contraction rates are a function of fast-neutron exposure, graphite type, irradiation temperature and sample size. The moderator depression rates are the cumulative result of many contraction (and expansion) rates weighted by the relative exposure-rate and amount of graphite at each temperature in the moderator column.

MEASUREMENTS

In contrast to the method employed at the six old reactors, where the top center depression is monitored in a process tube,¹ stack distortion is routinely measured in a bare test channel, Y-2 at the K Reactors. The equipment used in making the measurements is the same as that used at the other reactors.¹

The Y-2 test hole is located two lattice spacings (15 in.) above the top process-tube row and over vertical tube column 65.² The front face of the reactors, showing the location of the Y-2 hole and the approximate position of the enrichment ring, is shown in Fig. 1.

Figures 2 and 3 show typical traverse readings obtained at KE and KW respectively. Several curves are drawn on each of the figures showing the history of the Y-2 distortion.

DECLASSIFIED

-4-

HW-76060

Standard-size (0.43-in. diameter by 4-in. long) samples of TSGBF graphite have been irradiated in test holes at the K Reactors. Contraction rates were obtained from samples irradiated in 2C at KW between August 1960 and March 1962. Length changes on these samples have been measured with a precision of about ± 0.005 per cent by use of a micrometer.

DISTORTION TRENDS IN K REACTORS

The displacement of the Y-2 hole at the point of maximum change is plotted versus cumulative power generation in Fig. 4. Both KE and KW are plotted together and calculations of slopes, rates, etc., considers both reactors as identical in their distortion behavior. It is possible to fit the data about equally well with a quadratic equation or with two straight lines intersecting at a cumulative power generation of about 4×10^6 Mwd. As discussed later there are valid reasons for choosing two straight lines as shown in Fig. 4.

Because the graphite moderator was not operated for any extended period at low temperatures, only a small amount of expansion occurred during the initial operating period. In this respect the K Reactors are similar to H, DR and C. As shown in Fig. 4, after a cumulative power generation of 0.6×10^6 Mwd, the top center of the graphite stack was below lay-up level. The rate of depression continued linearly until mid-1960 and then apparently increased.

The most probable depression rate for the K Reactors up to mid-1960 is $0.64 \text{ in./}10^6 \text{ Mwd}$. An analysis of the variability of the data points shows that there is less than 1 chance in 100 that the slope is in error by more than $\pm 0.08 \text{ in./}10^6 \text{ Mwd}$.

DECLASSIFIED

-5-

HW-76060

Since mid-1960 the depression has proceeded at a rate of $0.82 \text{ in./}10^6 \text{ Mwd.}$ There is only 1 chance in 100 that the slope determined from the data since mid-1960 is in error by more than $\pm 0.13 \text{ in./}10^6 \text{ Mwd.}$ A statistical comparison of the two different slopes shows that there is less than 1 chance in 100 that the two slopes are the same.

The intercept of the two slopes was fixed on the basis of the changes in operating conditions which went into effect at about that date. Variations in the location of the intercept, within reasonable limits, would only produce small changes in the magnitude of the slope and would not alter the basic conclusion of two different slopes. The changes in operating conditions, and possibly physical reasons for the change in rate of depression, are discussed in the next section.

EFFECT OF TEMPERATURE

Before contraction rates can be calculated from the moderator depression rates presented in the previous section, one must determine where the depression is occurring. As was noted in Part I the depression of H Reactor moderator had occurred essentially as if all filler bars, both inside and outside the enrichment ring, were contributing an equal amount of depression per bar. Since the rate of exposure accumulation and irradiation temperature outside the enrichment ring are both lower than inside the enrichment ring, this result is an indication that the contraction rate of the filler bars is a function of either the irradiation temperature or the rate of exposure accumulation.

DECLASSIFIED

-6-

HW-76060

The maximum depression of the process tubes near the central column and inside the enrichment ring of KE Reactor is plotted as a function of stack depression and tube row in Fig. 5. The relationship between the total stack depression and the depression rate of the graphite inside the enrichment ring can be obtained directly from the slopes of the lines. As can be seen from this figure, prior to mid-1960 the dimensional changes of the bars outside the enrichment ring must have resulted in a small net expansion. By mid-1962, however, the average of the changes outside the enrichment ring has resulted in more contraction per bar than that occurring inside the enrichment ring. It can be shown that these results are compatible if the contraction rates of the bars are dependent upon the temperature. Thus, on the basis of the above data, it is concluded that the contraction rate of filler-size graphite bars is dependent on some function of the irradiation temperature, and this function may be similar to that previously observed for small samples of reactor-grade graphites. The contraction rate of small samples of graphite have been shown³ to increase with increasing temperature from about 300° C to near 450° C, and then to decrease with increasing temperature to near 800° C.

Outside the enrichment there are changes in the temperature and rate of exposure accumulation with distance from the central zone. In this region there exists a spectrum of contraction rates and, where the temperature is below about 300° C a spectrum of expansion rates. The depression rate is a complex function of these many rates. It is therefore apparent that a change in temperature at any position in the central column can change the relationship between the stack depression rate and the rate of contraction of the central-zone graphite.

DECLASSIFIED

-7-

HW-76060

A number of changes in the operating procedures at the K Reactors were put into effect in mid-1960 as a result of two production tests.^{4,5} The net effect of these production tests was to allow increased graphite temperatures. PT-IP-312-A authorized an increase in operating temperature at both KE and KW to a maximum of 700° C with provision for certain readings to be 750 and 800° C. PT-358-AC authorized the use of N₂ instead of CO₂ as a constituent of the reactor atmosphere at KE Reactor. Temperature limits remained as given in IP-312-A with N₂ being treated as helium in determining the maximum allowable temperature. The referenced production tests were extended^{6,7} to June 20, 1962.

In June 1962, a Process Improvement Transition Authorization was issued⁸ which permitted both reactors to use nitrogen with a maximum graphite temperature of 700° C at any helium concentration. A maximum temperature of 850° C was allowed in the 0.130-in. coring zone. This type of operation is authorized for 18 months following the approval date of June 26, 1962.

These production tests have resulted in an increase of average central-zone temperatures of about 50° C. Fringe-area temperatures have increased more than 100° C at some positions.⁹ In addition to the changes due to increased temperature, the use of splines and supplemental enrichment has resulted in increased flattening of the reactor power generation. This flattening has resulted in a decrease in the average Mw/At per Mw for the central columns and therefore has resulted in a decrease in depression rate. However, the net result of all the changes, as is indicated in

DECLASSIFIED

-8-

HW-76060

Fig. 4, has been to produce a moderator depression rate which is more rapid than that found prior to the increase in temperatures. Qualitatively, the reasons for the increased depression rate are as follows:

- (1) The increase in central filler-graphite temperature to about 625° C has probably resulted in a decreased contraction rate in the central zone;
- (2) The increase in temperature in parts of the fringe region, which may have experienced only negligible contraction prior to mid-1960, has probably resulted in faster contraction rates than those in the central zone of the reactor;
- (3) The temperature increases may have resulted in some annealing of the graphite expansion which had occurred in regions of the reactors where the temperatures were below about 300° C prior to mid-1960.

The increase in depression occurring in the fringe regions due to (2) and (3) has apparently resulted in a net increase in stack depression rate. The relative magnitude of the effects due to annealing and those due to increased contraction are not known. If the annealing effect was large compared to the effect of increased contraction rates of the fringe graphite, a rapid quasi-exponential change in depression rate would be expected. Since there has been no apparent exponential change in the depression rate, probably most of the apparent increase in rate since mid-1960 is due to the increased contraction rate of graphite in the fringe zones of the reactors. Traverses of tubes at several elevations near the central column are needed to determine where the increase in contraction rate is occurring.

DECLASSIFIED

-9-

HW-76060

CONTRACTION RATES

The reactor depression rates obtained for the two different time intervals will now be used to calculate a central-zone contraction rate for the moderate-graphite bars. When the comparisons are made on the basis of exposure to neutrons with energy above 0.18 Mev reasonably good agreement is obtained between the contraction rate of small samples. Therefore, the contraction rates of the reactor filler-bar graphite are reported here as a function of nvt, $E > 0.18$ Mev.

The depression rates of the reactor moderator and the relationship of central-moderator depression to total stack depression were obtained in the previous two sections. In order to obtain the contraction rates of the central filler-bar graphite as a function of neutron exposure, it is first necessary to derive the relationship between the total reactor power (Mw) and the specific power (Mw/At). It is assumed that the ratio of Mw/At to Mw has been approximately constant over periods of several years. The coolant flow rate (G) and the coolant temperature rise (ΔT) were obtained¹⁰ for a representative central tube of both reactors during a period of near-equilibrium operation. From these data and the conversion data of HW-63991¹¹ the ratio of total reactor power to specific power given in Table I was calculated.

TABLE I - CONVERSION OF REACTOR POWER TO SPECIFIC POWER

Reactor	Date	G (gal/min)	ΔT (°C)	Mw/At	Reactor power (Mw)	Mw/At/Mw
KE	1-15-62	63.8	97.8	17.2	4400	3.90×10^{-3}
KW	1-19-62	61.0	100.8	16.9	4400	3.84×10^{-3}
Average =						3.87×10^{-3}

DECLASSIFIED

-10-

HW-76060

The average neutron exposure* per Mwd/At for the hot test holes of KE and KW Reactors has been determined¹² as 2.35×10^{17} nvt per Mwd/At. There is a cyclic variation between process channels of ± 10 per cent relative to this average. The contraction rate in the reactor, which represents an average of the minimum contraction rates of the individual filler bars, is therefore calculated on the basis of the lower average ratio, 2.12×10^{17} nvt per Mwd/At. This ratio multiplied by the ratio, $\frac{Mw/At}{Mw}$, derived in Table I gives a value for the conversion factor of 8.20×10^{14} nvt per Mwd of total reactor power.

The relative amount of depression of the central moderator zone obtained from Fig. 5 is about 1.38 times the stack depression between October 1958 and May 1960. The two vertical-height traverses available since mid-1960 indicate that the central-zone depression is about 0.95 times the stack depression at the present time. This relationship may change slightly as more vertical-height traverse data become available, or if operating conditions are changed. In the following calculations it is assumed that the total contraction measured over a lattice unit is proportional to the contraction per unit time at the date of measurement. This assumption is, of course, a good approximation for the case where a large amount of the total contraction occurred at the rate prevailing at the time of measurement. It is therefore believed that relationships derived for the K Reactors between October 1958 and May 1960 are reliable. However, the relationships derived for the later period (data obtained during September 1962) are not as reliable due to both the small amount of additional contraction and the limited amount of data. The rates listed in Table II assume that the contracting columns are 450 inches high.

DECLASSIFIED

-11-

HW-76060

TABLE II - CONTRACTION RATES AS A FUNCTION OF EXPOSURE

Reactor	Date	Total stack depression rate		Central zone depression rate, % per 10^6 Mwd	Ratio of central zone to total stack [†]	Central-zone contraction rate, % per 10^{20} nv
		in. per 10^6 Mwd*	% per 10^6 Mwd			
KE & KW	Oct. 1958 to May 1960	0.64	0.14	0.20	1.38	0.024
KE & KW	Sept. 1962	0.82	0.18	0.17	0.95	0.021

* As obtained from Fig. 4.

† As obtained from Fig. 5.

COMPARISON OF CONTRACTION RATES

A comparison between the calculated contraction rate of the moderator filler-bars and the experimental contraction rates obtained on small laboratory samples will now be made.

KE and KW Reactors are constructed of TSGBF graphite. Of the TSGBF type graphites most irradiation data is available on the SGBF grade.¹³ SGBF graphite is nominally the same as TSGBF except that it was made by a different manufacturer. The contraction rate at 550° C obtained from transverse SGBF samples is 0.010 per cent per 10^{20} nvt. Assuming that the same dependence of contraction rate on temperature holds for SGBF as that found for CSF graphite³, this rate can be extrapolated to 0.0098 per cent per 10^{20} nvt at 575° C.

A few standard-size samples of TSGBF have been irradiated in the hot test holes of the K Reactors¹⁴ at about 625° C. These data indicate a contraction rate of about 0.0075 per cent per 10^{20} nvt. Extrapolating

DECLASSIFIED

this contraction rate to 575° C yields a contraction rate of about 0.0099 per cent per 10^{20} nvt, in good agreement with the SGBF standard-size sample data from C Reactor.

Using a contraction rate of 0.01 per cent per 10^{20} nvt for the standard-size samples and the central-moderator contraction rate obtained for the K Reactors prior to mid-1960, the ratio of standard-size sample to reactor-moderator contraction rates is 0.42. This is in good agreement with the contraction-rate ratios obtained for CSF and CSGBF graphite in H and C Reactors.¹

As discussed earlier the temperature of the central region has increased from 575° C to about 625° C since mid-1960. The contraction rate for standard-size samples of TSGBF was found to be about 0.0075 per cent per 10^{20} nvt at 625° C as was noted earlier. This yields a ratio of standard-size sample contraction rate to filler bar contraction rate of 0.36 which again is in fair agreement with previous results. However, when the vertical displacements of several more process channels of a central column are measured, this ratio may change slightly.

A summary of contraction data determined in this report is given in Table III.

TABLE III - SUMMARY OF CONTRACTION DATA FOR KE AND KW REACTOR MODERATORS - TSGBF GRAPHITE

Stack depression rate, in. per 10^6 Mwd	Date	Central-zone contraction rate, % per 10^{20} nvt	Average central-zone temp., °C	Std. sample contraction rate, % per 10^{20} nvt	Ratio, Std. sample to central zone
0.64	Oct 1958- May 1960	0.024	~ 575	0.010	0.42
0.82	Sept. 1962	0.021	~ 625	0.0075	0.36

DECLASSIFIED**RECOMMENDATIONS**

It is recommended that vertical-height traverses be obtained on a routine basis for several tubes of a central column of each of the production reactors. These data can be used to: (1) determine where the moderator contraction is occurring; (2) determine more precisely the relationship between contraction rates of standard-size samples and the reactor filler bars. This information will:

1. Provide a better understanding of the effect of changes in operating conditions on the depression rate.
 2. Enable a prediction of the results of changes in operating conditions on the depression rate prior to the introduction of such changes.
 3. Enable predictions of the contraction rates of future reactors (e.g. NPR) from data on small samples.
-

DECLASSIFIED

REFERENCES

1. R. C. Giberson and W. C. Morgan, "Contraction of Graphite: A Comparison of Laboratory and Production Reactor Data, Part I - B, D, F, H, DR, and C Reactors," HW-74155, August 6, 1962 (Secret).
2. Hanford Drawing No. H-1-21410.
3. J. M. Davidson and J. W. Helm, "The H-1 High Temperature Graphite Irradiation Experiment," HW-64286, April 1961.
4. R. C. Giberson and R. W. Benoliel, "Production Test IP-312-A; Increase of Graphite Temperature Limit at 105-KE and KW," HW-64374, May 20, 1960 (Secret).
5. G. F. Bailey and R. W. Benoliel, "Replacement of Carbon Dioxide with Nitrogen as a Constituent of the K Reactor Atmosphere," HW-66973, October 3, 1960 (Secret).
6. R. W. Benoliel, "Supplement B to Production Test IP-358-AC," HW-71635, November 8, 1961 (Secret).
7. R. E. Baars, "Supplement B to Production Test IP-312-A and Supplement C to Production Test IP-358-AC," HW-73703, May 1962 (Unclassified).
8. R. E. Baars, "Process Improvement Transition Authorization IP-20-I, Increased Graphite Temperature Limits and Use of Nitrogen in the K Reactors," HW-73991, June 13, 1962 (Secret).
9. Letter, R. C. Giberson to R. E. Nightingale, "Operating History Relative to KER-1," April 6, 1962 (Secret Rough Draft).
10. K. W. Powers, personal communication, May 28, 1962.
11. W. C. Morgan and W. L. Bunch, "Neutron Flux as a Function of Tube Power," HW-63991, February 22, 1960 (Secret).
12. H. H. Yoshikawa and W. C. Morgan, "Fast Neutron Fluxes in Hanford Irradiation Facilities, Interim Report No. 3," to be published.
13. R. E. Nightingale, "Summary of Recent Hanford Graphite Irradiations," HW-SA-2467, March 2, 1962.
14. E. M. Woodruff, unpublished data, September 1962.

DECLASSIFIED

FIGURE 1

Diagram of K Reactor Front Face

DECLASSIFIED

FIGURE 2

Vertical - Traverse History Y-2 at KE

DECLASSIFIED

FIGURE 3

Vertical - Traverse History Y-2 at KW

FIGURE 4

Elevation of Y-2 Channel at Point of Maximum Depression vs Cumulative Power Generation at KE and KW Reactors

DECLASSIFIED

DECLASSIFIED

FIGURE 5

Relative Depression of KE Reactor as a Function of Tube Row

DATE

FILMED

6/30/94

END