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HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

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TITLE

Letter to G. L. Harbo

EQUIVALENT N-FRACTURE ANALYSIS

AUTHOR

ISSUING FILE

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D. H. Curtiss
 1100 N Building
 100 N Area

GETR GRAPHITE IRRADIATION CAPSULES: H-4,5,6
EQUIVALENT N-REACTOR EXPOSURE

References: HW-77149, N-Reactor Department 02 Research and
 Development Program for FY-1964 - FY-1965.
 April 1, 1963, Pgs. 50-53.

A program for the irradiation of samples of N-Reactor graphite has been in progress since November 30, 1961, in the General Electric Test Reactor (GETR). The basic purpose of the program is to achieve an exposure to the samples equivalent to 20 years of operation of N-Reactor and to relate the physical distortion of the samples to the expected behavior of the N-Reactor moderator stack. Theoretical studies to relate sample exposure in the GETR to exposure in N-Reactor have been underway since the program began. The conversion of exposure depends on three main items: the flux and exposure in the GETR test position; the flux and exposure in the N-Reactor stack; and the relationship of the amount of carbon damage per unit flux in N-Reactor to that in the GETR. To date all three items of the conversion have been based strictly on computer calculations. The first item (the GETR flux) has been calculated as group one, $E > 0.18$ Mev, of the three-group computation made every reactor cycle by the GETR physics group. This computation is normalized to reactor conditions by comparison of group three, $E < 0.17$ ev, with measured cobalt-alloy monitors. No direct comparison of group one with monitor materials is made; however, efforts to correlate these are now underway. On this basis, it was estimated that the test samples accumulated exposure at the rate of 4 to 5 years of equivalent N-Reactor exposure per year of test irradiation.

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Data are now available so that the GETR flux can be based on activation measurements of monitors of nickel, iron, and titanium located in each irradiation capsule. Sample exposures based on these activation rates can be calculated through use of recent computations of neutron spectra utilizing 18 energy groups, of which 16 are greater than 0.18 Mev, improved cross-section data, and resolution of problems of counting of monitor activity. Based on data from the flux monitors contained in the first eight capsules in the program (through the H-5-3 capsule removed from the GETR on January 6, 1964), the new conversion factor is: 1 year of test irradiation at the highest flux position is equivalent to approximately 2.3 years of N-Reactor exposure. Since the exposures determined from these fluxes have a direct bearing on the irradiation unit and operating budgets, this information is being transmitted to you at this time even though the other two parts of the conversion must still be based on computations.

The details of the conversion calculation are given in Attachment I. To achieve an exposure to samples at the maximum temperature equivalent to 20 years of N-Reactor operation, it would be necessary to continue the test irradiation program through FY 1970.

All fluxes and exposures given are based on the maximum flux along the length of the irradiation capsule, which approximately corresponds to an irradiation temperature of 775° C. Fluxes vary to 0.4 of this maximum flux along the capsule length. A detailed summary of estimated equivalent years of N-Reactor operation for various irradiation temperatures at the end of fiscal years through FY 1970 are given in Attachment II.

The limitations to the conversion factor should be kept in mind. The primary limitation is that only in the GETR is the flux a measured value, while the N-Reactor flux and the equivalence of carbon damage per unit flux are computed values. A direct measurement of N-Reactor flux in the near future will be useful since a direct comparison of flux monitor results can then be made. At that time, the absolute value of the flux may still be in doubt as discussed in Attachment III, but the relative fluxes should be known.

Data on length changes obtained from the capsules previously irradiated are being analyzed and a document on the program to date is under preparation.

J. W. Helm
Graphite Research & Development

JWH:jkf

Attachments (3)

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ATTACHMENT I

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Calculation of Equivalent Exposure in N-Reactor for Graphite
Samples Irradiated in GETR

- References: 1. "Neutron Spectra Calculations for Radiation-Damage Studies," R. E. Dahl and H. H. Yoshikawa, Nuclear Science and Engineering, Vol. 17, Pgs. 398-403.
2. Nuclear Graphite, R. E. Nightingale, Academic Press Co., (1962) Chapter 7.

GETR**Basis:**

Activation rates from nickel and iron flux monitors contained in 8 capsules through H-5-3.

Effective cross sections from 2DXY computer calculations¹ using presently available nickel and iron activation cross sections.

Fast Flux D7 and F7 (maximum)	1.7×10^{14} nv, E > 0.18 Mev
Effective Days per Cycle	23
Cycles per Year	5-9
Mean (Depends on capsule irradiation schedule. See Attachment II for detailed estimate of cycles for each fiscal year).	7
Exposure per Cycle (maximum)	3.5×10^{20} nvt, E > 0.18 Mev.
(Average equals 0.69 times maximum)	
Exposure per Year (maximum)	$2.44 \times 10^{21} \frac{\text{nvt}_{\text{GETR}}}{\text{year}}$

N-REACTOR**Basis:**

Power Level	4000 MW
Operating Efficiency	80 %
Operating Days per Year	300
Fuel Loading	21.6 lb/ft.
Power Generation	188 kw/ft.

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$$\frac{188 \text{ kw/ft}}{21.6 \text{ lb/ft}} = 17.4 \frac{\text{Mwd/At}}{\text{day}}$$

Conversion Mwd/At to nvt

Based on 2DXY computer calculation.¹

$$\frac{\int \text{flux (E > 0.18)/Area}}{\int \text{fission/atoms fuel}} = 1.88 \times 10^{17} \frac{\text{nvt}}{\text{Mwd/At}}$$

Computed Exposure per Year

$$17.4 \frac{\text{Mwd/At}}{\text{day}} \times 300 \frac{\text{days}}{\text{year}} \times 1.88 \times 10^{17} \frac{\text{nvt}}{\text{Mwd/At}} = 9.82 \times 10^{20} \frac{\text{nvt}_N}{\text{year}}$$

EXPOSURE EQUIVALENCE

Basis:

Two independent 2DXY computer calculations¹
Carbon damage, C_D , based on de Halas' model²

GETRN-REACTORCarbon Damage, C_D , per unit flux, ϕ C_D/ϕ

3020

3280

Exposure Equivalence

$$\frac{C_D/\phi_N}{C_D/\phi_{\text{GETR}}} = \frac{3280}{3020} = 1.09 \quad \begin{array}{l} 1 \text{ nvt} \\ 1.09 \text{ nvt} \end{array} = \begin{array}{l} 0.92 \text{ nvt} \\ 1 \text{ nvt} \end{array}$$

Exposure per Year

From data above	$2.44 \times 10^{21} \text{ nvt}$	$0.98 \times 10^{21} \text{ nvt}$
Based on equal carbon damage	$2.44 \times 10^{21} \text{ nvt}$	$1.07 \times 10^{21} \text{ nvt}$

Exposure Equivalence

Maximum flux position	1 Year	=	2.3 Years
Average flux position	1 Year	=	1.6 Years

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ATTACHMENT IICumulative GETR Irradiation Cycles

Date June 30	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>
GETR Cycles-Max.	4	9	18	24	30	38	45	52	59

Estimated Equivalent Years of N-Reactor Operation

(Based on Calculations in Attachment I)

Average Position	0.9	2.1	4.0	5.4	6.7	8.5	10.1	11.7	13.3
450° C Position	0.6	1.2	2.3	3.2	3.9	5.0	6.0	6.9	7.9
575° C Position	0.8	2.0	3.7	5.0	6.4	8.0	9.4	10.9	12.4
700° C Position	1.2	2.6	5.2	6.9	8.6	10.8	12.9	15.0	17.0
775° C Position	1.3	3.0	5.8	7.8	9.7	12.3	14.6	16.9	19.2

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ATTACHMENT IIINeutron Exposures Determined from Flux Monitors

Neutron exposures to samples being irradiated should be based on three items: (1) activation rate of the flux monitor; (2) effective cross section for the monitor in the specific reactor location where it was irradiated; and (3) the relative flux intensities between the monitor location and the sample position.

Item 1 is well understood and laboratories around the U.S. can count monitors of nickel, iron, and titanium with agreement to ± 5 per cent.

Item 2 must be calculated by means of a computer code. For the H-4,5,6 capsules the 2DXY code is used (Reference 1 of Attachment I). One item of input required is the energy-dependent activation cross section for the respective flux monitor. The activation cross section is quite well known for nickel with the exception of a region between 2.5 and 5.0 Mev. This region has a large influence on the computed effective cross section and is under investigation. This information should be available in a few months. Another source of error with nickel monitors is the large cobalt-60 burnout correction which must be made. Further investigations on this are also underway.

The iron activation cross section is currently based on only four points. Additional data should be available within two months. At present, results based on nickel and iron monitors agree within ± 2 per cent, but this may be fortuitous.

The activation cross section for titanium is presently unknown. Preliminary investigations are now beginning. Currently, titanium monitors are used for comparison only.

Item 3 must also be obtained by computation. For the H-4,5,6 capsules, this is also obtained from the 2DXY computer calculation. The error in this calculation is probably less than for Item 2.

SUMMARY

<u>Source of Error</u>	<u>Improved Data Available</u>
A. Activation cross section for nickel.	Few months
B. Cobalt-60 burnout correction.	Possibly in several months
C. Activation cross section for iron.	Two months

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Source of ErrorImproved Data Available

D. Activation cross section for titanium

Possibly in several months

E. Computer calculation of effective cross section

Best available being used.
Will be modified as better data for A,B,C and D are available.

F. Computer calculation of flux intensity

Best available being used.

G. Correlation of GETR group 1 physics calculation with monitor results

Few months

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