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The Effect of Cold-Seeding on Irradiation-Induced Length Changes of Graphites

MASTER

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S u m m a r y:

Graphite samples have been irradiated at temperatures between 50°C and 500°C to fluences ranging from 10^{18} to 10^{20} n/cm² ($E > 0.18$ MeV) and then irradiated to high fluences at temperatures between 500°C and 1300°C. Dimensional-change rates of these cold-seeded samples are compared to those of samples irradiated under identical conditions minus the brief irradiation at low temperatures. With only a couple of exceptions, cold-seeding under these conditions has no effect on those samples subsequently irradiated at 1000°C or above. However, cold-seeding does alter the dimensional-change rates for samples subsequently irradiated at 750°C by up to a factor of two. At that temperature, differences of about 50 percent were observed even when the fluence for the low temperature portion of the irradiation was as low as 10^{18} n/cm².

1. I n t r o d u c t i o n

In 1964, Nightingale and Woodruff⁽¹⁾ reported that irradiation-induced dimensional changes of nuclear graphite appeared to be a function of sample size. Since that time, a considerable effort has been expended at Battelle-Northwest Laboratory to investigate this phenomenon. Initially, the study emphasized differences associated only with sample size. However, controlled irradiation of different sizes of samples failed to show the large contraction differences observed with less carefully controlled irradiations.⁽²⁾ The program, therefore, was expanded to include an investigation of a phenomenon called "cold-seeding" wherein graphite samples are irradiated briefly at low temperatures prior to the normal high temperature irradiation.

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Cold-seeding has been studied previously at fluences up to 1.5×10^{21} n/cm² (E > 0.18 MeV). (3-5)
 The objective of the present program is to determine whether or not the effects of cold-seeding persist to high fluences.

2. Experimental and Results

The following two widely different types of graphite were selected for the cold-seeding study: TSX, a production grade nuclear graphite, and Poco graphite (AXF-8QBG1), a high-strength, very isotropic specialty graphite. Both materials are more fully described in Table I.

Table I. Graphite Description

<u>Manufacturer*/ Grade</u>	<u>Coke</u>	<u>Density (g/cm³)</u>	<u>CTE(1/11)x10⁶ (25-425°)</u>	<u>Remarks</u>
UCC/TSX	Needle	1.71	3.5/0.9	Extruded, impregnated, graphitized at 3000°C.
Poco/AXF-8QBG1	Proprietary (very fine grained, equiaxed)	1.89	6.5/6.5	Isostatically molded, impregnated, graphitized at 2800°C, very strong.

* UCC = Union Carbide Corporation

For each type of graphite, both "cold-seeded" and control samples were machined from the same blocks of graphite. They were then irradiated under identical conditions except for the brief low-temperature irradiation experienced by the "cold-seeded" samples. The irradiation conditions and length-change results are shown in Table II. Several things should be noted about these data:

- (1) Cold-seeding has apparently had a significant effect on length-change rates in many cases, even for fluences as low as 10^{18} n/cm² ($E > 0.18$ MeV).
- (2) In general, the effect of cold seeding has been less pronounced in the parallel orientation.
- (3) Samples irradiated at 1000°C or above have not, in general, been affected by cold-seeding (differences of less than about 20% are probably not significant). Poco graphite seeded at 200°C and then irradiated at 1000°C appears to be an exception to this. The other possible exception, TSX graphite seeded at 500°C and then irradiated at 1300°C, is somewhat in doubt because of the large difference between the perpendicular and parallel orientation.
- (4) The effect of cold seeding, if any, on TSX graphite has been to cause an increase in the contraction rate whereas the effect on Poco graphite has been a reduction of the expansion rate.
- (5) Because of this difference between Poco and TSX graphite, the percentage differences between seeded and control samples shown in the last column of Table II has a somewhat different significance. It should be noted, therefore, that the differences of 59% and 47% shown for Poco graphite actually reflect a reduction in expansion rate by a factor of about two.

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Table II. Irradiation Conditions and Length Changes of Seeded and Control Samples

Orientation	Temperature °C		Total Fluence ($E > 0.18$ MeV)			Length Change Rate ⁽¹⁾ (%/10 ²¹)		% Increase ⁽²⁾ $\left(\frac{\alpha_s - \alpha_c}{\alpha_c}\right) \cdot 100$
	Low	High	Low Temp	High Temp		Seeded	Control	
				1st	2nd			
				TSX GRAPHITE				
I	200	750	10^{18}	0.84×10^{21}	2.37×10^{21}	-0.184	-0.126	46
II						-0.412	-0.323	28

11	200	750	5×10^{18}	0.84	2.37	-0.412	-0.323	20
11						-0.205	-0.126	63
11						-0.420	-0.323	30
11	500	750	10^{19}	0.84	2.37	-0.166	-0.126	32
11						-0.295	-0.323	- 9
11	200	1000		0.99	2.85	-0.163	-0.156	4
11						-0.806	-0.775	4
11	200	750	5×10^{19}	0.84	2.37	-0.278	-0.126	121
11						-0.508	-0.323	57
11	300	500		0.55	1.48	-0.250	-0.196	28
11						-0.380	-0.390	- 3
11	500	1000		0.99	2.85	-0.157	-0.156	0
11						-0.792	-0.775	2
11	50	750	10^{20}	0.84	2.37	-0.214	-0.126	70
11						-0.513	-0.323	59
11	200	500		0.55	1.48	-0.300	-0.196	53
11						-0.564	-0.390	45
11	200	750		0.84	2.37	-0.263	-0.126	109
11						-0.556	-0.323	72
11	200	1000		0.99	2.85	-0.198	-0.156	27
11						-0.791	-0.775	2
11	500	750		0.84	2.37	-0.115	-0.126	- 9
11						-0.283	-0.323	-12
11	500	1000		0.99	2.85	-0.149	-0.156	- 4
11						-0.855	-0.775	10

TABLE II. Cont'd

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Orientation	Temperature °C		Total Fluence (E > 0.18 MeV)		Length Change Rate ⁽¹⁾ (%/10 ²¹)		% Increase ⁽²⁾ $\left(\frac{\alpha_s - \alpha_c}{\alpha_c}\right) \cdot 100$	
	Low	High	Low Temp	High Temp		Seeded	Control	
				1st	2nd			
TSX GRAPHITE (Cont'd)								
I	500	1300		1.05	3.02	-0.219	-0.100	119
II						-0.582	-0.743	-22
Poco (AXF-8QBG1) GRAPHITE								
Isotropic	500	1000	10 ¹⁹	0.99x10 ²¹	2.85x10 ²¹	+0.501	+0.514	- 3
Isotropic	200	750	10 ²⁰	0.84	2.37	+0.103	+0.250	-59
Isotropic	200	1000		0.99	2.85	+0.272	+0.514	-47
Isotropic	500	1000		0.99	2.85	+0.491	+0.514	- 4
Isotropic	500	1300		1.05	3.02	-0.038	-0.046	-17

(1) Length change rate computed between 1st and 2nd high-temperature irradiation only (numbers represent the average length-change rates for 3 to 6 samples in each case).

(2) α_s = length change rate of seeded samples.
 α_c = length change rate of control samples.

The results of the cold-seeding study are of interest not only in regards to the "size-effect" observation but also as they may apply to the operation of graphite moderated reactors such as High-Temperature Gas-Cooled Reactors. Graphite temperatures during initial startup of these reactors may be low enough to produce cold-seeding effects similar to that shown here. If so, irradiation behavior will certainly be different than predicted on the basis of

constant-temperature tests.

It remains to be seen whether the effect of cold-seeding will persist to still higher fluences. All the samples listed in Table II are currently being irradiated for a third period at high temperatures. Results from this irradiation with total fluences up to about $5 \times 10^{21} \text{ n/cm}^2$ ($E > 0.18 \text{ MeV}$) will be available for presentation at CARBON '72.

References:

- 1) R. E. Nightingale and E. M. Woodruff, Nucl. Sci. and Eng. 19, 390 (1964).
- 2) W. J. Gray, "The Effect of Sample Size on the Irradiation-Induced Contraction of Nuclear Graphite," presented at Ninth Biennial Conference on Carbon, Boston, Massachusetts, June 16-20, 1969.
- 3) W. N. Reynolds and P.A. Thrower, Carbon 1, 185 (1964).
- 4) W. N. Reynolds and P. A. Thrower, Phil. Mag. 12, 573 (1965).
- 5) J. H. Cox and E. M. Woodruff, "Irradiation Induced Contraction of Graphites at High Temperature Following Cold Pre-Irradiation and Intermittent Thermal Anneals," USAEC Report, BNWL-215, January 1966.