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Constant-Stress Irradiation Creep Experiments on Graphite

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S u m m a r y:

Constant-stress irradiation creep capsules have been developed which permit application of a load to a stack of several graphite samples by a single pneumatic bellows. Currently, one tensile creep capsule is operating at 800°C and two compressive creep capsules are operating at 550°C and 800°C, respectively. Three types of graphite are being irradiated under stresses up to 3,000 psi. No tensile creep data are yet available. Data for the compressive creep experiments following the third irradiation period with total fluences up to about 1.0×10^{22} n/cm² (E > 0.18 MeV) indicate that, at 550°C, the creep is still essentially linear. At 800°C, however, the creep coefficient changes markedly at fluences above 6×10^{21} n/cm². For one graphite the creep coefficient increases, while for the other two graphites, it decreases and even becomes negative in some cases. Such behavior has not been reported previously and is cause for increased interest in this area of graphite research.

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

The irradiation creep behavior of graphite is normally assumed to have the form

$$\epsilon = x + k\sigma \phi t$$

where

ϵ = irradiation creep strain.

x = transient creep which quickly approaches a saturation value about equal to the elastic strain after a few times 10^{20} n/cm².

k = creep coefficient.

σ = stress.

ϕt = fast neutron fluence

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The creep coefficient has been reported to be essentially constant to a fluence of a few times 10^{21} n/cm².⁽¹⁻⁴⁾ For that reason, the second term of the above equation is known as the steady-state creep.

While the creep coefficient is known to be nearly constant at low fluences, it appears unlikely to remain so indefinitely. Experiments designed to investigate high-fluence creep behavior are essential because this information is of considerable practical importance to reactor designers. Much of the available graphite creep data has been acquired via restrained-shrinkage experiments as described by Blackstone et al.^(3,4) At high fluences, however, where the creep behavior is suspected to be more complex, a constant-stress type of experiment is much more satisfactory.

2. Experimental and Results

A drawing of the compressive creep capsule is shown in Figure 1. The tensile capsule is quite similar in design. In this case, the dumbbell-shaped samples have threaded ends and are joined with threaded connectors. Thermal creep tests of similar threaded arrangements were performed to show that the sample train could be disassembled after creep had occurred. Because the stress would be removed from all samples if one should break, a sample break-detector was incorporated into the tensile creep capsule.

Currently, one tensile creep capsule is operating at 800°C and two compressive creep capsules are operating at 550°C and 800°C, respectively. Samples of three types of graphite, described in Table I, are being irradiated under stresses up to 3,000 psi.

Table I. Graphite Description.

<u>Manufacturer*/ Grade</u>	<u>Coke</u>	<u>Density (g/cm³)</u>	<u>CTE x 10⁶ (25-550°C)</u>	<u>Remarks</u>
UCC/AGOT Type EGCR	Needle	1.71	1.3**	Extruded, impregnated, graph- itized at 3000°C.
GLCC/H337	Raw	1.96	5.1	Proprietary forming process, graphitized at 2800°C, strong.
Poco/AXF-8QBG1	Proprietary (very fine-grained equi-axed)	1.89	6.5	Isostatically molded, impregnated, graphitized at 2800°C, very strong.

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* UCC = Union Carbide Corporation. GLCC = Great Lakes Carbon Corporation.

** Measured parallel to the extrusion direction.

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The tensile samples have been irradiated for only one period to fluences up to about 1.5×10^{21} n/cm² (E > 0.18 MeV), but the data have not yet been analyzed. The compressive samples have been irradiated for three periods, and total fluences are now up to about 1.0×10^{22} n/cm² (E > 0.18 MeV).

The compressive creep results for the Poco and H337 graphites are similar. At 550°C, the creep coefficient for these graphites remains reasonably constant to 1.0×10^{22} n/cm². At 800°C, however, the creep coefficient decreases markedly at fluences above 6×10^{21} n/cm². In fact, it passes through zero and even becomes negative in some instances. Another way of describing this is to note that the stressed samples have begun to contract at a slower rate than the unstressed samples. The H337 samples at 2000 and 3000 psi have, in fact, begun to expand at the maximum fluences. Perhaps these results are not too surprising if one simply considers that the maximum contraction is reached earlier when the samples are subjected to

a compressive stress.

The compressive creep results for the AGOT graphite at 550°C also indicate a reasonably constant creep coefficient up to 1×10^{22} n/cm². In contrast to the other graphites at 800°C, however, the creep coefficient increases at fluences above 6×10^{21} n/cm², at least at 2000 and 3000 psi. No simple explanation for this behavior suggests itself as it did in the case of the other two graphites. Different mechanisms may prevail in the two cases, but further analysis of the data will be required before additional comments are justified.

The results presented here mark the first time that the creep coefficient has been shown to be a nonlinear function of fluence. They also mark the first time that different graphites have demonstrated creep behavior that is markedly different in character.

A better understanding of high-fluence creep behavior is obviously needed. Continuation of the present experiments will provide some answers, but it is hoped that other workers will be encouraged to conduct research in this area also.

References:

- 1) C. R. Kennedy, USAEC Reports ORNL-3470, p. 132 (1963) and ORNL-3523, p. 227 (1963).
- 2) A. J. Perks and J. H. W. Simmons, Carbon 4, 85 (1966).
- 3) R. Blackstone, D. P. Report 563 (1968).
- 4) R. Blackstone, L. W. Graham, M. R. Everett, Report RCN-Int-69-084 (1969).

GRAPHITE COMPRESSIVE CREEP CAPSULE

TWO CAPSULES : 550°C AND 800°C

- ① TEMPERATURE CONTROLLED BY ADJUSTING COMPOSITION OF He AND Ar GAS MIXTURE
- ② GAS GAP VARIED TO COMPENSATE FOR AXIAL DIFFERENCES IN NUCLEAR HEATING
- ③ BELLOWS PRESSURIZED TO 700 psi WITH He GAS TO PRODUCE 200 lb. LOAD ON SAMPLES