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FINAL REPORT ON GRAPHITE IRRADIATION TEST OG-3

by
R. J. PRICE and L. A. BEAVAN

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ABSTRACT

This report documents the results of dimensional, thermal expansivity, thermal conductivity, Young's modulus, and tensile strength measurements on graphite specimens irradiated in capsule OG-3. The graphite grades investigated included near-isotropic H-451 (three different preproduction lots), TS-1240, and S0818; needle coke H-327; and European coal tar pitch coke grades P_3JHA_2N, P_3JHAN, and ASI2-500. Data were obtained in the temperature range 823 K to 1673 K. The peak fast neutron fluence in the experiment was 3×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$; the total accumulated fluence exceeded 9×10^{25} n/m^2 on some H-451 specimens and 6×10^{25} n/m^2 on some TS-1240 specimens.

Irradiation-induced dimensional changes on H-451 graphite differed slightly from earlier predictions. For an irradiation temperature of about 1225 K, axial shrinkage rates at high fluences were somewhat higher than predicted, and the fluence at which radial expansion started (about 9×10^{25} n/m^2 at 1275 K) was lower. TS-1240 graphite underwent smaller dimensional changes than H-451 graphite, while limited data on S0818 and ASI2-500 graphites showed similar behavior to H-451. P_3JHAN and P_3JHA_2N graphites displayed anisotropic behavior with rapid axial shrinkage. Comparison of dimensional changes between specimens from three logs of H-451 and of TS-1240 graphites showed no significant log-to-log variations for H-451, and small but significant log-to-log variations for TS-1240.

The thermal expansivity of the near-isotropic graphites irradiated at 865-1045 K first increased by 5% to 10% and then decreased. At higher irradiation temperatures the thermal expansivity decreased by up to 50%. Changes in thermal conductivity were consistent with previously established curves. Specimens which were successively irradiated at two different temperatures took on the saturation conductivity for the new temperature.

The fractional increase in Young's modulus as a function of irradiation conditions was similar for all near-isotropic graphite specimens, regardless of orientation or location in the parent log. The tensile strength increased in a manner similar to Young's modulus, but the exact relationship between strength and modulus was different for different materials. The coefficient of variation of the strength determinations was not significantly changed by irradiation.

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FIGURES (Continued)

TABLES

TABLES (Continued)

TABLES (Continued)

1. INTRODUCTION

This report documents the results of physical property measurements on graphite specimens irradiated in the third of the OG-series of graphite capsules irradiated in the Oak Ridge Reactor (ORR) under the ERDA-sponsored HTGR Fuels and Core Development Program. The test plan for the irradiation experiment is given in Ref. 1, and engineering details of the capsule fabrication and assembly are contained in Ref. 2. A complete inventory of specimens is available in Ref. 3. Full results from the first two irradiation experiments in the OG-series are contained in Refs. 4 and 5. For convenience, the present report also includes data from the two earlier capsules.

Neutron fluences are given in this report in terms of neutrons with energies greater than 29 fJ (0.18 MeV) in a typical HTGR spectrum, calculated from the dosimetry measurements according to the number of displaced carbon atoms based on the Thompson and Wright model. Conversion factors for other fluence units are:

Fluence with $E > 29$ fJ in the ORR C-3 position = 1.12 x fluence $(E > 29\ \mathrm{fJ})_{HTGR}$

Equivalent fission fluence for graphite damage = 1.25 x fluence $(E > 29\ \mathrm{fJ})_{HTGR}$

Nickel-Dido equivalent fission fluence = 0.67 x fluence $(E > 29\ \mathrm{fJ})_{HTGR}$

2. TEST DESCRIPTION AND OBJECTIVES

Capsule OG-3 was the third in a series of graphite irradiation capsules which are operated to obtain design-basis data on the effects of neutron irradiation on the physical properties of candidate graphites for HTGR fuel and replaceable reflector blocks. The range of operating temperatures along the length of a capsule is approximately 823 K to 1673 K (550° to 1400°C). All capsules have identical thermal design. After irradiation, many specimens are transferred to the same location in the next capsule in order to build up isothermal data at incremental fluences.

The principal objective of the OG-3 experiment was to provide additional irradiation data on Great Lakes Carbon Company grade H-451 near-isotropic petroleum coke-based graphite which is the reference graphite for HTGR moderator and reflector blocks. Specimens from three different pre-production lots were included. Specimens of two other candidate petroleum coke near-isotropic graphites (Union Carbide grade TS-1240 and Airco-Speer grade S0818) were also irradiated. Some comparative dimensional change experiments using European coal tar pitch coke-based graphites (Pechiney grades P_3JHA_2N and P_3JHAN and Sigri grade ASI2-500) were also included.

3. MATERIALS INVESTIGATED

A summary table showing the number of specimens of each material included in the experiment appears in Table 3-1. Further details of the principal grades are contained in Refs. 6 and 7.

The largest proportion of capsule space was allotted to grade H-451 graphite. Specimens were taken from the following three preproduction lots, which were made with minor differences in their coke formulation:

1. Lot 266, previously irradiated in capsules OG-1 and OG-2 (one log sampled). The fluence accumulated by these specimens at the higher irradiation temperatures now exceeds the end-of-life fluence for large HTGR designs.

2. Lot 408, previously irradiated in capsule OG-2 (one log sampled).

3. Lot 426, virgin specimens (three logs sampled).

In addition, a few previously irradiated specimens of grade H-429 (small-diameter prototype for H-451) were continued.

The next largest proportion of space was given to another petroleum-coke-based, near-isotropic graphite, Union Carbide grade TS-1240. Some specimens previously irradiated in capsule OG-2 were continued. Fresh specimens sampled from three different logs (all from the same preproduction lot) were added. Only a minority of the irradiated specimens of TS-1240 graphite were tensile-tested; the remainder were held for possible future reirradiation.

Dimensional change, thermal expansivity, and thermal conductivity specimens from a single log of Airco-Speer grade SO 818 (preproduction lot 4B) were irradiated. No tensile specimens of this material were included.

Previously irradiated specimens taken from a single log of Great Lakes Carbon needle coke graphite grade H-327, which was used for the core of the Fort St. Vrain HTGR, were reirradiated. The planned irradiations on this material are complete.

A limited number of dimensional change specimens made from pitch-coke-based graphites (Pechiney grades P_3JHAN and P_3JHA_2N and Sigri grade ASI2-500) and a fine-grained isostatically molded graphite (Stackpole Carbon Co. grade 2020) were included for comparison with the major candidate graphites.

The following standard specimen shapes were used:

Shape	Dimensions	Type of Test	Technique
Cylinder	5.1 mm dia. x 11.4 mm long	Dimensional Thermal expansivity	Optical gauge Silica dilatometer
Cylinder	6.3 mm dia. x 22.9 mm long	Dimensional Thermal expansivity Tensile test	Optical gauge Silica dilatometer Uniaxial tension
Disc	10.2 mm dia. x 1.3 mm thick	Thermal diffusivity	Heat pulse

All virgin specimens were annealed at 1773 K (1500°C) for 1800s in an argon atmosphere after machining.

TABLE 3-1
MATERIALS IRRADIATED IN CAPSULE OG-3

Graphite Grade	Coke Type	Manufacturer	Production Lot	Previous Irradiations	Type of Test Specimen	Number of Specimens
H-451	Near-isotropic petroleum	Great Lakes Carbon Co.	266	OG-1, OG-2	Dimensional/CTE	96
					Dimensional/fatigue	21
					Dimensional/tensile	34
					Thermal diffusivity	28
			408	OG-2	Dimensional/tensile	96
			426	--	Dimensional/CTE	40
					Dimensional/tensile	102
					Thermal diffusivity	20
H-429	Near-isotropic petroleum	Great Lakes Carbon Co.	--	GEH-422, OG-1, OG-2	Dimensional/CTE	23
TS-1240	Near-isotropic petroleum	Union Carbide	--	OG-2	Dimensional/tensile	50
					Thermal diffusivity	24
				--	Dimensional/CTE	16
					Dimensional/tensile	128
H-327	Needle	Great Lakes Carbon Co.	FSV-42	OG-1, OG-2	Dimensional/CTE	44
				OG-2	Dimensional/tensile	10
					Dimensional/tensile	26
SO 818	Near-isotropic petroleum	Airco-Spear	4B	--	Dimensional/CTE	16
					Thermal diffusivity	18
P_3JHAN	Pitch	Pechiney	--	OG-1, OG-2	Dimensional/CTE	29
P_3JHA_2N	Pitch	Pechiney	--	--	Dimensional/CTE	22
ASI2-500	Pitch	Sigri	--	--	Dimensional/CTE	22
2020	Fine grained petroleum	Stackpole	--	OG-1, OG-2	Dimensional	78

4. CAPSULE OPERATING CONDITIONS

4.1. DESCRIPTION OF CAPSULE

Capsule OG-3 was a fully instrumented, controlled-temperature, doubly contained irradiation capsule which was irradiated in the C-3 position of the Oak Ridge Reactor (ORR) between June 21, 1975, and December 5, 1975. The total residence time in the reactor was 14.4 Ms with 12.8 Ms at a power level of 30 MW, yielding a capsule cumulative power of 4452 MWd.

The capsule contained two cells, each with its own sweep-gas system. Adjustment of the helium-argon ratio in the sweep gas allowed independent temperature control in the upper and lower cells. The cells contained a total of 10 graphite crucibles approximately 57 mm in diameter by 51 mm high (except for crucible No. 3, which was 76 mm high). The crucibles were drilled with holes to act as specimen holders. The crucibles were contained in Inconel 600 cans, which were housed in an annular aluminum thermal bond inside two 304 stainless steel containment tubes. The heat transfer gap between each crucible and the containment can was designed according to the gamma heating rate to allow the crucible to operate at the desired temperature. During operation the sweep gas composition was periodically adjusted to maintain the centerline temperature of crucible 3 (in cell 1) and crucible 7 (in cell 2) at 1273 K.

The capsule contained 21 chromel-alumel thermocouples and 12 tungsten-rhenium thermocouples. All crucibles contained at least one thermocouple on the centerline and at least one thermocouple near the outside. Six sets of chromel-alumel/tungsten-rhenium thermocouple pairs were located in various crucibles to provide in-situ decalibration data for the tungsten-rhenium thermocouples used alone in the two highest-temperature crucibles, 4 and 5. A schematic diagram of the capsule layout and thermocouple locations is shown in Fig. 4-1. All thermocouples operated reliably for the full life of the capsule except thermocouple W5 in crucible 3, which operated erratically from the start.

4.2. OPERATING TEMPERATURES

Each thermocouple reading was recorded four times per day, but the data analysis was based on one reading per day (148 data points per thermocouple). The chromel-alumel readings were assumed to represent the true operating temperatures, but the tungsten-rhenium readings had to be corrected for neutron-induced decalibration. The decalibration factors were estimated from the ratios of the chromel-alumel/tungsten-rhenium pairs as a function of thermal fluence. The factor applied to thermocouples W19, W20, W29, and W30 in crucibles 4 and 5 was determined from the pairs in crucibles 3 and 7, which were the closest in temperature to crucibles 4 and 5. The relationship between the true temperature, T_t, and the indicated temperature in crucibles 4 and 5, T_i, was taken to be

$$T_t = \frac{T_i}{1 - 7 \times 10^{-27} f} ,$$

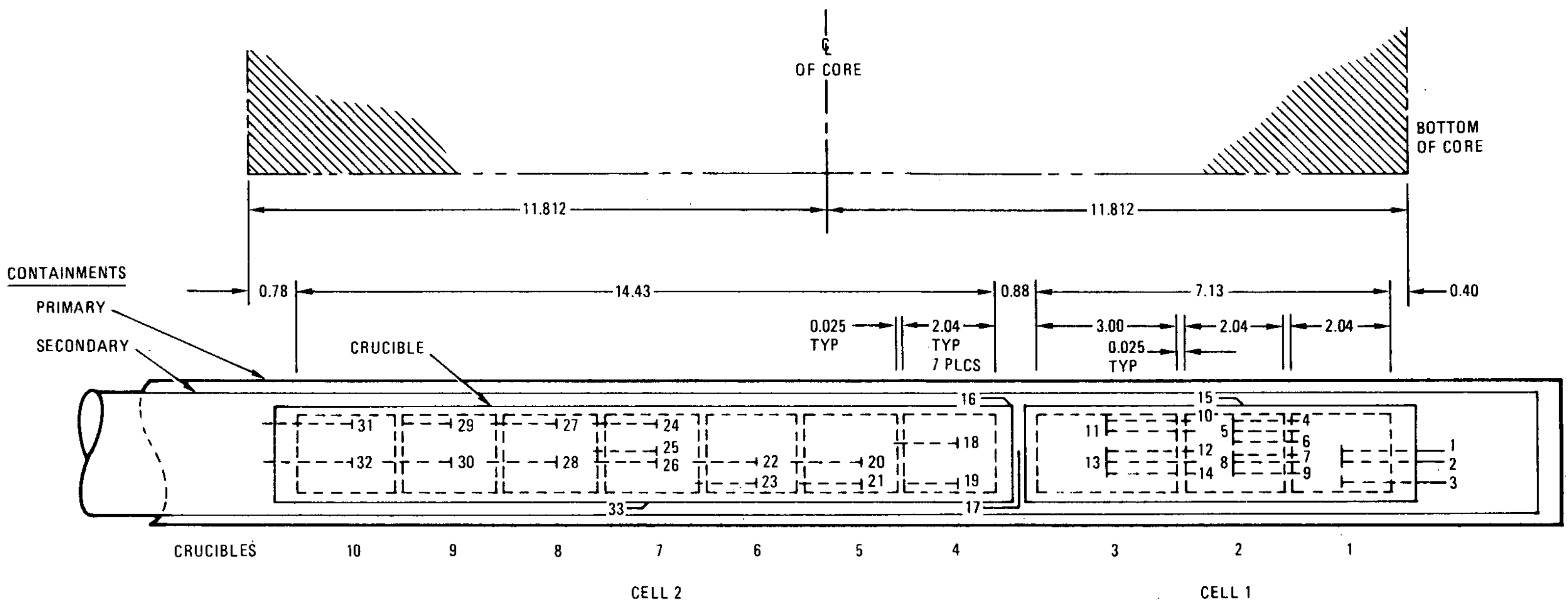
where f is the thermal fluence (n/m^2).

The averaged daily temperatures at the centerline and outside of each crucible are listed in Table 4-1. The values are based on chromel-alumel thermocouple readings except for crucibles 4 and 5, which are based on tungsten-rhenium thermocouples. The irradiation-induced change in the thermal conductivity of the graphite crucibles caused a 10 to 30 K long-term drift in the temperatures of the crucibles running at 1273 K or less, while crucibles 4 and 5 experienced a downward drift in temperature amounting to about 80 K over the life of the capsule. In addition, the control rod bank travel caused sawtooth-shaped fluctuations in temperature which were most marked in crucibles 4, 5, 9, and 10. The upper and lower limits of the fluctuations, defining the band within which the temperature remained for 90% of the time at power, are included in Table 4-1.

The mean operating temperatures of individual specimens were calculated from the centerline and outside temperatures of the crucible, assuming a parabolic temperature distribution along the radius.

4.3. NEUTRON FLUENCE

Dosimetry for the capsule was obtained from flux wires of vanadium - 0.216% cobalt, vanadium - 0.52% iron (88.25% enriched in Fe-54), and titanium. The wires were encapsuled in quartz vials and placed in grooves in the aluminum thermal bond at seven axial locations. In each axial location there were four sets of flux wires spaced 90 deg apart circumferentially. All flux wires were recovered from the irradiated capsule and analyzed by gamma-ray spectroscopy. The measured activities were decayed back to the end of irradiation and used to calculate the thermal and fast fluences, taking into account the disappearance of target atoms by competing nuclear reactions and the burn-out of product atoms. The values used for the principal effective activation cross sections were 36.8×10^{-28} m^2 for the Co-59 (n,γ) Co-60 reaction (thermal fluence), 46.56 $\times 10^{-31}$ m^2 for the Fe-54 (n,p) Mn-54 reaction (fast fluence, E > 29 fJ, ORR spectrum), and 6.61×10^{-31} m^2 for the Ti-46 (n,p) Sc-46 reaction (fast fluence, E > 29 fJ, ORR spectrum). The fluences obtained for the four circumferential positions at a given axial location were averaged, and the fast fluence results from the iron and titanium flux wires were combined. The average fluences were plotted against the axial location, and third order polynomial curves were fitted through the data and used to obtain the fluence at the center of each crucible. The curves are shown in Fig. 4-2. The equivalent fluences for each crucible, expressed in terms of neutrons with energies exceeding 29 fJ in a typical HTGR spectrum and as the equivalent fission fluence for graphite damage, are given in Table 4-1.



THERMOCOUPLE ID						
1-K7	6-W2	11-K11	16-K17	21-W29	26-K22	31-K32
2-W4	7-K9	12-W5	17-K16	22-K21	27-K27	32-K25
3-K13	8-W10	13-K3	18-W19	23-K28	28-K23	33-K18
4-K8	9-K12	14-W1	19-W30	24-K33	29-K31	
5-W6	10-W14	15-K15	20-W20	25-W26	30-K24	

K = CHROMEL/ALUMEL THERMOCOUPLE
W = W/3% Re W/25% Re THERMOCOUPLE

ALL DIMENSIONS IN INCHES

Fig. 4-1. Schematic layout of capsule OG-3 with thermocouple locations

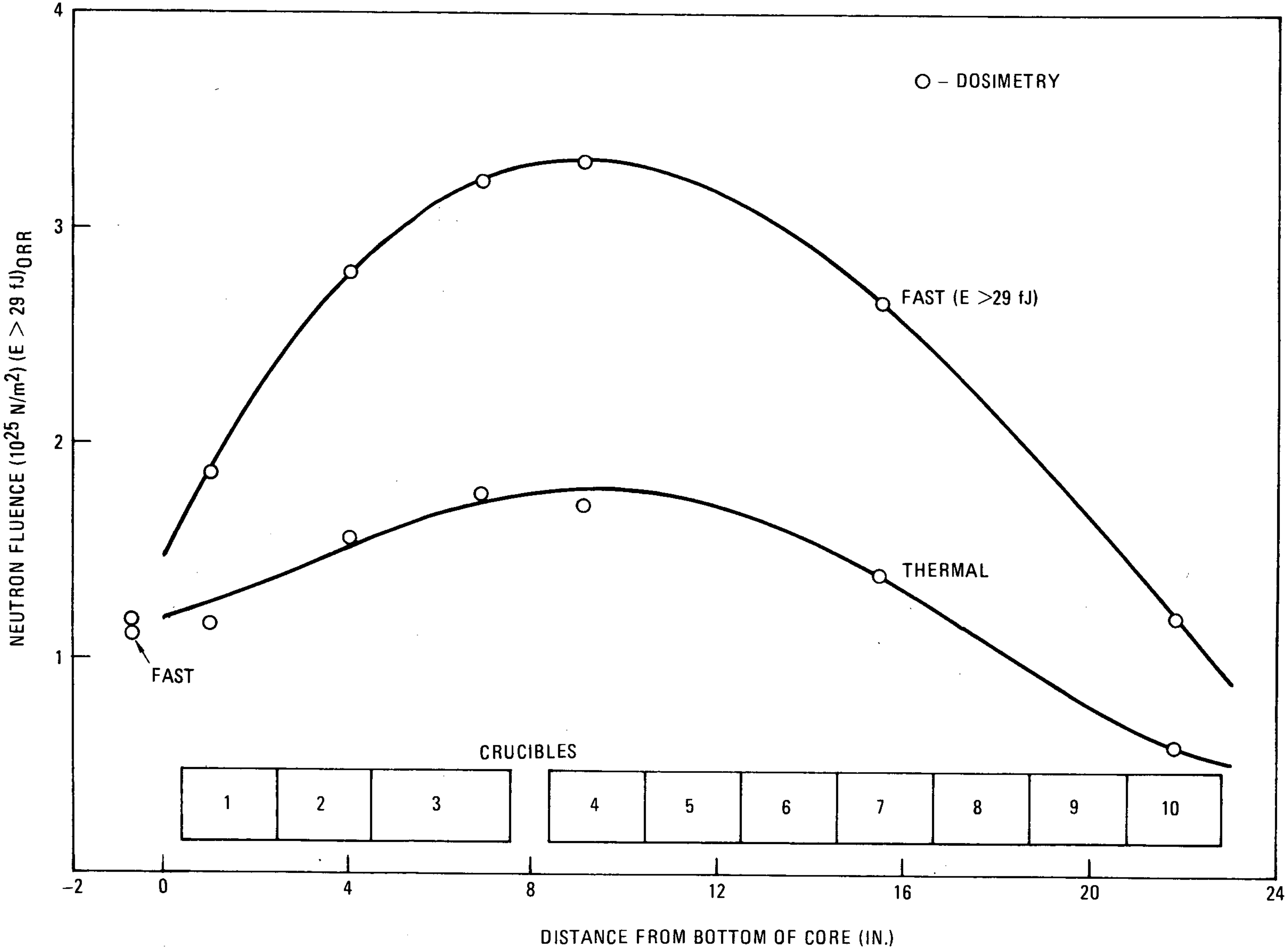


Fig. 4-2. Measured fast and thermal fluence for OG-3 experiment

TABLE 4-1
TEMPERATURES AND FLUENCES IN CAPSULE OG-3

Crucible	Neutron Fluence x 10^{-25} (n/m^2)			Operating Temperature											
				Center						Outside					
				Mean		Maximum[a]		Minimum[a]		Mean		Maximum[a]		Minimum[a]	
	Thermal	E>29fJ, HTGR	Equivalent Fission Fluence for Graphite Damage	K	°C	K	°C	K	°C	K	°C	K	°C	K	°C
1	1.29	1.84	2.30	979	706	1000	727	957	684	889	616	911	638	870	597
2	1.47	2.40	3.00	1052	779	1076	803	1031	758	927	654	951	678	907	634
3	1.68	2.82	3.52	1271	998	1286	1013	1255	982	1182	909	1199	926	1166	893
4	1.79	2.97	3.71	1576	1303	1658	1385	1491	1218	1409	1136	1494	1221	1320	1047
5	1.75	2.89	3.61	1661	1388	1726	1453	1586	1313	1580	1307	1644	1371	1513	1240
6	1.61	2.68	3.35	1314	1041	1347	1074	1273	1000	1173	900	1223	950	1128	855
7	1.39	2.39	2.99	1262	989	1280	1007	1237	964	1189	916	1217	944	1161	888
8	1.12	2.01	2.52	1160	887	1193	920	1122	849	1090	817	1130	857	1054	781
9	0.83	1.57	1.97	1055	782	1113	840	1041	741	981	708	1030	757	943	670
10	0.61	1.11	1.39	888	615	940	667	847	574	807	534	858	585	773	500

[a] Maximum and minimum temperatures indicate range within which the temperature remained for 90% of the time at power.

5. EXPERIMENTAL RESULTS - DIMENSIONAL CHANGES

5.1. INTRODUCTION

Capsule OG-3 contained dimensional change specimens of eight near-isotropic graphites, needle coke H-327 graphite, and several miscellaneous graphites. The design data bases for calculating irradiation-induced dimensional change in H-451, TS-1240, and H-327 graphites were significantly enlarged by the addition of OG-3 data. In addition, spot comparisons of dimensional change between domestic and foreign grades of near-isotropic graphite were carried out.

Dimensional change data are reported as percent strain $[(\ell - \ell_o)/\ell_o \times 100]$, where ℓ is the post-OG-3 irradiation length and ℓ_o is the original (unirradiated) length. The average irradiation temperature and fast neutron fluence experienced by specimens while in OG-3 were assigned as discussed in Section 4. Specimens which were re-irradiated in OG-3 were assigned fluence-weighted average temperatures corresponding to the aggregate fast neutron fluence of the specimen.

5.2. IRRADIATION-INDUCED DIMENSIONAL CHANGE IN NEAR-ISOTROPIC GRAPHITES

5.2.1. H-451

Two hundred and nineteen axial and 170 radial dimensional change specimens of H-451 graphite were irradiated in capsule OG-3. Many of these specimens were previously irradiated in the OG capsule series (Ref. 5); thus, the total fast fluence of some H-451 specimens exceeded the lifetime reactor fluence for fuel element graphite.

Specimens were irradiated at average temperatures ranging from 880 K to 1670 K to total neutron fluences of 1.55×10^{25} to 9.2×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$. The total dimensional change of each specimen is tabulated in Tables 5-1 and 5-2. The data have been plotted as open symbols in Figs. 5-1 and 5-2. The closed symbols in these figures represent irradiation data from previous OG series capsules reported in Ref. 5.

The H-451 OG-3 data generally agree with previous H-451 data for GLCC production lots 266 and 408 (see Section 3). Radial H-451 specimens were irradiated to sufficient fluences to show turnaround in the dimensional change and, in two specimens, net radial expansion. The earliest change in linear dimensional change to net expansion occurred in H-451 graphite irradiated at approximately 1275 K. Radial specimens appear to go to net expansion when exposed to approximately 9×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$ neutron fluence. Higher irradiation temperatures create a greater initial contraction which delays crossover to net expansion until fast fluences greater than 9×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$.

These data and related effects were incorporated into the design curves following the procedures outlined in Ref. 5. Since H-451 data now extend through reactor lifetime fluence, the H-429 graphite (pilot-scale precurser to H-451) data are no longer included in the data base to be fit by computer. As a result, the scatter in data about the design surface decreased. Isothermal sections through the design surface are plotted in Fig. 5-3. The polynomial which describes the design surface is listed in Table 8-1(a).

5.2.2. H-429

Twelve axial and 11 radial H-429 graphite specimens continued irradiation in capsule OG-3. The data provide high fluence [up to 11.4×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$] definition of the shape of petroleum coke, near-isotropic graphite dimensional change curves. Table 5-3 lists the OG-3 H-429 graphite data.

5.2.3. TS-1240

Capsule OG-3 included 96 axial and 98 radial dimensional change specimens of graphite TS-1240. The specimens were irradiated at average temperatures of 865 K to 1655 K to neutron fluences of 1.55×10^{25} n/m^2 to 5.9×10^{25} n/m^2 $(E > 29\ fJ)_{HTGR}$. Tables 5-4 and 5-5 list the total dimensional change for TS-1240 OG-3 specimens. Data at higher fluences are shown as open symbols in Figs. 5-4 and 5-5. For comparison, dimensional changes observed in the OG-2 experiment (Ref. 5) are also included in Figs. 5-4 and 5-5 as closed symbols.

TS-1240 graphite continues to exhibit excellent dimensional stability under neutron irradiation. Dimensional changes observed in TS-1240 are approximately 50 to 70% the magnitude of those in H-451 graphite.

5.2.4. SO-818

A third potential fuel element graphite, SO-818, was irradiated in the OG-3 experiment. Eight dimensional change specimens for each orientation were irradiated. Observed dimensional changes were about equal to those of H-451 graphite. The data are listed in Table 5-6.

5.2.5. Pitch Coke Graphites

Several pitch coke graphites developed by European programs were irradiated in the OG-3 experiment. ASI2-500 exhibited moderate dimensional change similar to H-451. The two graphites of French origin, P_3JHAN and P_3JHA$_2$N, underwent considerably more contraction than any other near-isotropic graphites. ASI2-500 and P_3JHA$_2$N data are included in Tables 5-7 and 5-8.

P_3JHAN specimens from earlier experiments were reirradiated in capsule OG-3. As shown in Table 5-9, some of the P_3JHAN specimens were broken during removal from the experiment after irradiation at high fluence levels

[8.5 x 10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$]. The unbroken specimens demonstrated large net expansions in the radial direction at 8.5 x 10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$ while the axial specimens went through turnaround at the same fluence. The large dimensional changes of the P_3JHAN specimens caused mechanical interaction between the specimen and the graphite crucible severe enough that specimens were fractured during removal from the crucibles.

5.2.6. 2020

The 28 axial and 50 radial specimens of 2020 graphite were reirradiated in the OG-3 experiment after previous irradiation in OG-1 and OG-2. Tables 5-10 and 5-11 contain the results of the OG-3 irradiation. Radial dimensional change is somewhat greater than axial dimensional change in 2020 because the graphite is isostatically molded rather than extruded as are the other graphites discussed above. The spread of observed dimensional change between axial and radial orientations is about the same as in H-451 graphite, but 2020 graphite contracts less and expands more than H-451.

5.3. IRRADIATION-INDUCED DIMENSIONAL CHANGE IN NEEDLE-COKE H-327 GRAPHITE

Specimens of H-327 graphite which were previously irradiated in OG capsules were reirradiated in the OG-3 experiment. Tables 5-12 and 5-13 list the 41 axial and 39 radial H-327 specimens irradiated in OG-3. The data were added to the data base of H-327 graphite and computer fit by FUNFIT as described in Ref. 5. The resultant design curves for H-327 graphite are shown as isotherms through the design surface in Fig. 5-6 which is generated from the polynomial given in Table 8-1(b).

5.4. MISCELLANEOUS GRAPHITES

The OG-3 experiment contained miscellaneous graphite specimens, the most important of which are contained in Table 5-6. Laboratory grade 565161 graphite, made from Robinson coke at Oak Ridge National Laboratory, showed larger net expansion than other near-isotropic graphites following the OG-3 irradiation. Grade H-451C, which was H-451 graphite infiltrated with binder pitch during cure-in-place process studies, continues to demonstrate about the same dimensional changes as observed in H-451 graphite. The mean axial dimensional change for H-451C is -2.78%, compared with -2.93% for H-451 at approximately the same irradiation conditions.

5.5. SIDE-BY-SIDE COMPARISON OF DIMENSIONAL CHANGES IN DIFFERENT GRAPHITES

To facilitate direct comparison, groups of four replicate axial and radial specimens (midlength-center location) of H-451, TS-1240, SO-818, P_3JHA_2N, and ASI2-500 graphites were irradiated side-by-side at 1040 K in crucible 2 and at 1653 K in crucible 5. The mean dimensional changes are listed in Table 5-14. At both irradiation temperatures grade TS-1240 showed less shrinkage (in both directions) and grade P_3JHA_2N showed more shrinkage (in the axial direction) than the other three grades. Grade P_3JHA_2N behaved more anisotropically than the other materials.

5.6. EFFECT OF CHANGING IRRADIATION TEMPERATURE ON DIMENSIONAL CHANGES

After irradiation in capsule OG-1, two sets of four axial and four radial specimens of H-451 graphite were interchanged between crucibles 1 and 6 for the next two irradiation increments. Their mean operating temperature was 948 K (675°C) in crucible 1 and 1323 K (1050°C) in crucible 6. The dimensional changes of the specimens are plotted as functions of neutron fluence in Fig. 5-7. Isothermal curves for specimens irradiated continuously in crucibles 1 and 6 are included in the figure. When the irradiation temperature of the axial specimens was increased, the shrinkage rate increased to that of specimens irradiated isothermally at the higher temperature. The shrinkage rate of axial specimens decreased when their irradiation temperature was reduced, but remained higher than that of specimens isothermally irradiated at the lower temperature to the same fluence. The shape of the curves suggests that the new shrinkage rate may correspond to the lower temperature isothermal curve extrapolated to the higher strain of the stepped-down specimens. The data points for radial specimens are too closely clustered to draw firm conclusions, but the trends appear similar to those of the axial specimens.

5.7. BETWEEN-LOG AND WITHIN-LOG VARIATIONS IN DIMENSIONAL CHANGE

Several groups of H-451 and TS-1240 specimens were made up from three different logs out of the same lot. In some cases specimens from both the midlength-center location and the midlength-edge location in the log were included. Four or five replicates were used for each log and location. After post-irradiation length measurements, the data were analyzed by the analysis-of-variance method to find whether the between-log and within-log variations were statistically significant. Individual measurements are included in Tables 5-1 through 5-5. Summaries of the results of the analyses of variance are given in Tables 5-15 through 5-18. For H-451 graphite, neither the between-log nor the within-log variations were significant at the 95% confidence level. Shrinkage of TS-1240 graphite showed significant between-log differences among the specimens irradiated at the highest temperature (Table 5-16). However, the differences were small (0.33% or less). Differences in shrinkage between midlength-center and midlength-edge specimens were not statistically significant for H-451 graphite, but the TS-1240 graphite showed slightly more shrinkage at the edge of the log than at the center (Table 5-18).

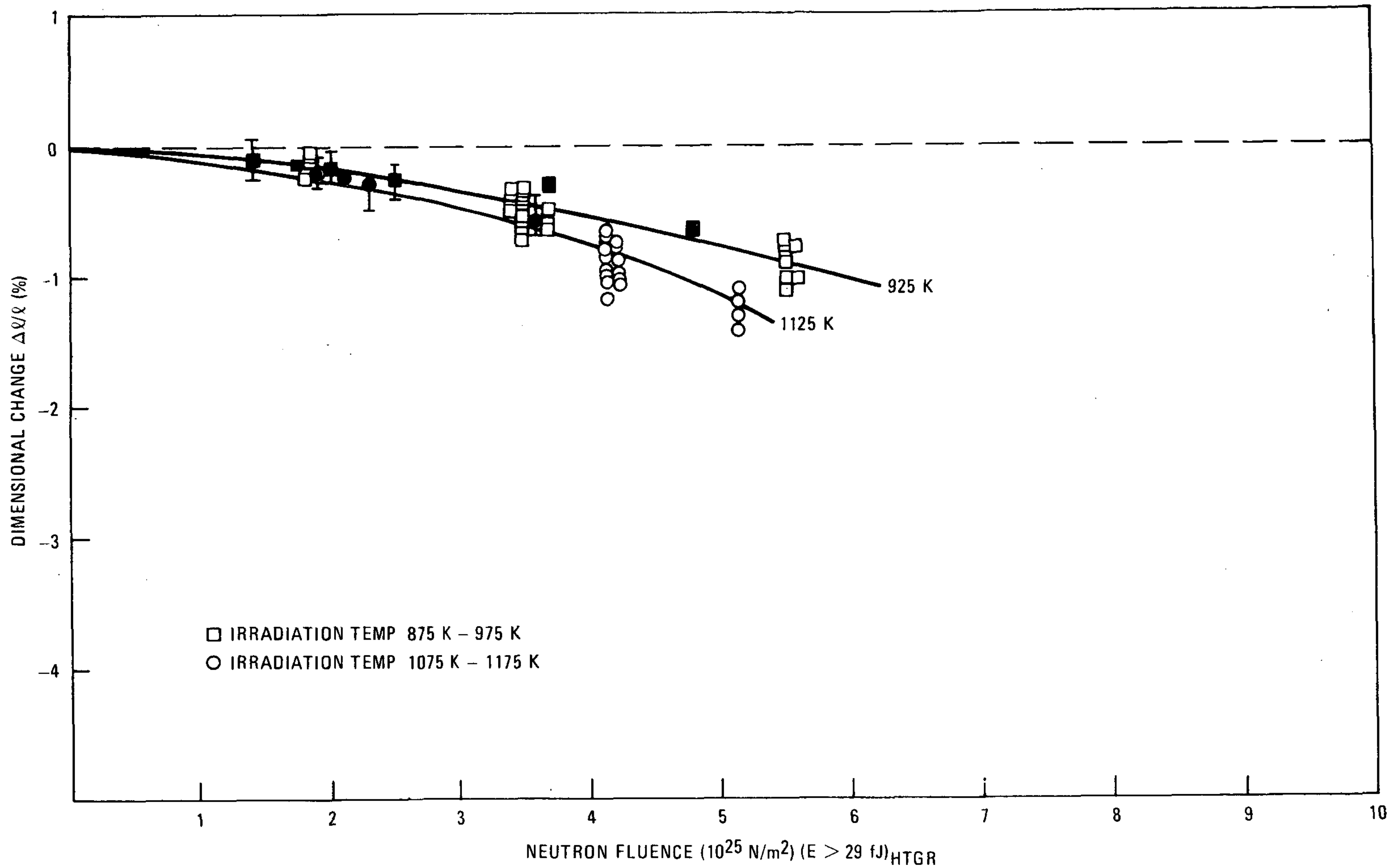


Fig. 5-1 (a). Dimensional change in H-451 graphite, axial orientation: irradiation temperatures 875 K to 975 K and 1075 K to 1175K

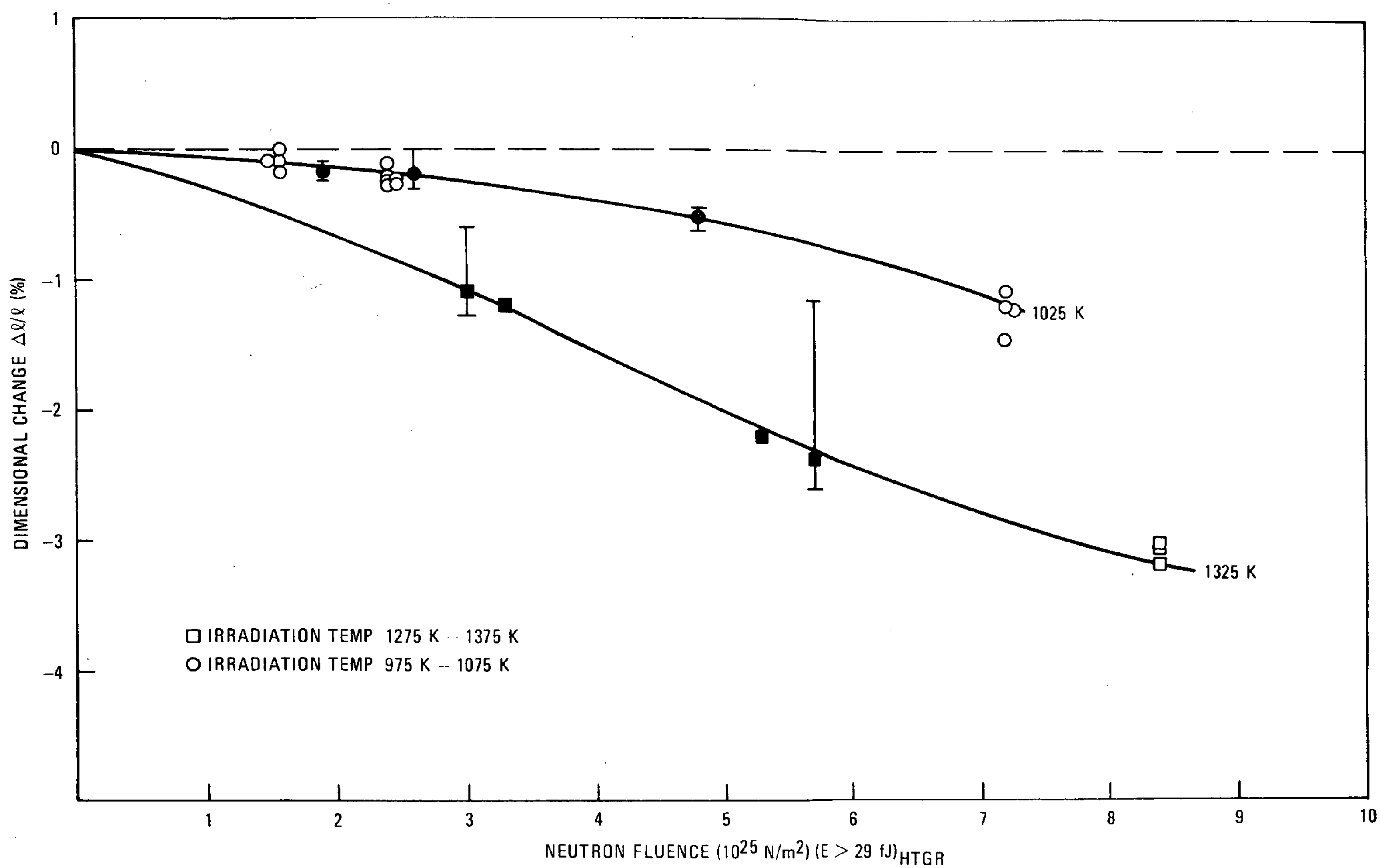


Fig. 5-1 (b). Dimensional change in H-451 graphite, axial orientation: irradiation temperatures 1275 K to 1375 K and 975 K to 1075 K

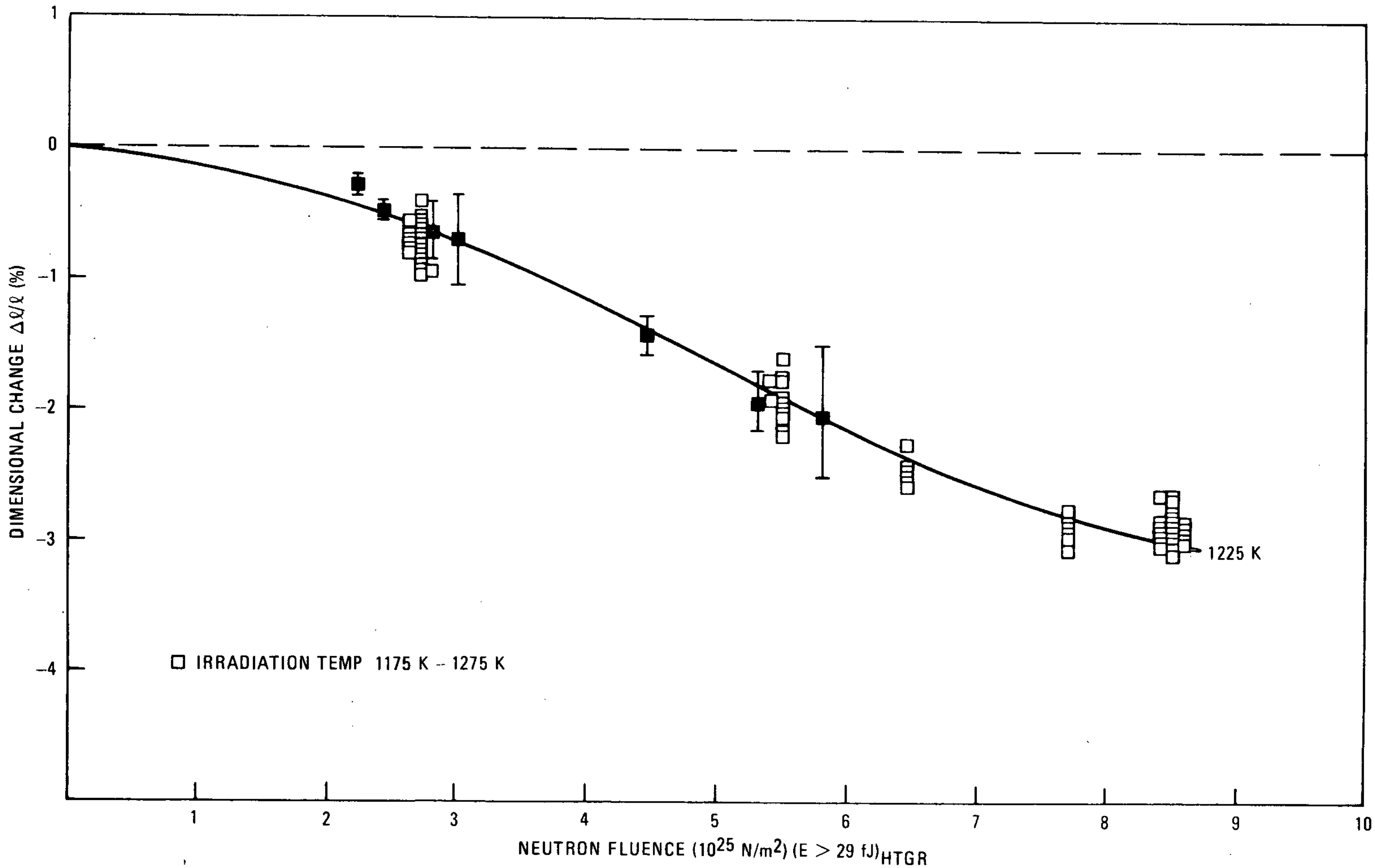


Fig. 5-1 (c). Dimensional change in H-451 graphite, axial orientation: irradiation temperatures 1175 K to 1275 K

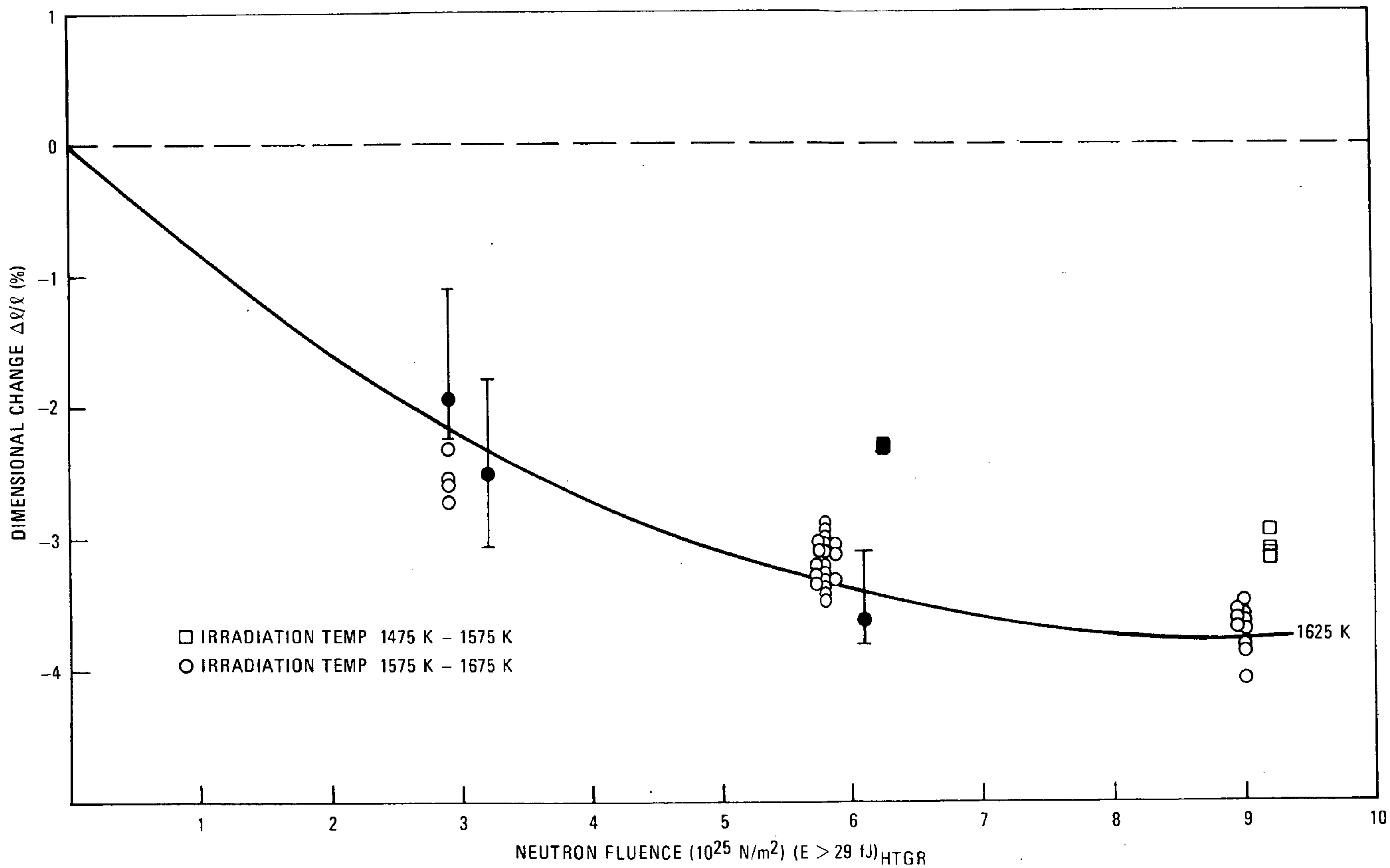


Fig. 5-1 (d). Dimensional change in H-451 graphite, axial orientation: irradiation temperatures 1475 K to 1575 K and 1575 K to 1675 K

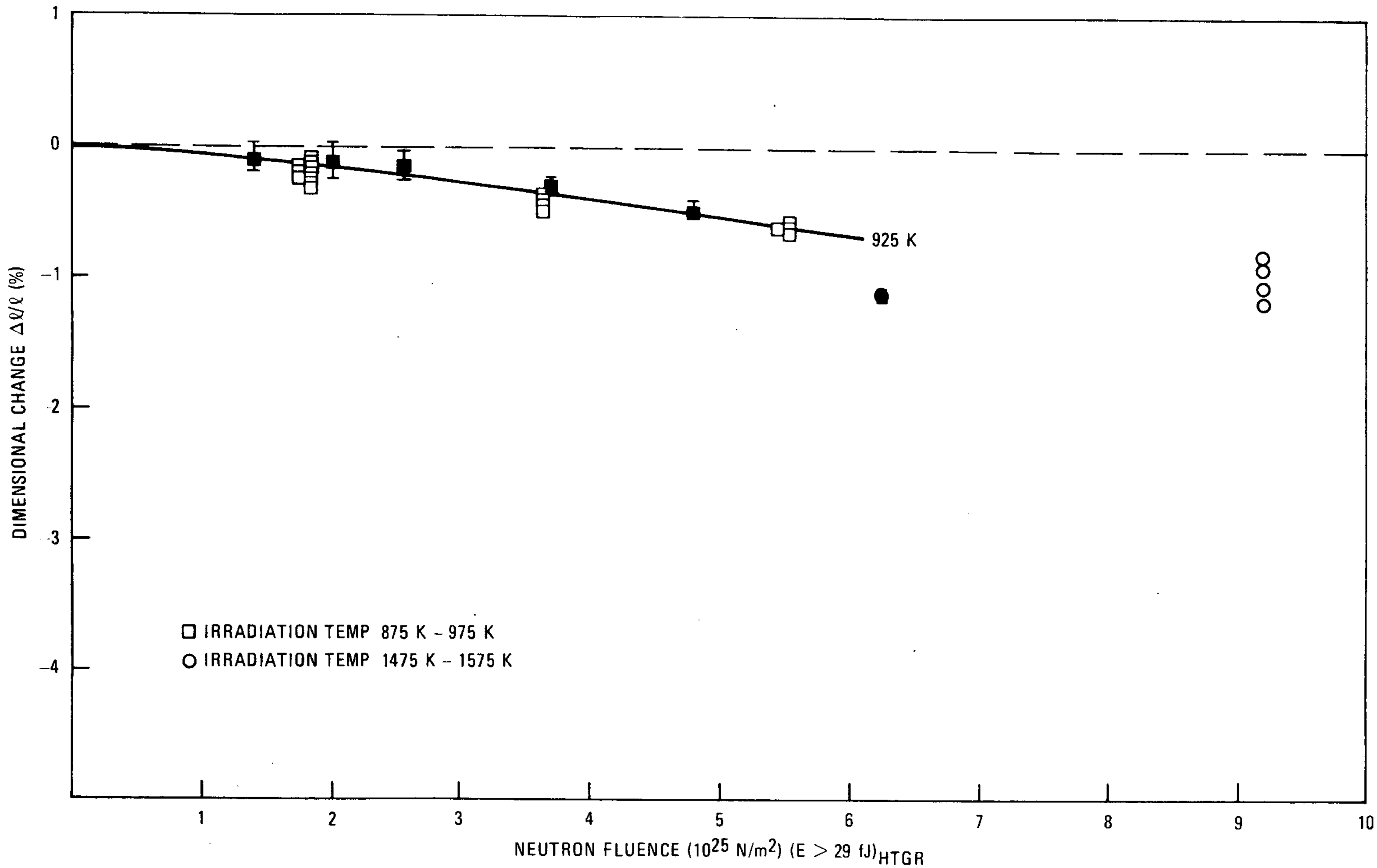


Fig. 5-2 (a). Dimensional change in H-451 graphite, radial orientation: irradiation temperatures 875 K to 975 K and 1475 K to 1575 K

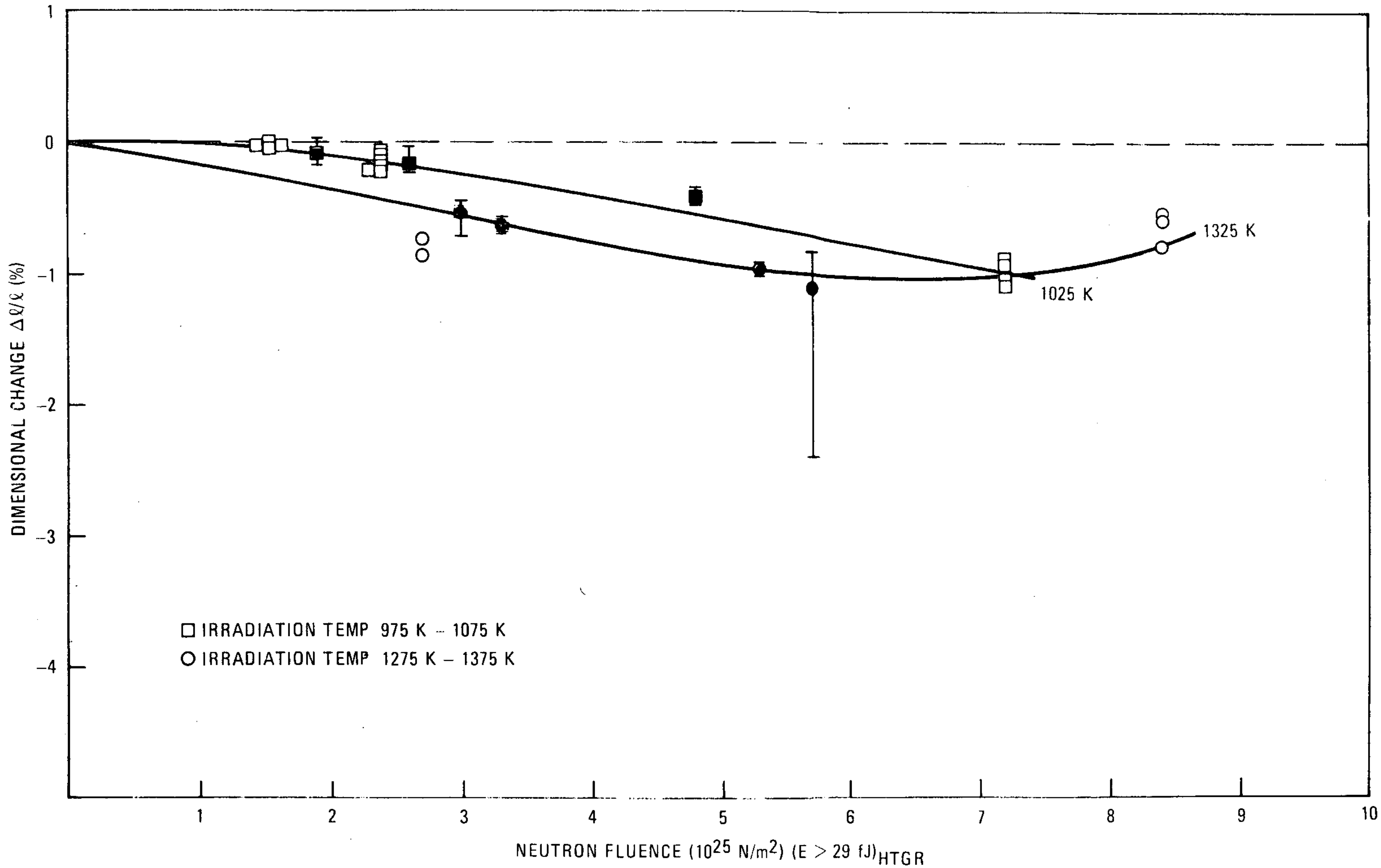


Fig. 5-2 (b). Dimensional change in H-451 graphite, radial orientation: irradiation temperatures 975 K to 1075 K and 1275 K to 1375 K

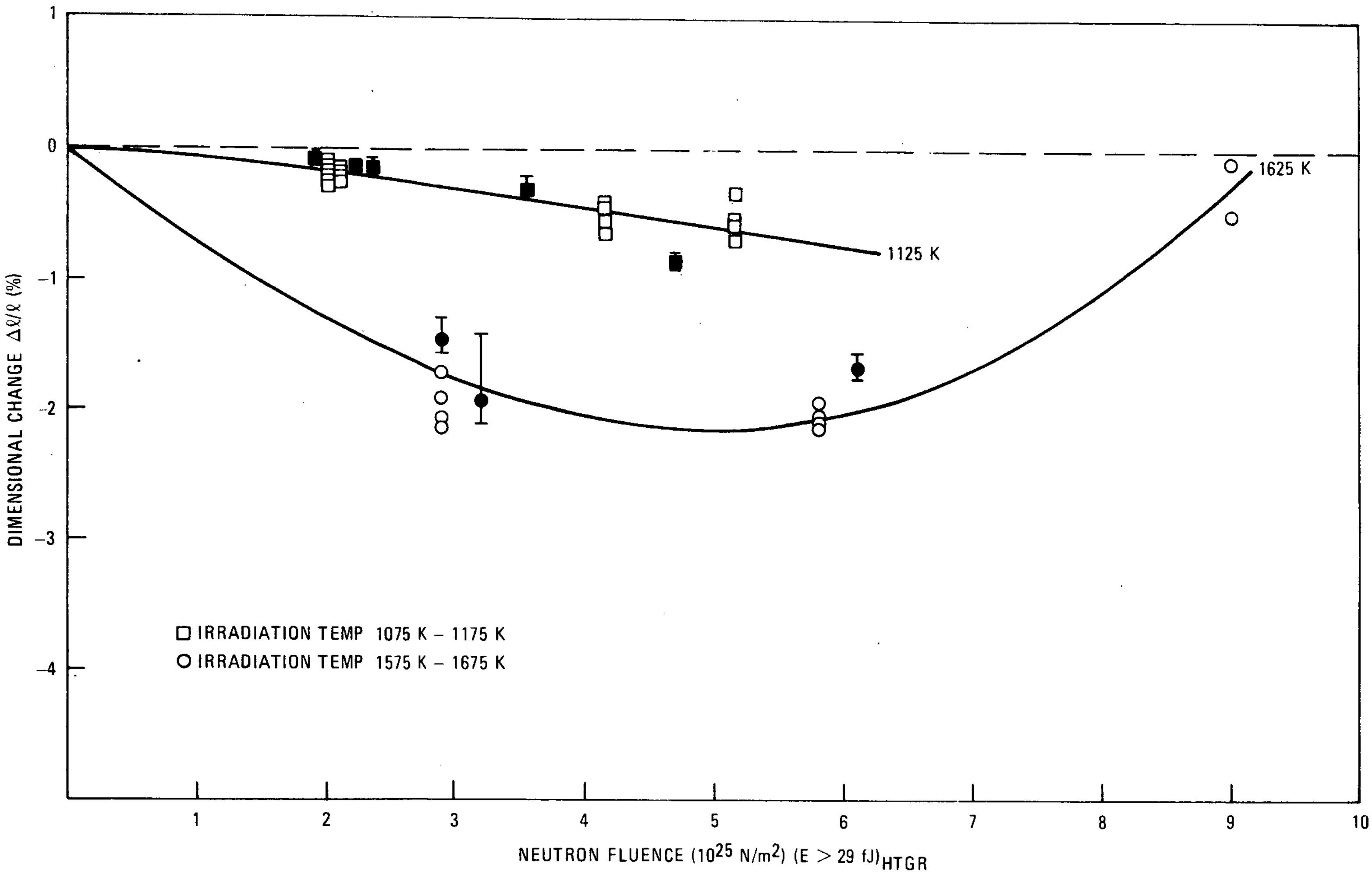


Fig. 5-2 (c). Dimensional change in H-451 graphite, radial orientation: irradiation temperatures 1075 K to 1175 K and 1575 K to 1675 K

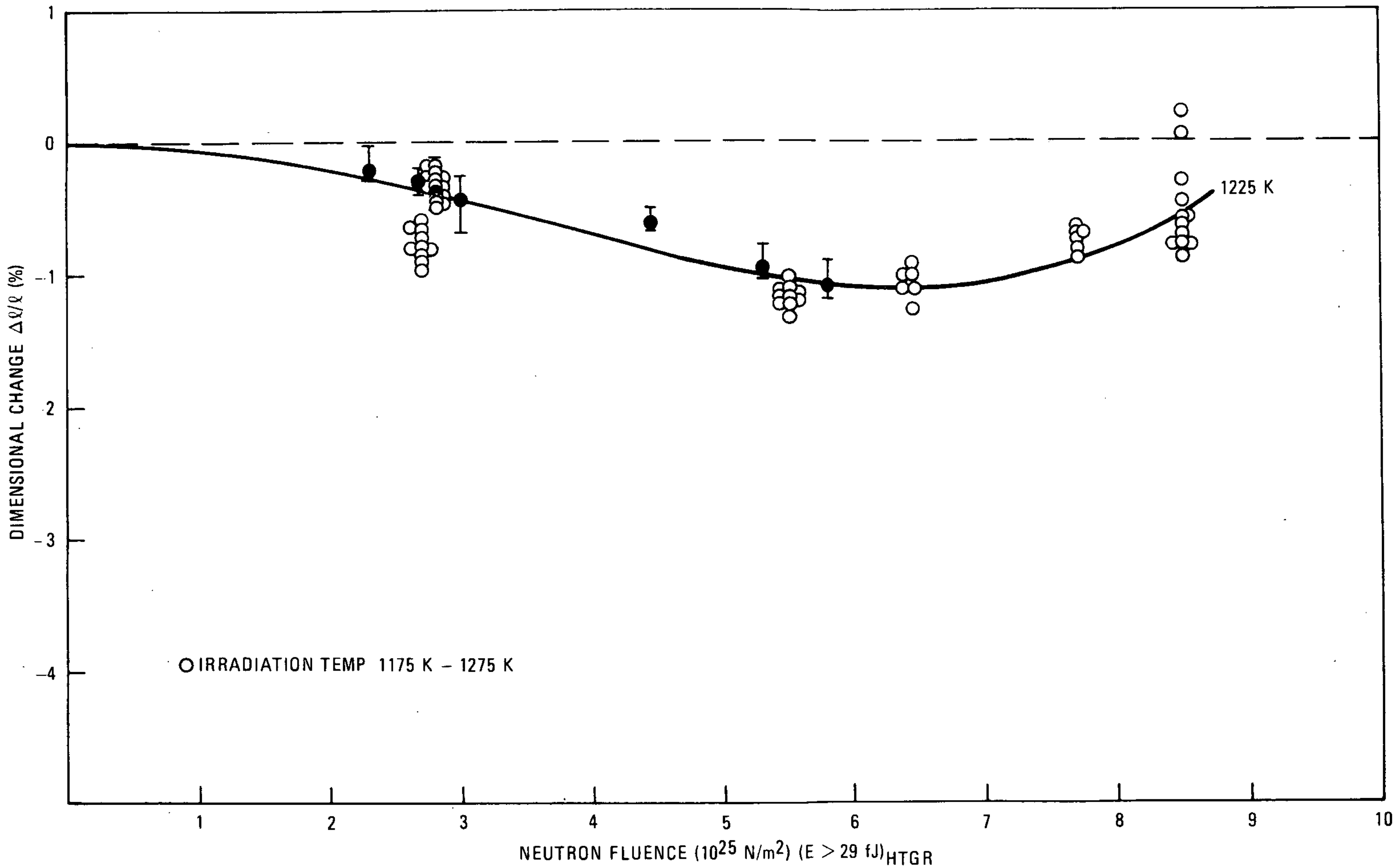


Fig. 5-2 (d). Dimensional change in H-451 graphite, radial orientation: irradiation temperature 1175 K to 1275 K

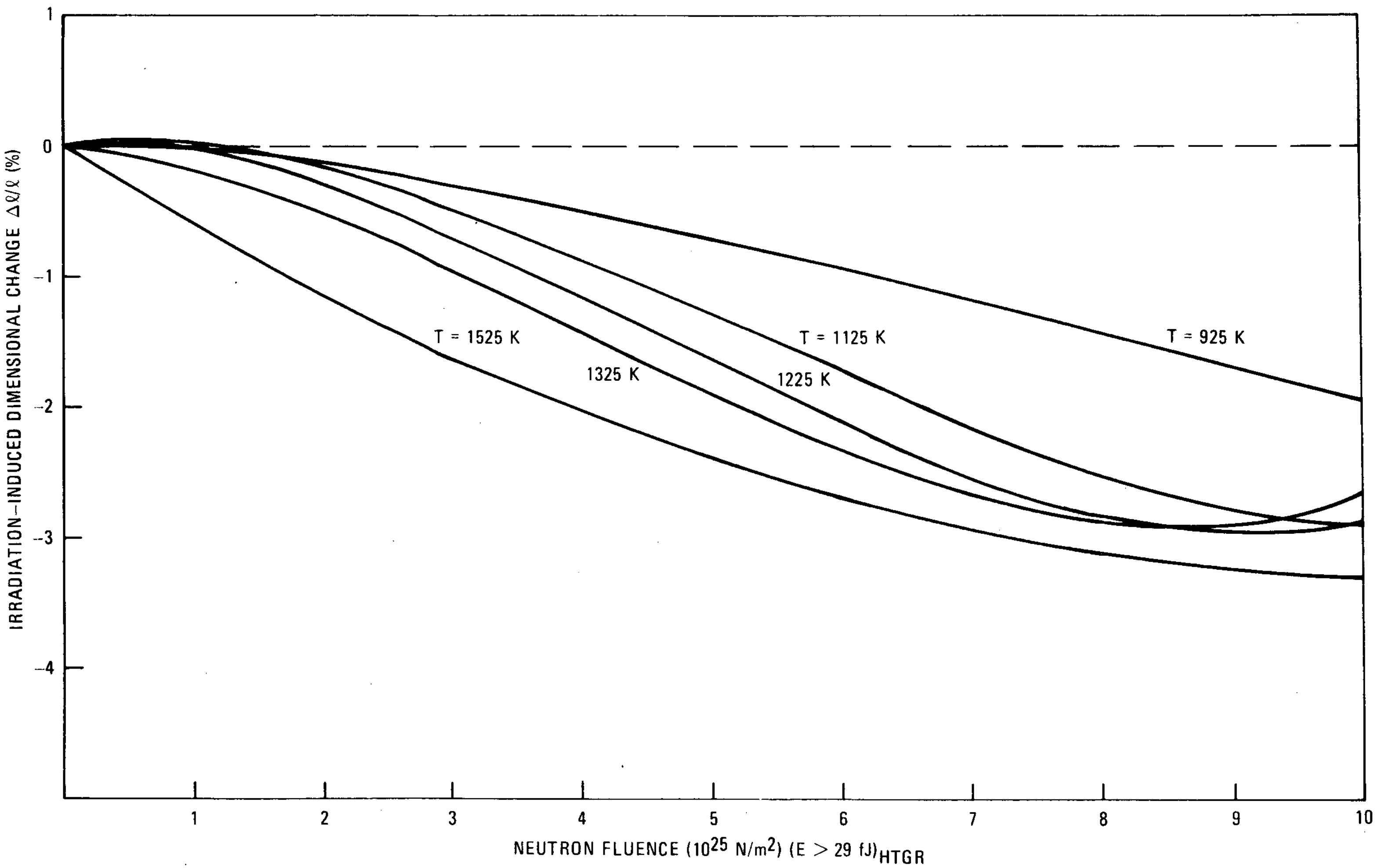


Fig. 5-3 (a). Irradiation-induced dimensional change in H-451 graphite, axial orientation - design curves

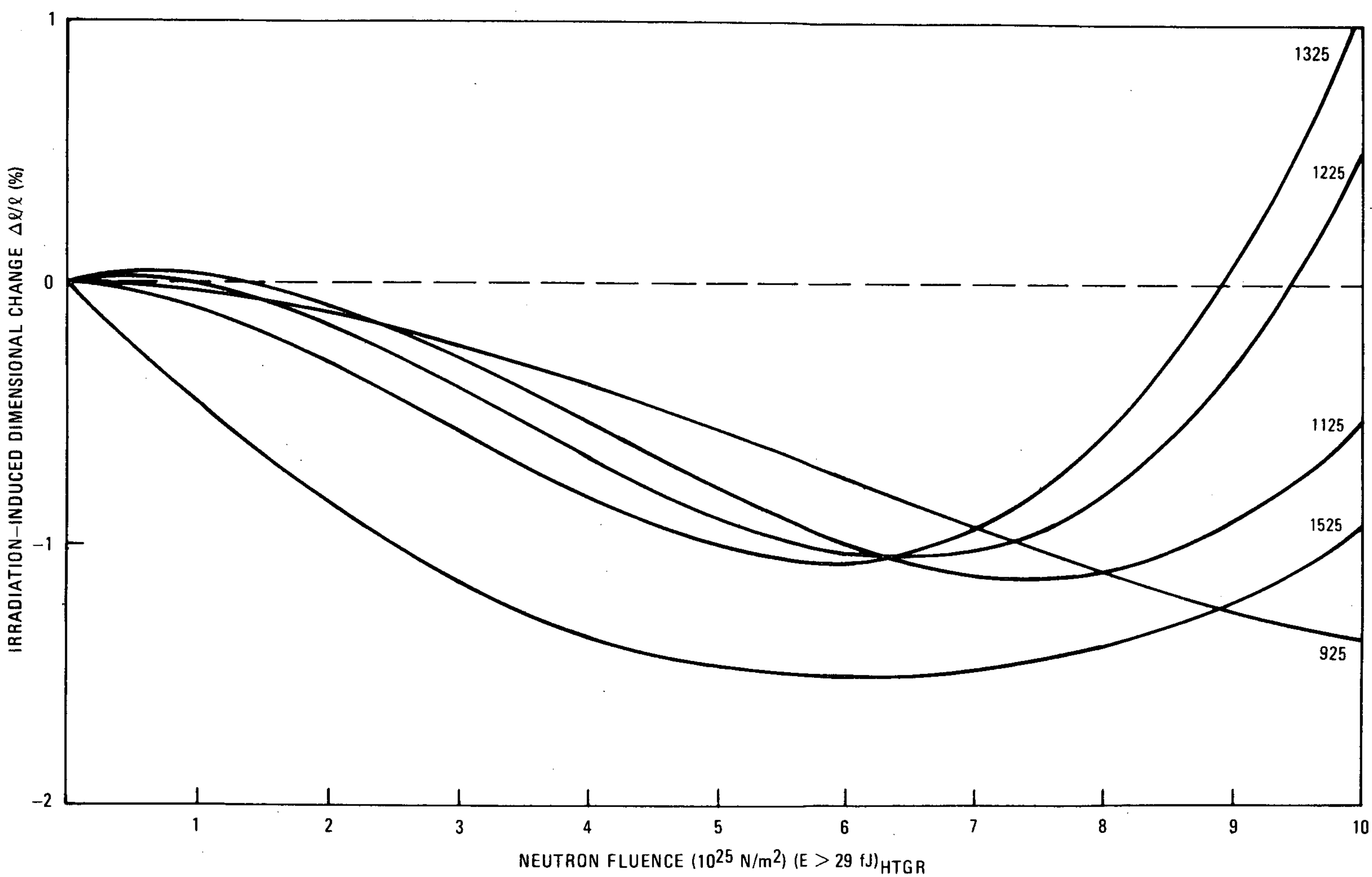


Fig. 5-3 (b). Irradiation-induced dimensional change in H-451 graphite, radial orientation - design curves

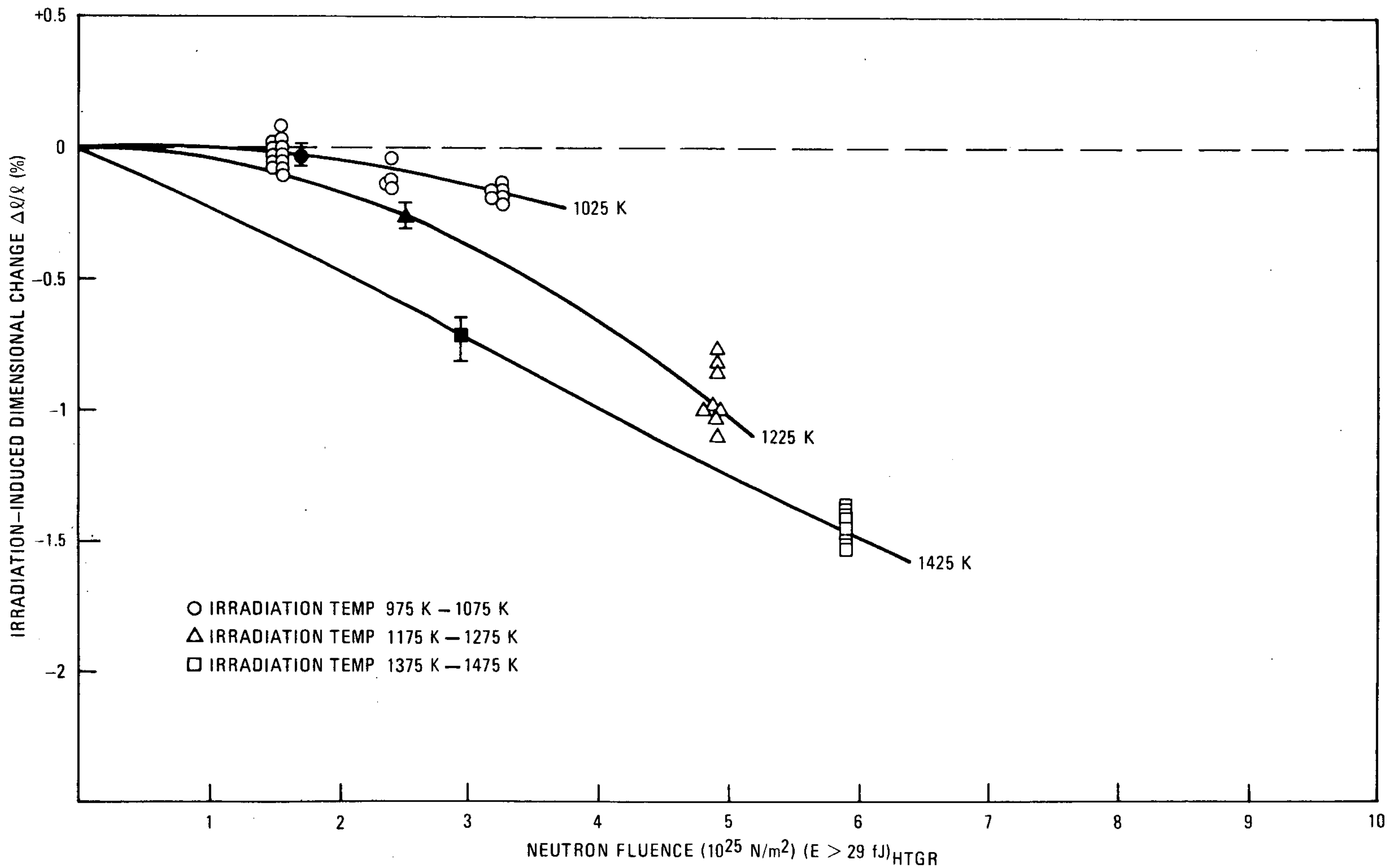


Fig. 5-4. Dimensional change in TS-1240 graphite, axial orientation

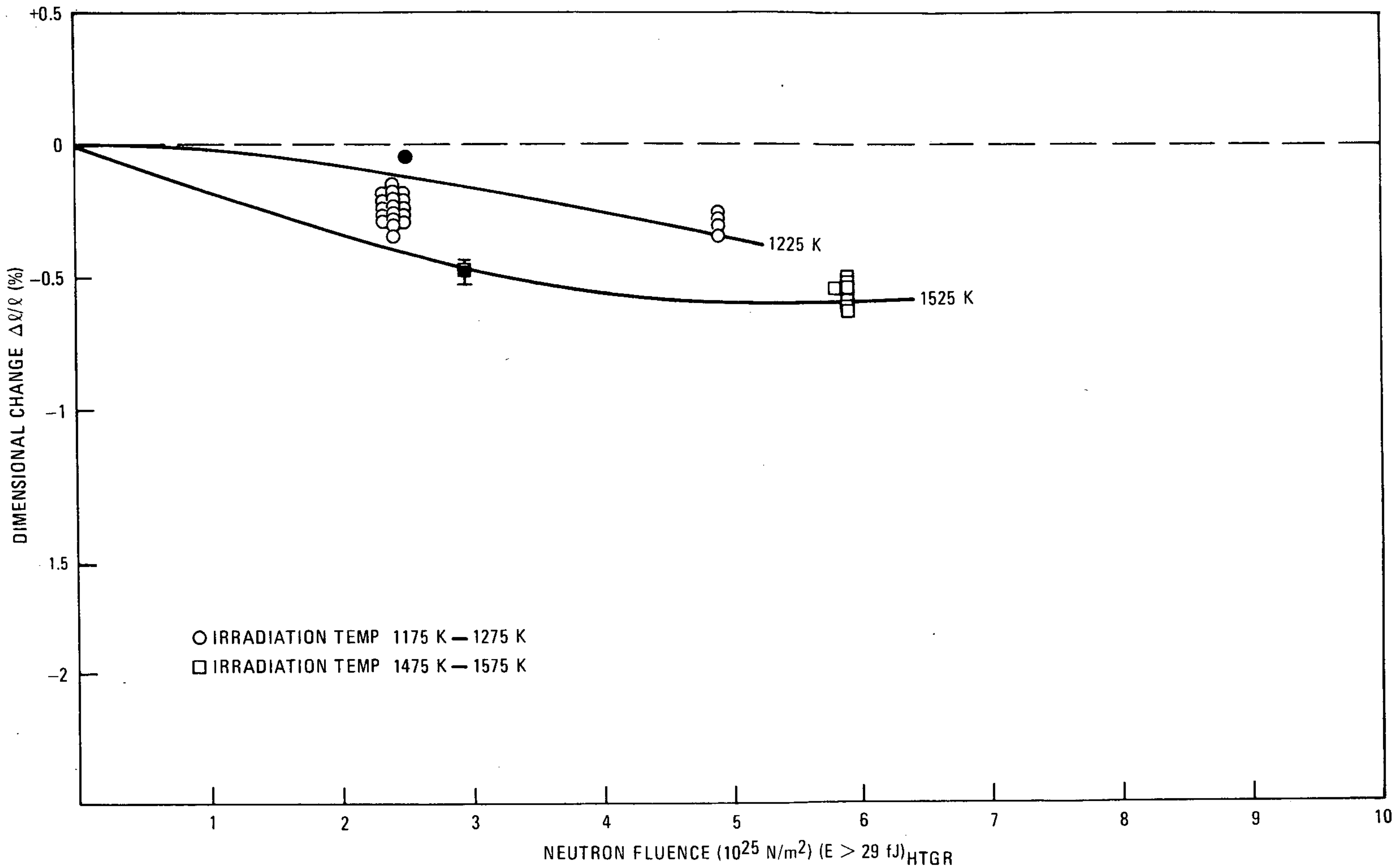


Fig. 5-5. Dimensional change in TS-1240 graphite, radial orientation

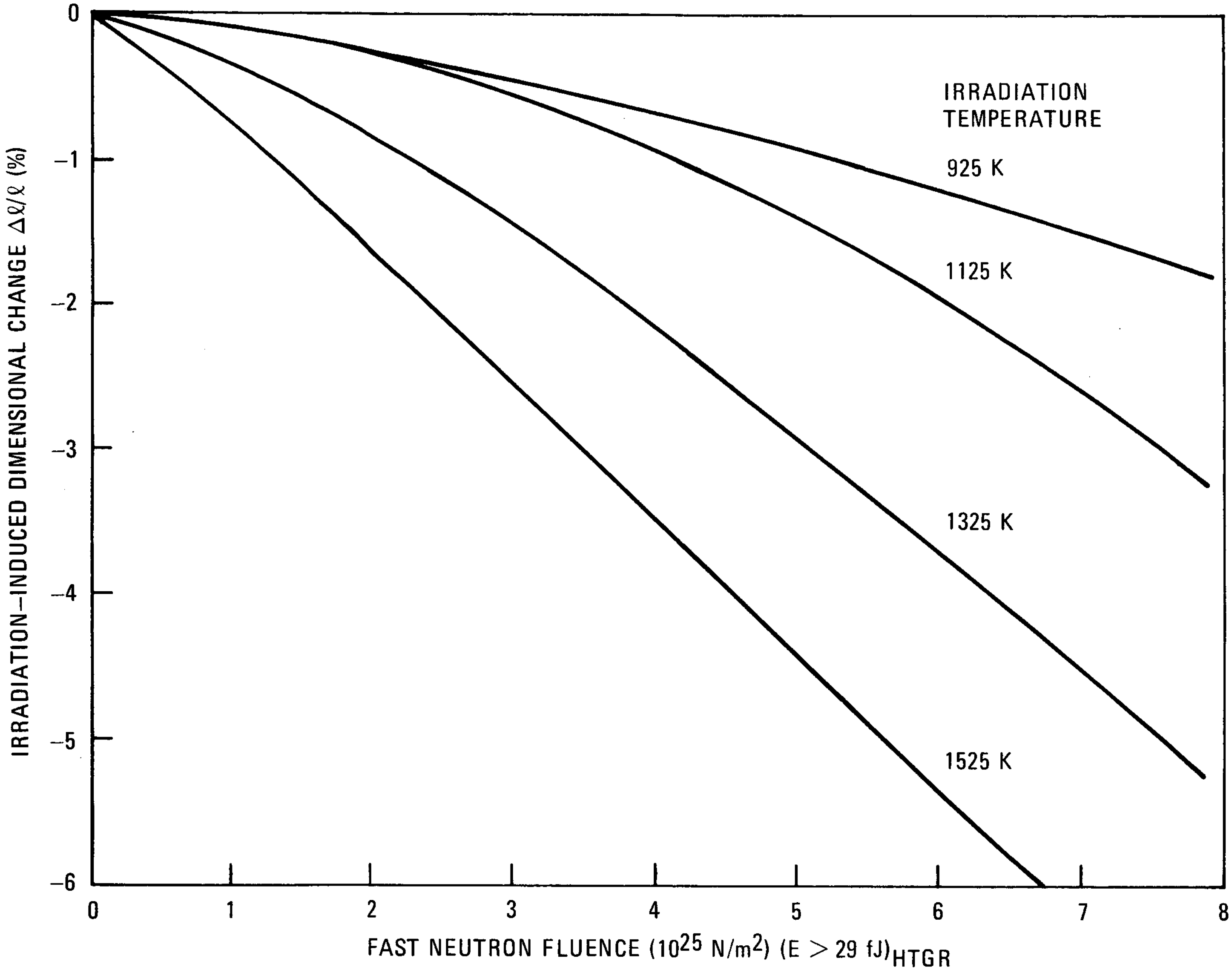


Fig. 5-6 (a). Irradiation-induced dimensional change in H-327 graphite, axial orientation - design curves

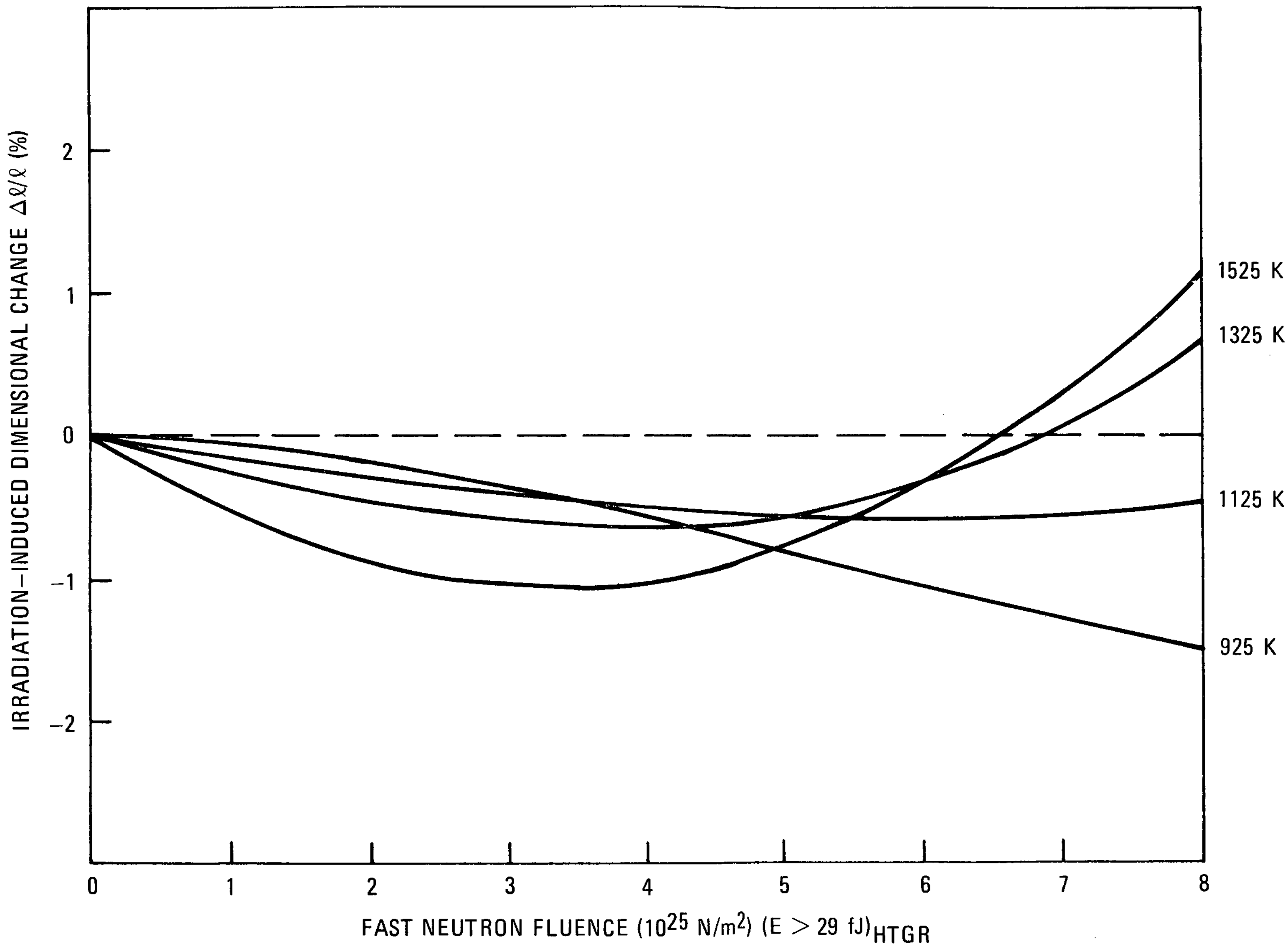


Fig. 5-6 (b). Irradiation-induced dimensional change in H-327 graphite, radial orientation - design curves

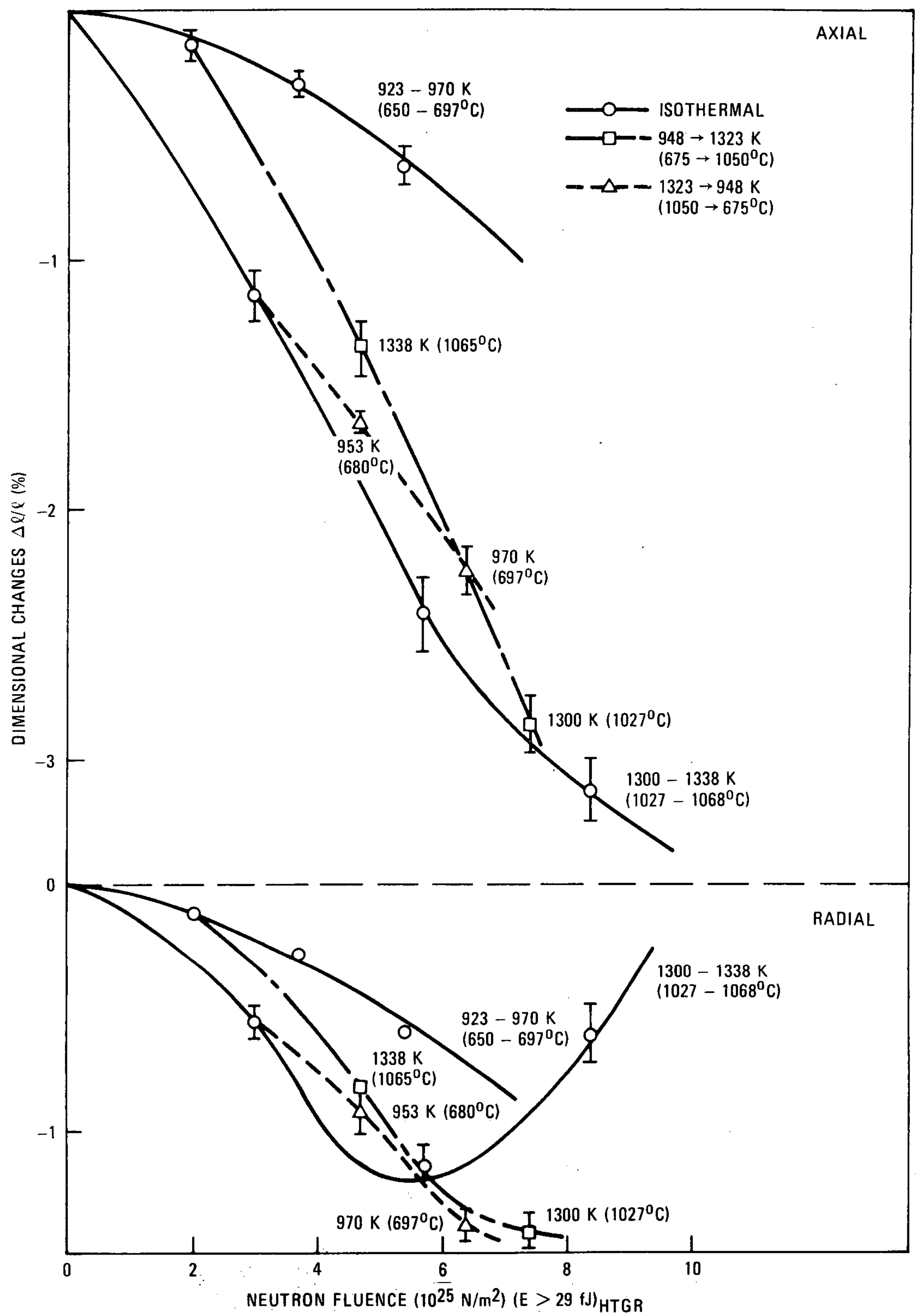


Fig. 5-7. Dimensional changes in H-451 graphite irradiated with changes in temperature

TABLE 5-1
DIMENSIONAL CHANGE IN H-451 GRAPHITE, AXIAL ORIENTATION

Record Number	Specimen Number		Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average (°C)	Irrad. Temp (K)
7797	OG-3	T-113	MC	1	22	6607	590.0	-.757	5.55	605.0	878
7798	OG-3	T-114	MC	1	22	6608	590.0	-1.028	5.55	605.0	878
7799	OG-3	T-115	MC	1	23	6609	590.0	-.801	5.55	605.0	878
7800	OG-3	T-116	MC	1	23	6610	590.0	-1.026	5.55	605.0	878
7801	OG-3	T-117	MC	1	24	6611	590.0	-.785	5.55	605.0	878
7802	OG-3	T-118	MC	1	24	6612	590.0	-1.122	5.55	605.0	878
7748	OG-3	T-111	MC	1	16	6605	590.0	-.713	5.55	620.0	893
7749	OG-3	T-112	MC	1	16	6606	590.0	-.923	5.55	620.0	893
7803	OG-3	T40741	ME	1	25	6613	615.0	-.433	3.55	630.0	903
7804	OG-3	T40743	ME	1	25	6614	615.0	-.540	3.55	630.0	903
7805	OG-3	T40745	ME	1	26	6615	615.0	-.433	3.55	630.0	903
7806	OG-3	T40747	ME	1	26	6616	615.0	-.465	3.55	630.0	903
7807	OG-3	T40749	ME	1	27	6617	615.0	-.413	3.55	630.0	903
7808	OG-3	T40751	ME	1	27	6618	615.0	-.514	3.55	630.0	903
7809	OG-3	T40753	ME	1	28	6619	615.0	-.502	3.55	630.0	903
7810	OG-3	T40755	ME	1	28	6620	615.0	-.547	3.55	630.0	903
7811	OG-3	T40757	ME	1	29	6621	615.0	-.467	3.55	630.0	903
7812	OG-3	T40759	ME	1	29	6622	615.0	-.443	3.55	630.0	903
7813	OG-3	T40761	ME	1	30	6623	615.0	-.378	3.55	630.0	903
7814	OG-3	T40763	ME	1	30	6624	615.0	-.511	3.55	630.0	903
8693	OG-3	.380.	MC	10	2	7532	640.0	-.658	3.65	630.0	903
8697	OG-3	.381.	MC	10	3	7536	640.0	-.613	3.65	630.0	903
8701	OG-3	.382.	MC	10	4	7540	640.0	-.490	3.65	630.0	903
8689	OG-3	.379.	MC	10	1	7528	650.0	-.597	3.65	640.0	913
7736	OG-3	T40501	MC	1	10	6536	660.0	-.318	3.55	670.0	943
7737	OG-3	T40503	MC	1	10	6537	660.0	-.449	3.55	670.0	943
7738	OG-3	T40505	MC	1	11	6538	660.0	-.319	3.55	670.0	943
7739	OG-3	T40507	MC	1	11	6539	660.0	-.311	3.55	670.0	943
7740	OG-3	T40509	MC	1	12	6540	660.0	-.409	3.55	670.0	943
7741	OG-3	T40511	MC	1	12	6541	660.0	-.514	3.55	670.0	943
7742	OG-3	T40513	MC	1	13	6542	660.0	-.310	3.55	670.0	943
7743	OG-3	T40515	MC	1	13	6543	660.0	-.486	3.55	670.0	943
7744	OG-3	T40517	MC	1	14	6544	660.0	-.383	3.55	670.0	943
7745	OG-3	T40519	MC	1	14	6545	660.0	-.506	3.55	670.0	943
7746	OG-3	T40521	MC	1	15	6546	660.0	-.349	3.55	670.0	943
7747	OG-3	T40523	MC	1	15	6547	660.0	-.494	3.55	670.0	943
7704	OG-3	.303.	MC	1	2	6504	660.0	-.564	5.55	670.0	943
7708	OG-3	.304.	MC	1	3	6508	660.0	-.617	5.55	670.0	943
7712	OG-3	.347.	MC	1	4	6520	660.0 (a)	-2.195	5.55	(a)	(a)
7713	OG-3	.348.	MC	1	4	6521	660.0 (a)	-2.325	5.55	(a)	(a)

TABLE 5-1 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	Average Irrad. Temp (K)
7716	OG-3 .349.	MC	1	5	6524	660.0 (a)	-2.204	5.55	(a)	(a)
7717	OG-3 .350.	MC	1	5	6525	660.0 (a)	-2.326	5.55	(a)	(a)
7700	OG-3 .301.	MC	1	1	6500	675.0	-.615	5.55	685.0	958
7701	OG-3 .302.	MC	1	1	6501	675.0	-.717	5.55	685.0	958
7724	OG-3 2A 8A	MC	1	7	0	.0	-.078	1.85	695.0	968
7725	OG-3 2A 8B	MC	1	7	0	.0	-.155	1.85	695.0	968
7728	OG-3 2A 8C	MC	1	8	0	.0	-.091	1.85	695.0	968
7729	OG-3 2A 8D	MC	1	8	0	.0	-.191	1.85	695.0	968
7732	OG-3 2B 9A	MC	1	9	0	.0	-.126	1.85	695.0	968
7733	OG-3 2B 9B	MC	1	9	0	.0	-.186	1.85	695.0	968
7829	OG-3 .553.	ME	2	2	6629	750.0	-1.077	7.20	755.0	1028
7830	OG-3 .554.	ME	2	2	6633	750.0	-1.201	7.20	755.0	1028
7833	OG-3-2B- 5A	MC	2	3	0	.0	-.191	2.40	765.0	1038
7834	OG-3-2B 5B	MC	2	3	0	.0	-.206	2.40	765.0	1038
7837	OG-3 2B 5C	MC	2	4	0	.0	-.244	2.40	765.0	1038
7842	OG-3-2B 5D	MC	2	5	0	.0	-.126	2.40	765.0	1038
7847	OG-3 2B 6A	MC	2	6	0	.0	-.244	2.40	765.0	1038
7852	OG-3 2B 6B	MC	2	7	0	.0	-.273	2.40	765.0	1038
8597	OG-3 2A 7B	MC	9	5	0	.0	-.153	1.55	775.0	1048
8600	OG-3 2A 9D	MC	9	5	0	.0	-.080	1.55	775.0	1048
8603	OG-3 2A 7C	MC	9	6	0	.0	-.009	1.55	775.0	1048
8615	OG-3 2A 9C	MC	9	9	0	.0	-.084	1.55	775.0	1048
7825	OG-3 .551.	ME	2	1	6625	770.0	-1.212	7.20	775.0	1048
7826	OG-3 .552.	ME	2	1	6626	770.0	-1.458	7.20	775.0	1048
8585	OG-3 .614.	ME	9	2	7426	835.0	-1.337	5.15	815.0	1088
8587	OG-3 .615.	ME	9	2	7428	835.0	-1.101	5.15	815.0	1088
8583	OG-3 .613.	ME	9	1	7424	845.0	-1.202	5.15	825.0	1098
8581	OG-3 .612.	ME	9	1	7422	850.0	-1.434	5.15	830.0	1103
8549	OG-3 T40615	MC	8	23	7416	850.0	-.806	4.15	845.0	1118
8550	OG-3 T40783	ME	8	23	7417	850.0	-.655	4.15	845.0	1118
8519	OG-3 T40609	MC	8	14	7410	850.0	-1.003	4.15	855.0	1128
8520	OG-3 T40777	ME	8	14	7411	850.0	-.742	4.15	855.0	1128
8521	OG-3 T40611	MC	8	15	7412	850.0	-.985	4.15	855.0	1128
8522	OG-3 T40779	ME	8	15	7413	850.0	-.697	4.15	855.0	1128
8523	OG-3 T40613	MC	8	16	7414	850.0	-.943	4.15	855.0	1128
8524	OG-3 T40781	ME	8	16	7415	850.0	-.734	4.15	855.0	1128
8509	OG-3 T40599	MC	8	9	7363	905.0	-1.063	4.15	885.0	1158
8510	OG-3 T40767	ME	8	9	7364	905.0	-.794	4.15	885.0	1158
8511	OG-3 T40601	MC	8	10	7365	905.0	-1.032	4.15	885.0	1158
8512	OG-3 T40769	ME	8	10	7366	905.0	-.814	4.15	885.0	1158

TABLE 5-1 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8513	OG-3 T40603	MC	8 11	7367	905.0	-1.073	4.15	885.0	1158
8514	OG-3 T40771	ME	8 11	7368	905.0	-.861	4.15	885.0	1158
8515	OG-3 T40605	MC	8 12	7369	905.0	-1.084	4.15	885.0	1158
8516	OG-3 T40773	ME	8 12	7370	905.0	-.847	4.15	885.0	1158
8517	OG-3 T40607	MC	8 13	7371	905.0	-1.042	4.15	885.0	1158
8518	OG-3 T40775	ME	8 13	7372	905.0	-.828	4.15	885.0	1158
8507	OG-3 T40597	MC	8 8	7361	905.0	-1.188	4.15	895.0	1168
8508	OG-3 T40765	ME	8 8	7362	905.0	-.878	4.15	895.0	1168
8483	OG-3 .373.	MC	8 2	7329	920.0	-2.554	6.45	910.0	1183
8484	OG-3 .374.	MC	8 2	7330	920.0	-2.244	6.45	910.0	1183
8487	OG-3 .375.	MC	8 3	7333	920.0	-2.535	6.45	910.0	1183
8488	OG-3 .376.	MC	8 3	7334	920.0	-2.403	6.45	910.0	1183
8040	OG-3 F-16	NC	3 24	6845	910.0	-2.721	8.50	915.0	1188
8041	OG-3 F 17	MC	3 24	6846	910.0	-2.840	8.50	915.0	1188
8042	OG-3 F-18	MC	3 24	6847	910.0	-2.892	8.50	915.0	1188
8043	OG-3 F-19	MC	3 25	6848	910.0	-2.625	8.50	915.0	1188
8044	OG-3 F-20	MC	3 25	6849	910.0	-2.898	8.50	915.0	1188
8045	OG-3 F-21	MC	3 25	6850	910.0	-3.050	8.50	915.0	1188
8046	OG-3 T-135	MC	3 26	6821	910.0	-2.625	8.50	915.0	1188
8047	OG-3 T-136	MC	3 26	6822	910.0	-2.993	8.50	915.0	1188
8049	OG-3 T-137	MC	3 27	6824	910.0	-2.812	8.50	915.0	1188
8050	OG-3 T-138	MC	3 27	6825	910.0	-2.910	8.50	915.0	1188
8479	OG-3 .371.	MC	8 1	7325	930.0	-2.450	6.45	920.0	1193
8480	OG-3 .372.	MC	8 1	7326	930.0	-2.426	6.45	920.0	1193
7998	OG-3 T-131	MC	3 16	6815	910.0	-2.852	8.50	930.0	1203
7999	OG-3 T-132	MC	3 16	6816	910.0	-2.966	8.50	930.0	1203
8001	OG-3 T-133	MC	3 17	6818	910.0	-2.820	8.50	930.0	1203
8002	OG-3 T-134	MC	3 17	6819	910.0	-2.991	8.50	930.0	1203
8346	OG-3-2A 1A	MC	6 24	0	.0	-.775	2.70	935.0	1208
8347	OG-3-2A 1A	MC	6 24	0	.0	-.404	2.70	935.0	1208
8348	OG-3-2A-101A	ME	6 25	0	.0	-.795	2.70	935.0	1208
8349	OG-3-2A-101A	ME	6 25	0	.0	-.537	2.70	935.0	1208
8350	OG-3-2A- 1B	MC	6 26	0	.0	-.677	2.70	935.0	1208
8351	OG-3-2A 1B	MC	6 26	0	.0	-.552	2.70	935.0	1208
8352	OG-3-2A-101B	ME	6 27	0	.0	-.729	2.70	935.0	1208
8353	OG-3-2A 101A	ME	6 27	0	.0	-.505	2.70	935.0	1208
8354	OG-3-2A- 1A	MC	6 28	0	.0	-.758	2.70	935.0	1208
8355	OG-3-2A 1B	MC	6 28	0	.0	-.544	2.70	935.0	1208
8356	OG-3-2A-101B	ME	6 29	0	.0	-.749	2.70	935.0	1208
8357	OG-3-2A-101B	ME	6 29	0	.0	-.625	2.70	935.0	1208

TABLE 5-1 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8358	OG-3 2A 2A	MC	6	30	0	.0	-.818	2.70	935.0	1208
8359	OG-3-2A- 8A	MC	6	30	0	.0	-.633	2.70	935.0	1208
8360	OG-3-2A-102A	ME	6	31	0	.0	-.932	2.70	935.0	1208
8361	OG-3-2A-102A	ME	6	31	0	.0	-.637	2.70	935.0	1208
8362	OG-3-2A- 8B	MC	6	32	0	.0	-.898	2.70	935.0	1208
8363	OG-3-2A- 2A	MC	6	32	0	.0	-.730	2.70	935.0	1208
8364	OG-3 2A-102B	ME	6	33	0	.0	-.933	2.70	935.0	1208
8365	OG-3-2A-102A	ME	6	33	0	.0	-.752	2.70	935.0	1208
8366	OG-3-2A- 2B	MC	6	34	0	.0	-1.001	2.70	935.0	1208
8367	OG-3-2A- 3A	MC	6	34	0	.0	-.698	2.70	935.0	1208
8368	OG-3-2A-102B	ME	6	35	0	.0	-.711	2.70	935.0	1208
8369	OG-3-2A-102B	ME	6	35	0	.0	-.799	2.70	935.0	1208
8370	OG-3-2A 2B	MC	6	36	0	.0	-.718	2.70	935.0	1208
8371	OG-3 2A- 10A	MC	6	36	0	.0	-.715	2.70	935.0	1208
8372	OG-3-2A-103A	ME	6	37	0	.0	-.999	2.70	935.0	1208
8373	OG-3 2B-101A	ME	6	37	0	.0	-.702	2.70	935.0	1208
8374	OG-3 2B 101A	ME	6	38	0	.0	-.833	2.70	935.0	1208
8375	OG-3 2A 3A	MC	6	38	0	.0	-.685	2.70	935.0	1208
7973	OG-3 F-9	MC	3	7	6808	910.0	-3.027	8.50	935.0	1208
7974	OG-3 F-10	MC	3	8	6839	910.0	-2.976	8.50	935.0	1208
7975	OG-3 F-11	MC	3	8	6840	910.0	-2.874	8.50	935.0	1208
7976	OG-3 F-12	MC	3	8	6841	910.0	-2.842	8.50	935.0	1208
7977	OG-3 F-13	MC	3	9	6842	910.0	-2.842	8.50	935.0	1208
7978	OG-3 F-14	MC	3	9	6843	910.0	-2.949	8.50	935.0	1208
7979	OG-3 F-15	MC	3	9	6844	910.0	-2.926	8.50	935.0	1208
7980	OG-3 T40525	MC	3	10	6776	970.0	-1.608	5.50	970.0	1243
7981	OG-3 T40527	MC	3	10	6777	970.0	-1.908	5.50	970.0	1243
7982	OG-3 T40529	MC	3	10	6778	970.0	-1.964	5.50	970.0	1243
7983	OG-3 T40531	MC	3	11	6779	970.0	-1.730	5.50	970.0	1243
7984	OG-3 T40533	MC	3	11	6780	970.0	-1.953	5.50	970.0	1243
7985	OG-3 T40535	MC	3	11	6781	970.0	-2.075	5.50	970.0	1243
7986	OG-3 T40537	MC	3	12	6782	970.0	-1.764	5.50	970.0	1243
7987	OG-3 T40539	MC	3	12	6783	970.0	-2.022	5.50	970.0	1243
7988	OG-3 T40541	MC	3	12	6784	970.0	-2.135	5.50	970.0	1243
7989	OG-3 T40543	MC	3	13	6785	970.0	-1.754	5.50	970.0	1243
7990	OG-3 T40545	MC	3	13	6786	970.0	-2.151	5.50	970.0	1243
7991	OG-3 T40547	MC	3	13	6787	970.0	-1.899	5.50	970.0	1243
7965	OG-3 F-1	MC	3	5	6800	960.0	-2.845	8.50	970.0	1243
7966	OG-3 F-2	MC	3	5	6801	960.0	-2.967	8.50	970.0	1243
7967	OG-3 F-3	MC	3	5	6802	960.0	-2.756	8.50	970.0	1243

TABLE 5-1 (Continued)

Record Number	Specimen Number		Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
7968	OG-3	F-4	MC	3	6	6803	960.0	-2.904	8.50	970.0	1243
7969	OG-3	F-5	MC	3	6	6804	960.0	-2.935	8.50	970.0	1243
7970	OG-3	F-6	MC	3	6	6805	960.0	-2.950	8.50	970.0	1243
7971	OG-3	F-7	MC	3	7	6806	960.0	-2.953	8.50	970.0	1243
7972	OG-3	F-8	MC	3	7	6807	960.0	-3.120	8.50	970.0	1243
8380	OG-3	.596.	ME	7	2	7219	985.0	-2.850	7.70	985.0	1258
8384	OG-3	.597.	ME	7	3	7223	985.0	-2.802	7.70	985.0	1258
8388	OG-3	.598.	ME	7	4	7227	985.0	-2.819	7.70	985.0	1258
8392	OG-3	.600.	ME	7	5	7235	985.0	-2.754	7.70	985.0	1258
8393	OG-3	.601.	ME	7	5	7236	985.0	-2.922	7.70	985.0	1258
8376	OG-3	.595.	ME	7	1	7215	1000.0	-3.058	7.70	995.0	1268
7941	OG-3	.405.	MC	3	1	6731	995.0	-2.995	8.50	995.0	1268
7943	OG-3	.632.	ME	3	1	6733	995.0	-2.614	8.50	995.0	1268
7945	OG-3	.406.	MC	3	1	6735	995.0	-3.016	8.50	995.0	1268
8285	OG-3	F-44	MC	6	2	7099	1010.0	-3.030	8.40	1015.0	1288
8287	OG-3	F-45	MC	6	3	7101	1010.0	-2.997	8.40	1015.0	1288
8289	OG-3	.323.	MC	6	4	7127	1035.0(a)	-2.813	7.40	(a)	(a)
8290	OG-3	.324.	MC	6	4	7128	1035.0(a)	-3.035	7.40	(a)	(a)
8293	OG-3	.325.	MC	6	5	7131	1035.0(a)	-2.797	7.40	(a)	(a)
8294	OG-3	.326.	MC	6	5	7132	1035.0(a)	-2.851	7.40	(a)	(a)
8283	OG-3	F-43	MC	6	1	7097	1055.0	-3.166	8.40	1050.0	1323
8086	OG-3	.583.	ME	4	2	6903	1195.0	-2.926	9.20	1225.0	1498
8087	OG-3	.584.	ME	4	2	6904	1195.0	-3.150	9.20	1225.0	1498
8082	OG-3	.581.	ME	4	1	6899	1215.0	-3.087	9.20	1245.0	1518
8083	OG-3	.582.	ME	4	1	6900	1215.0	-3.105	9.20	1245.0	1518
8269	OG-3	T40569	MC	5	25	7083	1325.0	-3.205	5.80	1325.0	1598
8270	OG-3	T40571	MC	5	25	7084	1325.0	-3.132	5.80	1325.0	1598
8271	OG-3	T40573	MC	5	26	7085	1325.0	-3.209	5.80	1325.0	1598
8272	OG-3	T40575	MC	5	26	7086	1325.0	-3.012	5.80	1325.0	1598
8273	OG-3	T40577	MC	5	27	7087	1325.0	-3.111	5.80	1325.0	1598
8274	OG-3	T40579	MC	5	27	7088	1325.0	-2.959	5.80	1325.0	1598
8275	OG-3	T40581	MC	5	28	7089	1325.0	-3.091	5.80	1325.0	1598
8276	OG-3	T40583	MC	5	28	7090	1325.0	-3.023	5.80	1325.0	1598
8277	OG-3	T40585	MC	5	29	7091	1325.0	-3.078	5.80	1325.0	1598
8278	OG-3	T40587	MC	5	29	7092	1325.0	-2.898	5.80	1325.0	1598
8261	OG-3	T-147	MC	5	21	7075	1330.0	-4.042	9.00	1330.0	1603
8262	OG-3	T-148	MC	5	21	7076	1330.0	-3.658	9.00	1330.0	1603
8263	OG-3	T-149	MC	5	22	7077	1330.0	-3.797	9.00	1330.0	1603
8264	OG-3	T-150	MC	5	22	7078	1330.0	-3.659	9.00	1330.0	1603
8265	OG-3	T-151	MC	5	23	7079	1330.0	-3.824	9.00	1330.0	1603

TABLE 5-1 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8266	OG-3 T-152	MC	5 23	7080	1330.0	-3.571	9.00	1330.0	1603
8267	OG-3 T-153	MC	5 24	7081	1330.0	-3.704	9.00	1330.0	1603
8268	OG-3 T-154	MC	5 24	7082	1330.0	-3.646	9.00	1330.0	1603
8259	OG-3 T40565	MC	5 20	7029	1365.0	-3.363	5.80	1345.0	1618
8260	OG-3 T40567	MC	5 20	7030	1365.0	-3.071	5.80	1345.0	1618
8214	OG-3 T40549	MC	5 12	7021	1365.0	-3.244	5.80	1365.0	1638
8215	OG-3 T40551	MC	5 12	7022	1365.0	-3.090	5.80	1365.0	1638
8216	OG-3 T40553	MC	5 13	7023	1365.0	-3.473	5.80	1365.0	1638
8217	OG-3 T40555	MC	5 13	7024	1365.0	-3.288	5.80	1365.0	1638
8218	OG-3 T40557	MC	5 14	7025	1365.0	-3.449	5.80	1365.0	1638
8219	OG-3 T40559	MC	5 14	7026	1365.0	-3.344	5.80	1365.0	1638
8220	OG-3 T40561	MC	5 15	7027	1365.0	-3.310	5.80	1365.0	1638
8221	OG-3 T40563	MC	5 15	7028	1365.0	-3.278	5.80	1365.0	1638
8174	OG-3-2B- 6C	MC	5 2	0	.0	-2.544	2.90	1380.0	1653
8179	OG-3-2B- 6D	MC	5 3	0	.0	-2.716	2.90	1380.0	1653
8184	OG-3-2B- 7A	MC	5 4	0	.0	-2.619	2.90	1380.0	1653
8189	OG-3-2B- 7B	MC	5 5	0	.0	-2.316	2.90	1380.0	1653
8170	OG-3 .331.	MC	5 1	6985	1395.0	-3.562	9.00	1395.0	1668
8171	OG-3 .332.	MC	5 1	6986	1395.0	-3.467	9.00	1395.0	1668

(a) Specimens whose temperature was deliberately changed between capsules OG-1 and OG-2

TABLE 5-2
DIMENSIONAL CHANGE IN H-451 GRAPHITE, RADIAL ORIENTATION

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta \ell / \ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average (°C)	Irrad. Temp (K)
8695	OG-3 .505.	MC	10	2	7534	640.0	-.446	3.650	630.0	903
8699	OG-3 .506.	MC	10	3	7538	640.0	-.436	3.650	630.0	903
8703	OG-3 .507.	MC	10	4	7542	640.0	-.318	3.650	630.0	903
7815	OG-3 2A 31A	MC	1	31	0	.0	-.166	1.850	640.0	913
7816	OG-3 2B 40A	MC	1	31	0	.0	-.105	1.850	640.0	913
7817	OG-3 2A 31A	MC	1	32	0	.0	-.139	1.850	640.0	913
7818	OG-3 2A 31B	MC	1	32	0	.0	-.214	1.850	640.0	913
7819	OG-3 2B 40B	MC	1	33	0	.0	-.125	1.850	640.0	913
7820	OG-3 2A 31B	MC	1	33	0	.0	-.192	1.850	640.0	913
7821	OG-3 2A 32A	MC	1	34	0	.0	-.137	1.850	640.0	913
7822	OG-3 2A 41A	MC	1	34	0	.0	-.180	1.850	640.0	913
7823	OG-3 2A 32A	MC	1	35	0	.0	-.144	1.850	640.0	913
7824	OG-3-2A -32B	MC	1	35	0	.0	-.195	1.850	640.0	913
8691	OG-3 .504.	MC	10	1	7530	650.0	-.380	3.650	640.0	913
7706	OG-3 .428.	MC	1	2	6506	660.0	-.614	5.550	670.0	943
7710	OG-3 .429.	MC	1	3	6510	660.0	-.661	5.550	670.0	943
7714	OG-3 .472.	MC	1	4	6522	660.0(a)	-1.500	5.550	(a)	(a)
7715	OG-3 .473.	MC	1	4	6523	660.0(a)	-1.386	5.550	(a)	(a)
7718	OG-3 .474.	MC	1	5	6526	660.0(a)	-1.504	5.550	(a)	(a)
7719	OG-3 .475.	MC	1	5	6527	660.0(a)	-1.317	5.550	(a)	(a)
7702	OG-3 .426.	MC	1	1	6502	675.0	-.582	5.550	685.0	958
7703	OG-3 .427.	MC	1	1	6503	675.0	-.614	5.550	685.0	958
7726	OG-3 2B 39A	MC	1	7	0	.0	-.156	1.85	695.0	968
7727	OG-3 2B 39B	MC	1	7	0	.0	-.160	1.85	695.0	968
7730	OG-3 2B 39C	MC	1	8	0	.0	-.066	1.85	695.0	968
7731	OG-3 2B 39D	MC	1	8	0	.0	-.128	1.85	695.0	968
7734	OG-3 2B 40A	MC	1	9	0	.0	-.155	1.85	695.0	968
7735	OG-3 2B 40B	MC	1	9	0	.0	-.267	1.85	695.0	968
7862	OG-3 2B 36D	MC	2	10	0	.0	-.182	2.40	740.0	1013
7867	OG-3 2B 37A	MC	2	11	0	.0	-.162	2.40	740.0	1013
7872	OG-3 3B 52B	MC	2	12	0	.0	-.073	2.40	740.0	1013
7831	OG-3 .653.	ME	2	2	6631	750.0	-.952	7.20	755.0	1028
7832	OG-3 .654.	ME	2	2	6635	750.0	-.948	7.20	755.0	1028
7835	OG-3-2B 36A	MC	2	3	0	.0	-.213	2.40	765.0	1038
7836	OG-3-2B 36B	MC	2	3	0	.0	-.211	2.40	765.0	1038
7857	OG-3 2B 36C	MC	2	9	0	.0	-.033	2.40	765.0	1038
8606	OG-3 2B 38B	MC	9	7	0	.0	-.033	1.55	775.0	1048
8609	OG-3 2B 38C	MC	9	8	0	.0	-.053	1.55	775.0	1048
8612	OG-3 2B 38D	MC	9	8	0	.0	-.016	1.55	775.0	1048
8616	OG-3 2B 40C	MC	9	9	0	.0	-.033	1.55	775.0	1048

TABLE 5-2 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Irrad. Temp (°C)	Total $\Delta \ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
7827	OG-3 .651.	ME	2	1	6627	770.0	-1.067	7.20	775.0	1048
7828	OG-3 .652.	ME	2	1	6628	770.0	-1.073	7.20	775.0	1048
8586	OG-3 .714.	ME	9	2	7427	835.0	-.670	5.15	815.0	1088
8588	OG-3 .715.	ME	9	2	7429	835.0	-.579	5.15	815.0	1088
8584	OG-3 .713.	ME	9	1	7425	845.0	-.435	5.15	825.0	1098
8582	OG-3 .712.	ME	9	1	7423	850.0	-.641	5.15	830.0	1103
8555	OG-3 2A 32A	MC	8	26	0	.0	-.163	2.00	835.0	1108
8556	OG-3 2B 41A	MC	8	26	0	.0	-.144	2.00	835.0	1108
8557	OG-3 2A-133A	ME	8	27	0	.0	-.177	2.00	835.0	1108
8558	OG-3 2A 133A	ME	8	27	0	.0	-.081	2.00	835.0	1108
8559	OG-3 2B 41B	MC	8	28	0	.0	-.149	2.00	835.0	1108
8560	OG-3 2B 32B	MC	8	28	0	.0	-.140	2.00	835.0	1108
8561	OG-3 2A 135A	ME	8	29	0	.0	-.173	2.00	835.0	1108
8562	OG-3 2A 160A	ME	8	29	0	.0	-.119	2.00	835.0	1108
8563	OG-3 2A 32A	MC	8	30	0	.0	-.239	2.00	835.0	1108
8564	OG-3 2B 33A	MC	8	30	0	.0	-.173	2.00	835.0	1108
8565	OG-3 2A 160B	ME	8	31	0	.0	-.296	2.00	835.0	1108
8566	OG-3 2A 133B	ME	8	31	0	.0	-.180	2.00	835.0	1108
8567	OG-3 2B 33B	MC	8	32	0	.0	-.220	2.00	835.0	1108
8568	OG-3 2B 46A	MC	8	32	0	.0	-.143	2.00	835.0	1108
8569	OG-3 2A 134A	ME	8	33	0	.0	-.262	2.00	835.0	1108
8570	OG-3 2A 134A	ME	8	33	0	.0	-.162	2.00	835.0	1108
8571	OG-3 2B 46B	MC	8	34	0	.0	-.231	2.00	835.0	1108
8572	OG-3 2B 33A	MC	8	34	0	.0	-.153	2.00	835.0	1108
8573	OG-3 2A 133B	ME	8	35	0	.0	-.228	2.00	835.0	1108
8574	OG-3 2A 162A	ME	8	35	0	.0	-.160	2.00	835.0	1108
8575	OG-3 2B 33B	MC	8	36	0	.0	-.240	2.00	835.0	1108
8576	OG-3 2B 32B	MC	8	36	0	.0	-.181	2.00	835.0	1108
8577	OG-3 2A 162B	ME	8	37	0	.0	-.241	2.00	835.0	1108
8578	OG-3 2A 134B	ME	8	37	0	.0	-.203	2.00	835.0	1108
8579	OG-3 2B 34A	MC	8	38	0	.0	-.235	2.00	835.0	1108
8580	OG-3 2A 134B	ME	8	38	0	.0	-.121	2.00	835.0	1108
8551	OG-3 T40661	MC	8	24	7418	850.0	-.664	4.15	845.0	1118
8552	OG-3 T40663	MC	8	24	7419	850.0	-.404	4.15	845.0	1118
8553	OG-3 T40665	MC	8	25	7420	850.0	-.552	4.15	845.0	1118
8554	OG-3 T40667	MC	8	25	7421	850.0	-.447	4.15	845.0	1118
8485	OG-3 .498.	MC	8	2	7331	920.0	-1.129	6.45	910.0	1183
8486	OG-3 .499.	MC	8	2	7332	920.0	-1.120	6.45	910.0	1183
8489	OG-3 .500.	MC	8	3	7335	920.0	-1.017	6.45	910.0	1183
8490	OG-3 .501.	MC	8	3	7336	920.0	-1.282	6.45	910.0	1183

TABLE 5-2 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Irrad. Temp (°C)	Total $\Delta \ell / \ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	Average Irrad. Temp (K)
8048	OG-3 T-209	MC	3 26	6823	910.0	-.801	8.50	915.0	1188
8051	OG-3 T-210	MC	3 27	6826	910.0	-.634	8.50	915.0	1188
8481	OG-3 .496.	MC	8 1	7327	930.0	-.923	6.45	920.0	1193
8482	OG-3 .497.	MC	8 1	7328	930.0	-1.002	6.45	920.0	1193
8052	OG-3 T40621	MC	3 28	6827	920.0	-1.058	5.50	925.0	1198
8053	OG-3 T40623	MC	3 28	6828	920.0	-1.238	5.50	925.0	1198
8054	OG-3 T40625	MC	3 28	6829	920.0	-1.245	5.50	925.0	1198
8055	OG-3 T40627	MC	3 29	6830	920.0	-1.071	5.50	925.0	1198
8056	OG-3 T40629	MC	3 29	6831	920.0	-1.173	5.50	925.0	1198
8057	OG-3 T40631	MC	3 29	6832	920.0	-1.213	5.50	925.0	1198
8058	OG-3 T40633	MC	3 30	6833	920.0	-1.122	5.50	925.0	1198
8059	OG-3 T40635	MC	3 30	6834	920.0	-1.193	5.50	925.0	1198
8060	OG-3 T40637	MC	3 30	6835	920.0	-1.342	5.50	925.0	1198
8061	OG-3 T40639	MC	3 31	6836	920.0	-1.029	5.50	925.0	1198
8062	OG-3 T40641	MC	3 31	6837	920.0	-1.184	5.50	925.0	1198
8063	OG-3 T40643	MC	3 31	6838	920.0	-1.174	5.50	925.0	1198
8064	OG-3 2A 33A	MC	3 32	0	.0	-.213	2.80	930.0	1203
8065	OG-3 2A 46A	MC	3 32	0	.0	-.405	2.80	930.0	1203
8066	OG-3 2A 33A	MC	3 32	0	.0	-.486	2.80	930.0	1203
8067	OG-3 2A 131A	ME	3 33	0	.0	-.293	2.80	930.0	1203
8068	OG-3 2A-131A	ME	3 33	0	.0	-.336	2.80	930.0	1203
8069	OG-3 2A 152A	ME	3 33	0	.0	-.438	2.80	930.0	1203
8070	OG-3 2A- 46B	MC	3 34	0	.0	-.319	2.80	930.0	1203
8071	OG-3 2A- 33B	MC	3 34	0	.0	-.435	2.80	930.0	1203
8072	OG-3 2A 33B	MC	3 34	0	.0	-.443	2.80	930.0	1203
8073	OG-3 2A 131B	ME	3 35	0	.0	-.198	2.80	930.0	1203
8074	OG-3 2A-152B	ME	3 35	0	.0	-.350	2.80	930.0	1203
8075	OG-3 2A-131B	ME	3 35	0	.0	-.378	2.80	930.0	1203
8076	OG-3 2A- 34A	MC	3 36	0	.0	-.370	2.80	930.0	1203
8077	OG-3 2A- 34A	MC	3 36	0	.0	-.347	2.80	930.0	1203
8078	OG-3 2B 56A	MC	3 36	0	.0	-.392	2.80	930.0	1203
8079	OG-3-2A-156A	ME	3 37	0	.0	-.260	2.80	930.0	1203
8080	OG-3-2A-132A	ME	3 37	0	.0	-.285	2.80	930.0	1203
8081	OG-3-2A-132A	ME	3 37	0	.0	-.274	2.80	930.0	1203
8800	OG-3-2A- 34B	MC	3 38	0	.0	-.168	2.80	930.0	1203
8801	OG-3 2B 56B	MC	3 38	0	.0	-.344	2.80	930.0	1203
8802	OG-3-2A- 34B	MC	3 38	0	.0	-.422	2.80	930.0	1203
8803	OG-3-2A-132B	ME	3 39	0	.0	-.193	2.80	930.0	1203
8804	OG-3 2A-132B	ME	3 39	0	.0	-.285	2.80	930.0	1203
8805	OG-3 2A-156B	ME	3 39	0	.0	-.370	2.80	930.0	1203

TABLE 5-2 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Irrad. Temp (°C)	Total Δℓ/ℓo (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	Average Irrad. Temp (K)
7996	OG-3 T-205	MC	3 15	6815	910.0	-.716	8.50	930.0	1203
7997	OG-3 T-206	MC	3 15	6814	910.0	-.590	6.50	930.0	1203
8000	OG-3 T-207	MC	3 16	6817	910.0	-.734	8.50	930.0	1203
8003	OG-3 T-208	MC	3 17	6820	910.0	-.797	8.50	930.0	1203
7992	OG-3 T-201	MC	3 14	6809	935.0	-.793	8.50	945.0	1218
7993	OG-3 T-202	MC	3 14	6810	935.0	-.587	8.50	945.0	1218
7994	OG-3 T-203	MC	3 14	6811	935.0	-.444	8.50	945.0	1218
7995	OG-3 T-204	MC	3 15	6812	935.0	-.789	8.50	945.0	1218
8382	OG-3 .696.	ME	7 2	7221	985.0	-.878	7.70	985.0	1258
8386	OG-3 .697.	ME	7 3	7225	985.0	-.848	7.70	985.0	1258
8390	OG-3 .698.	ME	7 4	7229	985.0	-.644	7.70	985.0	1258
8394	OG-3 .700.	ME	7 5	7237	985.0	-.686	7.70	985.0	1258
8395	OG-3 .701.	ME	7 5	7238	985.0	-.728	7.70	985.0	1258
8307	OG-3 2A 35A	MC	6 9	0	.0	-.851	2.70	995.0	1268
8308	OG-3 2A 35B	MC	6 9	0	.0	-.660	2.70	995.0	1268
8309	OG-3 2A 56B	MC	6 10	0	.0	-.782	2.70	995.0	1268
8310	OG-3 2A 35B	MC	6 10	0	.0	-.601	2.70	995.0	1268
8311	OG-3 2B 31A	MC	6 11	0	.0	-.848	2.70	995.0	1268
8312	OG-3 2A 40A	MC	6 11	0	.0	-.668	2.70	995.0	1268
8313	OG-3 2B 31A	MC	6 12	0	.0	-1.000	2.70	995.0	1268
8314	OG-3 2B 31B	MC	6 12	0	.0	-.764	2.70	995.0	1268
8315	OG-3 2A 40B	MC	6 13	0	.0	-.929	2.70	995.0	1268
8316	OG-3 2B 31B	MC	6 13	0	.0	-.807	2.70	995.0	1268
8378	OG-3 .695.	ME	7 1	7217	1000.0	-.694	7.70	995.0	1268
7942	OG-3 .530.	MC	3 1	6732	995.0	-.300	8.50	995.0	1268
7944	OG-3 .732.	ME	3 1	6734	995.0	.051	8.50	995.0	1268
7946	OG-3 .531.	MC	3 1	6736	995.0	.233	8.50	995.0	1268
8286	OG-3 F-73	MC	6 2	7100	1010.0	-.797	8.40	1015.0	1288
8288	OG-3 F-74	MC	6 3	7102	1010.0	-.545	8.40	1015.0	1288
8305	OG-3 2A 35A	MC	6 8	0	.0	-.887	2.70	1030.0	1303
8306	OG-3 2A 56A	MC	6 8	0	.0	-.748	2.70	1030.0	1303
8291	OG-3 .448.	MC	6 4	7129	1035.0(a)	-1.420	7.40	(a)	(a)
8292	OG-3 .449.	MC	6 4	7130	1035.0(a)	-1.389	7.40	(a)	(a)
8295	OG-3 .450.	MC	6 5	7133	1035.0(a)	-1.519	7.40	(a)	(a)
8296	OG-3 .451.	MC	6 5	7134	1035.0(a)	-1.433	7.40	(a)	(a)
8284	OG-3 F-72	MC	6 1	7098	1055.0	-.602	8.40	1050.0	1323
8088	OG-3 .683.	ME	4 2	6905	1195.0	-1.040	9.20	1225.0	1498
8089	OG-3 .684.	ME	4 2	6906	1195.0	-1.187	9.20	1225.0	1498
8084	OG-3 .681.	ME	4 1	6901	1215.0	-.833	9.20	1245.0	1518
8085	OG-3 .682.	ME	4 1	6902	1215.0	-.881	9.20	1245.0	1518

TABLE 5-2 (Continued)

Record Number	Specimen Number	Position in Log	Crucible/Hole		Previous Record No.	Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average (°C)	Irrad. Temp (K)
8279	OG-3 T40669	MC	5	30	7093	1325.0	-2.116	5.80	1325.0	1598
8280	OG-3 T40671	MC	5	30	7094	1325.0	-1.940	5.80	1325.0	1598
8281	OG-3 T40673	MC	5	31	7095	1325.0	-2.171	5.80	1325.0	1598
8282	OG-3 T40675	MC	5	31	7096	1325.0	-2.052	5.80	1325.0	1598
8209	OG-3-2B- 38A	MC	5	10	0	.0	-1.700	2.90	1360.0	1633
8194	OG-3-2B 40D	MC	5	7	0	.0	-2.081	2.90	1380.0	1653
8199	OG-3-2B- 37C	MC	5	8	0	.0	-2.150	2.90	1380.0	1653
8204	OG-3-2B- 37D	MC	5	9	0	.0	-1.918	2.90	1380.0	1653
8172	OG-3 .456.	MC	5	1	6987	1395.0	-.075	9.00	1395.0	1668
8173	OG-3 .457.	MC	5	1	6988	1395.0	-.482	9.00	1395.0	1668

(a) Specimens whose temperature was deliberately changed between capsules capsules OG-1 and OG-2

TABLE 5-3
DIMENSIONAL CHANGE IN H-429 GRAPHITE

Record Number	Sample Number	Location in Log	Irrad. Position Crucible/Hole	Previous Record Number	Previous Irrad. Temp (°C)	$\Delta\ell/\ell_o$ (%)	Total Fast Neutron Fluence 10^{25} n/m^2	Average Irrad. Temp (°C)	
								(°C)	K
Axial Orientation									
8099	404		4/5	6924	1170	-2.60	11.4	1200	1473
8101	405		4/5	6926	1170	-2.67	11.4	1200	1473
8103	406		4/6	6928	1185	-3.13	11.4	1210	1483
8105	407		4/6	6930	1185	-3.04	11.4	1210	1483
8503	392		8/7	7357	905	-2.46	7.15	900	1173
8504	393		8/7	7358	905	-2.26	7.15	900	1173
8505	397		8/7	7359	905	-2.22	7.15	900	1173
8506	398		8/7	7360	905	-2.15	7.15	900	1173
8710	385		10/6	7557	630	-0.90	3.9	625	898
8712	386		10/6	7559	630	-0.68	3.9	625	898
8714	387		10/7	7561	630	-0.99	3.9	625	898
8716	388		10/7	7563	630	-0.58	3.9	625	898
Radial Orientation									
8098	434		4/5	6923	1170	-0.83	11.4	1200	1473
8100	435		4/5	6925	1170	-0.88	11.4	1200	1473
8102	436		4/6	6927	1185	-0.99	11.4	1210	1483
8104	437		4/6	6929	1185	-0.76	11.4	1210	1483
8499	419		8/6	7349	905	-1.04	7.15	900	1173
8500	420		8/6	7350	905	-1.13	7.15	900	1173
8501	421		8/6	7351	905	-1.03	7.15	900	1173
8502	422		8/6	7352	905	-1.09	7.15	900	1173
8709	415		10/6	7556	630	-0.86	3.9	625	898
8711	416		10/6	7558	630	-0.68	3.9	625	898
8713	417		10/7	7560	630	-0.86	3.9	625	898

TABLE 5-4
DIMENSIONAL CHANGE IN TS-1240 GRAPHITE, AXIAL ORIENTATION

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8727	OG-3 T40245	ME	10 11	7613	590.0	-.236	2.25	590.0	863
8728	OG-3 T40247	ME	10 11	7614	590.0	-.159	2.25	590.0	863
8729	OG-3 T40249	ME	10 12	7615	590.0	-.139	2.25	590.0	863
8730	OG-3 T40251	ME	10 12	7616	590.0	-.120	2.25	590.0	863
8731	OG-3 T40253	ME	10 13	7617	590.0	-.257	2.25	590.0	863
8732	OG-3 T40255	ME	10 13	7618	590.0	-.178	2.25	590.0	863
8733	OG-3 T40257	ME	10 14	7619	590.0	-.252	2.25	590.0	863
8734	OG-3 T40259	ME	10 14	7620	590.0	-.181	2.25	590.0	863
8725	OG-3 T40241	ME	10 10	7574	620.0	-.263	2.25	605.0	878
8726	OG-3 T40243	ME	10 10	7575	620.0	-.162	2.25	605.0	878
8657	OG-3 3A 107B	MC	9 24	0	.0	-.004	1.55	725.0	998
8658	OG-3 2A 4A	MC	9 24	0	.0	-.093	1.55	725.0	998
8659	OG-3 3A 111A	ME	9 25	0	.0	-.024	1.55	725.0	998
8660	OG-3 3A-152A	ME	9 25	0	.0	.025	1.55	725.0	998
8661	OG-3 2A 4B	MC	9 26	0	.0	-.092	1.55	725.0	998
8662	OG-3 3B 1B	MC	9 26	0	.0	-.050	1.55	725.0	998
8663	OG-3 3A 152B	ME	9 27	0	.0	-.006	1.55	725.0	998
8664	OG-3 2A 103B	ME	9 27	0	.0	.079	1.55	725.0	998
8665	OG-3 3B 2B	MC	9 28	0	.0	.020	1.55	725.0	998
8666	OG-3 3A 110A	MC	9 28	0	.0	.008	1.55	725.0	998
8667	OG-3 2A 104A	ME	9 29	0	.0	-.028	1.55	725.0	998
8668	OG-3 3A 111B	ME	9 29	0	.0	.000	1.55	725.0	998
8669	OG-3 3A 110B	MC	9 30	0	.0	-.046	1.55	725.0	998
8670	OG-3 2B 2A	MC	9 30	0	.0	-.093	1.55	725.0	998
8671	OG-3 3B 111A	ME	9 31	0	.0	-.060	1.55	725.0	998
8672	OG-3 3A 154A	ME	9 31	0	.0	-.031	1.55	725.0	998
8673	OG-3 2B 2B	MC	9 32	0	.0	-.123	1.55	725.0	998
8674	OG-3 3A 17B	MC	9 32	0	.0	-.017	1.55	725.0	998
8675	OG-3 3A 154B	ME	9 33	0	.0	-.020	1.55	725.0	998
8676	OG-3 2A 104B	ME	9 33	0	.0	-.007	1.55	725.0	998
8677	OG-3 3A 18B	MC	9 34	0	.0	-.017	1.55	725.0	998
8678	OG-3 3B 132A	MC	9 34	0	.0	.006	1.55	725.0	998
8679	OG-3 3B 157A	ME	9 35	0	.0	-.028	1.55	725.0	998
8680	OG-3 3B 111B	ME	9 35	0	.0	.012	1.55	725.0	998
8681	OG-3 T40089	MC	9 36	7520	765.0	-.216	3.25	745.0	1018
8682	OG-3 T40091	MC	9 36	7521	765.0	-.182	3.25	745.0	1018
8683	OG-3 T40093	MC	9 37	7522	765.0	-.145	3.25	745.0	1018
8684	OG-3 T40095	MC	9 37	7523	765.0	-.196	3.25	745.0	1018
8685	OG-3 T40097	MC	9 38	7524	765.0	-.161	3.25	745.0	1018
8686	OG-3 T40099	MC	9 38	7525	765.0	-.166	3.25	745.0	1018

TABLE 5-4 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta \ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2	Average (°C)	Irrad. Temp (K)
8687	OG-3 T40101	MC	9 39	7526	765.0	-.193	3.25	745.0	1018
8688	OG-3 T40103	MC	9 39	7527	765.0	-.145	3.25	745.0	1018
8629	OG-3 3A 11B	MC	9 16	0	.0	-.036	1.55	760.0	1033
8630	OG-3 3A 107A	MC	9 16	0	.0	-.025	1.55	760.0	1033
8631	OG-3 2A 103A	ME	9 17	0	.0	-.038	1.55	760.0	1033
8632	OG-3 3B 110B	ME	9 17	0	.0	-.061	1.55	760.0	1033
7838	OG-3 3B 5A	MC	2 4	0	.0	-.036	2.40	765.0	1038
7843	OG-3 3A 20B	MC	2 5	0	.0	-.158	2.40	765.0	1038
7848	OG-3 3B 3B	MC	2 6	0	.0	-.129	2.40	765.0	1038
7853	OG-3 3A 30B	MC	2 8	0	.0	-.133	2.40	765.0	1038
8406	OG-3 T40041	MC	7 9	7253	970.0	-.986	4.90	970.0	1243
8407	OG-3 T40043	MC	7 9	7254	970.0	-.773	4.90	970.0	1243
8408	OG-3 T40045	MC	7 10	7255	970.0	-.991	4.90	970.0	1243
8409	OG-3 T40047	MC	7 10	7256	970.0	-.854	4.90	970.0	1243
8410	OG-3 T40049	MC	7 11	7257	970.0	-1.031	4.90	970.0	1243
8411	OG-3 T40051	MC	7 11	7258	970.0	-.826	4.90	970.0	1243
8404	OG-3 T40037	MC	7 8	7251	970.0	-1.106	4.90	975.0	1248
8405	OG-3 T40039	MC	7 8	7252	970.0	-1.003	4.90	975.0	1248
8160	OG-3 T40001	MC	4 29	6967	1105.0	-1.396	5.90	1140.0	1413
8161	OG-3 T40003	MC	4 29	6968	1105.0	-1.506	5.90	1140.0	1413
8162	OG-3 T40005	MC	4 30	6969	1105.0	-1.364	5.90	1140.0	1413
8163	OG-3 T40007	MC	4 30	6970	1105.0	-1.538	5.90	1140.0	1413
8164	OG-3 T40009	MC	4 31	6971	1105.0	-1.410	5.90	1140.0	1413
8165	OG-3 T40011	MC	4 31	6972	1105.0	-1.456	5.90	1140.0	1413
8166	OG-3 T40013	MC	4 32	6973	1105.0	-1.385	5.90	1140.0	1413
8167	OG-3 T40015	MC	4 32	6974	1105.0	-1.521	5.90	1140.0	1413
8144	OG-3 3A 151A	ME	4 21	0	.0	-.975	2.95	1180.0	1453
8145	OG-3 2A 101B	ME	4 21	0	.0	-1.494	2.95	1180.0	1453
8146	OG-3 3A 5B	MC	4 22	0	.0	-.947	2.95	1180.0	1453
8147	OG-3 3A 119B	MC	4 22	0	.0	-1.023	2.95	1180.0	1453
8148	OG-3 2A 102A	ME	4 23	0	.0	-1.366	2.95	1180.0	1453
8149	OG-3 3B 101B	ME	4 23	0	.0	-1.173	2.95	1180.0	1453
8150	OG-3-3B-141A	MC	4 24	0	.0	-.945	2.95	1180.0	1453
8151	OG-3-2A 2A	MC	4 24	0	.0	-1.246	2.95	1180.0	1453
8152	OG-3-3B 102B	ME	4 25	0	.0	-1.067	2.95	1180.0	1453
8153	OG-3-3A-151B	ME	4 25	0	.0	-.975	2.95	1180.0	1453
8154	OG-3-2A- 2B	MC	4 26	0	.0	-1.015	2.95	1180.0	1453
8155	OG-3-3A- 8B	MC	4 26	0	.0	-1.026	2.95	1180.0	1453
8156	OG-3-3A-153A	ME	4 27	0	.0	-.845	2.95	1180.0	1453
8157	OG-3-2A-102B	ME	4 27	0	.0	-1.342	2.95	1180.0	1453

TABLE 5-4 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8158	OG-3-3A- 1B	MC	4 28	0	.0	-.692	2.95	1180.0	1453
8159	OG-3-3A 110B	ME	4 28	0	.0	-1.034	2.95	1180.0	1453
8114	OG-3 3A- 3B	MC	4 11	0	.0	-1.159	2.95	1250.0	1523
8115	OG-3 3B 135A	MC	4 11	0	.0	-1.011	2.95	1250.0	1523
8116	OG-3 2A 101B	ME	4 12	0	.0	-1.366	2.95	1250.0	1523
8117	OG-3 3A 101B	ME	4 12	0	.0	-1.174	2.95	1250.0	1523
8118	OG-3 3B 135B	MC	4 13	0	.0	-.961	2.95	1250.0	1523
8119	OG-3 2A 3B	MC	4 13	0	.0	-1.367	2.95	1250.0	1523
8120	OG-3 3B 101A	ME	4 14	0	.0	-1.118	2.95	1250.0	1523
8121	OG-3 3A 119A	ME	4 14	0	.0	-1.005	2.95	1250.0	1523
8122	OG-3-2A 3A	MC	4 15	0	.0	-1.143	2.95	1250.0	1523
8123	OG-3 3A 4B	MC	4 15	0	.0	-1.084	2.95	1250.0	1523
8175	OG-3-3A 29B	MC	5 2	0	.0	-1.790	2.90	1380.0	1653
8180	OG-3-3A- 26B	MC	5 3	0	.0	-1.794	2.90	1380.0	1653
8185	OG-3-3A- 22B	MC	5 4	0	.0	-1.612	2.90	1380.0	1653
8190	OG-3-3A- 21B	MC	5 6	0	.0	-1.868	2.90	1380.0	1653

TABLE 5-5
DIMENSIONAL CHANGE IN TS-1240 GRAPHITE, RADIAL ORIENTATION

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8760	OG-3 3A 45B	MC	10 22	0	.0	-.026	1.10	555.0	828
8761	OG-3 3B 173A	MC	10 22	0	.0	-.034	1.10	555.0	828
8762	OG-3 2A 133A	ME	10 23	0	.0	-.077	1.10	555.0	828
8763	OG-3 3A 132B	ME	10 23	0	.0	-.042	1.10	555.0	828
8764	OG-3 3B 173B	MC	10 24	0	.0	-.002	1.10	555.0	828
8765	OG-3 2B 33A	MC	10 24	0	.0	.030	1.10	555.0	828
8766	OG-3 3A 132B	ME	10 25	0	.0	-.040	1.10	555.0	828
8767	OG-3 3B 185A	ME	10 25	0	.0	-.056	1.10	555.0	828
8768	OG-3 2B 33B	MC	10 26	0	.0	-.028	1.10	555.0	828
8769	OG-3 3A 39B	MC	10 26	0	.0	.021	1.10	555.0	828
8770	OG-3 3B 185B	ME	10 27	0	.0	-.045	1.10	555.0	828
8771	OG-3 2A 133B	ME	10 27	0	.0	-.032	1.10	555.0	828
8772	OG-3 3A 57B	MC	10 28	0	.0	-.053	1.10	555.0	828
8773	OG-3 3B 176A	MC	10 28	0	.0	-.037	1.10	555.0	828
8774	OG-3 2A 134A	ME	10 29	0	.0	-.040	1.10	555.0	828
8775	OG-3 3B 132B	ME	10 29	0	.0	.041	1.10	555.0	828
8776	OG-3 3B 176B	MC	10 30	0	.0	.019	1.10	555.0	828
8777	OG-3 2B 34A	MC	10 30	0	.0	.004	1.10	555.0	828
8778	OG-3 3A 131A	ME	10 31	0	.0	-.048	1.10	555.0	828
8779	OG-3 3B 187A	ME	10 31	0	.0	-.019	1.10	555.0	828
8780	OG-3 2B 34B	MC	10 32	0	.0	-.024	1.10	555.0	828
8781	OG-3 3A 44B	MC	10 32	0	.0	.004	1.10	555.0	828
8782	OG-3 3B 187B	ME	10 33	0	.0	-.070	1.10	555.0	828
8783	OG-3 2A 134B	ME	10 33	0	.0	-.053	1.10	555.0	828
8735	OG-3 T40149	MC	10 15	7621	590.0	-.296	2.25	590.0	863
8736	OG-3 T40151	MC	10 15	7622	590.0	-.159	2.25	590.0	863
8737	OG-3 T40153	MC	10 16	7623	590.0	-.193	2.25	590.0	863
8738	OG-3 T40155	MC	10 16	7624	590.0	-.168	2.25	590.0	863
7929	OG-3-3A-161A	MC	2 34	0	.0	-.081	2.40	685.0	958
7930	OG-3-3A- 33B	MC	2 34	0	.0	-.123	2.40	685.0	958
7931	OG-3-2A 33B	MC	2 35	0	.0	-.123	2.40	685.0	958
7932	OG-3-3A-161B	MC	2 35	0	.0	-.120	2.40	685.0	958
7933	OG-3-3B- 34B	MC	2 36	0	.0	-.106	2.40	685.0	958
7934	OG-3-2A- 34B	MC	2 36	0	.0	-.174	2.40	685.0	958
7935	OG-3-3A-168A	MC	2 37	0	.0	-.094	2.40	685.0	958
7936	OG-3-3B- 35B	MC	2 37	0	.0	-.117	2.40	685.0	958
7937	OG-3-2A- 35B	MC	2 38	0	.0	-.103	2.40	685.0	958
7938	OG-3-3A-168B	MC	2 38	0	.0	-.078	2.40	685.0	958
7939	OG-3-3B- 38B	MC	2 39	0	.0	-.037	2.40	685.0	958
7940	OG-3-2A- 34A	MC	2 39	0	.0	-.019	2.40	685.0	958

TABLE 5-5 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_0$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
7863	OG-3 3B 58B	MC	2	10	0	.0	-.169	2.40	740.0	1013
7868	OG-3 3B 58A	MC	2	11	0	.0	-.051	2.40	740.0	1013
7873	OG-3 3B 57B	MC	2	13	0	.0	-.024	2.40	740.0	1013
8617	OG-3 3A 30B	MC	9	10	0	.0	.014	1.55	760.0	1033
8618	OG-3 3A 163A	MC	9	10	0	.0	.013	1.55	760.0	1033
8619	OG-3 2B 31A	MC	9	11	0	.0	-.002	1.55	760.0	1033
8620	OG-3 3B 40B	MC	9	11	0	.0	.074	1.55	760.0	1033
8621	OG-3 3A 163B	MC	9	12	0	.0	.016	1.55	760.0	1033
8622	OG-3 2B 31B	MC	9	12	0	.0	-.003	1.55	760.0	1033
8623	OG-3 3B 32B	MC	9	13	0	.0	.014	1.55	760.0	1033
8624	OG-3 3A 166A	MC	9	13	0	.0	.023	1.55	760.0	1033
8625	OG-3 2B 32A	MC	9	14	0	.0	.039	1.55	760.0	1033
8626	OG-3 3A 53B	MC	9	14	0	.0	-.019	1.55	760.0	1033
8627	OG-3 3A 166B	MC	9	15	0	.0	-.011	1.55	760.0	1033
8628	OG-3 2B 32B	MC	9	15	0	.0	-.050	1.55	760.0	1033
7858	OG-3 3B 59B	MC	2	9	0	.0	-.053	2.40	765.0	1038
8475	OG-3 T40121	MC	7	29	7321	920.0	-.365	4.90	925.0	1198
8476	OG-3 T40123	MC	7	29	7322	920.0	-.267	4.90	925.0	1198
8477	OG-3 T40125	MC	7	30	7323	920.0	-.311	4.90	925.0	1198
8478	OG-3 T40127	MC	7	30	7324	920.0	-.291	4.90	925.0	1198
8455	OG-3-3A-131B	ME	7	19	0	.0	-.231	2.40	935.0	1208
8456	OG-3 3A 184A	ME	7	19	0	.0	-.193	2.40	935.0	1208
8457	OG-3-2A- 31B	MC	7	20	0	.0	-.285	2.40	935.0	1208
8458	OG-3-3A- 31B	MC	7	20	0	.0	-.221	2.40	935.0	1208
8459	OG-3-3A 184B	ME	7	21	0	.0	-.195	2.40	935.0	1208
8460	OG-3-2A 131B	ME	7	21	0	.0	-.362	2.40	935.0	1208
8461	OG-3 3B 41B	MC	7	22	0	.0	-.269	2.40	935.0	1208
8462	OG-3 3B 178A	MC	7	22	0	.0	-.181	2.40	935.0	1208
8463	OG-3 2A 132A	ME	7	23	0	.0	-.255	2.40	935.0	1208
8464	OG-3 3B 131B	ME	7	23	0	.0	-.258	2.40	935.0	1208
8465	OG-3-3B-178B	MC	7	24	0	.0	-.269	2.40	935.0	1208
8466	OG-3-2A- 32A	MC	7	24	0	.0	-.308	2.40	935.0	1208
8467	OG-3-3B-141B	ME	7	25	0	.0	-.277	2.40	935.0	1208
8468	OG-3-3B-186A	ME	7	25	0	.0	-.232	2.40	935.0	1208
8469	OG-3-2A- 32B	MC	7	26	0	.0	-.247	2.40	935.0	1208
8470	OG-3-3B- 31B	MC	7	26	0	.0	-.245	2.40	935.0	1208
8471	OG-3-3B-186B	ME	7	27	0	.0	-.222	2.40	935.0	1208
8472	OG-3-2A-132B	ME	7	27	0	.0	-.261	2.40	935.0	1208
8473	OG-3-3A- 40B	MC	7	28	0	.0	-.263	2.40	935.0	1208
8474	OG-3-3A-140B	MF	7	28	0	.0	-.159	2.40	935.0	1208

TABLE 5-5 (Continued)

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta \ell / \ell_o$ (%)	Total Fluence (E 29fJ, HTGR) (10^{25} n/m^2)	Average (C°)	Irrad. Temp (K)
8412	OG-3 3A 41B	MC	7	12	0	.0	-.286	2.40	965.0	1238
8413	OG-3 3B 171A	MC	7	12	0	.0	-.171	2.40	965.0	1238
8414	OG-3 2A 131A	ME	7	13	0	.0	-.272	2.40	965.0	1238
8415	OG-3-3A 141B	ME	7	13	0	.0	-.187	2.40	965.0	1238
8416	OG-3-3B 171B	MC	7	14	0	.0	-.191	2.40	965.0	1238
8417	OG-3-2A- 31A	MC	7	14	0	.0	-.229	2.40	965.0	1238
8110	OG-3 T40165	MC	4	9	6939	1200.0	-.545	5.90	1225.0	1498
8111	OG-3 T40167	MC	4	9	6940	1200.0	-.588	5.90	1225.0	1498
8112	OG-3 T40169	MC	4	10	6941	1200.0	-.508	5.90	1225.0	1498
8113	OG-3 T40171	MC	4	10	6942	1200.0	-.534	5.90	1225.0	1498
8106	OG-3 T40157	MC	4	7	6935	1200.0	-.620	5.90	1245.0	1518
8107	OG-3 T40159	MC	4	7	6936	1200.0	-.550	5.90	1245.0	1518
8108	OG-3 T40161	MC	4	8	6937	1200.0	-.616	5.90	1245.0	1518
8109	OG-3 T40163	MC	4	8	6938	1200.0	-.591	5.90	1245.0	1518
8210	OG-3 3B- 54A	MC	5	11	0	.0	-1.117	2.90	1360.0	1633
8195	OG-3-3B- 57A	MC	5	7	0	.0	-1.155	2.90	1380.0	1653
8200	OG-3 3B 52A	MC	5	8	0	.0	-1.132	2.90	1380.0	1653
8205	OG-3-3B- 56A	MC	5	9	0	.0	-1.021	2.90	1380.0	1653

TABLE 5-6
DIMENSIONAL CHANGE IN MISCELLANEOUS GRAPHITES

Record Number	Sample Number	Location in Log	Irrad. Position Crucible/Hole	Previous Record Number	Previous Irrad. Temp (°C)	$\Delta\ell/\ell_o$ (%)	Total Fast Neutron Fluence 10^{25} n/m^2	Average Irrad. Temp (°C)	Average Irrad. Temp K
Axial Orientation									
S0-818									
7841	1A-1A	MC	2/5			-0.21	2.4	765	1038
7846	1A-1B	MC	2/6			-0.15	2.4	765	1038
7851	1A-1C	MC	2/7			-0.21	2.4	765	1038
7856	1A-1D	MC	2/8			-0.28	2.4	765	1038
8178	1A-2A	MC	5/3			-2.31	2.9	1380	1653
8183	1A-2B	MC	5/4			-2.27	2.9	1380	1653
8188	1A-2C	MC	5/5			-2.44	2.9	1380	1653
8193	1A-2D	MC	5/6			-2.25	2.9	1380	1653
5651-61									
8008	S-525		3/18	6855	925	+2.22	8.5	940	1213
8014	S-528		3/19	6861	925	+2.57	8.5	940	1213
8020	S-531		3/20	6867	925	+2.07	8.5	940	1213
8027	S-534		3/21	6873	925	+2.22	8.5	940	1213
8032	S-537		3/22	6879	925	+2.83	8.5	940	1213
8038	S-540		3/23	6885	925	+2.52	8.5	940	1213
H-451C									
8332	S-951		6/20	7195	980	-2.48	8.4	985	1258
8333	S-963		6/20	7196	980	-3.22	8.4	985	1258
8334	S-952		6/20	7197	920	-2.68	8.4	985	1258
8335	S-964		6/20	7198	980	-2.78	8.4	985	1258
8336	S-953		6/21	7199	980	-2.46	8.4	985	1258
8337	S-965		6/21	7200	980	-2.13	8.4	985	1258
8338	S-954		6/21	7201	980	-3.52	8.4	985	1258
8339	S-966		6/21	7202	980	-2.83	8.4	985	1258
8340	S-955		6/22	7203	980	-2.75	8.4	985	1258
8341	S-967		6/22	7204	980	-2.31	8.4	985	1258
8342	S-956		6/22	7205	980	-3.36	8.4	985	1258
8343	S-968		6/22	7206	980	-2.82	8.4	985	1258
Radial Orientation									
S0-818									
7861	1A-61A	MC	2/10			-0.11	2.4	740	1013
7866	1A-61B	MC	2/11			-0.24	2.4	740	1013
7871	1A-61C	MC	2/12			-0.23	2.4	740	1013
7876	1A-61D	MC	2/13			-0.22	2.4	740	1013
8198	1A-68A	MC	5/8			-1.54	2.9	1380	1653
8203	1A-68B	MC	5/9			-1.45	2.9	1380	1653
8208	1A-68C	MC	5/10			-1.28	2.9	1380	1653
8213	1A-68D	MC	5/11			-1.40	2.9	1380	1653
5651-61									
8009	S-625		3/18	6856	925	+1.16	8.5	940	1213
8015	S-628		3/19	6862	925	+0.98	8.5	940	1213
8021	S-631		3/20	6868	925	+1.56	8.5	940	1213
8026	S-634		3/21	6874	925	+1.53	8.5	940	1213
8033	S-637		3/22	6880	925	+1.26	8.5	940	1213
8039	S-640		3/23	6886	925	+1.29	8.5	940	1213

TABLE 5-7
DIMENSIONAL CHANGE IN ASI 2-500 GRAPHITE

Record Number	Sample Number	Location in Log	Irrad. Position Crucible/Hole	Previous Record Number	Previous Irrad. Temp (°C)	$\Delta\ell/\ell_o$ (%)	Total Fast Neutron Fluence 10^{25} n/m^2	Average Irrad. Temp (°C)	Average Irrad. Temp K
Axial Orientation									
7840	1A-5A	EE	2/4			-0.30	2.4	765	1038
7845	1A-5B	EE	2/6			-0.20	2.4	765	1038
7850	1A-5C	EE	2/7			-0.23	2.4	765	1038
7855	1A-5D	EE	2/8			-0.18	2.4	765	1038
8177	1A-5E	EE	5/2			-1.70	2.9	1380	1653
8182	1A-5F	EE	5/4			-1.88	2.9	1380	1653
8187	1A-5G	EE	5/5			-2.08	2.9	1380	1653
8192	1A-5H	EE	5/6			-2.06	2.9	1380	1653
8599	1A-5L	EE	9/5			-0.11	1.55	775	1048
8602	1A-5J	EE	9/6			-0.06	1.55	775	1048
8605	1A-5K	EE	9/7			-0.27	1.55	775	1048
Radial Orientation									
7860	1A-4A	EE	2/9			-0.18	2.4	765	1038
7865	1A-4B	EE	2/11			-0.26	2.4	740	1013
7870	1A-4C	EE	2/12			-0.16	2.4	740	1013
7875	1A-4D	EE	2/13			-0.17	2.4	740	1013
8197	1A-4E	EE	5/7			-1.30	2.9	1380	1653
8202	1A-4F	EE	5/9			-1.35	2.9	1380	1653
8207	1A-4G	EE	5/10			-1.41	2.9	1380	1653
8212	1A-4H	EE	5/11			-1.44	2.9	1380	1653
8608	1A-4J	EE	9/7			-0.03	1.55	775	1048
8611	1A-4K	EE	9/18			-0.09	1.55	775	1048
8614	1A-4L	EE	9/9			-0.33	1.55	775	1048

TABLE 5-8
DIMENSIONAL CHANGE IN P_3JHA_2N GRAPHITE

Record Number	Sample Number	Location in Log	Irrad. Position Crucible/Hole	Previous Record Number	Previous Irrad. Temp (°C)	$\Delta\ell/\ell_o$ (%)	Total Fast Neutron Fluence 10^{25} n/m^2	Average Irrad. Temp (°C)	Average Irrad. Temp K
			Axial Orientation						
7839	3A-1A	MC	2/4			-0.35	2.4	765	1038
7844	3A-1B	MC	2/5			-0.43	2.4	765	1038
7849	3A-1C	MC	2/7			-0.31	2.4	765	1038
7854	3A-1D	MC	2/8			-0.29	2.4	765	1038
8176	3A-1E	MC	5/2			-3.22	2.9	1380	1653
8181	3A-1F	MC	5/3			-3.02	2.9	1380	1653
8186	3A-1G	MC	5/5			-3.27	2.9	1380	1653
8191	3A-1H	MC	5/6			-3.21	2.9	1380	1653
8598	3A-33A	MC	9/5			-0.30	1.55	775	1048
8601	3A-33B	MC	9/6			-0.17	1.55	775	1048
8604	3A-33C	MC	9/6			-0.16	1.55	775	1048
			Radial Orientation						
7859	3A-3A	MC	2/9			-0.17	2.4	765	1038
7864	3A-3B	MC	2/10			-0.13	2.4	740	1013
7869	3A-3C	MC	2/12			-0.19	2.4	740	1013
7874	3A-3D	MC	2/13			-0.15	2.4	740	1013
8196	3A-2A	MC	5/7			-1.63	2.9	1380	1653
8201	3A-2B	MC	5/8			-1.65	2.9	1380	1653
8206	3A-2C	MC	5/10			-1.68	2.9	1380	1653
8211	3A-2D	MC	5/11			-1.49	2.9	1380	1653
8607	3A-2E	MC	9/7			-0.06	1.55	775	1048
8610	3A-2F	MC	9/8			-0.06	1.55	775	1048
8613	3A-2G	MC	9/9			-0.04	1.55	775	1048

TABLE 5-9
DIMENSIONAL CHANGE IN P_3JHAN GRAPHITE

Record Number	Sample Number	Location in Log	Irrad. Position Crucible/Hole	Previous Record Number	Previous Irrad. Temp (°C)	$\Delta\ell/\ell_o$ (%)	Total Fast Neutron Fluence 10^{25} n/m^2	Average Irrad. Temp	
								(°C)	K
Axial Orientation									
7947	0.851		3/2	6737	985	Broken	8.5	985	1258
7949	0.852		3/2	6739	985	-2.29	8.5	985	1258
7951	0.853		3/2	6741	985	-0.87	8.5	985	1258
8297	0.864		6/6	7170	995	Broken	8.4	1005	1278
8299	0.865		6/6	7172	995	-3.14	8.4	1005	1278
8300	0.868		6/6	7178	995	-0.66	8.4	1005	1278
8301	0.866		6/7	7174	995	Broken	8.4	1005	1278
8303	0.867		6/7	7176	995	-2.62	8.4	1005	1278
8304	0.869		6/7	7180	995	-2.34	8.4	1005	1278
8589	0.884		9/3	7450	795	-2.10	5.15	790	1063
8590	0.885		9/3	7451	795	-1.99	5.15	790	1063
8593	0.886		9/4	7454	795	-2.16	5.15	790	1063
8594	0.887		9/4	7455	795	-1.86	5.15	790	1063
8717	0.876		10/8	7597	600	-0.99	3.65	600	873
8719	0.877		10/8	7599	600	-0.93	3.65	600	873
8721	0.878		10/9	7601	600	-0.86	3.65	600	873
8723	0.879		10/9	7603	600	-0.67	3.65	600	873
Radial Orientation									
7948	0.901		3/2	6738	985	+4.57	8.5	985	1258
7950	0.902		3/2	6740	985	Broken	8.5	985	1258
8298	0.914		6/6	7171	995	+7.01	8.4	1005	1278
8302	0.916		6/7	7175	995	+7.93	8.4	1005	1278
8591	0.934		9/3	7452	795	-0.87	5.15	790	1063
8592	0.935		9/3	7453	795	-0.84	5.15	790	1063
8595	0.936		9/4	7456	795	-0.92	5.15	790	1063
8596	0.937		9/4	7457	795	-0.77	5.15	790	1063
8718	0.926		10/8	7598	600	-0.70	3.65	600	873
8720	0.927		10/8	7600	600	-0.54	3.65	600	873
8722	0.928		10/9	7602	600	-0.55	3.65	600	873
8724	0.929		10/9	7604	600	-0.51	3.65	600	873

TABLE 5-10
DIMENSIONAL CHANGE IN 2020 GRAPHITE, AXIAL ORIENTATION

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	(K)
8739	OG-3 S-581		10 17	7576	615.0	-.729	3.65	610.0	883
8741	OG-3 S-582		10 17	7578	615.0	-.700	3.65	610.0	883
8743	OG-3 S-583		10 18	7580	615.0	-.660	3.65	610.0	883
8745	OG-3 S-584		10 18	7582	615.0	-.668	3.65	610.0	883
8747	OG-3 S-585		10 19	7584	615.0	-.664	3.65	610.0	883
8749	OG-3 S-586		10 19	7586	615.0	-.677	3.65	610.0	883
7750	OG-3 S-501		1 17	6548	615.0	-.833	5.55	635.0	908
7751	OG-3 S-502		1 17	6549	615.0	-.827	5.55	635.0	908
7754	OG-3 S-503		1 18	6552	615.0	-.826	5.55	635.0	908
7755	OG-3 S-504		1 18	6553	615.0	-.711	5.55	635.0	908
7758	OG-3 S-505		1 19	6556	615.0	-.679	5.55	635.0	908
7759	OG-3 S-506		1 19	6557	615.0	-.720	5.55	635.0	908
7885	OG-3 S-511		2 18	6675	695.0	-.403	7.20	710.0	983
7887	OG-3 S-512		2 18	6677	695.0	-.207	7.20	710.0	983
7889	OG-3 S-513		2 19	6679	695.0	-.285	7.20	710.0	983
7891	OG-3 S-514		2 19	6681	695.0	-.380	7.20	710.0	983
7893	OG-3 S-515		2 20	6683	695.0	-.577	7.20	710.0	983
7895	OG-3 S-516		2 20	6685	695.0	-.224	7.20	710.0	983
7897	OG-3 S-517		2 21	6687	695.0	-.299	7.20	710.0	983
7899	OG-3 S-518		2 21	6689	695.0	-.501	7.20	710.0	983
8633	OG-3 S-569		9 18	7472	795.0	.434	5.15	785.0	1058
8635	OG-3 S-570		9 18	7474	795.0	-.217	5.15	785.0	1058
8637	OG-3 S-571		9 19	7476	795.0	.078	5.15	785.0	1058
8639	OG-3 S-572		9 19	7478	795.0	-.101	5.15	785.0	1058
8641	OG-3 S-573		9 20	7480	795.0	.141	5.15	785.0	1058
8643	OG-3 S-574		9 20	7482	795.0	-.234	5.15	785.0	1058
8645	OG-3 S-575		9 21	7484	795.0	-.044	5.15	785.0	1058
8647	OG-3 S-576		9 21	7486	795.0	-.203	5.15	785.0	1058

TABLE 5-11
DIMENSIONAL CHANGE IN 2020 GRAPHITE, RADIAL ORIENTATION

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole	Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E 29fJ, HTGR) (10^{25} n/m^2)	Average Irrad. Temp (°C)	Average Irrad. Temp (K)
8740 OG-3	S-681		10 17	7577	615,0	-1,159	3,65	610,0	883
8742 OG-3	S-682		10 17	7579	615,0	-,704	3,65	610,0	883
8744 OG-3	S-683		10 18	7581	615,0	-,958	3,65	610,0	883
8746 OG-3	S-684		10 18	7583	615,0	-,707	3,65	610,0	883
8748 OG-3	S-685		10 19	7585	615,0	-,931	3,65	610,0	883
8750 OG-3	S-686		10 19	7587	615,0	-1,105	3,65	610,0	883
7752 OG-3	S-601		1 17	6550	615,0	-1,065	5,55	635,0	908
7753 OG-3	S-602		1 17	6551	615,0	-1,293	5,55	635,0	908
7756 OG-3	S-603		1 18	6554	615,0	-1,008	5,55	635,0	908
7757 OG-3	S-604		1 18	6555	615,0	-1,181	5,55	635,0	908
7760 OG-3	S-605		1 19	6558	615,0	-1,183	5,55	635,0	908
7761 OG-3	S-606		1 19	6559	615,0	-1,213	5,55	635,0	908
7886 OG-3	S-611		2 18	6676	695,0	-1,329	7,20	710,0	983
7888 OG-3	S-612		2 18	6678	695,0	-1,195	7,20	710,0	983
7890 OG-3	S-613		2 19	6680	695,0	-1,131	7,20	710,0	983
7892 OG-3	S-614		2 19	6682	695,0	-,970	7,20	710,0	983
7894 OG-3	S-615		2 20	6684	695,0	-1,498	7,20	710,0	983
7896 OG-3	S-616		2 20	6686	695,0	-,715	7,20	710,0	983
7898 OG-3	S-617		2 21	6688	695,0	-1,611	7,20	710,0	983
7900 OG-3	S-618		2 21	6690	695,0	-,935	7,20	710,0	983
8634 OG-3	S-669		9 18	7473	795,0	-,570	5,15	785,0	1058
8636 OG-3	S-670		9 18	7475	795,0	-,822	5,15	785,0	1058
8638 OG-3	S-671		9 19	7477	795,0	-,815	5,15	785,0	1058
8640 OG-3	S-672		9 19	7479	795,0	-,744	5,15	785,0	1058
8642 OG-3	S-673		9 20	7481	795,0	-,973	5,15	785,0	1058
8644 OG-3	S-674		9 20	7483	795,0	-,703	5,15	785,0	1058
8646 OG-3	S-675		9 21	7485	795,0	-,766	5,15	785,0	1058
8648 OG-3	S-676		9 21	7487	795,0	-,734	5,15	785,0	1058
8527 OG-3	S 659		8 17	7374	875,0	-1,016	6,45	870,0	1143
8528 OG-3	S 660		8 17	7376	875,0	-,928	6,45	870,0	1143
8531 OG-3	S 661		8 18	7378	875,0	-1,079	6,45	870,0	1143
8532 OG-3	S 662		8 18	7380	875,0	-1,014	6,45	870,0	1143
8535 OG-3	S-663		8 19	7382	875,0	-1,121	6,45	870,0	1143
8536 OG-3	S-664		8 19	7384	875,0	-,973	6,45	870,0	1143
8006 OG-3	S-623		3 18	6852	925,0	-,888	8,50	940,0	1213
8007 OG-3	S-624		3 18	6854	925,0	-,702	8,50	940,0	1213
8012 OG-3	S-626		3 19	6858	925,0	-,871	8,50	940,0	1213
8013 OG-3	S-627		3 19	6860	925,0	-,754	8,50	940,0	1213
8018 OG-3	S-629		3 20	6864	925,0	-,601	8,50	940,0	1213
8019 OG-3	S-630		3 20	6866	925,0	-,545	8,50	940,0	1213

TABLE 5-11 (Continued)

Record Number	Specimen Number		Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2)	Average (°C)	Irrad. Temp (K)
8024	OG-3	S-632		3	21	6870	925.0	-1.262	8.50	940.0	1213
8025	OG-3	S-633		3	21	6872	925.0	-.549	8.50	940.0	1213
8030	OG-3	S-635		3	22	6876	925.0	-.523	8.50	940.0	1213
8031	OG-3	S-636		3	22	6878	925.0	-.483	8.50	940.0	1213
8036	OG-3	S-638		3	23	6882	925.0	-1.164	8.50	940.0	1213
8037	OG-3	S-639		3	23	6884	925.0	-.631	8.50	940.0	1213
8132	OG-3	S-641		4	18	6952	1125.0	-1.096	9.20	1165.0	1438
8133	OG-3	S-642		4	18	6954	1125.0	-1.069	9.20	1165.0	1438
8136	OG-3	S-643		4	19	6956	1125.0	-.997	9.20	1165.0	1438
8137	OG-3	S-644		4	19	6958	1125.0	-1.164	9.20	1165.0	1438

TABLE 5-12
DIMENSIONAL CHANGE IN H-327 GRAPHITE, AXIAL ORIENTATION

Record Number	Specimen Number		Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta \ell / \ell_o$ (%)	Total Fluence (E>29fJ, HTGR) (10^{25} n/m^2	Average Irrad. Temp (°C)	(K)
8707	OG-3	3	MC	10	5	7550	630.0	-1.221	4.35	625.0	898
8708	OG-3	4	ME	10	5	7551	630.0	-.949	4.35	625.0	898
7720	OG-3	.201.	ME	1	6	6589	590.0	-.724	5.55	625.0	898
7721	OG-3	.202.	ME	1	6	6590	590.0	-.867	5.55	625.0	898
8694	OG-3	.40.	MC	10	2	7533	640.0	-.658	3.65	630.0	903
8698	OG-3	.41.	MC	10	3	7537	640.0	-.710	3.65	630.0	903
8702	OG-3	.42.	MC	10	4	7541	640.0	-.566	3.65	630.0	903
8690	OG-3	.39.	MC	10	1	7529	650.0	-.634	3.65	640.0	913
7923	OG-3	T-255	MC	2	31	6711	655.0	-1.329	7.20	665.0	938
7924	OG-3	T-256	MC	2	31	6712	655.0	-1.337	7.20	665.0	938
7925	OG-3	T-257	MC	2	32	6713	655.0	-1.264	7.20	665.0	938
7926	OG-3	T-258	MC	2	32	6714	655.0	-1.352	7.20	665.0	938
7927	OG-3	T-259	MC	2	33	6715	655.0	-1.258	7.20	665.0	938
7928	OG-3	T-260	MC	2	33	6716	655.0	-.322	7.20	665.0	938
7705	OG-3	.1.	MC	1	2	6505	660.0	-.840	5.55	670.0	943
7709	OG-3	.2.	MC	1	3	6509	660.0	-.832	5.55	670.0	943
7919	OG-3	T-251	MC	2	29	6707	690.0	-.142	7.20	690.0	963
7920	OG-3	T-252	MC	2	29	6708	690.0	-1.305	7.20	690.0	963
7921	OG-3	T-253	MC	2	30	6709	690.0	-1.364	7.20	690.0	963
7922	OG-3	T-254	MC	2	30	6710	690.0	-1.367	7.20	690.0	963
7881	OG-3	T-321	MC	2	16	6717	680.0	-.656	4.60	710.0	983
7882	OG-3	T-322	MC	2	16	6718	680.0	-.723	4.60	710.0	983
7883	OG-3	T-323	MC	2	17	6719	680.0	-.681	4.60	710.0	983
7884	OG-3	T-324	MC	2	17	6720	680.0	-.680	4.60	710.0	983
7877	OG-3	T-317	MC	2	14	6671	740.0	-.642	4.60	740.0	1013
7878	OG-3	T-318	MC	2	14	6672	740.0	-.799	4.60	740.0	1013
7879	OG-3	T-319	MC	2	15	6673	740.0	-.696	4.60	740.0	1013
7880	OG-3	T-320	MC	2	15	6674	740.0	-.809	4.60	740.0	1013
8495	OG-3	140	MC	8	5	7347	.0	-5.272	1.03	880.0	1153
8497	OG-3	136	MC	8	5	7343	.0	-5.643	1.03	880.0	1153
8498	OG-3	137	ME	8	5	7344	.0	-5.252	1.03	880.0	1153
8493	OG-3	176	MC	8	4	7339	900.0	-3.772	8.25	895.0	1168
8494	OG-3	177	ME	8	4	7340	900.0	-3.617	8.25	895.0	1168
7958	OG-3	.24.	MC	3	3	6773	970.0	-4.568	8.50	975.0	1248
7962	OG-3	.21.	MC	3	4	6767	970.0	-4.336	8.50	975.0	1248
7963	OG-3	.22.	MC	3	4	6768	970.0	-4.737	8.50	975.0	1248
7964	OG-3	.23.	MC	3	4	6769	970.0	-4.734	8.50	975.0	1248
8381	OG-3	.222.	ME	7	2	7220	985.0	-4.724	7.70	985.0	1258
8385	OG-3	.223.	ME	7	3	7224	985.0	-4.987	7.70	985.0	1258
8389	OG-3	.224.	ME	7	4	7228	985.0	-4.811	7.70	985.0	1258
8377	OG-3	.221.	ME	7	1	7216	995.0	-5.126	7.70	995.0	1268

TABLE 5-13
DIMENSIONAL CHANGE IN H-327 GRAPHITE, RADIAL ORIENTATION

Record Number	Specimen Number	Position in Log	Irrad. Crucible/Hole		Previous Record No.	Prior Irrad. Temp (°C)	Total $\Delta\ell/\ell_o$ (%)	Total Fluence (E>29fJ, HTGR) 10^{25} n/m^2	Average Irrad. Temp (°C)	Average Irrad. Temp (K)
8705	OG-3 1	MC	10	5	7548	630.0	-1.023	4.35	625.0	898
8706	OG-3 2	ME	10	5	7549	630.0	-.852	4.35	625.0	898
7722	OG-3 .251.	ME	1	6	6591	590.0	-.691	5.55	625.0	898
7723	OG-3 .252.	ME	1	6	6592	590.0	-.671	5.55	625.0	898
8696	OG-3 .140.	MC	10	2	7535	640.0	-.370	3.65	630.0	903
8700	OG-3 .141.	MC	10	3	7539	640.0	-.375	3.65	630.0	903
8704	OG-3 .142.	MC	10	4	7543	640.0	-.329	3.65	630.0	903
8692	OG-3 .139.	MC	10	1	7531	650.0	-.366	3.65	640.0	913
7707	OG-3 .101.	MC	1	2	6507	660.0	-.643	5.55	670.0	943
7711	OG-3 .102.	MC	1	3	6511	660.0	-.735	5.55	670.0	943
7909	OG-3 T-411	MC	2	24	6721	680.0	-.571	4.60	685.0	958
7910	OG-3 T-412	MC	2	24	6722	680.0	-.623	4.60	685.0	958
7911	OG-3 T-413	MC	2	25	6723	680.0	-.581	4.60	685.0	958
7912	OG-3 T-414	MC	2	25	6724	680.0	-.599	4.60	685.0	958
7913	OG-3 T-415	MC	2	26	6725	680.0	-.521	4.60	685.0	958
7914	OG-3 T-416	MC	2	26	6726	680.0	-.598	4.60	685.0	958
7915	OG-3 T-417	MC	2	27	6727	680.0	-.538	4.60	685.0	958
7916	OG-3 T-418	MC	2	27	6728	680.0	-.609	4.60	685.0	958
7917	OG-3 T-419	MC	2	28	6729	680.0	-.534	4.60	685.0	958
7918	OG-3 T-420	MC	2	28	6730	680.0	-.624	4.60	685.0	958
8496	OG-3 135	ME	8	5	7342	.0	4.144	10.3	880.0	1153
8491	OG-3 174	MC	8	4	7337	900.0	-.374	8.25	895.0	1168
8492	OG-3 175	ME	8	4	7338	900.0	.145	8.25	895.0	1168
8344	OG-3 T-427	MC	6	23	7168	960.0	-.992	5.40	950.0	1223
8345	OG-3 T-428	MC	6	23	7169	960.0	-.723	5.40	950.0	1223
8317	OG-3 T-421	MC	6	14	7162	960.0	-.906	5.40	970.0	1243
8318	OG-3 T-422	MC	6	14	7163	960.0	-.975	5.40	970.0	1243
8319	OG-3 T-423	MC	6	15	7164	960.0	-.743	5.40	970.0	1243
8320	OG-3 T-424	MC	6	15	7165	960.0	-.987	5.40	970.0	1243
8321	OG-3 T-425	MC	6	16	7166	960.0	-.838	5.40	970.0	1243
8322	OG-3 T-426	MC	6	16	7167	960.0	-.934	5.40	970.0	1243
7957	OG-3 .124.	MC	3	3	6770	970.0	.686	8.50	975.0	1248
7959	OG-3 .121.	MC	3	4	6764	970.0	.483	8.50	975.0	1248
7960	OG-3 .122.	MC	3	4	6765	970.0	1.372	8.50	975.0	1248
7961	OG-3 .123.	MC	3	4	6766	970.0	1.124	8.50	975.0	1248
8383	OG-3 .272.	ME	7	2	7222	985.0	-.058	7.70	985.0	1258
8387	OG-3 .273.	ME	7	3	7226	985.0	-.211	7.70	985.0	1258
8391	OG-3 .274.	ME	7	4	7230	985.0	-.151	7.70	985.0	1258
8379	OG-3 .271.	ME	7	1	7218	995.0	.555	7.70	995.0	1268

TABLE 5-14
SIDE-BY-SIDE COMPARISON OF IRRADIATION-INDUCED DIMENSIONAL CHANGES IN NEAR-ISOTROPIC PETROLEUM COKE AND PITCH-COKE-BASED GRAPHITES

Grade	Crucible 2: 2.4 x 10^{25} n/m^2 at 1040 K		Crucible 5: 2.9 x 10^{25} n/m^2 at 1653 K	
	Percent Axial Change (± std. dev.)	Percent Radial Change (± std. dev.)	Percent Axial Change (± std. dev.)	Percent Radial Change (± std. dev.)
H-451	-0.21 ± 0.05	-0.15 ± 0.08	-2.55 ± 0.17	-1.96 ± 0.20
TS-1240	-0.11 ± 0.05	-0.07 ± 0.06	-1.77 ± 0.11	-1.11 ± 0.06
SO 818	-0.21 ± 0.05	-0.20 ± 0.06	-2.32 ± 0.09	-1.42 ± 0.11
P_3JHAN_2N	-0.35 ± 0.06	-0.16 ± 0.03	-3.18 ± 0.11	-1.67 ± 0.17
ASI2-500	-0.23 ± 0.05	-0.19 ± 0.05	-1.92 ± 0.17	-1.38 ± 0.06

TABLE 5-15
BETWEEN-LOG VARIATIONS IN IRRADIATION-INDUCED SHRINKAGE OF H-451 GRAPHITE, LOT 426

Orientation	Crucible	Irrad. Temp (K)	Neutron Fluence x 10^{-25} (n/m^2, E>29fJ, HTGR)	Mean Shrinkage (%)			Is Variation Significant at 95% Confidence Level?
				Log 6484-33	Log 6484-34	Log 6484-41	
Axial	6	1210	2.68	0.71	0.79	0.69	No
Radial	1	910	1.84	0.18	0.16	0.14	No
Radial	8	1110	2.01	0.17	0.20	0.19	No
Radial	3	1200	2.83	0.28	0.36	0.36	No
Radial	6	1270	2.68	0.79	0.82	0.79	No

TABLE 5-16
BETWEEN-LOG VARIATIONS IN IRRADIATION-INDUCED SHRINKAGE OF TS-1240 GRAPHITE

Orientation	Crucible	Irrad. Temp (K)	Neutron Fluence x 10^{-25} (n/m^2, E>29fJ, HTGR)	Mean Shrinkage (%)			Is Variation Significant at95% Confidence Level?
				Log 5651-72	Log 5651-73	Log 6489-29	
Axial	9	1000	1.57	0.02	0.01	0.05	No
Axial	4	1450	2.97	1.07	0.96	1.29	Yes
Radial	10	830	1.11	0.02	0.03	0.03	No
Radial	2	960	2.40	0.09	0.10	0.10	No
Radial	9	1030	1.57	0.02	0.01	0.00	No
Radial	7	1210	2.39	0.24	0.21	0.28	Yes

TABLE 5-17

WITHIN-LOG VARIATION IN IRRADIATION-INDUCED SHRINKAGE OF H-451 GRAPHITE, LOT 426

Orientation	Crucible	Irrad. Temp (K)	Neutron Fluence x 10^{-25} (n/m^2, E>29fJ, HTGR)	Mean Shrinkage (%)		Is Variation Significant at 95% Confidence Level?
				Center of Logs	Edge of Logs	
Axial	6	1210	2.68	0.71	0.75	No
Radial	8	1110	2.01	0.18	0.18	No
Radial	3	1200	2.83	0.36	0.30	No

TABLE 5-18
WITHIN-LOG VARIATIONS IN IRRADIATION-INDUCED SHRINKAGE OF TS-1240 GRAPHITE

Orientation	Crucible	Irrad. Temp (K)	Neutron Fluence x 10^{-25} (n/m^2, E>29fJ, HTGR)	Mean Shrinkage (%)		Is Variation Significant at 95% Confidence Level?
				Center of Logs	Edge of Logs	
Axial	9	1000	1.57	0.04	0.01	No
Axial	4	1450	2.97	1.06	1.15	Yes
Radial	10	830	1.11	0.01	0.04	Yes
Radial	7	1210	2.39	0.24	0.24	No

6. EXPERIMENTAL RESULTS - THERMAL PROPERTIES

6.1. THERMAL EXPANSIVITY

The thermal expansivity of representative groups of cylindrical specimens was measured between ambient temperature and 100 K below the irradiation temperature, using a silica dilatometer (ASTM Method of Test E288). Measurements were made on H-451 graphite (lots 266 and 426), H-429, TS-1240, and SO-818. All except the H-451 (lot 426) and the SO-818 had been irradiated in previous capsules.

The mean thermal expansivity between ambient temperature and 773 K is listed in Tables 6-1 through 6-5. Summary tables showing the fractional increase or decrease in thermal expansivity of H-451, H-429, TS-1240, and SO-818 graphites irradiated in capsules OG-1, OG-2, and OG-3 appear as Tables 6-6 through 6-9. The fractional change in thermal expansivity is plotted as a function of fast neutron fluence in Fig. 6-1. At the lowest irradiation temperatures (865 to 1045 K) the thermal expansivity first increases by 5% to 10% and then slowly decreases. At higher irradiation temperatures, the thermal expansivity decreases by as much as 50% of its preirradiation value, with the decrease most marked at the highest irradiation temperatures. Data from all the near-isotropic graphites fall into the same band regardless of orientation and log location, with the exception of H-429 whose irradiation-induced changes in thermal expansivity are somewhat lower than the others.

For convenience in design calculations, the data for irradiation-induced fractional changes in thermal expansivity, $(\alpha_i - \alpha_o)/\alpha_o$, of H-451, TS-1240, and SO-818 graphites were fit to the following polynomial:

$$(\alpha_i - \alpha_o)/\alpha_o = (0.27830 - 4.2734 \times 10^{-4}\ T + 1.7815 \times 10^{-7}\ T^2)\Phi$$
$$-2.0664 \times 10^{-2}\ \Phi^2 + 1.3601 \times 10^{-3}\ \Phi^3$$

where T is the irradiation temperature (°C) and Φ is the neutron fluence $[10^{25}\ n/m^2,\ E > 29\ fJ)_{HTGR}]$. Curves calculated from the equation are included in Fig. 6-1. The standard deviation of data points from the design curves is 0.063.

6.2. THERMAL CONDUCTIVITY

Thermal diffusivity measurements were made on discs of H-451 (lots 266 and 426), TS-1240, and SO-818 graphites irradiated at three temperatures (925, 1220, and 1615 K). The H-451 (lot 266) and the TS-1240 specimens had been previously irradiated in earlier OG capsules. The measurements were made by the heat-pulse method (ASTM Method of Test C714), and the thermal diffusivity value was converted to the thermal conductivity by multiplying by the density and heat capacity. Readings were taken every 100 K between ambient temperature and 1073 K, except for the specimens irradiated at 925 K, when the upper measurement temperature was limited to 773 K to avoid the possibility of annealing.

The measurements are listed in Tables 6-10 through 6-13. The tables include values for the conductivity extrapolated to the irradiation temperature. The accumulated data on near-isotropic graphites from capsules OG-1, OG-2, and OG-3 are summarized in Tables 6-14 through 6-16. The conductivity at the irradiation temperature is plotted as a function of fast neutron fluence in Fig. 6-2. Irradiation rapidly reduces the thermal conductivity to a saturation level which increases with increasing irradiation temperature. The thermal conductivity of all the near-isotropic graphites falls into the same band after irradiation, in spite of some differences in preirradiation conductivity. The irradiated values are in excellent agreement with the design equations currently in use (Ref. 5).

Two radial specimens of H-451 graphite which had been irradiated previously in capsule OG-1 at 1625 K were reirradiated in OG-3 at 925 K. Two more specimens, formerly irradiated at 875 K, were reirradiated at 1615 K. The conductivities are shown in Table 6-17. In both cases the new conductivities were equal to the saturation level for the new irradiation temperature. This behavior is consistent with the currently used design model for the conductivity of graphite subjected to a changing irradiation temperature.

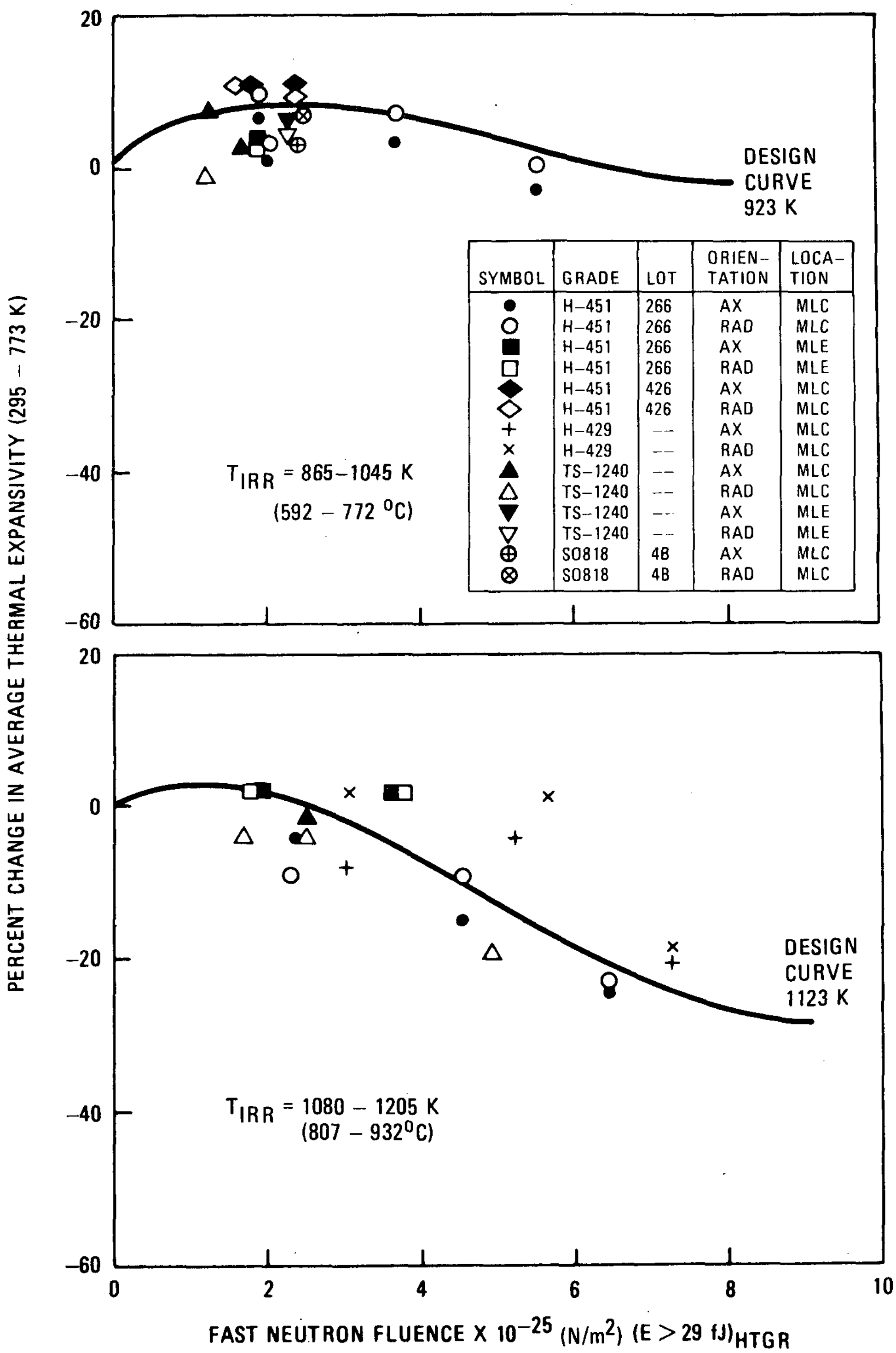


Fig. 6-1(a). Percent change in thermal expansivity (295 K to 773 K) of near-isotropic graphites as a function of fast neutron fluence, irradiation temperature 865 K to 1205 K

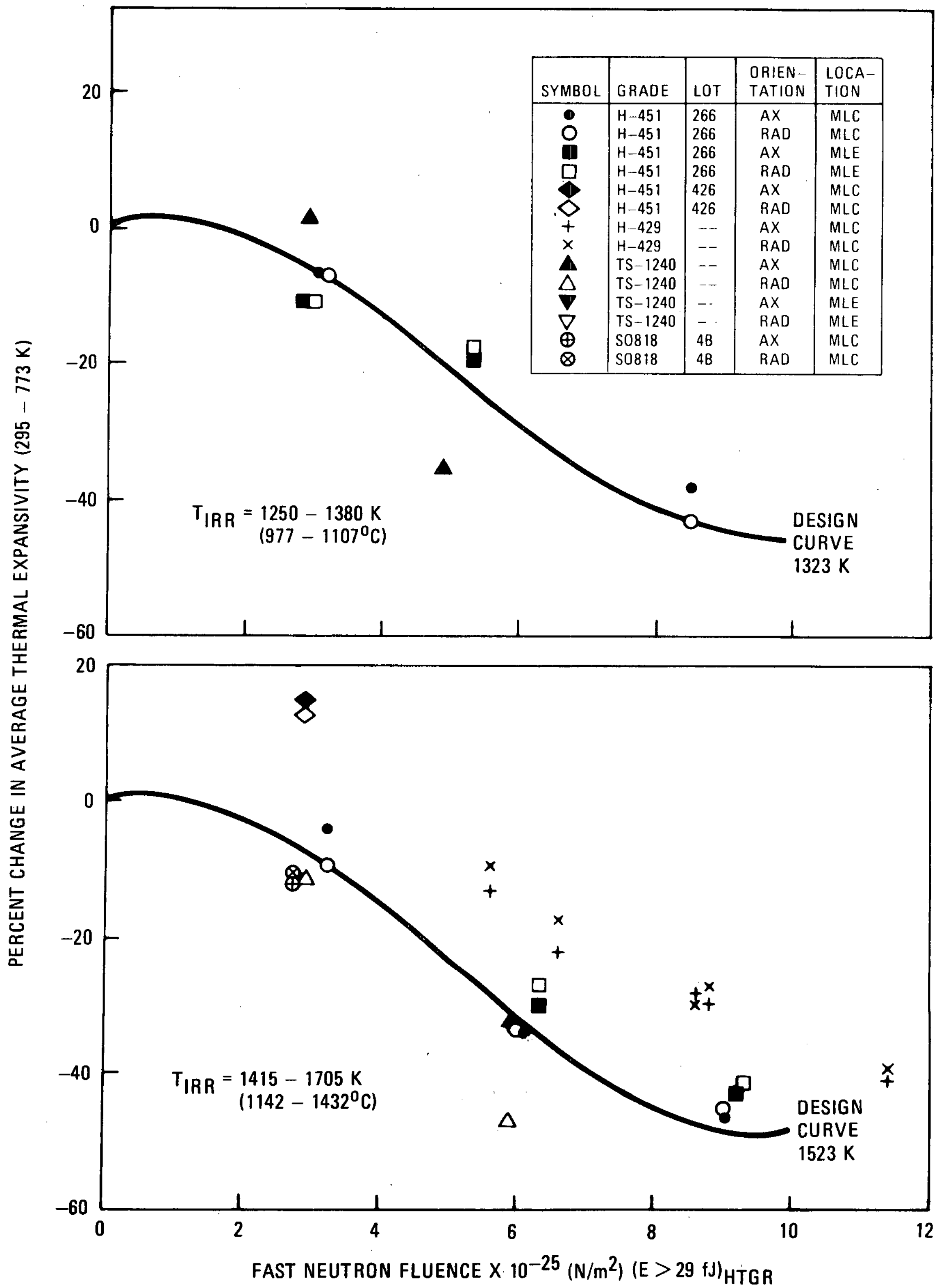


Fig. 6-1(b). Percent change in thermal expansivity (295 K to 773 K) of near isotropic graphites as a function of fast neutron fluence, irradiation temperature 1250 K to 1705 K

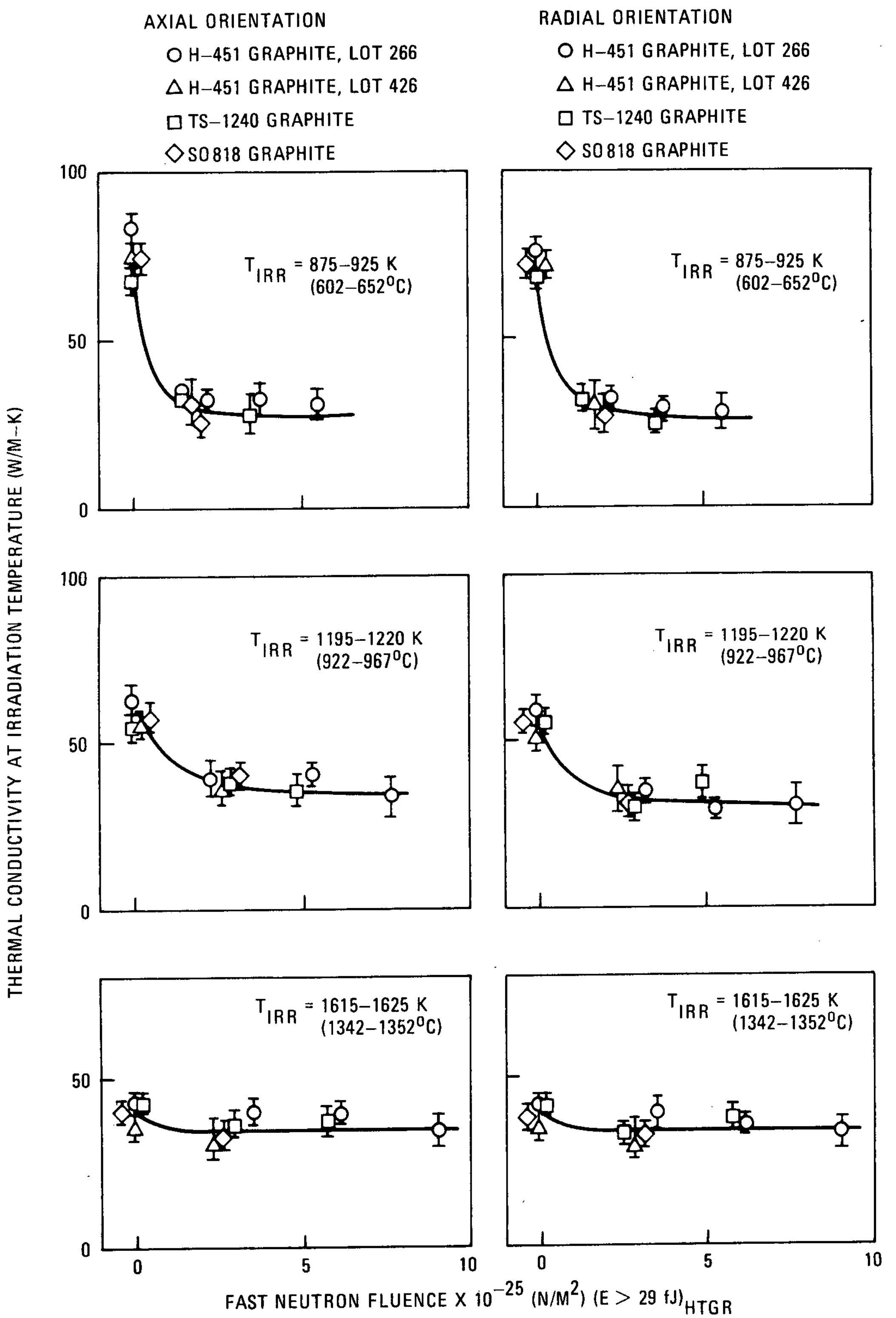


Fig. 6-2. Thermal conductivity at the irradiation temperature for near-isotropic graphites as a function of fast neutron fluence

TABLE 6-1
THERMAL EXPANSIVITY OF H-451 GRAPHITE, LOT 266,
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 266 LOG NUMBER(S): 5651-28

ORIEN-TATION	LOCA-TION	CRUC-IBLE	HOLE	MEAN IRR. TEMP. (K)	FLUENCE (10EXP25 N/M**2, E>.18MEV)	SPECIMEN NUMBER	C.T.E. (10EXP-6/K) 295K-773K (22C-500C)
AXIAL	MLC	1	1	935	5.5	.301.	3.65
			1	(662 C)		.302.	3.69
			2			.303.	3.70
						MEAN:	3.67
						STD. DEV:	.04
AXIAL	MLC	8	1	1170	6.4	.371.	2.85
			1	(897 C)		.372.	2.98
			2			.373.	2.83
						MEAN:	2.89
						STD. DEV:	.09
AXIAL	MLC	3	1	1270	8.5	.405.	2.43
			1	(997 C)		.632.	2.38
			1			.406.	2.20
						MEAN:	2.34
						STD. DEV:	.12
AXIAL	MLE	4	1	1515	9.2	.581.	2.18
			1	(1242 C)		.582.	2.22
			2			.583.	2.19
						MEAN:	2.20
						STD. DEV:	.02
AXIAL	MLC	5	1	1660	9.0	.331.	2.12
			1	(1387 C)		.332.	1.90
						MEAN:	2.01
						STD. DEV:	.15

TABLE 6-1 (Continued)

LOT NUMBER: 266 LOG NUMBER(S): 5651-28

ORIENTATION	LOCATION	CRUCIBLE	HOLE	MEAN IRR. TEMP. (K)	FLUENCE (10EXP25 N/M**2, E>.18MEV)	SPECIMEN NUMBER	C.T.E. (10EXP-6/K) 295K-773K (22C-500C)
RADIAL	MLC	1	1	935	5.5	.426.	4.61
			1	(662 C)		.427.	4.69
			2			.428.	4.75
						MEAN:	4.68
						STD. DEV:	.07
RADIAL	MLC	8	1	1170	6.4	.496.	3.54
			1	(897 C)		.497.	3.70
			2			.498.	3.54
						MEAN:	3.60
						STD. DEV:	.09
RADIAL	MLC	3	1	1270	8.5	.530.	2.81
			1	(997 C)		.732.	2.48
			1			.531.	2.68
						MEAN:	2.66
						STD. DEV:	.16
RADIAL	MLE	4	1	1515	9.2	.681.	2.66
			1	(1242 C)		.682.	2.73
			2			.683.	3.07
						MEAN:	2.82
						STD. DEV:	.22
RADIAL	MLC	5	1	1660	9.0	.456.	2.48
			1	(1387 C)		.457.	2.60
						MEAN:	2.54
						STD. DEV:	.08

TABLE 6-2
THERMAL EXPANSIVITY OF H-451 GRAPHITE, LOT 426,
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 426 LOG NUMBER(S): 6484-34

ORIEN-TATION	LOCA-TION	CRUC-IBLE	HOLE	MEAN IRR. TEMP. (K)	FLUENCE (10EXP25 N/M**2, E>.18MEV)	SPECIMEN NUMBER	C.T.E. (10EXP-6/K) 295K-773K (22C-500C)
AXIAL	MLC	1	7	970	1.8	34-2A-8A	3.67
			7	(697 C)		34-2A-8B	3.86
			8			34-2A-8C	3.65
						MEAN:	3.73
						STD. DEV:	.12
AXIAL	MLC	2	4	1040	2.4	34-2B-5C	3.89
			5	(767 C)		34-2B-5D	3.78
			6			34-2B-6A	3.63
						MEAN:	3.77
						STD. DEV:	.13
AXIAL	MLC	5	2	1655	2.9	34-2B-6C	3.92
			3	(1382 C)		34-2B-6D	3.87
			4			34-2B-7A	3.89
						MEAN:	3.90
						STD. DEV:	.03
RADIAL	MLC	1	7	970	1.8	34-2B-39A	4.41
			7	(697 C)		34-2B-39B	4.40
			8			34-2B-39C	4.43
						MEAN:	4.41
						STD. DEV:	.01
RADIAL	MLC	2	9	1010	2.4	34-2B-36C	4.26
			10	(737 C)		34-2B-36D	4.39
			11			34-2B-36A	4.49
						MEAN:	4.38
						STD. DEV:	.12
RADIAL	MLC	5	7	1655	2.9	34-2B-40D	4.60
			8	(1382 C)		34-2B-37C	4.42
			9			34-2B-37D	4.67
						MEAN:	4.56
						STD. DEV:	.13

TABLE 6-3
THERMAL EXPANSIVITY OF H-429 GRAPHITE IRRADIATED
IN CAPSULE OG-3

LOT NUMBER: --   LOG NUMBER(S): 4974- 04A

ORIEN-TATION	LOCA-TION	CRUC-IBLE	HOLE	MEAN IRR. TEMP. (K)	FLUENCE (10EXP25 N/M**2, E>.18MEV)	SPECIMEN NUMBER	C.T.E. (10EXP-6/K) 295K-773K (22C-500C)
AXIAL		8	7	1170	7.2	392	3.20
			7	(897 C)		393	3.44
			7			397	3.48
						MEAN:	3.38
						STD. DEV:	.15
AXIAL		4	5	1480	11.4	404	2.57
			5	(1207 C)		405	2.67
			6			406	2.33
						MEAN:	2.52
						STD. DEV:	.17
RADIAL		8	6	1170	7.2	419	3.90
			6	(897 C)		420	4.05
			6			421	4.20
						MEAN:	4.05
						STD. DEV:	.15
RADIAL		4	5	1480	11.4	434	3.09
			5	(1207 C)		435	3.05
			6			436	3.04
						MEAN:	3.06
						STD. DEV:	.03

TABLE 6-4
THERMAL EXPANSIVITY OF TS-1240 GRAPHITE
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 1 LOG NUMBER(S): 5651-73

ORIEN-TATION	LOCA-TION	CRUC-IBLE	HOLE	MEAN IRR. TEMP. (K)	FLUENCE (10EXP25 N/M**2, E>.18MEV)	SPECIMEN NUMBER	C.T.E. (10EXP-6/K) 295K-773K (22C-500C)
AXIAL	MLE	10	10	880	2.3	T40241	4.62
			10	(607 C)		T40243	4.50
			11			T40245	4.55
						MEAN:	4.55
						STD. DEV:	.06
AXIAL	MLC	7	8	1250	4.9	T40037	2.60
			8	(977 C)		T40039	2.86
			9			T40041	2.66
						MEAN:	2.71
						STD. DEV:	.13
AXIAL	MLC	4	29	1415	5.9	T40001	2.91
			29	(1142 C)		T40003	2.63
			30			T40005	3.00
						MEAN:	2.85
						STD. DEV:	.19
RADIAL	MLC	10	15	880	2.3	T40149	5.08
			15	(607 C)		T40151	5.15
			16			T40153	4.82
						MEAN:	5.02
						STD. DEV:	.17
RADIAL	MLC	7	29	1200	4.9	T40121	3.77
			29	(927 C)		T40123	4.04
			30			T40125	3.79
						MEAN:	3.87
						STD. DEV:	.15
RADIAL	MLC	4	7	1500	5.9	T40157	2.64
			7	(1227 C)		T40159	2.57
			8			T40161	2.56
						MEAN:	2.59
						STD. DEV:	.04

TABLE 6-5
THERMAL EXPANSIVITY OF S0818 GRAPHITE
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 4-B   LOG NUMBER(S): 6484-22

ORIEN-TATION	LOCA-TION	CRUC-IBLE	HOLE	MEAN IRR. TEMP. (K)	FLUENCE (10EXP25 N/M**2, E>.18MEV)	SPECIMEN NUMBER	C.T.E. (10EXP-6/K) 295K-773K (22C-500C)
AXIAL	MLC	2	5	1040	2.4	22-1A-1A	4.71
			6	(767 C)		22-1A-1B	4.75
			7			22-1A-1C	4.49
						MEAN:	4.65
						STD. DEV:	.14
AXIAL	MLC	5	3	1655	2.9	22-1A-2A	4.16
			4	(1382 C)		22-1A-2B	3.89
			5			22-1A-2C	3.95
						MEAN:	4.00
						STD. DEV:	.14
RADIAL	MLC	2	10	1010	2.4	22-1A-61A	5.53
			11	(737 C)		22-1A-61B	5.26
			12			22-1A-61C	5.50
						MEAN:	5.43
						STD. DEV:	.15
RADIAL	MLC	5	8	1655	2.9	22-1A-68A	4.55
			9	(1382 C)		22-1A-68B	4.54
			10			22-1A-68C	4.47
						MEAN:	4.52
						STD. DEV:	.04

TABLE 6-6
SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL EXPANSIVITY OF H-451 GRAPHITE IRRADIATED IN CAPSULES OG-1, OG-2, AND OG-3

Lot	Log No.	Orientation	Location in Log	Mean Irradiation Temperature (K)	Fluence x 10^{-25} (n/m^2) $(E>29\ fJ)_{HTGR}$	Average Percent Change in CTE (295-773 K)
266	5651-28	Axial	Midlength center	915	2.0	+1
				935	3.7	+3
				935	5.5	-3
				1045	1.9	+6
				1195	2.3	-4
				1205	4.5	-15
				1170	6.4	-24
				1270	8.5	-38
				1335	3.0	-7
				1665	3.2	-4
				1660	6.1	-34
				1660	9.0	-47
			Midlength edge	1045	1.9	+4
				1125	1.9	+2
				1110	3.6	+2
				1255	2.8	-11
				1260	5.3	-20
				1480	6.3	-30
				1515	9.2	-43

TABLE 6-6 (Continued)

Lot	Log No.	Orientation	Location in Log	Mean Irradiation Temperature (K)	Fluence x 10^{-25} (n/m^2) $(E>29\ fJ)_{HTGR}$	Average Percent Change in CTE (295-773 K)
266	5651-28	Radial	Midlength center	915	2.0	+3
				935	3.7	+7
				935	5.5	0
				1045	1.9	+9
				1195	2.3	-9
				1205	4.5	-9
				1170	6.4	-23
				1270	8.5	-43
				1335	3.0	-7
				1665	3.2	-9
				1660	6.1	-34
				1660	9.0	-46
			Midlength edge	1045	1.9	+2
				1125	1.9	+2
				1110	3.6	+2
				1255	2.8	-11
				1260	5.3	-18
				1480	6.3	-27
				1515	9.3	-41
426	6484-34	Axial	Midlength center	970	1.8	+10
				1040	2.4	+11
				1655	2.9	+15
		Radial	Midlength center	970	1.8	+10
				1010	2.4	+9
				1655	2.9	+13

TABLE 6-7
SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL EXPANSIVITY OF H-429 GRAPHITE IRRADIATED IN CAPSULES OG-1, OG-2, AND OG-3

Log No.	Orientation	Mean Irradiation Temperature (K)	Fluence (X 10^{25} n/m^2) $(E > 29\ fJ)_{HTGR}$	Average Percent Change in CTE (295-773 K)
4974-04A	Axial	1165	3.0	-8
		1180	5.2	-4
		1170	7.2	-21
		1435	5.6	-13
		1460	8.6	-28
		1480	11.4	-41
		1705	6.6	-22
		1675	8.8	-30
	Radial	1165	3.0	+2
		1145	5.6	+1
		1170	7.2	-19
		1435	5.6	-9
		1460	8.6	-29
		1480	11.4	-39
		1705	6.6	-17
		1675	8.8	-27

TABLE 6-8
SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL EXPANSIVITY OF TS-1240 GRAPHITE IRRADIATED IN CAPSULES OG-2 AND OG-3

Log No.	Orientation	Location in Log	Mean Irradiation Temperature (K)	Fluence (X 10^{25} n/m^2) (E > 29 fJ)$_{HTGR}$	Average Percent Change in CTE (295-773 K)
5651-73	Axial	Midlength-center	895	1.2	+7
			1040	1.7	+2
			1195	2.5	-1
			1250	4.9	-36
			1380	2.9	+1
			1415	5.9	-33
		Midlength-edge	880	2.3	+6
	Radial	Midlength-center	865	1.2	-1
			1080	1.7	-4
			1195	2.5	-4
			1200	4.9	-20
			1475	2.9	-11
			1500	5.9	-47
		Midlength-edge	880	2.3	+4

TABLE 6-9
SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL EXPANSIVITY OF
SO818 GRAPHITE IRRADIATED IN CAPSULE OG-3

Lot	Log No.	Orientation	Location in Log	Mean Irradiation Temperature (K)	Fluence x 10^{-25} (n/m^2) $(E>29\ fJ)_{HTGR}$	Average Percent Change in CTE (295-773 K)
4B	6484-22	Axial	Midlength	1040	2.4	+3
			center	1655	2.9	-12
		Radial	Midlength	1010	2.4	+7
			center	1655	2.9	-11

TABLE 6-10
THERMAL CONDUCTIVITY OF H-451 GRAPHITE, LOT 266,
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 266 LOG NUMBER(S):5651-28

ORIENTATION: AXIAL LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1 FLUENCE: 5.50*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
900	201	30.8	38.1	38.7			33.9
(627 C)	202	29.3	32.2	34.9			30.2
*	203	30.6	37.9	38.5			33.9
*	204	27.7	31.9	30.8			28.2
	MEAN:	29.6	35.0	35.7			31.5
	STD. DEV:	1.4	3.4	3.7			4.4

CRUCIBLE NO: 7 FLUENCE: 7.70*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1210	205	35.7	38.4	37.0	33.7	32.8	29.8
(937 C)	206	40.5	41.5	39.1	33.3	31.0	30.2
*	207	51.3	50.2	52.9	50.8	45.6	39.6
*	208	46.8	53.1	48.3	45.4	39.1	36.8
	MEAN:	43.6	45.8	44.3	40.8	37.1	34.1
	STD. DEV:	6.8	7.0	7.5	8.7	6.6	5.9

CRUCIBLE NO: 5 FLUENCE: 9.00*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1620	210	61.0	66.2	56.8	52.6	50.8	33.0
(1347 C)	211	66.8	69.7	61.4	55.7	54.2	34.1
*	212	65.8	68.1	59.3	55.2	50.7	33.5
*	213	82.1	82.4	75.9	63.2	67.7	37.3
	MEAN:	68.9	71.6	63.3	56.7	55.8	34.5
	STD. DEV:	9.2	7.3	8.6	4.6	8.1	3.8

TABLE 6-10 (Continued)

LOT NUMBER: 266 LOG NUMBER(S):5651-28

ORIENTATION: RADIAL LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1 FLUENCE: 5.50*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
900	221	26.7	34.2	33.0			29.9
(627 C)	222	25.1	33.0	33.4			29.9
*	223	25.4	27.5	27.8			25.8
*	224	26.3	29.4	29.6			26.6
	MEAN:	25.9	31.0	31.0			28.0
	STD. DEV:	.8	3.1	2.7			4.7

CRUCIBLE NO: 7 FLUENCE: 7.70*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1210	231	32.1	41.2	39.9	38.8	38.3	32.8
(937 C)	232	24.6	30.4	28.4	27.4	27.2	24.9
*	233	31.1	37.6	36.3	36.7	33.6	29.9
*	234	37.0	45.4	41.6	44.2	44.4	35.2
	MEAN:	31.2	38.6	36.6	36.8	35.9	30.7
	STD. DEV:	5.1	6.3	5.9	7.0	7.3	6.1

CRUCIBLE NO: 5 FLUENCE: 9.00*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1620	242	56.5	63.7	59.4	53.4	48.4	33.5
(1347 C)	243	53.9	62.0	51.6	49.1	44.6	31.8
*	244	60.0	68.3	60.6	56.8	51.7	34.7
*	245	54.4	62.0	56.1	50.7	46.3	32.6
	MEAN:	56.2	64.0	56.9	52.5	47.8	33.1
	STD. DEV:	2.8	3.0	4.0	3.4	3.1	4.4

TABLE 6-11
THERMAL CONDUCTIVITY OF H-451 GRAPHITE, LOT 426,
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 426 LOG NUMBER(S):6484-34

ORIENTATION: AXIAL LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1 FLUENCE: 1.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
925	34-2B-L-1A	30.5	37.0	33.6			30.1
(652 C)	34-2B-L-1B	35.6	38.6	36.5			31.6
*	34-2B-L-1C	35.7	41.6	40.7			34.4
	MEAN:	34.0	39.1	36.9			32.0
	STD. DEV:	3.0	2.3	3.6			6.6

CRUCIBLE NO: 7 FLUENCE: 2.40*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1220	34-2B-L1G	65.7	63.7	54.4	46.3	43.3	38.4
(947 C)	34-2B-L1H	63.3	67.6	57.1	51.4	46.2	40.1
*	34-2B-L1I	60.4	65.1	60.8	53.4	50.6	41.2
*	34-2B-L1J	53.8	59.9	51.4	43.5	38.8	36.1
	MEAN:	60.8	64.1	55.9	48.7	44.7	39.0
	STD. DEV:	5.1	3.2	4.0	4.6	5.0	6.7

CRUCIBLE NO: 5 FLUENCE: 2.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1615	34-2B-L1D	81.6	82.5	71.2	63.2	58.7	33.1
(1342 C)	34-2B-L1E	82.1	81.8	71.4	62.7	56.3	32.8
*	34-2B-L1F	83.6	73.9	65.2	56.4	52.3	31.5
	MEAN:	82.4	79.4	69.3	60.7	55.8	32.5
	STD. DEV:	1.1	4.8	3.5	3.8	3.2	6.3

TABLE 6-11 (Continued)

LOT NUMBER: 426 LOG NUMBER(S):6484-34

ORIENTATION: RADIAL LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1 FLUENCE: 1.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
925	34-2B-L-6A	24.9	33.0	29.2			27.1
(652 C)	34-2B-L-6B	31.6	36.2	35.2			30.8
*	34-2B-L-6C	32.4	37.5	36.2			31.4
	MEAN:	29.6	35.6	33.5			29.8
	STD. DEV:	4.1	2.3	3.8			6.7

CRUCIBLE NO: 7 FLUENCE: 2.40*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1220	34-2B-L-6G	55.8	52.5	47.8	44.9	41.0	35.6
(947 C)	34-2B-L-6H	59.7	60.6	52.9	44.0	41.5	37.1
*	34-2B-L-6I	62.9	53.1	48.3	41.1	39.1	35.0
*	34-2B-L-6J	57.2	53.9	47.0	40.2	35.6	34.0
	MEAN:	58.9	55.0	49.0	42.6	39.3	35.4
	STD. DEV:	3.1	3.7	2.7	2.3	2.7	6.4

CRUCIBLE NO: 5 FLUENCE: 2.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1615	34-2B-L6D	73.2	77.1	65.7	57.8	55.2	32.1
(1342 C)	34-2B-L6E	70.8	81.7	64.6	56.2	53.4	32.1
*	34-2B-L6F	73.0	74.1	65.0	55.6	53.3	31.5
	MEAN:	72.4	77.6	65.1	56.5	54.0	31.9
	STD. DEV:	1.3	3.8	.6	1.2	1.1	6.3

TABLE 6-12
THERMAL CONDUCTIVITY OF TS-1240 GRAPHITE
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 1 LOG NUMBER(S):5651-73

ORIENTATION: AXIAL LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1 FLUENCE: 3.50*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
915	74D63	26.3	29.8	26.8			26.0
(642 C)	74D64	27.7	33.5	30.9			28.6
*	74D65	26.4	36.0	36.6			31.5
*	74D66	25.6	28.5	27.0			25.4
	MEAN:	26.5	32.0	30.3			27.9
	STD. DEV:	.9	3.4	4.6			5.0

CRUCIBLE NO: 7 FLUENCE: 4.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1220	74D71	50.1	48.2	47.7	44.0	37.6	36.4
(947 C)	74D72	54.3	53.2	51.3	48.2	44.0	39.4
*	74D73	51.7	47.7	43.7	38.6	35.4	34.4
*	74D74	49.8	48.0	47.4	41.2	35.6	35.6
	MEAN:	51.5	49.3	47.5	43.0	38.2	36.5
	STD. DEV:	2.1	2.7	3.1	4.1	4.0	4.0

CRUCIBLE NO: 5 FLUENCE: 5.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1615	74D067	72.4	76.7	66.1	57.5	55.1	39.1
(1342 C)	74D068	62.8	69.6	58.3	54.6	49.0	36.9
*	74D069	72.5	75.5	64.7	58.5	56.8	39.1
*	74D070	56.3	63.2	54.7	48.6	46.6	35.0
	MEAN:	66.0	71.2	61.0	54.8	51.9	37.5
	STD. DEV:	7.9	6.2	5.4	4.4	4.8	4.6

TABLE 6-12 (Continued)

LOT NUMBER: 1   LOG NUMBER(S): 5651-73

ORIENTATION: RADIAL   LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1   FLUENCE: 3.50*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
915	74D93	27.0	30.0	28.4			26.2
(642 C)	74D94	26.5	29.3	25.3			25.0
*	74D95	27.9	29.8	26.2			24.8
*	74D96	28.4	27.8	26.7			24.4
	MEAN:	27.5	29.2	26.7			25.1
	STD. DEV:	.8	1.0	1.3			3.4

CRUCIBLE NO: 7   FLUENCE: 4.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1220	74D109	48.9	52.4	48.4	43.0	40.9	37.9
(947 C)	74D110	49.0	59.2	52.9	46.0	43.4	40.3
*	74D111	50.6	48.7	48.2	39.5	34.6	35.9
*	74D112	51.8	47.8	47.3	42.3	35.5	36.2
	MEAN:	50.1	52.0	49.2	42.7	38.6	37.6
	STD. DEV:	1.4	5.2	2.5	2.7	4.2	4.7

CRUCIBLE NO: 5   FLUENCE: 5.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1615	74D101	66.5	71.6	61.4	54.5	54.1	36.8
(1342 C)	74D102	63.2	66.6	57.7	53.6	51.8	35.6
*	74D103	68.8	74.1	64.9	60.2	55.9	38.1
*	74D104	63.2	73.8	63.7	56.2	53.3	37.6
	MEAN:	65.4	71.5	61.9	56.1	53.8	37.0
	STD. DEV:	2.8	3.5	3.2	2.9	1.7	3.5

TABLE 6-13
THERMAL CONDUCTIVITY OF SO818 GRAPHITE
IRRADIATED IN CAPSULE OG-3

LOT NUMBER: 4-B   LOG NUMBER(S):6484-22

ORIENTATION: AXIAL   LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1   FLUENCE: 1.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
925	22-3A-L51A	27.7	30.4	29.3			26.7
(652 C)	22-3A-L51B	28.9	28.6	26.7			24.7
*	22-3A-L51C	29.2	32.8	31.5			28.6
	MEAN:	28.6	30.6	29.2			26.7
	STD. DEV:	.8	2.1	2.4			4.6

CRUCIBLE NO: 7   FLUENCE: 2.40*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1220	22-3A-L55A	51.1	58.6	49.3	42.7	39.4	36.7
(947 C)	22-3A-L55B	49.7	55.2	50.4	44.4	40.1	37.0
*	22-3A-L55C	50.7	54.5	51.0	42.7	38.4	36.4
	MEAN:	50.5	56.1	50.2	43.3	39.3	36.7
	STD. DEV:	.8	2.2	.9	1.0	.8	4.2

CRUCIBLE NO: 5   FLUENCE: 2.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1615	22-3A-L81A	69.6	75.5	69.8	63.0	58.7	35.2
(1342 C)	22-3A-L81B	59.8	68.6	61.5	53.7	49.8	32.6
*	22-3A-L81C	64.1	77.3	68.9	62.0	57.4	35.1
	MEAN:	64.5	73.8	66.7	59.6	55.3	34.3
	STD. DEV:	4.9	4.6	4.5	5.1	4.8	4.4

TABLE 6-13 (Continued)

LOT NUMBER: 4-B   LOG NUMBER(S): 6484-22

ORIENTATION: RADIAL   LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 1   FLUENCE: 1.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
925	22-3A-L78A	27.4	28.0	25.7			24.3
(652 C)	22-3A-L78B	29.0	31.6	30.2			27.0
*	22-3A-L78C	28.8	34.5	32.6			29.6
	MEAN:	28.4	31.4	29.5			27.0
	STD. DEV:	.8	3.2	3.5			5.0

CRUCIBLE NO: 7   FLUENCE: 2.40*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1220	22-3B-L90A	39.7	45.1	42.9	37.3	34.2	31.6
(947 C)	22-3B-L90B	43.4	47.0	42.3	35.4	36.0	31.9
*	22-3B-L90C	48.0	50.3	44.0	37.5	37.0	33.3
	MEAN:	43.7	47.5	43.0	36.7	35.7	32.3
	STD. DEV:	4.2	2.6	.9	1.2	1.4	4.3

CRUCIBLE NO: 5   FLUENCE: 2.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1615	22-3B-L62A	67.8	70.3	62.5	57.9	53.8	33.4
(1342 C)	22-3B-L62B	63.3	68.6	60.0	52.9	52.3	32.6
*	22-3B-L62C	66.4	70.4	63.9	59.0	49.6	33.1
	MEAN:	65.8	69.8	62.1	56.6	51.9	33.0
	STD. DEV:	2.3	1.0	2.0	3.3	2.2	4.2

TABLE 6-14

SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL CONDUCTIVITY OF H-451 GRAPHITE IRRADIATED IN CAPSULES OG-1, OG-2, AND OG-3

(ALL SPECIMENS FROM MIDLENGTH-CENTER OF PARENT LOG)

Lot	Log No.	Orientation	Mean Irradiation Temperature (K)	Fluence x 10^{-25} (n/m^2) ($E > 29$ fJ)$_{HTGR}$	Mean Thermal Conductivity (W/m-K) ± Std. Dev.	
					At 293 K	At Irradiation Temperature
266	5651-28	Axial	--	0	145.2 ± 1.3	--
			875	2.0	34.7 ± 1.4	33.3 ± 2.7
			890	3.7	30.1 ± 0.9	32.5 ± 4.3
			900	5.5	29.6 ± 1.4	31.5 ± 4.4
			1195	2.8	48.8 ± 1.8	40.0 ± 1.7
			1205	5.3	41.3 ± 8.4	39.8 ± 3.0
			1210	7.7	43.6 ± 6.8	34.1 ± 5.9
			1625	3.2	79.8 ± 4.2	41.1 ± 1.2
			1625	6.1	80.9 ± 4.0	40.7 ± 0.6
			1620	9.0	68.9 ± 9.2	34.5 ± 3.8
266	5651-28	Radial	--	0	123.0 ± 7.1	--
			875	2.0	32.0 ± 1.9	33.3 ± 2.7
			890	3.7	27.8 ± 3.1	29.5 ± 3.2
			900	5.5	25.9 ± 0.8	28.0 ± 4.7
			1195	2.8	42.9 ± 3.3	36.1 ± 2.8
			1205	5.3	34.2 ± 4.3	29.5 ± 2.0
			1210	7.7	31.2 ± 5.1	30.7 ± 6.1
			1625	3.2	83.5 ± 7.2	39.3 ± 3.4
			1625	6.1	65.7 ± 8.2	36.4 ± 2.0
			1620	9.0	56.2 ± 2.8	33.1 ± 4.4
426	6484-34	Axial	--	0	136.0 ± 17.2	--
			925	1.8	34.0 ± 3.0	32.0 ± 6.6
			1220	2.4	60.8 ± 5.1	39.0 ± 6.7
			1615	2.9	82.4 ± 1.1	32.5 ± 6.3
		Radial	--	0	128.9 ± 10.0	--
			925	1.8	29.6 ± 4.1	29.8 ± 6.7
			1220	2.4	58.9 ± 3.1	35.4 ± 6.4
			1615	2.9	72.4 ± 1.3	31.9 ± 6.3

TABLE 6-15
SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL CONDUCTIVITY OF TS-1240 GRAPHITE IRRADIATED IN CAPSULES OG-2 AND OG-3
(ALL SPECIMENS FROM MIDLENGTH-CENTER OF PARENT LOG)

Lot	Log No.	Orientation	Mean Irradiation Temperature (K)	Fluence x 10^{-25} (n/m^2) ($E > 29$ fJ)$_{HTGR}$	Mean Thermal Conductivity (W/m-K) ± Std. Dev.	
					At 293 K	At Irradiation Temperature
	5651-73	Axial	--	0	97.9 ± 8.4	--
			910	1.7	30.5 ± 1.2	34.1 ± 1.7
			915	3.5	26.5 ± 0.9	27.9 ± 5.0
			1220	2.5	45.5 ± 3.7	38.2 ± 2.4
			1220	4.9	51.5 ± 2.1	36.5 ± 4.0
			1620	2.9	68.8 ± 3.4	37.2 ± 1.5
			1615	5.8	66.0 ± 7.9	37.5 ± 4.6
	5651-73	Radial	--	0	103.3 ± 4.2	--
			910	1.7	28.5 ± 2.8	32.6 ± 0.3
			915	3.5	27.5 ± 0.8	25.1 ± 3.4
			1220	2.5	37.0 ± 2.2	29.9 ± 1.7
			1220	4.9	50.1 ± 1.4	37.6 ± 4.7
			1620	2.9	64.5 ± 5.5	33.5 ± 1.2
			1615	5.8	65.4 ± 2.8	37.0 ± 3.5

TABLE 6-16
SUMMARY OF IRRADIATION-INDUCED CHANGES IN THERMAL CONDUCTIVITY OF SO818 GRAPHITE IRRADIATED IN CAPSULE OG-3
(ALL SPECIMENS FROM MIDLENGTH-CENTER OF PARENT LOG)

Lot	Log No.	Orientation	Mean Irradiation Temperature (K)	Fluence x 10^{-25} (n/m^2) $(E > 29\ fJ)_{HTGR}$	Mean Thermal Conductivity (W/m-K) ± Std. Dev.	
					At 293 K	At Irradiation Temperature
4-B	6484-22	Axial	--	0	135.1 ± 5.0	--
			925	1.8	28.6 ± 0.8	26.7 ± 4.6
			1220	2.4	50.5 ± 0.8	36.7 ± 4.2
			1615	2.9	64.5 ± 4.9	34.3 ± 4.4
4-B	6484-22	Radial	--	0	125.9 ± 5.0	--
			925	1.8	28.4 ± 0.8	27.0 ± 5.0
			1220	2.4	43.7 ± 4.2	32.3 ± 4.3
			1615	2.9	65.8 ± 2.3	33.0 ± 4.2

TABLE 6-17

THERMAL CONDUCTIVITY OF H-451 GRAPHITE IRRADIATED AT TWO DIFFERENT TEMPERATURES: (1) 3×10^{25} n/m^2 AT 1625 K, THEN 1.8×10^{25} n/m^2 AT 925 K; (2) 2×10^{25} n/m^2 at 875 K, THEN 2.9×10^{25} n/m^2 AT 1615 K

LOT NUMBER: 266 LOG NUMBER(S): 5651-28

ORIENTATION: RADIAL LOG LOCATION: MIDLENGTH-CENTER

CRUCIBLE NO: 5-1 FLUENCE: 4.80*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
1625-925	250	26.5	28.3	29.2			25.5
STEP DOWN	251	25.2	30.6	29.9			27.0
	MEAN:	25.8	29.4	29.5			26.2
	STD. DEV:	.9	1.6	.5			4.3

CRUCIBLE NO: 1-5 FLUENCE: 4.90*EXP25 N/M**2, E>.18MEV

MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	THERMAL CONDUCTIVITY (W/M-K) AT: 295K (22 C)	473K (200C)	673K (400C)	873K (600C)	1073K (800C)	IRRAD. TEMP.
875-1615	229	71.5	80.0	64.9	55.5	53.2	36.0
STEP UP	230	71.7	77.8	62.9	59.3	53.4	36.4
	MEAN:	71.6	78.9	63.9	57.4	53.3	36.2
	STD. DEV:	.1	1.6	1.5	2.7	.1	4.2

7. EXPERIMENTAL RESULTS - MECHANICAL PROPERTIES

7.1. TENSILE STRENGTH AND YOUNG'S MODULUS

More than 200 ambient-temperature tensile tests were conducted on graphite specimens irradiated at several different fluences and temperatures. Specimens of H-451 graphite (lots 266, 408, and 426), TS-1240 graphite, and H-327 graphite were tested. Many specimens had been previously irradiated in capsules OG-1 and OG-2. An Instron tensile-testing machine with a crosshead speed of 2 μm/s was used, and strains were measured with a 12.6 mm gauge length extensometer. The specimens were cemented to metal end pieces with high strength epoxy cement, and the load was applied through roller-link chains to maintain uniaxial alignment. The specimens were loaded to 7 MPa, unloaded to 0.7 MPa, and reloaded to failure. Young's modulus was measured from the 0.7 MPa to 7 MPa portion of the reloading curve.

The tensile strengths, strains at failure, and Young's moduli are listed in Tables 7-1 through 7-5. Summary tables of all tensile data obtained in capsules OG-1, OG-2, and OG-3, including unirradiated controls, appear as Tables 7-6 through 7-8. The percent increases in strength and Young's modulus (referenced to unirradiated control specimens from the same location in the same log) are plotted as functions of fast neutron fluence in Figs. 7-1 through 7-3. For H-451 and TS-1240 graphites the data for all orientations, locations, and lots fall in the same scatter bands. For H-327 graphite the increase in Young's modulus is the same in the axial and radial directions, but the fractional increase in tensile strength is somewhat lower for radial specimens than for axial specimens.

The statistical spread in strength values is an important parameter in the mechanical design of graphite structures. Irradiation causes a significant increase in the standard deviation (Tables 7-6 through 7-8). However, the coefficient of variation (standard deviation divided by the mean) appears to be unaffected by irradiation. Figures 7-4 and 7-5 show the estimated coefficient of variation, together with its 95% confidence interval, plotted as a function of fast neutron fluence. There are considerable differences in the coefficients of variation for different materials, with TS-1240 graphite and radial specimens of H-327 having higher coefficients of variation than H-451 or axial specimens of H-327, but no definite trend with irradiation is apparent. Possible exceptions are the H-327 axial specimens irradiated beyond 5×10^{25} n/m^2, where an apparent increase in coefficient of variation may occur (Fig. 7-5). This may be explained by the slight warping which develops in highly irradiated specimens of needle coke graphite and prevents perfect axial alignment of the tensile specimens.

7.2. DESIGN CURVES

The design curves presently used for the irradiation-induced increase in Young's modulus (Ref. 5) are based on Dragon project data for the change in sonic modulus of a near-isotropic pitch coke graphite. The data on H-451 and TS-1240 graphites are in excellent agreement with these curves (see Figs. 7-1 and 7-2). However, the high fluence data on H-327 graphite for an irradiation temperature around 1200 K does not show the second increase in modulus seen in near-isotropic graphites. Reference to the Dragon project data (Ref. 8) shows that, in general, the second increase is not present in the curves relating Young's modulus to fluence for needle coke graphites. A new set of design curves were prepared for H-327 graphite, based on Dragon project data for a needle coke graphite (Dragon Code No. 120) (Ref. 8). As before, it was assumed that the static Young's modulus of unirradiated graphite is 0.8 x the sonic modulus, but the two values coincide after irradiation. The new design curves are shown in Fig. 7-6. The experimental data on H-327 Young's modulus agrees well with the new design curves (Fig. 7-3).

The present design method for accounting for the irradiation-induced strength increase assumes that the strength increases in proportion to the square root of the fractional change in Young's modulus. Consideration of all the data now available (Tables 7-6 through 7-8) leads to the conclusion that different graphites behave differently. An alternative method is now recommended. The increase in strength (S) is assumed to be related to the irradiation-induced increase in Young's modulus (E) thus:

$$S/S_o = (E/E_o)^k \quad ,$$

where the exponent, k, depends on the graphite grade. The following average values for k were obtained from the data in Tables 7-6 through 7-8:

H-451, axial and radial:	$k = 0.64$
TS-1240, axial and radial:	$k = 0.48$
H-327, axial:	$k = 0.67$
H-327, radial:	$k = 0.40$

The revised k values are reflected in the "design curves" for the strength data plotted in Figs. 7-1 through 7-3.

7.3. BETWEEN-LOG AND WITHIN-LOG VARIATIONS IN STRENGTH INCREASE

Three groups of tensile specimens of H-451 graphite were made up from three different logs from lot 426 of H-451 graphite, and three groups contained specimens from both the midlength-center location and the midlength-edge location. Five or more replicate specimens were used from each log and location. The irradiation-induced percent strength increases (referenced to control specimens from the same log and location) were analyzed by the analysis-of-variance method. Individual strength values appear in Tables 7-2 and 7-3. The results of the comparison are summarized in Tables 7-9 and 7-10. Among one group of specimens, those from log 6484-34 showed a significantly smaller increase than those from the other two logs, but this was not so for the other two groups (Table 7-9). There were no significant differences in the strength increases between specimens from the center of the log and specimens from the edge of the log (Table 7-10).

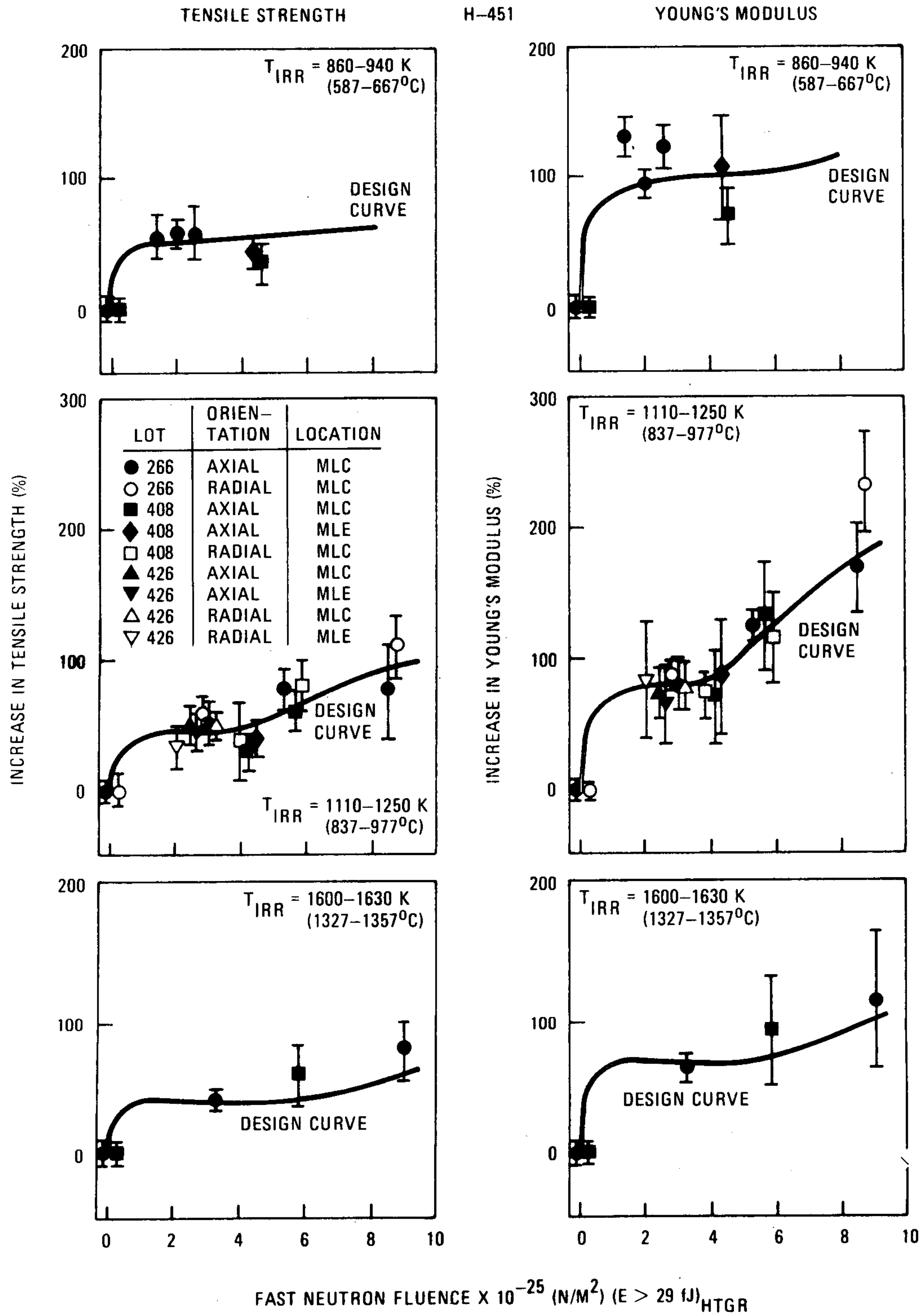


Fig. 7-1. Changes in tensile strength and Young's modulus of H-451 graphite as a function of fast neutron fluences. Error bars denote ± one standard deviation

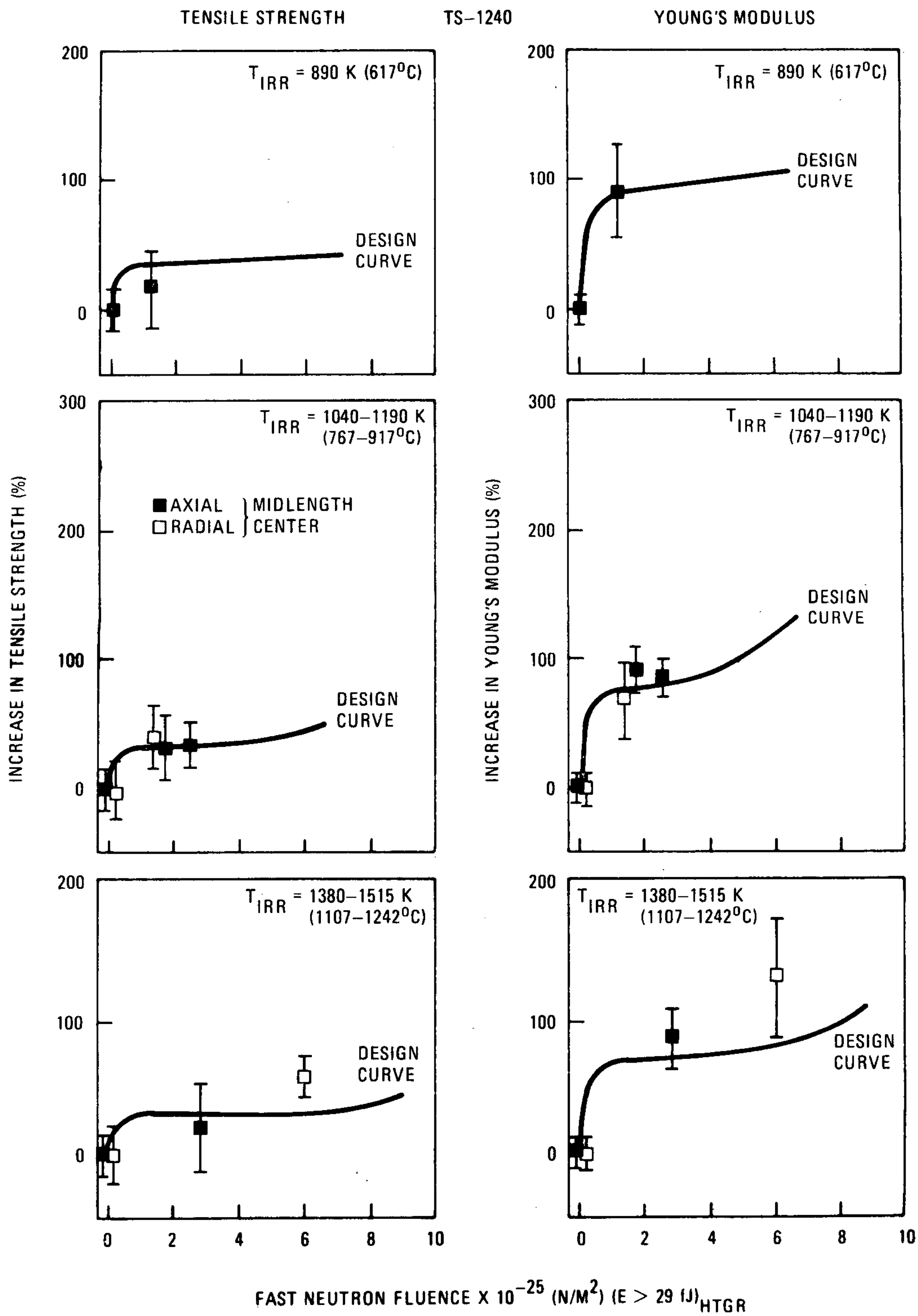


Fig. 7-2. Changes in tensile strength and Young's modulus of TS-1240 graphite as a function of fast neutron fluence. Error bars denote ± one standard deviation

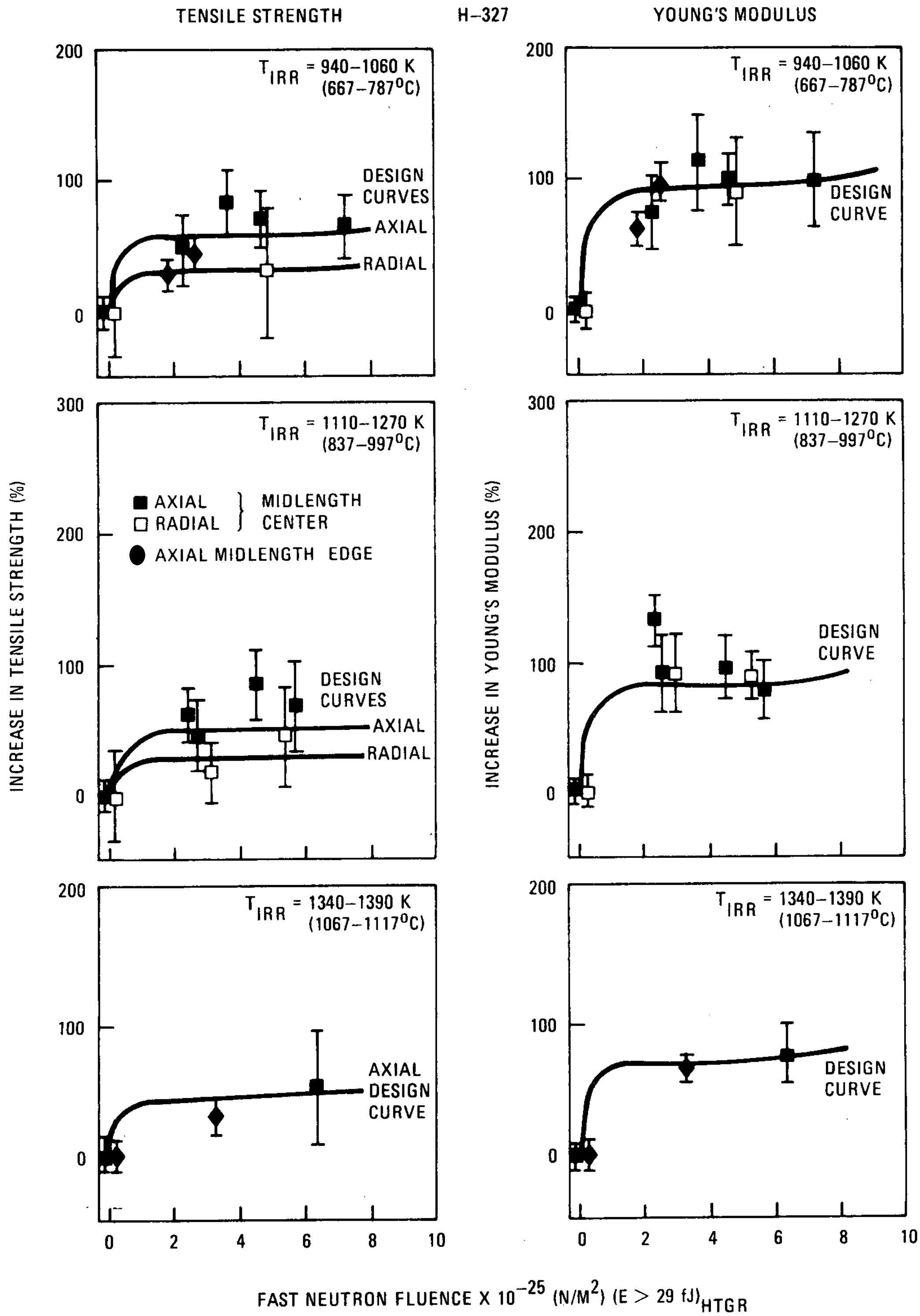


Fig. 7-3. Changes in tensile strength and Young's modulus of H-327 graphite as a function of fast neutron fluence. Error bars denote ± one standard deviation

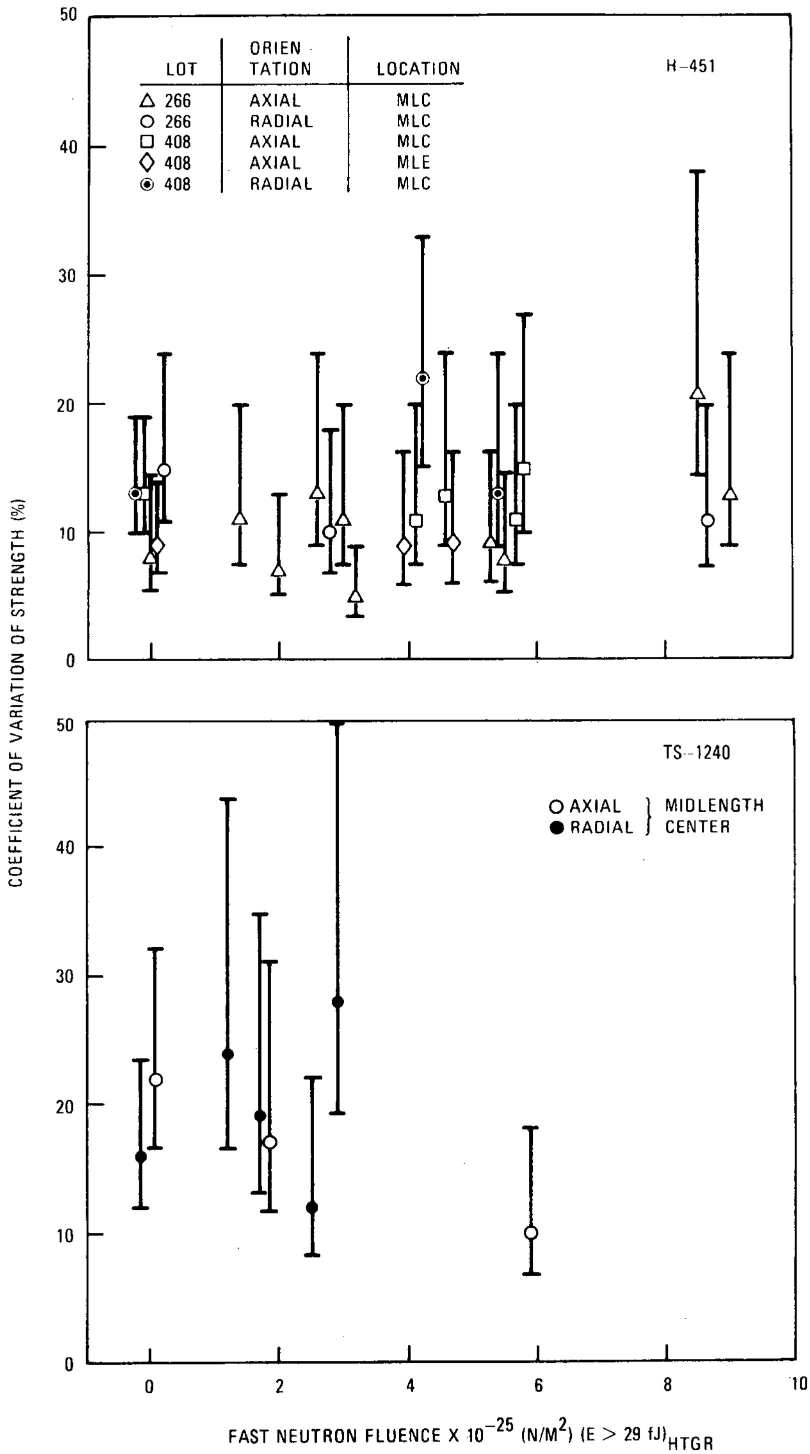


Fig. 7-4. Coefficient of variation of the tensile strength of H-451 and TS-1240 graphites as a function of fast neutron fluence. Error bars denote 95% confidence interval

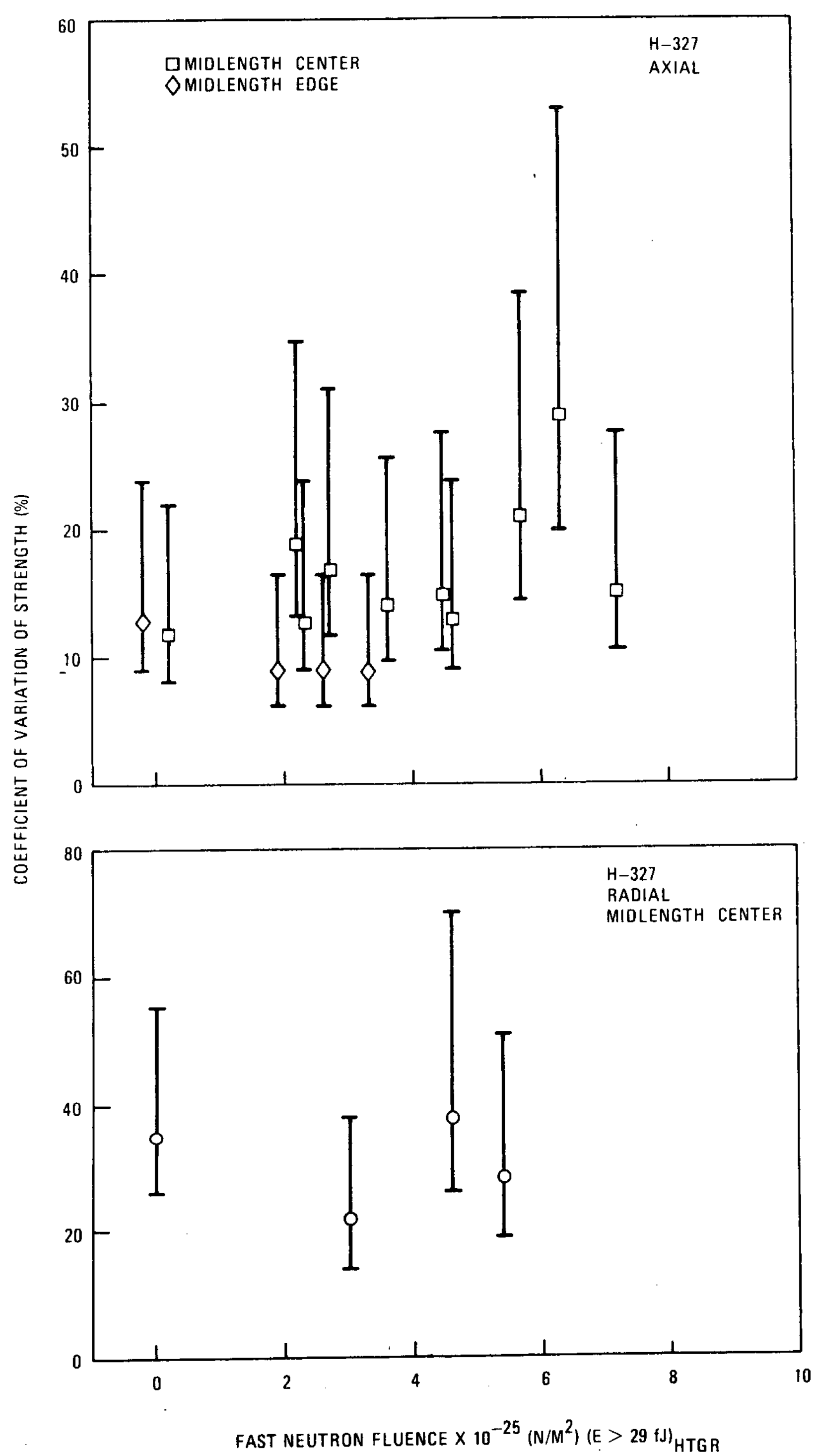


Fig. 7-5. Coefficient of variation of tensile strength determinations on H-327 graphite as a function of fast neutron fluence. Error bars denote 95% confidence interval

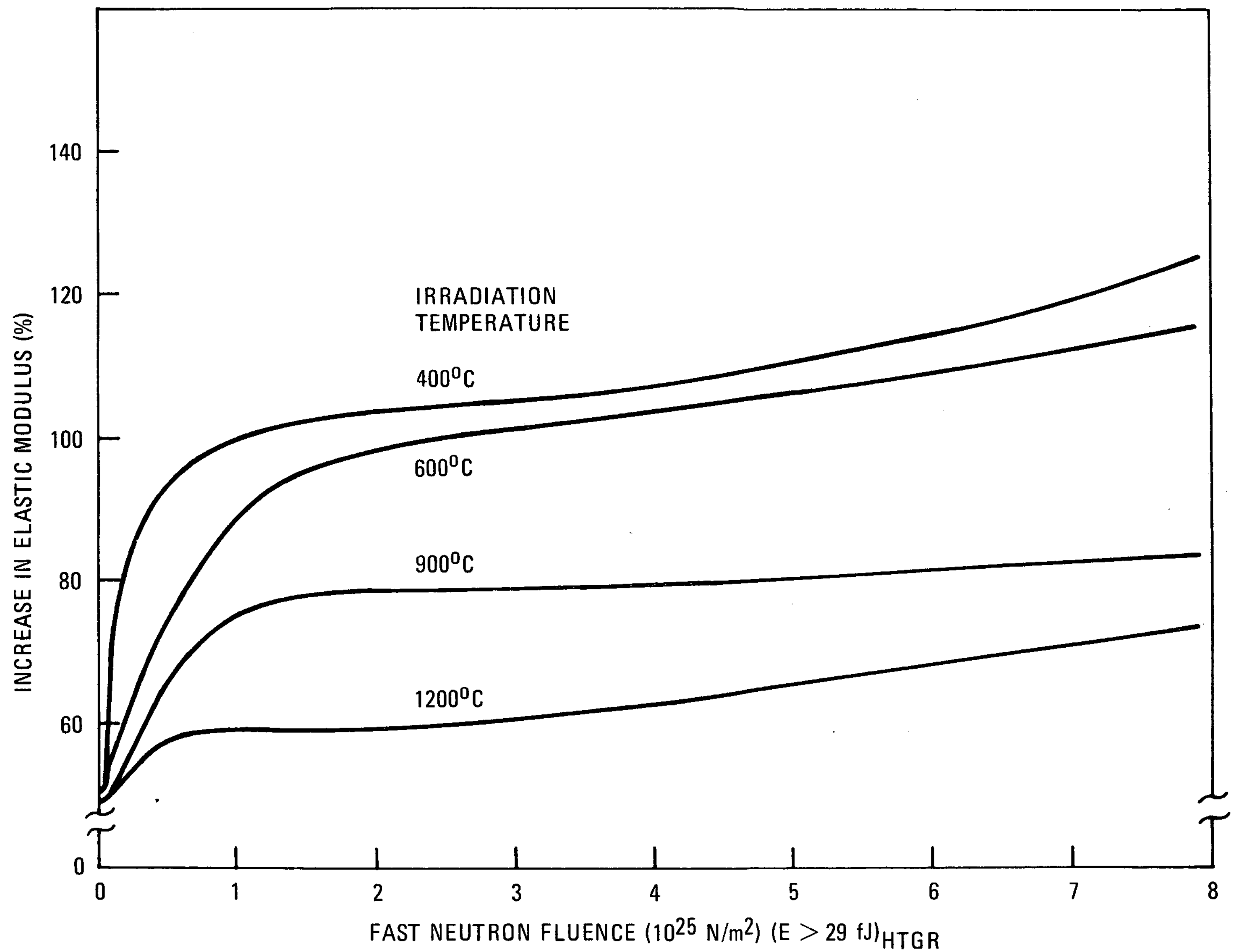


Fig. 7-6. Calculated curves for percent increase in Young's modulus of H-327 graphite as a function of fast neutron fluence and irradiation temperature

TABLE 7-1
TENSILE PROPERTIES OF H-451 GRAPHITE, LOT 266,
IRRADIATED IN CAPSULE OG-3

GRAPHITE GRADE: H-451

LOT NUMBER: 266

LOG NUMBER(S): 5651-28

ORIENTATION: AXIAL CRUCIBLE NO: 1

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 5.50*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
16	885	T-111	17.2	.133	15.3
16	(612 C)	T-112	15.5	.105	18.1
22	870	T-113	17.6	.131	18.1
22	(597 C)	T-114	18.5		19.1
23	*	T-115	19.9	.125	20.7
23	*	T-116	18.3		14.4
24	*	T-117	18.9	.132	16.4
24	*	T-118	19.3	.167	12.6
		MEAN:	18.2 MPA (2633. PSI)	.132 PCT	16.6 GPA (2.44 MPSI)
		STD. DEV:	1.4 MPA (199. PSI)	.020 PCT	2.7 GPA (.39 MPSI)

ORIENTATION: AXIAL CRUCIBLE NO: 3

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 8.50*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
16	1205	T-131	15.4	.100	24.5
16	(932 C)	T-132	20.2	.135	17.8
17	*	T-133	20.9	.120	22.4
17	*	T-134	14.9	.105	19.7
26	1190	T-135	21.0	.140	20.4
26	(917 C)	T-136	26.5	.152	20.9
27	*	T-137	15.9	.083	25.6
27	*	T-138	16.1	.112	18.4
		MEAN:	18.9 MPA (2735. PSI)	.118 PCT	21.2 GPA (3.08 MPSI)
		STD. DEV:	4.0 MPA (582. PSI)	.023 PCT	2.8 GPA (.41 MPSI)

TABLE 7-1 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 266

LOG NUMBER(S): 5651-28

ORIENTATION: AXIAL   CRUCIBLE NO: 5

LOG LOCATION: MIDLENGTH-CENTER   FLUENCE: 9.00*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
21	1600	T-147	21.0	.193	11.5
21	(1327 C)	T-148	23.8	.143	22.7
22	*	T-149	18.4	.129	14.7
22	*	T-150	16.8	.115	15.7
23	*	T-151	20.5	.121	18.5
23	*	T-152	21.6	.110	23.6
24	*	T-153	18.4	.160	16.0
24	*	T-154	16.1	.103	16.1
		MEAN:	19.6 MPA (2842. PSI)	.134 PCT	17.3 GPA (2.52 MPSI)
		STD. DEV:	2.6 MPA (379. PSI)	.030 PCT	4.1 GPA (.59 MPSI)

ORIENTATION: RADIAL   CRUCIBLE NO: 3

LOG LOCATION: MIDLENGTH-CENTER   FLUENCE: 8.50*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
14	1220	T-201	23.3	.145	20.8
14	(947 C)	T-202	22.9	.121	22.2
14	*	T-203	21.1	.115	21.2
15	*	T-204	25.5	.122	25.0
15	1205	T-205	26.7	.143	24.0
15	(932 C)	T-206	23.2	.123	25.5
16	*	T-207	24.1	.145	19.9
17	*	T-208	28.9	.167	21.0
26	1190	T-209	26.5	.139	23.3
27	(917 C)	T-210	19.9	.100	28.6
		MEAN:	24.2 MPA (3511. PSI)	.132 PCT	23.2 GPA (3.36 MPSI)
		STD. DEV:	2.7 MPA (397. PSI)	.019 PCT	2.7 GPA (.39 MPSI)

TABLE 7-2
TENSILE PROPERTIES OF H-451 GRAPHTIE, LOT 408,
IRRADIATED IN CAPSULE OG-3

GRAPHITE GRADE: H-451

LOT NUMBER: 408

LOG NUMBER(S): 5651-86

ORIENTATION: AXIAL CRUCIBLE NO: 1

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 4.60*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
10	940	T-40501	20.4	.173	15.0
10	(667 C)	T-40503	15.8	.145	10.2
11	*	T-40505	17.3	.180	11.6
11	*	T-40507	12.8	.111	12.4
12	*	T-40509	18.5	.184	12.2
12	*	T-40511	17.8	.155	12.0
13	*	T-40513	16.2	.140	13.3
13	*	T-40515	19.0	.184	12.2
14	*	T-40517	18.2	.159	12.6
14	*	T-40519	13.7	.110	16.0
15	*	T-40521	18.3	.182	12.0
15	*	T-40523	18.5	.186	11.0
		MEAN:	17.2 MPA (2497. PSI)	.159 PCT	12.5 GPA (1.82 MPSI)
		STD. DEV:	2.2 MPA (322. PSI)	.028 PCT	1.6 GPA (.23 MPSI)

ORIENTATION: AXIAL CRUCIBLE NO: 1

LOG LOCATION: MIDLENGTH-EDGE FLUENCE: 4.60*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
25	900	T-40741			
25	(627 C)	T-40743	25.1	.200	14.4
26	*	T-40745	26.9	.215	14.1
26	*	T-40747	23.8	.188	15.7
27	*	T-40749	25.5	.145	22.0
27	*	T-40751	26.4	.170	21.4
28	*	T-40753	19.5	.119	24.3
28	*	T-40755	26.8	.182	16.4
29	*	T-40757	26.4	.160	19.1
29	*	T-40759	24.7	.220	12.4
30	*	T-40761	22.7	.178	17.2
30	*	T-40763	25.4	.155	16.8
		MEAN:	24.8 MPA (3602. PSI)	.176 PCT	17.6 GPA (2.55 MPSI)
		STD. DEV:	2.2 MPA (319. PSI)	.030 PCT	3.7 GPA (.54 MPSI)

TABLE 7-2 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 408

LOG NUMBER(S): 5651-86

ORIENTATION: AXIAL CRUCIBLE NO: 8

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 4.10*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
8	1160	T-40597	17.7	.196	10.8
9	(887 C)	T-40599	17.8	.162	12.7
10	*	T-40601	14.7	.131	12.7
11	*	T-40603	14.7	.189	9.0
12	*	T-40605	18.7	.171	15.2
13	*	T-40607	14.5	.133	15.5
14	1130	T-40609	17.2	.183	10.6
15	(857 C)	T-40611	15.5	.193	11.9
16	*	T-40613	19.0	.130	16.5
23	*	T-40615	18.9	.223	10.7
		MEAN:	16.9 MPA (2447. PSI)	.171 PCT	12.6 GPA (1.82 MPSI)
		STD. DEV:	1.8 MPA (267. PSI)	.032 PCT	2.5 GPA (.36 MPSI)

ORIENTATION: AXIAL CRUCIBLE NO: 8

LOG LOCATION: MIDLENGTH-EDGE FLUENCE: 4.10*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
8	1160	T-40765	28.8	.248	13.4
9	(887 C)	T-40767	26.5	.195	18.2
10	*	T-40769	25.5	.155	24.4
11	*	T-40771	24.2	.183	15.5
12	*	T-40773	26.6	.235	12.3
13	*	T-40775	22.9	.212	12.7
14	1130	T-40777	21.9	.210	11.6
15	(857 C)	T-40779	22.3	.202	15.1
16	*	T-40781	24.9	.212	14.8
23	*	T-40783	26.2	.202	14.7
		MEAN:	25.0 MPA (3622. PSI)	.205 PCT	15.3 GPA (2.21 MPSI)
		STD. DEV:	2.2 MPA (319. PSI)	.026 PCT	3.7 GPA (.54 MPSI)

TABLE 7-2 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 408

LOG NUMBER(S): 5651-86

ORIENTATION: AXIAL CRUCIBLE NO: 3

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 5.50*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
10	1245	T-40525	18.9	.109	24.7
10	(972 C)	T-40527	19.1	.161	14.3
10	*	T-40529	22.4	.176	14.7
11	*	T-40531	22.1	.156	18.0
11	*	T-40533	21.6	.160	17.6
11	*	T-40535	23.6	.177	16.8
12	*	T-40537	17.4	.159	12.8
12	*	T-40539	21.8	.175	16.3
12	*	T-40541	20.3	.170	15.3
13	*	T-40543	18.2	.131	17.1
13	*	T-40545	23.3	.163	20.6
13	*	T-40547	18.1	.125	17.5
		MEAN:	20.6 MPA (2984. PSI)	.155 PCT	17.1 GPA (2.49 MPSI)
		STD. DEV:	2.2 MPA (315. PSI)	.022 PCT	3.1 GPA (.45 MPSI)

ORIENTATION: AXIAL CRUCIBLE NO: 5

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 5.80*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
12	1635	T-40549	22.0	.150	16.2
12	(1362 C)	T-40551	17.5	.167	13.2
13	*	T-40553	23.1	.183	14.1
13	*	T-40555	21.1	.223	13.3
14	*	T-40557	21.9	.150	17.8
14	*	T-40559	23.3	.165	16.3
15	*	T-40561	13.6	.173	11.3
15	*	T-40563	20.0	.247	9.8
20	1620	T-40565	22.2	.250	10.9
20	(1347 C)	T-40567	23.3	.151	20.3
		MEAN:	20.8 MPA (3015. PSI)	.186 PCT	14.3 GPA (2.08 MPSI)
		STD. DEV:	3.1 MPA (447. PSI)	.039 PCT	3.3 GPA (.48 MPSI)

TABLE 7-2 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 408

LOG NUMBER(S): 5651-86

ORIENTATION: RADIAL CRUCIBLE NO: 8

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 4.10*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
24	1115	T-40661	21.4	.206	11.2
24	(842 C)	T-40663	15.8	.186	11.2
25	*	T-40665	12.8	.100	13.9
25	*	T-40667	17.0	.167	12.7
		MEAN:	16.7 MPA (2429. PSI)	.165 PCT	12.3 GPA (1.78 MPSI)
		STD. DEV:	3.6 MPA (519. PSI)	.046 PCT	1.3 GPA (.19 MPSI)

ORIENTATION: RADIAL CRUCIBLE NO: 3

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 5.50*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
28	1200	T-40621	25.5	.192	16.4
28	(927 C)	T-40623	16.1	.131	14.8
28	*	T-40625	23.5	.162	17.6
29	*	T-40627	17.5	.158	13.1
29	*	T-40629	24.5	.171	18.4
29	*	T-40631	22.3	.195	12.7
30	*	T-40633	21.7	.194	12.7
30	*	T-40635	22.0	.147	20.1
30	*	T-40637	23.2	.167	16.8
31	*	T-40639	22.5	.205	12.7
31	*	T-40641	23.3	.203	15.0
31	*	T-40643	18.3	.149	14.8
		MEAN:	21.7 MPA (3145. PSI)	.173 PCT	15.4 GPA (2.24 MPSI)
		STD. DEV:	2.9 MPA (419. PSI)	.025 PCT	2.5 GPA (.36 MPSI)

TABLE 7-3
TENSILE PROPERTIES OF H-451 GRAPHITE, LOT 426, IRRADIATED IN CAPSULE OG-3

GRAPHITE GRADE: H-451

LOT NUMBER: 426

LOG NUMBER(S): 6484-33

ORIENTATION: AXIAL CRUCIBLE NO: 6

LOG LOCATION: MIDLENGTH-CENTER FLUENCE: 2.70*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
24	1210	33-2A-1A	27.8	.229	12.5
28	(937 C)	33-2A-1B	21.4	.201	14.2
30	*	33-2A-2A	26.0	.228	16.5
36	*	33-2A-2B	21.1	.183	14.5
34	*	33-2A-3A	22.4	.213	13.9
		MEAN:	23.7 MPA (3442. PSI)	.211 PCT	14.3 GPA (2.08 MPSI)
		STD. DEV:	3.0 MPA (434. PSI)	.019 PCT	1.5 GPA (.21 MPSI)

LOG NUMBER(S): 6484-34

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
28	1210	34-2A-1A	21.8	.197	12.5
26	(937 C)	34-2A-1B	20.7	.200	11.1
32	*	34-2A-2A	22.6	.210	11.8
34	*	34-2A-2B	22.7	.192	14.6
38	*	34-2A-3A	16.3	.174	10.8
		MEAN:	20.8 MPA (3020. PSI)	.195 PCT	12.1 GPA (1.76 MPSI)
		STD. DEV:	2.6 MPA (382. PSI)	.013 PCT	1.5 GPA (.22 MPSI)

LOG NUMBER(S): 6484-41

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
24	1210	41-2A-1A	18.3	.165	15.8
26	(937 C)	41-2A-1B	21.3	.192	14.5
30	*	41-2A-8A	19.9	.163	15.4
32	*	41-2A-8B	21.5	.242	10.3
36	*	41-2A-10A	19.5	.184	12.9
		MEAN:	20.1 MPA (2914. PSI)	.189 PCT	13.8 GPA (2.00 MPSI)
		STD. DEV:	1.3 MPA (193. PSI)	.032 PCT	2.2 GPA (.32 MPSI)

TABLE 7-3 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 426

LOG NUMBER(S): 6484-33

ORIENTATION: AXIAL   CRUCIBLE NO: 6

LOG LOCATION: MIDLENGTH-EDGE   FLUENCE: 2.70*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
25	1210	33-2A-101A	27.9	.218	15.4
27	(937 C)	33-2A-101B	18.5	.143	19.2
31	*	33-2A-102A	24.0	.240	11.3
33	*	33-2A-102B	24.1	.186	18.3
37	*	33-2B-101A	32.0	.313	10.8
		MEAN:	25.3 MPA (3669. PSI)	.220 PCT	15.0 GPA (2.17 MPSI)
		STD. DEV:	5.0 MPA (732. PSI)	.064 PCT	3.9 GPA (.56 MPSI)

LOG NUMBER(S): 6484-34

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
25	1210	34-2A-101A	30.9	.271	16.9
29	(937 C)	34-2A-101B	28.1	.235	14.5
31	*	34-2A-102A	26.8	.230	14.5
35	*	34-2A-102B	27.0	.251	10.5
37	*	34-2B-103A	26.2		14.3
		MEAN:	27.8 MPA (4033. PSI)	.247 PCT	14.1 GPA (2.05 MPSI)
		STD. DEV:	1.9 MPA (272. PSI)	.018 PCT	2.3 GPA (.34 MPSI)

LOG NUMBER(S): 6484-41

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
27	1210	41-2A-101A	25.3	.221	15.4
29	(937 C)	41-2A-101B	24.3	.185	16.5
33	*	41-2A-102A	25.5	.280	10.3
35	*	41-2A-102B	24.7	.263	11.3
38	*	41-2B-101A	28.4	.231	15.9
		MEAN:	25.6 MPA (3718. PSI)	.236 PCT	13.9 GPA (2.01 MPSI)
		STD. DEV:	1.6 MPA (237. PSI)	.037 PCT	2.8 GPA (.41 MPSI)

TABLE 7-3 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 426

LOG NUMBER(S): 6484-33

ORIENTATION: RADIAL　　CRUCIBLE NO: 3

LOG LOCATION: MIDLENGTH-CENTER　　FLUENCE: 2.80*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
32	1205	33-2A-33A	14.1	.143	12.5
34	(932 C)	33-2A-33B	13.2	.130	13.1
36	*	33-2A-34A	12.0	.137	10.1
38	*	33-2A-34B	14.1	.155	11.3
		MEAN:	13.3 MPA (1935. PSI)	.141 PCT	11.7 GPA (1.70 MPSI)
		STD. DEV:	1.0 MPA (141. PSI)	.011 PCT	1.3 GPA (.19 MPSI)

LOG NUMBER(S): 6484-34

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
32	1205	34-2A-33A	17.9	.188	10.3
34	(932 C)	34-2A-33B	18.4	.172	12.2
38	*	34-2A-34A	17.7	.185	12.2
36	*	34-2A-34B	17.5	.186	11.7
		MEAN:	17.9 MPA (2595. PSI)	.183 PCT	11.6 GPA (1.68 MPSI)
		STD. DEV:	.4 MPA (57. PSI)	.007 PCT	.9 GPA (.13 MPSI)

LOG NUMBER(S): 6484-41

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
32	1205	41-2A-46A	18.3	.183	11.8
34	(932 C)	41-2A-46B	18.2	.192	11.4
36	*	41-2B-56A	18.0	.205	10.0
38	*	41-2B-56B	19.6	.177	14.2
		MEAN:	18.5 MPA (2685. PSI)	.189 PCT	11.9 GPA (1.72 MPSI)
		STD. DEV:	.7 MPA (103. PSI)	.012 PCT	1.7 GPA (.25 MPSI)

TABLE 7-3 (Continued)

GRAPHITE GRADE: H-451

LOT NUMBER: 426

LOG NUMBER(S): 6484-33

ORIENTATION: RADIAL CRUCIBLE NO: 8

LOG LOCATION: MIDLENGTH-EDGE FLUENCE: 2.00*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
27	1105	33-2A-133A	17.1	.113	21.3
35	(832 C)	33-2A-133B	22.0	.240	10.4
33	*	33-2A-134A	21.7	.189	14.1
38	*	33-2A-134B	20.7	.171	18.1
29	*	33-2A-135A	24.4	.221	14.1
		MEAN:	21.2 MPA (3073. PSI)	.187 PCT	15.6 GPA (2.26 MPSI)
		STD. DEV:	2.7 MPA (388. PSI)	.049 PCT	4.2 GPA (.61 MPSI)

LOG NUMBER(S): 6484-34

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
27	1105	34-2A-133A	27.3	.265	11.6
31	(832 C)	34-2A-133B	18.8	.226	9.5
33	*	34-2A-134A	23.9	.243	15.0
37	*	34-2A-134B	17.1	.138	16.0
		MEAN:	21.8 MPA (3155. PSI)	.218 PCT	13.0 GPA (1.89 MPSI)
		STD. DEV:	4.7 MPA (680. PSI)	.056 PCT	3.0 GPA (.44 MPSI)

LOG NUMBER(S): 6484-41

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
29	1105	41-2A-160A	21.8	.256	12.1
31	(832 C)	41-2A-160B	19.4	.248	9.0
35	*	41-2A-162A	22.0	.270	9.8
37	*	41-2A-162B	17.3	.151	17.6
		MEAN:	20.1 MPA (2922. PSI)	.231 PCT	12.1 GPA (1.76 MPSI)
		STD. DEV:	2.2 MPA (319. PSI)	.054 PCT	3.9 GPA (.56 MPSI)

TABLE 7-4
TENSILE PROPERTIES OF TS-1240 GRAPHITE IRRADIATED
IN CAPSULE OG-3

GRAPHITE GRADE: TS1240

LOT NUMBER: 1

LOG NUMBER(S): 5651-73

ORIENTATION: RADIAL   CRUCIBLE NO: 4

LOG LOCATION: MIDLENGTH-CENTER   FLUENCE: 5.90*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
7	1515	T-40157	13.2	.110	13.2
7	(1242 C)	T-40159	13.9	.119	14.1
8	*	T-40161	16.0	.117	14.6
8	*	T-40163	15.9	.112	15.6
9	1500	T-40165	16.8	.154	12.0
9	(1227 C)	T-40167	13.9	.120	13.0
10	*	T-40169	14.7	.099	21.1
10	*	T-40171	17.4	.160	12.6
		MEAN:	15.2 MPA (2209. PSI)	.124 PCT	14.5 GPA (2.11 MPSI)
		STD. DEV:	1.5 MPA (221. PSI)	.022 PCT	2.9 GPA (.42 MPSI)

TABLE 7-5
TENSILE PROPERTIES OF H-327 GRAPHITE IRRADIATED
IN CAPSULE OG-3

GRAPHITE GRADE: H-327

LOT NUMBER: --

LOG NUMBER(S): 4974-03

ORIENTATION: AXIAL — CRUCIBLE NO: 2

LOG LOCATION: MIDLENGTH-CENTER — FLUENCE: 7.20*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
29	960	T-251	16.8	.110	19.1
29	(687 C)	T-252	10.9	.078	17.7
30	*	T-253	16.2	.154	14.7
30	*	T-254	16.8	.147	14.4
31	940	T-255	15.5	.113	18.1
31	(667 C)	T-256	18.4	.135	20.2
32	*	T-257	12.1	.121	13.8
32	*	T-258	15.1	.135	15.0
33	*	T-259	14.4	.090	22.7
33	*	T-260	14.9	.090	22.0
		MEAN:	15.1 MPA (2194. PSI)	.117 PCT	17.8 GPA (2.58 MPSI)
		STD. DEV:	2.3 MPA (327. PSI)	.026 PCT	3.2 GPA (.47 MPSI)

ORIENTATION: AXIAL — CRUCIBLE NO: 2

LOG LOCATION: MIDLENGTH-CENTER — FLUENCE: 4.60*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
14	1015	T-317	18.2	.140	18.0
14	(742 C)	T-318	13.6	.105	16.3
15	*	T-319	17.2	.135	14.6
15	*	T-320	12.7	.114	18.0
16	985	T-321	13.5	.116	18.0
16	(712 C)	T-322	17.2	.110	21.2
17	*	T-323	16.7	.126	17.5
17	*	T-324	15.4	.115	18.4
		MEAN:	15.6 MPA (2257. PSI)	.120 PCT	17.8 GPA (2.58 MPSI)
		STD. DEV:	2.1 MPA (303. PSI)	.012 PCT	1.9 GPA (.27 MPSI)

TABLE 7-5 (Continued)

GRAPHITE GRADE: H-327

LOT NUMBER: --

LOG NUMBER(S): 4974-03

ORIENTATION: RADIAL — CRUCIBLE NO: 2

LOG LOCATION: MIDLENGTH-CENTER — FLUENCE: 4.60*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
24	955	T-411	10.3	.121	9.6
24	(682 C)	T-412	4.1	.165	
25	*	T-413	2.4	.054	
25	*	T-414	9.8	.160	7.5
26	*	T-415	7.8	.100	9.3
26	*	T-416	8.9	.135	6.7
27	*	T-417	7.8	.161	5.6
27	*	T-418	4.5	.100	
28	*	T-419	10.6	.134	11.1
28	*	T-420	7.5	.100	8.6
		MEAN:	7.4 MPA (1070. PSI)	.123 PCT	8.4 GPA (1.21 MPSI)
		STD. DEV:	2.8 MPA (408. PSI)	.035 PCT	1.9 GPA (.27 MPSI)

ORIENTATION: RADIAL — CRUCIBLE NO: 6

LOG LOCATION: MIDLENGTH-CENTER — FLUENCE: 5.40*10EXP 25 N/M**2, E>0.18 MEV

HOLE NO.	MEAN IRR. TEMP. (K)	SPECIMEN NUMBER	TENSILE STRENGTH (MPA)	FRACTURE STRAIN (PCT)	YOUNG'S MODULUS (GPA)
14	1250	T-421	9.1	.145	8.0
14	(977 C)	T-422	10.8	.163	9.0
15	*	T-423	10.3	.150	9.2
15	*	T-424	8.6	.148	8.0
16	*	T-425	5.9	.090	
16	*	T-426	9.2	.140	8.5
23	1220	T-427	3.8	.161	
23	(947 C)	T-428	7.6	.148	7.1
		MEAN:	8.2 MPA (1184. PSI)	.143 PCT	8.3 GPA (1.20 MPSI)
		STD. DEV:	2.3 MPA (339. PSI)	.023 PCT	.8 GPA (.11 MPSI)

TABLE 7-6
SUMMARY OF TENSILE PROPERTY DATA FOR H-451 GRAPHITE IRRADIATED IN CAPSULES OG-1, OG-2, AND OG-3

				Irradiation Conditions		Ultimate Tensile Strength			Young's Modulus		
Lot	Log No.	Orien-tation	Location in Log	Mean Irrad. Temp. (K)	Fluence ($\times 10^{25}$ n/m^2) ($E > 29$ fJ)$_{HTGR}$	Observed Value ± Std. Dev. (MPa)	Percent Increase ± Std. Dev.	Coefficient of Variation (%)	Observed Value ± Std. Dev. (GPa)	Percent Increase ± Std. Dev.	Coefficient of Variation (%)
266	5651-28	Axial	Midlength-center	--	0	10.8 ± 0.9	--	8	7.9 ± 0.6	--	8
				890	1.4	16.7 ± 1.8	55 ± 17	11	18.1 ± 1.4	131 ± 18	8
				870	2.0	17.1 ± 1.2	59 ± 11	7	15.3 ± 0.8	95 ± 10	5
				860	2.6	17.1 ± 2.2	59 ± 21	13	17.5 ± 1.4	123 ± 18	8
				880	5.5	18.2 ± 1.4	68 ± 13	8	16.8 ± 2.7	114 ± 34	16
				1200	3.0	16.3 ± 1.9	52 ± 17	12	14.2 ± 1.7	81 ± 21	12
				1200	5.3	19.1 ± 1.8	78 ± 17	9	17.6 ± 1.0	124 ± 13	6
				1200	8.5	18.9 ± 4.0	75 ± 37	21	21.2 ± 2.8	170 ± 36	13
				1630	3.2	15.4 ± 0.8	43 ± 7	5	13.0 ± 0.9	65 ± 11	7
				1600	9.0	19.6 ± 2.6	81 ± 24	13	17.3 ± 4.1	119 ± 52	24
		Radial	Midlength center	--	0	11.5 ± 1.7	--	15	7.0 ± 0.3	--	4
				1190	2.8	18.3 ± 1.9	58 ± 16	10	13.0 ± 0.9	88 ± 13	7
				1200	8.5	24.2 ± 2.7	110 ± 24	11	23.2 ± 2.7	236 ± 39	12
408	5651-86	Axial	Midlength-center	--	0	12.9 ± 1.7	--	13	7.4 ± 0.7	--	9
				940	4.6	17.2 ± 2.2	33 ± 17	13	12.5 ± 1.6	69 ± 21	13
				1150	4.1	16.9 ± 1.8	31 ± 14	11	12.6 ± 2.5	70 ± 34	20
				1250	5.5	20.6 ± 2.2	59 ± 17	11	17.1 ± 3.1	131 ± 42	18
				1630	5.8	20.8 ± 3.1	61 ± 24	15	14.3 ± 3.3	93 ± 45	23
			Midlength-edge	--	0	17.4 ± 1.5	--	9	8.3 ± 0.7	--	8
				900	4.6	24.8 ± 2.2	43 ± 13	9	17.6 ± 3.7	111 ± 45	21
				1150	4.1	25.0 ± 2.2	44 ± 13	9	15.3 ± 3.7	84 ± 45	24
		Radial	Midlength-center	--	0	12.2 ± 1.6	--	13	7.2 ± 0.8	--	11
				1120	4.1	16.7 ± 3.6	37 ± 30	22	12.3 ± 1.3	71 ± 18	11
				1200	5.5	21.7 ± 2.9	77 ± 24	13	15.4 ± 2.5	115 ± 35	16
426	6484-33	Axial	Midlength-center	--	0	16.4 ± 1.4	--	8	7.8 ± 0.8	--	10
				1210	2.7	23.7 ± 3.0	45 ± 18	13	14.3 ± 1.5	83 ± 19	10
			Midlength-edge	--	0	18.6 ± 1.9	--	10	9.3 ± 1.4	--	15
				1210	2.7	25.3 ± 5.0	36 ± 27	20	15.0 ± 3.9	61 ± 42	26
		Radial	Midlength-center	--	0	8.5 ± 2.4	--	28	6.3 ± 0.5	--	8
				1210	2.8	13.3 ± 1.0	56 ± 12	8	11.7 ± 1.3	86 ± 21	11
			Midlength-edge	--	0	16.6 ± 1.2	--	7	7.6 ± 0.7	--	9
				1110	2.0	21.2 ± 2.7	28 ± 16	13	15.6 ± 4.2	105 ± 55	27
	6484-34	Axial	Midlength-center	--	0	12.9 ± 2.2	--	17	7.5 ± 0.7	--	9
				1210	2.7	20.8 ± 2.6	61 ± 20	13	12.1 ± 1.5	61 ± 20	12
			Midlength-edge	--	0	18.5 ± 1.3	--	7	8.7 ± 0.9	--	10
				1210	2.7	27.8 ± 1.9	50 ± 10	7	14.1 ± 2.3	62 ± 26	16
		Radial	Midlength-center	--	0	13.3 ± 0.9	--	6	7.0 ± 0.5	--	6
				1210	2.8	17.9 ± 0.4	35 ± 3	2	11.6 ± 0.9	66 ± 13	8
			Midlength-edge	--	0	16.5 ± 1.7	--	10	7.3 ± 0.5	--	7
				1110	2.0	21.8 ± 4.7	32 ± 28	22	13.0 ± 3.0	78 ± 41	23
	6484-41	Axial	Midlength-center	--	0	14.0 ± 1.3	--	9	7.7 ± 0.6	--	8
				1210	2.7	20.1 ± 1.3	44 ± 9	6	13.8 ± 2.2	79 ± 29	16
			Midlength-edge	--	0	16.8 ± 1.3	--	8	8.1 ± 0.7	--	8
				1210	2.7	25.6 ± 1.6	52 ± 10	6	13.9 ± 2.8	72 ± 35	20
		Radial	Midlength-center	--	0	11.6 ± 1.7	--	14	6.4 ± 0.6	--	9
				1210	2.8	18.5 ± 0.7	59 ± 6	4	11.9 ± 1.7	86 ± 27	14
			Midlength-edge	--	0	14.5 ± 1.1	--	8	7.0 ± 0.6	--	9
				1110	2.0	20.1 ± 2.2	39 ± 15	11	12.1 ± 3.9	73 ± 56	32

TABLE 7-7
SUMMARY OF TENSILE PROPERTY DATA FOR TS-1240 GRAPHITE IRRADIATED IN CAPSULES OG-1, OG-2, AND OG-3

Lot	Log No.	Orientation	Location in Log	Irradiation Conditions		Ultimate Tensile Strength			Young's Modulus		
				Mean Irrad. Temp. (K)	Fluence (X 10^{25} n/m^2) (E > 29 fJ)$_{HTGR}$	Observed Value ± Std. Dev. (MPa)	Percent Increase ± Std. Dev.	Coefficient of Variation (%)	Observed Value ± Std. Dev. (GPa)	Percent Increase ± Std. Dev.	Coefficient of Variation (%)
1	5651-73	Axial	Midlength-center	--	0	10.8 ± 1.7	--	16	6.2 ± 0.7	--	11
				890	1.2	12.7 ± 3.1	17 ± 29	24	11.9 ± 2.2	91 ± 36	18
				1040	1.7	14.3 ± 2.7	32 ± 25	19	11.9 ± 1.2	91 ± 19	10
				1190	2.5	14.6 ± 1.8	35 ± 16	12	11.4 ± 0.9	84 ± 14	8
				1380	2.9	13.1 ± 3.7	21 ± 34	28	11.7 ± 1.4	88 ± 23	12
		Radial	Midlength-center	--	0	9.5 ± 2.1	--	22	6.2 ± 0.8	--	13
				1080	1.7	13.5 ± 2.3	41 ± 24	17	10.3 ± 1.8	67 ± 29	17
				1515	5.9	15.2 ± 1.5	60 ± 16	10	14.5 ± 2.9	134 ± 47	20

TABLE 7-8
SUMMARY OF TENSILE PROPERTY DATA FOR H-327 GRAPHITE IRRADIATED IN CAPSULES OG-1, OG-2, AND OG-3

				Irradiation Conditions		Ultimate Tensile Strength			Young's Modulus		
Lot	Log No.	Orien-tation	Location in Log	Mean Irrad. Temp. (K)	Fluence (x 10^{25} n/m^2) (E > 29 fJ)$_{HTGR}$	Observed Value ± Std. Dev. (MPa)	Percent Increase ± Std. Dev.	Coefficient of Variation (%)	Observed Value ± Std. Dev. (GPa)	Percent Increase ± Std. Dev.	Coefficient of Variation (%)
FSV-42	4974-03	Axial	Midlength-center	--	0	9.1 ± 1.1	--	12	9.0 ± 0.8	--	9
				1010	2.2	13.4 ± 2.6	47 ± 29	19	15.5 ± 2.8	73 ± 31	18
				1000	4.6	15.6 ± 2.1	71 ± 23	13	17.8 ± 1.9	98 ± 21	11
				950	7.2	15.1 ± 2.3	66 ± 25	15	17.8 ± 3.2	98 ± 36	18
				1060	3.6	16.7 ± 2.4	83 ± 26	14	19.1 ± 3.4	113 ± 38	18
				1110	4.5	16.8 ± 2.5	84 ± 27	15	17.6 ± 2.2	96 ± 25	13
				1150	2.3	14.7 ± 1.9	61 ± 21	13	20.8 ± 1.9	132 ± 21	9
				1270	2.7	13.4 ± 2.3	47 ± 25	17	17.1 ± 2.8	91 ± 31	16
				1260	5.7	15.3 ± 3.2	68 ± 35	21	16.0 ± 2.1	78 ± 24	13
				1390	6.3	13.8 ± 4.0	52 ± 44	29	16.0 ± 2.1	78 ± 23	13
			Midlength-edge	--	0	15.1 ± 2.0	--	13	13.3 ± 1.7	--	13
				940	2.6	21.7 ± 1.9	44 ± 13	9	26.5 ± 2.3	99 ± 17	9
				1060	1.9	19.2 ± 1.7	27 ± 11	9	21.4 ± 1.8	61 ± 13	8
				1340	3.3	19.5 ± 1.8	29 ± 12	9	22.3 ± 1.3	67 ± 10	6
		Radial	Midlength-center	--	0	5.7 ± 2.0	--	35	4.4 ± 0.6	--	14
				960	4.6	7.4 ± 2.8	30 ± 50	38	8.4 ± 1.9	91 ± 42	23
				1260	3.0	6.6 ± 1.4	17 ± 24	21	8.5 ± 1.4	92 ± 31	16
				1240	5.4	8.2 ± 2.3	44 ± 40	28	8.3 ± 0.8	89 ± 18	10

TABLE 7-9

BETWEEN-LOG VARIATIONS IN IRRADIATION-INDUCED STRENGTH INCREASE OF H-451 GRAPHITE, LOT 426

Orientation	Crucible	Irrad. Temp (K)	Fluence x 10^{-25} (n/m^2, E>29fJ, HTGR)	Mean Strength Increase (%)			Is Variation Significant at 95% Confidence Level?
				Log 6484-33	Log 6484-34	Log 6484-41	
Radial	8	1110	2.01	28	32	39	No
Radial	3	1200	2.83	57	35	60	Yes
Axial	6	1210	2.68	41	56	48	No

TABLE 7-10

WITHIN-LOG VARIATIONS IN IRRADIATION-INDUCED STRENGTH INCREASE OF H-451 GRAPHITE, AXIAL ORIENTATION

Lot	Crucible	Irrad. Temp (K)	Neutron Fluence $\times 10^{-25}$ (n/m^2, E>29fJ, HTGR)	Mean Strength Increase (%)		Is Variation Significant at 95% Confidence Level?
				Center of Logs	Edge of Logs	
408	1	940	4.6	33	43	No
408	8	1150	4.1	31	44	No
426	6	1210	2.7	50	46	No

8. IMPACT OF TEST DATA ON CURRENT DESIGN METHODS

8.1. DIMENSIONAL CHANGE

The available H-451 dimensional change data now extend through fuel element lifetime fluence limits at higher temperatures. In addition, the new H-451 high fluence data from OG-3 differ from the high fluence H-429 graphite data. Therefore, all H-429 graphite dimensional change data were deleted from the data base, OG-3 H-451 data were added, and the data base fit to a polynomial expression in fluence and temperature by the computer code FUNFIT. The resultant dimensional change surface was a better fit to the H-451 data as evidenced by a decrease of 20% in the standard deviation of the data points from the curve in the axial direction. Polynomial coefficients for the new design curves are listed in Table 8-1a for H-451 graphite and in Table 8-1b for H-327 graphite.

Compared with the design curves currently in use, the new isothermal cuts through the dimensional change surfaces reflect 0.1% to 0.3% more contraction at 6×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$ in the axial direction. At a fluence of 8×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$, the curves show 0.1 to 0.4% more contraction at temperatures of 1225 K to 1425 K. Dimensional change in the radial direction is characterized by the earliest crossover to net expansion at an irradiation temperature of 1275 K and neutron fluence of about 9×10^{25} n/m^2 (E > 29 fJ)$_{HTGR}$. At higher temperatures, the crossover is delayed to higher fluences.

There are insufficient data on TS-1240 graphite to make a polynomial fit. Measurements so far show dimensional changes smaller by 30% to 50% than H-451 graphite.

8.2. THERMAL EXPANSIVITY

All current data on the fractional change in thermal expansivity ($\Delta\alpha/\alpha$) of H-451, TS-1240, and SO-818 graphites were used in a least-squares procedure to fit the following polynomial:

$$\Delta\alpha/\alpha = (0.27830 - 4.2734 \times 10^{-4}\, T + 1.7815 \times 10^{-7}\, T^2)\, \Phi$$
$$- 2.0664 \times 10^{-2}\, \Phi^{-2} + 1.3601 \times 10^{-3}\, \Phi^3 \quad ,$$

where T is the irradiation temperature (°C) and Φ is the fast neutron fluence $[10^{25}\ n/m^2\ (E > 29\ fJ)_{HTGR}]$.

This expression may be used to estimate the irradiation-induced change in thermal expansivity for both axial and radial orientations at temperatures between 800 K and 1600 K and fluences up to 8 x 10^{25} n/m^2. The changes predicted from the equation are very close to the emprical curves currently being used.

8.3. THERMAL CONDUCTIVITY

The thermal conductivity values obtained in the OG-3 experiment are in good agreement with the design values presently in use (Ref. 5), and no changes are required. The tests in which specimens were successively irradiated at two different temperatures verified the model presently being used to account for changes in irradiation temperature.

8.4. MECHANICAL PROPERTIES

Young's modulus values measured on H-451 and TS-1240 specimens irradiated in the OG-3 capsule agree well with the design curves presently in use (Ref. 5), and no changes are needed in the design curves for near-isotropic graphites. Revised design curves for H-327 graphite are shown in Fig. 7-6.

Present design practice assumes that the fractional increase in tensile strength, S, is proportional to the square root of the fractional increase in Young's modulus, E. The new data indicate that this relationship is not exact for all graphites (see Section 7.2). Revised analysis gives the following relationships:

H-451, axial and radial: $S/S_o = (E/E_o)^{0.64}$

TS-1240, axial and radial: $S/S_o = (E/E_o)^{0.48}$

H-327, axial: $S/S_o = (E/E_o)^{0.67}$

H-327, radial: $S/S_o = (E/E_o)^{0.40}$

Thus, the strength increase for H-451 graphite is slightly higher than currently assumed, but that of TS-1240 graphite is essentially unchanged.

TABLE 8-1(a)
POLYNOMIAL COEFFICIENT FOR DIMENSIONAL CHANGE DESIGN EQUATIONS: H-451 GRAPHITE

$$\varepsilon^o = (C_1 + C_2T_\phi + C_3T_\phi^2 + C_4T_\phi^3 + C_5T_\phi^4)\,\Phi$$
$$+ (C_6 + C_7T_\phi + C_8T_\phi^2 + C_9T_\phi^3 + C_{10}T_\phi^4)\,\Phi^2 + C_{16}\,\Phi^2T^5$$
$$+ (C_{11} + C_{12}T_\phi + C_{13}T_\phi^2 + C_{14}T_\phi^3 + C_{15}T_\phi^4 + C_{17}T^5 + C_{18}T^6)\,\Phi^3$$

where ε^o = irradiation strain (dimensional change) $\Delta\ell/\ell$ (%)

Φ = fast neutron fluence $(E > 29\ \mathrm{fJ})_{\mathrm{HTGR}}$ $(10^{25}\ \mathrm{n/m^2})$

T_ϕ = average irradiation temperature (°C)

C_i = coefficients determined for each orientation of graphite. Coefficients listed in tables

	H-451	
	Axial	Radial
C_1	1.098172	1.158111
C_2	$-0.9131061 \times 10^{-2}$	$-0.8374059 \times 10^{-2}$
C_3	$+0.2032687 \times 10^{-4}$	$+0.1728673 \times 10^{-4}$
C_4	$-0.1637322 \times 10^{-7}$	$-0.1288228 \times 10^{-7}$
C_5	$+0.4062104 \times 10^{-11}$	$+0.2846460 \times 10^{-11}$
C_6	+0.6525928	+0.3958980
C_7	$-0.5715322 \times 10^{-2}$	$-0.3689394 \times 10^{-2}$
C_8	$+0.1903633 \times 10^{-4}$	$+0.1287180 \times 10^{-4}$
C_9	$-0.2936923 \times 10^{-7}$	$-0.2043258 \times 10^{-7}$
C_{10}	$+0.2049909 \times 10^{-10}$	$+0.1438031 \times 10^{-10}$
C_{11}	$-0.5931751 \times 10^{-2}$	$+0.1306940 \times 10^{-1}$
C_{12}	$-0.6867503 \times 10^{-5}$	$-0.1877240 \times 10^{-3}$
C_{13}	$+0.3302258 \times 10^{-6}$	$+0.1022022 \times 10^{-5}$
C_{14}	$-0.1353233 \times 10^{-8}$	$-0.2709323 \times 10^{-8}$
C_{15}	$+0.2236601 \times 10^{-11}$	$+0.3665231 \times 10^{-11}$
C_{16}	$-0.5213917 \times 10^{-14}$	$-0.3621619 \times 10^{-14}$
C_{17}	$-0.1612017 \times 10^{-14}$	$-0.2369797 \times 10^{-14}$
C_{18}	$+0.4196564 \times 10^{-18}$	$+0.5766467 \times 10^{-18}$

TABLE 8-1(b)
POLYNOMIAL COEFFICIENT FOR DIMENSIONAL CHANGE DESIGN EQUATIONS:
H-327 GRAPHITE

$$\varepsilon^{o} = (C_1 + C_2T_\phi + C_3T_\phi{}^2 + C_4T_\phi{}^3 + C_5T_\phi{}^4)\ \Phi$$
$$+ (C_6 + C_7T_\phi + C_8T_\phi{}^2 + C_9T_\phi{}^3 + C_{10}T_\phi{}^4)\ \Phi^2$$
$$+ (C_{11} + C_{12}T_\phi + C_{13}T_\phi{}^2 + C_{14}T_\phi{}^3 + C_{15}T_\phi{}^4)\ \Phi^3$$

H-327

	Axial	Radial
C_1	-6.901536	0.122708
C_2	$+0.214790 \times 10^{-1}$	$+0.225189 \times 10^{-2}$
C_3	-0.209455×10^{-4}	-0.842109×10^{-5}
C_4	$+0.615816 \times 10^{-8}$	$+0.941604 \times 10^{-8}$
C_5	0.00	$-0.360083 \times 10^{-11}$
C_6	+0.718380	-0.265774
C_7	-0.209419×10^{-2}	-0.531424×10^{-3}
C_8	$+0.179240 \times 10^{-5}$	$+0.344720 \times 10^{-5}$
C_9	-0.485434×10^{-9}	-0.427347×10^{-8}
C_{10}	0.00	$+0.162954 \times 10^{-11}$
C_{11}	-0.356955×10^{-2}	$+0.725128 \times 10^{-1}$
C_{12}	$+0.605363 \times 10^{-5}$	-0.164812×10^{-3}
C_{13}	0.00	0.00
C_{14}	0.00	$+0.204765 \times 10^{-9}$
C_{15}	0.00	$-0.108765 \times 10^{-12}$

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