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**POSTIRRADIATION EXAMINATION
AND EVALUATION OF PEACH BOTTOM
FUEL TEST ELEMENTS FTE-14 AND FTE-15**

by

**J. F. HOLZGRAF, F. McCORD, C. M. MILLER,
B. L. NORMAN, J. J. SAURWEIN, and C. F. WALLROTH**

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ABSTRACT

Peach Bottom fuel test elements FTE-14 and FTE-15 were companion non-accelerated tests of fuel rods and fuel particles representative of the Large High-Temperature Gas-Cooled Reactor (LHTGR). The purpose of the tests was to broaden the data base of H-327 graphite and various fuel types; specifically, UO_2 , UC_2 , weak acid resin UC_xO_y , and several fertile fuel types were tested. The irradiation reached peak fuel temperatures of 1600°C , volume- and time-averaged temperatures of 1300°C , and fast fluence exposures up to $2 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR}. Experimental results were compared with predictions based on accelerated irradiation tests, postirradiation heating, and other Peach Bottom test elements to validate HTGR design codes. The nuclear design predictions were modified by measurements which allowed the verification of thermal design calculations and thermocouple readings.

Fuel kernel migration in all fuel types was overpredicted by design data; only ThC_2 and $(\text{Th,U})\text{O}_2$ fuel kernels showed measurable migration. SiC thinning rates from attack by fission products in UC_2 TRISO particles irradiated in 11 different Peach Bottom test elements indicate overprediction based on out-of-pile design data above 1300°C . Observed outer pyrolytic carbon failure of TRISO particles was related to particle size and coating parameters. Irradiation-induced strain in large H-327 graphite fuel bodies from 12 different test elements revealed less radial and axial shrinkage than predicted for irradiation temperatures between 600° and 1100°C and fast fluence exposures up to $4.2 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR}. The fuel performance and graphite strain predictions would be judged conservative based on these results.

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1. INTRODUCTION

For the development of the Large High-Temperature Gas-Cooled Reactor (LHTGR) concept, an extensive irradiation test program has been carried out over the past two decades in the United States, Europe, and Japan. Accelerated and non-accelerated testing has been used to substantiate fuel and graphite performance predictions for design verification.

Non-accelerated testing was carried out in the Peach Bottom reactor facility, which offered a unique testing environment with a typical HTGR neutron spectrum, helium coolant, and temperature regime. Test elements FTE-14 and FTE-15 were part of the fuel test program in the Peach Bottom reactor, which contained a total of 33 test elements. The objectives of the test program were:

1. To test LHTGR and Fort St. Vrain (FSV) fuel rod and fuel types in a non-accelerated environment at various temperatures and fast fluence exposures of up to $5 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR}.
2. To provide design information on fuel rod and structural graphite performance from a large sample population which would allow statistically significant conclusions.
3. To generate information regarding fuel particle thermal stability, fission product diffusion, and structural stability of reactor components.
4. To validate HTGR design codes with respect to:
 - a. Fluence and depletion.
 - b. Thermal performance of fuels and graphite.

- c. Thermal and Wigner stress and strain in graphite.
- d. Fission product behavior.

FTE-14 and FTE-15 were unique in that they were a demonstration test of the LHTGR fuel rod, which is larger than the FSV type. The fuel was tested in H-327 graphite fuel bodies to very high temperatures (designed for 1440°C versus >1600°C achieved) and moderate fast fluence exposures. This report describes the experiment, gives the irradiation history, and presents the postirradiation examination (PIE) results. Whenever possible, measurements are reported together with confidence estimates and are evaluated against state-of-the-art design predictions.

2. EXPERIMENT DESCRIPTION

FTE-14 and FTE-15 were nearly identical test elements that were manufactured at General Atomic Company (GA) and irradiated in the Peach Bottom reactor. The preirradiation design is outlined in Ref. 2-1. Preirradiation metrology data were obtained from Ref. 2-2 and preirradiation fuel data from Ref. 2-3.

The design of FTE-14 and FTE-15 consisted of three nearly identical six-hole teledial fuel bodies in a standard Peach Bottom driver containment; 198 fuel rods and 19 centrally located spine samples were tested per element. FTE-14 and FTE-15 were assembled with two thermocouples at 1766.6 mm (69.55 in.) total core height [i.e., 1153.2 mm (45.40 in.) active core height].* Thermocouple A was a W/Re type thermocouple located near the spine samples, and thermocouple B was a C/A type thermocouple located near the outer sleeve.

The FTE-14 and FTE-15 assembly is shown in Fig. 2-1.** The detailed drawings for all the test element components are listed in Tables 2-1 and 2-2. The sleeve and upper and lower reflectors were standard Peach Bottom driver element designs; the materials used in these components are listed in Table 2-3. The purge flow in these elements was down the center of the top reflector, through the upper porous plug, down the gap between the sleeve inside diameter and the fuel body outside diameter, through the internal trap in the bottom reflector and the standoff pin, and into the main manifold of the purge system. No individual fission gas release measurements were taken.

* Active core height begins at 664.2 mm (26.15 in.) above the core bed or the start of total core height. Peach Bottom driver fuel commenced at 660.4 mm (26.00 in.) above the core bed. Total core height is referenced throughout this report, if not stated differently.

** Figures and tables appear in Appendixes A and B, respectively.

The fuel zone consisted of three 787.4-mm (31-in.) long fuel bodies of a six-hole teledial configuration which were stacked on top of each other. Bodies 1 and 2 were azimuthally oriented to one another by means of the two thermocouples, the locations of which are shown in the cross section of the fuel body in Fig. 2-2. Body 3 did not contain any thermocouples and therefore was subject to azimuthal movement. Eleven fuel rods were loaded into each of the six teledial holes. Spine samples were loaded into the 19.1-mm (0.75-in.) diameter hole in the center of the bodies. Bodies 2 and 3 had stepped or tapered outside diameters to achieve variable temperatures. A schematic view of all the fuel bodies is shown in Fig. 2-3.

FTE-14 and FTE-15 each contained 198 fuel rods that were carbonized in Al_2O_3 beds. These rods consisted of a closely packed bed of blended fissile and fertile coated fuel particles bonded together in a carbonaceous matrix. The matrix was a blend of 27% to 30% natural flake Asbury 6353 graphite flour and 70% to 73% Barrett 15V coal tar pitch. The matrix was prepared by hot mixing the ingredients to form a homogeneous blend, followed by cooling to room temperature, and then grinding the solid matrix into granules suitable for use in the fuel rod injection equipment. The impurities in the matrix were kept in the low ppm range.

Both the fuel particles and the fuel rods were made in production equipment using the then-available production processes and quality control techniques. The hot matrix was injected into the particle bed with a prototype injection machine similar to that built for manufacturing FSV fuel. After cooling, the fuel rods were removed from the injection die; at this point, the rods were referred to as "green" rods. The green rods were then packed into Al_2O_3 powder beds and subjected to a carbonization treatment.

The carbonization cycle consisted of heating the fuel rods to 750°C in 2 hr in a flowing nitrogen atmosphere and holding at that temperature for 0.5 hr. The fuel rods were then heat treated by passing them through

a furnace, which had a hot zone 1814.4 mm (72 in.) long, at 1800°C and at a rate of 25.4 mm (1 in.) per minute. The atmosphere in the furnace was argon. The cured rods were measured for length and diameter and loaded into the three graphite fuel bodies.

The fuel bodies contained a variety of fuel blends. Table 2-4 shows the location of the various fuel blends, and Table 2-5 gives the preirradiation attributes of the fuel particles. The properties of the fuel rods are presented in Tables 2-6a and 2-6b. The spine samples and their location in FTE-14 and FTE-15 are given in Tables 2-7 and 2-8, respectively.

REFERENCES

- 2-1. Scheffel, W. J., "Design and Operational Evaluation for Fuel Test Elements No. 14 and 15," USAEC Informal Report GA-B12344, Gulf General Atomic, November 3, 1972.
- 2-2. Hanson, D. L., "Phase 3 Test Element Program Pre-Irradiation Data Collected by the Fuel Design Branch," Gulf General Atomic, unpublished data.
- 2-3. Housman, J. J., "Final Report on FTE-14 and FTE-15 Rod Fabrication," Gulf General Atomic, unpublished data.

3. IRRADIATION CONDITIONS

In the analysis of FTE-14 and FTE-15, the calculated absolute power and relative power profiles were corrected using burnup measurements and axial isotope profiles derived from gamma scanning. From the burnup measurements it was determined that the power in FTE-14 was underpredicted, while the power in FTE-15 was predicted correctly. The ratios of the measured to the calculated power on an element average basis were 1.071 ± 0.027 (1σ) and 0.998 ± 0.014 (1σ) for FTE-14 and FTE-15, respectively. The corrected power bias and axial profiles were used to calculate temperatures with the TREVER code. Calculated fluence and power statements in this report were also modified in the following manner:

Parameter	Progressed Power Corrections	
	Absolute	Relative [*]
Temperature	Yes	Yes
Power	Yes	Yes
Flux	Yes	No (correction could be made for thermal flux)
Fast fluence ^{**}	Yes	No (not necessary)
Thermal fluence	Yes	No (correction could be made with Cs-134/Cs-137 ratio)
Burnup	(normalized parameter - all calculated burnups are uncorrected in text; correction could be done with power bias)	

^{*} Axial profile.

^{**} The assumption is made that the region around FTE-14 and FTE-15 is uniformly depressed.

3.1. IRRADIATION HISTORIES

Fuel test elements FTE-14 and FTE-15 began irradiation at 385.4 EFPD.* FTE-14 was in Core 2 position B03-02 from June 18, 1972, through September 14, 1973, for 511.9 EFPD. FTE-15 began irradiation on July 6, 1972, in Core 2 position A03-03, where it remained for 315.8 EFPD; it was then moved to Core 2 position A14-08 for 196.1 EFPD. End of life for this element occurred on October 31, 1974.

The following HTGR design codes simulated the thermal and nuclear irradiation histories:

GAUGE (Ref. 3-1), a two-dimensional (x-y geometry), four group diffusion depletion code, collapses the Peach Bottom core into one layer and calculates the nuclide densities as a function of time and radial core location.

FEVER (Ref. 3-2), a one-dimensional, multigroup diffusion-depletion code, analyzes fuel regions or subregions in the axial direction. (The GAUGE-calculated collapsed nuclide densities are stretched over the axial fuel height. FEVER is used to produce the axial power profile for the thermal analysis. These profiles are corrected as described in Section 3.3.1.)

BUG-2 (Ref. 3-3), a two-dimensional (r-z geometry), multigroup burnup code, models the influence of partially inserted control rods.

TREVER (Ref. 3-4), a one-dimensional heat transfer code, calculates the axial temperature distribution for several specific points along the radial cross section of the fuel test element.

TAC2D (Ref. 3-5), a two-dimensional finite-difference heat transfer code, calculates radial or axial heat transfer characteristics for

* EFPD is defined as equivalent full-power day of 115.0 MW(t), which has been used historically for Core 1 and 2. The power was generated from 804 elements.

specific geometries. The radial temperature profile correlations were determined for input into the TREVER code.

TAC3D (Ref. 3-6), a three-dimensional finite-difference heat transfer code, computes radial and axial heat transfer characteristics. The impact of the variable gaps between the graphite body and sleeve was evaluated for FTE-14 and FTE-15.

GTEPC-2D (Ref. 3-7), a two-dimensional finite element code, models the heat transfer and viscoelastic stress of graphite.

The reactor history for Core 2 was modeled via a step function in several time intervals. Reference 3-8 gives the reactor operation history. Figure 3-1 shows the TREVER-simulated operating parameters, and Fig. 3-2 shows the TREVER-simulated reactor power history. Figures 3-3a and 3-3b display the corrected (see Section 3.3.1) GAUGE power histories for FTE-14 and FTE-15, respectively. Tables 3-1 and 3-2 show summaries of the power, flow, and four group flux histories of FTE-14 and FTE-15, respectively. The time-averaged values are given in Table 3-3.

The temporal root mean square (RMS_t) deviation (Ref. 3-9) represents long-term time variation information stemming from the GAUGE and TREVER selected time intervals. The coolant power factor represents the equivalent coolant channel power obtained by accounting for different power levels from neighboring elements. The GAUGE derived fast flux group has been modified by a factor of 0.85 in order to convert from a cutoff energy of 13.86 fJ used in GAUGE to the value of 28.84 fJ used for HTGR spectra. Consequently, the 0.15 fraction of the fast flux falls into the energy range between 13.86 fJ and 28.84 fJ.

3.2. FLUENCE

3.2.1. Fluence Calculations

Fast and thermal fluence values are calculated from GAUGE average values and FEVER axial profile information as described in Ref. 3-10. The fluence values for fuel rods and spine samples are presented in Tables 3-4 and 3-5, respectively. Calculated fast and thermal fluence values were corrected for the power bias discussed in Section 3.3.1, but not for relative power profiles.

The corrected fluence values for FTE-14 and FTE-15 are given in Table 3-6. There is an inversion in the fuel body ranking from highest to lowest fuel body fluence between body 1 and body 3 for FTE-14 and FTE-15. Body 2 always achieved the highest fluence values with the lowest axial fluence gradients. Owing to the longer irradiation cycle for FTE-15, both axial and temporal RMS terms are greater than for FTE-14.

3.2.2. Fluence Measurements

FTE-14 and FTE-15 were two out of four test elements in the Peach Bottom reactor to contain dosimetry packages. These dosimeters (Fig. 3-4) were assembled with the following graphite tensile assemblies:

Element	Tensile Sample	Core Height (mm)	Dosimeter Status
FTE-14	H887-19	1294	Three dosimeters recovered intact.
FTE-14	H888-22	1753	Two dosimeters stuck in crucible.
FTE-15	11952-19	1296	Two dosimeters recovered intact.
FTE-15	11953-22	1756	Undetermined number of dosimeters stuck in crucible.

The axial locations and irradiation conditions of the graphite tensile samples are given in Tables 2-7 and 2-8.

A typical dosimetry package is shown in Fig. 3-5. Each package contained Ni-0.4% Co, vanadium, and V-Fe wires encapsulated in a niobium can which was back-filled with argon. During the disassembly of the element, the dosimeters were partially recovered. In FTE-14 three dosimeters were removed from graphite sample H887-19 with no difficulty. Two dosimeters in spine sample H888-22 from body 2 were stuck in crucible piggyback holes 1 and 8 as a result of high-temperature reactions between the niobium can and the graphite. The dosimeter from piggyback hole 1 was sent for analysis in pieces because of unloading damage, and the one in hole 8 was left in the crucible and submitted for in situ analysis. The unloading of dosimetry in FTE-15 revealed a similar problem of crucible and graphite reactions in sample 11953-22, which was located in high-temperature body 2. In this case the whole crucible was sent for in situ analysis. No problems were encountered in unloading sample 11952-19 from body 1 in FTE-15, and two dosimeters were recovered intact.

The dosimetry packages from body 1 in both FTE-14 and FTE-15 were unloaded from their niobium containers without difficulty. The V-Fe wire was embrittled in both cases, and the Ni-0.4% Co wire had reacted slightly with the containment. Also, in FTE-15 one piece of V-Fe wire had bonded to the other iron wire. Each of the wires was gamma counted for pertinent isotopes, and this information was fed into the DOSE-1 program (Ref. 3-11), which back-calculated the flux and fluence using the known reactor power history. These results are summarized in Table 3-7. In all cases only the pure iron wire was used to calculate the fast fluence because of insufficient archive information on the Fe-V wires.

The analysis of the body 2 dosimetry from both FTE-14 and FTE-15 proved to be too difficult because of questionable recovery of various wires. In FTE-14 the dosimeter that was left in the crucible (hole 8) was

recovered by muffle furnace burning of the crucible and acid dissolution of the residue. Aliquot sampling of this solution was then submitted for gamma counting. The Co-60 and Mn-54 activities were much lower than expected, and therefore the results are not considered reliable. The dosimeter recovered from hole 1 of crucible H884-22 had reasonable thermal fluence values from the Co-60 activity, but because there was no measurable Mn-54 the fast fluence could not be calculated.

The recovery of the FTE-15 dosimeters from crucible 11953-22 was performed with the same muffle furnace burn and acid leach technique used for FTE-14. The thermal flux and fluence measurements from the hole 1 and 8 aliquot solutions showed a probable loss of Ni-Co wires from hole 8, and therefore only the results of hole 1 are reported. The Mn-54 derived fast fluence results from the analysis of holes 1 and 8 in crucible 11953-22 are presented in two sets in Table 3-7. The first represents the values if the Mn-54 is assumed to come from both the iron and V-Fe wires, and the second gives the values assuming the activity is from the iron wire alone and the Fe-V wire was lost.

The comparison of the fast and thermal fluences in Table 3-7 shows good agreement between calculated and measured fast fluences and poor agreement for the thermal fluences. The observed bias of $6.4\% \pm 9.6\%$ (2σ) for the fast fluence is ignored due to the large uncertainty; however, the bias of $-24.4\% \pm 6.5\%$ (2σ) for the thermal fluence is significant from a statistical viewpoint. This result is rejected, however, in view of the more precise burnup measurements, which have been used to correct the nuclear and thermal predictions.

A summary of the calculated and measured results is given in Table 3-8.

3.3. TEMPERATURE

3.3.1. Determination of Test Element Power

Two refinements to fuel test element thermal analysis which have been introduced for the analysis of FTE-14 and FTE-15 are the inclusion of power tilts to account for azimuthal power variations resulting from non-uniform heavy metal loadings and the use of gamma scan information and burnup measurements to establish axial power profiles and element average power. It is hypothesized that these refinements will enable more reliable temperatures to be calculated.

The power generated at a given axial location (z) in a given fuel hole (h) of fuel test element x at time point t is given by the equation

$$P_{x,h,z,t} = (CPF_{x,t})(TILT_{h,t})(APF_{h,z,t})(\bar{P}_{core,t}) \quad , \quad (3-1)$$

where $CPF_{x,t} = \bar{P}_{x,t} / \bar{P}_{core,t}$, element average (radial) power factor at time t,

$TILT_{h,t} = \bar{P}_{h,t} / \bar{P}_{x,t}$, average power tilt for fuel hole h at time t,

$APF_{h,z,t} = P_{h,z,t} / \bar{P}_{h,t}$, axial power factor for axial location z of fuel hole h at time t,

$P_{subscript} =$ power generated by entity denoted by subscript.

The power tilt is calculated as a function of the fuel hole, axial position, and time using the equation

$$TILT_{h,z,t} = \frac{\sum_{i=1}^4 \left[f_i(W_{h,z,t})_i \sum_{j=1}^4 \phi_{j,t} \sigma_{i,j} \right]}{\sum_{i=1}^4 \left[f_i(W_{x,z,t})_i \sum_{j=1}^4 \phi_{j,t} \sigma_{i,j} \right]} \quad , \quad (3-2)$$

where $(i=1,4)$ = four fissionable nuclides (U-233, U-235, Pu-239, Pu-241),

$(j=1,4)$ = four energy groups for which GAUGE computes neutron flux,

f_i = relative power generated by fission of nuclide i ,

$\phi_{j,t}$ = neutron flux for energy group j at time t ,

$\sigma_{i,j}$ = fission micro cross section for nuclide i and energy group j ,

$(w_{h,z,t})_i$ = nuclide density at axial position z of fuel hole h at time t ,

$(w_{x,z,t})_i$ = element average nuclide density for axial position z at time t .

The average power tilt for a given fuel hole is given by

$$\overline{\text{TILT}}_{h,t} = \frac{\sum_{z=1}^n \text{TILT}_{h,z,t}}{n},$$

where n is the number of axial positions z . The power tilts for FTE-14 and FTE-15 are given in Table 3-9. Because the uranium loadings do not vary greatly from fuel hole to fuel hole in these elements, the power tilts are fairly small, ranging from 0.962 to 1.021 in FTE-14 and 0.944 to 1.044 in FTE-15.

The axial power profiles used in the thermal analysis of FTE-14 and FTE-15 were obtained through modifications to FEVER power profiles based on actual fuel loadings and gamma scan information. The FEVER

power profiles were generated for the standard Peach Bottom fuel elements, each of which had uniform heavy metal loadings along its length. Since the heavy metal loadings were not uniform throughout the length of each fuel hole in FTE-14 and FTE-15, it was necessary to adjust the FEVER profiles in order to obtain predicted axial power profiles for these elements. These predicted profiles were obtained by applying the following correction to the FEVER profiles:

$$\begin{aligned} \text{APF}_{h,z,t} = (\text{APF}_{x,z,t}) \left(\frac{\text{TILT}_{h,z,t}}{\text{TILT}_{h,t}} \right) \left[(f_1)_t \left(\frac{U_z}{U_x} \right) \right. \\ \left. + (f_2)_t \left(\frac{\text{Th}_z}{\text{Th}_x} \right) \right] , \end{aligned} \quad (3-3)$$

where $(f_1)_t$ = fraction of total fissions occurring in fed U-235, Pu-239, and Pu-241 at time point t ,

$(f_2)_t$ = fraction of total fissions occurring in U-233 and bred U-235 at time point t ,

U_z = beginning of life average uranium loading at axial position z ,

U_x = beginning of life element average uranium loading,

Th_z = beginning of life average thorium loading at axial position z ,

Th_x = beginning of life element average thorium loading.

Every fuel rod in fuel hole 1 of FTE-15 and 26 of the 33 fuel rods in fuel hole 1 of FTE-14 were gamma scanned in the hot cell at GA, yielding the counts per minute (CPM) for a variety of nuclides. The CPM values for fuel rods which were not scanned were obtained through

interpolation. Since Cs-137 and Zr-95 have very long (~ 30 -yr) and very short (~ 65 -day) half-lives, respectively, it was concluded that the normalized Cs-137 profiles would be representative of the time-averaged power profiles and the Zr-95 profiles would be representative of the end of life axial power distributions. However, since the FTE-14 and FTE-15 rods were scanned after most of the zirconium had decayed away and the scanning time was insufficient to obtain a large Zr-95 peak, the errors associated with the CPM values for Zr-95 are relatively large. Due to the magnitude of these errors ($2\sigma \approx 10\%$), it was decided not to use the Zr-95 profiles to represent the end of life axial power distributions in the thermal analysis.

A number of fuel rods in each of the other fuel holes of FTE-14 and FTE-15 were also gamma scanned. However, in each case the sampling was insufficient to provide a normalized profile, and uncertainties concerning the relationship of gamma scan data from fuel hole to fuel hole caused by gamma ray attenuation and non-standardization of gamma scans (in FTE-14) precluded the use of fuel hole 1 data to fill in the missing data for other fuel holes. Therefore, the time-averaged measured axial power profiles for fuel holes 2 through 6 of both FTE-14 and FTE-15 were obtained from the time-averaged measured power (Cs-137) profiles and power tilts for fuel hole 1 using the following equation:

$$\left(\text{APF}_{h=2-6,z,\bar{t}} \right)_{\text{Meas.}} = \left(\text{APF}_{h=1,z,\bar{t}} \right)_{\text{Meas.}} \cdot \frac{\text{TILT}_{h=2-6,z,\bar{t}}}{\text{TILT}_{h=1,z,\bar{t}}} \quad (3-4)$$

The time-averaged measured axial power profiles for each fuel hole in FTE-14 and FTE-15 are shown in Figs. 3-6 and 3-7, respectively.

The axial power factors used in the TREVER simulation were obtained by multiplying each predicted axial power factor by the ratio of the appropriate factors from the time-averaged measured power profile and

the time-averaged predicted profile:

$$APF_{h,z,t} = (APF_{h,z,t})_{Pred.} \cdot f_{h,z} \quad , \quad (3-5)$$

where

$$f_{h,z} = \frac{(APF_{h,z,\bar{t}})_{Meas.}}{(APF_{h,z,\bar{t}})_{Pred.}} \quad . \quad (3-6)$$

The time-averaged measured and predicted power profiles for FTE-14 and FTE-15 are compared in Figs. 3-8 and 3-9, respectively. A comparison of the predicted and measured end of life axial power profiles for FTE-15 is given in Fig. 3-10. As can be seen, the errors on the measurements are relatively large, and for this reason the measured profile was not used to describe the axial power distribution at end of life in the thermal analysis.

Correction factors for the element average (radial) power (CPF_x) calculated by GAUGE for FTE-14 and FTE-15 were obtained using burnup measurements on loose fuel particles taken from spine samples. Measured burnups were obtained at three axial locations (one per fuel body) for both FTE-14 and FTE-15. Since burnup is directly related to power,

$$\frac{(CPF_x)_{GAUGE} (APF_{1,z,\bar{t}})_{Pred.}}{(CPF_x)_{Actual} (APF_{1,z,\bar{t}})_{Meas.}} = \frac{(F_{1,z})_{Pred.}}{(F_{1,z})_{Meas.}} \quad , \quad (3-7)$$

where $(CPF_x)_{GAUGE}$ = time-averaged radial power calculated by GAUGE,

$(APF_{1,z,\bar{t}})_{Pred.}$ = predicted time-averaged axial power factor for fuel hole 1 and axial location z (fuel hole 1 is used since it is the only fuel hole having a true measured axial power profile),

$(CPF_x)_{Actual}$ = actual time-averaged radial power,

$(APF_{1,z,\bar{t}})_{Meas.}$ = measured time-averaged axial power factor for fuel hole 1 and axial location z (burnup sample location),

$(F_{1,z})_{Pred.}$ = predicted composite burnup at axial location z of fuel hole 1,

$(F_{1,x})_{Meas.}$ = measured composite burnup at axial location z of fuel hole 1.

The above can be written as follows:

$$CF_z = \frac{(CPF_x)_{Actual}}{(CPF_x)_{GAUGE}} = \frac{(F_{1,z})_{Meas.}}{(F_{1,z})_{Pred.}} \cdot \frac{(APF_{1,z,\bar{t}})_{Pred.}}{(APF_{1,z,\bar{t}})_{Meas.}}, \quad (3-8)$$

where CF_z is the element average power correction as determined from calculations at axial position z . The element average power corrections for FTE-14 or FTE-15 used in the thermal analysis were obtained by averaging the three values of CF_z for each element. The power corrections were calculated to be 1.071 ± 0.027 (1σ) for FTE-14 and 0.998 ± 0.014 (1σ) for FTE-15. Measured and calculated burnups and axial power factors at each of the spine sample locations are given in Table 3-10.

The element average power corrections are also used to correct the fast and thermal neutron fluence. Correction of the fast fluence is based on the assumption that the discrepancy between the actual and predicted element average power is a result of the inability of GAUGE to accurately predict the power in a given region of the core so that the power in the elements surrounding the element of interest is under-predicted or overpredicted by a similar amount.

3.3.2. Temperature Calculations

A modified version of TREVER (Ref. 3-4), a one-dimensional HTGR heat transfer code, was used to calculate temperatures for FTE-14 and FTE-15. The Peach Bottom TREVER version divides the irradiation history of Peach Bottom Core 2 into 22 time intervals, each of which has the average core operating conditions for that interval. The irradiation histories of FTE-14 and FTE-15 are simulated by four and 13 of these time intervals, respectively. Temperature shaping factors obtained from the two-dimensional heat transfer code TAC2D (Ref. 3-5) are used by TREVER to account for the effect of test element geometry on heat flow within the elements. TREVER computes all material properties (H-327 graphite thermal conductivity, fuel rod dimensional change, etc.), using material properties data and calculation techniques given in the Fuel Design Data Manual (Ref. 3-12).

Figures 3-11a through 3-11d and 3-12a through 3-12k present the temperature history for fuel hole 1 of FTE-14 and FTE-15, respectively. These figures show the coolant, minimum and maximum sleeve, minimum and median fuel body, and minimum and maximum fuel temperatures as a function of core height. The irregular shape of the fuel body and fuel rod temperature profiles in fuel body 2 is caused by steps in the fuel body surface which were designed to increase the fuel body-sleeve gap and raise fuel temperature to a higher level than would have occurred with a nominal fuel body diameter (Ref. 3-13). The nearly constant fuel body and fuel temperatures in the bottom half of fuel body 3 are a result of tapering of the fuel body diameter, which was done to achieve this effect. The temperature drops at the end of each fuel body are caused by the loss of heat from the fuel rods to the adjacent unfueled graphite via axial conduction. Axial heat conduction at the ends of the fuel bodies was simulated in TREVER by using a correlation giving the temperature reduction due to axial conduction as a function of the temperature that would have been experienced without it and as a function of distance from the

end of a fuel stack. This correlation was derived from TAC3D (Ref. 3-6) calculations. Although it was originally suspected that axial heat conduction would also reduce peak fuel temperatures which occur in the portion of fuel body 2 having the smallest fuel body diameter, TAC3D calculations indicated the reduction would be less than 10°C. Time-averaged temperatures and temperature envelopes for FTE-14 and FTE-15 are shown in Figs. 3-13 and 3-14, respectively.

Tables 3-11a through 3-11f and 3-12a through 3-12f present temperature data for each of the six 60° sections containing a fuel hole of FTE-14 and FTE-15, respectively. The variation in temperatures from section to section within each element is caused by non-uniform heavy metal loadings and the different dimensional change characteristics of the various types of fuel, which result in different size fuel rod-fuel hole gaps. The fuel hole-fuel body gap is discussed in Section 4.3.5. Figures 3-15a and 3-15b give radial temperature profiles at the axial location [1766 mm (69.55 in.)] of the thermocouple hot junction for FTE-14 and FTE-15, respectively. This location is within the section of fuel body 2 having the minimum fuel body diameter, which is the hottest portion of each element. The peak maximum fuel temperatures and peak time-averaged fuel temperatures for the hottest fuel rod in each fuel stack of each fuel body are given in Table 3-13. Fuel hole 5 experienced the highest fuel temperatures in both FTE-14 and FTE-15; a summary of temperatures in this fuel hole is given in Table 3-14.

The uncertainties in the time-averaged element average power ($\bar{P}$) for FTE-14 and FTE-15 have been determined through comparison of measured and calculated burnups to be $\pm 2.7\%$ (1 σ) and $\pm 1.4\%$ (1 σ), respectively. The uncertainty in the time-averaged axial power factors (APFs) determined from gamma spectroscopic measurement of Cs-137 inventories in FTE-14 and FTE-15 is approximately 0.5% (1 σ). The uncertainties in the average power at a given axial location ($\bar{P} \times \text{APF}$) are therefore $\pm 2.7\%$ (1 σ) and $\pm 1.5\%$ (1 σ) for FTE-14 and FTE-15, respectively. For fuel rods 5 and 6 of body 2 in FTE-14 and FTE-15, these power uncertainties correspond to peak fuel temperature uncertainties of approximately $\pm 27^\circ\text{C}$ (1 σ) and $\pm 15^\circ\text{C}$ (1 σ), respectively.

The W/Re thermocouples in FTE-14 and FTE-15 were positioned to measure maximum fuel body temperatures at 1766 mm total core height, which is about halfway between the midpoints of fuel rods 5 (1738 mm) and 6 (1802 mm) of body 2. In FTE-14, the agreement between the recalibrated W/Re temperatures and TREVER-calculated temperatures is $\pm 14^{\circ}\text{C}$ (1 σ) with no apparent bias. This agreement is in line with the predictive uncertainty of $\pm 27^{\circ}\text{C}$ established from power measurements and therefore verifies the thermal model. Since FTE-15 was identical to FTE-14 in design and operated at a similar temperature level, it can be assumed that the uncertainty in the calculated temperatures for fuel rods 5 and 6 of body 2 of FTE-15 are given by the predictive accuracy established from power measurements ($\pm 15^{\circ}\text{C}$), although failure of the thermocouple precludes direct verification.

Spine sample temperatures are given in Tables 2-7 and 2-8. Spine sample temperatures have been averaged using both linear and exponential weighting. (The details of these time-weighting methods are discussed in Ref. 3-14.) Linear weighting is appropriate for general fuel and material performance correlations, while exponential weighting is required for SiC attack, fission product diffusion, and other kinetic effects. Exponentially weighted temperatures are given in Tables 2-7 and 2-8 for cases with activation energies of 143,700 J/mole (cesium diffusion in graphite), 267,000 J/mole (strontium, barium, europium, and samarium diffusion in graphite), and 328,300 J/mole (SiC attack). An example of these temperatures is presented below for the thermal stability spine samples that experienced the highest temperatures in FTE-14 and FTE-15:

	Calculated Spine Temperatures ($^{\circ}\text{C}$)			
	Linear Time Averaged		Exponentially Time Weighted ($Q = 3.283 \times 10^5$ J/mole)	
	Mean	RMS_t	Mean	RMS_t
FTE-14, TS-8 (1-3)	1534	± 88	1604	± 61
FTE-15, TS-8 (1-3)	1468	± 93	1553	± 66

3.3.3. Temperature Measurements

FTE-14 and FTE-15 each contained two thermocouples, a W/Re type thermocouple located near the center spine and a C/A type located near the outer surface of the graphite fuel body. The hot junction of each thermocouple was situated at 1766 mm (69.5 in.) total core height. Figures 2-1 and 2-2 show detailed axial and radial thermocouple locations. Readings were recorded on a weekly basis and had to be corrected for:

1. Changes in cold junction temperature for both thermocouple types.
2. Adjustment in calibration equipment for the W/Re type because readings were 22°C too high owing to a change from the W-5% Re/W-26% Re type used in Core 1 to the W-3% Re/W-25% Re type used in Core 2.
3. Decalibration of the W/Re type for permutation effect on emf output caused by neutron bombardment.

The following calibration formula, based on the recalibration of W/Re type thermocouples recovered from Peach Bottom test elements (Refs. 3-9, 3-10), has been derived:

$$T_a = a \left(\psi + \frac{b}{a} \psi^2 \right) + (1 + c\psi)(T_i - T_s) + T_s \quad , \quad (3-9)$$

where T_a = actual temperature (corrected signal) (°C),

T_i = indicated temperature (uncorrected signal) (°C),

T_s = standoff pin temperature (cold junction) (°C),

ψ = thermal fluence in 10^{25} n/m^2 ($E < 38\text{aJ}$),

$$a = -1.303 \cdot 10^{-4} gh^{1.667},$$

$$b = -0.0699a,$$

$$c = 2.916 \cdot 10^{-3} gh^{0.4544},$$

h = thermocouple length within the active core (mm),

g = geometry factor; $g = 1$ if the hot junction is within the fuel,
 $g = 1.64 \pm 0.018$ if the hot junction is surrounded by graphite.

The error (1σ) on the recalibration is approximated by the equation

$$S_1 = [a + 2b\psi + c (T_i - T_s)]S_\psi. \quad (3-10)$$

$S_\psi = 0.07\psi$. The 7% (1σ) error on the thermal fluence was determined by calibrated gamma spectroscopy of 48 standard fuel elements in Peach Bottom as described in Ref. 3-15.

The performance of the FTE-14 and FTE-15 thermocouples is summarized below:

<u>Element</u>	<u>Thermocouple</u>	<u>Remarks</u>
FTE-14	C/A	Failed at beginning of life.
FTE-14	W/Re	Reliable readings throughout life.
FTE-15	C/A	Functional until 700 EFPD. Readings appear to be from a location lower in the core than 1765 mm total core height, indicating a probable short circuit.
FTE-15	W/Re	Readings obtained until approximately 780 EFPD. Readings are erratic and apparently from a location (or locations) other than 1765 mm total core height. Failure of the thermocouple is indicated.

The conclusions regarding thermocouple functionality given above are based on observation of thermocouple readings and are confirmed by thermocouple resistance measurements (see Section 4.2).

Only the W/Re thermocouple in FTE-14 performed reliably throughout its irradiation history. Figure 3-16a and Table 3-15a give the measured and corrected readings and calculated temperatures for this thermocouple. The measured and calculated temperatures are compared below:

Temperature Source	Peak Temp. (°C)	Mean Temp. (°C)	Long-Term RMS _t (°C)	Medium-Term RMS _t (°C)
TREVER prediction for FTE-14 at 1765 mm total core height	1426	1306	±97	NA
FTE-14 recalibrated W/Re thermocouple	1404	1307	±89	±105

Since the FTE-15 C/A thermocouple gave reasonable readings, although at a location lower in the core than 1765 mm total core height due to a short circuit, it was assumed that the hot junction was situated at the location where the readings and temperature calculations agree for the first TREVER time interval. This location was determined to be 1115.8 mm (43.9 in.) total core height. The FTE-15 calculated temperatures are compared with thermocouple readings in Fig. 3-16b and Table 3-15b. The results of this trend analysis are summarized below:

Temperature Source	Peak Temp. (°C)	Mean Temp. (°C)	Long-Term RMS _t (°C)	Medium-Term RMS _t (°C)
TREVER prediction for FTE-15 at 1116 mm total core height	849	774	±57	NA
FTE-15 C/A thermocouple	834	771	±47	±57

The conclusions from the thermal analysis are as follows:

1. The FTE-14 C/A thermocouple was not functional.
2. The FTE-15 W/Re thermocouple performed too erratically to obtain any useful information from it.
3. The time-averaged recalibrated W/Re temperature and time-averaged TREVER-calculated temperature for FTE-14 agree within the predictive uncertainty of $\pm 27^{\circ}\text{C}$ (as established from power measurements).
4. The temperature history at 1766 mm total core height calculated by TREVER for FTE-14 is verified by the recalibrated W/Re thermocouple temperatures. The RMS deviation between predicted and measured temperatures for all TREVER time intervals was within $\pm 14^{\circ}\text{C}$ (1σ). The RMS on the calculated temperatures is $\pm 97^{\circ}\text{C}$ and the RMS on the thermocouple temperatures is $\pm 89^{\circ}\text{C}$.
5. If one assumes for trend analysis purposes that the FTE-15 C/A thermocouple was reading the temperature at approximately 1116 mm total core height, the temperature readings and calculations are in close agreement. The time-averaged difference between measured and calculated temperatures are within the predictive uncertainty and the RMS deviation for all TREVER time intervals is within $\pm 29^{\circ}\text{C}$ (1σ).
6. The closeness of the agreement between the FTE-14 recalibrated W/Re thermocouple temperatures and TREVER-calculated temperatures gives credibility to both the thermal calculations and the recalibration formula.
7. The feedback of gamma scan information and burnup measurements into the thermal analysis enhances the reliability of calculated temperatures and constitutes a significant advancement in the area of thermal analysis (with direct applicability to FSV reactor fuel elements).

3.4. BURNUP

As in previous Peach Bottom fuel test element examinations, the burnup and uranium isotopic concentrations were measured by mass spectroscopy. Radiochemistry, isotope dilution mass spectroscopy (IDMS), and fuel rod gamma scanning were also used in the verification of these measurements. The algorithms and methods and associated error analysis are described in detail in Refs. 3-9 and 3-14. Loose particles from thermal stability spine samples were used in the measurement of fissile and fertile FIMA at several axial locations in both FTE-14 and FTE-15. Burnup from gamma scanning of fuel rods was calculated using Cs-137 as a fission monitor and the initial heavy metal loadings from Tables 3-16a and 3-16b, which determines a composite FIMA (see Section 3.4.3). All calculated burnup and uranium isotopic concentrations were determined from GAUGE average values and FEVER axial profiles. A summary of the calculated burnups is given below:

	Calculated Burnup			
	Peak	Mean	RMS _t	Fuel Body Mean/ Gradient Sequence
FTE-14				
Fissile FIMA (%)	24.53	19.76	±4.29	213/132
Fertile FIMA (%)	0.37	0.24	±0.11	213/132
FTE-15				
Fissile FIMA (%)	37.71	31.36	±6.65	213/132
Fertile FIMA (%)	1.03	0.68	±0.30	213/132

3.4.1. Isotopic Analysis

Uranium isotopic concentrations in relative atom percent for both fissile and fertile particles were determined from mass spectroscopy results. Summaries of the measured and calculated fertile and fissile isotopic analysis are shown in Tables 3-17a and 3-17b, respectively. The average relative bias for the fissile and fertile fuel in both FTE-14 and FTE-15 is given in Table 3-18.

Imprecise FEVER predictions limit the conclusions concerning the predictive accuracy of isotopic concentrations. If FEVER were modified to reflect the power and power shape corrections, the agreement between measured and predicted isotopic concentrations might improve.

3.4.2. Fissile and Fertile Burnup Analysis

The measured fissile and fertile burnups for FTE-14 and FTE-15 are presented in Tables 3-19 and 3-20. As mentioned previously, the methods and error analysis of these measurements are explained in detail in Refs. 3-9 and 3-14. The calculated fissile and fertile burnups for the fuel rods are shown in Tables 3-21 and 3-22 for FTE-14 and FTE-15, respectively.

The following general conclusions can be made about the burnup analysis:

1. Mass spectroscopy measured fissile burnups in both FTE-14 and FTE-15 were consistently higher than the predicted values for bodies 2 and 3. In FTE-14 the measured burnup of body 1 was near the predicted value, and in body 1 of FTE-15 the calculated value was higher than the measured value.
2. In all cases the radiochemistry measured fissile FIMA was 5% to 10% below the mass spectroscopy measured FIMA.
3. Fertile burnups in both FTE-14 and FTE-15 were in close agreement with predictions in three out of five samples measured. Differences in the calculations and measurements are considered to be caused by the relatively high measurement errors associated with the fertile burnup.

The fissile and fertile burnups for FTE-14 and FTE-15 are summarized in Table 3-23.

3.4.3. Composite Burnup Analysis

The composite burnup is calculated from the fissile and fertile burnups using the relationship

$$F_c = xF_5 + (1 - x)F_3 \quad , \quad (3-11)$$

where $x = U_o / (Th_o + U_o)$,

F_c = composite burnup (%),

F_5 = fissile burnup (%),

F_3 = fertile burnup (%),

U_o = initial uranium atoms,

Th_o = initial thorium atoms.

A measured composite burnup was determined for each of the scanned fuel rods using Cs-137 as a fission monitor. The algorithms and error progression of these calculations are discussed in detail in Ref. 3-14. For comparison, a measured composite burnup was also determined from the fissile and fertile spine sample burnup measurements at specific axial locations. As a comparison between the calculated and measured values, the fuel rods in stack 1 of both FTE-14 and FTE-15 were compared with the GAUGE/FEVER calculated values (Table 3-24). Other stacks were not compared on a full stack basis because of limited sampling.

Based on an individual agreement test, 13 out of 26 fuel rods in FTE-14 and 2 out of 33 fuel rods in FTE-15 had gamma scan measured composite FIMA values that were significantly different from calculated values. It was interesting to note that in many cases the largest

discrepancies between calculated and measured values were at the ends of the fuel stacks, which suggests that the present modeling of end zones is not correct. These end effects were also obvious in the analysis of the Peach Bottom driver elements FTE-4 (Ref. 3-14) and FTE-6 (Ref. 3-9). A group agreement test for stack 1 fuel rods from FTE-14 and FTE-15 showed a significant difference between the calculated and measured composite FIMA for FTE-14 but not for FTE-15. A group "goodness of fit test" was also done for both test elements, and again FTE-14 showed a significant difference between measurements and calculations and FTE-15 did not. These statistical tests are described in detail in the PIE report on FTE-6 (Ref. 3-9).

Using Eq. 3-11, the composite burnup was calculated for the thermal stability spine sample locations using the mass spectroscopy derived fissile FIMA and radiochemistry measured fertile FIMA values. A comparison between spectroscopic and destructive burnup measurements with the calculated burnup of the specific spine sample location is given below:

Core Location (mm)	Calculated FIMA (%)	FIMA $\pm 1\sigma$	
		Gamma Scan Measurements on Fuel Rod	Destructive Measurement on Spine Sample (%)
FTE-14			
1164	1.80	2.01 ± 0.18	1.80 ± 0.03
1642	3.48	4.08 ± 0.28	$3.24 \pm 0.04^{(a)}$
2387	2.69	3.37 ± 0.25	3.20 ± 0.04
FTE-15			
1166	3.19	2.66 ± 0.27	2.94 ± 0.06
1854	5.54	5.67 ± 0.46	5.73 ± 0.05
2424	4.46	4.70 ± 0.48	4.92 ± 0.05

(a) Using calculated fertile FIMA.

In all cases the measured gamma scan values and the spine sample burnups were within the 1σ counting errors. For FTE-14 the agreement in body 1 between measurements and predictions is good. In body 3 the calculated FIMA was significantly less than the measurements. For FTE-15, body 1 was overpredicted, body 2 was close to prediction, and body 3 was underpredicted. These biases between calculated and measured burnups are introduced as corrections into the thermal analysis (see Section 3.3). The calculated and measured fuel rod composite FIMAs as well as the spine sample measurements are shown in relation to core heights in Fig. 3-17.

3.5. STRESS ANALYSIS

3.5.1. Residual Stress Calculations

The methods and material properties used in the stress analysis are essentially identical to those used in the stress analyses described in previous fuel test element PIE and evaluation reports (Refs. 3-9, 3-14). The computer codes and material properties data used in the analysis were taken from Refs. 3-4, 3-5, 3-7, and 3-16 through 3-21.

Previous stress analyses were performed for fuel test elements with an eight-hole teledial configuration. FTE-14 and FTE-15 are both six-hole teledial elements. Therefore, the finite element model of the fuel body and sleeve was redefined for the new geometry. The model uses a 30° sector of unit thickness at the midplane of each of the six-hole teledial fuel bodies. The finite element mesh for FTE-14 and FTE-15 consists of 450 nodes and 713 elements as compared with 334 nodes and 524 elements in the eight-hole model (see Fig. 3-18).

3.5.1.1. Initial Thermal Stress. A summary of the initial thermal stresses is given below for TREVER axial positions 5, 15, and 25, which are midplane locations for bodies 1, 2, and 3, respectively, of FTE-14 and FTE-15. Results are presented in Tables 3-25 and 3-26 and in Figs. 3-19 through 3-48. Maximum initial tensile stresses occurred at the

midplane of body 2 at element position 230, which is located at the outer fuel hole surface in the in-plane direction.

The initial tensile strength at room temperature is shown in Table 3-27 for the midlength edge of the log. This selection is explained in Refs. 3-9 and 3-14. In summary, the midlength edge strength is believed to be an unbiased best estimate of tensile strength at the midplanes of the test element bodies.

Comparison of the stress results with the ultimate tensile strength (UTS) values for H-327 graphite in Table 3-27 shows that initial thermal stresses are less than the ultimate strength values. For example, the in-plane tensile stress for FTE-14 is 39% of the corresponding strength. The strength is obtained by correcting the initial strength at room temperature for the effects of temperature and fast neutron irradiation according to Ref. 3-16.

For the initial compressive strength, which has not been characterized as a function of position in the log, a conservative minimum value of 27.5 MPa (4000 psi) was used. All compressive stress values have been found to be small in comparison with the ultimate compressive strength (UCS) value and are not included in the tables.

Peak initial thermal stresses obtained for FTE-14 and FTE-15 are given in Table 3-28. In each case for both elements, body 2 experiences the highest beginning of life stresses. The stress level is well below the ultimate strength values.

Temperature and stress contour plots for startup at beginning of life are presented in Figs. 3-19 through 3-21 and Figs. 3-34 through 3-36 for the center region of each fuel body (in MPa) of FTE-14 and FTE-15, respectively. Figures 3-22 and 3-37 give the stress direction in each plane for the two elements, which is the same for all three bodies of each.

3.5.1.2. Peak Stress During Life. The stress distribution changes rapidly with time due to increased irradiation strain in the hotter areas of the fuel body. The higher-temperature areas toward the center of the body reverse from initial compressive stress to a state of tensile stress at end of life, while the cooler areas near the edge of the element sleeve go into compression. This stress reversal is predicted by the GTEPC-2D code at all three axial locations.

Tables 3-25 and 3-26 contain the peak operating stresses found in FTE-14 and FTE-15, respectively, during the irradiation simulation. The time points (Core 2 reactor hours at operation) and finite elements where the peak stresses occur are also included. Time points refer to TREVER simulation intervals, and element locations refer to the finite element mesh in Fig. 3-18. Temperature and stress contour plots for end of life operation are presented in Figs. 3-23 through 3-25 for FTE-14 and Figs. 3-38 through 3-40 for FTE-15, and stress directions are shown in Figs. 3-26 and 3-41 for all three planes. Figures 3-27 through 3-29 and 3-42 through 3-44 give the history of the elements with the maximum and minimum temperature and show maximum and minimum tensile stress (in-plane and axial) during operation and shutdown of the midplane of each body. Finite elements with peak-in-time condition were selected for the presentation.

Peak operational and shutdown stress values during the irradiation life of FTE-14 and FTE-15 are given in Table 3-29.

With the exception of the axial tensile stress in body 1, all peak operating stress conditions of FTE-14, both in-plane and axial, coincide with the initial thermal stress at beginning of life. The same holds true for the FTE-15 in-plane operational stress. The shutdown stresses of FTE-14 all occur at end of life. However, with the exception of body 3 for the in-plane tensile stress, the peak shutdown stresses of FTE-15 always occur at midlife of the element (701 EFPD shutdown). Again, all peak stresses occur in body 2 of each element.

The tabulated stress values are the peak values seen at any time point during irradiation (including end of life) of the fuel test elements, as obtained from the stress predictions. The highest tensile stress during the entire life of the six-hole elements occurred in body 2 of both elements at the end of life shutdown (701 EFPD) for FTE-14 and at the midlife shutdown for FTE-15 in the in-plane direction, giving a stress-strength ratio of 0.54.

3.5.1.3. Peak Stress at End of Life. Peak end of life operating and shutdown stresses have been determined for each six-hole element (see Tables 3-25 and 3-26). As mentioned earlier, an inversion took place between beginning of life and end of life for the peak stress locations. The highly compressed areas became subject to tensile stresses and vice versa. On end of life shutdown, these tensile and compression stresses increased at least threefold in every case for FTE-14 and FTE-15, over the end of life operating stresses.

Temperature and stress contour plots for shutdown stresses are presented in Figs. 3-30 through 3-32 and Figs. 3-45 through 3-47. The shutdown temperature is 20°C; for better comparison, the temperature field prior to shutdown has been included in these figures and is also presented in the contour plots for end of life operation (Figs. 3-23 through 3-25 and Figs. 3-39 through 3-41). Figures 3-33 and 3-48 contain the end of life shutdown stress directions for each element, which vary slightly from body to body.

The peak end of life stresses for FTE-14 and FTE-15 are summarized in Table 3-30. Peak operational and shutdown stresses all occur in body 2 at end of life in both the axial and in-plane directions for each element. These stresses are always lower than the strength. As previously mentioned, peak tensile shutdown stresses occur in FTE-14 where the in-plane stress-strength ratio reaches a maximum of 0.54 at end of life for body 2. The peak axial stress occurs in FTE-15, however, where the midlife shutdown stress in body 2 has a ratio of 0.48.

3.5.1.4. Conclusions. The conclusions from the stress analysis of FTE-14 and FTE-15 can be summarized as follows:

1. Neither six-hole element can be considered a high-stress experiment, since the highest stresses in each element reached only 54% of the UTS. Compressive stresses were small in comparison with the UCS of the material.
2. The highest in-plane stresses were found at the same location (216) for both elements and were of the same magnitude (54%). The highest axial stresses were found in body 2 of FTE-15 in the midlife shutdown situation.
3. Compared with the stress levels in previously analyzed eight-hole elements, the stress levels are small owing to the absence of stress concentration slots at the inner cavity of the teledial elements.

3.5.2. Destructive Stress Examination

The purpose of the destructive stress examination program is to verify the predicted residual stress distributions by experimental examination of the graphite fuel bodies from Peach Bottom fuel elements. A number of experiments were designed to accomplish this primary objective by comparing the predictions made using analytical methods with the measured deflections and fracture loads. Detailed experimental and analytical results for the stress verification of FTE-14 and FTE-15 are reported separately (Refs. 3-22 through 3-25). A summary of the experimental results is presented in this report.

Before any cutting was attempted, deformation measurements were taken on the intact fuel bodies during postirradiation disassembly of the fuel element. These dimensions were compared with those measured before irradiation, and an assessment was made of the axial and radial strains during irradiation (Section 4.3.2). The postirradiation deformation

measurements were then used as a reference for comparison of strip and slice deformation before and after cutting. The quantities measured were the extent of axial and radial (or diametral) shrinkage and of bowing.

Following deformation measurements, the fuel bodies were cut into sections for structural examination. The teledial elements were cooled only externally, so that the graphite near the central hole was up to 200°C hotter than the outside surface. As a result of these temperature gradients, comparatively high residual axial and in-plane stresses were expected to be present within the irradiated graphite.

The most effective method of determining residual axial strain distributions in irradiated graphite bodies is to section the bodies, allowing deformation to occur through relieved stresses. This is accomplished by strip-cutting thin specimens parallel to the extrusion axis of the graphite body. To provide for maximum deformation, the location of the cuts is selected to provide a strip with residual tensile stress on one side and compressive stress on the other. Following the cutting operation, the strip bows to relieve the bending moment that was previously present.

A double-bladed saw was used to "straddle cut" strips 8.9 mm wide x 0.45 m long from the web between the fuel holes by using a single blade of the saw and dissecting the fuel hole to the central cavity of the teledial design.

The length (at location of the neutral fiber) and curvature of the strips were measured before and after cutting, the differential deformation representing the residual strain distribution. Table 3-31 summarizes the strip cutting results from 48 strips cut from 4 bodies (body 2 of FTE-14, bodies 1, 2, and 3 of FTE-15). The relative length change of each strip will be compared with that predicted from the average stress over the cross section of the strip, while the radius of curvature of bow will be compared with the estimated stress distribution in the strip and by applying beam theory.

The mean elongation of thin strips was found to be +0.15 mm after cutting, with body 2 of FTE-14 showing the largest change of +0.22 mm and body 1 of FTE-15 the smallest of +0.10 mm. This is approximately 50% greater than the elongation expected from the predicted residual compressive stresses. The thick strips lengthened +0.10 mm, even though mean stresses and elongations were predicted to be near zero or slightly negative. Because there can be no stress equilibrium if all the material elongates, an artificial elongation effect, unrelated to the release of residual stress, was concluded. This is supported by the evidence gained from cutting unirradiated (and therefore unstressed) H-327 graphite of the same six-hole teledial configuration. This resulted in elongations of +0.04 and +0.09 mm for thin and thick strips, respectively, which brings the observations in much better agreement with predictions when the unirradiated results are used to correct the elongation measurements for the irradiated graphite. This bias was traced to the use of two different calibration standards and metrology devices for fuel bodies prior to cutting and strips after cutting. A more closely controlled experiment on another fuel test element (FTE-16) revealed very small elongations within the measurement uncertainties. Elongation results for FTE-14 and FTE-15 therefore do not contradict the predicted axial stress distributions.

The predicted axial stress distribution, with tension near the center of the element and compression near the outside diameter, is caused by thermal and irradiation-induced shrinkage. The central portion of the element shrinks more rapidly under irradiation because irradiation strain rates are higher at the higher temperature (up to 200°C) in the center; when the reactor is shut down, the hotter central portion also contracts more thermally on cooling to room temperature. As a result, the residual stresses in the test elements should cause the strips to bow such that the radius of curvature is concave toward the central axis of the element.

This has been found true for all the thick strips of FTE-14 and FTE-15. However, with the exception of body 1 from FTE-15, all the thin strips have shown bow inversion (or negative bow). Unirradiated H-327 specimens cut by the identical method have indicated randomly distributed bow deflections.

FTE-14 and FTE-15 reached the highest temperatures during irradiation of any of the fuel test elements, which may be a factor contributing to bow inversion for these thin strips. Systematic variations of the thermal expansibility of graphite under creep strain are suspected as the possible cause.

Results were averaged for adjacent strips taken from the same fuel body and are presented in Table 3-31. The amount of azimuthal variation can be recognized from the RMS variation shown. Individual azimuthal values for bow and elongation of strips indicate that one of the factors contributing to residual stress and strain present in irradiated graphite is the azimuthal fuel loading variation, which originated from different thorium loadings and consequently different U-233 conversions. The azimuthal variation of bow deflection magnitude and elongation is not random, but has a form of symmetry in most cases where the side of the body with the least bow or elongation diametrically opposes the side with the most pronounced bow or elongation.

Experiments to study residual in-plane stresses were performed using ring-shaped disks of 20-mm thickness cut perpendicular to the extrusion axis of the teledial graphite bodies. Residual in-plane strain was released by a single radial cut from the outer surface to an uncooled center hole (Fig. 3-49). The extent of closure of the ring due to the relief of the in-plane (hoop) stress gradient was determined by measuring the distance between grooves on either side of the cut, as well as the outside diameter change. The results are given in Table 3-32. Body 2 of both elements has the highest diametral change, which agrees with the higher calculated temperatures that body 2 experiences.

Two primary load tests were designed for comparing stress distributions and strength variations of irradiated graphite based on calculated and measured fracture loads and failure modes. Some of the disks were diametrically loaded to failure by compression between two parallel plates in an Instron tension/compression machine, while others were tested by pressurizing fuel holes to failure by hydraulic fluid and a Tygon tubing medium. Unirradiated disks were also tested and their failure loads

were compared with those of irradiated disks. The irradiated disks were found to be stronger where the residual stresses at the point of failure were compressive, which is the case for six-hole teledial geometry test elements. Since tension at the fuel hole surface adjacent to the outer diameter web is the failure mode for both primary load tests, the compressive stresses must be overcome before the slice is tensile loaded to failure, causing the irradiated sample to fail at a higher value than the unirradiated and unstressed sample.

As with the in-plane strain measurements, body 2 of both elements showed the highest failure loads, which is consistent with the above explanation that the higher-temperature bodies were in a state of higher residual compressive stress at the location of failure. FTE-15 tends to have a higher failure stress than FTE-14, which should agree with predictions since the strength of the irradiated graphite increases with increasing fluence.

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4. POSTIRRADIATION EXAMINATION AND EVALUATION

4.1. NUCLEAR MEASUREMENTS

During the unloading of FTE-15 at the Peach Bottom reactor site on December 9, 1974, the fuel element was gamma scanned in situ to obtain information on axial isotope distributions. Individual fuel rods and graphite sections from both FTE-14 and FTE-15 were gamma scanned separately after disassembly of the test element at the GA hot cells. These scans were used in composite burnup measurements and the determination of fission product distributions. FTE-14 was scanned at the reactor site on September 13, 1973, for a fuel stack length determination only.

4.1.1. Fuel Gamma Scan at Peach Bottom

The procedure used to gamma scan FTE-14 and FTE-15 in situ at the Peach Bottom site on September 13, 1973, and December 9, 1974, respectively, is reported in detail in Ref. 4-1. The element was lowered slowly within the fuel handling machine past a collimator that was positioned perpendicular to the element. The cross section of the element seen by the collimator is shown in Fig. 4-1. FTE-14 was only scanned for axial fuel stack information by a sodium iodine detector system, whereas FTE-15 was analyzed for fission product inventories as well via a Ge-Li drifted detector (Ref. 4-1). Because of the complications of several different fuel varieties being scanned at once and different fuels in each body of FTE-15, the Peach Bottom scans gave only relative axial information. For reference, the counts per minute of each isotope are given in Table 4-1 for each axial location for FTE-15. The strip charts from single-channel analyzers were used for measurement of the overall fuel stack length as shown in Fig. 4-2 for both test elements; the same techniques have been employed

for previous test and driver elements (Refs. 4-2, 4-3). For FTE-14, the accumulative and indirect fuel stack measurements were determined from the metrology of the fuel rods and fuel hole plenum distance but no composite fuel stack measurements were taken.* For FTE-15, all the fuel stack length measurement techniques were used. A comparison of preirradiation and postirradiation fuel stack measurements is given in Tables 4-2 and 4-3.

The following comparisons between the different methods of fuel stack length determinations were carried out:

1. Accumulative versus indirect composite stack length at beginning of life for detection of axial gaps between fuel rods (see Table 4-2).
2. Accumulative versus composite stack length at end of life (for FTE-15 only, because no composite stack measurements were taken for FTE-14) (see Table 4-3a).
3. FTE-15 composite fuel stack length at end of life versus gamma scan derived fuel stack length to establish the adequacy of both methods (see Table 4-3b).
4. FTE-15 gamma scan derived versus indirect composite fuel stack length to identify in situ changes due to fuel element handling after removal from the core (see Table 4-3b).

* Accumulated stack length is derived from individual fuel rod length measurements of all or representative samples of the specific stack. Composite stack length is the length measurement over the composited fuel rods, usually available only after irradiation. Indirect composite stack length is determined via plenum and fuel hole depth measurements, usually done before and after irradiation.

The results are presented in Tables 4-2 and 4-3, from which the following conclusions can be drawn:

1. The accumulative fuel stack length is greater than the composite fuel stack length in both FTE-14 and FTE-15 at beginning of life. The average relative difference between composite and accumulative fuel stack lengths is $0.38\% \pm 0.01\%$ and $0.46\% \pm 0.01\%$ for FTE-14 and FTE-15, respectively (see Table 4-2). In nearly every case, there were significant differences between the composite and accumulative fuel stack lengths based on an individual agreement test. The rods in body 1 from both FTE-14 and FTE-15 had much larger differences than the stacks in bodies 2 and 3. The conclusion from these data is that the ends of the fuel rods must be shaped so that their irregular surfaces fit together to make an overall shorter stack than the sum of the fuel rod measurements.
2. At end of life the accumulative fuel stack length is still greater than the composite fuel stack length but to a lesser degree than at beginning of life. The relative difference between composite and accumulative fuel stack lengths for FTE-15 decreased from $0.46\% \pm 0.01\%$ at beginning of life to $0.14\% \pm <0.005\%$ at end of life. Again, the body 1 fuel stacks showed larger differences than the other fuel stacks in FTE-15 (see Table 4-3).
3. Gamma scanning and metrology (either composite or indirect composite) give the same average fuel stack lengths within the accuracy of the measurements in FTE-15 (see Table 4-3b).

4.1.2. Component Gamma Scan Analysis

After disassembly of the elements in the GA hot cells, the fuel and graphite components from both FTE-14 and FTE-15 were scanned to determine

fission product inventories and composite burnup in the fuel rods and fission product accumulation in the graphite.

The scanning geometry of the fuel rods was the same as used in previous test elements (Refs. 4-2, 4-3). The rods were slowly traversed past a collimator with a 21.6 x 0.6 mm cross section that had its long axis perpendicular to the long axis of the fuel rods. Several spectra were collected along the length of the rods, and these scans were then combined and reduced in a rigorous statistical manner using the PBEOLGS program described in Ref. 4-1. The calibration of this scanning geometry that allowed quantitative results was achieved during the scanning of capsule P13Q (Ref. 4-4).

The composite burnups determined from the gamma scanning from a representative fuel stack are compared in Table 3-24 for FTE-14 and FTE-15. This composite burnup comparison is discussed in Section 3.4.3. The isotope profiles of Cs-134, Cs-137, and Zr-95 were used in the thermal analysis discussed in detail in Section 3.3.

Most of the sleeve and graphite was scanned at 0° and 180° orientations; the area scanned on the graphite fuel is shown in Fig. 4-3. In no case was a significant isotope activity found on the graphite above background levels in the scanning geometry. It was therefore concluded that fission product release to the graphite was relatively low. This conclusion is substantiated by the low fuel failure and low activity seen in radial sectioning of the graphite fuel bodies, as described in Section 4.4.

4.2. DISASSEMBLY AND VISUAL EXAMINATION

All disassembly operations were performed as described in Refs. 4-5 and 4-6 for FTE-14 and FTE-15, respectively. FTE-14 and FTE-15 were injected into the high-level cell from the Hallam cask without incident after their arrival at GA on January 22, 1974, and June 24, 1975, respectively. Removal of both test elements from their respective helium-filled

aluminum canisters was done in the same way. The canister was girdle cut approximately 4.76 mm (3/16 in.) deep and 914 mm (3 ft) from the top end of the canister and the piece was removed. The element was pulled out until clear of the canister, thereby exposing the thermocouple contacts. The remaining portion of the canister was discarded. At this point, the identity of each element was checked and the element was photographed (Fig. 4-4). Composite photographs of FTE-14 and FTE-15 are shown in Figs. 4-5 and 4-6, respectively; neither has evidence of cracks or abnormalities. Thermocouple resistance measurements were then taken and are recorded in Table 4-4. It was concluded that the W/Re thermocouple for FTE-14 performed satisfactorily, that there was an open circuit for the C/A thermocouple of FTE-14 and the W/Re thermocouple of FTE-15, and that there was a short circuit with loss of grounding for the C/A thermocouple of FTE-15. The resistance measurements confirm the conclusions regarding functionality presented in Section 3.3.2.

For sectioning, the fuel element was supported horizontally by a series of V-rollers, which facilitated horizontal and rotational movement. A special extension drill was inserted through the purge gas inlet hole in the upper reflector, and a hole was drilled through the porous graphite plug. The fuel bodies were then seated against the bottom connector by inserting a push rod through this hole and applying force. While the bodies were held down, the upper reflector was removed by plunge cutting through the sleeve at a point about 50.8 mm (2 in.) below the sleeve-reflector joint. This section was stored for later gamma scanning. The sleeve was then girdle cut ~9 mm (0.37 in.) deep at a point ~635 mm (25 in.) from the bottom of the element without hitting the lower reflector. The top section was pulled away from the bottom section, exposing the thermocouples. No particles were found in either element during the cutting. In FTE-14, the bottom section of the lower reflector was removed and only 127 mm (5 in.) of the C/A thermocouple cold junction was saved. The bottom section in FTE-15 was plunge cut ~51 mm (2 in.) from the bottom of the element, and the whole intact thermocouples were then removed. During this operation the lower reflector and trap from FTE-15 were accidentally tilted and some charcoal

particles were lost. The bottom reflector and trap section was stored for later gamma scanning. Figures 4-7 and 4-8 show top and bottom views of the cut.

The fuel bodies were subsequently removed from the sleeve of each element by inserting a push rod into the upper opening, holding the sleeve, and applying force. The sleeve was then cut, and inside diameter measurements were performed according to the PIE plan. Each fuel body was carefully examined externally, and graphite integrity was assessed (Figs. 4-9 through 4-14); no cracks or abnormalities were found. Following visual inspection, bow measurements, and dimensional measurements, the fuel bodies were placed in a special holding fixture to facilitate the removal of center samples. A hole was drilled through the bottom sample hole plug and a push rod was inserted. The upper sample hole plug was then unscrewed, and the distance from the top of the spine samples to the edge of the holes was measured. These measurements are compared with preirradiation measurements in Table 4-5. Contraction in length was observed as expected for H-327 graphite except for the spine stack in body 3 of FTE-14, which indicated an increase in length. However, this could have been caused by a small piece of debris caught between two of the samples. The spine samples were pushed out one at a time, identified, and placed in a pan. During these operations no loose fuel particles from the drilled holes were observed, and no problems were encountered during the removal of the spine samples, although some difficulty existed in identifying the samples. In FTE-14, a tensile sample from body 1 was listed as 11959-19 in the as-built drawing and was actually identified as 11952-19. The creep samples in FTE-15 were marked 8C, 2C, 13C, and 5C but were described in the drawings as 1888-25, 1888-24, 1888-23, and 1889-19, respectively. The description, metrology, temperature, irradiation exposure, and activity of the spine samples are recorded in Tables 2-7 and 2-8 for FTE-14 and 15, respectively. All the spine samples were distributed to cognizant investigators according to the PIE plan. Flux dosimetry from the tensile samples and loose particles from the thermal stability samples were used for fluence and burnup analysis; these results are reported in Sections 3.2 and 3.4.

Upon discharge of the spine samples, holes were drilled in the bottom of the fuel bodies to enable the fuel to be pushed out using the special discharge fixture. Figure 4-15 shows the typical setup. The graphite plugs capping the fuel holes were easily removed, and the distance from the top of the fuel rods to the edge of the fuel holes was measured. These measurements, as well as fuel stack lengths, are compared with preirradiation measurements in Table 4-2.

Holes were then drilled in the bottom of the fuel bodies to enable the fuel rods to be pushed out. In FTE-14, a 3.2-mm (1/8-in.) diameter push rod was used to push the rods out in a trough for subsequent examination. A mechanical push device with a Dillon load gauge (0 to 113.4 kg) was developed for the FTE-15 fuel unloading. In no case did the load required to start fuel stack movement exceed 28 kg (see Table 4-6). The stacks were then visually examined (see Section 4.4.1) and the stack length was measured (Table 4-2). After all the fuel rods were removed, the fuel bodies were sectioned, as shown in Figs. 4-16 through 4-21. These pieces were used for autoradiography, residual stress analysis, and radial cesium and Sr-90 profile determinations.

4.3. DIMENSIONAL CHANGE EVALUATION

The results of the metrology of the components in FTE-14 and FTE-15 have been rigorously analyzed using the algorithm developed in previous test element PIEs (Refs. 4-2, 4-3) in conjunction with several computer codes (Ref. 4-6). In all cases the measurements reported here are presented with confidence statements and whenever possible are compared with HTGR design code predictions. Because FTE-14 and FTE-15 are nearly identical in design, the results for the two elements are directly comparable; where possible, other test element metrology has been compared with the present analysis.

4.3.1. Fuel Element and Sleeve

The total length of the elements was first measured with a steel rule and then confirmed by traversing a saw head with a calibrated travel over the length of the element. The precision and calibration errors of this measurement were each considered to be ± 0.8 mm ($\pm 1/32$ in.). Results for FTE-14 and FTE-15 are given in Table 4-7 and are compared with other test element results in Table 4-8.

The length changes confirm results reported earlier for FTE-6 (Ref. 4-3). The length expands slightly at low exposures and then shrinks after an irradiation time of 500 EFPD.

Fuel body weight changes are also compared in Table 4-7. These measurements, as discussed in Ref. 4-3, are unreliable. There was a 180-g weight gain in body 1 of FTE-14, which is unrealistic. The relative weight changes are included below for completeness:

Fuel Element	Relative Fuel Body Weight Change (%)		
	Body 1	Body 2	Body 3
FTE-14	+3.43	+0.22	+0.13
FTE-15	+0.03	+0.11	-0.03

Outside diameter sleeve measurements were made with snap-on dial gauges; in FTE-15 a few inside diameter sleeve measurements were made with inner micrometers. The relative sleeve strain and a comparison with TREVER predictions are presented in Fig. 4-22 and Tables 4-9 and 4-10. In nearly all cases, calculated strain was within the 95% confidence limit of the measurements.

4.3.2. Fuel Bodies

After all the fuel was unloaded from the separate bodies, the fuel body bow, outside diameter, and length were measured. In all cases the bow was small and did not cause any sleeve-fuel body interactions.

During the graphite stress examination of FTE-14 and FTE-15 (Ref. 4-7), the outside diameter was remeasured with more systematic sampling than was used during the disassembly. These radial dimensional change data for the individual fuel bodies are presented in Tables 4-11 and 4-12 and are summarized in Tables 4-13 and 4-14. In Figs. 4-23 and 4-24, the measured radial fuel body strain is compared with FEVER predictions. The axial and radial strains of FTE-14 and FTE-15 are compared with the results for ten other test elements in Figs. 4-25 and 4-26, respectively. These plots show a clear overprediction of the axial and radial strains in large H-327 graphite bodies as compared with material design data derived from a small sample graphite irradiation (see Ref. 4-8).

The axial and radial strain results obtained for the fuel bodies are given in Table 4-15. The results can be compared with previously analyzed experiments as shown in Table 4-16. The trend in the data shows an increase in strain and anisotropy with irradiation exposure.

The radial strains are also compared with predictions in Table 4-17 and are illustrated in Figs. 4-23 and 4-24. The radial strains can be summarized as follows:

CALCULATED VERSUS TREVER MEASURED FUEL BODY RADIAL STRAIN

	C/M-1	2 σ	RMS
FTE-14			
Body 1 (bottom)	2.33	± 7.41	± 5.61
Body 2 (middle)	4.78	± 2.27	± 4.82
Body 3 (top)	1.75	± 5.15	± 2.53
Total element avg.	3.16	± 3.33	± 4.99
FTE-15			
Body 1 (bottom)	0.37	± 0.19	± 1.03
Body 2 (middle)	1.70	± 1.30	± 3.38
Body 3 (top)	0.54	± 0.14	± 0.08
Total element avg.	0.94	± 0.16	± 1.23

Some of the deviations for FTE-14 could be explained by large measurement uncertainties; however, the combined results for 12 Peach Bottom test elements lead to the obvious conclusion of an approximate 60% overprediction of the radial strain of the H-327 graphite fuel bodies when compared with the material design data base (Ref. 4-8). GTEPC and TREVER predictions are shown in Figs. 4-23 and 4-24 to be in good agreement. It is concluded that the creep term in the GTEPC code has little effect on the predictions.

4.3.3. Sleeve-Fuel Body Gaps

Sleeve and fuel body shrinkage was determined from outside and inside diameter measurements on the sleeve and extensive fuel body measurements. Only a few sleeve outside diameter measurements and no inside diameter measurements were available in FTE-14. No preirradiation gaps were available because of lack of sleeve dimensions; instead, nominal preirradiation data (Ref. 4-9 for the sleeve and Ref. 4-10 for the assembled fuel bodies) were used.

The actual measurements for FTE-14 and FTE-15 are presented in Table 4-18 and are plotted in comparison with TREVER predictions in Fig. 4-27.

A summary of the sleeve-fuel body gap information is given below:

Fuel Element	Sleeve-Fuel Body Gap		
	BOL (mm)	EOL (mm)	BOL/EOL-1 (%)
FTE-14			
Body 1 (bottom)	0.16	0.15	-10.2
Body 2 (middle)	0.33	0.37	13.0
Body 3 (top)	0.72	0.76	5.6
Total element average	0.37	0.36	-4.1
FTE-15			
Body 1 (bottom)	0.16	0.18	13.3
Body 2 (middle)	0.33	0.37	13.2
Body 3 (top)	0.79	0.82	4.5
Total element average	0.35	0.39	12.4

A -9% element average decrease was observed in the sleeve-fuel body gap for FTE-6 (Ref. 4-3), and a +13% increase was observed for FTE-4 (Ref. 4-3). An average for FTE-4, FTE-6, FTE-14, and FTE-15 gives an increase of +3.1% in the gap with a root mean square deviation of 9.8%, which indicates a random change in gap size in these four test elements.

4.3.4. Fuel Rods

Axial and diametral dimensions were determined on 54 fuel rods from FTE-14 and 123 fuel rods from FTE-15. For both elements, all available fuel blends from the three fuel bodies were sampled. Diameter measurements were taken at arbitrary 0° and 90° positions at top-middle-bottom locations; the length of the fuel rods was also determined at both the 0° and 90° positions. This scheme was consistent with preirradiation measurements (Ref. 4-10).

The data reduction and statistical analysis of data were done with the STAT code (Ref. 4-9). Because of the large variety of fuel blends in FTE-14 and FTE-15, blends of fuel rods with all-TRISO loadings and with similar TRISO/BISO volume loadings were grouped together for convenience when comparing calculations and measurements. These data are presented in Tables 4-19 through 4-25 for FTE-14 and in Tables 4-26 through 4-32 for FTE-15. The average fuel rod dimensional change data for each fuel stack along with the associated errors are shown in Tables 4-33 and 4-34. Data summaries for each fuel stack are shown in Tables 4-35 and 4-36 for FTE-14 and FTE-15, respectively. Calculated and measured strain data are also plotted for fuel stacks 1 through 6 for each element in Figs. 4-28 and 4-29, giving a direct comparison between fuel stacks, which usually contained the same or similar fuel combinations in both elements.

At the present time, TRISO and BISO shrinkage models are being perfected. All the predictions made in this report are from the current SHRINK code (Ref. 4-11). The TRISO/TRISO shrinkage model was updated

recently by Kovacs (Ref. 4-12) to take into account diametral-axial anisotropy shrinkage. These new modifications were not introduced into the STAT code predictions for FTE-14 and FTE-15; however, the predicted and measured anisotropy of all-TRISO loaded fuel rods was compared with new predictions (Ref. 4-12).

As in FTE-3, FTE-4, and FTE-6 (Refs. 4-13, 4-2, 4-3), the average of the radial and the axial fuel rod strains for TRISO/TRISO fuel blends was consistently underpredicted. This is related to the anisotropy of these fuel rods, which is compared with predictions below:

TRISO/TRISO ANISOTROPY COMPARISON

Body No.	Hole No.	Anisotropy ($\epsilon_A - \epsilon_R = \Delta\epsilon$)	
		Meas. $\pm 1\sigma$ (%)	Calc.* (%)
FTE-14			
2	2	0.13 ± 0.19	0.09
2	6	0.57 ± 0.24	0.09
3	2	0.80 ± 0.39	0.07
3	6	0.43 ± 0.30	0.07
FTE-15			
2	2	-0.06 ± 0.21	0.11
2	6	0.42 ± 0.21	0.11
3	2	-0.04 ± 0.19	0.09
3	6	0.28 ± 0.13	0.09

In all cases the measured anisotropy of the FTE-14 and FTE-15 TRISO/TRISO fuel rods was significantly larger than predictions based on Ref. 4-12 except for body 2, stack 2 and body 3, stack 2 from FTE-15. These particular stacks had the same fuel that exhibited high OPyC failure in both the fissile and fertile particles, which conceivably allowed more isotropic fuel rod shrinkage. The reason for the general discrepancy between the measured and predicted anisotropy on the other fuel stacks

* $\Delta\epsilon = 0.04014 \psi + 0.035$, where ψ is fast fluence.

could be related to irradiation temperature; both FTE-14 and FTE-15 had higher irradiation temperatures than any of the fuel rods used in the empirically derived predictions (Ref. 4-12).

TRISO/BISO fuel varieties were loaded with approximately the same volume loading of 25% TRISO and 75% BISO particles, except for hole 4 in bodies 2 and 3, which had 55% TRISO and 45% BISO particles (see Tables 2-4 and 2-5). The general trend of the data showed a consistent over-prediction of all the TRISO/BISO strain data except for some cases with low fast fluence exposures. This is consistent with FTE-4 and FTE-6, where a similar fuel blend was overpredicted by 30%. The relative difference between predictions and calculations (C/M-1) can also be related to the fast fluence, as shown in Fig. 4-30. Both TRISO/BISO and TRISO/TRISO fuel blends show an increase in the relative difference with fast fluence. The TRISO/BISO fuel variety is closest to the predictions at relatively low fluences, i.e., $1.0 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR}, and the TRISO/TRISO variety is closer at $\sim 2.0 \times 10^{25} \text{ n/m}^2$.

The average anisotropy of all the fuel rods is shown in Tables 4-30 and 4-31 and illustrated in Figs. 4-31 and 4-32. The anisotropy of the FTE-14 and FTE-15 fuel rods with ~ 25 vol % TRISO fissile particles is summarized below on a fuel stack basis:

ANISOTROPY* OF 25% TRISO/75% BISO FUEL RODS					
Body No.	Hole No.	FTE-14		FTE-15	
		Y/x (%)	1 σ (%)	Y/x (%)	1 σ (%)
1	1	159	± 38	144	± 15
1	3	ND	ND	150	± 30
1	4	154	± 30	161	± 39
1	5	ND	ND	155	± 21
2	1	95	± 8	98	± 12
2	3	100	± 7	105	± 6
2	5	99	± 9	103	± 9
3	1	103	± 28	94	± 6
3	3	101	± 11	105	± 8
3	5	91	± 12	85	± 13

* Anisotropy is described here as the ratio between the axial and radial strain. Earlier, the axial minus radial strain was used as an alternative way to describe anisotropy.

All the fuel rods in body 1 contained the same fuel blend, resulting in anisotropy values of around 160%. Fuel from bodies 2 and 3 with higher temperatures and fast fluence exposures showed anisotropy values between 85% and 105%. In FTE-4 and FTE-6, the anisotropies of fuel rods with similar fuel loadings were 94% and 92%, respectively.

4.3.5. Fuel Body-Fuel Rod Gaps

The gap between the fuel rods and the fuel body could be critical for an accurate thermal analysis. The controlling factor in the gap formation is the fuel rod shrinkage, which is an order of magnitude higher than the fuel body shrinkage. Because of uncertainties in the predictions of both the fuel rod and graphite fuel body strains, the combined effect of the gap is considerably more difficult to predict.

The indirectly measured radial fuel rod-fuel body gap is compared with predictions in Tables 4-37 and 4-38 and is visually displayed in Figs. 4-33 and 4-34. The measured radial gaps ranged between 0.1 and 0.4 mm for fuel varieties in FTE-14 and FTE-15. In all cases the predicted and measured gaps were in good agreement.

4.3.6. Dimensional Change Summary

Fuel rod, fuel body, sleeve, and total element metrology results were rigorously compared with predictions and results for previous test elements to broaden the data base for H-327 graphite strain and LHTGR fuel rods. The general conclusions are as follows:

1. Total element length and sleeve diameter changes were as expected. The length changes followed the general trend observed for other test elements with a slight expansion of elements at lower exposures followed by shrinkage after 500 EFPD. The predicted sleeve diameter strain agrees with the measurements within the uncertainty limits.

2. Axial and radial H-327 graphite shrinkage for teledial fuel bodies was underpredicted by application of material design data with the TREVER and GTPEC codes. Bow of the fuel bodies was insignificant for FTE-14 and FTE-15.
3. The SHRINK code consistently underpredicted TRISO/TRISO fuel rod strain in both FTE-14 and FTE-15. A new empirical correlation for anisotropy of TRISO/TRISO fuel rods (Ref. 4-12) consistently underpredicted the observed anisotropy.
4. TRISO/BISO fuel rod strain showed good agreement with predictions up to $1.0 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR}. With increasing fast fluence the relative difference between predictions and measurements increased up to ~45% in one fuel stack.
5. Radial fuel hole-fuel body gaps were reasonably well predicted in both FTE-14 and FTE-15.

4.4. FUEL IRRADIATION PERFORMANCE

4.4.1. Visual Examination

During the unloading of both the FTE-14 and FTE-15 fuel rods, there was evidence of matrix end cap cracking and some striations caused by surface debris being caught between the fuel rods and the graphite fuel hole inside diameter. Fuel stacks 4 and 5 from body 2 of FTE-15 showed extensive fuel rod failure (Figs. 4-35 and 4-36), which was highest in the high-temperature body 2. It was found during metallographic examination that this was caused by a lower than specified matrix^{*} loading with consequent lower fuel rod strengths and subsequent fuel rod cracking.

^{*}The specification limit was $\leq 40\%$ macroporosity. The preirradiation quality control value was 27% to 28%.

Fuel rods selected for fission gas release measurements were examined with a Bausch and Lomb stereomicroscope. Photomicrographs of both the FTE-14 and FTE-15 fuel rods are shown in Figs. 4-37 through 4-60. The black soot marks on some of the rods were caused by in-service surface failure. The unloading damage is evident in these photographs, which show numerous surface particle failures associated with this damage. The number of surface failures is given in Tables 4-39 and 4-40 for FTE-14 and FTE-15, respectively.

4.4.2. Fission Gas Release Measurements

Representative fuel rods containing various fuel varieties were chosen from FTE-14 and FTE-15 for measurement of Kr-85m release at 1100°C in the GA TRIGA reactor facility. The measured release to birth (R/B) rates were corrected for contamination and defective particle fractions using algorithms developed in Ref. 4-14. Using a fractional release of Kr-85m per failure of 0.0053 ± 0.0027 (2σ) (Ref. 4-15), the fraction of equivalent exposed U-235 was calculated and is given in Table 4-41. The error on the exposed amount of U-235 is reported to be $0.344P < P < 2.99P$. (Ref. 4-16).

All the fuel rod varieties of FTE-14 had less than 2% measured equivalent U-235 exposure in the fuel rods except for the UC_2 TRISO-ThC₂ BISO fuel in hole 1 of body 2, which had 5% to 20% exposed U-235 as determined from the Kr-85m measurement. This result is not consistent with the metallography, which showed low total coating failure in this fuel blend. It is concluded that damage during unloading, which affected about 40 to 80 particles (see Table 4-39), and subsequent hydrolysis of the carbide fuel were the cause of the unexpectedly high Kr-85m R/B from these particular fuel rods rather than irradiation-induced effects.

The Kr-85m R/B of the FTE-15 fuel rods was also low except in several cases. Unloading damage of 51 failed particles and probable carbide hydrolysis in fuel rod 3-2-3 caused high fission gas release.

Some low pressure vessel failure seen in the metallography of fuel rods 2-5-2 (1.4%), 2-4-3 (1.6%), and 2-3-9 (1.8%) was reflected in 4% to 9% measured equivalent exposed U-235; it is possible that carbide hydrolysis in rods 2-4-3 and 2-5-2 caused higher than expected Kr-85m release. The high ThC₂ fertile failure in stack 2 of body 2 resulted in high fission gas release in these fuel rods. Rods 2-2-4 and 2-2-5 had measured equivalent U-235 exposures of 8.4% and 12.5%, respectively, by comparison the pressure vessel failure measured during metallography of the ThC₂ TRISO particles in rod 2-2-5 was 19.7%.

4.4.3. Fuel Rod Metallography

The primary objective of the companion test elements FTE-14 and FTE-15 was to test the performance of large-size (15.9-mm diameter) HTGR fuel rods containing reference and near reference fuel types in an operating HTGR environment to high temperatures and moderate fast fluence exposures. P13N and P13P (Refs. 4-17, 4-18) were accelerated tests where the same fuel types were irradiated up to full LHTGR fast fluence exposures. A general comparison of the irradiation conditions in these four tests is shown below:

Test	Time-Averaged Temperature Range (°C)	Fast Fluence Range (10 ²⁵ n/m ²) (E > 29 fJ)
FTE-14	600-1300	0.5-1.5
FTE-15	600-1300	0.7-2.0
P13N*	1000-1750	1.5-5.5
P13P*	1200-1400	3.0-8.0

Of particular interest in all these tests was the performance comparison between UO₂ TRISO and UC₂ (VSM) TRISO and the evaluation of alternate reference UC_xO_y (WAR) fuel.

* Design values

Five fuel rods from FTE-14 and seven from FTE-15 were chosen for metallographic examination. These rods represented all the fuel types tested in the elements and were selected primarily from body 2, which had the highest irradiation temperatures. The preirradiation attributes of these rods are given in Table 2-6, and the postirradiation summary is shown in Tables 4-39 and 4-40 for FTE-14 and FTE-15, respectively. A radial metallographic cross section and a representative photomicrograph of the matrix of these fuel rods are shown in Figs. 4-61 through 4-72; representative photomicrographs of the fuel particles in each of the fuel rods are shown in Figs. 4-73 through 4-87. A single-channel gamma scan plot of five of the fuel rods examined in FTE-15 is shown in Fig. 4-90.

In general, the performance of the various fuel types was satisfactory at these high temperatures and moderate fast fluence exposures. Outer pyrolytic carbon (OPyC) failure was high in some cases but was attributed to high OPTAF* values caused by the low coating rates ($<3\mu\text{m}/\text{min}$) and high densities (Ref. 4-19). Total coating failure was low in all cases except for the ThC_2 TRISO batch (4252-00-010), whose higher failure rate was partially related to hydrolysis during the fuel examination. SiC attack by lanthanide fission products was evident in the UC_2 (VSM) TRISO fuel from both test elements and is discussed in detail in Section 4.5.4. Up to 10- to 20- μm kernel migration was observed in several $(\text{Th,U})\text{O}_2$ and ThC_2 particles, but no failure was associated with any of these thermochemical effects. Kernel migration of all fuel types was underpredicted by the out-of-pile data base. The low matrix content in fuel rods from stacks 4 and 5 in body 2 of FTE-15 caused fuel rod failure. (See fuel rod 2-4-3 in Fig. 4-69 for a comparison of other fuel rod matrix loadings.)

4.4.3.1. Fertile Particles. The ThO_2 and ThC_2 BISO fuel batches from both FTE-14 and FTE-15 showed low failure and good thermal stability. Figures 4-76 and 4-83 of ThO_2 BISO batch 4252-00-011 and Figs. 4-77 and

* OPTAF = optical anisotropy factor.

and 4-84 of ThC₂ BISO batch 4251-01-021 reveal good irradiation performance. Figure 4-80 of fuel rod 2-1-5 from FTE-15 shows the only case of observed ThC₂ kernel migration which had measured penetration of 10 to 20 μm into the buffer layer; ThC₂ kernel migration was predicted to be up to 50 μm in FTE-14 and >100 μm in FTE-15. Both the ThO₂ and ThC₂ BISO particle batches had a high OPyC failure at higher fast fluence in both P13N and P13P (Refs. 4-17, 4-18). This was most likely caused by the relatively high OPTAF values of 1.13 to 1.14 for the OPyC layers, resulting in OPyC instability at high fast fluences. Reference 4-19 gives BAF^{*} values of 1.03 to 1.04 as the limit for structural stability of OPyC coatings at high fast fluence. Correlations shown in Ref. 4-17 also show that the high density and low coating rate of the OPyC layer were responsible for the high OPTAF values in both of the particle batches.

The ThO₂ TRISO batch 4262-00-051 in Figs. 4-78 and 4-86 showed no irradiation-induced OPyC coating failure in FTE-14 and 1.3% failure in FTE-15. This is consistent with the low failure fraction observed in P13N and P13P. This batch, with its high apparent coating rate of 7.7 μm/min, high density of 1.81 Mg/m³, and low OPTAF of 1.08, confirmed the good performance predicted from Ref. 4-19. The high SiC failure in the TRISO ThO₂ particles in both FTE-14 and FTE-15 was attributed to sample preparation damage due to the relative thinness of the SiC coating. This was substantiated by low fission gas release measurements made on the rods. As noted in P13N and P13P (Refs. 4-17, 4-18), there were lenticular defects, or so-called "gold spots," in the SiC layers in several of these ThO₂ TRISO particles. Metallographic examination did not show failure traceable to these defects.

The predicted structural stability of the OPyC layer of ThC₂ TRISO batch 4261-00-011 with a 1.14 OPTAF is marginal. In FTE-14, the OPyC failure fraction could not be assessed because of extensive hydrolysis of the ThC₂ fuel. In rod 2-2-5 from FTE-15, the OPyC failure was near

* BAF values of 1.03 to 1.04 correspond to OPTAF values of 1.09 to 1.16 according to Ref. 4-20.

50% with a corresponding 20% total coating failure (Fig. 4-82). The high OPyC failure of this ThC_2 TRISO batch was also observed in P13N and P13P.

4.4.3.2. Fissile Particles. The UC_2 , UO_2 , and $(\text{Th,U})\text{O}_2$ fissile fuel types performed satisfactorily in FTE-14 and FTE-15. The UC_2 fissile TRISO particles (batch 4161-01-031) underwent buffer densification and debonding as well as SiC attack by lanthanide fission products in both FTE-14 and FTE-15. This is consistent with results from P13N and P13P and with a detailed spine sample examination of this same particle batch described in Section 4.5. The SiC attack cases found in Peach Bottom test elements are compared with out-of-pile reaction rate studies in Section 4.5.4. FTE-14 fuel rods had only one case of observable SiC attack (in rod 2-1-7) that penetrated approximately 3 to 5 μm into the surface (see Fig. 4-73). In rod 2-2-6 from FTE-14, there was graphitization of the IPyC, which indicated mixed fission product concentrations but no attack of the SiC layer (Fig. 4-75). In FTE-15 with longer irradiation times, the SiC attack increased significantly. There was obvious SiC attack in 15% to 60% of the particles in rods 2-1-5 and 2-2-5 from FTE-15. Figure 4-81 shows the degree of this attack, which in rod 2-2-5 extended half-way through the SiC coating in one case. Because SiC failure in both of these rods consisted of hairline cracking, it was difficult to determine if it was an irradiation effect or polishing damage. Fission gas release measurements (Table 4-41) of rods 2-1-4 and 2-1-5 were low, indicating polishing damage. Because of masking from the high fission gas release and high ThC_2 pressure vessel failure of fuel rod 2-2-5, it could not be determined whether or not the UC_2 particle failure was irradiation induced.

The fuel kernel performance of $(\text{Th,U})\text{O}_2$ batch 4163-00-011 in fuel rods 2-4-7 from FTE-14 and FTE-15 and 2-4-3 from FTE-15 was good, with little coating failure. The buffer densified in all cases and the kernel extruded into cracks when present. (See the radial cross section of fuel rod 2-4-7 in Fig. 4-64.) There was no evidence of mixed fission product

concentrations in the IPyC layer of the $(\text{Th,U})\text{O}_2$ particles; this was indicative of the oxygen content in the kernel, which ties up the lanthanide fission products. $(\text{Th,U})\text{O}_2$ kernel migration was evident in several particles from fuel rod 2-4-7 in FTE-14 and extended up to 15 μm into the buffer layer. The migration tended to be random, which was attributed to a non-uniform temperature gradient throughout the fuel rod. By comparison, rod 2-4-3 from FTE-15 did not show $(\text{Th,U})\text{O}_2$ kernel migration, which was consistent with lower predicted migration (see Table 4-42).

The UO_2 kernel behavior was unexpected. In P13N and P13P and FTE-6 (Refs. 4-17, 4-18, 4-3), the migration of these kernels was large enough to cause pressure vessel failure in some cases (see Fig. 4-88). In FTE-14 and FTE-15, the UO_2 kernel showed no migration in rods where TREVER predicted up to 90 μm of kernel migration from KMC (kernel migration coefficient) data extrapolated from lower-temperature experiments (Ref. 4-8). Particles from rod 2-3-6 in FTE-14 (Fig. 4-76) and rods 2-3-9, 2-5-2, 2-6-5, and 3-6-10 in FTE-15 (Figs. 4-83, 4-85, 4-86, and 4-87, respectively) were all consistent in this respect; i.e., there was no kernel migration. Because the majority of the data base for UO_2 migration was derived from experiments with temperatures below 1300°C, it is possible that an extrapolation of the kernel migration coefficient toward higher temperatures is not valid.* The kernel morphology could be associated with this behavior. The UO_2 kernels seen in P13N and P13P had large gas bubbles because of the accelerated rates of gas evolution from fission products, which in turn causes some kernel deformation and apparent migration (Fig. 4-89). In FTE-14 and FTE-15, the gas bubbles were smaller, which could be related to lower gas release rates in a non-accelerated experiment and higher gas diffusion out of the kernel into the buffer at higher temperatures. UO_2 particles (Figs. 4-83, 4-85, 4-86, and 4-87) from FTE-14 and FTE-15 show much better structural stability for the kernel. This is conclusive evidence that fuel is subjected to a more severe environment in an accelerated test than in a non-accelerated test, which leads to conservative fuel designs.

*It is noted that UO_2 kernel migration has been seen above 1300°C in Dragon Project fuel experiments (Ref. 4-21). These fuel kernels are different in size and density from the kernels tested in FTE-14 and FTE-15.

The high OPyC coating failure of UC_2 TRISO batch 4162-01-021 was caused by the high OPTAF. Comparison of this batch with the performance of batch 4162-00-031 in rod 2-3-9 shows a much lower OPyC failure with a correspondingly lower OPTAF of 1.07 for the latter, as would be predicted.

4.4.4. Fuel Performance Predictions

Using the technique outlined in Ref. 4-3 for FTE-6 and accepted design criteria, kernel migration was predicted for the different fuel varieties irradiated in FTE-14 and FTE-15. The SiC attack in the UC_2 TRISO particles was also predicted and is included in the discussion of spine sample metallography (Section 4.5.4).

In Table 4-42, the predicted fuel kernel migration for the fuel rods used in the fuel examination is summarized, and the measured maximum migration is included for comparison. Only two rods had observable kernel migration: rod 2-4-6 in FTE-14 with 14 μm of $(Th,U)O_2$ migration and rod 2-1-5 in FTE-15 with 15 μm of ThC_2 kernel migration. An interesting point of this comparison is the lack of ThC_2 kernel migration in rod 2-2-5 of FTE-15, which had nearly the same predicted ThC_2 migration as rod 2-1-5, where 15 μm of migration was measured. The reason that ThC_2 migration occurred in the BISO particles but not in the TRISO particle is not known.

The kernel migrations for UC_2 , UO_2 , $(Th,U)O_2$, ThC_2 , and ThO_2 fuel were all overpredicted, which suggests some conservatism in the design criteria. ThO_2 kernel migration was partially overpredicted because the time threshold described in Ref. 4-22 was not included in the prediction. As mentioned previously, the UO_2 kernel migration was grossly overpredicted; this was attributed partly to less kernel deformation by gas bubbles at higher temperatures, as discussed in Section 4.4.3.2. It is also possible that out of pile testing does not fully reflect the variable temperature field and multiple shutdowns of a power reactor.

In summary, the predicted SiC attack discussed in Section 4.5.4 and the kernel migration discussed here show a consistent conservatism. Measured SiC attack rates were lower than predicted above 1300°C, and kernel migration in all fuel types was almost nonexistent, whereas predictions indicated large mobility.

4.4.5. Radial Cesium and Strontium Determination

Cesium and strontium profiles were determined on four fuel body sections from FTE-14 and FTE-15 using the sectioning techniques developed for the analysis of diffusion samples in FTE-4 and FTE-6 (Ref. 4-23). This work was performed to provide a further check on the time-averaged temperatures calculated by TREVER.

One cross-sectional slice from FTE-14 (body 2, at 2111.0 mm active core height) and three cross-sectional slices from FTE-15 (body 1, 850.9 mm; body 2, 2116.0 mm; body 3, 2438.4 mm) were sectioned according to the procedures used on FTE-4 and FTE-6 (Refs. 4-2, 4-3) and analyzed for Cs-134, Cs-137, and Sr-90. Figures 4-91 through 4-98 show the diffusion profiles obtained from the analysis for Cs-134 and Cs-137. The results of the strontium analysis are shown in Figs. 4-99 and 4-100. The error bars on the measured data represent the 2σ counting error associated with the gamma scan results. In some cases, the error bars are not shown; this reflects the fact that the error bars are located within the limits of the plotted symbol. The error involved in sectioning the fuel body graphite webs on the milling machine is small and is also contained within the limits of the plotted symbol.

As in previous fuel body sectioning experiments, the shapes of the Cs-137 and Cs-134 concentration profiles are similar and differ quantitatively by a factor of approximately 10, partially due to the time lag and concentrations involved in activating the fission product Cs-133 to Cs-134. The similar curves confirm the hypothesis that the fission products Xe-133 and Xe-137 have little effect on the concentration profiles of Cs-134 and Cs-137 (Ref. 4-3).

FIPERQ was used to fit the Cs-137 and Sr-90 data. This code models fission metal release from fuel elements by calculating the birth, decay, and subsequent diffusion through the kernel fuel rod, fuel body, and fuel element sleeve (Refs. 4-24, 4-25). The input consists of time-averaged temperatures calculated by TREVER (Ref. 4-26) and interpolated by TEMP (Ref. 4-27) and fuel element dimensions. Due to the uncertainty of the time-dependent variation of the source term, the actual isotope release is not calculated but a steady rate of cesium or strontium production is assumed. This does not change the shape of the diffusion profile because the Fick's law diffusion coefficient which is assumed to apply to metallic diffusion through the fuel element is independent of concentration. The dashed error lines on the predicted profiles are obtained from the 1 σ uncertainties of the diffusion coefficient given in Ref. 4-8.

Figure 4-92 compares the measured Cs-137 data and the calculated FIPERQ profile for the FTE-14 fuel body 2 section at 2110.0-mm active core height. The predicted curve is somewhat flatter than the measured profile, suggesting that the TREVER time-averaged temperature could be slightly higher than the actual temperature or that the diffusion coefficient should be valued more toward the upper limit of uncertainty. The shapes of the measured and predicted profiles in Fig. 4-94 for the FTE-15 fuel body 1 section at 850.9-mm active core height could indicate an underprediction of temperature by TREVER at this axial location. The FIPERQ predicted profile is somewhat steep in comparison with the flatter curve of the measured data. Figure 4-96 (FTE-15 fuel body 2 at 2116.0-mm active core height) shows good agreement between the shapes of the measured and predicted profiles, indicating an accurate temperature prediction. The measured data between 2.0- and 3.0-mm penetration depth from the fuel hole could indicate back-diffusion from the purge stream which increased the cesium distribution toward the outer edge of the fuel body. Figure 4-98 (FTE-15 fuel body 3 at 2438.4-mm active core height) shows an almost flat measured profile. This usually arises from a long period of high-temperature irradiation. The profile might suggest that the TREVER-calculated temperature could be somewhat low. Figure 4-99 (FTE-15 fuel

body 1 at 850.9 mm) shows measured and predicted curves for Sr-90 at 619°C. The discrepancy between the measured and predicted profiles is probably due to the Kr-90 precursor, which seems to be more important than the direct release of Sr-90 at this temperature. Comparison of Fig. 4-100 (FTE-15 fuel body 2 at 2116.0-mm core height) and Fig. 4-96 shows the similarity of the predicted and measured values of strontium and cesium in the same sample. Again, as in Figs. 4-95 and 4-96, the higher concentration toward the outer edge of the sample seems to indicate back-diffusion from the purge stream.

The time-averaged temperatures calculated by TREVER and used in FIPERQ are in good agreement with the measured profiles when account is taken of the error of those temperatures, which is conservatively (i.e., 3σ) estimated to be $\pm 100^\circ\text{C}$, and the large scatter in the measured data. As in previous work (Ref. 4-3), no significant gaseous precursor contribution to cesium distribution was found.

The significance of the two strontium profiles lies in the temperature of the fuel at the time of release. At lower temperatures of 600° to 700°C , the decay of Kr-90 to Sr-90 could be the primary contributing factor in the strontium diffusion profile. At higher temperatures, the direct release of Sr-90 is probably more important to the diffusion profile, as the precursor would then contribute little to the overall profile.

4.4.6. Autoradiography

Beta-gamma autoradiography was used to show relative fission product migration into the graphite fuel bodies. Cross-sectional slices were cut from the fuel bodies and ground flat with abrasive paper. The slices were then placed on top of Kodak Industrial M type film and exposed for 70 min in FTE-14 and 10 min in FTE-15. In all cases the relative release to the fuel bodies was considered low in comparison with that in FTE-6 autoradiography, where high fissile fuel failure occurred (Ref. 4-3).

Figures 4-101 and 4-102 show autoradiography photographs of bodies 2 and 3 from FTE-14 and FTE-15, respectively. In fuel body 2 of both FTE-14 and FTE-15, the highest release was from holes 1 and 5, which contained UC_2 TRISO/ ThC_2 BISO and UO_2 TRISO/ ThC_2 BISO fuel blends, respectively. The lowest release in body 2 was from hole 2, which contained UC_2 TRISO/ ThC_2 TRISO fuel. An interesting observation about the fission product behavior in FTE-14 body 2 is that the diffusive release from the ThC_2 BISO fuel blends in holes 1 and 5 was higher than the release from the 20% total coating failure of ThC_2 TRISO fuel in hole 2 of FTE-15.

In body 3, the results of FTE-14 and FTE-15 are also consistent. Hole 1 with a UC_2 TRISO/ ThC_2 BISO fuel blend had the highest release. The other fuel blends had about equal release. Hole 4 with a $(\text{Th,U})\text{O}_2$ TRISO/ ThC_2 BISO blend appeared to have the lowest release in body 3 of FTE-14, and hole 6 with a UO_2 TRISO/ ThC_2 TRISO blend appeared to have the lowest release in body 3 of FTE-15.

The FTE-15 slice from body 3 has a different appearance from the FTE-14 slice from body 3. In hole 2 the slit put in the fuel body to measure the release of in-plane hoop stress is evident as a light spot. This slice also had detectable activity within the center spine hole, whereas the spine holes of the other graphite slices from FTE-14 and FTE-15 did not. This was due to the fact that slice 15-3-1-10 was taken at a position adjacent to a thermal stability sample (TS-8), which apparently contained releasing fuel.

4.5. THERMAL STABILITY SPINE SAMPLES

Nine type II thermal stability crucibles were irradiated in both FTE-14 and FTE-15. A description of these six-hole crucibles is given in Ref. 4-3, and the position, irradiation exposure, and metrology data are given in Tables 2-7 and 2-8. Eighteen different fuel particle batches were loaded into these crucibles according to the loading plan given in Table 4-43. Temperatures quoted in the text are time and volume averaged.

The purpose of these experiments was to irradiate different fuel batches in a relatively isothermal environment to a variety of irradiation exposures. The general irradiation conditions were high temperatures (1000° to 1400°C) and moderate fast fluence exposures, i.e., up to $2.0 \times 10^{25} \text{ n/m}^2$ ($E \geq 29 \text{ fJ}$)_{HTGR}. ThO₂ BISO, UC₂ TRISO (VSM), and UC_xO_y TRISO (WAR) fuels were chosen for detailed analysis. These batches were a test of near reference design particles and allowed a direct comparison between the performance of VSM and WAR uranium carbide fuels.

4.5.1. Visual Examination

All the spine sample batches were examined with a Bausch and Lomb stereomicroscope after unloading. Stereophotographs of the FTE-14 and FTE-15 spine samples are shown in Figs. 4-103 through 4-108. A summary of the failure fraction of the OPyC coatings observed during stereoexamination is given in Table 4-44. All the fuel particle types had good exterior appearances except for UC_xO_y (WAR) particle batch OR-1694. In the four experiments where this particle batch was tested in FTE-14 and FTE-15, a 6% to 8% OPyC failure fraction was observed. From the stereophotograph of the WAR particles in Figs. 4-103 and 4-107, it is obvious that the larger particles failed more frequently than the smaller particles. This particular particle batch was unusual because it had a wide range of particle diameters.

The effect of OPyC coating failure in TRISO particles has been examined using Weibull statistics (Ref. 4-28). The general mathematical formulation is shown in Eq. 4-1, which is based on the assumption that the probability of finding a critical flaw in a brittle material is proportional to the volume of the material under stress:

$$F = 1 - \exp \left[- \int_V \left(\frac{\sigma}{\sigma_o} \right)^M dV \right] , \quad (4-1)$$

where F = failure probability,
 V = volume under stress,
 σ = uniaxial stress,
 σ_o = normalizing material property parameter,
 M = Weibull modulus.

For comparison purposes, in this particular case the stresses in the OPyC layer are assumed to be constant in all of the particles because of similar coating conditions and irradiation exposures. With this assumption and the fact that the volume of the OPyC is proportional to the difference between the cube of the outside and inside OPyC diameters, Eq. 4-1 reduces to Eq. 4-2:

$$\log(1 - F) = C_1[d^3 - (d - 2t)^3] + C_2, \quad (4-2)$$

where C_1 and C_2 = constants,
 d = particle diameter,
 $1 - F$ = survival fraction,
 t = OPyC coating thickness = 40 μm .

If $d^3 - (d - 2t)^3$ and $\log(1 - F)$ are plotted, the least-squares fit of the data should be a straight line with slope C_1 and intercept C_2 . Taking the four particle batches of OR-1694, a survival fraction $(1 - F)$ was determined for particle sizes in 25- μm -diameter increments. These data are plotted in Fig. 4-109 and a least-squares fit of the data is shown. The good correlation in this particular case shows that when the irradiation conditions and OPyC stresses are constant, the particle size is a critical factor in determining the OPyC failure level. This analysis indicates the possible applicability of Weibull statistics for models of OPyC failure.

4.5.2. Fission Gas Release Measurements

The Kr-85m fission gas release measurements at 1100°C are shown in Table 4-44 for all the thermal stability spine samples examined from FTE-14

and FTE-15. All the samples showed low release, indicating no total coating failure except for the OR-1694 WAR batches. Metallography was performed on batch TS6-6 from FTE-14 after the fission gas release measurement, and it was found that the OPyC failure was 24% ($17\% < P < 34\%$) with an associated 11% ($6\% < P < 18\%$) pressure vessel failure. For comparison, the metallography done on these samples at the time of unloading from the element showed only 9% ($6\% < P < 12.6\%$) OPyC failure and 1% ($0.1\% < P < 2\%$) pressure vessel failure. This confirmed a suspicion that storage of these particular particles with initially high OPyC failure in a glass bottle with periodic handling caused additional fuel failure not associated with irradiation.

4.5.3. Radiography

Contact radiographic plates were made of two batches of 20 particles each of the seven spine samples from FTE-14 submitted for initial examination. Representative photographs of these samples are shown in Figs. 4-110 through 4-112.

The UC_2 (200- μ m) VSM particles showed metallic fission product buildup in the IPyC coating and SiC attack in some cases, as seen in Fig. 4-110. The UC_xO_y WAR particles showed a buildup of metallic fission products in the recoil zone of the buffer layer next to the kernel (Fig. 4-111). No migration of fission products beyond this zone was observed. The ThO_2 particles in Fig. 4-112 showed no failure.

4.5.4. Metallography

A summary of the metallographic examination of both the FTE-14 and FTE-15 spine samples is presented in Table 4-44. Representative photomicrographs of the metallography are shown in Figs. 4-113 through 4-123. The ThO_2 BISO fertile particle batch 4252-02-070 showed good thermal stability in both FTE-14 and FTE-15 to peak exposures of 2×10^{25} n/m² ($E > 29$ fJ)_{HTGR} at $\sim 1300^\circ\text{C}$. The fissile particles allowed an equivalent comparison between the thermal stability of UC_2 (VSM) and UC_xO_y (WAR) TRISO fuel.

The UC₂ (VSM) TRISO particle batches (4161-00-030 and 4161-00-020) showed buffer densification and debonding. SiC and total coating failures seen in some of the samples were primarily caused by polishing damage. This is substantiated by the low fission gas release measurements in all of these particles. The thermal stability of the kernel was good in that there was no observable kernel migration, but mixed fission product attack of the SiC layer was observed in six of the eight UC₂ (VSM) spine samples examined.

These six batches showed increasing SiC attack by fission products with increasing irradiation temperature and exposure time. In samples TS1-4 from FTE-14 and FTE-15, no graphitization of the IPyC was evident at temperatures for which high concentrations of fission products would be expected (Figs. 4-111 through 4-116). In samples TS5-6, which had the highest irradiation temperatures, the visible SiC attack zone had moved half-way through the SiC layer (Figs. 4-115 and 4-121). Samples with intermediate temperatures correspondingly showed various degrees of attack. The large number of samples examined allowed a comparison of current out-of-pile data with data from non-accelerated in-pile tests. The rate of SiC thinning is described in Ref. 4-29 by the Arrhenius relationship

$$\dot{x} = 4.2 \cdot 10^{-7} \exp(-3.283 \cdot 10^5 / RT) \text{ (}\mu\text{m/h)} \quad , \quad (4-3)$$

where $\dot{x}$ = SiC thinning rate ($\mu\text{m/h}$),

R = gas constant (J/mole/ $^{\circ}\text{K}$),

T = temperature (K).

Because of in-pile temperature variations with time, an exponentially time-weighted average temperature was used in the determination of an average thinning rate. This was done for each sample using an algorithm outlined in Ref. 4-2. In addition to the six UC₂ spine samples from FTE-14 and FTE-15 that showed SiC attack, an additional 18 cases of SiC attack

on UC_2 were observed in various Peach Bottom test elements during PIEs at ORNL and GA (Refs. 4-2, 4-3, 4-30). The predicted curves and measured results are given in Table 4-45 and plotted in Fig. 4-124. Both loose particle and fuel rods are included in the comparison with the assumption that loose particles saw a non-shifting thermal gradient. This is substantiated by the concentration of fission products in localized areas where SiC attack occurred.

In all cases the observed SiC thinning rates were less than those measured in out-of-pile experiments at temperatures above 1300°C. This is possibly due to a threshold fission product concentration necessary for attack to commence; Smith (Ref. 4-29) estimated this to be ~5% FIMA in UC_2 particles. The predicted SiC attack in the above examples did not take a burnup threshold into account (i.e., attack was assumed to commence at beginning of life).

It has also been suggested (Ref. 4-29) that the large thermal gradient used in the out-of-pile tests could give higher rates of SiC attack than under typical in-pile thermal conditions. There were also a few cases of SiC attack below 1300°C which showed slightly higher attack rates than predicted. This is possibly related to palladium attack seen at <1300°C in HRB-12 (Ref. 4-30) and P13Q (Ref. 4-4) but cannot be substantiated without microprobe examination.

In comparison with the performance of the UC_2 (VSM) particles, the $UC_{4.3}O_{1.3}$ (WAR) TRISO fissile particles showed good kernel and fission product performance. Photomicrographs of the four batches of OR-1694 particles are presented in Figs. 4-116, 4-122, and 4-123. Because of the shrinkage of the low-density kernel, the WAR particles have a large void in the center. The dark field photomicrographs in Figs. 4-122 and 4-123 show that no significant metallic fission products have migrated out of the kernel, and subsequently no SiC attack was observed. This is due to the fact that the O_2 -doped kernels retain the metallic fission products as oxides and inhibit their diffusion to the SiC interface.

4.6. FUEL PERFORMANCE SUMMARY

Fuel in the form of LHTGR fuel rods and loose particle samples was irradiated to moderate fast fluence exposures of $1 \text{ to } 2 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR} and up to 1300° to 1600°C in FTE-14 and FTE-15. In most cases the performance of the fuel was satisfactory; fuel rod integrity was good, fuel failure was low, and thermochemical fuel failure mechanisms were less pronounced than expected.

Some of the highlights of the examinations are as follows:

1. The integrity of all fuel rods was good with little cracking or spalling except in stacks 4 and 5 of FTE-15, which had lower than specified matrix loadings. These rods showed major cracking which was more pronounced in the high-temperature, high-fluence portion of the element.
2. Kr-85m fission gas release measurements at 1100°C generally showed low levels of exposed fissionable material in both FTE-14 and FTE-15. High ThC_2 TRISO particle failure and associated carbide hydrolysis in rods 2-2-4 and 2-2-5 of FTE-15 gave the highest R/B results. Other significantly high R/B measurements were associated with unloading damage and/or hydrolysis.
3. Fuel coating failure in FTE-14 was low in all cases but was significantly higher in several cases in FTE-15. A high OPyC coating failure was seen in UO_2 TRISO batch 4162-01-021 and ThC_2 TRISO batch 4262-00-011; both cases are attributed to low coating rates which caused high PyC anisotropy and poor structural stability during irradiation. Lenticular defects were evident in SiC layers of ThO_2 TRISO batch 4262-00-051, but in no case was there fuel failure associated with these defects.

4. Kernel migration was evident only in the ThC_2 and $(\text{Th,U})\text{O}_2$ kernels with a maximum migration of 15 μm in each case. UO_2 , UC_2 , and ThO_2 kernels did not migrate, and in all cases the predicted migration was significantly higher than the measured.
5. Extrapolation of empirically derived UO_2 KMC data to high temperature and non-accelerated irradiation conditions is not justified. The stability of this kernel at higher temperatures appears to be related to the morphology of the kernel. Smaller bubble formation at higher irradiation temperatures results in less kernel swelling and deformation and consequently less kernel movement.
6. SiC attack rates measured on UC_2 particles from 11 Peach Bottom test elements indicate significantly lower values than those measured in out-of-pile experiments above 1300°C. Between 1100° and 1200°C there were a few cases of underpredicted SiC attack which could be related to low-temperature palladium attack as seen in UC_2 particles from HRB-13 and P13Q.
7. Autoradiography and radial graphite sectioning showed low fission product activity in the graphite fuel bodies from fuel failure and diffusive release from BISO fuel. In all cases the graphite showed higher activity levels when adjacent to BISO fuel rather than to all-TRISO fuel.

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5. DISCUSSION AND CONCLUSIONS

FTE-14 and FTE-15 fuel and graphite preirradiation, postirradiation, and irradiation history measurements were collected and analyzed in a statistical manner. An attempt was made to compare postirradiation test results with current HTGR design and performance models and to test eventual discrepancies for significance. Data from previously analyzed Peach Bottom test elements were also included in the analysis where possible as a comparison. Major conclusions are as follows:

1. Gamma scan and burnup measurements showed an underprediction of the power in FTE-14, while the power in FTE-15 was correctly predicted. The power measurements were used to correct the power history of the element, which resulted in temperature calculations agreeing well with thermocouple readings.
2. Fluence dosimetry in both FTE-14 and FTE-15 showed insignificant differences between the measured and calculated fast fluences and a significant underprediction of the thermal fluence. The thermal fluence bias was rejected because evidence from extensive burnup measurements does not support a flux depression.
3. Isotopic analyses of loose particles used in the burnup measurements showed 1% to 3% differences between measured and predicted U-233 and U-235 concentrations in the fertile and fissile particles and up to 15% differences in uranium isotopes with low concentrations. This is consistent with observations from previous test elements, and therefore it is concluded that FEVER predictions of U-234, U-236, and U-238 distributions are not well modeled.

4. The composite burnup of the fuel rods was determined by gamma spectroscopy and was found to agree within the 2σ confidence limits with destructive FIMA measurements of loose particle samples. This comparison substantiates an earlier gamma spectroscopic calibration for 15.9-mm (5/8-in.) diameter fuel rods.
5. The highest stresses in FTE-14 and FTE-15 were 54% of the UTS in the radial direction at end of life shutdown. Compressive stresses were small compared with the ultimate compressive strength of the material.
6. With the exception of the inverted bow found for graphite strips, the results of the destructive stress examination were in reasonable agreement with design predictions.
7. Fuel stack lengths measured during the postirradiation disassembly and during in situ gamma scanning at Peach Bottom agreed within measurement uncertainties.
8. H-327 graphite fuel body strains were overpredicted in the radial and axial directions by present design codes and material property data.
9. Fuel rod strain data showed that anisotropy in close-packed TRISO/TRISO fuel rods was significantly larger than that predicted by an empirical model based on earlier TRISO/TRISO fuel rod strain results. This may be related to higher irradiation temperatures of these elements.
10. TRISO/BISO fuel rod strain was reasonably well predicted. The relative difference between measurements and predictions ($C/M - 1$) increased with increasing fast fluence from -20% to +30% over the fluence range from 1 to $2 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR}.

11. The fuel rods appeared to be structurally sound with little cracking or spalling except for several stacks in FTE-15 which had extensive failure because of a low matrix loading.
12. Kr-85m fission gas release measurements generally indicated low amounts of exposed fissionable material in loose particles and fuel rods. Several relatively high fission gas release measurements were related to unloading damage and/or hydrolysis of carbide fuel. The most obvious contribution of high fission gas release from failed fuel was in rods from FTE-15 containing ThC_2 TRISO batch 4261-00-011, which had a metallographically measured total coating failure in ~20% of the observed particle populations..
13. Fertile fuel in both FTE-14 and FTE-15 showed only one case of ThC_2 kernel migration and no ThO_2 kernel migration. Of the UO_2 , UC_2 , and $(\text{Th,U})\text{O}_2$ fissile kernels, only the $(\text{Th,U})\text{O}_2$ kernels showed ~15-mm migration. The kernels migration was overpredicted in both fissile and fertile fuel.
14. OPyC failure in fuel rods was attributed to high OPyC densities and low coating rates. OPyC failure in UC_xO_y batch OR-1694 (ORNL fuel) was found to correlate well with Weibull statistics which predict higher failure rates in larger particles.
15. SiC attack in UC_2 TRISO particles in FTE-14 and FTE-15 as well as nine other test elements was less than expected from out-of-pile heating experiments for temperatures above 1300°C.
16. Graphite fuel body autoradiography showed significant fission product release by diffusion out of BISO particles and low release from all-TRISO fuel blends. Gamma scanning of the fuel bodies indicated that the absolute release of gamma-emitting radionuclides was low. Radial Cs-137, Cs-134, and Sr-90 profiles determined by sectioning showed fair agreement with FIPERQ predicted values.

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APPENDIX A

FIGURES

Fig. 2-1. FTE-14 and FTE-15 assembly

FUEL BODY

O.D. 69.60 $+0.000$
 -0.51

(2.740 $+0.000$
 -0.002)

I.D. 20.32 $+0.25$
 -0.000

(0.80 $+0.01$
 -0.00)

CHROMEL-ALUMEL
 THERMOCOUPLE

PURGE GROOVE: 3.56 (0.14) WIDE
 BY 1.40 (0.055) DEEP

FUEL ROD 15.62 ± 0.08
 (0.615 ± 0.003)

DIMENSIONS IN MM (IN.)

Fig. 2-2. FTE-14 and FTE-15 cross section

Fig. 2-3. FTE-14 and FTE-15 outside fuel body dimensions

Fig. 3-1. Peach Bottom Core 2 operating parameters, TREVER simulation

A-7

Fig. 3-2. Peach Bottom Core 2 thermal power history, TREVER simulation

Fig. 3-3a. FTE-14 power history, TREVER simulation

Fig. 3-3b. FTE-15 power history, TREVER simulation

K7359-1

Fig. 3-4. FTE-14 dosimetry capsule from spine sample H887-19 in body 1

Fig. 3-5. FTE-14 and FTE-15 dosimetry capsule assembly

Fig. 3-6. FTE-14 measured time-averaged power profiles

Fig. 3-7. FTE-15 measured time-averaged power profiles

A-13

Fig. 3-8. FTE-14 comparison of calculated and measured time-averaged power profiles for fuel stack 1

Fig. 3-9. FTE-15 comparison of calculated and measured time-averaged power profiles for fuel stack 1

Fig. 3-10. FTE-15 comparison of calculated and measured end of life power profiles for fuel stack 1

Fig. 3-11a. FTE-14 axial temperature profile (385-500 EFPD) for fuel stack 1

Fig. 3-11b. FTE-14 axial temperature profile (500-564 EFPD) for fuel stack 1

Fig. 3-11c. FTE-14 axial temperature profile (564-610 EFPD) for fuel stack 1

Fig. 3-11d. FTE-14 axial temperature profile (610-701 EFPD) for fuel stack 1

Fig. 3-12a. FTE-15 axial temperature profile (385-500 EFPD) for fuel stack 1

Fig. 3-12b. FTE-15 axial temperature profile (500-564 EFPD) for fuel stack 1

Fig. 3-12c. FTE-15 axial temperature profile (564-610 EFPD) for fuel stack 1

Fig. 3-12d. FTE-15 axial temperature profile (610-701 EFPD) for fuel stack 1

Fig. 3-12e. FTE-15 axial temperature profile (701-748 EFPD) for fuel stack 1

Fig. 3-12f. FTE-15 axial temperature profile (748-788 EFPD) for fuel stack 1

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Fig. 3-13a. FTE-14 time-averaged temperatures for fuel stack 1

Fig. 3-13b. FTE-14 temperature envelope for fuel stack 1

Fig. 3-14a. FTE-15 time-averaged temperatures for fuel stack 1

Fig. 3-14b. FTE-15 temperature envelope for fuel stack 1

Fig. 3-15a. FTE-14 radial temperature at axial location of thermocouple hot junction for time interval 564-610 EFPD

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Fig. 3-16a. FTE-14 measured and calculated W/Re thermocouple results

Fig. 3-16b. FTE-15 measured and calculated W/Re thermocouple results

Fig. 3-17a. FTE-14 composite FIMA comparison - stack 1

Fig. 3-17b. FTE-15 composite FIMA comparison - stack 1

Fig. 3-18a. Finite element model for thermal analysis

Fig. 3-18b. Finite element model for residual stress analysis

Fig. 3-19. FTE-14 fuel body 1 temperature and stress contour plots for startup at beginning of life

Fig. 3-20. FTE-14 fuel body 2 temperature and stress contour plots for startup at beginning of life

Fig. 3-21. FTE-14 fuel body 3 temperature and stress contour plots for startup at beginning of life

Fig. 3-22. FTE-14 fuel body 1, 2, and 3 stress directions for startup at beginning of life

Fig. 3-23. FTE-14 fuel body 1 temperature and stress contour plots for operation at end of life

Fig. 3-24. FTE-14 fuel body 2 temperature and stress contour plots for operation at end of life

Fig. 3-25. FTE-14 fuel body 3 temperature and stress contour plots for operation at end of life

Fig. 3-26. FTE-14 fuel body 1, 2, and 3 stress directions for operation at end of life

Fig. 3-27. FTE-14 fuel body 1 MAX-MIN temperatures and MAX-MIN stress histories for operation and shutdown

Fig. 3-28. FTE-14 fuel body 2 MAX-MIN temperatures and MAX-MIN stress histories for operation and shutdown

Fig. 3-29. FTE-14 fuel body 3 MAX-MIN temperatures and MAX-MIN stress histories for operation and shutdown

Fig. 3-30. FTE-14 fuel body 1 temperature at end of life operation and stress contour plots for end of life shutdown

Fig. 3-31. FTE-14 fuel body 2 temperature at end of life operation and stress contour plots for end of life shutdown

Fig. 3-32. FTE-14 fuel body 3 temperature at end of life operation and stress contour plots for end of life shutdown

Fig. 3-33. FTE-14 fuel body 1, 2, and 3 stress directions for end of life shutdown

Fig. 3-34. FTE-15 fuel body 1 temperature and stress contour plots for startup at beginning of life

Fig. 3-35. FTE-15 fuel body 2 temperature and stress contour plots for startup at beginning of life

Fig. 3-36. FTE-15 fuel body 3 temperature and stress contour plots for startup at beginning of life

Fig. 3-37. FTE-15 fuel body 1, 2, and 3 stress directions for startup at beginning of life

Fig. 3-38. FTE-15 fuel body 1 temperature and stress contour plots for operation at end of life

Fig. 3-39. FTE-15 fuel body 2 temperature and stress contour plots for operation at end of life

Fig. 3-40. FTE-15 fuel body 3 temperature and stress contour plots for operation at end of life

Fig. 3-41. FTE-15 fuel body 1, 2, and 3 stress directions for operation at end of life

Fig. 3-42. FTE-15 fuel body 1 MAX-MIN temperatures and MAX-MIN stress histories for operation and shutdown

Fig. 3-43. FTE-15 fuel body 2 MAX-MIN temperatures and MAX-MIN stress histories for operation and shutdown

Fig. 3-44. FTE-15 fuel body 3 MAX-MIN temperatures and MAX-MIN stress histories for operation and shutdown

Fig. 3-45. FTE-15 fuel body 1 temperature at end of life operation and stress contour plots for end of life shutdown

Fig. 3-46. FTE-15 fuel body 2 temperature at end of life operation and stress contour plots for end of life shutdown

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Fig. 3-49. Cross sections of Peach Bottom teledial fuel test elements

Fig. 4-1. Collimator scan path of FTE-15 during Peach Bottom scanning

Fig. 4-2a. FTE-14 γ -scan strip chart

Fig. 4-2b. FTE-15 γ -scan strip chart

Fig. 4-3. FTE-15 graphite fuel body gamma-scanned areas

Fig. 4-4a. FTE-14 fuel test element identification

Fig. 4-4b. FTE-15 fuel test element identification (mirror image)

K7359 (7-23)

Fig. 4-5. FTE-14 composite photograph of total element

Fig. 4-6. FTE-15 composite photograph of total element (mirror image)

Fig. 4-7. FTE-14 thermocouple cut (lower reflector)

Fig. 4-8. FTE-15 thermocouple cut (bottom of body 1)

K7359 (Top 66-67, Bottom 70-71)

Fig. 4-9. FTE-14 composite photograph of fuel body 1: top, 90° line; bottom, 180° line

K7359 (Top 39-41, Bottom 42-44)

Fig. 4-10. FTE-14 composite photograph of fuel body 2: top, 90° line;
bottom, 180° line

K7359 (Top 26-28, Bottom 29-31)

Fig. 4-11. FTE-14 composite photograph of fuel body 3: top, 0° line; bottom, 180° line

Fig. 4-12. FTE-15 composite photograph of fuel body 1

Fig. 4-13. FTE-15 composite photograph of fuel body 2

Fig. 4-14. FTE-15 composite photograph of fuel body 3

Fig. 4-15. Typical fuel body discharge setup

Fig. 4-16. FTE-14 sectioning of fuel bodies for measurement and autoradiography

Fig. 4-17. FTE-15 sectioning of fuel bodies for measurement and autoradiography

K7359-97 (a)

K7359-98 (b)

K7359-99 (c)

K7359-100 (d)

Fig. 4-18. FTE-14 photographs of fuel body 1: (a) top of section 1-1, (b) top of section 1-2, (c) top of section 1-3, and (d) bottom of section 1-4

K7359-102 (a)

K7359-103 (b)

K7359-101 (c)

Fig. 4-19. FTE-14 photographs of fuel body 2: (a) top of section 2-1, (b) top of section 2-2, and (c) bottom of section 2-3

7359-104 (a)

K7359-105 (b)

K7359-106 (c)

Fig. 4-20. FTE-14 photographs of fuel body 3: (a) top of section 3-1, (b) top of section 3-2, and (c) bottom of section 3-3

Fig. 4-21a. FTE-15 slice 1-2 (top view)

Fig. 4-21b. FTE-15 slice 2-2 (top view)

Fig. 4-21c. FTE-15 slice 2-3 (bottom view)

Fig. 4-21d. FTE-15 slice 3-2 (top view)

Fig. 4-22a. FTE-14 measured and calculated sleeve strain

Fig. 4-22b. FTE-15 measured and calculated sleeve strain

Fig. 4-23. FTE-14 measured and calculated fuel body strain for H-327 graphite

Fig. 4-24. FTE-15 measured and calculated fuel body strain for H-327 graphite

Fig. 4-25. H-327 graphite axial strain data from 31-in. and 15-in.-long teledial fuel bodies of 2-74-in. diameter irradiated in fuel and recycle test elements in the Peach Bottom HTGR

Fig. 4-26. H-327 graphite radial strain data from 31-in.- and 15-in.-long teledial fuel bodies of 2.74-in. diameter irradiated in fuel and recycle test elements in the Peach Bottom HTGR

Fig. 4-27a. FTE-14 measured and calculated sleeve-fuel body gaps

Fig. 4-27b. FTE-15 measured and calculated sleeve-fuel body gaps

Fig. 4-28a. FTE-14 measured and calculated fuel rod strain - fuel hole 1

Fig. 4-28b. FTE-15 measured and calculated fuel rod strain - fuel hole 1

Fig. 4-28c. FTE-14 measured and calculated fuel rod strain - fuel hole 2

Fig. 4-28d. FTE-15 measured and calculated fuel rod strain - fuel hole 2

Fig. 4-28e. FTE-14 measured and calculated fuel rod strain - fuel hole 3

Fig. 4-28f. FTE-15 measured and calculated fuel rod strain - fuel hole 3

Fig. 4-29a. FTE-14 measured and calculated fuel rod strain - fuel hole 4

Fig. 4-29b. FTE-15 measured and calculated fuel rod strain - fuel hole 4

Fig. 4-29c. FTE-14 measured and calculated fuel rod strain - fuel hole 5

Fig. 4-29d. FTE-15 measured and calculated fuel rod strain - fuel hole 5

Fig. 4-29e. FTE-14 measured and calculated fuel rod strain - fuel hole 6

Fig. 4-29f. FTE-15 measured and calculated fuel rod strain - fuel hole 6

Fig. 4-30. FTE-14 and FTE-15 difference between predicted and measured fuel rod strain versus fast fluence

Fig. 4-31a. FTE-14 fuel rod anisotropy - fuel stack 1

Fig. 4-31b. FTE-15 fuel rod anisotropy - fuel stack 1

Fig. 4-31c. FTE-14 fuel rod anisotropy - fuel stack 2

Fig. 4-31d. FTE-15 fuel rod anisotropy - fuel stack 2

Fig. 4-31e. FTE-14 fuel rod anisotropy - fuel stack 3

Fig. 4-31f. FTE-15 fuel rod anisotropy - fuel stack 3

Fig. 4-32a. FTE-14 fuel rod anisotropy - fuel stack 4

Fig. 4-32b. FTE-15 fuel rod anisotropy - fuel stack 4

Fig. 4-32c. FTE-14 fuel rod anisotropy - fuel stack 5

Fig. 4-32d. FTE-15 fuel rod anisotropy - fuel stack 5

Fig. 4-32e. FTE-14 fuel rod anisotropy - fuel stack 6

Fig. 4-32f. FTE-15 fuel rod anisotropy - fuel stack 6

Fig. 4-33a. FTE-14 measured and calculated fuel rod-fuel hole gaps - fuel hole 1

Fig. 4-33b. FTE-15 measured and calculated fuel rod-fuel hole gaps - fuel hole 1

Fig. 4-33c. FTE-14 measured and calculated fuel rod-fuel hole gaps - fuel hole 2

Fig. 4-33d. FTE-15 measured and calculated fuel rod-fuel hole gaps - fuel hole 2

Fig. 4-33e. FTE-14 measured and calculated fuel rod-fuel hole gaps - fuel hole 3

Fig. 4-33f. FTE-15 measured and calculated fuel rod-fuel hole gaps - fuel hole 3

Fig. 4-34a. FTE-14 measured and calculated fuel rod-fuel hole gaps - fuel hole 4

Fig. 4-34b. FTE-15 measured and calculated fuel rod-fuel hole gaps - fuel hole 4

Fig. 4-34c. FTE-14 measured and calculated fuel rod-fuel hole gaps - fuel hole 5

Fig. 4-34d. FTE-15 measured and calculated fuel rod-fuel hole gaps - fuel hole 5

Fig. 4-34e. FTE-14 measured and calculated fuel rod-fuel hole gaps - fuel hole 6

Fig. 4-34f. FTE-15 measured and calculated fuel rod-fuel hole gaps - fuel hole 6

B
A—C

B
A—C

Fig. 4-35. FTE-15 composite photograph of
stack 4, body 2 (center body)

Fig. 4-36. FTE-15 composite photograph of
stack 5, body 2 (center body)

S7359 (114, 115, 120)

S7359 (112, 113, 119)

S7359-116

S7359-118

Fig. 4-37. FTE-14 fuel rod 2-1-7 (UC_2 TRISO - ThC_2 TRISO blend) visual examination. Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1251°C . This rod was broken during handling.

S7359 (18-20)

S7359 (14-16)

S7359-11

S7359-12

Fig. 4-38. FTE-14 fuel rod 2-2-6 (UC_2 TRISO - ThC_2 TRISO blend) visual examination. Irradiation conditions: $1.45 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})]$ at $1257^\circ\text{C}.$
HTGR

S7359 (56-58)

S7359 (59-61)

S7359-54

S7359-55

Fig. 4-39. FTE-14 fuel rod 2-3-6 (UO_2 TRISO - ThO_2 BISO blend) visual examination. Irradiation conditions: $1.45 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1286°C .

S7359 (62-64)

S7359 (65-67)

S7359-70

S7359-71

Fig. 4-40. FTE-14 fuel rod 2-4-7 [(Th,U)O₂ TRISO - ThC₂ BISO blend]
visual examination. Irradiation conditions: 1.44×10^{25}
n/m² [(E > 29 fJ)_{HTGR}] at 1229°C.

S7359 (39-41)

S7359 (43-45)

S7359-36

S7359-37

Fig. 4-41. FTE-14 fuel rod 2-6-7 (UO_2 TRISO - ThO_2 TRISO blend) visual examination. Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1248°C .

S7437 (123-125)

S7437 (127-129)

S7437-122

S7437-121

Fig. 4-42. FTE-15 fuel rod 2-1-4 (UC_2 TRISO - ThC_2 BISO blend) visual examination. Irradiation conditions: $2.00 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1255°C .

S7437 (132-134)

S7437 (135-137)

S7437-131

S7437-130

Fig. 4-43. FTE-15 fuel rod 2-1-5 (UC₂ TRISO - UC₂ BISO blend) visual examination. Irradiation conditions: $2.00 \times 10^{25} \text{ n/m}^2$ [(E > 29 fJ)_{HTGR}] at 1296°C.

S7437 (73-75)

S7437 (76-78)

S7437-71

S7437-70

Fig. 4-44. FTE-15 fuel rod 2-2-4 (UC_2 TRISO - ThC_2 TRISO blend) visual examination. Irradiation conditions: $2.00 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1235°C .

S7437 (81-83)

S7437 (84-86)

S7437-79

S7437-80

Fig. 4-45. FTE-15 fuel rod 2-2-5 (UC_2 TRISO - ThC_2 TRISO blend) visual examination. Irradiation conditions: $2.00 \times 10^{25} \text{ n/m}^2$ [$E > 29 \text{ fJ}$]_{HTGR} at 1276°C .

S7437 (51-53)

S7437 (56-58)

S7437-50

S7437-49

Fig. 4-46. FTE-15 fuel rod 2-2-7 (UC₂ TRISO - ThC₂ TRISO blend) visual examination. Irradiation conditions: $2.02 \times 10^{25} \text{ n/m}^2$ [(E > 29 fJ)_{HTGR}] at 1214°C.

S7437 (150-152)

S7437 (153-155)

S7437-149

S7437-148

Fig. 4-47. FTE-15 fuel rod 2-3-4 (UO_2 TRISO - ThO_2 BISO blend) visual examination. Irradiation conditions: $2.00 \times 10^{25} \text{ n/m}^2$ [$E > 29 \text{ fJ}$]_{HTGR} at 1270°C .

S7437 (140-142)

S7437 (143-145)

S7437-138

S7437-139

Fig. 4-48. FTE-15 fuel rod 2-3-5 (UO_2 TRISO - ThO_2 BISO blend) visual examination. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1310°C .

S7437 (61-63)

S7437 (64-66)

S7437-60

S7437-59

Fig. 4-49. FTE-15 fuel rod 2-3-7 (UO_2 TRISO - ThO_2 BISO blend) visual examination. Irradiation conditions: $2.02 \times 10^{25} \text{ n/m}^2$ [(E > 29 fJ)_{HTGR}] at 1246°C .

S7437 (43-45)

S7437 (46-48)

S7437-42

S7437-41

Fig. 4-50. FTE-15 fuel rod 2-3-8 (UO_2 TRISO - ThO_2 BISO blend) visual examination. Irradiation conditions: $2.03 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1228°C .

S7437 (34-36)

S7437 (38-40)

S7437-33

S7437-32

Fig. 4-51. FTE-15 fuel rod 2-3-9 (UO_2 TRISO - ThO_2 BISO blend) visual examination. Irradiation conditions: $2.02 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1174°C .

S7437 (99-101)

S7437 (102-104)

S7437-97

S7437-96

Fig. 4-52. FTE-15 fuel rod 2-4-3 [(Th,U)O₂ TRISO - ThC₂ BISO blend] visual examination. Irradiation conditions: 1.98×10^{25} n/m² [(E > 29 fJ)_{HTGR}] at 1151°C.

S7437 (8-10)

S7437 (11, 12A, 12)

S7437-5

S7437-6

Fig. 4-53. FTE-15 fuel rod 2-5-2 (UO_2 TRISO - ThC_2 BISO blend) visual examination. Irradiation conditions: $1.96 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1163°C .

S7437 (15-17)

S7437 (19-21)

S7437-14

S7437-13

Fi . 4-54. FTE-15 fuel rod 2-6-4 (UO_2 TRISO - ThO_2 TRISO blend) visual examination. Irradiation conditions: $2.00 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1265°C .

S7437 (24-26)

S7437 (27-29)

S7437-22

S7437-23

Fig. 4-55. FTE-15 fuel rod 2-6-5 (UO_2 TRISO - ThO_2 TRISO blend) visual examination. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1305°C .

S7437 (89-91)

S7437 (93-95)

S7437-88

S7437-87

Fig. 4-56. FTE-15 fuel rod 2-6-11 (UO_2 TRISO - ThO_2 TRISO blend) visual examination. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1138°C .

S7437 (178-180)

S7437 (181-183)

S7437-174

S7437-173

Fig. 4-57. FTE-15 fuel rod 3-2-3 (UC_2 TRISO - ThC_2 TRISO blend) visual examination. Irradiation conditions: $1.89 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1193°C .

S7437 (159-161)

S7437 (162-164)

S7437-156

S7437-157

Fig. 4-53. FTE-15 fuel rod 3-2-4 (UC₂ TRISO - ThC₂ TRISO blend) visual examination. Irradiation conditions: $1.83 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1199°C.

S7437 (187-189)

S7437 (190-192)

S7437-184

S7437-185

Fig. 4-59. FTE-15 fuel rod 3-3-3 (UO₂ TRISO - ThO₂ TRISO blend) visual examination. Irradiation conditions: $1.89 \times 10^{25} \text{ n/m}^2$ [(E > 29 fJ)_{HTGR}] at 1223°C.

S7437 (167-169)

S7437 (170-172)

S7437-166

S7437-165

Fig. 4-60. FTE-15 fuel rod 3-3-4 (UO_2 TRISO - ThO_2 TRISO blend) visual examination. Irradiation conditions: $1.83 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1226°C .

L7359-290

(a)

L7359 (276-288)

(b)

Fig. 4-61. FTE-14 photomicrographs of fuel rod 2-1-7 (UC_2 TRISO - ThC_2 TRISO blend). Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1251°C . (a) Typical appearance of matrix graphite and (b) composite radial cross section showing ThC_2 beginning to hydrolyze.

L7359-124

(a)

L7359 (109-122)

(b)

Fig. 4-62. FTE-14 photomicrographs of fuel rod 2-2-6 (UC_2 TRISO - ThC_2 TRISO blend).
Irradiation conditions: $1.45 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1257°C .
(a) Typical graphite matrix and (b) composite radial cross section.

L7359-254

(a)

L7359 (46-59)

(b)

Fig. 4-63. FTE-14 photomicrographs of fuel rod 2-3-6 (UO_2 TRISO - ThO_2 BISO blend). Irradiation conditions: $1.45 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at $\sim 1286^\circ\text{C}$. (a) Typical graphite matrix and (b) composite radial cross section.

L7359-192

(a)

L7359 (195-208)

(b)

Fig. 4-64. FTE-14 photomicrographs of fuel rod 2-4-7 [(Th,U)O₂ TRISO - ThC₂ BISO blend]. Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ [(E > 29 fJ)_{HTGR}] at 1251°C. (a) Typical appearance of matrix graphite and (b) composite radial cross section.

L7359-82

(a)

L7359 (55-68)

(b)

Fig. 4-65. FTE-14 photomicrographs of fuel rod 2-6-7 (UO_2 TRISO - ThO_2 TRISO blend).
Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1248°C .
(a) Typical graphite matrix and (b) composite radial cross section.

L7437-99

(a)

L7437 (87-93)

(b)

Fig. 4-66. FTE-15 photomicrographs of fuel rod 2-1-5 (UC₂ TRISO - ThC₂ BISO blend). Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR} at 1296°C. (a) Typical graphite matrix and (b) composite radial cross section.

L7437-183

(a)

L7437 (174-181)

(b)

Fig. 4-67. FTE-15 photomicrographs of fuel rod 2-2-5 (UC_2 TRISO - ThC_2 TRISO blend). Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR} at 1276°C . (a) Typical graphite matrix and (b) composite radial cross section.

L7437-109

(a)

L7437 (110-117)

(b)

Fig. 4-68. FTE-15 photomicrographs of fuel rod 2-3-9 (UO_2 TRISO - ThO_2 BISO blend). Irradiation conditions: $2.02 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR} at 1174°C . (a) Typical graphite matrix and (b) composite radial cross section.

L7437-159

(a)

L7437(148-155)

(b)

Fig. 4-69. FTE-15 photomicrographs of fuel rod 2-4-3 [(Th,U)O₂ TRISO - ThC₂ BISO blend]. Irradiation conditions: $1.98 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR} at 1151°C. (a) Typical graphite matrix and (b) composite radial cross section.

L7437-194

(a)

L7437 (197-204)

(b)

Fig. 4-70. FTE-15 photomicrographs of fuel rod 2-5-2 (UO_2 TRISO - ThC_2 BISO blend). Irradiation conditions: $1.96 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$)_{HTGR} at 1163°C . (a) Typical graphite matrix and (b) composite radial cross section.

L7437-140

(a)

L7437 (127-134)

(b)

Fig. 4-71. FTE-15 photomicrographs of fuel rod 2-6-5 (UO_2 TRISO - ThO_2 TRISO blend). Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ ($E > 29 \text{ fJ}$) HTGR at 1305°C . (a) Typical graphite matrix and (b) composite radial cross section.

L7437-343

20 μm

(a)

L7437(334-341)

200 μm

(b)

Fig. 4-72. FTE-15 photomicrographs of fuel rod 3-6-10 irradiated to 1.04×10^{25} n/m² ($E > 29$ fJ)_{HTGR} at 1067°C: (a) typical graphite matrix, (b) composite radial cross section

L7359-255

Fig. 4-73. FTE-14 representative UC_2 TRISO and ThC_2 BISO particles from fuel rod 2-1-7. Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1251°C .

L7359-259 (a)

L7359-260 (b)

L7359-261 (c)

Fig. 4-74. FTE-14 UC_2 particle in fuel rod 2-1-7 showing SiC attack. Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1251°C . (a) Light field, (b) dark field showing metallic fission products in IPyC coating, and (c) area of SiC attack.

L7359-93 (a)

L7359-95 (b)

L7359-96 (c)

Fig. 4-75. FTE-14 representative particles from fuel rod 2-2-6. Irradiation conditions: 1.45×10^{25} n/m^2 [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1257°C . (a) ThC_2 ($400 \mu\text{m}$) TRISO, (b) UC_2 ($200 \mu\text{m}$) TRISO, and (c) the same particle as in (b) with dark field showing metallic fission products in the IPyC coating. No SiC interaction was observed.

L7359-222

(a)

L7359-220

(b)

Fig. 4-76. FTE-14 representative particles from fuel rod 2-3-6. Irradiation conditions: $1.45 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1286°C .
 (a) UO_2 (200 μm) TRISO and (b) UO_2 TRISO/ ThO_2 (400 μm) BISO.

L7359-193

(a)

L7359-188

(b)

Fig. 4-77. FTE-14 representative particles from fuel rod 2-4-7. Irradiation conditions: $1.44 \times 10^{25} \text{ n/m}^2$ [$E > 29 \text{ fJ}$]_{HTGR} at 1251°C . (a) ThC_2 ($450 \mu\text{m}$) BISO that has partially hydrolyzed and (b) $(\text{Th},\text{U})\text{O}_2$ ($250 \mu\text{m}$) TRISO that showed some kernel migration into the buffer.

L7359-34

(a)

L7359-42

(b)

Fig. 4-78. FTE-14 representative particles from fuel rod 2-6-7. Irradiation conditions: 1.44×10^{25} n/m² [(E > 29 fJ)HTGR] at 1248°C.
(a) UO₂ (200 μm) TRISO and (b) ThO₂ (400 μm) TRISO.

L7437-84 (a)

L7437-85 (b)

L7437-86 (c)

Fig. 4-79. FTE-15 representative fissile UC_2 particle from fuel rod 2-1-5 showing SiC attack. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1296°C . (a) Bright field, (b) dark field showing concentration of metallic fission products at SiC-OPyC interface, and (c) high magnification of SiC attack.

L7437-81

(a)

L7437-78

(b)

Fig. 4-80. FTE-15 representative fertile ThC_2 particle from fuel rod 2-1-5 showing kernel migration. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1296°C . (a) Bright field, (b) dark field showing kernel migration toward center of rod.

L7437-163 (a)

L7437-164 (b)

L7437-165 (c)

Fig. 4-81. FTE-15 representative fissile UC_2 TRISO particles in fuel rod 2-2-5 showing SiC attack. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$E > 29 \text{ fJ}$] HTGR at 1276°C . (a) Bright field, (b) dark field showing metallic fission product concentration in IPyC, and (c) high magnification of SiC attack.

L7437-166

(a)

L7437-173

(b)

Fig. 4-82. FTE-15 representative fertile ThC_2 TRISO particles in fuel rod 2-2-5. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1276°C . (a) ThC_2 TRISO pair showing OPyC failure and (b) production ThC_2 TRISO failure.

L7437-104

(a)

L7437-105

(b)

Fig. 4-83. FTE-15 representative fissile UO_2 and fertile ThO_2 pair from fuel rod 2-3-9. Irradiation conditions: $2.02 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1174°C . (a) Bright field and (b) dark field.

L7437-146

(a)

L7437-147

(b)

Fig. 4-84. FTE-15 representative $(\text{Th,U})\text{O}_2$ TRISO and ThC_2 BISO particles from fuel rod 2-4-3. Irradiation conditions: $1.98 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1151°C . (a) Bright field and (b) dark field.

L7437-184 (a)

L7437-185 (b)

L7437-192 (c)

Fig. 4-85. FTE-15 representative UO_2 fissile and ThC_2 fertile particles from fuel rod 2-5-2. Irradiation conditions: $1.96 \times 10^{25} \text{ n/m}^2 [(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1163°C . (a) Bright field, (b) dark field, and (c) ThC_2 production failure.

L7437-135

(a)

L7437-136

(b)

Fig. 4-86. FTE-15 representative fertile ThO_2 TRISO and fissile UO_2 TRISO particles from fuel rod 2-6-5. Irradiation conditions: $2.01 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1305°C . (a) Bright field and (b) dark field.

L7437-231

100 μm

(a)

L7437-233

100 μm

(b)

Fig. 4-87. FTE-15 representative UO_2 TRISO and ThC_2 TRISO particles from fuel rod 3-6-10. Irradiation conditions: $1.04 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1067°C . (a) UO_2 TRISO particle, (b) ThC_2 TRISO particle with OPyC failure

L7519-58 (a)

L7519-59 (b)

L7519-60 (c)

Fig. 4-88. FTE-6 photomicrographs of UO_2 TRISO particle showing SiC attack from fuel rod 2-1-7

Fig. 4-89. Representative UO_2 particle from fuel rod 2D-16 irradiated in capsule P13N to 5.4×10^{21} n/cm² at 1350°C

Fig. 4-90. FTE-15 single-channel gamma scans of representative fuel rods used in fuel examination

Fig. 4-91. FTE-14 Cs-134 profile, fuel body 2, outer graphite web at 2110.0-mm core height

Fig. 4-92. FTE-14 Cs-137 profile, fuel body 2, outer graphite web at 2110.0-mm core height

Fig. 4-93. FTE-15 Cs-134 profile, fuel body 1, outer graphite web at 850.9-mm core height

Fig. 4-94. FTE-15 Cs-137 profile, fuel body 1, outer graphite web at 850.9-mm core height

Fig. 4-95. FTE-15 Cs-134 profile, fuel body 2, outer graphite web at 2116.0-mm core height

Fig. 4-96. FTE-15 Cs-137 profile, fuel body 2, outer graphite web at 2116.0-mm core height

Fig. 4-97. FTE-15 Cs-134 profile, fuel body 3, outer graphite web at 2438.4-mm core height

Fig. 4-98. FTE-15 Cs-137 profile, fuel body 3, outer graphite web at 2438.4-mm core height

Fig. 4-99. FTE-15 Sr-90 profile, fuel body 1, outer graphite web at 850.9-mm core height

Fig. 4-100. FTE-15 Sr-90 profile, fuel body 2, outer graphite web at 2116.0-mm core height

Fig. 4-101a. FTE-14 autoradiography of slice 2-2 from body 2, located ~2087 mm from bottom of core

Fig. 4-101b. FTE-14 autoradiography of slice 3-2 from body 3, located ~1045 mm from bottom of core

Fig. 4-102a. FTE-15 autoradiography of slice 15-2-2 from body 2, located 2116 mm from bottom of core

Fig. 4-102b. FTE-15 autoradiography of slice 15-3-1-10 from body 3, located 2438 mm from bottom of core

S7359-90

(a)

S7359-101

(b)

Fig. 4-103. FTE-14 stereophotographs of UC_2 ($314\ \mu\text{m}$) WAR particles from spine samples TS2-6 and TS6-6. Irradiation conditions: (a) $1.29 \times 10^{25}\ \text{n/m}^2$ [$(E > 29\ \text{fJ})_{\text{HTGR}}$] at 1213°C in location TS2-6 and (b) $1.42 \times 10^{25}\ \text{n/m}^2$ [$(E > 29\ \text{fJ})_{\text{HTGR}}$] at 1454°C in location TS6-6. Both samples showed $\sim 7\%$ OPyC failure.

S7359-93 (a)

S7359-97 (b)

S7359-95 (c)

Fig. 4-104. FTE-14 stereophotographs of UC_2 ($200\ \mu\text{m}$) VSM particles from spine samples TS3-6, TS4-6, and TS5-6. Irradiation conditions: $1.32 \times 10^{25}\ \text{n/m}^2$ $[(E > 29\ \text{fJ})_{\text{HTGR}}]$ at 1095°C in TS3-6, (b) $1.45 \times 10^{25}\ \text{n/m}^2$ $[(E > 29\ \text{fJ})_{\text{HTGR}}]$ at 1418°C in TS5-6, and (c) $1.44 \times 10^{25}\ \text{n/m}^2$ $[(E > 29\ \text{fJ})_{\text{HTGR}}]$ at 1328°C in TS4-6.

S7359-99

Fig. 4-105. FTE-14 stereophotograph of ThO_2 particles from spine sample TS6-1. Irradiation conditions: $1.42 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1325°C .

S7437-118 (a)

S7437-120 (b)

S7437-112 (c)

Fig. 4-106. FTE-15 stereophotographs of UC_2 TRISO fissile particle batch 4161-01-030. (a) Spine sample TS3-6 irradiated to $1.8 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1086°C , (b) spine sample TS4-6 irradiated to $2.0 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1355°C , and (c) spine sample TS5-6 irradiated to $2.0 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1389°C .

L7437-115

(a)

L7437-110

(b)

Fig. 4-107. FTE-15 stereophotographs of UC_xO_y TRISO (WAR) fissile batch OR-1694. (a) Spine sample TS2-6 irradiated to $1.8 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1208°C and (b) spine sample TS6-6 irradiated to $2.0 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1419°C .

S7437-106

Fig. 4-108. FTE-15 stereophotomicrographs of ThO_2 BISO fertile batch 4252-02-070 from spine sample TS6-1. Irradiation conditions: $2.0 \times 10^{25} \text{ n/m}^2$ $[(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 300°C .

Fig. 4-109. Particle size effect on OPyC failure

Fig. 4-110. FTE-14 radiographs of representative UC_2 ($200\ \mu\text{m}$) VSM particles from spine, samples TS3-6, TS4-6, and TS5-6. (a) TS3-6 irradiated to $1.32 \times 10^{25}\ \text{n/m}^2$ [$(E > 29\ \text{fJ})_{\text{HTGR}}$] at 1095°C , (b) TS5-6 irradiated to $1.44 \times 10^{25}\ \text{n/m}^2$ [$(E > 29\ \text{fJ})_{\text{HTGR}}$] at 1418°C , and (c) TS4-6 irradiated to $1.45 \times 10^{25}\ \text{n/m}^2$ [$(E > 29\ \text{fJ})_{\text{HTGR}}$] at 1418°C showing metallic fission product buildup in IPyC coating.

HA 322

(a)

HA 320

(b)

Fig. 4-111. FTE-14 radiographs of representative UC_2O_3 (314 μm) WAR particles from spine samples TS2-6 and TS6-6. (a) TS2-6 irradiated to $1.29 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1213°C showing metallic fission products in recoil zone in buffer and (b) TS6-6 irradiated to $1.42 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1454°C also showing a buildup of fission products in recoil zone.

HA 318

Fig. 4-112. Radiograph of a representative ThO_2 BISO particle from spine sample TS6-1. Irradiation conditions: $1.42 \times 10^{25} \text{ n/m}^2$ [(E > 29 fJ)_{HTGR}] at 1325°C.

(a)

(b)

Fig. 4-113. FTE-14 photomicrographs of a representative UC_2 (150 μm) VSM particle from spine sample TS1-4. Irradiation conditions: $1.27 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1282°C . (a) Bright field, (b) dark field showing no graphitization of the IPyC layer.

L7359-149

(a)

L7359-150

(b)

Fig. 4-114. FTE-14 photomicrographs of representative UC_2 (200 μm) VSM particles from spine sample TS5-6. Irradiation conditions: 1.44×10^{25} [(E > 29 fJ)_{HTGR}] at 1418°C. (a) Bright field and (b) dark field showing metallic fission product concentration in lower section of IPyC coating.

L7359-158

(a)

L7359-160

(b)

Fig. 4-115. FTE-14 photomicrographs of representative UC₂ (200 μm) VSM particles from spine sample TS5-6. The SiC attack by metallic fission products illustrated was characteristic of particles from spine samples TS5-6, TS4-6, and TS8-3.

L7359-1 (a)

L7359-7 (b)

L7359-26 (c)

Fig. 4-116. FTE-14 photomicrographs of representative UC_xO_y (314 μm) WAR particles from spine samples TS2-6 and TS6-6. Irradiation conditions: $1.29 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{HTGR}$] at $1213^\circ C$ (TS2-6) and $1.42 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{HTGR}$] at $1454^\circ C$ (TS6-6). (a) TS2-6 particle, (b) TS2-6 particle showing total coating failure, and (c) TS6-6 particle.

L7359-170

(a)

L7359-171

(b)

Fig. 4-117. FTE-14 photomicrographs of a representative ThO_2 BISO particle from spine sample TS6-1. Irradiation conditions: $1.42 \times 10^{25} \text{ n/m}^2 [(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1325°C . (a) Bright field and (b) dark field showing anisotropy of OPyC (especially at buffer interface).

(a)

(b)

Fig. 4-118. FTE-15 photomicrographs of a representative UC₂ (150 μm) VSM particle from spine sample TS1-4. Irradiation conditions: $1.75 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1294°C. (a) Bright field, (b) dark field showing no graphitization of the IPyC layer.

L7437-36

(a)

L7437-37

(b)

Fig. 4-119. FTE-15 photomicrographs of UC_2 TRISO (VSM) fissile particle batch 4161-01-030 from spine sample TS3-6. Irradiation conditions: $1.8 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{HTGR}$] at 1086°C . (a) Bright field and (b) dark field showing concentration of metallic fission products in IPyC.

L7437-46 (a)

L7437-47 (b)

L7437-48 (c)

Fig. 4-120. FTE-15 photomicrographs of UC₂ TRISO (VSM) fissile particle batch 4161-01-030 from spine sample TS4-6. Irradiation conditions: 2.0×10^{25} n/m² [$E > 29$ fJ]_{HTGR} at 1355°C. (a) Bright field, (b) dark field, and (c) high magnification of SiC attack.

L7437-63 (a)

L7437-64 (b)

L7437-22 (c)

Fig. 4-121. FTE-15 photomicrographs of UC₂ TRISO (VSM) fissile particle batch 4161-01-030 from spine sample TS5-6. Irradiation conditions: $2.0 \times 10^{25} \text{ n/m}^2 [(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1389°C .
 (a) Bright field, (b) dark field, and (c) high magnification of SiC attack.

L7437-13

(a)

L7437-14

(b)

Fig. 4-122. FTE-15 photomicrographs of UC_xO_y TRISO (WAR) fissile particle batch OR-1694 from spine sample TS2-6. Irradiation conditions: $1.8 \times 10^{25} \text{ n/m}^2 [(E > 29 \text{ fJ})_{\text{HTGR}}]$ at 1208°C . (a) Bright field and (b) dark field.

L7437-30

(a)

L7437-31

(b)

Fig. 4-123. FTE-15 photomicrographs of UC_xO_y TRISO (WAR) fissile particle batch OR-1694 from spine sample TS6-6. Irradiation conditions: $2.0 \times 10^{25} \text{ n/m}^2$ [$(E > 29 \text{ fJ})_{\text{HTGR}}$] at 1418°C .
(a) Bright field and (b) dark field.

Fig. 4-124. SiC thinning rates in Peach Bottom test elements

APPENDIX B

TABLES

TABLE 2-1
FTE-14 DRAWING/PARTS LIST

Dwg./Part No.	Issue	Title	Dwg./Part No.	Issue	Title
11890-1	B	Assembly	127800-1	A	Plug
11666-1	B	Sleeve	11888-1	D	Fuel body assembly, 14-2
11668-1	B	Brazing Ring	12791-1	A	Fuel stack assembly
11669-6	B	Upper reflector	12792-1	A	Fuel stack assembly
11670-2	B	Bottom connector	12793-1	B	Fuel stack assembly
11671-1	B	Screen	12880-1	B	Fuel stack assembly
			11865-1	B	Fuel stack assembly
11672-1,2	B	W/Rh, C/A thermocouple	11871-1	B	Fuel stack assembly
11673-1	B	Upper contacts	11835-1	C	Fuel body
11674-1	A	Thermocouple mounting ring	11916-1	B	Compact pusher
11675-1	A	Contact spring	11917-1	B	Fuel hole plug
			11918-1	B	Sample hole plug
11676-1	A	Insulator	12840-3,4	A	Spines
11677-1	A	Nut	12798-4,5,6	A	Thermal stability sample
1804-00		Washer	12799-4,5,6	A	Body
11541-1	B	Spacer	127800-1	A	Plug
11542-1	A	Internal trap assembly	11889-1	E	Fuel body assembly, 14-3
11550-1	B	Trap	11859-1	B	Fuel stack assembly
11667-3,4	B	Filter, pin	11862-1	B	Fuel stack assembly
11552-1	A	Nut	11865-1	B	Fuel stack assembly
11551-1	A	Disk	12880-1	B	Fuel stack assembly
			11871-1	C	Fuel stack assembly
11958-1	A	Lower reflector	12793-1	B	Fuel stack assembly
11887-1	E	Fuel body assembly, 14-1	11886-1	C	Fuel body
11859-1	B	Fuel stack assembly	11916-1	B	Compact pusher
11862-1	B	Fuel stack assembly	11917-1	B	Fuel hole plug
11865-1	B	Fuel stack assembly	11918-1	B	Sample hole plug
12880-1	B	Fuel stack assembly			
11871-1	C	Fuel stack assembly	12840-1,2	A	Spines
12793-1	B	Fuel stack assembly	12798-7,8,9	A	Thermal stability sample
11884-1	C	Fuel body	12799-7,8,9	A	Body
11916-1	B	Compact pusher	12780-1	A	Plug
11917-1	B	Fuel hole plug			
11918-1	B	Sample hole plug			
12840-5,6	A	Spines			
12798-1,2,3	A	Thermal stability sample			
12799-1,2,3	A	Body			

TABLE 2-2
FTE-15 DRAWING/PARTS LIST

Dwg./Part No.	Issue	Title	Dwg./Part No.	Issue	Title
11891-1,-2	C	Assembly	12800-1	A	Plug
11666-1	B	Sleeve	11952-1	D	Fuel body assembly, 15-2
11668-1	B	Brazing ring	12791-1	A	Fuel stack assembly
11669-6	B	Upper reflector	12792-1	A	Fuel stack assembly
11670-2	B	Bottom connector	12793-1	B	Fuel stack assembly
11671-1	B	Screen	12880-1	A	Fuel stack assembly
11672-1,-2	B	W/Re, C/A thermocouples	11865-1	B	Fuel stack assembly
11673-1	B	Upper contacts	11871-1	C	Fuel stack assembly
11674-1	A	Thermocouple mounting ring	11885-1	C	Fuel body
11675-1	A	Contact spring	11916-1	B	Compact pusher
11676-1	A	Insulator	11917-1	B	Fuel hole plug
11677-1	A	Nut	11918-1	B	Sample hole plug
1804-00		Washer	12840-3,-4	A	Spines
11541-1	B	Spacer	12798-4,-5,-6	A	Thermal stability sample
11958-1	A	Lower reflector	12799-4,-5,-6	A	Body
11542-1	B	Internal trap assembly	127300-1	A	Plug
11550-1	B	Trap	11954-1	C	Fuel body assembly, 15-3
11662-3,-4	B	Filter, pin	11859-1	B	Fuel stack assembly
11552-1	A	Nut	11862-1	B	Fuel stack assembly
11551-1	A	Disk	11865-1	B	Fuel stack assembly
11952-1	E	Fuel body assembly, 15-1	12880-1	B	Fuel stack assembly
11859-1	B	Fuel stack assembly	11871-1	C	Fuel stack assembly
11862-1	B	Fuel stack assembly	12793-1	B	Fuel stack assembly
11865-1	B	Fuel stack assembly	11886-1	C	Fuel body
12880-1	B	Fuel stack assembly	11916-1	B	Compact pusher
11871-1	C	Fuel stack assembly	11917-1	B	Fuel hole plug
12793-1	B	Fuel stack assembly	11918-1	B	Sample hole plug
11884-1	C	Fuel body	12840-1,-2	A	Spines
11916-1	B	Compact pusher	12798-7,-8,-9	A	Thermal stability sample
11917-1	B	Fuel hole plug	12799-7,-8,-9	A	Body
11918-1	B	Sample hole plug	127800-1	A	Plug
12870-5,-6	A	Spines			
12793-1,-2,-3	A	Thermal stability sample			
12799-1,-2,-3	A	Body			

TABLE 2-3
GRAPHITE MATERIALS USED IN PEACH BOTTOM FUEL ELEMENTS

Fuel Element Component	Core 1 Driver Graphite Type		Core 2 Driver Graphite Type		FTE-3,-4,-5,-6 Graphite Type	
	Base Stock	Manufacturer	Base Stock	Manufacturer	Base Stock	Manufacturer
Top reflector	H-253 ^(a)	GLCC	H-381 ^(b)	GLCC	H-381 ^(b)	GLCC
Top spine	711-GSXY	SPEER	711-T	SPEER	H-327	GLCC
Lower two spines (with T/C slots for instrumented drivers)	711-GSXY	SPEER	711-GSXY	SPEER	H-327	GLCC
Fuel compact or rod filler binder	GP-38 flour Barrett No. 30	UCC Allied Chemical	GP-38 flour Barrett No. 30	UCC Allied Chemical	6353 15V	Ashbury Allied Chemical
Graphite fuel body	N/A		N/A		H-327	GLCC
Sleeve	H-253 ^(a)	GLCC	H-382 ^(b)	GLCC	H-382 ^(b)	GLCC
Internal trap	806 RL	SPEER	580	SPEER	580	SPEER
Lower reflector	806 RL	SPEER	580	SPEER	H-327	GLCC
Bottom connector	H-253 ^(a)	GLCC	H-381	GLCC	H-253 ^(a)	GLCC

(a) Also referred to as HLM-85-10; made with Texas Lockport coke.

(b) Also referred to as HLM-85-10; made with "Y" coke. Discrimination into H-381 and H-382 lacks explanation. It should be noted that most of the core 1 and all Core 2 HLM-85-10 material was graphitized in a standard Acheson type furnace for about 28 days with temperatures up to 2800°C. However, some of the Core 1 material went through a rapid graphitization process in a tube furnace for about 1 hr at 2800°C (which also has been used for impregnation purposes of Core 1 and 2 sleeves after machining). About 40 elements in Core 2 have been made out of leftover Core 1 rapid graphitized material. During the Core 2 unloading exercise, it was discovered that this material happened to shrink more than the Core 2 standard material.

TABLE 2-4
FTE-14 AND FTE-15 FUEL ROD PARTICLE LOADING COMBINATIONS

Upper End	Body No. 3					
Body No. 3	Fuel Hole No.	Item No.	Fissile Particle	Item No.	Fertile Particle	
	1	21	(200μm)UC ₂ TRISO	17	(400μm)ThC ₂ BISO	
	2	12	(200μm)UO ₂ TRISO	18	(400μm)ThO ₂ TRISO FTE-14 only	
	2	21	(200μm)UC ₂ TRISO	15	(400μm)ThC ₂ TRISO FTE-15 only	
	3	12	(200μm)UO ₂ TRISO	13	(400μm)ThO ₂ BISO	
	4	23	(250μm)(Th,U)O ₂ TRISO	24	(450μm)ThC ₂ BISO	
	5	16	(150μm)UO ₂ TRISO	24	(450μm)ThC ₂ BISO	
Body No. 2	6	12	(200μm)UO ₂ TRISO	15	(400μm)ThC ₂ TRISO	
	Body No. 2					
	1	21	(200μm)UC ₂ TRISO	17	(400μm)ThC ₂ BISO	
	2	21	(200μm)UC ₂ TRISO	15	(400μm)ThC ₂ TRISO	
	3	12	(200μm)UO ₂ TRISO	13	(400μm)ThO ₂ BISO	
	4	23	(250μm)(Th,U)O ₂ TRISO	24	(450μm)ThC ₂ BISO	
	5	16	(150μm)UO ₂ TRISO	24	(450μm)ThC ₂ BISO	
Body No. 1	6	12	(200μm)UO ₂ TRISO	18	(400μm)ThO ₂ TRISO	
	Body No. 1					
	1, 2, 3 4, 5, 6	14	(150μm)UC ₂ TRISO	24	(450μm)ThC ₂ BISO

Fuel hole identification

TABLE 2-5
FTE-14 AND FTE-15 FUEL ROD PARTICLE SPECIFICATIONS

Item No.	FMB No. (a)	Kernel			As-Manufactured Coating Parameters								OPyC Coating Rate (μm/min)
		Type	Nominal Diameter (μm)	Particle Type	Mean Thickness (μm)					OPyC Density (Mg/m ³)	OPyC OPTAF	SiC Density (Mg/m ³)	
					Buffer	IPyC	SiC	OPyC	Total				
12	4162-00-031	UO ₂	200	TRISO	92	26	26	37	175	1.83	1.07	3.18	3.89
13	4252-00-011	ThO ₂	400	BISO	73	--	--	70	156	2.00	1.14	--	2.06
14	4161-00-011	UC ₂	145	TRISO	47	23	22	25	112	1.82	1.09	3.20	3.78
15	4261-00-011	ThC ₂	358	TRISO	54	35	25	38	135	1.81	1.14	3.19	2.87
16	4162-01-021	UO ₂	150	TRISO	51	24	26	25	123	1.86	1.09	3.19	2.88
17	4251-00-031	ThC ₂	368	BISO	68	--	--	54	122	1.98	1.16	--	2.49
18	4262-00-051	ThO ₂	400	TRISO	71	16	35	25	138	1.81	1.08	3.21	7.69
21	4161-01-031	UC ₂	200	TRISO	87	28	29	38	162	1.80	1.11	3.20	3.53
23	4163-00-011	(Th,U)O ₂ ^(b)	250	TRISO	69	32	36	72	218	1.77	1.09	3.20	4.11
25	4251-01-021	ThC ₂	433	BISO	82	--	--	64	133	1.96	1.13	--	2.07

(a) Fuel Materials Branch data retrieval number.

(b) Th/U ratio = 1.0.

TABLE 2-6a
FTE-14 FUEL ROD PREIRRADIATION ATTRIBUTES

Body	Hole	Fuel Blend	Preirradiation Fission Gas Release ^(a) Kr-85m at 1100°C	Exposed Heavy Metal ^(b) (kg Th/kg Th)	Heavy Metal Loadings ^(c)		Impurities								
					Th (10 ⁻³ kg)	U (10 ⁻³ kg)	B (ppm)	Fe (ppm)	S (ppm)	Ti (ppm)	V (ppm)	Residual Hydrogen (ppm)	Residual Ash (ppm)	H ₂ O (ppm)	Cl (ppm)
1	1-3	150-μm UC ₂ TRISO 450-μm ThC ₂ BISO	2.8 x 10 ⁻⁵	8.5 x 10 ⁻⁴	13.28	0.962	3	80	340	<40	<40	240	NA ^(d)	<1	46
1	4-6	150-μm UC ₂ TRISO 450-μm ThC ₂ BISO	4.6 x 10 ⁻⁶	8.2 x 10 ⁻⁷	10.63	0.962	3	80	340	<40	<40	290	1350	<1	30
2	1	200-μm UC ₂ TRISO 400-μm ThC ₂ BISO	7.3 x 10 ⁻⁷	3.7 x 10 ⁻⁵	6.59	0.991	4	80	1190	<40	<40	200	1500	4	NA
2	2	200-μm UC ₂ TRISO 400-μm ThC ₂ TRISO	3.6 x 10 ⁻⁶	5.0 x 10 ⁻⁵	7.88	0.991	4	<200	1020	<40	<40	<1	250	6	NA
2	3	200-μm UO ₂ TRISO 400-μm ThO ₂ BISO	5.0 x 10 ⁻⁶	1.7 x 10 ⁻⁴	8.65	0.962	8	<40	1180	<40	<40	700	600	3	NA
2	4	250-μm (Th,U)O ₂ TRISO 450-μm ThC ₂ BISO	2.8 x 10 ⁻⁷	7.8 x 10 ⁻⁵	5.565	0.961	8	<40	1180	<40	<40	700	600	3	NA
2	5	150-μm UO ₂ TRISO 450-μm ThC ₂ BISO	1.4 x 10 ⁻⁶	5.3 x 10 ⁻⁶	11.05	0.917	4	80	1180	<40	<40	700	600	3	NA
2	6	200-μm UO ₂ TRISO 400-μm ThO ₂ TRISO	3.3 x 10 ⁻⁶	1.8 x 10 ⁻³	10.31	0.962	8	<40	1180	<40	<40	700	600	3	NA
3	1	200-μm UC ₂ TRISO 400-μm ThC ₂ BISO	8.2 x 10 ⁻⁷	1.5 x 10 ⁻⁵	6.59	0.991	4	<200	1020	<40	<40	<1	250	6	NA
3	2	200-μm UO ₂ TRISO 400-μm ThO ₂ TRISO	3.3 x 10 ⁻⁶	1.8 x 10 ⁻³	10.31	0.962	8	<40	1180	<40	<40	700	600	3	NA
3	3	200-μm UO ₂ TRISO 400-μm ThO ₂ BISO	5.0 x 10 ⁻⁶	1.7 x 10 ⁻⁴	8.67	0.962	8	<40	1180	<40	<40	700	600	3	NA
3	4	250-μm (Th,U)O ₂ TRISO 450-μm ThC ₂ BISO	2.8 x 10 ⁻⁷	7.8 x 10 ⁻⁵	5.565	0.961	8	<40	1180	<40	<40	700	600	3	NA
3	5	150-μm UO ₂ TRISO 450-μm ThC ₂ BISO	1.4 x 10 ⁻⁶	5.3 x 10 ⁻⁶	11.05	0.917	4	80	1180	<40	<40	700	600	3	NA
3	6	200-μm UO ₂ TRISO 400-μm ThC ₂ TRISO	8.4 x 10 ⁻⁶	7.1 x 10 ⁻⁵	8.64	0.962	8	<40	1180	<40	<40	700	600	3	NA

(a) Corrected for steady state.

(b) Hydrolysis measurement.

(c) Target uranium loading was 0.962 g. All values are "as built" data.

(d) NA = not available.

TABLE 2-6b
FTE-15 FUEL ROD PREIRRADIATION ATTRIBUTES

Body	Hole	Fuel Blend	Preirradiation Fission Gas Release (a) Kr-85m at 1100°C	Exposed Heavy Metal (b) (kg Th/kg Th)	Heavy Metal Loadings (c)		Impurities								
					Th (10 ⁻³ kg)	U (10 ⁻³ kg)	B (ppm)	Fe (ppm)	S (ppm)	Ti (ppm)	V (ppm)	Residual Hydrogen (ppm)	Residual Ash (ppm)	H ₂ O (ppm)	Cl (ppm)
1	1-2	150-μm UC ₂ TRISO 450-μm ThC ₂ BISO	6.8 x 10 ⁻⁶	6.7 x 10 ⁻⁷	13.28	0.962	<1	<40	340	<40	<40	290	938	<1	46
1	3-4	150-μm UC ₂ TRISO 450-μm ThC ₂ BISO	4.5 x 10 ⁻⁶	1.5 x 10 ⁻⁶	10.63	0.962	3	80	340	<40	<40	290	600	<1	46
1	5	150-μm UC ₂ TRISO 450-μm ThC ₂ BISO	1.7 x 10 ⁻⁶	2.5 x 10 ⁻⁴	12.18	0.962	3	<40	280	<40	<40	560	550	<1	16
1	6	150-μm UC ₂ TRISO 450-μm ThC ₂ BISO	4.6 x 10 ⁻⁶	8.2 x 10 ⁻⁷	10.63	0.962	3	80	340	<40	<40	290	1350	<1	30
2	1	200-μm UC ₂ TRISO 400-μm ThC ₂ BISO	7.3 x 10 ⁻⁷	3.7 x 10 ⁻⁵	6.59	0.991	4	80	1190	<40	<40	200	1500	4	NA ^(d)
2	2	200-μm UC ₂ TRISO 400-μm ThC ₂ TRISO	3.6 x 10 ⁻⁶	5.0 x 10 ⁻⁵	7.89	0.991	4	<200	1020	<40	<40	<1	250	6	NA
2	3	200-μm UO ₂ TRISO 400-μm ThO ₂ BISO	5.0 x 10 ⁻⁶	1.7 x 10 ⁻⁴	8.65	0.962	8	<40	1180	<40	<40	700	600	3	NA
2	4	250-μm (Th,U)O ₂ TRISO 450-μm ThC ₂ BISO	2.8 x 10 ⁻⁷	7.8 x 10 ⁻⁵	5.565	0.961	8	<40	1180	<40	<40	700	600	3	NA
2	5	150-μm UO ₂ TRISO 450-μm ThC ₂ BISO	1.4 x 10 ⁻⁶	5.3 x 10 ⁻⁶	11.05	0.917	4	80	1180	<40	<40	700	600	3	NA
2	6	200-μm UO ₂ TRISO 400-μm ThO ₂ TRISO	3.3 x 10 ⁻⁶	1.8 x 10 ⁻³	10.31	0.962	8	<40	1180	<40	<40	700	600	3	NA
3	1	200-μm UC ₂ TRISO 400-μm ThC ₂ BISO	8.2 x 10 ⁻⁷	1.5 x 10 ⁻⁵	6.59	0.991	4	<200	1020	<40	<40	<1	250	6	NA
3	2	200-μm UC ₂ TRISO 400-μm ThC ₂ TRISO	2.0 x 10 ⁻⁶	5.3 x 10 ⁻⁶	7.88	0.991	4	<200	1020	<40	<40	<41	250	6	NA
3	3	200-μm UO ₂ TRISO 400-μm ThO ₂ BISO	5.0 x 10 ⁻⁶	1.7 x 10 ⁻⁴	8.65	0.962	8	<40	1180	<40	<40	700	600	3	NA
3	4	250-μm (Th,U)O ₂ TRISO 450-μm ThC ₂ BISO	2.8 x 10 ⁻⁷	7.8 x 10 ⁻⁵	5.565	0.961	8	<40	1180	<40	<40	700	600	3	NA
3	5	150-μm UO ₂ TRISO 450-μm ThC ₂ BISO	1.4 x 10 ⁻⁶	5.3 x 10 ⁻⁶	11.05	0.917	4	80	1180	<40	<40	700	600	3	NA
3	6	200-μm UO ₂ TRISO 400-μm ThC TRISO	8.4 x 10 ⁻⁶	7.1 x 10 ⁻⁵	8.64	0.962	8	<40	1180	<40	<40	700	600	3	NA

(a) Corrected for steady state.

(b) Hydrolysis measurement.

(c) Target uranium loading was 0.962 g. All values are "as built" data.

(d) NA = not available.

TABLE 2-7
FTE-14 SPINE SAMPLE SUMMARY

Position	Preirrad. Length (mm)	Preirrad. Weight (g)	Mean Core Height ^(a) (mm)	Sample Type	Ident. No.	Composite Spine Length			Gamma Activity Readings (1/30/74)		Thermal Stability Sample Temperatures				FIMA (c)		Fluence (c) (10 ²⁵ n/m ²)	
						Preirrad. (mm)	Postirrad. (mm)	Length Ah/L (%)	At 1 ft (mr)	At Contact (mr)	Sample		Linear Weighted Average (°C)	Exponential Weighted Average (b) (°C)	Fissile (%)	Fertile (%)	Fast (E > 29 fJ)	Thermal (E < 0.38 aJ)
											I.D.	Hole No.						
Bottom																		
Body 1																		
Δ	9.65																	
1	482.47	212.5	882	Graphite	1	764.7	763.9	-0.10	--	200	TS-1	1-3	1135	1341	17.90	0.20	0.81	0.83
2	23.83	14.680	1135	Thermal stability	TS-1				10R	--	TS-1	4-6	1282	1497	22.93	0.24	1.27	1.53
3	33.32	14.732	1164	Thermal stability	TS-2				10R	--	TS-2	1-3	1116	1249	23.21	0.25	1.29	1.58
4	30.43	14.727	1196	Thermal stability	TS-3				9.4R	--	TS-2	4-6	1213	1361	23.47	0.25	1.32	1.63
5	166.42	71.34	1294	Tensile sample	H887-19				--	4.4R	TS-3	1-3	1216	1311	24.00	0.26	1.38	1.72
6	28.19	13.29	1391	Graphite	9				--	100	TS-3	4-6	1095	1204	24.16	0.27	1.40	1.76
P(d)	13.08																	
Σ	787.43																	
Body 2																		
Δ	9.65																	
1	195.12	88.35	1528	Graphite	3	751.5	747.3	-0.54	--	200					24.19	0.27	1.43	1.80
2	31.75	14.657	1642	Thermal stability	TS-4				10R	--	TS-4	1-3	1328	1417	23.98	0.27	1.45	1.83
3	12.70	5.703	1664	Pyrocarbon	1888-20				100	--	TS-4	4-6	1364	1447	23.94	0.28	1.45	1.83
4	165.10	71.090	1753	Tensile sample	H888-22				--	2.5R					23.60	0.27	1.45	1.84
5	30.18	14.690	1851	Thermal stability	TS-5				10R	--	TS-5	1-3	1360	1454	23.12	0.26	1.44	1.82
6	17.45	5.688	1874	Pyrocarbon	1888-19				--	100	TS-5	4-6	1418	1504	23.00	0.26	1.44	1.81
7	34.93	17.161	1901	Creep sample	13C				--	150					22.86	0.26	1.43	1.80
8	31.75	14.730	1934	Thermal stability	TS-6				10R	--	TS-6	1-3	1325	1421	22.60	0.25	1.42	1.79
9	38.10	17.764	1969	Creep sample	2C				--	150	TS-6	4-6	1454	1538	22.34	0.25	1.41	1.77
10	38.10	18.506	2007	Creep sample	8C				--	150					22.02	0.24	1.40	1.74
11	12.70	5.537	2032	Pyrocarbon	1888-21				--	100					21.86	0.24	1.39	1.73
12	143.59	65.22	2110	Graphite	5				--	200					21.33	0.24	1.36	1.65
P(d)	26.04																	
Σ	787.19																	
Body 3																		
Δ	9.65																	
1	99.44	45.49	2261	Graphite	6	746.0	748.6	+0.35	--	200	TS-7	1-3	1422	1505	20.61	0.22	1.62	1.54
2	12.70	5.569	2317	Pyrocarbon	1889-20				--	100	TS-7	4-6	1422	1605	20.08	0.21	1.29	1.51
3	38.10	17.300	2342	Creep sample	5C				--	150					19.81	0.21	1.27	1.47
4	31.75	13.980	2377	Thermal stability	TS-7				9R	--	TS-8	1-3	1534	1604	19.43	0.21	1.24	1.42
5	31.75	14.556	2409	Thermal stability	TS-8				15R	--	TS-8	4-6	1410	1494	19.09	0.21	1.22	1.38
6	31.75	14.625	2441	Thermal stability	TS-9				9R	--					18.59	0.21	1.19	1.33
7	500.71	223.80	2707	Graphite	11				--	100	TS-9	1-3	1402	1488	14.60	0.19	0.87	0.92
P(d)	29.72										TS-9	4-6	1302	1399				
Σ	785.37																	
Top																		

(a) "0" on reference Drawing 11890.

(b) For SiC thinning rate analysis ($Q = 3.283 \times 10^5$ J/mol).

(c) Calculated with GAUGE/FEVER.

(d) p = plenum.

TABLE 2-8
FTE-15 SPINE SAMPLE SUMMARY

Position	Preirrad. Length (mm)	Preirrad. Weight (g)	Mean Core Height ^(a) (mm)	Sample Type	Ident. No.	Composite Spine Length			Gamma Activity Readings (4/11/75)		Thermal Stability Sample Temperatures				FIMA ^(c)		Fluence ^(c) (10 ²⁵ n/m ²)	
						Preirrad. (mm)	Postirrad. (mm)	Length Ah/L (%)	At 1 ft (mr)	At Contact (mr)	Sample		Linear Weighted Average (°C)	Exponential Weighted Average ^(b) (°C)	Fissile (%)	Fertile (%)	Fast (E > 29 fJ)	Thermal (E < 0.38 aJ)
											I.D.	Hole No.						
Bottom																		
Body 1																		
Δ	9.65																	
1	478.76	210.30	880	Graphite	10	766.88	765.91	-0.13	--	100	TS-1	1-3	1155	1306	27.52	0.52	1.32	1.32
2	30.18	14.683	1135	Thermal stability	TS-1				16.5R	--	TS-1	4-6	1294	1442	35.27	0.81	1.75	2.38
3	31.75	14.623	1166	Thermal stability	TS-2				16.5R	--	TS-2	1-3	1162	1302	35.75	0.83	1.78	2.51
4	31.75	14.580	1197	Thermal stability	TS-3				19.5R	--	TS-2	4-6	1207	1330	36.16	0.85	1.81	2.63
5	165.10	72.35	1296	Tensile sample	11952-19				500	--	TS-3	1-3	1193	1314	37.03	0.84	1.88	2.85
6	29.34	12.91	1393	Graphite	8				25	--	TS-3	4-6	1086	1229	37.29	0.86	1.91	2.96
P _(d)	13.54																	
Σ	790.07																	
Body 2																		
Δ	9.65																	
1	197.79	87.49	1530	Graphite	2	753.62	745.11	-1.13	--	50	TS-4	1-3	1323	1450	37.55	0.88	1.95	3.09
2	31.75	14.650	1645	Thermal stability	TS-4				20R	--	TS-4	4-6	1355	1473	37.59	0.92	1.99	3.20
3	12.70	5.583	1667	Pyrocarbon	11953-20				--	100					37.56	0.93	2.00	3.22
4	165.10	72.275	1756	Tensile sample	11953-22				--	50					37.24	0.92	2.01	3.25
5	31.75	14.660	1854	Thermal stability	TS-5				19.5R	--	TS-5	1-3	1338	1457	36.64	0.90	2.02	3.23
6	12.70	5.529	1876	Pyrocarbon	11953-19				--	50	TS-5	4-6	1389	1499	36.48	0.89	2.02	3.22
7	38.10	17.066	1902	Creep sample	11953-23-4C				50	--					36.28	0.88	2.03	3.21
8	31.75	14.588	1937	Thermal stability	TS-6				20R	--	TS-6	1-3	1299	1429	35.96	0.86	2.03	3.19
9	38.10	17.761	1972	Creep sample	11953-24-9C				--	100	TS-6	4-6	1418	1532	35.62	0.83	2.02	3.16
10	36.52	18.478	2009	Creep sample	11953-25-14C				--	100					35.27	0.80	2.02	3.12
11	14.27	5.519	2034	Pyrocarbon	11953-21				--	50					35.01	0.80	2.02	3.09
12	143.08	64.680	2113	Graphite	4				--	100					34.13	0.77	2.00	2.94
P _(d)	26.80																	
Σ	790.07																	
Body 3																		
Δ	9.65																	
1	104.22	45.77	2273	Graphite	7	753.19	747.45	-0.76	--	75	TS-7	1-3	1367	1466	33.28	0.73	1.97	2.77
2	12.70	5.578	2332	Pyrocarbon	11954-20				--	100	TS-7	4-6	1367	1466	32.36	0.70	1.94	2.62
3	38.10	18.478	2357	Creep sample	11954-19-1K				--	50					31.84	0.68	1.92	2.55
4	31.75	13.988	2392	Thermal stability	TS-7				15R	--	TS-8	1-3	1468	1553	31.04	0.66	1.90	2.45
5	31.75	14.691	2424	Thermal stability	TS-8				15R	--	TS-8	4-6	1358	1455	30.27	0.63	1.87	2.36
6	31.75	14.608	2455	Thermal stability	TS-9				15R	--					29.51	0.61	1.84	2.27
7	502.92	224.50	2723	Graphite	12				--	100	TS-9	1-3	1351	1449	23.59	0.42	1.41	1.47
P _(d)	27.31										TS-9	4-6	1262	1373				
Σ	790.14																	
Top																		

(a) "g" on reference Drawing 11890.

(b) For SiC thinning rate analysis ($Q = 3.283 \times 10^5$ J/mol).

(c) Calculated with GAUGE/FEVER.

(d) _p = plenum.

TABLE 3-1
FTE-14 POWER, FLOW, AND FLUX HISTORY

Interval Reference		Thermal Analysis						Nuclear Analysis					
Equ. Full Power Time		Irradiation Time ^(a) (Δ Days)	Absolute Radial Power ^(b) (kW)	Rel. Radial Power	Coolant Rel. Radial Power Factor	Tricuspid Channel Flow (kg/s)	Real Time ^(c) (Δ Days)	GAUGE Power (kW)	Flux Groups ^(d) from GAUGE				
From EFPD	To EFPD								Group 1A ^(e) (10 ¹⁷ n/m ² /s)	Group 1B ^(f) (10 ¹⁷ n/m ² /s)	Group 2 (10 ¹⁷ n/m ² /s)	Group 3 (10 ¹⁷ n/m ² /s)	Group 4 (10 ¹⁷ n/m ² /s)
385.44	499.59	141.93	100.21	0.893	0.960	0.0305	145.87	97.50	2.9243	0.5161	6.0015	0.9769	3.2323
499.59	564.07	72.69	128.44	1.038	1.091	0.0340	80.59	115.84	3.1818	0.5615	6.5243	1.0764	3.9688
564.07	610.25	49.63	138.63	1.068	1.108	0.0336	51.56	133.45	3.7104	0.6548	7.6575	1.2618	4.6970
610.25	701.23	98.73	127.18	0.989	1.006	0.0331	98.73	127.18	3.5624	0.6286	7.4778	1.2122	4.4472
Sum/time weighted average		362.98	118.45	0.972	1.019	0.0323	376.75	114.12	3.2542	0.5743	6.7268	1.0988	3.9087
Root mean square		--	15.05	0.068	0.059	0.0015	--	14.26	0.3109	0.0548	0.6920	0.1134	0.5822

(a) Time at non-zero power used in thermal analysis.

(b) Corrected for power bias as described in Section 3.3.1.

(c) Real calendar days used in nuclear analysis. Some short-term zero power periods are included.

(d) The energy ranges for the flux groups are as follows:

Group 1A:	14.96 MeV > E >	0.18 MeV	or	2.40 pJ > E >	28.84 fJ
Group 1B:	0.18 MeV > E >	8.65 x 10 ⁴ eV	or	28.84 fJ > E >	13.86 fJ
Group 2:	8.65 x 10 ⁴ eV > E >	17.60 eV	or	13.86 fJ > E >	2.82 aJ
Group 3:	17.60 eV > E >	2.38 eV	or	2.82 aJ > E >	0.38 aJ
Group 4:	2.38 eV > E >	0.0	or	0.38 aJ > E >	0.0

(e) Group 1A, the fast flux group, has been modified from the GAUGE output by a factor of 0.85. This accounts for the Peach Bottom energy cutoff of 8.65 x 10⁴ eV instead of 0.18 MeV.

(f) Nominal prediction.

TABLE 3-2
FTE-15 POWER, FLOW, AND FLUX HISTORY

Interval Reference		Thermal Analysis					Nuclear Analysis						
Equ. Full Power Time		Irradiation Time(a) (Δ Days)	Absolute Radial Power(b) (kW)	Rel. Radial Power	Coolant Rel. Radial Power Factor	Tricusp Channel Flow (kg/s)	Real Time(c) (Δ Days)	GAUGE Power (kW)	Flux Groups(d) from GAUGE				
From EFPD	To EFPD								Group 1A(e) (10 ¹⁷ n/m ² /s)	Group 1B(f) (10 ¹⁷ n/m ² /s)	Group 2 (10 ¹⁷ n/m ² /s)	Group 3 (10 ¹⁷ n/m ² /s)	Group 4 (10 ¹⁷ n/m ² /s)
385.44	499.59	141.93	93.25	0.831	0.894	0.0307	145.87	90.73	2.9103	0.5136	5.9896	0.9760	3.2581
499.59	564.07	72.69	119.19	0.963	1.013	0.0343	80.59	107.47	3.1684	0.5591	6.5450	1.0759	3.9928
564.07	610.25	49.63	128.63	0.991	1.028	0.0339	51.56	123.82	3.6955	0.6522	7.6478	1.2614	4.7260
610.25	701.23	98.73	117.93	0.917	0.935	0.0334	98.73	117.92	3.5478	0.6261	7.4680	1.2119	4.4813
701.23	701.23	0.00	122.81	0.955	0.957	0.0333	0.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000
701.23	748.00	50.74	138.12	1.074	1.015	0.0336	50.74	138.11	3.4192	0.6034	6.7096	1.0938	5.4961
748.00	788.00	50.00	117.19	1.050	0.989	0.0284	50.00	117.18	2.9920	0.5280	5.9099	0.9634	4.8070
788.00	818.00	39.20	111.54	1.045	0.977	0.0290	37.50	116.62	2.9610	0.5225	5.8636	0.9555	4.9394
818.00	835.00	30.00	85.66	1.078	0.998	0.0240	30.00	85.61	2.0992	0.3705	4.1476	0.6752	3.6236
835.00	858.00	29.00	113.43	1.022	0.945	0.0316	29.00	113.44	2.8115	0.4961	5.5967	0.9122	4.8546
858.00	889.00	47.00	93.28	0.992	0.914	0.0300	47.00	93.29	2.3090	0.4075	4.6182	0.7531	4.0609
889.00	897.30	12.00	82.78	0.992	0.910	0.0287	12.00	82.80	2.0408	0.3601	4.0873	0.6663	3.6610
Sum/time weighted average		620.92	110.16	0.960	0.957	0.0314	632.99	108.06	3.0527	0.5387	6.2267	1.0164	4.2211
Root mean square		--	15.66	0.085	0.049	0.0026	--	15.54	0.4428	0.0781	0.9834	0.1615	0.6949

(a) Time at non-zero power used in thermal analysis.

(b) Connected for power bias as described in Section 3.3.1.

(c) Real calendar days used in nuclear analysis. Some short-term zero power periods are included.

(d) The energy ranges for the flux groups are as follows:

Group 1A:	14.96 MeV > E >	0.18 MeV	2.40 pJ > E >	28.84 fJ
Group 1B:	0.18 MeV > E >	8.65 x 10 ⁴ eV	28.84 fJ > E >	13.86 fJ
Group 2:	8.65 x 10 ⁴ eV > E >	17.60 eV	13.86 fJ > E >	2.82 aJ
Group 3:	17.60 eV > E >	2.38 eV	2.82 aJ > E >	0.38 aJ
Group 4:	2.38 eV > E >	0.0	0.38 aJ > E >	0.0

(e) Group 1A, the fast flux group, has been modified from the GAUGE output by a factor of 0.85. This accounts for the Peach Bottom energy cutoff of 8.65 x 10⁴ eV instead of 0.18 MeV.

(f) Nominal prediction.

TABLE 3-3
TIME-AVERAGED VALUES^(a) FOR FTE-14 AND FTE-15 POWER HISTORY

Power History	FTE-14			FTE-15		
	Mean	$1\sigma^{(b)}$	RMS _t	Mean	$1\sigma^{(b)}$	RMS _t
Irradiation time (EFPD)	315.8	--	--	511.9	--	--
Irradiation time, real ^(c) (thermal analysis)	363.0	--	--	620.9	--	--
Irradiation time, real ^(c,d) (nuclear analysis)	376.7	--	--	633.0	--	--
Element power ^(c) (thermal analysis) (kW)	116.07	±2.93	±14.75	108.85	±1.53	±15.47
Element power ^(c) (nuclear analysis) (kW)	111.82	±2.82	±13.97	106.78	±1.50	±15.36
Linear power rating ^(c) (W/cm)	89.90	±2.27	--	85.70	±1.20	--
Element power factor ^(c,e)	0.952	±0.02	±0.067	0.949	±0.01	±0.08
Coolant power factor ^(c,e)	0.998	±0.02	±0.058	0.946	±0.01	±0.048
Coolant flow of triscup channel (kg/s)	0.032	--	±0.002	0.031	--	±0.003
Flux ^(c) (10^{17} n/m ² /s)						
Fast ($E > 28.84$ fJ)	3.46	±0.09	±0.33	3.04	±0.04	±0.43
Fast ($13.86 \text{ fJ} \leq E < 28.84 \text{ fJ}$)	0.61	±0.02	±0.05	0.54	±0.01	±0.08
Epithermal ($2.82 \text{ aJ} \leq E < 13.86 \text{ fJ}$)	7.17	±0.18	±0.73	6.22	±0.09	±0.98
Epithermal ($0.38 \text{ aJ} \leq E < 2.82 \text{ aJ}$)	1.18	±0.03	±0.12	1.02	±0.01	±0.16
Thermal ($0 \leq E < 0.38 \text{ aJ}$)	4.16	±0.10	±0.62	4.21	±0.06	±0.69

(a) Time-averaged using real time at operation.

(b) Relative power bias error applied to each power-corrected parameter.

(c) Corrected for power bias as described in Section 3.3.1.

(d) Includes shutdown periods.

(e) Relative to core average.

TABLE 3-4
FTE-14 FAST AND THERMAL FLUENCES^(a)

Fuel Body	Fuel Rod	Core Height (mm)	Fast Fluence (10^{25} n/m ²) (E > 0.18 MeV)	Thermal Fluence (10^{25} n/m ²) (E < 2.38 eV)
1	1	696	0.477	0.554
	2	759	0.664	0.679
	3	822	0.806	0.826
	4	885	0.930	0.980
	5	948	1.039	1.136
	6	1012	1.126	1.284
	7	1075	1.202	1.418
	8	1138	1.268	1.539
	9	1201	1.322	1.641
	10	1264	1.360	1.695
	11	1327	1.391	1.741
Mean		1012	1.053	1.226
Range/rms		695	± 0.288	± 0.402
2	1	1486	1.417	1.783
	2	1549	1.436	1.807
	3	1612	1.447	1.825
	4	1675	1.451	1.835
	5	1738	1.451	1.837
	6	1802	1.447	1.828
	7	1865	1.438	1.812
	8	1928	1.423	1.791
	9	1991	1.403	1.756
	10	2054	1.381	1.708
	11	2117	1.357	1.642
Mean		1802	1.423	1.784
Range/rms		694	± 0.030	± 0.058
3	1	2276	1.317	1.560
	2	2339	1.273	1.475
	3	2402	1.225	1.386
	4	2465	1.164	1.292
	5	2528	1.098	1.198
	6	2592	1.027	1.102
	7	2655	0.944	1.001
	8	2718	0.852	0.908
	9	2781	0.748	0.826
	10	2844	0.618	0.763
	11	2907	0.437	0.708
Mean		2592	0.973	1.111
Range/rms		695	± 0.271	± 0.281
Total mean		1802	1.150	1.374
Total range/rms		2275	± 0.301	± 0.409

(a) The fluence values were corrected in accordance with the power correction described in Section 3.3.1.

TABLE 3-5
FTE-15 FAST AND THERMAL FLUENCES^(a)

Fuel Body	Fuel Rod	Core Height (mm)	Fast Fluence (10 ²⁵ n/m ²) (E > 0.18 MeV)	Thermal Fluence (10 ²⁵ n/m ²) (E < 2.38 eV)
1	1	696	0.695	0.750
	2	759	0.966	0.860
	3	822	1.165	1.080
	4	885	1.331	1.339
	5	948	1.472	1.613
	6	1012	1.586	1.875
	7	1075	1.674	2.135
	8	1138	1.750	2.393
	9	1201	1.812	2.646
	10	1264	1.857	2.783
	11	1327	1.897	2.907
Mean		1012	1.473	1.853
Range/rms		695	± 0.375	± 0.745
2	1	1486	1.933	3.032
	2	1549	1.962	3.114
	3	1612	1.984	3.176
	4	1675	1.998	3.221
	5	1738	2.009	3.252
	6	1802	2.017	3.245
	7	1865	2.024	3.222
	8	1928	2.025	3.201
	9	1991	2.022	3.145
	10	2054	2.013	3.060
	11	2117	1.998	2.936
Mean		1802	1.999	3.146
Range/rms		694	± 0.028	± 0.096
3	1	2276	1.969	2.772
	2	2339	1.934	2.600
	3	2402	1.893	2.424
	4	2465	1.833	2.240
	5	2528	1.761	2.062
	6	2592	1.676	1.884
	7	2655	1.558	1.673
	8	2718	1.418	1.486
	9	2781	1.253	1.327
	10	2844	1.037	1.222
	11	2907	0.739	1.114
Mean		2592	1.552	1.891
Range/rms		695	± 0.382	± 0.547
Total mean		1802	1.675	2.297
Total range/rms		2275	± 0.387	± 0.805

(a) The fluence values were corrected in accordance with the power correction described in Section 3.3.1.

TABLE 3-6
FTE-14 AND FTE-15 CORRECTED FLUENCE VALUES

EOL Fluences	Element	Peak	1σ	Mean	1σ	RMS _a	RMS _t	Fuel Body/ Gradient Sequence
Fast fluence (10^{25} n/m ²) (E > 29 fJ)	FTE-14	1.45	±0.03	1.15	±0.02	±0.30	±0.11	213/231
	FTE-15	2.03	±0.06	1.68	±0.05	±0.39	±0.24	231/213
Thermal fluence (10^{25} n/m ²) (E < 0.38 aJ)	FTE-14	1.84	±0.03	1.37	±0.03	±0.41	±0.21	213/231
	FTE-15	3.25	±0.10	2.30	±0.07	±0.81	±0.38	231/231

TABLE 3-7
FTE-14 AND FTE-15 FAST AND THERMAL NEUTRON FLUX AND FLUENCE COMPARISON^(a)

Sample I.D.	Core Location (mm)	Neutron Flux (n/m ² /s)	Neutron Fluence				Relative Difference		Test 1	Test 2	Test 1 Result (D ≥ 1.96 for Sign.)
			Meas. M (n/m ²)	S _M (1σ) (n/m ²)	Calc. C (n/m ²)	S _C (1σ) (n/m ²)	C/M-1 = Z	S _Z (1σ)	Test 1	Test 2	
									D = Z/S _Z	D ²	
Fast (E ≥ 29 fJ)											
FTE-14 H888-22	1294	3.91E13	1.21E21	+0.07E21	1.38E21	+0.04E21	0.14	+0.07	1.90	3.62	Not significant
FTE-15 11952-19	1296	3.42E13	1.83E21	+0.15E21	1.88E21	+0.04E21	0.03	+0.09	0.31	0.10	Not significant
11953-22 (Fe + Fe-V)	1756	3.66E13	1.96E21	+0.20E21	2.01E21	+0.04E21	0.03	+0.11	0.24	0.06	Not significant
11953-22 (Fe only)	1756	3.18E13	1.70E21	+0.17E21	2.01E21	+0.04E21	0.18	+0.12	1.51	2.29	Not significant
Thermal (E < 0.38 fJ)											
FTE-14 H888-22	1294	6.71E13	2.08E21	+0.12E21	1.72E21	+0.05E21	-0.17	+0.05	-3.24	10.50	Significant
H887-19	1753	9.06E13	2.81E21	+0.28E21	1.83E21	+0.05E21	-0.35	+0.07	-5.18	26.86	Significant
FTE-15 11952-19	1296	6.68E13	3.58E21	+0.32E21	2.85E21	+0.05E21	-0.20	+0.07	-2.81	7.91	Significant
11953-22	1756	8.08E13	4.32E21	+0.43E21	3.25E21	+0.06E21	-0.25	+0.08	-3.25	10.58	Significant

^(a) Fluence predictions have been corrected with power bias described in Section 3.3.1. (1σ) error is relative power bias error.

TABLE 3-8
FTE-14 AND FTE-15 SUMMARY OF CALCULATED AND MEASURED FAST AND THERMAL FLUENCES

Core Location (mm)	Meas, M (10^{25} n/m ²)	Error (1 σ) $\pm S_M$ (10^{25} n/m ²)	Calc, C (10^{25} n/m ²)	Error (1 σ) $\pm S_C$	Difference $Z = C/M - 1$	Error (1 σ) $\pm S_Z$	Individual Agreement Test, $D = S_Z/Z$ ($D \geq 1.96$ for Significant)
Fast Fluence (E > 29 fJ)							
FTE-14							
1294	1.21	0.07	1.38	0.04	0.14	0.07	Not significant
FTE-15							
1296	1.83	0.15	1.88	0.04	0.03	0.09	Not significant
1756 (a)	1.95	0.20	2.01	0.04	0.03	0.11	Not significant
1756 (b)	1.70	0.18	2.01	0.04	0.18	0.12	Not significant
Mean $\bar{X}$, $\bar{S}_X$ RMS, error $S_{\bar{X}}$					0.06 ± 0.05	0.09 0.05	Bias not significant
Thermal Fluence (E < 0.38 aJ)							
FTE-14							
1294	2.08	0.12	1.72	0.05	-0.17	0.05	Significant
1753	2.81	0.28	1.83	0.05	-0.35	0.07	Significant
FTE-15							
1296	3.58	0.32	3.25	0.06	-0.20	0.07	Significant
1756	4.32	0.43	3.25	0.06	-0.25	0.08	Significant
Mean $\bar{X}$, $\bar{S}_X$ RMS, error $S_{\bar{X}}$					-0.24 ± 0.07	0.07 0.03	Bias significant but rejected (see text)

(a) Iron and V-Fe wires assumed to be present.

(b) Iron wire only assumed to be present; a less likely event when compared with companion test in FTE-15. Result is not included in average.

TABLE 3-9
FTE-14 AND FTE-15 CALCULATED POWER TILTS

Time Interval (EFPD)	Fuel Hole 1	Fuel Hole 2	Fuel Hole 3	Fuel Hole 4	Fuel Hole 5	Fuel Hole 6
FTE-14						
385 - 500	1.021	1.010	1.000	1.000	0.969	1.000
500 - 564	1.019	1.011	1.001	0.997	0.972	1.001
564 - 610	1.008	1.015	1.005	0.979	0.988	1.005
610 - 701	1.003	1.017	1.008	0.972	0.994	1.006
701	0.997	1.020	1.010	0.962	1.002	1.008
FTE-15						
385 - 500	1.018	1.018	0.998	0.998	0.967	0.998
500 - 564	1.011	1.018	0.997	0.985	0.985	1.002
564 - 610	1.007	1.018	0.996	0.979	0.993	1.005
610 - 701	1.004	1.018	0.995	0.972	1.003	1.006
701	0.999	1.018	0.995	0.964	1.014	1.009
701 - 748	0.997	1.018	0.995	0.961	1.020	1.011
748 - 788	0.996	1.018	0.994	0.958	1.022	1.011
788 - 818	0.994	1.018	0.994	0.954	1.028	1.012
818 - 835	0.988	1.018	0.994	0.949	1.035	1.015
835 - 858	0.988	1.017	0.994	0.949	1.037	1.015
858 - 890	0.987	1.016	0.993	0.947	1.038	1.016
890 - 897	0.987	1.016	0.993	0.944	1.042	1.016
897	0.986	1.016	0.993	0.944	1.044	1.018

TABLE 3-10
FTE-14 AND FTE-15 BURNUPS AND AXIAL POWER FACTORS AT SPINE SAMPLE LOCATIONS

Spine Sample	Axial Location (mm)	FIMA									Axial Power Factors			(a) CPF _{Actual}	
		Measured						Calculated						CPF _{GAUGE}	
		Fissile		Fertile		Composite					Measured		Calc.	x	1σ
		x	1σ	x	1σ	x	1σ	Fissile	Fertile	Composite	x	1σ			
FTE-14															
TS2-6	1164	23.109	±0.306	0.25	±0.100	1.793	±0.096	23.13	0.25	1.79	1.159	±0.005	1.225	1.056	±0.057
TS4-6	1653	25.302	±0.353	0.33 ^(b)	±0.100 ^(b)	3.568	±0.098	24.09	0.28	3.39	1.250	±0.006	1.247	1.050	±0.029
TS7-3	2387	22.773	±0.303	0.30	±0.027	3.237	±0.046	19.37	0.21	2.71	1.035	±0.006	0.962	1.107	±0.017
$\bar{x}, S_{\bar{x}}$														1.071	±0.027
FTE-15															
TS2-6	1166	34.042	±0.348	0.68	±0.110	2.867	±0.105	35.63	0.83	3.18	1.131	±0.002	1.233	0.983	±0.036
TS5-6	1854	38.604	±0.356	0.85	±0.037	5.784	±0.057	36.82	0.90	5.59	1.219	±0.003	1.185	1.005	±0.010
TS8-3	2424	33.491	±0.351	0.68	±0.040	4.968	±0.058	30.25	0.63	4.50	1.028	±0.004	0.937	1.006	±0.012
$\bar{x}, S_{\bar{x}}$														0.998	±0.014

$$(a) \frac{CPF_{Actual}}{CPF_{GAUGE}} = \frac{FIMA_{Meas.}}{FIMA_{Calc.}} \cdot \frac{APF_{Calc.}}{APF_{Meas.}}$$

(b) Estimated.

TABLE 3-11a
FTE-14 IRRADIATION TEMPERATURES FOR STACK 1

MEAN POS CORE HT (mm)	FUEL MAX	TEMPERATURE ENVELOPE (C)						TIME WEIGHTED AVERAGES (C)										COOLANT
		FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN		FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
696.	741.	513.	594.	509.	498.	427.		661.	620.	580.	551.	547.	543.	466.	452.	438.		352.
759.	806.	557.	636.	533.	536.	448.		706.	661.	615.	583.	578.	573.	495.	478.	460.		356.
822.	866.	583.	675.	557.	567.	464.		753.	702.	652.	615.	609.	603.	521.	499.	478.		363.
885.	930.	618.	718.	588.	599.	484.		809.	752.	695.	653.	646.	640.	549.	525.	500.		372.
948.	1001.	655.	767.	623.	634.	508.		869.	805.	742.	695.	687.	680.	580.	553.	526.		382.
1012.	1072.	695.	821.	660.	673.	533.		934.	863.	793.	741.	732.	724.	614.	584.	554.		393.
1075.	1152.	736.	874.	697.	712.	560.		998.	921.	843.	786.	777.	768.	647.	615.	584.		405.
1138.	1211.	769.	918.	728.	745.	583.		1050.	967.	883.	824.	814.	804.	675.	642.	609.		419.
1201.	1251.	792.	951.	750.	771.	601.		1086.	999.	912.	851.	841.	831.	698.	664.	630.		432.
1264.	1278.	806.	974.	764.	791.	613.		1107.	1018.	930.	869.	858.	847.	712.	678.	644.		446.
1327.	1274.	800.	973.	759.	788.	609.		1101.	1013.	924.	864.	853.	842.	708.	673.	638.		461.
MEAN	1012.	1054.	686.	809.	652.	665.	530.	916.	847.	779.	730.	722.	714.	606.	578.	551.		398.
RANGE/RMS	695.	167.	97.	133.	90.	100.	65.	158.	141.	123.	112.	110.	107.	65.	76.	72.		36.
1486.	1312.	915.	1030.	862.	784.	641.		1202.	1109.	1015.	955.	944.	933.	731.	697.	662.		475.
1549.	1357.	952.	1070.	898.	820.	675.		1243.	1149.	1054.	992.	981.	971.	765.	732.	698.		490.
1612.	1387.	972.	1095.	918.	843.	694.		1268.	1172.	1076.	1014.	1003.	992.	786.	752.	719.		505.
1675.	1464.	1063.	1194.	1010.	862.	709.		1363.	1266.	1169.	1111.	1100.	1089.	802.	768.	735.		520.
1738.	1534.	1108.	1248.	1056.	878.	722.		1411.	1313.	1216.	1160.	1149.	1138.	816.	783.	750.		534.
1802.	1507.	1076.	1219.	1024.	893.	734.		1380.	1263.	1185.	1128.	1117.	1106.	828.	796.	763.		549.
1865.	1479.	1044.	1189.	991.	907.	745.		1347.	1251.	1154.	1096.	1085.	1074.	840.	808.	776.		564.
1926.	1460.	1023.	1169.	971.	920.	755.		1325.	1229.	1134.	1074.	1064.	1053.	851.	819.	788.		578.
1991.	1405.	972.	1113.	920.	931.	764.		1268.	1174.	1080.	1019.	1008.	997.	860.	829.	798.		591.
2054.	1399.	975.	1112.	923.	933.	770.		1265.	1172.	1078.	1019.	1008.	998.	863.	833.	803.		605.
2117.	1371.	957.	1089.	906.	914.	755.		1241.	1149.	1056.	999.	988.	978.	846.	815.	785.		618.
MEAN	1802.	1427.	1005.	1139.	952.	860.	724.	1301.	1206.	1111.	1052.	1041.	1030.	817.	785.	753.		548.
RANGE/RMS	694.	67.	58.	66.	58.	46.	39.	64.	62.	61.	62.	62.	62.	40.	42.	43.		45.
2276.	1378.	968.	1112.	922.	919.	757.		1246.	1158.	1070.	1018.	1008.	998.	848.	820.	793.		630.
2339.	1445.	1032.	1184.	987.	953.	789.		1309.	1223.	1136.	1086.	1077.	1067.	879.	853.	826.		642.
2402.	1458.	1056.	1209.	1014.	956.	794.		1323.	1241.	1158.	1111.	1102.	1093.	882.	857.	832.		654.
2465.	1463.	1066.	1226.	1027.	956.	794.		1325.	1246.	1168.	1124.	1116.	1107.	880.	857.	834.		665.
2528.	1458.	1075.	1233.	1038.	954.	796.		1323.	1248.	1174.	1133.	1125.	1117.	879.	857.	835.		675.
2592.	1447.	1081.	1234.	1046.	951.	797.		1317.	1246.	1175.	1137.	1129.	1122.	876.	856.	836.		684.
2655.	1425.	1073.	1225.	1040.	947.	796.		1298.	1231.	1164.	1129.	1122.	1115.	873.	854.	835.		693.
2718.	1390.	1055.	1203.	1024.	941.	794.		1266.	1204.	1142.	1109.	1102.	1096.	868.	850.	833.		701.
2781.	1353.	1038.	1179.	1009.	933.	793.		1235.	1177.	1120.	1089.	1083.	1077.	862.	847.	831.		709.
2844.	1305.	1011.	1147.	985.	917.	785.		1192.	1139.	1087.	1059.	1054.	1049.	848.	835.	821.		715.
2907.	1206.	951.	1069.	928.	866.	749.		1106.	1060.	1014.	991.	967.	982.	804.	792.	761.		720.
MEAN	2592.	1393.	1037.	1184.	1002.	936.	786.	1267.	1198.	1128.	1090.	1082.	1075.	863.	843.	823.		681.
RANGE/RMS	695.	77.	42.	51.	41.	26.	16.	66.	57.	49.	46.	46.	45.	22.	20.	16.		29.
MEAN	1802.	1291.	909.	1044.	869.	827.	680.	1161.	1084.	1006.	957.	948.	940.	762.	736.	709.		542.
RANGE/RMS	2275.	209.	173.	190.	168.	134.	118.	204.	192.	181.	180.	179.	178.	125.	125.	126.		121.

TABLE 3-11b
FTE-14 IRRADIATION TEMPERATURES FOR STACK 2

	MEAN POS		TEMPERATURE ENVELOPE (C)					TIME WEIGHTED AVERAGES (C)										COOLANT
	COPE HT (MM)	FUEL MAX	FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
	696.	741.	533.	594.	509.	498.	427.	661.	620.	580.	551.	547.	543.	466.	452.	438.	352.	
	759.	806.	557.	635.	533.	536.	448.	706.	661.	615.	583.	578.	573.	495.	478.	460.	356.	
	822.	866.	593.	675.	557.	567.	464.	753.	702.	652.	615.	609.	603.	521.	499.	478.	363.	
	885.	930.	618.	718.	588.	599.	484.	809.	752.	695.	653.	646.	640.	549.	525.	500.	372.	
	948.	1001.	655.	767.	623.	634.	508.	869.	805.	742.	695.	687.	680.	580.	553.	526.	382.	
	1012.	1078.	695.	821.	660.	673.	533.	934.	863.	793.	741.	732.	724.	614.	584.	554.	393.	
	1075.	1152.	736.	874.	697.	712.	560.	998.	921.	843.	786.	777.	768.	647.	615.	584.	405.	
	1138.	1211.	769.	918.	728.	745.	583.	1050.	967.	883.	824.	814.	804.	675.	642.	609.	419.	
	1201.	1251.	792.	951.	750.	771.	601.	1086.	999.	912.	851.	841.	831.	698.	664.	630.	432.	
	1264.	1278.	806.	974.	764.	790.	613.	1107.	1018.	930.	869.	856.	847.	712.	676.	644.	446.	
	1327.	1274.	800.	973.	759.	788.	609.	1101.	1013.	924.	864.	853.	842.	708.	673.	638.	441.	
MEAN	1012.	1054.	686.	809.	652.	665.	530.	916.	847.	779.	730.	722.	714.	606.	576.	551.	398.	
RANGE/RMS	695.	187.	97.	133.	90.	100.	65.	158.	141.	123.	112.	110.	107.	85.	76.	72.	36.	
	1486.	1283.	901.	1032.	858.	785.	639.	1176.	1083.	990.	953.	942.	931.	730.	696.	661.	475.	
	1549.	1328.	938.	1071.	894.	821.	673.	1217.	1123.	1028.	990.	980.	969.	764.	731.	697.	490.	
	1612.	1357.	958.	1096.	914.	844.	692.	1242.	1146.	1050.	1012.	1002.	991.	785.	751.	718.	505.	
	1675.	1455.	1049.	1197.	1005.	863.	707.	1338.	1241.	1144.	1109.	1098.	1087.	801.	766.	734.	520.	
	1738.	1506.	1094.	1250.	1051.	879.	720.	1386.	1289.	1191.	1158.	1147.	1135.	815.	782.	749.	534.	
	1802.	1478.	1063.	1220.	1019.	894.	731.	1354.	1257.	1160.	1126.	1115.	1104.	827.	795.	762.	549.	
	1865.	1449.	1030.	1190.	987.	907.	743.	1321.	1225.	1129.	1094.	1083.	1072.	839.	807.	775.	564.	
	1928.	1430.	1010.	1170.	967.	920.	753.	1299.	1203.	1108.	1072.	1062.	1051.	849.	818.	787.	578.	
	1991.	1375.	959.	1113.	916.	931.	762.	1242.	1146.	1054.	1017.	1006.	996.	859.	828.	798.	591.	
	2054.	1372.	962.	1115.	920.	936.	769.	1242.	1149.	1056.	1020.	1009.	999.	864.	834.	804.	605.	
	2117.	1355.	948.	1100.	906.	924.	756.	1226.	1133.	1040.	1005.	994.	984.	851.	821.	791.	618.	
MEAN	1802.	1399.	992.	1141.	949.	882.	722.	1277.	1182.	1087.	1051.	1040.	1029.	817.	785.	752.	546.	
RANGE/RMS	694.	66.	56.	65.	58.	47.	39.	63.	62.	60.	62.	61.	61.	41.	42.	43.	45.	
	2276.	1377.	989.	1106.	911.	917.	751.	1246.	1164.	1082.	1009.	999.	990.	843.	815.	788.	630.	
	2339.	1442.	1052.	1177.	976.	950.	783.	1308.	1228.	1147.	1076.	1067.	1058.	874.	848.	822.	642.	
	2402.	1454.	1074.	1201.	1002.	952.	789.	1321.	1244.	1167.	1101.	1092.	1084.	876.	852.	828.	654.	
	2465.	1457.	1082.	1216.	1016.	952.	789.	1322.	1249.	1176.	1113.	1105.	1097.	875.	852.	829.	665.	
	2528.	1451.	1089.	1222.	1027.	949.	791.	1319.	1250.	1180.	1121.	1114.	1107.	873.	852.	831.	675.	
	2592.	1439.	1094.	1222.	1035.	946.	792.	1313.	1247.	1181.	1125.	1118.	1111.	871.	851.	832.	684.	
	2655.	1416.	1085.	1212.	1029.	941.	792.	1293.	1231.	1170.	1117.	1110.	1104.	867.	849.	831.	693.	
	2718.	1381.	1066.	1190.	1013.	935.	790.	1262.	1204.	1147.	1097.	1091.	1085.	862.	846.	829.	701.	
	2781.	1344.	1049.	1167.	999.	927.	789.	1231.	1178.	1125.	1078.	1072.	1067.	857.	842.	827.	709.	
	2844.	1300.	1022.	1137.	976.	914.	782.	1192.	1143.	1095.	1051.	1046.	1041.	845.	832.	819.	715.	
	2907.	1210.	964.	1066.	923.	868.	749.	1113.	1071.	1028.	989.	964.	980.	805.	794.	783.	720.	
MEAN	2592.	1368.	1051.	1174.	992.	932.	782.	1266.	1201.	1136.	1080.	1073.	1066.	859.	839.	820.	681.	
RANGE/RMS	695.	74.	41.	49.	40.	24.	15.	63.	54.	47.	44.	44.	43.	20.	18.	17.	29.	
MEAN	1802.	1280.	910.	1042.	864.	826.	678.	1153.	1077.	1001.	953.	945.	936.	760.	734.	708.	542.	
RANGE/RMS	2275.	202.	175.	188.	165.	133.	116.	198.	188.	179.	177.	176.	175.	124.	124.	124.	121.	

TABLE 3-11c
FTE-14 IRRADIATION TEMPERATURES FOR STACK 3

	MEAN POS		TEMPERATURE ENVELOPE (C)					TIME WEIGHTED AVERAGES (C)										COOLANT
	CORE HT (MM)	FUEL MAX	FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
	696.	741.	533.	594.	509.	498.	427.	661.	620.	580.	551.	547.	543.	466.	452.	438.	352.	
	759.	806.	557.	635.	533.	536.	448.	706.	661.	615.	583.	578.	573.	495.	478.	460.	356.	
	822.	866.	583.	675.	557.	567.	464.	753.	702.	652.	615.	609.	603.	521.	499.	478.	363.	
	885.	930.	618.	718.	588.	599.	484.	809.	752.	695.	653.	646.	640.	549.	525.	500.	372.	
	948.	1001.	655.	767.	623.	634.	505.	869.	805.	742.	695.	687.	680.	580.	553.	526.	382.	
	1012.	1078.	695.	821.	660.	673.	533.	934.	863.	793.	741.	732.	724.	614.	584.	554.	393.	
	1075.	1152.	736.	874.	697.	712.	560.	998.	921.	843.	786.	777.	768.	647.	615.	584.	405.	
	1138.	1211.	769.	918.	728.	745.	583.	1050.	967.	883.	824.	814.	804.	675.	642.	609.	419.	
	1201.	1281.	792.	951.	750.	771.	601.	1066.	999.	912.	851.	841.	831.	698.	664.	630.	432.	
	1264.	1278.	806.	974.	764.	790.	613.	1107.	1018.	930.	869.	858.	847.	712.	678.	644.	446.	
	1327.	1274.	800.	973.	759.	764.	609.	1101.	1013.	924.	864.	853.	842.	708.	673.	636.	451.	
MEAN	1012.	1054.	686.	809.	652.	665.	530.	916.	847.	779.	730.	722.	714.	606.	578.	551.	393.	
RANGE/RMS	695.	187.	97.	133.	90.	100.	65.	158.	141.	123.	112.	110.	107.	85.	76.	72.	36.	
	1466.	1339.	910.	1043.	852.	792.	636.	1207.	1114.	1021.	953.	943.	932.	731.	696.	662.	475.	
	1549.	1381.	948.	1080.	889.	827.	670.	1248.	1154.	1060.	991.	980.	969.	765.	731.	698.	490.	
	1612.	1409.	967.	1105.	908.	850.	689.	1273.	1177.	1082.	1013.	1002.	991.	785.	752.	718.	505.	
	1675.	1505.	1057.	1206.	949.	869.	703.	1367.	1270.	1174.	1109.	1098.	1087.	801.	768.	734.	520.	
	1738.	1555.	1101.	1258.	1044.	885.	716.	1414.	1317.	1220.	1158.	1147.	1136.	815.	782.	749.	534.	
	1802.	1527.	1070.	1228.	1013.	900.	728.	1383.	1286.	1190.	1126.	1115.	1104.	828.	795.	762.	549.	
	1865.	1498.	1039.	1197.	981.	913.	739.	1350.	1254.	1159.	1094.	1083.	1072.	839.	807.	775.	564.	
	1926.	1477.	1019.	1176.	961.	925.	750.	1327.	1233.	1138.	1072.	1062.	1051.	850.	818.	787.	578.	
	1991.	1422.	968.	1119.	911.	936.	759.	1271.	1178.	1084.	1017.	1006.	995.	859.	828.	797.	591.	
	2054.	1413.	970.	1116.	914.	936.	764.	1266.	1174.	1081.	1016.	1005.	995.	861.	831.	800.	605.	
	2117.	1381.	952.	1091.	896.	916.	749.	1240.	1148.	1057.	994.	983.	973.	842.	812.	782.	618.	
MEAN	1802.	1446.	1000.	1147.	943.	886.	719.	1304.	1210.	1115.	1049.	1039.	1028.	816.	784.	751.	546.	
RANGE/RMS	694.	66.	57.	66.	58.	45.	39.	64.	62.	61.	63.	62.	62.	40.	41.	42.	45.	
	2276.	1389.	965.	1114.	913.	921.	752.	1247.	1160.	1074.	1014.	1004.	995.	846.	818.	790.	630.	
	2339.	1454.	1029.	1184.	978.	953.	784.	1310.	1224.	1139.	1081.	1072.	1062.	876.	850.	824.	642.	
	2402.	1464.	1052.	1209.	1005.	956.	790.	1322.	1241.	1159.	1106.	1097.	1088.	879.	854.	830.	654.	
	2465.	1467.	1062.	1223.	1017.	956.	790.	1323.	1246.	1168.	1119.	1110.	1102.	877.	854.	831.	665.	
	2528.	1460.	1071.	1230.	1029.	953.	792.	1320.	1247.	1173.	1127.	1119.	1111.	875.	854.	832.	675.	
	2592.	1447.	1076.	1229.	1036.	949.	793.	1313.	1244.	1174.	1130.	1123.	1115.	873.	853.	833.	684.	
	2655.	1423.	1068.	1219.	1031.	944.	792.	1293.	1228.	1162.	1122.	1115.	1108.	869.	851.	833.	693.	
	2718.	1387.	1050.	1197.	1015.	937.	791.	1261.	1200.	1140.	1102.	1095.	1089.	864.	847.	831.	701.	
	2781.	1347.	1034.	1172.	1001.	929.	790.	1230.	1173.	1117.	1082.	1076.	1070.	858.	843.	828.	709.	
	2844.	1297.	1007.	1138.	977.	912.	781.	1196.	1134.	1083.	1051.	1046.	1041.	844.	831.	818.	715.	
	2907.	1195.	946.	1058.	919.	860.	745.	1098.	1054.	1009.	962.	978.	973.	799.	787.	776.	720.	
MEAN	2592.	1394.	1033.	1179.	993.	934.	782.	1264.	1196.	1127.	1083.	1076.	1069.	860.	840.	821.	681.	
RANGE/RMS	695.	82.	41.	53.	41.	27.	16.	68.	58.	50.	46.	46.	46.	23.	20.	16.	29.	
MEAN	1802.	1298.	906.	1045.	862.	828.	677.	1161.	1084.	1007.	954.	946.	937.	761.	734.	708.	542.	
RANGE/RMS	2275.	214.	171.	191.	164.	134.	116.	204.	193.	182.	178.	177.	176.	124.	124.	124.	121.	

TABLE 3-11d
FTE-14 IRRADIATION TEMPERATURES FOR STACK 4

	MEAN POS		TEMPERATURE ENVELOPE (C)					TIME WEIGHTED AVERAGES (C)										COOLANT
	CORE HT (MM)	FUEL MAX	FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
	696.	733.	538.	589.	510.	494.	427.	662.	622.	582.	549.	545.	541.	464.	451.	437.	352.	
	759.	792.	562.	627.	533.	530.	448.	704.	660.	616.	579.	575.	570.	493.	475.	458.	356.	
	822.	847.	589.	665.	557.	559.	464.	750.	700.	651.	611.	605.	600.	518.	497.	476.	363.	
	885.	907.	624.	706.	549.	589.	485.	803.	748.	693.	648.	641.	635.	546.	522.	498.	372.	
	948.	972.	661.	752.	623.	623.	508.	862.	800.	738.	688.	681.	674.	576.	549.	523.	382.	
	1012.	1043.	702.	802.	660.	660.	534.	925.	856.	787.	733.	725.	717.	608.	579.	551.	393.	
	1075.	1111.	743.	852.	697.	696.	540.	987.	911.	835.	777.	768.	759.	640.	610.	579.	405.	
	1138.	1167.	776.	893.	728.	727.	583.	1037.	956.	874.	813.	804.	795.	669.	636.	604.	419.	
	1201.	1207.	799.	924.	750.	751.	601.	1071.	987.	902.	840.	830.	820.	690.	657.	624.	432.	
	1264.	1233.	813.	946.	763.	769.	613.	1091.	1005.	919.	856.	846.	836.	704.	671.	638.	446.	
	1327.	1228.	806.	942.	757.	765.	606.	1084.	998.	912.	851.	840.	830.	698.	665.	631.	461.	
MEAN	1012.	1022.	692.	791.	652.	651.	530.	907.	840.	773.	722.	715.	707.	600.	574.	547.	398.	
RANGE/RMS	695.	174.	98.	125.	90.	94.	65.	152.	136.	119.	108.	106.	104.	82.	76.	70.	36.	
	1486.	1293.	896.	1021.	852.	779.	636.	1179.	1088.	997.	944.	933.	923.	725.	691.	657.	475.	
	1549.	1337.	933.	1060.	888.	815.	670.	1220.	1127.	1035.	981.	971.	960.	759.	726.	693.	490.	
	1612.	1367.	952.	1086.	907.	838.	688.	1244.	1151.	1057.	1003.	992.	982.	779.	746.	713.	505.	
	1675.	1463.	1043.	1166.	998.	856.	703.	1339.	1244.	1150.	1099.	1088.	1077.	795.	762.	730.	520.	
	1738.	1513.	1086.	1238.	1044.	872.	716.	1386.	1291.	1196.	1147.	1137.	1125.	809.	776.	744.	534.	
	1802.	1486.	1056.	1209.	1012.	887.	728.	1355.	1260.	1166.	1116.	1105.	1095.	821.	790.	758.	549.	
	1865.	1458.	1025.	1179.	981.	901.	739.	1323.	1229.	1135.	1084.	1074.	1063.	833.	802.	771.	564.	
	1924.	1439.	1005.	1159.	961.	914.	749.	1301.	1208.	1115.	1063.	1053.	1042.	844.	813.	783.	578.	
	1991.	1385.	954.	1104.	911.	925.	759.	1246.	1154.	1062.	1009.	998.	988.	853.	823.	793.	591.	
	2054.	1380.	958.	1104.	914.	928.	765.	1243.	1152.	1062.	1010.	999.	989.	857.	828.	798.	605.	
	2117.	1355.	941.	1083.	899.	911.	752.	1222.	1131.	1041.	991.	981.	970.	841.	811.	782.	618.	
MEAN	1802.	1407.	987.	1130.	942.	875.	719.	1278.	1185.	1092.	1041.	1030.	1020.	811.	779.	747.	548.	
RANGE/RMS	694.	66.	57.	65.	57.	46.	39.	63.	62.	60.	62.	61.	61.	40.	42.	43.	45.	
	2276.	1358.	951.	1102.	913.	914.	752.	1224.	1136.	1053.	1008.	998.	989.	842.	815.	788.	630.	
	2339.	1425.	1015.	1174.	978.	947.	784.	1267.	1203.	1119.	1076.	1066.	1057.	873.	847.	821.	642.	
	2402.	1438.	1039.	1200.	1094.	951.	790.	1302.	1221.	1141.	1101.	1092.	1083.	876.	852.	828.	654.	
	2465.	1443.	1050.	1216.	1017.	951.	790.	1304.	1228.	1151.	1114.	1105.	1097.	874.	852.	829.	665.	
	2528.	1439.	1059.	1223.	1029.	949.	791.	1303.	1230.	1157.	1122.	1115.	1107.	873.	852.	831.	675.	
	2592.	1428.	1066.	1224.	1036.	946.	793.	1297.	1226.	1159.	1127.	1119.	1112.	871.	851.	832.	684.	
	2655.	1407.	1058.	1215.	1031.	942.	792.	1278.	1214.	1149.	1118.	1112.	1105.	868.	849.	831.	693.	
	2718.	1373.	1041.	1194.	1015.	936.	791.	1248.	1188.	1128.	1099.	1093.	1086.	863.	846.	830.	701.	
	2781.	1336.	1025.	1171.	1001.	929.	790.	1218.	1162.	1105.	1080.	1075.	1069.	858.	843.	828.	709.	
	2844.	1291.	1000.	1140.	977.	914.	782.	1177.	1126.	1075.	1052.	1046.	1041.	845.	832.	818.	715.	
	2907.	1194.	942.	1065.	922.	864.	747.	1094.	1049.	1005.	985.	981.	977.	801.	790.	779.	720.	
MEAN	2592.	1376.	1022.	1175.	993.	931.	782.	1248.	1181.	1113.	1080.	1073.	1066.	859.	839.	819.	681.	
RANGE/RMS	695.	74.	41.	50.	40.	25.	16.	63.	54.	47.	45.	45.	44.	21.	19.	18.	29.	
MEAN	1802.	1268.	900.	1032.	862.	819.	677.	1144.	1069.	993.	948.	939.	931.	756.	731.	705.	542.	
RANGE/RMS	2275.	209.	164.	192.	164.	136.	116.	197.	186.	176.	178.	177.	176.	125.	125.	125.	121.	

TABLE 3-11e
FTE-14 IRRADIATION TEMPERATURES FOR STACK 5

	MEAN POS		TEMPERATURE ENVELOPE (C)					TIME WEIGHTED AVERAGES (C)										COOLANT
	CORE HT (MM)	FUEL MAX	FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
	696.	731.	538.	586.	510.	493.	427.	659.	619.	579.	547.	543.	539.	463.	449.	436.	352.	
	759.	792.	562.	625.	534.	530.	448.	701.	657.	613.	577.	573.	568.	492.	474.	457.	356.	
	822.	847.	589.	661.	558.	559.	464.	746.	697.	648.	608.	603.	597.	516.	496.	475.	363.	
	885.	905.	624.	700.	589.	588.	485.	799.	744.	690.	644.	638.	632.	544.	520.	496.	372.	
	948.	971.	661.	745.	623.	620.	508.	857.	796.	735.	685.	678.	671.	573.	547.	521.	382.	
	1012.	1042.	702.	794.	661.	656.	534.	920.	852.	783.	729.	721.	713.	606.	577.	549.	393.	
	1075.	1110.	743.	844.	698.	691.	560.	982.	907.	831.	773.	764.	755.	638.	607.	577.	405.	
	1138.	1165.	777.	884.	728.	721.	583.	1032.	951.	871.	809.	800.	790.	665.	634.	602.	419.	
	1201.	1202.	800.	914.	751.	743.	601.	1066.	982.	898.	835.	825.	816.	686.	654.	622.	432.	
	1264.	1224.	814.	932.	764.	757.	614.	1086.	1000.	915.	852.	842.	832.	700.	668.	635.	446.	
	1327.	1212.	806.	926.	757.	752.	607.	1078.	992.	907.	845.	835.	825.	694.	661.	629.	461.	
MEAN	1012.	1018.	692.	783.	652.	646.	530.	902.	836.	770.	719.	711.	704.	598.	572.	545.	398.	
RANGE/RMS	695.	171.	96.	121.	90.	90.	65.	151.	135.	118.	107.	105.	103.	82.	76.	69.	36.	
	1486.	1368.	899.	1058.	837.	802.	628.	1204.	1113.	1021.	948.	937.	926.	728.	693.	659.	475.	
	1549.	1410.	936.	1094.	873.	835.	662.	1245.	1153.	1060.	985.	974.	963.	762.	728.	695.	490.	
	1612.	1438.	955.	1119.	892.	859.	681.	1270.	1176.	1082.	1007.	996.	985.	782.	749.	715.	505.	
	1675.	1527.	1043.	1217.	981.	877.	695.	1362.	1267.	1173.	1102.	1091.	1080.	798.	765.	731.	520.	
	1738.	1574.	1086.	1267.	1026.	893.	708.	1408.	1313.	1218.	1151.	1139.	1128.	812.	779.	746.	534.	
	1802.	1546.	1056.	1237.	996.	907.	720.	1377.	1282.	1188.	1119.	1108.	1097.	824.	792.	759.	549.	
	1865.	1516.	1025.	1205.	964.	919.	731.	1345.	1251.	1157.	1066.	1076.	1065.	836.	804.	772.	564.	
	1928.	1495.	1006.	1183.	946.	931.	742.	1322.	1229.	1136.	1065.	1054.	1044.	846.	815.	783.	578.	
	1991.	1438.	958.	1125.	897.	941.	751.	1267.	1175.	1084.	1010.	1000.	989.	854.	824.	793.	591.	
	2054.	1428.	961.	1122.	901.	942.	757.	1262.	1172.	1081.	1010.	1000.	989.	857.	827.	798.	605.	
	2117.	1399.	944.	1099.	885.	923.	744.	1238.	1149.	1059.	990.	980.	969.	840.	811.	781.	618.	
MEAN	1802.	1467.	988.	1157.	927.	893.	711.	1300.	1207.	1115.	1043.	1032.	1021.	813.	781.	748.	548.	
RANGE/RMS	694.	64.	56.	65.	56.	44.	39.	63.	61.	60.	62.	62.	61.	39.	41.	42.	45.	
	2276.	1410.	969.	1114.	899.	922.	745.	1254.	1169.	1084.	1005.	996.	986.	840.	813.	786.	630.	
	2339.	1472.	1031.	1183.	963.	954.	776.	1314.	1231.	1148.	1072.	1062.	1053.	871.	845.	819.	642.	
	2402.	1480.	1053.	1204.	990.	955.	783.	1325.	1246.	1167.	1096.	1087.	1078.	874.	849.	825.	654.	
	2445.	1479.	1062.	1220.	1002.	954.	783.	1324.	1249.	1174.	1108.	1100.	1091.	872.	849.	827.	665.	
	2428.	1470.	1070.	1224.	1014.	950.	785.	1320.	1249.	1178.	1115.	1108.	1100.	870.	849.	828.	675.	
	2592.	1453.	1075.	1223.	1022.	945.	787.	1317.	1244.	1177.	1119.	1111.	1104.	867.	848.	829.	684.	
	2655.	1427.	1067.	1212.	1017.	940.	787.	1291.	1226.	1165.	1110.	1103.	1096.	864.	846.	828.	693.	
	2718.	1389.	1048.	1188.	1001.	933.	786.	1258.	1200.	1141.	1090.	1064.	1076.	856.	842.	826.	701.	
	2781.	1347.	1033.	1163.	988.	924.	785.	1226.	1172.	1118.	1070.	1065.	1059.	853.	838.	824.	709.	
	2844.	1297.	1007.	1128.	966.	908.	778.	1183.	1134.	1084.	1041.	1036.	1031.	840.	827.	814.	715.	
	2907.	1195.	948.	1051.	911.	857.	743.	1098.	1055.	1012.	974.	970.	966.	796.	785.	774.	720.	
MEAN	2592.	1402.	1033.	1174.	979.	931.	776.	1264.	1198.	1132.	1073.	1066.	1058.	855.	836.	816.	681.	
RANGE/RMS	695.	86.	40.	53.	39.	28.	16.	69.	59.	50.	45.	45.	44.	22.	19.	18.	29.	
MEAN	1802.	1296.	904.	1038.	853.	824.	672.	1156.	1080.	1005.	945.	936.	928.	755.	729.	703.	542.	
RANGE/RMS	2275.	230.	166.	199.	158.	140.	113.	207.	196.	166.	178.	177.	176.	125.	125.	125.	121.	

TABLE 3-11f
FTE-14 IRRADIATION TEMPERATURES FOR STACK 6

	MEAN POS		TEMPERATURE ENVELOPE (C)					TIME WEIGHTED AVERAGES (C)										COOLANT
	CORE HT (MM)	FUEL MAX	FUEL MIN	RODY MEDIAN	RODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
	696.	730.	538.	585.	509.	493.	427.	659.	619.	579.	547.	543.	539.	463.	449.	436.	352.	
	759.	791.	562.	625.	533.	529.	448.	702.	658.	614.	577.	573.	568.	492.	475.	457.	356.	
	822.	846.	589.	661.	557.	558.	464.	747.	698.	649.	608.	603.	597.	517.	496.	475.	363.	
	885.	905.	624.	700.	588.	588.	484.	800.	745.	690.	645.	639.	632.	544.	520.	496.	372.	
	948.	970.	661.	744.	622.	620.	508.	858.	797.	736.	685.	678.	671.	574.	547.	521.	382.	
	1012.	1041.	702.	794.	659.	656.	533.	921.	853.	784.	729.	722.	714.	606.	577.	549.	393.	
	1075.	1109.	743.	843.	697.	691.	559.	983.	907.	832.	773.	764.	756.	638.	607.	577.	405.	
	1133.	1164.	776.	883.	728.	720.	582.	1033.	952.	871.	809.	800.	791.	665.	634.	602.	419.	
	1201.	1202.	800.	913.	750.	743.	601.	1067.	983.	899.	836.	826.	817.	687.	655.	622.	432.	
	1264.	1223.	813.	932.	763.	760.	613.	1087.	1001.	916.	852.	842.	832.	701.	668.	636.	446.	
	1327.	1213.	806.	929.	757.	757.	608.	1080.	994.	909.	847.	836.	826.	696.	663.	629.	461.	
MEAN	1012.	1018.	692.	783.	651.	647.	530.	903.	837.	771.	719.	711.	704.	598.	572.	546.	398.	
RANGE/RMS	695.	171.	98.	121.	90.	91.	65.	152.	135.	119.	108.	106.	103.	82.	76.	70.	36.	
	1486.	1332.	919.	1053.	850.	802.	635.	1198.	1109.	1019.	956.	945.	935.	733.	698.	663.	475.	
	1549.	1376.	957.	1092.	887.	837.	669.	1239.	1149.	1058.	993.	983.	972.	767.	733.	699.	490.	
	1612.	1406.	977.	1118.	906.	860.	688.	1264.	1172.	1080.	1015.	1005.	994.	788.	754.	720.	505.	
	1675.	1502.	1065.	1219.	996.	879.	702.	1358.	1265.	1172.	1111.	1101.	1090.	863.	770.	736.	520.	
	1738.	1552.	1108.	1271.	1042.	895.	715.	1404.	1311.	1218.	1160.	1149.	1138.	817.	784.	750.	534.	
	1802.	1524.	1077.	1241.	1010.	909.	727.	1373.	1280.	1187.	1128.	1117.	1106.	830.	796.	763.	549.	
	1865.	1493.	1046.	1209.	979.	922.	738.	1340.	1248.	1156.	1095.	1085.	1074.	841.	808.	776.	564.	
	1928.	1472.	1026.	1187.	959.	934.	749.	1317.	1226.	1135.	1073.	1063.	1053.	851.	820.	788.	578.	
	1991.	1416.	977.	1129.	909.	944.	758.	1261.	1171.	1082.	1016.	1008.	998.	860.	829.	798.	591.	
	2054.	1413.	960.	1131.	913.	949.	764.	1261.	1172.	1083.	1021.	1011.	1001.	866.	835.	805.	605.	
	2117.	1396.	967.	1118.	906.	938.	753.	1246.	1158.	1069.	1008.	997.	987.	854.	824.	793.	618.	
MEAN	1802.	1444.	1009.	1161.	941.	897.	716.	1296.	1206.	1115.	1053.	1042.	1032.	819.	786.	754.	548.	
RANGE/RMS	694.	66.	56.	65.	57.	46.	39.	62.	61.	60.	61.	61.	61.	41.	42.	43.	45.	
	2276.	1402.	976.	1123.	910.	928.	750.	1253.	1166.	1079.	1015.	1005.	995.	846.	819.	791.	630.	
	2339.	1457.	1039.	1194.	974.	960.	782.	1315.	1229.	1143.	1082.	1072.	1063.	877.	850.	824.	642.	
	2402.	1477.	1061.	1217.	1001.	961.	786.	1327.	1245.	1164.	1106.	1097.	1088.	879.	854.	830.	654.	
	2465.	1478.	1070.	1230.	1013.	960.	788.	1327.	1249.	1172.	1118.	1109.	1101.	877.	854.	831.	665.	
	2528.	1470.	1078.	1235.	1024.	956.	790.	1323.	1250.	1177.	1126.	1118.	1110.	875.	853.	832.	675.	
	2592.	1456.	1083.	1234.	1033.	951.	791.	1317.	1247.	1177.	1129.	1122.	1114.	873.	853.	833.	684.	
	2655.	1432.	1075.	1223.	1027.	946.	791.	1246.	1231.	1166.	1120.	1113.	1106.	869.	850.	832.	693.	
	2718.	1394.	1056.	1199.	1011.	939.	789.	1264.	1203.	1143.	1100.	1093.	1087.	863.	847.	830.	701.	
	2781.	1354.	1039.	1174.	998.	931.	789.	1233.	1177.	1121.	1080.	1074.	1069.	858.	843.	828.	709.	
	2844.	1308.	1013.	1142.	974.	916.	781.	1192.	1141.	1090.	1052.	1047.	1041.	846.	832.	819.	715.	
	2907.	1214.	956.	1069.	921.	868.	748.	1111.	1067.	1022.	988.	984.	979.	804.	793.	782.	720.	
MEAN	2592.	1405.	1041.	1186.	990.	938.	781.	1269.	1200.	1132.	1083.	1076.	1068.	861.	841.	821.	681.	
RANGE/RMS	695.	60.	40.	51.	40.	26.	15.	66.	56.	48.	45.	44.	44.	21.	18.	17.	29.	
MEAN	1802.	1269.	914.	1043.	861.	827.	676.	1156.	1081.	1006.	952.	943.	935.	759.	733.	707.	542.	
RANGE/RMS	2275.	224.	172.	203.	163.	142.	116.	206.	195.	185.	182.	181.	180.	127.	127.	127.	121.	

TABLE 3-12a
FTE-15 IRRADIATION TEMPERATURES FOR STACK 1

MEAN POS CORE HT (MM)	FUEL MAX	TEMPERATURE ENVELOPE (C)					TIME WEIGHTED AVERAGES (C)										SLV AVG	SLV MIN	COOLANT
		FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX						
696.	757.	520.	594.	486.	506.	391.	657.	619.	581.	536.	531.	526.	462.	442.	423.	346.			
759.	851.	558.	655.	520.	555.	421.	728.	683.	637.	582.	576.	570.	500.	476.	453.	352.			
822.	906.	580.	689.	540.	583.	434.	771.	721.	671.	610.	603.	596.	522.	496.	469.	358.			
885.	955.	605.	721.	563.	607.	445.	811.	757.	703.	636.	629.	621.	543.	514.	485.	366.			
948.	1014.	635.	760.	588.	637.	458.	858.	799.	740.	669.	660.	652.	563.	536.	505.	375.			
1012.	1098.	676.	817.	622.	679.	478.	925.	859.	794.	715.	705.	695.	601.	567.	532.	385.			
1075.	1163.	714.	877.	660.	721.	499.	994.	922.	849.	763.	753.	743.	636.	599.	562.	396.			
1138.	1246.	752.	922.	691.	755.	518.	1047.	969.	891.	801.	790.	779.	664.	625.	587.	408.			
1201.	1297.	778.	960.	715.	783.	534.	1088.	1006.	925.	832.	820.	809.	687.	648.	608.	420.			
1264.	1325.	793.	983.	728.	801.	541.	1111.	1028.	944.	850.	839.	827.	702.	662.	622.	433.			
1327.	1337.	797.	995.	732.	806.	533.	1121.	1035.	950.	857.	845.	833.	704.	662.	619.	446.			
MEAN	1012.	1088.	674.	814.	622.	676.	919.	854.	769.	714.	705.	696.	599.	566.	533.	390.			
RANGE/RMS	695.	145.	95.	134.	95.	100.	157.	141.	125.	109.	107.	104.	82.	75.	68.	32.			
1485.	1371.	865.	1061.	770.	805.	534.	1186.	1100.	1015.	934.	923.	912.	715.	675.	635.	460.			
1549.	1436.	912.	1113.	812.	846.	548.	1245.	1156.	1067.	983.	971.	960.	754.	715.	676.	473.			
1612.	1454.	931.	1134.	831.	865.	564.	1266.	1176.	1086.	1002.	990.	979.	772.	733.	694.	486.			
1675.	1537.	1003.	1223.	910.	879.	575.	1345.	1255.	1166.	1087.	1076.	1065.	785.	746.	708.	500.			
1738.	1578.	1042.	1270.	953.	892.	586.	1366.	1295.	1207.	1132.	1120.	1109.	797.	759.	721.	513.			
1802.	1551.	1070.	1238.	926.	903.	617.	1356.	1287.	1177.	1100.	1089.	1078.	808.	771.	733.	527.			
1865.	1522.	957.	1265.	900.	914.	629.	1326.	1236.	1147.	1068.	1057.	1045.	819.	782.	745.	540.			
1924.	1500.	985.	1181.	885.	924.	640.	1304.	1216.	1127.	1046.	1035.	1024.	828.	792.	756.	553.			
1991.	1444.	942.	1120.	839.	931.	648.	1251.	1163.	1074.	991.	979.	968.	836.	801.	766.	565.			
2054.	1431.	940.	1115.	836.	929.	649.	1245.	1158.	1070.	989.	978.	966.	837.	803.	768.	578.			
2117.	1360.	912.	1078.	811.	901.	627.	1203.	1119.	1036.	950.	947.	936.	812.	776.	744.	590.			
MEAN	1802.	1474.	959.	1158.	881.	890.	1293.	1195.	1107.	1026.	1015.	1004.	797.	760.	722.	526.			
RANGE/RMS	694.	66.	52.	66.	54.	37.	62.	60.	59.	61.	61.	61.	36.	36.	39.	41.			
2275.	1345.	929.	1104.	850.	905.	646.	1204.	1128.	1048.	982.	972.	962.	817.	785.	754.	601.			
2339.	1448.	993.	1173.	911.	934.	675.	1270.	1191.	1112.	1049.	1039.	1029.	846.	817.	787.	613.			
2402.	1459.	1018.	1197.	942.	935.	683.	1286.	1210.	1135.	1075.	1055.	1056.	849.	822.	794.	623.			
2465.	1459.	1027.	1209.	941.	932.	686.	1288.	1216.	1144.	1087.	1079.	1070.	847.	821.	795.	633.			
2528.	1448.	1035.	1213.	972.	926.	699.	1283.	1215.	1147.	1094.	1086.	1078.	845.	820.	796.	643.			
2592.	1427.	1037.	1207.	977.	917.	637.	1271.	1207.	1143.	1094.	1086.	1079.	840.	817.	795.	652.			
2655.	1397.	1026.	1191.	971.	909.	639.	1247.	1187.	1128.	1082.	1075.	1068.	834.	813.	793.	660.			
2718.	1369.	1004.	1167.	943.	900.	648.	1216.	1161.	1105.	1062.	1056.	1049.	826.	810.	792.	668.			
2781.	1319.	991.	1140.	933.	890.	685.	1184.	1133.	1081.	1041.	1035.	1030.	822.	805.	789.	674.			
2844.	1267.	959.	1103.	898.	871.	673.	1140.	1093.	1046.	1010.	1005.	1000.	807.	793.	776.	689.			
2907.	1187.	863.	1027.	822.	821.	632.	1056.	1015.	974.	943.	939.	935.	762.	751.	739.	685.			
MEAN	2592.	1376.	997.	1157.	926.	904.	1223.	1160.	1096.	1047.	1040.	1032.	827.	805.	783.	648.			
RANGE/RMS	695.	89.	52.	56.	49.	32.	70.	60.	52.	47.	47.	46.	24.	20.	16.	27.			
MEAN	1402.	1312.	874.	1044.	803.	823.	1142.	1070.	997.	929.	920.	911.	741.	710.	679.	521.			
RANGE/RMS	2275.	209.	158.	186.	146.	123.	191.	180.	170.	171.	170.	170.	114.	115.	116.	111.			

TABLE 3-12b
FTE-15 IRRADIATION TEMPERATURES FOR STACK 2

MEAN POS COPE HT (MM)	FUEL MAX	TEMPERATURE ENVELOPE (C)						TIME WEIGHTED AVERAGES (C)										SLV MIN	SLV AVG	SLV MAX	COOLANT
		FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN		FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX							
696.	756.	519.	596.	446.	506.	391.		655.	618.	580.	536.	531.	526.	462.	442.	423.	348.				
759.	850.	556.	655.	520.	555.	420.		727.	681.	636.	582.	576.	570.	500.	476.	453.	352.				
822.	906.	579.	690.	540.	593.	434.		770.	720.	669.	610.	603.	596.	523.	496.	469.	358.				
845.	954.	605.	721.	563.	608.	445.		810.	755.	701.	636.	629.	621.	543.	514.	465.	366.				
948.	1013.	634.	760.	587.	637.	458.		856.	798.	739.	666.	660.	651.	567.	536.	505.	375.				
1012.	1096.	675.	817.	621.	679.	477.		923.	853.	792.	714.	745.	690.	601.	567.	532.	385.				
1075.	1142.	710.	877.	659.	721.	499.		993.	920.	847.	763.	753.	743.	636.	599.	562.	396.				
1134.	1246.	751.	923.	690.	755.	518.		1046.	964.	890.	801.	790.	779.	664.	625.	587.	408.				
1201.	1296.	777.	960.	714.	784.	533.		1087.	1005.	923.	832.	820.	809.	687.	648.	608.	420.				
1244.	1324.	792.	981.	727.	801.	540.		1110.	1026.	942.	850.	839.	827.	702.	662.	622.	433.				
1327.	1336.	795.	995.	730.	806.	532.		1119.	1034.	948.	857.	845.	832.	704.	662.	619.	446.				
MEAN	1012.	1007.	673.	814.	621.	676.	477.	918.	853.	786.	714.	705.	696.	599.	566.	533.	390.				
RANGE/RMS	695.	195.	90.	134.	84.	100.	49.	157.	141.	125.	109.	107.	104.	82.	75.	68.	32.				
1456.	1374.	859.	1092.	797.	827.	551.		1190.	1102.	1013.	959.	948.	937.	733.	693.	653.	460.				
1549.	1415.	889.	1127.	826.	856.	575.		1225.	1137.	1046.	992.	980.	969.	760.	720.	681.	473.				
1612.	1434.	906.	1145.	843.	872.	589.		1245.	1153.	1062.	1008.	996.	985.	776.	736.	697.	486.				
1675.	1514.	941.	1234.	923.	884.	600.		1326.	1235.	1143.	1094.	1082.	1071.	789.	749.	710.	500.				
1738.	1556.	1020.	1280.	966.	898.	611.		1367.	1276.	1185.	1137.	1126.	1115.	800.	762.	723.	513.				
1802.	1526.	950.	1249.	939.	910.	622.		1334.	1245.	1154.	1105.	1094.	1083.	811.	774.	736.	527.				
1855.	1496.	972.	1216.	912.	920.	633.		1305.	1214.	1124.	1073.	1062.	1050.	822.	785.	747.	540.				
1924.	1473.	959.	1190.	895.	930.	644.		1283.	1192.	1102.	1051.	1040.	1028.	831.	795.	758.	553.				
1991.	1417.	914.	1129.	847.	938.	654.		1229.	1139.	1050.	996.	984.	973.	840.	804.	769.	565.				
2054.	1421.	924.	1136.	856.	946.	665.		1236.	1146.	1057.	1004.	993.	981.	849.	814.	780.	578.				
2117.	1430.	939.	1144.	871.	955.	675.		1247.	1157.	1067.	1015.	1003.	992.	859.	825.	790.	590.				
MEAN	1802.	1460.	942.	1174.	880.	903.	620.	1272.	1182.	1091.	1039.	1028.	1017.	806.	769.	731.	526.				
RANGE/RMS	694.	54.	40.	57.	49.	38.	37.	52.	52.	51.	54.	54.	54.	37.	39.	41.	41.				
2276.	1390.	935.	1134.	870.	926.	665.		1214.	1133.	1050.	1007.	997.	986.	837.	805.	773.	601.				
2339.	1431.	977.	1184.	922.	941.	681.		1257.	1177.	1097.	1056.	1046.	1036.	851.	821.	791.	613.				
2402.	1436.	1002.	1203.	950.	939.	686.		1269.	1193.	1117.	1078.	1069.	1060.	852.	823.	795.	623.				
2465.	1439.	1010.	1215.	947.	935.	689.		1272.	1199.	1127.	1090.	1082.	1073.	849.	823.	796.	633.				
2529.	1430.	1025.	1217.	978.	929.	690.		1269.	1200.	1131.	1097.	1089.	1081.	846.	821.	797.	643.				
2592.	1469.	1027.	1210.	962.	919.	601.		1257.	1193.	1124.	1096.	1088.	1081.	841.	818.	796.	652.				
2655.	1386.	1017.	1194.	974.	910.	691.		1234.	1174.	1114.	1083.	1076.	1070.	835.	814.	794.	660.				
2718.	1344.	996.	1169.	956.	901.	689.		1204.	1148.	1092.	1063.	1057.	1050.	829.	810.	792.	668.				
2781.	1396.	975.	1143.	936.	891.	687.		1174.	1122.	1070.	1042.	1037.	1031.	822.	806.	790.	674.				
2844.	1256.	945.	1115.	909.	880.	682.		1140.	1093.	1045.	1019.	1014.	1009.	814.	800.	786.	680.				
2907.	1220.	903.	1082.	871.	864.	671.		1103.	1060.	1016.	992.	988.	983.	802.	790.	778.	685.				
MEAN	2592.	1304.	984.	1170.	938.	913.	684.	1218.	1154.	1090.	1057.	1049.	1042.	834.	812.	790.	648.				
RANGE/RMS	695.	72.	39.	43.	36.	24.	8.	55.	45.	37.	35.	35.	34.	15.	10.	7.	27.				
MEAN	1802.	1305.	966.	1054.	813.	831.	594.	1136.	1063.	990.	937.	927.	918.	747.	716.	685.	521.				
RANGE/RMS	2275.	201.	152.	190.	150.	127.	94.	105.	174.	164.	174.	173.	173.	117.	116.	119.	111.				

TABLE 3-12c
FTE-15 IRRADIATION TEMPERATURES FOR STACK 3

MEAN POS CORE HT (MM)	FUEL MAX	TEMPERATURE ENVELOPE (C)						TIME WEIGHTED AVERAGES (C)										COOLANT
		FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN		FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
696.	752.	525.	592.	482.	503.	398.		655.	618.	581.	533.	528.	523.	460.	440.	421.	348.	
759.	842.	564.	649.	520.	551.	415.		724.	679.	635.	578.	572.	567.	498.	474.	451.	352.	
822.	853.	567.	661.	536.	577.	428.		764.	715.	666.	605.	598.	591.	519.	493.	466.	358.	
885.	938.	613.	710.	553.	600.	438.		802.	749.	686.	630.	622.	615.	539.	510.	482.	366.	
946.	992.	643.	747.	571.	628.	450.		847.	789.	732.	660.	652.	644.	562.	531.	501.	375.	
1012.	1071.	684.	801.	601.	667.	468.		911.	847.	783.	704.	695.	687.	594.	561.	528.	385.	
1078.	1151.	724.	856.	636.	706.	488.		977.	906.	836.	750.	741.	731.	627.	591.	556.	396.	
1138.	1219.	761.	899.	664.	732.	505.		1027.	952.	876.	787.	776.	766.	654.	617.	580.	406.	
1201.	1257.	788.	935.	686.	766.	519.		1066.	967.	908.	816.	805.	795.	677.	639.	601.	420.	
1264.	1284.	803.	957.	697.	782.	525.		1088.	1007.	926.	834.	823.	812.	690.	652.	613.	433.	
1327.	1292.	805.	965.	698.	785.	516.		1094.	1013.	930.	839.	827.	815.	691.	650.	610.	446.	
MEAN	1012.	1062.	682.	790.	664.	664.	467.	905.	842.	779.	703.	695.	686.	592.	560.	528.	390.	
RANGE/RMS	695.	182.	97.	124.	73.	94.	45.	149.	134.	119.	104.	102.	100.	78.	72.	65.	32.	
1426.	1404.	895.	1080.	789.	818.	543.		1201.	1114.	1028.	941.	930.	916.	720.	679.	638.	460.	
1549.	1471.	943.	1133.	833.	859.	578.		1261.	1171.	1081.	990.	979.	967.	759.	719.	679.	473.	
1612.	1493.	960.	1153.	852.	878.	594.		1282.	1191.	1100.	1009.	998.	986.	777.	737.	697.	486.	
1675.	1572.	1035.	1243.	933.	892.	605.		1361.	1270.	1179.	1095.	1084.	1072.	790.	751.	711.	500.	
1738.	1612.	1074.	1290.	976.	905.	616.		1401.	1310.	1220.	1139.	1128.	1116.	802.	763.	724.	513.	
1802.	1553.	1064.	1234.	944.	902.	634.		1357.	1277.	1157.	1104.	1093.	1082.	811.	773.	735.	527.	
1865.	1516.	1035.	1194.	940.	909.	647.		1334.	1246.	1156.	1071.	1060.	1048.	820.	783.	747.	540.	
1925.	1530.	952.	1198.	904.	935.	649.		1318.	1228.	1138.	1052.	1041.	1029.	832.	796.	759.	553.	
1991.	1472.	942.	1134.	852.	942.	657.		1264.	1174.	1065.	996.	984.	973.	840.	804.	768.	565.	
2054.	1455.	943.	1124.	850.	937.	656.		1254.	1167.	1079.	992.	980.	969.	839.	804.	769.	578.	
2117.	1397.	916.	1066.	820.	906.	629.		1209.	1125.	1041.	959.	947.	936.	812.	778.	743.	590.	
MEAN	1802.	1498.	982.	1171.	883.	884.	619.	1294.	1207.	1118.	1032.	1020.	1009.	800.	762.	725.	526.	
RANGE/RMS	694.	64.	59.	64.	50.	35.	35.	63.	61.	59.	61.	61.	61.	35.	37.	39.	41.	
2276.	1411.	930.	1114.	862.	912.	652.		1223.	1143.	1063.	985.	974.	964.	818.	787.	755.	601.	
2339.	1474.	993.	1162.	924.	940.	661.		1254.	1205.	1126.	1051.	1041.	1031.	848.	818.	788.	613.	
2402.	1433.	1017.	1205.	954.	941.	668.		1299.	1223.	1147.	1076.	1067.	1056.	851.	823.	794.	623.	
2465.	1479.	1025.	1216.	979.	936.	691.		1298.	1226.	1155.	1088.	1080.	1071.	848.	822.	796.	633.	
2528.	1466.	1032.	1218.	980.	929.	692.		1292.	1224.	1156.	1094.	1086.	1076.	845.	820.	796.	643.	
2592.	1442.	1034.	1211.	984.	920.	692.		1278.	1214.	1150.	1092.	1085.	1078.	839.	817.	795.	652.	
2655.	1410.	1024.	1194.	975.	910.	691.		1253.	1194.	1134.	1080.	1073.	1067.	833.	813.	793.	660.	
2718.	1371.	1000.	1169.	957.	901.	690.		1221.	1165.	1111.	1060.	1054.	1047.	827.	809.	791.	668.	
2781.	1328.	990.	1141.	934.	890.	685.		1188.	1137.	1085.	1038.	1033.	1027.	820.	804.	788.	674.	
2844.	1270.	953.	1100.	895.	869.	671.		1141.	1094.	1047.	1005.	1000.	995.	804.	790.	776.	680.	
2907.	1168.	861.	1020.	814.	616.	626.		1053.	1012.	972.	936.	932.	927.	757.	746.	735.	685.	
MEAN	2592.	1391.	980.	1161.	932.	906.	678.	1230.	1167.	1104.	1046.	1039.	1031.	826.	804.	782.	648.	
RANGE/RMS	695.	94.	51.	50.	52.	36.	20.	74.	64.	55.	49.	48.	47.	26.	22.	19.	27.	
MEAN	1302.	1317.	884.	1044.	805.	823.	588.	1144.	1072.	1000.	927.	918.	909.	739.	709.	678.	521.	
RANGE/RMS	2275.	223.	160.	194.	157.	128.	95.	199.	188.	177.	175.	175.	174.	117.	117.	118.	111.	

TABLE 3-12d
FTE-15 IRRADIATION TEMPERATURES FOR STACK 4

MEAN POS		TEMPERATURE ENVELOPE (C)						TIME WEIGHTED AVERAGES (C)											
CORE HT	FUEL	FUEL	BODY	BODY	SLV	SLV		FUEL	FUEL	FUEL	BODY	BODY	BODY	SLV	SLV	SLV			
(MM)	MAX	MIN	MEDIAN	MIN	MAX	MIN		MAX	AVG	MIN	MEDIAN	AVG	MIN	MAX	AVG	MIN	COOLANT		
696.	747.	523.	569.	483.	502.	387.		652.	615.	578.	532.	527.	523.	459.	440.	421.	348.		
759.	835.	561.	646.	520.	549.	416.		720.	675.	631.	577.	571.	565.	497.	473.	450.	352.		
822.	886.	564.	674.	539.	575.	429.		759.	711.	662.	603.	596.	589.	518.	492.	466.	358.		
885.	930.	610.	707.	553.	598.	439.		797.	744.	692.	628.	621.	613.	537.	509.	481.	366.		
948.	983.	640.	743.	572.	625.	450.		841.	784.	727.	659.	650.	642.	561.	530.	500.	375.		
1012.	1061.	681.	797.	602.	664.	468.		904.	841.	778.	702.	693.	685.	592.	559.	527.	385.		
1075.	1146.	724.	852.	637.	704.	488.		970.	900.	830.	748.	739.	729.	626.	590.	555.	396.		
1138.	1200.	757.	895.	655.	736.	505.		1024.	945.	870.	785.	775.	764.	653.	616.	579.	408.		
1201.	1246.	784.	931.	687.	763.	519.		1089.	981.	902.	814.	804.	793.	675.	638.	600.	420.		
1264.	1271.	799.	952.	698.	778.	526.		1081.	1000.	920.	832.	821.	810.	689.	651.	612.	433.		
1327.	1281.	801.	967.	700.	782.	518.		1089.	1006.	924.	836.	825.	813.	689.	649.	609.	446.		
MEAN	1012.	1053.	678.	796.	605.	468.		899.	837.	774.	701.	693.	684.	591.	559.	527.	390.		
RANGE/RMS	695.	100.	90.	125.	73.	45.		140.	133.	118.	104.	102.	99.	78.	72.	65.	32.		
1486.	1342.	848.	1044.	740.	796.	530.		1160.	1077.	994.	922.	911.	900.	707.	668.	630.	460.		
1549.	1406.	894.	1097.	802.	836.	564.		1218.	1131.	1045.	970.	959.	948.	747.	708.	670.	473.		
1612.	1428.	914.	1118.	820.	855.	579.		1239.	1151.	1053.	989.	977.	966.	764.	726.	688.	485.		
1675.	1508.	985.	1207.	899.	869.	591.		1314.	1231.	1143.	1074.	1063.	1052.	777.	739.	702.	500.		
1738.	1549.	1024.	1253.	941.	882.	602.		1359.	1271.	1184.	1117.	1107.	1096.	789.	752.	715.	513.		
1802.	1521.	1001.	1222.	915.	894.	613.		1320.	1242.	1155.	1086.	1075.	1064.	800.	764.	727.	527.		
1865.	1492.	979.	1190.	889.	905.	624.		1299.	1212.	1125.	1054.	1044.	1033.	811.	775.	739.	540.		
1928.	1470.	960.	1166.	873.	914.	635.		1274.	1191.	1105.	1033.	1023.	1012.	821.	786.	750.	553.		
1991.	1416.	924.	1106.	826.	922.	644.		1224.	1140.	1054.	979.	966.	957.	829.	795.	760.	565.		
2054.	1405.	924.	1102.	827.	921.	646.		1221.	1136.	1051.	978.	968.	957.	831.	797.	764.	576.		
2117.	1354.	898.	1069.	804.	895.	624.		1183.	1101.	1019.	950.	940.	929.	808.	774.	741.	590.		
MEAN	1802.	1445.	942.	1143.	851.	681.		1257.	1171.	1085.	1014.	1003.	992.	789.	753.	717.	526.		
RANGE/RMS	694.	65.	51.	65.	53.	37.		61.	59.	58.	60.	60.	60.	36.	38.	40.	41.		
2276.	1362.	916.	1090.	840.	896.	641.		1188.	1111.	1033.	971.	961.	951.	810.	779.	748.	601.		
2339.	1425.	979.	1159.	900.	925.	670.		1250.	1174.	1097.	1037.	1027.	1018.	839.	810.	782.	613.		
2402.	1436.	1004.	1183.	931.	925.	679.		1264.	1193.	1119.	1063.	1054.	1045.	843.	816.	789.	623.		
2465.	1436.	1014.	1196.	950.	924.	682.		1268.	1198.	1129.	1076.	1067.	1059.	841.	816.	790.	633.		
2528.	1427.	1022.	1194.	961.	919.	684.		1265.	1199.	1132.	1083.	1075.	1067.	839.	815.	791.	643.		
2592.	1406.	1024.	1193.	947.	911.	685.		1253.	1191.	1129.	1082.	1075.	1068.	834.	812.	791.	652.		
2655.	1377.	1014.	1178.	960.	902.	685.		1230.	1172.	1114.	1071.	1065.	1058.	829.	809.	789.	660.		
2718.	1341.	997.	1158.	943.	894.	684.		1200.	1146.	1092.	1052.	1046.	1040.	823.	805.	788.	668.		
2781.	1302.	979.	1129.	923.	884.	682.		1169.	1119.	1069.	1032.	1026.	1021.	817.	801.	785.	674.		
2844.	1250.	939.	1094.	869.	866.	670.		1127.	1081.	1035.	1001.	997.	992.	803.	789.	775.	680.		
2907.	1153.	855.	1018.	815.	819.	630.		1045.	1005.	965.	936.	932.	926.	759.	748.	737.	685.		
MEAN	2592.	1356.	977.	1145.	916.	697.		1206.	1144.	1083.	1037.	1030.	1022.	821.	800.	779.	648.		
RANGE/RMS	695.	84.	51.	54.	48.	31.		67.	58.	51.	46.	46.	45.	23.	20.	18.	27.		
MEAN	1802.	1285.	866.	1028.	791.	813.		1121.	1051.	981.	917.	908.	900.	734.	704.	674.	521.		
RANGE/RMS	2275.	207.	150.	184.	147.	123.		187.	177.	167.	170.	169.	169.	114.	115.	116.	111.		

TABLE 3-12e
FTE-15 IRRADIATION TEMPERATURES FOR STACK 5

MEAN POS		TEMPERATURE ENVELOPE (C)						TIME WEIGHTED AVERAGES (C)										COOLANT
CORE HT (MM)	FUEL MAX	FUEL MIN	RODY MEDIAN	RODY MIN	SLV MAX	SLV MIN	FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	RODY MIN	SLV MAX	SLV AVG	SLV MIN			
	696.	754.	523.	595.	486.	505.	389.	655.	617.	580.	535.	530.	526.	461.	442.	422.	348.	
	754.	846.	560.	653.	521.	554.	418.	725.	680.	635.	561.	575.	569.	500.	476.	452.	352.	
	822.	900.	583.	687.	542.	581.	431.	767.	717.	668.	608.	601.	595.	521.	495.	468.	358.	
	885.	947.	609.	716.	560.	605.	442.	804.	752.	698.	634.	627.	619.	542.	513.	484.	366.	
	946.	1003.	639.	756.	580.	634.	454.	852.	793.	735.	666.	657.	649.	565.	534.	503.	375.	
	1012.	1085.	680.	811.	612.	675.	473.	917.	852.	787.	711.	702.	693.	598.	565.	531.	385.	
	1075.	1159.	723.	870.	649.	717.	494.	966.	914.	841.	750.	746.	738.	633.	590.	560.	396.	
	1138.	1231.	756.	915.	672.	750.	512.	1037.	960.	883.	796.	785.	775.	660.	623.	585.	408.	
	1201.	1240.	783.	952.	701.	778.	527.	1078.	997.	916.	826.	815.	804.	684.	645.	606.	420.	
	1264.	1307.	798.	974.	713.	794.	533.	1100.	1017.	935.	844.	833.	821.	698.	658.	619.	433.	
	1327.	1317.	800.	984.	715.	799.	525.	1109.	1024.	939.	850.	838.	826.	698.	657.	616.	446.	
MEAN	1012.	1076.	678.	810.	614.	672.	472.	912.	848.	783.	710.	701.	692.	596.	564.	531.	390.	
RANGE/RMS	695.	139.	96.	131.	78.	98.	47.	154.	138.	122.	107.	105.	103.	80.	74.	67.	32.	
	1486.	1416.	863.	1095.	812.	829.	554.	1194.	1107.	1021.	945.	934.	922.	723.	681.	640.	460.	
	1549.	1482.	910.	1148.	857.	870.	589.	1253.	1163.	1073.	994.	982.	970.	763.	722.	681.	473.	
	1612.	1505.	926.	1169.	873.	890.	605.	1274.	1183.	1092.	1013.	1001.	990.	780.	740.	699.	486.	
	1675.	1584.	1005.	1258.	943.	903.	617.	1354.	1263.	1172.	1099.	1087.	1076.	793.	753.	713.	500.	
	1738.	1624.	1044.	1304.	953.	915.	628.	1393.	1303.	1212.	1142.	1131.	1119.	805.	765.	726.	513.	
	1802.	1594.	1012.	1270.	941.	926.	639.	1363.	1272.	1182.	1110.	1098.	1087.	815.	777.	738.	527.	
	1865.	1562.	960.	1236.	929.	935.	649.	1331.	1241.	1151.	1077.	1065.	1054.	825.	787.	749.	540.	
	1928.	1537.	960.	1210.	909.	944.	660.	1308.	1219.	1129.	1054.	1043.	1031.	834.	797.	760.	553.	
	1991.	1475.	911.	1145.	860.	950.	649.	1253.	1165.	1076.	994.	986.	974.	842.	805.	769.	565.	
	2054.	1461.	914.	1137.	863.	946.	647.	1245.	1158.	1071.	994.	983.	972.	842.	806.	771.	578.	
	2117.	1405.	869.	1098.	841.	916.	642.	1203.	1119.	1035.	963.	952.	940.	810.	781.	746.	590.	
MEAN	1802.	1513.	947.	1186.	855.	911.	629.	1268.	1199.	1110.	1035.	1024.	1012.	804.	765.	726.	526.	
RANGE/RMS	694.	69.	55.	68.	54.	35.	34.	63.	62.	60.	62.	62.	61.	35.	37.	39.	41.	
	2276.	1425.	917.	1119.	855.	916.	660.	1225.	1140.	1066.	984.	973.	963.	818.	787.	755.	601.	
	2339.	1485.	980.	1186.	915.	944.	688.	1265.	1207.	1129.	1049.	1039.	1029.	847.	817.	787.	613.	
	2402.	1491.	1004.	1202.	946.	943.	694.	1298.	1223.	1144.	1073.	1064.	1055.	849.	821.	793.	623.	
	2465.	1485.	1012.	1218.	959.	938.	696.	1296.	1225.	1154.	1085.	1076.	1067.	847.	820.	794.	633.	
	2528.	1471.	1020.	1218.	969.	930.	696.	1290.	1222.	1155.	1090.	1082.	1074.	843.	819.	794.	643.	
	2592.	1445.	1022.	1209.	975.	929.	696.	1274.	1211.	1149.	1068.	1060.	1073.	837.	815.	793.	652.	
	2655.	1410.	1012.	1191.	968.	909.	694.	1248.	1199.	1131.	1075.	1068.	1061.	831.	811.	791.	660.	
	2718.	1369.	994.	1165.	954.	900.	691.	1215.	1161.	1107.	1054.	1048.	1041.	825.	807.	789.	668.	
	2781.	1324.	950.	1134.	930.	888.	687.	1181.	1131.	1081.	1032.	1026.	1021.	818.	802.	786.	674.	
	2844.	1267.	956.	1094.	857.	868.	672.	1135.	1089.	1044.	1000.	995.	990.	802.	786.	775.	680.	
	2907.	1162.	800.	1017.	817.	815.	629.	1049.	1009.	970.	932.	928.	924.	757.	746.	735.	685.	
MEAN	2542.	1394.	970.	1160.	927.	908.	682.	1227.	1165.	1103.	1042.	1035.	1027.	825.	803.	781.	648.	
RANGE/RMS	695.	101.	40.	60.	49.	37.	20.	75.	65.	56.	48.	48.	47.	26.	21.	18.	27.	
MEAN	1302.	1326.	888.	1053.	812.	830.	504.	1142.	1071.	999.	929.	920.	911.	742.	711.	680.	521.	
RANGE/RMS	2275.	226.	152.	195.	153.	129.	96.	194.	185.	175.	173.	172.	171.	116.	116.	117.	111.	

TABLE 3-12f
FTE-15 IRRADIATION TEMPERATURES FOR STACK 6

MEAN POS COPE HT (MM)	TEMPERATURE ENVELOPE (C)							TIME WEIGHTED AVERAGES (C)										COOLANT
	FUEL MAX	FUEL MIN	BODY MEDIAN	BODY MIN	SLV MAX	SLV MIN		FUEL MAX	FUEL AVG	FUEL MIN	BODY MEDIAN	BODY AVG	BODY MIN	SLV MAX	SLV AVG	SLV MIN		
696.	749.	525.	589.	441.	502.	387.		653.	616.	579.	532.	527.	522.	459.	440.	421.	348.	
759.	837.	564.	645.	520.	549.	415.		721.	677.	633.	577.	571.	565.	496.	473.	450.	352.	
822.	887.	580.	677.	537.	574.	428.		761.	712.	664.	602.	596.	589.	517.	491.	465.	358.	
885.	933.	612.	707.	551.	597.	438.		799.	746.	694.	628.	620.	613.	537.	509.	481.	366.	
948.	987.	642.	743.	576.	625.	450.		843.	787.	730.	658.	650.	642.	560.	530.	500.	375.	
1012.	1066.	684.	797.	600.	664.	467.		908.	844.	781.	702.	693.	684.	592.	559.	527.	385.	
1075.	1146.	720.	853.	635.	705.	487.		974.	904.	834.	748.	739.	729.	626.	590.	555.	396.	
1138.	1205.	761.	895.	663.	736.	504.		1024.	949.	874.	784.	774.	764.	652.	616.	579.	408.	
1201.	1252.	787.	931.	685.	763.	518.		1063.	985.	906.	814.	803.	793.	675.	637.	600.	420.	
1264.	1279.	803.	954.	696.	780.	525.		1084.	1006.	925.	832.	821.	810.	690.	651.	613.	433.	
1327.	1290.	806.	964.	699.	785.	514.		1095.	1013.	930.	836.	827.	815.	691.	651.	611.	446.	
MEAN	1012.	1057.	682.	794.	603.	467.		903.	840.	777.	701.	693.	684.	591.	559.	527.	390.	
RANGE/RMS	695.	182.	97.	126.	73.	94.		150.	134.	119.	104.	102.	100.	78.	72.	65.	32.	
1446.	1394.	885.	1088.	803.	824.	549.		1197.	1109.	1022.	946.	934.	923.	723.	682.	640.	460.	
1549.	1460.	933.	1141.	848.	865.	584.		1257.	1165.	1074.	995.	984.	972.	763.	722.	681.	473.	
1612.	1482.	952.	1162.	866.	884.	600.		1277.	1185.	1093.	1014.	1002.	990.	780.	740.	700.	486.	
1675.	1562.	1027.	1252.	948.	897.	611.		1354.	1265.	1173.	1100.	1088.	1077.	793.	753.	713.	500.	
1738.	1603.	1067.	1298.	992.	910.	622.		1397.	1305.	1214.	1144.	1132.	1121.	805.	766.	726.	513.	
1802.	1573.	1042.	1264.	964.	921.	633.		1364.	1275.	1184.	1112.	1100.	1089.	816.	777.	739.	527.	
1865.	1542.	1017.	1230.	935.	931.	644.		1335.	1243.	1152.	1079.	1067.	1055.	826.	786.	750.	540.	
1928.	1517.	1000.	1204.	917.	939.	654.		1312.	1221.	1131.	1056.	1044.	1033.	835.	798.	761.	553.	
1991.	1460.	951.	1142.	865.	947.	664.		1258.	1168.	1078.	1000.	988.	977.	843.	807.	771.	565.	
2054.	1453.	953.	1147.	870.	949.	670.		1256.	1167.	1078.	1001.	990.	979.	847.	812.	776.	578.	
2117.	1415.	929.	1115.	853.	929.	657.		1225.	1138.	1052.	979.	967.	956.	829.	794.	759.	590.	
MEAN	1802.	1497.	978.	1185.	897.	626.		1294.	1204.	1114.	1039.	1027.	1016.	805.	767.	729.	526.	
RANGE/RMS	694.	65.	54.	65.	65.	37.		61.	59.	58.	60.	60.	60.	36.	38.	40.	41.	
2276.	1341.	903.	1104.	855.	906.	649.		1170.	1091.	1011.	979.	969.	959.	815.	783.	752.	601.	
2339.	1405.	961.	1172.	915.	934.	677.		1232.	1154.	1076.	1044.	1035.	1025.	844.	814.	785.	613.	
2402.	1417.	986.	1195.	945.	934.	685.		1240.	1174.	1099.	1070.	1061.	1052.	847.	819.	792.	623.	
2465.	1418.	1003.	1204.	962.	931.	687.		1252.	1181.	1110.	1082.	1074.	1065.	845.	819.	793.	633.	
2528.	1408.	1011.	1208.	972.	924.	689.		1240.	1182.	1115.	1063.	1080.	1072.	841.	817.	794.	643.	
2592.	1389.	1013.	1202.	976.	915.	689.		1238.	1175.	1112.	1087.	1080.	1072.	836.	814.	792.	652.	
2655.	1351.	1004.	1185.	960.	906.	688.		1216.	1157.	1099.	1075.	1068.	1062.	831.	811.	791.	660.	
2718.	1325.	984.	1160.	953.	897.	687.		1197.	1132.	1078.	1055.	1049.	1043.	825.	807.	789.	668.	
2781.	1287.	962.	1134.	929.	867.	684.		1157.	1107.	1056.	1035.	1029.	1023.	819.	803.	787.	674.	
2844.	1241.	927.	1105.	897.	871.	675.		1119.	1072.	1025.	1006.	1001.	996.	806.	792.	778.	680.	
2907.	1153.	654.	1030.	829.	825.	640.		1042.	1002.	962.	944.	940.	936.	766.	754.	743.	685.	
MEAN	2592.	1341.	965.	1154.	927.	677.		1192.	1130.	1067.	1042.	1035.	1026.	825.	803.	781.	648.	
RANGE/RMS	695.	61.	49.	54.	47.	31.		63.	54.	47.	45.	45.	44.	23.	19.	17.	27.	
MEAN	1802.	1298.	875.	1045.	809.	624.		1130.	1058.	986.	927.	918.	909.	740.	710.	679.	521.	
RANGE/RMS	2275.	210.	153.	197.	158.	130.		194.	181.	170.	176.	175.	175.	118.	118.	118.	111.	

TABLE 3-13
FTE-14 AND FTE-15 PEAK FUEL TEMPERATURE SUMMARY FOR EACH FUEL BODY (°C)

Fuel Body	Fuel Rod	Fuel Hole 1		Fuel Hole 2		Fuel Hole 3		Fuel Hole 4		Fuel Hole 5		Fuel Hole 6	
		Max.	Time & Vol. Average	Max.	Time & Vol. Average	Max.	Time & Vol. Average	Max.	Time & Vol. Average	Max.	Time & Vol. Average	Max.	Time & Vol. Average
FTE-14													
1	10	1278	1018	1278	1018	1278	1018	1233	1005	1224	1000	1223	1001
2	5	1534	1313	1506	1289	1555	1317	1513	1291	1574	1313	1552	1311
3	4 or 5	1463	1248	1457	1250	1467	1247	1443	1230	1480	1249	1478	1250
FTE-15													
1	11	1337	1035	1336	1034	1292	1013	1281	1006	1317	1024	1290	1013
2	5	1578	1296	1556	1276	1612	1310	1549	1271	1624	1303	1603	1305
3	3, 4, or 5	1459	1216	1439	1200	1479	1226	1436	1199	1491	1225	1418	1182

TABLE 3-14
FTE-14 AND FTE-15 TEMPERATURE SUMMARY

Parameter (Time Frame)	Calculated Temperatures (°C)			Fuel Body Sequence Mean/Gradient
	Maximum or Minimum	Hole Average	RMS Axial	
FTE-14 Fuel Hole 5				
Average fuel temperature (time averaged)	1313 (max.)	1080	±196	231/123
Maximum fuel temperature (peak in time)	1574 ^(a) (max.)	1296	±230	231/132
Minimum fuel temperature (minimum in time)	538 (min.)	904	±166	321/123
FTE-15 Fuel Hole 5				
Average fuel temperature (time averaged)	1303 (max.)	1071	±185	231/132
Maximum fuel temperature (peak in time)	1624 ^(a) (max.)	1328	±226	231/132
Minimum fuel temperature (minimum in time)	523 (min.)	868	±152	321/123

(a) These fuel temperatures are considerably higher than the nominal maximum fuel temperature of 1443°C (Ref. 3-13) which these elements were designed to produce.

TABLE 3-15a
FTE-14 THERMOCOUPLE DATA

TREVES SIMULATION										COMPARISON OF TREVES AND CORRECTED THERMOCOUPLE TEMP.					
REAL DAYS		TIME	EFPD		TEMP. ERROR		N	W/RE MEASURED TEMP.		W/RE CORRECTED TEMP.		RECAL ERROR EC*	DIFF TA-TC	ERROR ED*	
FROM	TO	W	FROM	TO	TA	EA*		MEAN TR	TRANS. SB	MEAN TC	TRANS SC				
413.75	555.68	141.93	385.44	499.59	1187.0	.0	20	1178.0	74.1	1197.7	79.1	.37	-10.7	.37	
555.68	628.37	72.69	499.59	564.07	1370.0	.0	10	1315.7	47.0	1384.1	85.7	1.48	-14.1	1.48	
628.37	678.00	49.63	564.07	610.25	1426.0	.0	8	1304.7	7.1	1404.1	6.9	2.57	21.9	2.57	
678.00	776.73	98.73	610.25	701.23	1371.0	.0	14	1226.1	11.5	1359.4	20.8	2.57	11.6	2.57	
GRAND TOTAL															
W,N,TW,SW,EW		362.98			1306.4	.0	52	1236.0	77.5	1307.2	105.3	88.85	-9.9	13.7	
SW (1 SIGMA)					97.3			57.1		88.8			13.7		

TABLE 3-15b
FTE-15 THERMOCOUPLE DATA

TREVER SIMULATION							THERMOCOUPLE DATA			COMPARISON OF TREVER AND MEASURED THERMOCOUPLE TEMP.	
REAL DAYS FROM	TO	TIME W	EFPD		TEMP. TA	ERROR EA*	C/A MEASURED TEMPERATURE			DIFF TA-TB	ERROR ED*
			FROM	TO			N	MEAN TB	TRANS. SB		
413.75	555.68	141.93	385.44	499.99	706.0	.0	20	716.0	48.8	-10.0	.0
555.68	628.37	72.69	499.59	564.07	796.0	.0	9	834.0	7.5	-38.0	.0
628.37	678.00	49.63	564.07	610.25	849.0	.0	8	813.0	4.8	36.0	.0
678.00	776.73	98.73	610.25	701.23	819.0	.0	13	783.1	4.5	35.9	.0
GRAND TOTAL											
W,N,TW,SW,EW		363.0			774.3	.0	50	771.1	56.7	3.2	.0
SW (1 SIGMA)					56.8			47.5		29.1	

TABLE 3-16a
FTE-14 AVERAGE PREDICTED NUCLIDE WEIGHTS FOR FUEL RODS, SPINE, AND TOTAL ELEMENT

Nuclide	Atomic Weight (g/mole)	Nuclide Weight Per Fuel Rod (g)																								Nuclide Weight (g)			
		Body 1						Body 2						Body 3						Bodies 2 and 3						Spine		Total Element	
		Holes 1,2,3		Holes 4,5,6		Hole 2		Hole 4		Hole 6		Hole 2		Hole 4		Hole 6		Hole 1		Hole 3		Hole 5		BOL	EOL	BOL	EOL	BOL ^(a)	EOL ^(b)
		BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL						
Th-232	232.038	13.280	13.051	10.680	10.496	7.880	7.744	6.532	6.419	10.310	10.132	10.310	10.132	6.530	6.417	8.640	8.491	6.590	6.476	8.670	8.520	11.050	10.859	2.50	2.46	1924.22	1890.98		
Pa-233	233.000	--	0.025	--	0.020	--	0.015	--	0.012	--	0.020	--	0.020	--	0.012	--	0.017	--	0.013	--	0.017	--	0.021	--	<<0.01	--	3.67		
U-233	233.040	--	0.165	--	0.133	--	0.098	--	0.081	--	0.128	--	0.128	--	0.081	--	0.108	--	0.082	--	0.108	--	0.138	--	0.03	--	23.98		
U-234	234.041	--	0.007	--	0.006	--	0.004	--	0.004	--	0.006	--	0.006	--	0.004	--	0.005	--	0.004	--	0.005	--	0.006	--	<<0.01	--	1.07		
U-235	235.044	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.01	--	0.06		
Th _o /Th _i	232.038/ 232.054	13.280	13.249	10.680	10.655	7.880	7.862	6.532	6.517	10.310	10.286	10.310	10.286	6.530	6.515	8.640	8.620	6.590	6.575	8.670	8.650	11.050	11.024	2.50	2.49	1924.22	1919.76		
U-234	234.041	0.014	0.012	0.014	0.012	0.015	0.013	0.014	0.012	0.014	0.012	0.014	0.012	0.015	0.013	0.014	0.012	0.015	0.013	0.014	0.012	0.014	0.012	0.02	0.01	2.88	2.47		
U-235	235.044	0.897	0.659	0.897	0.659	0.924	0.679	0.896	0.658	0.897	0.659	0.897	0.659	0.924	0.679	0.897	0.659	0.924	0.679	0.897	0.659	0.855	0.628	1.02	0.75	178.81	131.36		
U-236	236.046	0.005	0.053	0.005	0.053	0.005	0.055	0.005	0.053	0.005	0.053	0.005	0.053	0.005	0.055	0.005	0.053	0.005	0.055	0.005	0.053	0.005	0.051	0.01	0.06	0.96	10.62		
U-238	238.051	0.046	0.044	0.046	0.044	0.047	0.045	0.046	0.044	0.046	0.044	0.046	0.044	0.047	0.045	0.046	0.044	0.047	0.045	0.046	0.044	0.044	0.042	0.05	0.05	9.19	8.71		
Np-237	237.048	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.002	--	0.01	--	0.35		
Np-239	239.000	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	0.01	--	0.005		
Pu-238	238.050	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	--	--	0.03		
Pu-239	239.052	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	--	--	0.22		
Pu-240	240.054	--	<<0.001	--	<<0.001	--	<<0.001	--	0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	--	--	0.05		
Pu-241	241.059	--	<<0.001	--	<<0.001	--	<<0.001	--	0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	0.001	--	<<0.001	--	<<0.001	--	<<0.001	--	--	--	0.03		
U _o /U _i	235.178/ 235.281	0.962	0.772	0.962	0.772	0.991	0.795	0.961	0.771	0.962	0.772	0.962	0.772	0.991	0.795	0.962	0.772	0.991	0.795	0.962	0.772	0.917	0.735	1.09	0.87	191.84	153.87		
X _o /X _i	232.322/ 232.293	14.242	14.021	11.642	11.427	8.871	8.657	7.493	7.288	11.272	11.058	11.272	11.058	7.521	7.310	9.602	9.392	7.581	7.370	9.632	9.421	11.967	11.760	3.59	3.37	2116.06	2073.63		

(a) BOL data for the element from master FMB data retrieval center.

(b) BOL values from physics (GAUGE) calculations.

TABLE 3-16b
FTE-15 PREDICTED AVERAGE NUCLIDE WEIGHTS FOR FUEL RODS, SPINE, AND TOTAL ELEMENT

Nuclide	Atomic Weight (g/mole)	Nuclide Weight Per Fuel Rod (g)																								Nuclide Weight (g)				
		Body 1						Bodies 2 and 3						Body 2						Body 3										
		Holes 1 and 2		Holes 3, 4, 6		Hole 5		Hole 1		Hole 4		Hole 5		Hole 2		Hole 3		Hole 6		Hole 2		Hole 3		Hole 6		Spine		Total Element		
		BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL	EOL	BOL ^(a)	EOL ^(b)	
Th-232	232.03807	13.280	12.916	10.630	10.338	12.180	11.846	6.590	6.409	6.532	6.353	11.050	10.747	7.890	7.674	8.650	8.413	10.310	10.027	7.880	7.664	8.670	8.432	8.640	8.403	2.50	2.43	1883.65	1831.98	
Pa-233	233.000	--	0.017	--	0.013	--	0.015	--	0.008	--	0.008	--	0.014	--	0.010	--	0.011	--	0.013	--	0.010	--	0.011	--	0.011	--	<0.01	--	2.36	
U-233	233.03965	--	0.242	--	0.193	--	0.222	--	0.120	--	0.119	--	0.201	--	0.143	--	0.157	--	0.188	--	0.143	--	0.158	--	0.157	--	0.05	--	34.26	
U-234	234.04098	--	0.016	--	0.013	--	0.015	--	0.008	--	0.008	--	0.013	--	0.010	--	0.011	--	0.013	--	0.010	--	0.011	--	0.011	--	<0.01	--	2.30	
U-235	235.04394	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	<0.01	--	0.18	
Th ₂₃₀ /Th ₂₃₂	232.038/232.060	13.280	13.191	10.630	10.559	12.180	12.099	6.590	6.546	6.532	6.488	11.050	10.976	7.890	7.837	8.650	8.592	10.310	10.241	7.880	7.827	8.670	8.612	8.640	8.582	2.50	2.48	1883.65	1871.08	
U-234	234.04098	0.014	0.011	0.014	0.011	0.014	0.011	0.015	0.012	0.014	0.011	0.014	0.011	0.015	0.012	0.014	0.011	0.014	0.011	0.015	0.012	0.014	0.011	0.014	0.011	0.02	0.01	2.88	2.25	
U-235	235.04394	0.897	0.523	0.897	0.523	0.897	0.523	0.924	0.539	0.896	0.523	0.855	0.499	0.924	0.539	0.897	0.523	0.897	0.523	0.924	0.539	0.897	0.523	0.897	0.523	1.02	0.59	178.80	104.34	
U-236	236.04558	0.005	0.078	0.005	0.078	0.005	0.078	0.005	0.080	0.005	0.078	0.005	0.074	0.005	0.080	0.005	0.078	0.005	0.078	0.005	0.080	0.005	0.078	0.005	0.078	0.01	0.09	0.96	15.52	
U-238	238.05082	0.046	0.042	0.046	0.042	0.046	0.042	0.047	0.044	0.046	0.042	0.044	0.040	0.047	0.044	0.046	0.042	0.046	0.042	0.046	0.042	0.046	0.042	0.046	0.042	0.05	0.05	9.19	8.46	
Np-237	237.04819	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	0.004	--	<0.01	--	0.73	
Np-239	239.00000	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.01	--	0.002	
Pu-238	238.04958	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	<0.01	--	0.12	
Pu-239	239.05218	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	0.001	--	<0.01	--	0.21	
Pu-240	240.05383	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	0.001	--	<0.01	--	0.06	
Pu-241	241.05877	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	<0.001	--	0.001	--	<0.01	--	0.08	
U ₂₃₅ /U ₂₃₈	235.178/235.364	0.962	0.661	0.962	0.661	0.962	0.661	0.991	0.681	0.961	0.660	0.917	0.630	0.991	0.681	0.962	0.661	0.962	0.661	0.991	0.681	0.962	0.661	0.962	0.661	1.09	<0.75	191.83	131.77	
X ₂₃₅ /X ₂₃₈	232.328/232.278	14.242	13.852	11.592	11.220	13.142	12.760	7.581	7.227	7.493	7.149	11.967	11.606	8.881	8.518	9.612	9.253	11.272	10.902	8.871	8.508	9.632	9.273	9.602	9.243	3.59	3.23	2075.48	2002.85	

(a) BOL data for the element from master FME data retrieval center.

(b) EOL values from physics (GAUGE) calculations.

TABLE 3-17a
FTE-14 AND FTE-15 MEASURED AND CALCULATED ISOTOPIC URANIUM CONCENTRATION FOR FISSILE PARTICLES

Test Element I.D.	Spine and Core Location (mm)	Particle I.D.	Analysis Procedure	EOL Relative Atomic Concentration (At. %)									
				U-233		U-234		U-235		U-236		U-238	
				N ₃	S ₃ (1σ)	N ₄	S ₄ (1σ)	N ₅	S ₅ (1σ)	N ₆	S ₆ (1σ)	N ₈	S ₈ (1σ)
FTE-14	TS 2-6 (1164)	C2052	Calculated	--	--	1.11	--	83.56	--	8.34	--	7.01	--
			Mass. Spec.	--	--	1.052	+0.005	84.33	+0.02	7.609	+0.017	7.007	+0.019
			(Calc/meas - 1) (± 1σ)	--	--	0.055	+0.005	-0.0091	+0.00024	0.096	+0.0024	0.0004	+0.0027
FTE-14	TS 4-6 (1642)	C2051	Calculated	--	--	0.82	--	83.42	--	8.73	--	7.081	--
			Mass. Spec.	--	--	0.7356	+0.0042	83.570	+0.025	8.596	+0.031	7.099	+0.017
			(Calc/meas - 1) (± 1σ)	--	--	0.1147	+0.0064	-0.0018	+0.0003	0.0156	+0.0037	-0.0097	+0.0024
FTE-14	TS 7-3 (2377)	C2053	Calculated	--	--	0.66	--	85.80	--	6.53	--	7.01	--
			Mass. Spec.	--	--	0.671	+0.009	84.71	+0.05	7.39	+0.025	7.24	+0.03
			(Calc/meas - 1) (± 1σ)	--	--	-0.0164	+0.0132	0.0129	+0.0006	-0.116	+0.0030	-0.032	+0.004
	$\bar{x}$, $\bar{Sx}$		(Calc/meas - 1)	--	--	0.051	+0.0089	0.0007	+0.0004	-0.0015	+0.0031	-0.014	+0.0031
	RMS, Sx			--	--	+0.054	+0.0052	+0.0091	+0.0002	+0.0874	+0.0018	+0.014	+0.0018
FTE-15	TS 2-6 (1166)	C1859	Calculated	--	--	1.26	--	76.28	--	14.32	--	8.14	--
			Mass. Spec.	--	--	1.122	+0.011	78.23	+0.10	12.71	+0.06	7.94	+0.06
			(Calc/meas - 1) (± 1σ)	--	--	0.123	+0.011	-0.0249	+0.0012	0.127	+0.0053	0.0251	+0.0077
FTE-15	TS 5-6 (1854)	C1857	Calculated	--	--	0.95	--	75.98	--	14.90	--	8.18	--
			Mass. Spec.	0.00203	+0.00024	0.824	+0.007	75.64	+0.07	15.20	+0.07	8.34	+0.07
			(Calc/meas - 1) (± 1σ)	--	--	0.153	+0.010	0.0045	+0.0009	-0.0197	+0.0045	-0.0192	+0.008
FTE-15	TS 8-3 (2424)	C1860	Calculated	--	--	0.73	--	80.53	--	11.16	--	7.58	--
			Mass. Spec.	0.0022	+0.0005	0.788	+0.004	79.07	+0.012	12.32	+0.07	7.82	+0.06
			(Calc/meas - 1) (± 1σ)	--	--	-0.0736	+0.0047	0.0185	+0.0015	-0.0942	+0.0051	-0.031	+0.007
	$\bar{x}$, $\bar{Sx}$		(Calc/meas - 1)	--	--	0.067	+0.0090	-0.0006	+0.0012	+0.0044	+0.0050	-0.008	+0.0076
	RMS, Sx			--	--	+0.100	+0.0052	+0.0181	+0.0007	+0.0919	+0.0029	+0.024	+0.0044
FTE-14 and 15	$\bar{x}$, $\bar{Sx}$		(Calc/meas - 1)	--	--	0.059	+0.0090	0.00002	+0.00091	0.0015	+0.0041	-0.011	+0.0058
	RMS, Sx			--	--	+0.081	+0.0037	+0.0143	+0.00037	+0.090	+0.0017	+0.020	+0.0024

TABLE 3-17b
FTE-14 AND FTE-15 MEASURED AND CALCULATED ISOTOPIC URANIUM CONCENTRATION FOR FERTILE PARTICLES

Test Element I.D.	Spine and Core Location (mm)	Particle I.D.	Analysis Procedure	EOL Relative Atomic Concentration (At. %)									
				U-233		U-234		U-235		U-236		U-238	
				N ₃	S ₃ (1 σ)	N ₄	S ₄ (1 σ)	N ₅	S ₅ (1 σ)	N ₆	S ₆ (1 σ)	N ₈	S ₈ (1 σ)
FTE-14	TS 2-5 (1164)	C1570	Calculated Mass. Spec. (Calc/meas - 1)($\pm$ 1 σ)	96.54 95.63 $\pm$ 0.0095	-- $\pm$ 0.013 $\pm$ 0.00014	3.30 4.10 -0.195	-- $\pm$ 0.009 $\pm$ 0.0018	0.16 0.225 -0.289	-- $\pm$ 0.025 $\pm$ 0.079	-- 0.01 --	-- $\pm$ 0.00024 --	-- -- --	-- -- --
FTE-14	TS 7-2 (2377)	C1573	Calculated Mass. Spec. (Calc/meas - 1)($\pm$ 1 σ)	96.11 95.389 $\pm$ 0.0076	-- $\pm$ 0.019 $\pm$ 0.0002	3.69 4.212 -0.124	-- $\pm$ 0.0149 $\pm$ 0.0031	0.20 0.302 -0.338	-- $\pm$ 0.0012 $\pm$ 0.0026	-- 0.01 --	-- $\pm$ 0.040 --	-- -- --	-- -- --
	$\bar{x}$, $\bar{Sx}$ RMS, Sx		(Calc/meas - 1)	0.0086 $\pm$ 0.0010	$\pm$ 0.0002 $\pm$ 0.0001	-0.160 $\pm$ 0.036	$\pm$ 0.0025 $\pm$ 0.0018	-0.314 $\pm$ 0.025	$\pm$ 0.056 $\pm$ 0.040	-- --	-- --	-- --	-- --
FTE-15	TS 2-5 (1166)	C1858	Calculated Mass. Spec. (Calc/meas - 1)($\pm$ 1 σ)	93.78 92.786 $\pm$ 0.0107	-- $\pm$ 0.115 $\pm$ 0.0013	5.84 5.752 $\pm$ 0.0153	-- $\pm$ 0.014 $\pm$ 0.0025	0.39 0.820 -0.524	-- $\pm$ 0.089 $\pm$ 0.0516	-- 0.065 --	-- $\pm$ 0.014 --	-- 0.577 --	-- $\pm$ 0.034 --
FTE-15	TS 6-5 (1937)	C1862	Calculated Mass. Spec. (Calc/meas - 1)($\pm$ 1 σ)	93.64 90.278 $\pm$ 0.0374	-- $\pm$ 0.685 $\pm$ 0.0079	5.98 6.910 -0.135	-- $\pm$ 0.055 $\pm$ 0.007	0.38 1.904 -0.800	-- $\pm$ 0.577 $\pm$ 0.060	-- 0.281 --	-- $\pm$ 0.126 --	-- 0.630 --	-- $\pm$ 0.034 --
FTE-15	TS 7-2 (2392)	C1861	Calculated Mass. Spec. (Calc/mass - 1)($\pm$ 1 σ)	93.46 92.237 $\pm$ 0.0133	-- $\pm$ 0.153 $\pm$ 0.0017	6.05 5.963 $\pm$ 0.0146	-- $\pm$ 0.025 $\pm$ 0.0043	0.49 1.065 -0.540	-- $\pm$ 0.125 $\pm$ 0.054	-- 0.098 --	-- $\pm$ 0.025 --	-- 0.637 --	-- $\pm$ 0.111 --
	$\bar{x}$, $\bar{Sx}$ RMS, Sx		(Calc/meas - 1)	0.0205 $\pm$ 0.0120	$\pm$ 0.0047 $\pm$ 0.0039	-0.035 $\pm$ 0.071	$\pm$ 0.0050 $\pm$ 0.0029	-0.621 $\pm$ 0.127	$\pm$ 0.055 $\pm$ 0.032	-- --	-- --	-- --	-- --
FTE-14 and 15	$\bar{x}$, $\bar{Sx}$ RMS, Sx		(Calc/meas - 1)	0.0157 $\pm$ 0.0110	$\pm$ 0.0037 $\pm$ 0.0016	-0.085 $\pm$ 0.085	$\pm$ 0.0042 $\pm$ 0.0019	-0.498 $\pm$ 0.181	$\pm$ 0.056 $\pm$ 0.025	-- --	-- --	-- --	-- --

TABLE 3-18
FTE-14 AND FTE-15 AVERAGE RELATIVE BIAS FOR FISSILE AND FERTILE FUEL

	Z - Relative Difference (Calc/Meas - 1)(%)									
	U-233		U-234		U-235		U-236		U-238	
	Z	S _Z (1σ)	Z	S _Z (1σ)	Z	S _Z (1σ)	Z	S _Z (1σ)	Z	S _Z (1σ)

Fissile Isotopic Comparison

FTE-14	--	--	5.1	±0.5	0.1	<±0.05	-0.2	±0.2	-1.4	±0.2
FTE-15	--	--	6.7	±0.5	-0.1	±0.1	+0.4	±0.3	-0.8	±0.4
Total	--	--	5.9	±0.4	0.0	<±0.05	+0.2	±0.2	-1.1	±0.2

Fertile Isotopic Comparison

FTE-14	0.9	<±0.05	-16.0	±0.2	-31.4	±4.0	--	--	--	--
FTE-15	2.1	±0.4	-3.5	±0.3	-62.1	±3.2	--	--	--	--
Total	1.6	±0.2	-8.5	±0.2	-49.8	±2.5	--	--	--	--

TABLE 3-19a
FTE-14 FISSILE BURNUP COMPARISON

	Particle Batch No.	Spine and Core Location (mm)	Particle I.D.	Mass Spectroscopy FIMA				FIMA (Cs-137 Monitor)		GAUGE/ FEVER Calc. (%)
				ASTM Eq. 1 (%)	ASTM Eq. 2 (%)	ASTM Eq. 3 (%)	Mean (%)	IDMS U (%)	Chem. U (%)	
Mean $\bar{x}$ $S_{\bar{x}}$ C/M-1 = Z SZ	4161-01-030 OR1694	TS4-6 (1642)	C2051-2	ND ^(a)	ND	ND	ND	-- --	23.16 ±1.16	24.09
			C2051-3	ND	ND	ND	ND	22.60 ±0.99	23.31 ±1.17	24.09
			C2051-4	ND	ND	ND	ND	23.07 ±1.01	23.17 ±1.17	24.09
				25.040 ±0.478 -0.0380 ±0.0184	25.691 ±0.711 -0.0623 ±0.0260	25.206 ±0.395 -0.0443 ±0.0150	25.312 ±0.353 -0.0483 ±0.0133	22.84 ±0.73 +0.0547 ±0.0337	23.21 ±0.67 +0.0379 ±0.0300	
			C2052-4	ND	ND	ND	ND	-- --	20.31 ±1.74	23.13
			C2052-5	ND	ND	ND	ND	22.03 ±1.27	21.82 ±1.83	23.13
			C2052-7	ND	ND	ND	ND	21.57 ±1.24	21.86 ±1.83	23.13
				23.230 ±0.464 -0.0043 ±0.0199	22.943 ±0.661 +0.0082 ±0.0290	23.154 ±0.384 -0.0010 ±0.0166	23.109 ±0.306 +0.0009 ±0.0133	21.80 ±0.90 +0.061 ±0.0438	21.33 ±1.12 +0.084 ±0.057	
			C2053-1	ND	ND	ND	ND	19.26 ±0.87	21.05 ±1.08	19.37
			C2053-2	ND	ND	ND	ND	-- --	23.64 ±1.21	19.37
Mean $\bar{x}$ $S_{\bar{x}}$ C/M-1 = Z SZ	4413-5	TS7-3 (2377)	C2053-3	ND	ND	ND	ND	19.57 ±0.88	19.38 ±1.02	19.37
				22.745 ±0.482 -0.148 ±0.0180	22.792 ±0.660 -0.150 ±0.0246	22.783 ±0.395 -0.149 ±0.0147	22.773 ±0.303 -0.1494 ±0.0113	19.42 ±0.63 -0.0026 ±0.0324	21.36 ±1.20 -0.093 ±0.051	

(a) ND = not determined.

TABLE 3-19b
FTE-15 FISSILE BURNUP COMPARISON

	Particle Batch No.	Spine and Core Location (mm)	Particle I.D.	Mass Spectroscopy FIMA				FIMA (Cs-137 Monitor)		GAUGE/FEVER Calc. (%)
				ASTM Eq. 1 (%)	ASTM Eq. 2 (%)	ASTM Eq. 3 (%)	Mean (%)	IDMS U (%)	Chem. U (%)	
$\bar{x}$	4161-01-030	TS5-6 (1854)	C1857-1	ND ^(a)	ND	ND	ND	37.15	36.62	36.82
$S_{\bar{x}}$			C1857-1					±2.85	±2.90	
$\bar{x}$			C1857-2	ND	ND	ND	ND	--	36.71	36.82
$S_{\bar{x}}$			C1857-2					--	±2.90	
$\bar{x}$			C1857-3	ND	ND	ND	ND	35.82	35.51	36.82
$S_{\bar{x}}$			C1857-3	ND	ND	ND	ND	±2.80	±2.86	
Mean $\bar{x}$				-38.620	38.584	38.608	38.604	36.49	36.28	
$S_{\bar{x}}$				±0.454	±0.871	±0.417	±0.356	±2.05	±1.70	
C/M-1 = Z				-0.0466	-0.0457	-0.0463	-0.0462	+0.0090	+0.0149	
S_Z				±0.0112	±0.0215	±0.0103	±0.0088	±0.0567	±0.0476	
$\bar{x}$	OR1694	TS2-6 (1166)	C1859-1	ND	ND	ND	ND	32.69	32.82	35.63
$S_{\bar{x}}$			C1859-1	ND	ND	ND	ND	±2.69	±2.75	
$\bar{x}$			C1859-2	ND	ND	ND	ND	30.98	31.29	35.63
$S_{\bar{x}}$			C1859-2	ND	ND	ND	ND	±2.61	±2.69	
$\bar{x}$			C1859-3	ND	ND	ND	ND	--	19.55 ^(b)	35.63
$S_{\bar{x}}$			C1859-3	ND	ND	ND	ND	--	±1.97	
Mean $\bar{x}$				34.120	33.941	34.064	34.042	31.84	32.06	
$S_{\bar{x}}$				±0.468	±0.827	±0.409	±0.348	±1.97	±2.00	
C/M-1 = Z				+0.0443	+0.0498	+0.0460	+0.0466	+0.119	+0.111	
S_Z				±0.0143	±0.0256	±0.0126	±0.0107	±0.069	±0.069	
	4161-01-030	TS8-3 (2424)	C1860-1	ND	ND	ND	ND	--	31.78	30.25
			C1860-1	ND	ND	ND	ND	--	±2.71	
			C1860-3	ND	ND	ND	ND	32.80	34.17	30.25
			C1860-3	ND	ND	ND	ND	±2.69	±2.80	
			C1860-4	ND	ND	ND	ND	30.76	32.31	30.25
			C1860-4	ND	ND	ND	ND	±2.60	±2.73	
Mean $\bar{x}$				33.467	33.523	33.484	33.491	31.78	32.75	
$S_{\bar{x}}$				±0.490	±0.830	±0.423	±0.351	±2.00	±1.69	
C/M-1 = Z				-0.0961	-0.0976	-0.0966	-0.0968	-0.0481	-0.0763	
S_Z				±0.0132	±0.0223	±0.0114	±0.0095	±0.0599	±0.0477	

(a) ND = not determined.

(b) Not used in mean.

TABLE 3-20a
FTE-14 FERTILE BURNUP COMPARISON

Particle Batch No.	Spine and Core Location (mm)	Particle I.D.	FIMA (Cs-137 Monitor)		GAUGE/ FEVER Calc. (%)
			Chem. (%)	Error (1 σ) (%)	
4413-127	TS2-5 (1164)	C1570-7	0.235	± 0.017	0.25
		C1570-8	0.265	± 0.020	0.25
		C1570-9	0.119 ^(a)	± 0.0088	0.25
		C1570-10	0.247	± 0.018	0.25
Mean $\bar{x}$			0.249		0.25
$S_{\bar{x}}$			± 0.0249		
C/M-1 = Z			+0.0040		
S_Z			± 0.1004		
4423-89	TS7-2 (2387)	C1573-21	0.295	± 0.022	0.21
		C1573-22	0.313	± 0.023	0.21
		C1573-23	0.305	± 0.022	0.21
		C1573-24	0.274	± 0.020	0.21
		C1573-25	0.289	± 0.021	0.21
Mean $\bar{x}$			0.295		0.21
$S_{\bar{x}}$			+0.011		
C/M-1 = Z			-0.288		
S_Z			± 0.027		

(a) Not used in mean.

TABLE 3-20b
FTE-15 FERTILE BURNUP COMPARISON

Particle Batch No.	Spine and Core Location (mm)	Particle I.D.	FIMA (Cs-137 Monitor)		GAUGE/ FEVER Calc. (%)
			Chem. (%)	Error (1 σ) (%)	
1413-127	TS2-5 (1166)	C1858-1	0.671	0.035	0.83
		C1858-2	0.930	0.049	0.83
		C1858-3	0.565	0.030	0.83
		C1858-4	0.597	0.032	0.83
		C1858-5	0.626	0.034	0.83
Mean $\bar{x}$			0.678		0.83
$S_{\bar{x}}$			± 0.061		
C/M-1 = Z			+0.224		
S_Z			± 0.110		
1423-89	TS7-2 (2392)	C1861-1	0.691	0.037	0.66
		C1862-2	0.771	0.041	0.66
		C1862-3	0.627	0.033	0.66
		C1862-4	0.668	0.036	0.66
		C1862-5	0.641	0.035	0.66
Mean $\bar{x}$			0.680		0.66
$S_{\bar{x}}$			± 0.0280		
C/M-1 = Z			-0.0294		
S_Z			± 0.0400		
4413-137	TS6-6 (1937)	C1862-1	0.861	0.045	0.86
		C1862-2	0.807	0.043	0.86
		C1862-3	0.923	0.049	0.86
		C1862-4	0.869	0.047	0.86
		C1862-5	0.775	0.042	0.86
Mean $\bar{x}$			0.847		0.86
$S_{\bar{x}}$			± 0.0307		
C/M-1 = Z			+0.0153		
S_Z			± 0.0368		

TABLE 3-21
FTE-14 CALCULATED FIMA(a)

Body No.	Rod No.	Core Height (mm)	Fertile FIMA (%)	Fissile FIMA (%)	Mixed FIMA(b) (%)
1	1	696	0.032	9.716	0.898
	2	759	0.068	12.691	1.197
	3	822	0.109	15.043	1.444
	4	885	0.148	17.067	1.661
	5	948	0.185	18.626	1.835
	6	1012	0.222	19.953	1.987
	7	1075	0.256	21.012	2.112
	8	1138	0.284	21.782	2.207
	9	1201	0.310	22.494	2.294
	10	1264	0.329	23.041	2.360
	11	1327	0.343	23.495	2.414
Mean		1012	0.208	18.629	1.855
Range/RMS		695	± 0.103	± 4.322	± 0.479
2	1	1486	0.355	23.901	2.461
	2	1549	0.362	24.236	2.497
	3	1612	0.368	24.484	2.525
	4	1675	0.369	24.531	2.530
	5	1738	0.367	24.430	2.519
	6	1802	0.363	24.251	2.499
	7	1865	0.353	23.930	2.461
	8	1928	0.341	23.572	2.419
	9	1991	0.328	23.179	2.372
	10	2054	0.313	22.720	2.317
	11	2117	0.298	22.228	2.259
Mean		1802	0.347	23.769	2.442
Range/RMS		694	± 0.023	± 0.731	± 0.086
3	1	2276	0.277	21.589	2.183
	2	2339	0.256	20.894	2.102
	3	2402	0.235	20.085	2.010
	4	2465	0.209	19.057	1.895
	5	2528	0.184	17.999	1.777
	6	2592	0.159	16.952	1.661
	7	2655	0.134	15.876	1.542
	8	2718	0.110	14.841	1.427
	9	2781	0.086	13.806	1.313
	10	2844	0.060	12.738	1.194
	11	2907	0.036	11.715	1.081
Mean		2592	0.159	16.868	1.653
Range/RMS		695	± 0.077	± 3.205	± 0.357
Grand Mean		1802	0.238	19.756	1.983
Grand Range/RMS		2275	± 0.110	± 4.289	± 0.483

(a) These are nominal burnup predictions; i.e., power corrections have not been progressed.

(b) $Th/U = 10.182$.

TABLE 3-22
FTE-15 CALCULATED FIMA(a)

Body No.	Rod No.	Core Height (mm)	Fertile FIMA (%)	Fissile FIMA (%)	Mixed FIMA(b) (%)
1	1	696	0.092	16.530	1.592
	2	759	0.194	20.834	2.078
	3	822	0.307	24.247	2.491
	4	885	0.416	27.204	2.861
	5	948	0.521	29.556	3.171
	6	1012	0.622	31.469	3.437
	7	1075	0.713	32.910	3.651
	8	1138	0.787	33.976	3.816
	9	1201	0.856	34.953	3.967
	10	1264	0.906	35.673	4.079
	11	1327	0.947	36.292	4.172
Mean		1012	0.578	29.422	3.210
Range/RMS		695	± 0.281	± 6.220	± 0.821
2	1	1486	0.983	36.860	4.257
	2	1549	1.004	37.245	4.311
	3	1612	1.020	37.556	4.354
	4	1675	1.026	37.707	4.373
	5	1738	1.023	37.636	4.364
	6	1802	1.014	37.447	4.339
	7	1865	0.994	37.162	4.295
	8	1928	0.968	36.834	4.242
	9	1991	0.936	36.455	4.177
	10	2054	0.897	35.969	4.098
	11	2117	0.856	35.428	4.011
Mean		1802	0.975	36.936	4.256
Range/RMS		694	± 0.053	± 0.696	± 0.112
3	1	2276	0.808	34.566	3.889
	2	2339	0.756	33.671	3.760
	3	2402	0.697	32.685	3.616
	4	2465	0.626	31.318	3.427
	5	2528	0.555	29.774	3.222
	6	2592	0.488	27.309	2.935
	7	2655	0.383	25.301	2.657
	8	2718	0.341	24.939	2.586
	9	2781	0.271	23.517	2.393
	10	2844	0.199	21.836	2.174
	11	2907	0.130	20.130	1.955
Mean		2592	0.478	27.732	2.965
Range/RMS		695	± 0.220	± 4.746	± 0.632
Grand Mean		1802	0.677	31.363	3.477
Grand Range/RMS		2275	± 0.299	± 6.047	± 0.822

(a) These are nominal burnup predictions; i.e., power corrections have not been progressed.

(b) $Th/U = 9.958$.

TABLE 3-23
FTE-14 AND FTE-15 FISSILE AND FERTILE BURNUP SUMMARY

	Spine I.D.	Axial Core Location (mm)	Mass. Spec.		Radiochemistry		Calc. F _C (at. %)	Relative Difference, C/M - 1Z ± S _Z	
			F (at. %)	S _F (at. %)	F (at. %)	S _F (at. %)			
Fissile FIMA									
FTE-14	TS2-6	1164	23.11	±0.31	21.80	±0.90	23.13	+0.001	0.013
FTE-14	TS4-6	1642	25.31	±0.35	22.84	±0.73	24.09	-0.048	0.013
FTE-14	TS7-3	2377	22.77	±0.30	19.42	±0.63	19.37	-0.149	0.011
FTE-15	TS2-6	1166	34.04	±0.35	31.84	±1.97	35.63	0.047	0.011
FTE-15	TS5-6	1854	38.60	±0.36	36.49	±2.05	36.82	-0.046	0.009
FTE-15	TS8-3	2424	33.49	±0.35	31.78	±2.00	30.25	-0.097	0.010
Fertile FIMA									
FTE-14	TS2-5	1164			0.25	±0.03	0.25	+0.004	0.100
FTE-14	TS7-2	2387			0.30	±0.01	0.21	-0.288	0.027
FTE-15	TS2-5	1166			0.63	±0.06	0.83	+0.224	0.110
FTE-15	TS6-5	1937			0.85	±0.03	0.86	+0.015	0.037
FTE-15	TS7-2	2392			0.68	±0.03	0.86	-0.029	0.040

TABLE 3-24
FTE-14 AND FTE-15 COMPARISON OF COMPOSITE BURNUP

FTE-14								FTE-15							
Fuel Rod I.D.	Total FIMA			Relative Difference		Test 1	Test 2	Fuel Rod I.D.	Total FIMA			Relative Difference		Test 1	Test 2
	Calc.,	Meas.							Calc.,	Meas.					
		C (%)	M (%)	S _M (1σ) (%)	C/M-1 = Z					S _Z (1σ)	C (%)	M (%)	S _M (1σ) (%)		
1-1-1	0.69	1.12	+0.09	-0.384	+0.050	-7.76	60.14	1-1-1	1.21	1.43	+0.12	-0.154	+0.071	-2.17	4.69
1-1-2	0.92	1.04	+0.10	-0.115	+0.085	-1.36	1.84	1-1-2	1.59	1.52	+0.13	0.046	+0.089	0.51	0.26
1-1-3	1.12	1.11	+0.09	0.009	+0.082	0.11	0.01	1-1-3	1.93	1.59	+0.12	0.214	+0.092	2.33	5.45
1-1-4	1.30	1.18	+0.10	0.102	+0.093	1.09	1.19	1-1-4	2.24	1.96	+0.17	0.143	+0.099	1.44	2.08
1-1-5	1.44	1.33	+0.11	0.083	+0.090	0.92	0.85	1-1-5	2.49	2.13	+0.22	0.169	+0.121	1.40	1.96
1-1-6	1.57	1.53	+0.10	0.026	+0.067	0.39	0.15	1-1-6	2.71	2.22	+0.23	0.221	+0.126	1.75	3.05
1-1-7	1.66	1.81	+0.15	-0.083	+0.076	-1.09	1.19	1-1-7	2.89	2.55	+0.26	0.133	+0.116	1.15	1.33
1-1-8	1.74	1.98	+0.19	-0.121	+0.084	-1.44	2.07	1-1-8	3.04	2.57	+0.26	0.183	+0.120	1.53	2.34
1-1-9	1.81	2.05	+0.17	-0.117	+0.073	-1.60	2.56	1-1-9	3.17	2.78	+0.28	0.140	+0.115	1.22	1.49
1-1-10	1.87	2.15	+0.17	-0.130	+0.069	-1.89	3.59	1-1-10	3.27	2.66	+0.27	0.229	+0.125	1.84	3.38
1-1-11	1.91	2.26	+0.18	-0.155	+0.067	-2.30	5.29	1-1-11	3.35	3.01	+0.24	0.113	+0.089	1.27	1.62
2-1-1	3.40	4.12	+0.30	-0.175	+0.060	-2.91	8.46	2-1-1	5.62	5.60	+0.39	0.004	+0.070	0.05	<0.01
2-1-2	3.44	3.89	+0.28	-0.116	+0.064	-1.82	3.30	2-1-2	5.68	5.73	+0.46	-0.009	+0.080	-0.11	0.01
2-1-3	3.49	4.11	+0.29	-0.151	+0.060	-2.52	6.34	2-1-3	5.74	5.75	+0.57	-0.002	+0.099	-0.02	<0.01
2-1-4	3.49	4.05	+0.26	-0.138	+0.055	-2.50	6.25	2-1-4	5.77	5.56	+0.44	0.038	+0.082	0.46	0.21
2-1-5	3.48	NA	--	--	--	--	--	2-1-5	5.75	5.66	+0.76	0.016	+0.136	0.12	0.01
2-1-6	3.45	3.91	+0.28	-0.118	+0.063	-1.86	3.47	2-1-6	5.72	5.75	+0.46	-0.005	+0.080	-0.07	<0.00
2-1-7	3.40	NA	--	--	--	--	--	2-1-7	5.66	5.65	+0.45	0.002	+0.080	0.02	<0.01
2-1-8	3.34	3.71	+0.27	-0.100	+0.066	-1.52	2.32	2-1-8	5.60	5.55	+0.55	0.009	+0.100	0.09	<0.01
2-1-9	3.28	3.99	+0.29	-0.178	+0.060	-2.98	8.87	2-1-9	5.53	5.62	+0.56	-0.016	+0.100	-0.16	0.03
2-1-10	3.21	3.87	+0.25	-0.171	+0.054	-3.18	10.13	2-1-10	5.43	5.66	+0.56	-0.041	+0.095	-0.43	0.18
2-1-11	3.13	3.99	+0.29	-0.216	+0.057	-3.78	14.29	2-1-11	5.33	5.75	+0.46	-0.073	+0.074	-0.98	0.97
3-1-1	3.03	NA	--	--	--	--	--	3-1-1	5.17	5.39	+0.53	-0.041	+0.094	-0.43	0.19
3-1-2	2.93	3.58	+0.26	-0.182	+0.059	-3.05	9.33	3-1-2	5.01	5.05	+0.51	-0.008	+0.100	-0.08	0.01
3-1-3	2.80	3.30	+0.24	-0.152	+0.062	-2.46	6.03	3-1-3	4.83	4.75	+0.48	0.017	+0.103	0.16	0.03
3-1-4	2.65	3.03	+0.24	-0.125	+0.069	-1.81	3.28	3-1-4	4.60	4.60	+0.47	0.000	+0.102	0.00	0.00
3-1-5	2.48	2.96	+0.22	-0.162	+0.062	-2.60	6.78	3-1-5	4.33	4.37	+0.44	-0.009	+0.100	-0.09	0.01
3-1-6	2.33	2.82	+0.21	-0.174	+0.062	-2.82	7.98	3-1-6	3.96	4.07	+0.34	-0.027	+0.081	-0.33	0.11
3-1-7	2.16	NA	--	--	--	--	--	3-1-7	3.60	3.83	+0.40	-0.060	+0.098	-0.61	0.37
3-1-8	2.01	NA	--	--	--	--	--	3-1-8	3.52	3.54	+0.30	-0.006	+0.084	-0.07	<0.01
3-1-9	1.86	NA	--	--	--	--	--	3-1-9	3.27	3.38	+0.36	-0.033	+0.103	-0.32	0.10
3-1-10	1.70	2.07	+0.17	-0.179	+0.067	-2.65	7.02	3-1-10	3.00	3.10	+0.27	-0.032	+0.084	-0.38	0.15
3-1-11	1.55	NA	--	--	--	--	--	3-1-11	2.71	2.97	+0.26	-0.088	+0.080	-1.10	1.20
$\bar{x}, S_x$	2.35	2.78	+0.49	-0.124	+0.068	-2.05	7.03		4.05	+3.93	+0.60	+0.033	+0.098	0.242	0.95
RMS, S_x	+0.89	+1.13	+0.043	+0.095	+0.013	Sign.	Sign.		+1.40	+1.55	+0.07	+0.095	+0.017	Not	Not
Test						10.45	7.03							sign.	sign.
						>1.96	>1.44							1.39	0.95
														<1.96	<1.43

TABLE 3-25a
FTE-14 STRESS SUMMARY FOR MIDPLANE OF BODY 1 (AXIAL POSITION 5)

Time (hr)	Operating Condition (a)						Shutdown Condition (a)			
	Temperature		In-Plane Stress		Axial Stress		In-Plane Stress		Axial Stress	
	Max. (K)	Min. (K)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)
10440	989	910	2.73	-1.10	1.38	-1.45	0.00	-0.01	0.00	-0.00
	12	445	230	216	349	12	453	454	241	445
13944	1114	983	1.62	-0.71	1.68	-1.25	1.79	-3.74	2.77	-2.28
	12	445	230	216	337	12	216	216	12	409
15888	1164	1008	2.10	-0.94	1.97	-1.42	2.28	-4.71	3.75	-3.09
	12	445	230	216	349	12	216	252	12	349
17112	1145	984	0.64	-0.31	1.10	-0.51	2.84	-5.83	4.84	-4.02
	12	445	230	216	446	180	216	252	12	337
19487	1196	1009	0.14	-0.14	0.69	-0.49	3.76	-7.67	6.99	-6.02
	12	445	445	230	12	240	216	204	12	325

(a) The number under each temperature and stress value at each time point refers to the finite element.

TABLE 3-25b
FTE-14 STRESS SUMMARY FOR MIDPLANE OF BODY 2 (AXIAL POSITION 15)

Time (hr)	Operating Condition (a)						Shutdown Condition (a)			
	Temperature		In-Plane Stress		Axial Stress		In-Plane Stress		Axial Stress	
	Max. (K)	Min. (K)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)
10440	1442	1308	3.63	-1.78	3.23	-3.28	0.02	-0.00	0.00	-0.00
	12	445	230	216	446	12	445	421	12	241
13944	1635	1439	0.67	-1.32	1.14	-1.61	4.28	-8.72	8.27	-8.27
	12	445	216	444	12	444	216	228	12	349
15888	1755	1521	0.63	-1.22	0.93	-1.53	5.35	-10.83	9.90	-10.21
	12	445	216	444	12	444	216	204	12	349
17112	1701	1480	1.37	-2.67	1.91	-2.91	5.52	-11.17	9.99	-10.50
	12	445	216	444	12	444	216	228	12	337
19487	1760	1520	1.04	-1.98	1.46	-2.50	5.82	-11.69	10.55	-11.21
	12	445	216	444	12	444	216	252	12	349

(a) The number under each temperature and stress value at each time point refers to the finite element.

TABLE 3-25c
FTE-14 STRESS SUMMARY FOR MIDPLANE OF BODY 3 (AXIAL POSITION 25)

Time (hr)	Operating Condition(a)						Shutdown Condition(a)			
	Temperature		In-Plane Stress		Axial Stress		In-Plane Stress		Axial Stress	
	Max. (K)	Min. (K)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)
10440	1392	1297	2.53	-1.24	2.27	-2.30	0.02	-0.00	0.00	-0.00
	12	445	230	216	446	12	445	12	445	241
13944	1543	1407	0.30	-0.60	0.77	-0.92	2.74	-5.60	5.26	-5.31
	12	445	216	444	12	444	216	204	12	446
15888	1645	1482	0.46	-0.90	0.86	-1.17	3.53	-7.18	6.92	-6.95
	12	445	216	444	12	444	216	204	12	349
17112	1584	1430	0.84	-1.63	1.57	-2.05	3.58	-7.28	6.85	-6.93
	12	445	216	444	12	444	216	216	12	349
19487	1630	1462	0.85	-1.64	1.54	-2.15	3.91	-7.92	7.65	-7.79
	12	445	216	444	12	444	216	252	12	349

(a) The number under each temperature and stress value at each time point refers to the finite element.

TABLE 3-26a

FTE-15 STRESS SUMMARY FOR MIDPLANE OF BODY 1 (AXIAL POSITION 5)

Time (hr)	Operating Condition ^(a)						Shutdown Condition ^(a)			
	Temperature		In-Plane Stress		Axial Stress		In-Plane Stress		Axial Stress	
	Max. (K)	Min. (K)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)
9240	949	878	1.54	-0.75	1.13	-1.20	0.00	-0.01	0.00	-0.00
	12	445	230	216	349	12	453	454	241	445
12000	1067	947	0.92	-0.48	1.73	-1.23	1.63	-3.41	2.33	-1.77
	12	445	444	216	349	12	216	240	12	361
13536	1118	973	0.70	-0.38	1.57	-0.86	2.30	-4.80	3.69	-2.92
	12	445	444	216	446	1	216	252	12	337
14640	1102	951	0.50	-0.26	1.56	-0.74	2.56	-5.33	4.08	-3.18
	12	445	217	240	446	128	216	228	12	325
16824	1234	1020	0.35	-0.17	0.61	-0.59	4.14	-8.52	7.80	-6.64
	12	445	217	252	445	216	216	228	12	325
16825	1234	1019	0.34	-0.17	0.60	-0.59	4.14	-8.52	7.80	-6.65
	12	445	217	252	445	216	216	228	12	325
17952	1170	984	0.23	-0.53	1.10	-0.64	3.92	-7.96	7.23	-6.14
	12	445	216	444	12	205	216	204	12	325
18912	1155	971	0.29	-0.63	1.31	-0.74	3.92	-7.98	7.30	-6.14
	12	445	216	444	12	217	216	252	12	325
19632	1045	900	0.59	-1.20	1.59	-1.05	3.36	-6.85	5.98	-4.98
	12	445	216	444	12	217	216	216	12	444
20040	1171	967	0.24	-0.09	0.76	-0.65	4.08	-8.29	7.57	-6.24
	12	445	217	288	12	227	216	204	12	313
20592	1043	887	0.60	-1.24	1.55	-1.00	3.58	-7.28	6.24	-5.15
	12	445	216	444	12	217	216	216	12	444
21360	1007	863	0.48	-1.01	1.21	-0.76	3.21	-6.51	5.43	-4.34
	12	445	216	444	12	217	216	228	12	444
21528	1016	865	0.38	-0.81	1.02	-0.70	3.25	-6.60	5.47	-4.33
	12	445	216	444	12	195	216	216	12	444

(a) The number under each temperature and stress value at each time point refers to the finite element.

TABLE 3-26b
FTE-15 STRESS SUMMARY FOR MIDPLANE OF BODY 2 (AXIAL POSITION 15)

Time (hr)	Operating Condition ^(a)						Shutdown Condition ^(a)			
	Temperature		In-Plane Stress		Axial Stress		In-Plane Stress		Axial Stress	
	Max. (K)	Min. (K)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)
9240	1408	1281	3.35	-1.64	3.00	-3.06	0.02	-0.00	0.00	-0.00
	12	445	230	216	446	12	445	24	12	241
12000	1601	1412	0.93	-1.83	1.49	-2.08	4.27	-8.69	8.03	-8.09
	12	445	216	444	12	444	216	204	12	349
13536	1705	1483	0.42	-0.79	0.58	-1.28	4.74	-9.58	8.90	-9.11
	12	445	216	444	216	444	216	252	12	349
14640	1656	1446	1.44	-2.80	2.10	-3.12	5.25	-10.60	9.60	-10.03
	12	445	216	444	12	444	216	252	12	337
16824	1830	1562	0.40	-0.28	0.81	-0.82	5.67	-11.45	10.69	-11.08
	12	445	443	215	216	444	216	252	12	349
16825	1830	1562	0.29	-0.22	0.76	-0.90	5.73	-11.58	10.84	-11.19
	12	445	443	215	216	444	216	252	12	349
17952	1729	1502	1.45	-2.80	2.02	-3.16	5.78	-11.59	10.39	-11.17
	12	445	216	444	12	444	216	252	12	337
18912	1693	1475	1.41	-2.69	2.04	-3.24	5.50	-11.02	9.98	-10.77
	12	445	216	444	12	444	216	216	12	337
19632	1520	1354	1.87	-3.56	3.01	-4.32	4.69	-9.35	8.16	-9.24
	12	445	216	444	12	444	216	240	12	337
20040	1705	1472	1.19	-2.25	1.94	-3.07	5.64	-11.27	10.49	-11.30
	12	445	216	444	12	444	216	204	12	349
20592	1529	1347	1.67	-3.16	2.89	-4.07	4.81	-9.63	8.64	-9.65
	12	445	216	444	12	444	216	252	12	337
21360	1460	1296	1.83	-3.48	3.45	-4.66	4.62	-9.17	8.46	-9.51
	12	445	216	444	12	444	216	240	12	337
21528	1472	1301	1.74	-3.30	3.41	-4.59	4.68	-9.26	8.62	-9.68
	12	445	216	444	12	444	216	240	12	337

(a) The number under each temperature and stress value at each time point refers to the finite element.

TABLE 3-26c
FTE-15 STRESS SUMMARY FOR MIDPLANE OF BODY 3 (AXIAL POSITION 25)

Time (hr)	Operating Condition(a)						Shutdown Condition(a)			
	Temperature		In-Plane Stress		Axial Stress		In-Plane Stress		Axial Stress	
	Max. (K)	Min. (K)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)	Max. (MPa)	Min. (MPa)
9240	1345	1258	2.27	-1.11	2.04	-2.03	0.01	-0.00	0.00	-0.00
	12	445	230	216	446	12	445	12	445	241
12000	1491	1336	0.07	-0.04	0.40	-0.44	2.26	-4.63	4.47	-4.57
	12	445	217	240	12	445	216	204	12	446
13536	1579	1430	0.43	-0.85	0.98	-1.22	3.16	-6.46	6.17	-6.15
	12	445	216	444	12	444	216	228	12	361
14640	1523	1382	0.74	-1.44	1.57	-1.91	3.27	-6.63	6.12	-6.37
	12	445	216	444	12	444	216	216	12	349
16824	1661	1479	0.27	-0.50	0.64	-1.12	3.82	-7.75	7.49	-7.71
	12	445	216	444	12	444	216	228	12	446
16825	1661	1479	0.28	-0.53	0.69	-1.14	3.83	-7.78	7.53	-7.74
	12	445	216	444	12	444	216	228	12	446
17952	1590	1434	0.99	-1.91	1.97	-2.54	3.81	-7.69	7.39	-7.56
	12	445	216	444	12	444	216	252	12	349
18912	1556	1405	1.09	-2.10	2.26	-2.86	3.80	-7.65	7.23	-7.57
	12	445	216	444	12	444	216	216	12	349
19632	1414	1298	1.52	-2.92	3.12	-3.79	3.44	-6.88	6.61	-7.04
	12	445	216	444	12	444	216	228	12	337
20040	1555	1392	0.81	-1.55	1.96	-2.54	3.79	-7.61	7.36	-7.73
	12	445	216	444	12	444	216	216	12	349
20592	1479	1330	1.21	-2.31	2.73	-3.32	3.84	-7.72	7.36	-7.85
	12	445	216	444	12	444	216	216	12	337
21360	1413	1278	1.40	-2.68	3.15	-3.80	3.67	-7.36	7.25	-7.72
	12	445	216	444	12	444	216	252	12	337
21528	1421	1282	1.30	-2.49	3.09	-3.71	3.68	-7.37	7.36	-7.81
	12	445	216	444	12	444	216	252	12	337

(a) The number under each temperature and stress value at each time point refers to the finite element.

TABLE 3-27
H-327 GRAPHITE ULTIMATE TENSILE AND COMPRESSION STRENGTH AND ELASTIC MODULUS

Block Position, Orientation	Ultimate Strength for H-327 Graphite (Ref. 3-16)			
	Mean		Standard Deviation	
	psi	MPa	psi	MPa
Ultimate Tensile Strength				
End center, axial	2180	15.031	435	3.000
End edge, axial ^(a)	2395	16.514	480	3.310
Midlength center, axial	1630	11.239	325	2.240
Midlength edge, axial ^(b)	2395	16.514	480	3.310
End center, radial	1350	9.308	270	1.862
End edge, radial ^(a)	1350	9.308	270	1.862
Midlength center, radial	940	6.481	190	1.310
Midlength edge, radial ^(b)	1290	8.895	260	1.793
Ultimate compressive strength ^(b)	>4000	>27.580		

(a) End edge values obtained by taking midlength edge value for axial orientation and end center value for radial orientation. The standard deviation was calculated from 20% of the mean UTS value based upon characterization and QA test results.

(b) Used for unirradiated strength at room temperature in computing stress-to-strength ratios.

Pointwise Block Position, Orientation	Elastic Modulus for H-327 Graphite			
	Mean		Standard Deviation (Ref. 3-16)	
	10 ⁶ psi	10 ³ MPa	10 ⁶ psi	10 ³ MPa
End center, axial	1.42	9.79	0.3	2.07
End edge, axial ^(a)	2.02	13.93	0.6	4.14
Midlength center, axial	1.42	9.79	0.4	2.76
Midlength edge, axial ^(b)	2.02	13.93	0.6	4.14
End center, radial	0.754	5.20	0.3	2.07
End edge, radial	0.669	4.61	0.3	2.07
Midlength center, radial	0.571	3.94	0.2	1.38
Midlength edge, radial ^(b)	0.774	5.34	0.3	2.07

(a) End edge values obtained by taking midlength edge value for axial orientation and end center value for radial orientation.

(b) Average used in stress calculation.

TABLE 3-28
FTE-14 AND FTE-15 PEAK INITIAL THERMAL STRESSES

Initial Thermal Stress	Peak	Mean	RMS ^(a)	Fuel Body Sequence
Tensile stress (MPa)				
In-plane				
FTE-14 (element 230)	3.63	2.96	±0.48	213
FTE-15 (element 230)	3.35	2.39	±0.74	231
Stress-strength ratio				
FTE-14	0.39	0.32	±0.05	213
FTE-15	0.36	0.25	±0.08	231
Axial				
FTE-14 (element 446) ^(b)	3.23	2.29	±0.76	231
FTE-15 (element 446) ^(b)	3.00	2.06	±0.76	231
Stress-strength ratio				
FTE-14	0.18	0.13	±0.04	231
FTE-15	0.17	0.11	±0.04	231

^(a) The mean and RMS are used to describe the variation of calculated peak stresses between the three fuel body positions and are not representative of mean body stresses or of uncertainties in calculations.

^(b) Element 349 for body 1.

TABLE 3-29
FTE-14 AND FTE-15 PEAK OPERATIONAL AND SHUTDOWN STRESSES

	Peak	Mean	RMS	Fuel Body Sequence
Operational Stress				
Tensile stress (MPa)				
In-plane				
FTE-14 (element 230)	3.63	2.96	±0.48	213
FTE-15 (element 230)	3.35	2.39	±0.74	231
Stress-strength ratio				
FTE-14	0.39	0.32	±0.05	213
FTE-15	0.36	0.25	±0.08	231
Axial				
FTE-14 (element 446) (a)	3.23	2.49	±0.54	231
FTE-15 (element 12) (a)	3.45	2.78	±0.75	231
Stress-strength ratio				
FTE-14	0.18	0.13	±0.04	231
FTE-15	0.14	0.11	±0.03	231
Shutdown Stress				
Tensile stress (MPa)				
In-plane				
FTE-14 (element 216)	5.82	4.50	±0.94	231
FTE-15 (element 216)	5.78	4.59	±0.85	213
Stress-strength ratio				
FTE-14	0.54	0.41	±0.09	231
FTE-15	0.54	0.42	±0.08	213
Axial				
FTE-14 (element 12)	10.55	8.40	±1.55	231
FTE-15 (element 12)	10.84	8.72	±1.50	213 (b)
Stress-strength ratio				
FTE-14	0.47	0.36	±0.08	231
FTE-15	0.48	0.38	±0.07	231 (b)

(a) Element 349 for body 1.

(b) Body 3 of FTE-15 has lower stress (7.53 MPa) but also a lower increase in elastic modulus because of lower fluence exposure, which results in a higher stress-strength ratio (0.33) than for body 2 (0.32).

TABLE 3-30
FTE-14 AND FTE-15 PEAK END OF LIFE STRESS SUMMARY

	Peak	Mean	RMS	Fuel Body Sequence
EOL Shutdown Stress				
Tensile stress (MPa)				
In-plane				
FTE-14 (element 216)	5.82	4.50	±0.94	231
FTE-15 (element 216)	4.68	3.87	±0.60	231
Stress-strength ratio				
FTE-14	0.54	0.41	±0.09	231
FTE-15	0.44	0.35	±0.06	231
Axial				
FTE-14 (element 12)	10.55	8.40	±1.55	231
FTE-15 (element 12)	8.62	7.15	±1.29	231
Stress-strength ratio				
FTE-14	0.47	0.36	±0.08	231
FTE-15	0.38	0.31	±0.07	231
EOL Operational Stress				
Tensile stress (MPa)				
In-plane				
FTE-14 (element 216) ^(a)	1.04	0.68	±0.39	231
FTE-15 (element 216)	1.74	1.14	±0.57	231
Stress-strength ratio				
FTE-14	0.09	0.06	±0.03	231
FTE-15	0.15	0.10	±0.05	231
Axial				
FTE-14 (element 12)	1.54	1.23	±0.38	231
FTE-15 (element 12)	3.41	2.51	±1.06	231
Stress-strength ratio				
FTE-14	0.06	0.04	±0.02	231
FTE-15	0.14	0.10	±0.04	231

^(a) Element 445, body 1.

TABLE 3-31
SUMMARY OF RESIDUAL BOW AND ELONGATION MEASUREMENTS FOR 0.45-mm STRIPS
CUT FROM FTE-14 AND FTE-15

Quantity	Unirradiated 6-Hole Element	FTE-14 Body 2	FTE-15 Body 1	FTE-15 Body 2	FTE-15 Body 3
Fast fluence ($E > 29$ fJ) (10^{25} n/m ²) (a)	NA (b)	1.29	1.78	2.05	1.18
Irradiation temperature (°C) (a)					
Thin strip					
Mean	NA	988	753	1027	1012
ΔT	NA	14	21	18	10
Thick strip					
Mean	NA	1053	867	1111	1058
ΔT	NA	189	223	214	125
Thin strip, 457 mm long					
Maximum residual bow (c)					
Number of samples (-)	6	5	6	5	5
Mean (mm)	-0.55	-1.50	+0.56	-2.19	-2.82
$\pm$ RMS (mm)	1.03	0.41	0.18	0.35	0.42
Elongation (c)					
Number of samples (-)	5	5	6	5	5
Mean (mm)	+0.04	+0.22	+0.10	+0.15	+0.15
$\pm$ RMS (mm)	0.06	0.03	0.06	0.02	0.04
Thick strip, 457 mm long					
Maximum residual bow (c)					
Number of samples (-)	NA	6	6	5	6
Mean (mm)	NA	+0.74	+0.58	+0.53	+0.32
$\pm$ RMS (mm)	NA	0.10	0.07	0.14	0.09
Elongation (c)					
Number of samples (-)	6	6	6	5	6
Mean (mm)	+0.09	+0.14	+0.10	+0.07	+0.07
$\pm$ RMS (mm)	0.08	0.03	0.10	0.08	0.06

(a) Fluence and temperatures are time and/or volume averages.

(b) NA = not applicable.

(c) Measurement errors: residual bow = ± 0.07 mm (1 σ); elongation = ± 0.12 mm (1 σ).

TABLE 3-32
FTE-14 AND FTE-15 SUMMARY OF PRESSURE BURST, RADIAL COMPRESSION, AND IN-PLANE STRAIN MEASUREMENTS FOR 20-MM SLICES

Element Type	Body I.D.	Graphite I.D.	Pressure Burst Test			Radial Compression Test			In-Plane Strain Measurements					
			No. of Samples	Pressure ±0.4 MPa (1σ)		No. of Samples	Force ±0.02 kN (1σ)		No. of Samples	Groove Change		O.D. Change		
				Mean (MPa)	RMS (MPa)		Mean (kN)	RMS (kN)		±0.010 mm (1σ)	±0.002 mm (1σ)			
Unirradiated Control Tests														
6-hole	1	1390	69	3.41	±0.39	9	1.35	±0.16	3	-0.004	±0.003	-0.007	±0.006	
	2	1390	65	3.00	±0.42	9	1.34	±0.11	3	-0.025	±0.004	-0.003	±0.001	
	3	1390	138	3.33	±0.38	21	1.32	±0.13	7	-0.004	±0.011	-0.002	±0.003	
	4	1390	163	3.22	±0.48	22	1.45	±0.12	7	-0.009	±0.006	-0.003	±0.004	
	Mean		435	3.25	±0.44	61	1.38	±0.14	20	-0.001	±0.014	-0.004	±0.004	
Irradiated Tests														
FTE-14	1	2040	98	3.91	±0.62	9	1.75	±0.12	9	-0.150	±0.050	-0.028	±0.014	
	2	2040	27	4.36	±0.49	3	2.22	±0.54	3	-0.207	±0.018	-0.038	±0.011	
	3	2590	109	3.71	±0.63	11	1.80	±0.33	11	-0.148	±0.034	-0.029	±0.010	
	Mean		234	3.87	±0.64	23	1.84	±0.35	23	-0.157	±0.044	-0.030	±0.012	
FTE-15	1	2015	23	4.64	±0.31	3	1.79	±0.16	3	-0.072	±0.036	-0.009	±0.005	
	2	2040	27	5.07	±0.64	4	2.05	±0.07	2	-0.109	±0.013	-0.036	0	
	3	2040	34	3.76	±0.86	3	1.71	±0.22	4	-0.099	±0.017	-0.005	±0.011	
	Mean		84	4.43	±0.88	10	1.87	±0.23	9	-0.092	±0.028	-0.013	±0.014	

TABLE 4-1
FTE-15 PEACH BOTTOM GAMMA SCAN RESULTS

SPECTRUM I.D.	CORE LOCATION PARAMETERS	FUEL ELEMENT I.D.	NUCLIDE CPM + / - 1 SIGMA COUNTING ERROR									
GA.TAG NO.	AXIAL CORE LOC. CP (MM)	SCAN INTERVAL	CE-144 133 KEV	CE-141 145 KEV	PA-233 312 KEV	I-131 364 KEV	RU-103 497 KEV	RU-106 512 KEV	CS-137 661 KEV	ZR-95 724 KEV	CS-134 796 KEV	LA-140 1596 KEV
***	BEGIN STRATA # 1	***										
2235	.00	.00	.0	32.6	20.3	.0	.0	.0	15.6	.0	.0	.0
		AUTO #1 A14-08	.0	26.4	10.5	.0	.0	.0	4.4	.0	.0	.0
2236	42.96	62.87	.0	88.2	.0	.0	.0	.0	37.0	.0	.0	.0
		AUTO #2 A14-08	.0	25.3	.0	.0	.0	.0	7.4	.0	.0	.0
2237	111.48	64.12	.0	.0	.0	.0	.0	.0	12.0	.0	.0	.0
		AUTO #3 A14-08	.0	.0	.0	.0	.0	.0	3.9	.0	.0	.0
2238	180.63	64.12	.0	.0	.0	272.6	.0	12.9	8.4	5.5	2.5	.0
		AUTO #4 A14-08	.0	.0	.0	98.4	.0	4.2	5.2	3.2	1.8	.0
2239	249.78	64.12	.0	.0	.0	.0	.0	.0	18.0	.0	.0	.0
		AUTO #5 A14-08	.0	.0	.0	.0	.0	.0	4.8	.0	.0	.0
2240	318.31	62.87	.0	.0	.0	409.0	.0	2.6	26.5	.0	.0	.0
		AUTO #6 A14-08	.0	.0	.0	120.5	.0	1.9	5.8	.0	.0	.0
2241	386.82	64.12	.0	87.2	.0	.0	19.0	2.6	21.7	.0	.0	.0
		AUTO #7 A14-08	.0	32.0	.0	.0	6.9	1.9	5.2	.0	.0	.0
2242	455.97	64.12	.0	.0	.0	.0	.0	7.1	.0	.0	.0	.0
		AUTO #8 A14-08	.0	.0	.0	.0	.0	4.0	.0	.0	.0	.0
2243	525.13	64.12	.0	.0	.0	.0	.0	10.3	.0	.0	.0	.0
		AUTO #9 A14-08	.0	.0	.0	.0	.0	3.7	.0	.0	.0	.0
2244	594.27	64.12	.0	.0	.0	.0	.0	34.9	24.1	.0	2.5	.0
		AUTO #10 A14-08	.0	.0	.0	.0	.0	9.9	5.5	.0	1.8	.0
***	STRATA # 1 A14-08 TOTALS	***										
MEAN =	286.53	WT MEAN CPM =	.0	87.7	.0	340.2	19.0	11.8	21.0	5.5	2.5	.0
RMS =	193.92	WT MEAN 1SIGMA =	.0	28.9	.0	109.9	6.9	5.0	5.2	3.2	1.8	.0
MIDPT =	297.14	WT RMS =	.0	.5	.0	68.2	.0	11.0	8.8	.0	.0	.0
RANGE =	658.40	WT ERROR =	.0	20.4	.0	77.6	6.9	2.1	2.0	3.2	1.3	.0
2245	665.31	67.89	303.0	1736.1	19478.5	.0	2066.8	.0	327.2	2638.8	103.4	4251.8
		AUTO #11 A14-08	154.7	328.3	397.5	.0	177.0	.0	44.2	115.8	30.6	245.2
***	BEGIN STRATA # 2	***										
2246	743.28	77.95	855.1	4223.6	67538.1	9001.5	9250.7	.0	913.0	9460.0	409.2	17657.5
		AUTO #12 A14-08	260.3	456.4	749.8	4208.2	330.8	.0	80.2	205.5	63.5	477.0
2247	828.14	81.72	.0	4678.1	83232.2	5609.2	10246.3	.0	893.8	11300.7	568.4	19174.0
		AUTO #13 A14-08	.0	489.5	796.5	2829.1	353.7	.0	93.8	268.1	70.1	478.0
2248	916.16	84.24	450.1	4778.7	100076.9	14168.9	10770.5	413.1	1038.0	12466.6	592.6	22333.5
		AUTO #14 A14-08	217.0	639.0	890.9	3524.7	380.9	169.2	94.0	238.7	58.6	508.2
2249	1006.66	86.75	783.5	7506.3	109559.6	.0	12836.4	.0	1301.3	14086.8	791.8	25578.5
		AUTO #15 A14-08	258.9	749.9	942.1	.0	405.9	.0	112.2	269.7	64.2	541.7
2250	1100.97	91.78	752.5	8046.1	119259.3	13863.5	12561.2	.0	1089.9	15757.7	1089.5	29176.3
		AUTO #16 A14-08	258.9	808.3	1045.2	4088.6	463.5	.0	95.1	297.6	84.7	591.5
2251	1198.40	93.04	1008.1	10477.1	127581.4	.0	14111.4	.0	1850.6	17200.1	1012.6	32753.4
		AUTO #17 A14-08	254.1	940.6	1077.3	.0	437.5	.0	150.0	293.2	84.2	634.2

TABLE 4-1 (Continued)

SPECTRUM I.D.	CORE LOCATION PARAMETERS	FUEL ELEMENT I.D.	NUCLIDE CPM $\pm$ 1 SIGMA COUNTING ERROR									
GA. TAG NO.	AXIAL CORE LOC. CP (MM)	SCAN INTERVAL	CE-104 133 KEV	CE-141 145 KEV	PA-233 312 KEV	I-131 364 KEV	RU-103 497 KEV	RU-106 512 KEV	CS-137 661 KEV	ZR-95 724 KEV	CS-134 796 KEV	LA-140 1596 KEV
2283	3857.49	63.54	.0	.0	.0	.0	.0	404.1	30.4	.0	.0	.0
		AUTO #49 A14-08	.0	.0	.0	.0	.0	42.1	12.6	.0	.0	.0
* * * STRATA # 5 A14-08 TOTALS * * *												
MEAN =	3441.80	WT MEAN CPM =	.0	.0	.0	1879.8	63.0	425.4	41.3	52.0	33.7	.0
RMS =	258.05	WT MEAN 1SIGMA =	.0	.0	.0	1119.2	46.7	42.3	17.8	27.2	19.3	.0
MIDPT =	3449.86	WT RMS =	.0	.0	.0	.0	.0	96.1	19.0	16.8	11.5	.0
RANGE =	878.79	WT ERROR =	.0	.0	.0	1119.2	46.7	11.7	6.3	15.7	11.2	.0
2284	3240.71	1.00	.0	.0	.0	.0	.0	518.2	15.0	.0	.0	20.0
		GRAPHITE A14-08	.0	.0	.0	.0	.0	13.0	3.7	.0	.0	6.4
2285	2515.79	1.00	713.6	6241.4	88746.6	11256.5	10200.8	440.1	1102.7	12522.5	773.2	22276.7
		STAT #1 A14-08	129.2	333.0	367.3	1737.1	161.6	63.7	52.1	114.7	35.3	213.9
2286	2095.68	1.00	1102.6	10041.6	120995.7	11304.0	16260.0	360.6	1766.9	20983.1	1531.2	35293.5
		STAT #2 A14-08	174.9	389.7	454.1	1618.3	204.6	65.1	64.1	148.9	43.7	277.7
2287	1733.22	1.00	773.3	9596.6	125702.4	17774.6	15500.2	761.7	1637.6	20400.6	1342.1	36060.4
		STAT #3 A14-08	125.5	385.5	483.3	2791.3	232.8	124.5	54.9	141.0	37.7	287.0
2288	1486.08	1.00	954.0	10176.0	111147.1	16836.4	15344.6	164.6	1912.8	19304.6	1593.8	35237.4
		STAT #4 A14-08	137.3	365.9	432.7	2114.1	217.6	71.0	70.2	136.7	43.6	283.4
2289	927.58	1.00	683.9	7396.1	104568.4	17201.1	12810.0	480.3	1464.3	15940.8	854.1	26879.9
		STAT #5 A14-08	120.9	332.8	381.2	2595.0	184.4	71.4	57.2	144.4	29.0	234.2
2290	532.16	1.00	.0	.0	.0	.0	.0	.0	6.2	29.6	.0	.0
		TRAP A14-08	.0	.0	.0	.0	.0	4.1	4.8	.0	.0	.0
* * * BEGIN STRATA # 6 * * *												
2291	.00	.00	.0	.0	3542.5	.0	218.5	.0	.0	300.4	42.8	306.4
		AURS #1 A14-08	.0	.0	208.5	.0	58.3	.0	.0	30.0	9.2	56.1
2292	710.24	79.37	472.3	4200.8	63262.6	.0	8671.4	246.3	816.5	9312.0	406.1	17036.4
		AURS #2 A14-08	173.1	468.7	753.9	.0	319.4	146.0	75.2	245.2	47.3	491.0
2293	796.55	83.15	837.7	4975.6	78692.4	.0	9937.5	.0	1247.0	10171.7	462.7	18808.7
		AURS #3 A14-08	218.0	501.6	805.6	.0	343.6	.0	99.5	193.5	47.5	471.9
2294	886.63	86.93	486.2	7593.9	98494.9	.0	11022.4	.0	1236.6	12186.5	683.3	22519.1
		AURS #4 A14-08	211.5	883.1	916.6	.0	404.4	.0	96.9	233.7	61.7	515.2
2295	981.11	91.97	1436.7	6691.4	107326.1	28107.4	12791.0	981.5	1292.7	14484.1	892.0	25473.0
		AURS #5 A14-08	366.2	714.0	990.8	7486.2	414.7	185.6	104.0	261.3	72.3	551.6
2296	1078.75	93.23	.0	6384.8	120332.2	.0	12226.2	.0	1053.6	14717.0	937.8	27831.7
		AURS #6 A14-08	.0	695.2	998.5	.0	458.1	.0	93.6	257.0	71.3	570.0
2297	1179.53	98.27	1055.4	9019.8	127977.2	.0	14479.0	287.6	1402.4	18597.4	1194.4	32733.5
		AURS #7 A14-08	362.6	786.5	1048.4	.0	485.8	172.5	108.6	326.6	92.8	635.5
2298	1282.84	98.27	1592.4	7607.0	137140.9	7215.3	14549.0	.0	1890.8	18215.5	913.0	32229.4
		AURS #8 A14-08	404.9	664.7	1057.0	4022.6	522.5	.0	148.3	308.9	73.6	631.8
2299	1372.29	70.55	.0	.0	6807.8	.0	561.4	.0	.0	529.0	88.0	1006.0
		AURS #9 A14-08	.0	.0	339.3	.0	126.1	.0	.0	53.1	15.3	170.6

TABLE 4-1 (Continued)

SPECTRUM I.D.		CORE LOCATION PARAMETERS		FUEL ELEMENT I.D.		NUCLIDE CPM + / - 1 SIGMA COUNTING ERROR							
GA. TAG NO.	AXIAL CORE LOC. CP (MM)	SCAN INTERVAL		CE-144 133 KEV	CE-141 145 KEV	PA-233 312 KEV	I-131 364 KEV	RU-103 497 KEV	RU-106 512 KEV	CS-137 661 KEV	ZR-95 724 KEV	CS-134 796 KEV	LA-140 1596 KEV
2252	1297.10	94.30		701.2	7266.8	134926.4	14855.3	13985.8	.0	1471.2	18340.4	1246.9	32701.8
		AUTO #18 A14-08		364.8	780.9	1107.7	5600.7	506.0	.0	133.5	315.7	97.4	641.5
***	STRATA # 2	A14-08 TOTALS	***										
MEAN =	1012.96	WT MEAN CPM =		760.4	6828.3	107481.7	11690.6	12076.7	413.1	1238.9	14282.4	834.3	26005.4
RMS =	184.84	WT MEAN 1SIGMA =		274.4	738.8	951.7	4196.7	418.8	169.2	112.1	274.1	76.6	561.1
MIDPT =	1020.19	WT RMS =		168.0	2101.7	22134.9	3570.3	1737.5	.0	323.2	2966.2	286.1	5690.9
RANGE =	648.12	WT ERROR =		112.9	283.4	367.3	1902.1	160.0	169.2	42.9	104.6	29.3	214.1
2253	1364.48	70.41		.0	1193.2	15352.0	.0	1560.4	.0	199.1	1795.7	194.0	3255.2
		AUTO #19 A14-08		.0	415.0	409.8	.0	200.7	.0	47.3	102.1	42.5	253.5
2254	1464.32	79.21		.0	3415.9	54008.4	.0	6447.3	223.6	704.0	8364.2	654.8	14439.0
		AUTO #20 A14-08		.0	488.9	721.4	.0	313.7	100.0	85.7	221.7	64.4	469.2
***	BEGIN STRATA # 3	***											
2255	1556.11	94.30		.0	8781.8	123071.5	18465.6	14154.4	.0	1535.6	19409.9	1468.9	33575.4
		AUTO #21 A14-08		.0	838.0	1100.8	5487.0	537.4	.0	131.5	360.5	91.8	628.3
2256	1656.69	96.81		656.9	10407.4	126773.4	13332.8	14574.7	.0	1516.3	19322.1	1733.6	32967.6
		AUTO #22 A14-08		434.1	805.1	1120.8	5649.8	512.9	.0	123.8	319.3	120.7	650.1
2257	1758.54	96.81		1159.5	9419.0	121255.4	20951.6	14906.9	.0	1493.2	19013.1	1421.6	33695.1
		AUTO #23 A14-08		302.7	953.6	1189.5	6032.7	482.1	.0	133.7	316.5	104.2	624.0
2258	1860.37	96.81		.0	10402.3	127037.7	.0	15777.2	.0	1249.1	19642.2	983.8	33849.1
		AUTO #24 A14-08		.0	954.3	1103.6	.0	476.4	.0	109.3	329.5	73.6	651.1
2259	1962.22	96.81		2117.1	9314.9	125614.4	.0	14612.2	535.7	1535.6	19730.8	1528.3	34782.0
		AUTO #25 A14-08		500.8	939.6	1111.9	.0	450.4	159.1	145.5	358.1	102.5	647.0
2260	2063.44	95.55		1567.1	10211.9	126055.5	.0	14836.9	.0	1319.6	17385.9	1166.6	29450.3
		AUTO #26 A14-08		363.6	1106.5	1070.3	.0	501.6	.0	140.0	297.9	79.8	605.1
***	STRATA # 3	A14-08 TOTALS	***										
MEAN =	1809.56	WT MEAN CPM =		1374.5	9759.5	124973.9	17575.6	14813.2	535.7	1441.4	19086.3	1383.9	33058.8
RMS =	173.47	WT MEAN 1SIGMA =		407.3	939.6	1116.9	5729.8	494.0	159.1	131.1	331.3	96.8	634.6
MIDPT =	1809.77	WT RMS =		536.9	618.4	2105.1	3185.1	494.7	.1	114.0	792.2	245.2	1694.7
RANGE =	602.89	WT ERROR =		203.7	383.6	456.1	3309.5	201.6	159.1	53.5	135.3	39.5	259.1
2261	2155.21	77.95		.0	4294.0	52050.2	.0	5694.9	.0	873.3	7364.8	622.3	13108.0
		AUTO #27 A14-08		.0	656.5	700.8	.0	275.6	.0	97.1	204.0	52.5	433.7
2262	2236.32	74.18		.0	1526.1	34942.2	.0	3430.5	304.6	572.0	4178.9	360.4	7956.3
		AUTO #28 A14-08		.0	456.8	511.5	.0	279.1	100.0	97.8	146.4	42.1	356.6
***	BEGIN STRATA # 4	***											
2263	2325.57	94.30		1167.2	10828.1	130145.7	16715.6	13932.1	871.4	1259.8	18181.8	1305.0	31723.0
		AUTO #29 A14-08		309.8	969.9	1079.3	5591.6	501.4	213.1	107.6	316.8	95.5	652.9
2264	2424.90	94.30		.0	11552.5	126159.2	.0	13062.1	367.9	933.5	17492.2	1130.3	33196.9
		AUTO #30 A14-08		.0	978.0	1081.2	.0	509.5	152.4	100.4	307.2	96.3	627.2
2265	2522.98	91.78		767.1	8013.1	119898.6	.0	13303.1	592.8	1185.5	15458.6	956.1	27375.9
		AUTO #31 A14-08		334.3	757.8	1018.6	.0	451.5	211.8	111.4	289.4	80.2	571.4

TABLE 4-1 (Continued)

SPECTRUM I.D.	CORE LOCATION PARAMETERS	FUEL ELEMENT I.D.	NUCLIDE CPM + / - 1 SIGMA COUNTING ERROR									
GA, TAG NO.	AXIAL CORE LOC. CP (CM)	SCAN INTERVAL	CE-144 133 KEV	CE-141 145 KEV	PA-233 312 KEV	I-131 364 KEV	RU-103 497 KEV	RU-106 512 KEV	CS-137 661 KEV	ZR-95 724 KEV	CS-134 796 KEV	LA-140 1596 KEV
2266	2618.53	89.27	581.9	6001.9	109757.2	.0	12659.5	.0	944.3	14423.5	840.9	25949.6
		AUTO #32 A14-08	264.3	607.5	1029.7	.0	443.5	.0	89.8	263.6	84.3	556.5
2267	2712.19	86.01	739.5	7536.4	101604.1	.0	12805.7	819.6	1358.6	13030.4	703.0	23251.1
		AUTO #33 A14-08	333.8	670.7	949.4	.0	391.5	181.6	124.9	253.3	59.8	532.7
2268	2803.35	84.24	650.2	7571.1	90597.8	16162.4	11467.0	534.9	916.7	12278.4	470.8	22614.0
		AUTO #34 A14-08	314.6	758.1	880.9	4574.9	386.5	156.5	93.3	252.3	60.7	523.3
2269	2891.36	81.72	714.3	5309.9	76662.4	12082.0	9963.1	.0	1026.3	11299.6	424.7	18575.3
		AUTO #35 A14-08	266.6	530.5	821.3	4827.3	327.3	.0	110.4	277.9	53.9	466.2
***	STRATA # 4 A14-08 TOTALS ***											
MEAN =	2614.13	WT MEAN CPM =	775.8	8204.8	108737.2	15081.5	12400.8	637.3	1091.4	14712.4	847.8	26331.2
RMS =	188.86	WT MEAN 1SIGMA =	306.1	776.0	988.7	5041.8	437.3	185.4	106.0	281.9	78.3	559.5
MIDPT =	2608.47	WT RMS =	192.3	2156.6	17892.2	2042.3	1211.9	186.0	165.0	2410.1	301.7	4773.8
RANGE =	647.52	WT ERROR =	125.3	296.1	375.8	2931.7	166.6	83.2	40.1	107.0	29.9	216.5
2270	2970.57	66.64	.0	.0	4663.2	.0	822.1	537.2	228.0	1075.9	66.4	1473.1
		AUTO #36 A14-08	.0	.0	286.6	.0	127.0	72.2	44.8	67.5	31.5	185.1
***	BEGIN STRATA # 5 ***											
2271	3042.23	66.64	.0	.0	.0	.0	.0	411.8	74.3	.0	.0	.0
		AUTO #37 A14-08	.0	.0	.0	.0	.0	35.6	27.8	.0	.0	.0
2272	3091.90	64.79	.0	.0	.0	.0	.0	471.2	.0	.0	.0	.0
		AUTO #38 A14-08	.0	.0	.0	.0	.0	40.5	.0	.0	.0	.0
2273	3161.65	64.79	.0	.0	.0	.0	.0	606.0	.0	.0	.0	.0
		AUTO #39 A14-08	.0	.0	.0	.0	.0	56.8	.0	.0	.0	.0
2274	3231.43	64.79	.0	.0	.0	.0	.0	521.0	33.7	.0	.0	.0
		AUTO #40 A14-08	.0	.0	.0	.0	.0	45.5	16.2	.0	.0	.0
2275	3301.19	64.79	.0	.0	.0	.0	.0	471.8	.0	.0	.0	.0
		AUTO #41 A14-08	.0	.0	.0	.0	.0	52.7	.0	.0	.0	.0
2276	3370.96	64.79	.0	.0	.0	.0	.0	386.3	.0	.0	.0	.0
		AUTO #42 A14-08	.0	.0	.0	.0	.0	43.3	.0	.0	.0	.0
2277	3440.73	64.79	.0	.0	.0	.0	.0	418.3	69.2	63.1	48.5	.0
		AUTO #43 A14-08	.0	.0	.0	.0	.0	40.1	19.7	33.5	19.7	.0
2278	3510.50	64.79	.0	.0	.0	.0	.0	551.2	22.3	.0	.0	.0
		AUTO #44 A14-08	.0	.0	.0	.0	.0	42.4	10.7	.0	.0	.0
2279	3579.65	63.54	.0	.0	.0	.0	.0	407.9	31.0	.0	.0	.0
		AUTO #45 A14-08	.0	.0	.0	.0	.0	44.8	13.1	.0	.0	.0
2280	3648.80	64.79	.0	.0	.0	.0	.0	294.0	45.6	64.7	32.3	.0
		AUTO #46 A14-08	.0	.0	.0	.0	.0	35.4	17.2	28.1	17.2	.0
2281	3718.57	64.79	.0	.0	.0	1879.8	.0	266.8	.0	.0	.0	.0
		AUTO #47 A14-08	.0	.0	.0	1119.2	.0	27.3	.0	.0	.0	.0
2282	3788.34	64.79	.0	.0	.0	.0	63.0	323.4	22.9	28.2	20.4	.0
		AUTO #48 A14-08	.0	.0	.0	.0	46.7	34.5	19.0	17.4	21.0	.0

TABLE 4-2
FTE-14 AND FTE-15 COMPARISON OF PREIRRADIATION ACCUMULATIVE AND PLENUM-DERIVED
COMPOSITE FUEL STACK LENGTHS

Fuel Stack (a)	Accumulative Fuel Stack		Plenum-Derived Composite Fuel Stack		Absolute Difference	Relative Difference	$\pm S_Z$	Test 1 $D = Z/S_Z$	Test 2 D^2	Test 1 Results $D \geq 1.96$ for Sign.
	Length		Length							
	x_1 (in.)	$\pm S_{x_1}$ (in.)	x_2 (in.)	$\pm S_{x_2}$ (in.)	$d = x_2 - x_1$ (in.)	$Z = x_2/x_1 - 1$				
FTE-14										
1-1	27.701	0.0004	27.456	0.007	-0.245	-0.0088	0.0003	-34.94	1221.1	Sign. ↓ Sign. Not sign. ↓ Not sign. Sign. ↓ Sign. Not sign. Sign. Sign.
1-2	27.690	0.0004	27.415	0.007	-0.275	-0.0099	0.0003	-39.22	1538.4	
1-3	27.684	0.0004	27.417	0.007	-0.267	-0.0096	0.0003	-38.08	1450.2	
1-4	27.623	0.0004	27.347	0.007	-0.276	-0.0100	0.0003	-39.37	1549.6	
1-5	27.623	0.0004	27.344	0.007	-0.279	-0.0101	0.0003	-39.79	1583.5	
1-6	27.639	0.0004	27.354	0.007	-0.285	-0.0103	0.0003	-40.65	1652.3	
2-1	27.375	0.0004	27.365	0.007	-0.010	-0.0004	0.0003	-1.43	2.0	
2-2	27.448	0.0004	27.440	0.007	-0.008	-0.0003	0.0003	-1.14	1.3	
2-3	27.324	0.0004	27.313	0.007	-0.011	-0.0004	0.0003	-1.57	2.5	
2-4	27.445	0.0004	27.439	0.007	-0.006	-0.0002	0.0003	-0.86	0.7	
2-5	27.503	0.0004	27.454	0.007	-0.049	-0.0018	0.0003	-6.99	48.8	
2-6	27.529	0.0004	27.489	0.007	-0.040	-0.0015	0.0003	-5.71	32.6	
3-1	27.395	0.0004	27.376	0.007	-0.019	-0.0007	0.0003	-2.71	7.3	
3-2	27.551	0.0004	27.500	0.007	-0.051	-0.0019	0.0003	-7.27	52.9	
3-3	27.337	0.0004	27.323	0.007	-0.014	-0.0005	0.0003	-2.00	4.0	
3-4	27.437	0.0004	27.437	0.007	0.000	0.000	0.0003	0.00	0.0	
3-5	27.462	0.0004	27.425	0.007	-0.037	-0.0013	0.0003	-5.28	27.8	
3-6	27.508	0.0004	27.488	0.007	-0.020	-0.0007	0.0003	-2.85	8.1	
$\bar{x}, \bar{S}_{\bar{x}}$	27.515	± 0.0004	27.410	± 0.007	-0.105	-0.0038	± 0.0003	-14.99		
RMS, $\bar{S}_{\bar{x}}$	± 0.118	± 0.0001	± 0.057	± 0.002	± 0.118	± 0.0043	± 0.0001	± 16.83		
								14.99 > 1.6		Group goodness of fit is sign.
FTE-15										
1-1	27.688	0.0004	27.350	0.007	-0.338	-0.0122	0.0003	-48.21	2324.1	Sign. ↓ Sign. Not sign. Sign. ↓ Sign. Not sign. Sign. Not sign.
1-2	27.691	0.0004	27.358	0.007	-0.333	-0.0121	0.0003	-47.96	2255.8	
1-3	27.558	0.0004	27.230	0.007	-0.328	-0.0119	0.0003	-46.78	2188.6	
1-4	27.570	0.0004	27.234	0.007	-0.336	-0.0122	0.0003	-47.92	2296.7	
1-5	27.593	0.0004	27.261	0.007	-0.332	-0.0120	0.0003	-47.35	2242.3	
1-6	27.663	0.0004	27.308	0.007	-0.325	-0.0118	0.0003	-46.35	2148.7	
2-1	27.381	0.0004	27.355	0.007	-0.026	-0.0010	0.0003	-3.71	13.75	
2-2	27.495	0.0004	27.438	0.007	-0.057	-0.0021	0.0003	-8.13	66.1	
2-3	27.323	0.0004	27.309	0.007	-0.014	-0.0005	0.0003	-2.00	4.0	
2-4	27.471	0.0004	27.468	0.007	-0.003	-0.0001	0.0003	-0.43	0.2	
2-5	27.480	0.0004	27.444	0.007	-0.036	-0.0013	0.0003	-5.13	26.4	
2-6	27.532	0.0004	27.509	0.007	-0.023	-0.0008	0.0003	-3.28	10.8	
3-1	27.432	0.0004	27.395	0.007	-0.037	-0.0013	0.0003	-5.28	27.8	
3-2	27.479	0.0004	27.454	0.007	-0.025	-0.0009	0.0003	-3.57	12.7	
3-3	27.337	0.0004	27.321	0.007	-0.016	-0.0006	0.0003	-2.28	5.3	
3-4	27.476	0.0004	27.463	0.007	-0.013	-0.0005	0.0003	-1.85	3.4	
3-5	27.499	0.0004	27.463	0.007	-0.036	-0.0013	0.0003	-5.13	26.4	
3-6	27.498	0.0004	27.491	0.007	-0.007	-0.0003	0.0003	-1.00	1.0	
$\bar{x}, \bar{S}_{\bar{x}}$	27.508	± 0.0004	27.381	± 0.007	-0.127	-0.0046	± 0.0003	-18.13		
RMS, $\bar{S}_{\bar{x}}$	± 0.101	± 0.0001	± 0.087	± 0.002	± 0.145	± 0.0053	± 0.0001	± 20.71		
								18.13 > 1.60		Group goodness of fit is sign.
FTE-14 and FTE-15										
$\bar{x}, \bar{S}_{\bar{x}}$	27.511	0.0004	27.396	± 0.007	-0.116	-0.0042	± 0.0003	-16.56		Sign.
RMS, $\bar{S}_{\bar{x}}$	± 0.110	± 0.0001	± 0.072	± 0.001	± 0.132	± 0.0048	± 0.0001	± 18.77		
								16.56 > 1.40		Group goodness of fit is sign.

(a) 1-2 = fuel body 1, stack 2.

TABLE 4-3a
FTE-15 COMPARISON OF POSTIRRADIATION ACCUMULATIVE AND COMPOSITE FUEL STACK LENGTHS

Fuel Stack (a)	Accumulative Fuel Stack		Composite Fuel Stack		Absolute Difference d = x ₂ -x ₁ (in.)	Relative Difference		Test 1 D = Z/S _Z	Test 2 D ²	Test 1 Results D ≥ 1.96 for Sign.
	Length		Length			Difference				
	x ₁ (in.)	±S _{x₁} (in.)	x ₂ (in.)	±S _{x₂} (in.)		Z = x ₂ /x ₁ - 1	±S _Z			
1-1	26.894	0.0004	26.888	0.002	-0.006	-0.0002	0.0001	-2.94	8.70	Sign.
1-2	ND	---	26.654	0.002	--	--	--	--	--	--
1-3	26.852	0.0004	26.680	0.002	-0.172	-0.0064	0.0001	-84.35	7115.00	Sign.
1-4	26.824	0.0004	26.679	0.002	-0.231	-0.0054	0.0001	-71.11	5056.20	Sign.
1-5	26.910	0.0004	26.626	0.002	-0.284	-0.0106	0.0001	-139.30	19404.10	Sign.
1-6	ND	---	26.629	0.002	--	--	--	--	--	--
2-1	26.791	0.0004	26.725	0.002	-0.066	-0.0025	0.0001	-32.36	1047.30	Sign.
2-2	27.251	0.0004	27.230	0.002	-0.561	-0.0008	0.0001	-10.30	106.00	Sign.
2-3	26.730	0.0004	26.781	0.002	0.051	0.0019	0.0001	25.03	625.10	Sign.
2-4	26.888	0.0004	27.001	0.002	0.113	0.0042	0.0001	55.39	3068.50	Sign.
2-5	26.744	0.0004	26.771	0.002	0.027	0.0010	0.0001	13.37	175.20	Sign.
2-6	27.329	0.0004	27.320	0.002	-0.009	-0.0003	0.0001	-4.41	19.47	Sign.
3-1	26.839	0.0004	26.814	0.002	-0.025	-0.0009	0.0001	-12.26	150.25	Sign.
3-2	27.199	0.0004	27.179	0.002	-0.020	-0.0007	0.0001	-9.81	96.16	Sign.
3-3	26.783	0.0004	26.776	0.002	-0.007	-0.0003	0.0001	-3.43	11.78	Sign.
3-4	26.950	0.0004	26.936	0.002	-0.014	-0.0005	0.0001	-6.86	47.12	Sign.
3-5	26.985	0.0004	26.991	0.002	0.006	0.0002	0.0001	2.94	8.65	Sign.
3-6	27.203	0.0004	27.177	0.002	-0.026	-0.0010	0.0001	-12.75	162.51	Sign.
$\bar{x}, S_{\bar{x}}$	26.963	0.0004	26.911	0.002	-0.083	-0.0014	0.0001	-18.32	2318.90	
RMS, $S_{S_{\bar{x}}}$	0.183	0.0001	0.211	0.001	0.156	0.0034	<0.00005	44.54	4858.50	
								18.32 > 1.64		
Group goodness of fit is sign.										

(a) Stack 1-2 = fuel body 1, hole 2.

TABLE 4-3b
FTE-15 COMPARISON OF POSTIRRADIATION COMPOSITE AND PEACH BOTTOM GAMMA SCAN DERIVED FUEL STACK LENGTHS

Fuel Stack (a)	Composite Fuel Stack		Gamma Scan Fuel Stack		Absolute Difference	Relative Difference		Test 1 D = Z/S _Z	Test 2 D ²	Test 1 Results, D ≥ 1.96 for Sign.
	Length(b)		Length							
	x ₁ (in.)	±S _{x1} (in.)	x ₂ (in.)	±S _{x2} (in.)	x ₂ -x ₁ (in.)	Z = x ₂ /x ₁ - 1	±S _Z			
Composite Stack Versus γ-scan										
1-1, 1-3	26.719	0.100	26.895	0.066	0.176	0.0066	0.0045	1.46	2.14	Not sign.
1-4, 1-6										
2-1, 2-3	26.957	0.234	27.358	0.063	0.401	0.0149	0.0091	1.63	2.66	Not sign.
2-4, 2-6										
3-1, 3-3	26.926	0.157	27.374	0.013	0.448	0.0166	0.0056	2.80	7.83	Sign.
3-4, 3-6										
$\bar{x}, S_x$	26.867	0.173	27.209	0.053	0.342	0.0127	0.0067	1.96	4.21	Group goodness of fit is not sign.
RMS, S_{S_x}	0.106	0.100	0.222	0.031	0.119	0.0044	0.0039	0.60	2.57	
								1.96 < 2.60		
Plenum-Derived Composite Stack Versus γ-scan										
1-1, 1-3	26.878	0.045	26.895	0.066	0.017	0.0006	0.0030	0.21	0.05	Not sign.
1-4, 1-6										
2-1, 2-3	26.859	0.123	27.358	0.063	0.499	0.0186	0.0052	3.56	12.66	Sign.
2-4, 2-6										
3-1, 3-3	27.090	0.070	27.374	0.013	0.268	0.0105	0.0027	3.95	15.59	Sign.
3-4, 3-6										
$\bar{x}, S_x$	26.942	0.086	27.209	0.053	0.261	0.0099	0.0038	2.57	9.43	Group goodness of fit is not sign.
RMS, S_{S_x}	0.105	0.050	0.222	0.031	0.197	0.0074	0.0022	1.68	6.74	
								2.57 < 2.60		

(a) Stack 1-3 = body 1, hole 3.

(b) Average of stacks seen by collimator path (i.e., holes 1, 3, 4, 6).

TABLE 4-4a
FTE-14 THERMOCOUPLE RESISTANCE MEASUREMENTS^(a)

Thermocouple Type	+ to Ground Circuit (Ω)			- to Ground Circuit (Ω)			Loop (Ω)			Remarks
	Pre- irrad.	Post- irrad.	$\Delta\Omega$	Pre- irrad.	Post- irrad.	$\Delta\Omega$	Pre- irrad.	Post- irrad.	$\Delta\Omega$	
Thermocouple A (ARI S/N 38247), W-3% Re/W-25% Re	3.8	11.1	+7.3	9.6	11.3	+1.7	13.1	14.5	+1.4	Satisfactory
Thermocouple B, (ARI S/N 37047) C/A	28.0	--	--	12.0	--	--	39.6	--	--	No reading could be measured. An open circuit is suspected.

(a) Accuracy $\pm 1\Omega$.

TABLE 4-4b
FTE-15 THERMOCOUPLE RESISTANCE MEASUREMENTS^(a)

Thermocouple Type	+ to Ground Circuit (Ω)			- to Ground Circuit (Ω)			Loop (Ω)			Remarks
	Pre- irrad.	Post- irrad.	$\Delta\Omega$	Pre- irrad.	Post- irrad.	$\Delta\Omega$	Pre- irrad.	Post- irrad.	$\Delta\Omega$	
Thermocouple A (ARI S/N 38246) W-3% Re/W-25% Re	3.8	--	--	9.6	--	--	13.1	--	--	No reading, open circuit.
Thermocouple B (ARI S/N 22183) C/A	29.7	--	--	13.3	--	--	42.5	42.0	-0.5	Loss of grounding and possible short circuit.

(a) Accuracy $\pm 1\Omega$.

TABLE 4-5
FTE-14 AND FTE-15 DISTANCE (d) FROM TOP OF SPINE
SAMPLE TO EDGE OF HOLE^(a)

Element	Body No.	Spine Stack Length, L (mm)	Preirrad. d ₁ (mm)	Postirrad. d ₂ (mm)	Δd (mm)	$\Delta G^{(b)}$ (mm)	$-\Delta d + \Delta G$ L (%)
FTE-14	1	764.67	13.08	13.18	+0.10	-0.66	-0.10
FTE-14	2	751.46	26.29	27.61	+1.32	-2.90	-0.56
FTE-14	3	746.00	29.72	29.59	-3.12	-0.48	+0.35
FTE-15	1	766.88	13.54	14.12	+0.58	-1.89	-0.32
FTE-15	2	753.62	26.80	29.03	+2.24	-4.03	-0.83
FTE-15	3	753.19	27.305	27.99	+0.69	-3.18	-0.51

(a) Top surface of fuel body.

(b) Fuel body shrinkage.

TABLE 4-6
FTE-15 FUEL ROD REMOVAL SUMMARY

Body No.	Hole No.	Force (kg)	
		Initial	Sustaining
1	1	15.4	18.6
	2	15.4	≈ 0
	3	15.4	≈ 0
	4	4.8	≈ 0
	5	15.4	≈ 0
	6	10.0	≈ 0
2	1	13.6	9.1
	2	18.1	13.6
	3	13.6	4.5
	4	10.9	≈ 0
	5	24.5	5.0
	6	10.9	10.9
3	1	14.5	9.1
	2	10.0	≈ 0
	3	5.0	≈ 0
	4	9.1	4.5
	5	27.2	18.1
	6	2.3	≈ 0

TABLE 4-7a
FTE-14 TOTAL ELEMENT DATA

PARAMETER	VALUE	ACCURACY
PRE-IRRADIATION LENGTH (L1) (IN)	144.3030	.03125
POST-IRRADIATION LENGTH (L2) (IN)	144.4060	.03125
DIFFERENCE (L2-L1) (IN)	.10300	.06250
STRAIN (L2/L1-1) (%)	.07138	.04333

FUEL BODY WEIGHT, TEST ELEMENT FTE-14

FUEL BODY	PRE-IRRADIATION WEIGHT G	ACCURACY G	POST-IRRADIATION WEIGHT G	ACCURACY G	DIFFERENCE WEIGHT G	ACCURACY G	REL. CHANGE VALUE %	ACCURACY %
1	5243.50	1.0000	5423.20	1.0000	179.70	2.0000	3.4271	.0388
2	5207.50	1.0000	5219.00	1.0000	11.50	2.0000	.2208	.0384
3	5172.00	1.0000	5178.50	1.0000	6.50	2.0000	.1257	.0387

TABLE 4-7b
FTE-15 TOTAL ELEMENT DATA

PARAMETER	VALUE	ACCURACY
PRE-IRRADIATION LENGTH (L1) (IN)	145.6550	.03125
POST-IRRADIATION LENGTH (L2) (IN)	144.5000	.03125
DIFFERENCE (L2-L1) (IN)	*****	.06250
STRAIN (L2/L1-1) (%)	-.79297	.04274

FUEL BODY WEIGHT, TEST ELEMENT FTE-15

FUEL BODY	PRE-IRRADIATION WEIGHT G	ACCURACY G	POST-IRRADIATION WEIGHT G	ACCURACY G	DIFFERENCE WEIGHT G	ACCURACY G	REL. CHANGE VALUE %	ACCURACY %
1	5405.50	1.0000	5407.25	1.0000	1.75	2.0000	.0324	.0370
2	5191.50	1.0000	5197.25	1.0000	5.75	2.0000	.1108	.0385
3	5099.70	1.0000	5098.00	1.0000	-1.70	2.0000	-.0333	.0392

TABLE 4-8
COMPARISON OF FTE-14 AND FTE-15
TOTAL LENGTH DATA WITH OTHER TEST ELEMENT DATA

Fuel Element	Strain (%)	Error (1σ) (%)	Exposure (EFPD)	Mean Fast Fluence (nvt)	Mean Sleeve Temp. ($^{\circ}\text{C}$)
FTE-3	+0.07	± 0.08	133	0.43	661
FTE-14	+0.07	± 0.08	317	1.15	730
FTE-4	+0.35	± 0.08	449	1.53	696
FTE-18	-0.19	± 0.08	512	1.94	683
FTE-15	-0.79	± 0.08	512	1.68	709
FTE-6	-0.62	± 0.08	645	2.30	712
FTE-5	-0.39	± 0.08	897	2.99	686

TABLE 4-9
FTE-14 SLEEVE METROLOGY DATA

(Based on O.D. Measurements)

PRECISION1 DIAMETER = .00020 EQUIPMENT RANDOM ERROR DIAMETER = .00015					PRECISION1 DIAMETER = .00030 EQUIPMENT RANDOM ERROR DIAMETER = .00035												
CORE HEIGHT	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN					
	IN X1	NX1	MIL SX1	MIL EX1	IN X2	NX2	MIL SX2	MIL EX2	IN X21	MIL SX21	MIL DX21	% UX	% EX	% RX	% SX	% EPX	% DX
7.16	3.4868	1	.700	.718	3.5852	2	.582	.544	.0985	.910	1.766	2.824	.015	.011	.027	.026	.052
31.16	3.4868	1	.700	.718	3.5853	2	.283	.408	.0985	.755	1.619	2.825	.015	.011	.022	.024	.047
55.16	3.4868	1	.700	.718	3.5831	2	.495	.499	.0964	.857	1.714	2.763	.014	.011	.025	.026	.050
79.16	3.4868	1	.700	.718	3.5830	2	.707	.613	.0962	.995	1.851	2.759	.014	.011	.029	.028	.054
103.16	3.4868	1	.700	.718	3.5831	2	.283	.408	.0963	.755	1.619	2.762	.014	.011	.022	.024	.047
119.73	3.4868	1	.700	.718	3.5814	2	.483	.493	.0946	.851	1.707	2.713	.014	.011	.025	.025	.050
TEST ELEMENT AVG.	3.4868	6	.700	.324	3.5835	12	1.476	.552	.0967	1.633	1.254	2.774	.014	.011	.047	.018	.036

TABLE 4-10
FTE-15 SLEEVE METROLOGY DATA

(Based on O.D. Measurements)

PRECISION:
DIAMETER = .00020
EQUIPMENT RANDOM ERROR:
DIAMETER = .00015

PRECISION:
DIAMETER = .00030
EQUIPMENT RANDOM ERROR:
DIAMETER = .00035

CORE HEIGHT	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN					
	IN X1	NX1	MIL SX1	MIL EX1	IN X2	NX2	MIL SX2	MIL EX2	IN X21	MIL SX21	MIL DX21	% UX	% EX	% RX	% SX	% EPX	% DX
7.16	3.4868	1	.700	.718	3.4810	1	.600	.700	-.0058	.922	1.966	-.166	.014	.011	.026	.029	.056
31.16	3.4868	1	.700	.718	3.4840	1	.600	.700	-.0028	.922	1.966	-.080	.014	.011	.026	.029	.056
55.16	3.4868	1	.700	.718	3.4860	1	.600	.700	-.0008	.922	1.966	-.023	.014	.011	.026	.029	.056
79.16	3.4868	1	.700	.718	3.4800	1	.600	.700	-.0068	.922	1.966	-.195	.014	.011	.026	.029	.056
103.16	3.4868	1	.700	.718	3.4820	1	.600	.700	-.0048	.922	1.966	-.138	.014	.011	.026	.029	.056
119.73	3.4868	1	.700	.718	3.4850	1	.600	.700	-.0018	.922	1.966	-.052	.014	.011	.026	.029	.056
TEST ELEMENT AVG.	3.4868	6	.700	.324	3.4830	6	2.242	.981	-.0038	2.349	2.024	-.109	.014	.011	.067	.030	.058

(Based on I.D. Measurements)

PRECISION:
DIAMETER = .00020
EQUIPMENT RANDOM ERROR:
DIAMETER = .00015

PRECISION:
DIAMETER = .00030
EQUIPMENT RANDOM ERROR:
DIAMETER = .00035

CORE HEIGHT	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN					
	IN X1	NX1	MIL SX1	MIL EX1	IN X2	NX2	MIL SX2	MIL EX2	IN X21	MIL SX21	MIL DX21	% UX	% EX	% RX	% SX	% EPX	% DX
24.75	2.7522	1	.800	.816	2.7448	1	.500	.616	-.0074	.943	2.004	-.269	.018	.014	.034	.037	.073
72.24	2.7522	1	.800	.816	2.7449	1	.500	.616	-.0073	.943	2.004	-.265	.018	.014	.034	.037	.073
119.73	2.7522	1	.800	.816	2.7489	1	.500	.616	-.0033	.943	2.004	-.120	.018	.014	.034	.037	.073
TEST ELEMENT AVG.	2.7522	3	.800	.487	2.7462	3	1.974	1.193	-.0060	2.130	2.526	-.218	.018	.014	.077	.047	.092

TABLE 4-11a
FTE-14 FUEL BODY METROLOGY DATA - FUEL BODY 1

		PRECISION:				PRECISION:													
		LENGTH = .00040				LENGTH = .00060													
		DIAMETER = .00030				DIAMETER = .00030													
		EQUIPMENT RANDOM ERROR:				EQUIPMENT RANDOM ERROR:													
		LENGTH = .00200				LENGTH = .00200													
		DIAMETER = .00035				DIAMETER = .00035													
CORE HEIGHT	OUTER DIAMETER	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN						
		IN X1	NX1	MIL SX1	MIL EX1	IN X2	NX2	MIL SX2	MIL EX2	IN X21	MIL SX21	MIL DX21	% UX	% EX	% RX	% SX	% EPX	% DX	
25.85		2.7393	2	.410	.459	2.7380	2	.410	.459	-.0013	.580	1.271	-.047	.022	.018	.021	.024	.046	
26.85		2.7393	2	.410	.459	2.7379	2	.071	.359	-.0014	.416	1.141	-.051	.022	.018	.015	.021	.042	
27.85		2.7393	2	.410	.459	2.7380	2	.428	.467	-.0014	.593	1.283	-.049	.022	.018	.022	.024	.047	
29.00		2.7393	2	.410	.459	2.7385	3	.406	.424	-.0009	.577	1.225	-.032	.022	.018	.021	.023	.045	
30.85		2.7393	2	.410	.459	2.7387	4	.497	.431	-.0007	.644	1.234	-.025	.022	.018	.024	.023	.045	
32.75		2.7393	2	.410	.459	2.7387	4	.571	.454	-.0006	.703	1.265	-.022	.022	.018	.026	.024	.046	
34.70		2.7393	2	.000	.355	2.7389	5	.550	.429	-.0004	.550	1.092	-.013	.022	.018	.020	.020	.040	
36.85		2.7393	2	.000	.355	2.7389	4	.446	.417	-.0004	.446	1.074	-.016	.022	.018	.016	.020	.039	
39.00		2.7393	2	.000	.355	2.7395	4	1.207	.699	.0002	1.207	1.537	.006	.022	.018	.044	.029	.056	
41.00		2.7393	2	.000	.355	2.7386	4	.602	.464	-.0007	.602	1.145	-.024	.022	.018	.022	.021	.042	
43.00		2.7393	2	.000	.355	2.7387	4	.553	.448	-.0006	.553	1.121	-.021	.022	.018	.020	.021	.041	
45.00		2.7393	2	.000	.355	2.7386	4	.629	.472	-.0007	.629	1.159	-.024	.022	.018	.023	.022	.042	
46.90		2.7393	2	.000	.355	2.7385	4	.766	.521	-.0008	.766	1.235	-.030	.022	.018	.028	.023	.045	
48.85		2.7394	2	.000	.355	2.7382	4	.552	.448	-.0012	.552	1.120	-.045	.022	.018	.020	.021	.041	
50.85		2.7394	2	.000	.355	2.7382	4	.407	.407	-.0012	.407	1.059	-.042	.022	.018	.015	.020	.039	
52.85		2.7394	2	.000	.355	2.7380	4	1.557	.855	-.0014	1.557	1.815	-.050	.022	.018	.057	.034	.066	
53.85		2.7394	2	.000	.355	2.7387	3	.648	.515	-.0007	.648	1.226	-.024	.022	.018	.024	.023	.045	
54.85		2.7394	2	.000	.355	2.7382	2	.778	.655	-.0012	.778	1.460	-.042	.022	.018	.028	.027	.053	
BODY	0	31.1000	1	1.202	2.340	31.0735	2	1.202	2.177	-.0264	1.700	6.264	-.085	.004	.009	.005	.010	.020	
AVG.	X	2.7393	36	.175	.352	2.7386	63	.728	.362	-.0008	.749	.989	-.028	.022	.018	.027	.016	.036	
	(G+X)/2												-.057	.013	.010	.014	.011	.021	
	0/X												299.54	244.6	193.3	288.9	197.6	387.4	

TABLE 4-11b
FTE-14 FUEL BODY METROLOGY DATA - FUEL BODY 2

PRECISION:					PRECISION:														
LENGTH = .00060					LENGTH = .00060														
DIAMETER = .00030					DIAMETER = .00030														
EQUIPMENT RANDOM ERROR:					EQUIPMENT RANDOM ERROR:														
LENGTH = .00200					LENGTH = .00200														
DIAMETER = .00035					DIAMETER = .00035														
CORE HEIGHT	OUTER DIAMETER	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE				STRAIN					
		IN X1	MIL NX1	MIL SX1	MIL EX1	IN X2	MIL NX2	MIL SX2	MIL EX2	IN X21	MIL SX21	MIL DX21	% UX	% EX	% RX	% SX	% EPX	% DX	
57.96		2.7297	3	.700	.537	2.7284	4	1.485	.822	-.0013	1.642	1.925	-.048	.022	.018	.060	.036	.070	
58.96		2.7297	3	.700	.537	2.7279	3	2.043	1.232	-.0018	2.160	2.634	-.066	.022	.018	.079	.049	.096	
59.96		2.7297	3	.700	.537	2.7271	3	.712	.542	-.0027	.999	1.496	-.098	.022	.018	.037	.028	.055	
61.80		2.7297	3	.700	.537	2.7262	4	1.107	.656	-.0036	1.310	1.662	-.130	.022	.018	.048	.031	.061	
63.80		2.7297	3	.700	.537	2.7251	4	1.227	.708	-.0046	1.412	1.741	-.168	.022	.018	.052	.033	.064	
65.70		2.7030	3	.492	.453	2.7007	5	3.628	1.660	-.0023	3.661	3.373	-.084	.022	.018	.135	.064	.125	
67.70		2.7030	3	.492	.453	2.6975	5	2.448	1.150	-.0055	2.497	2.423	-.205	.022	.018	.092	.046	.090	
69.70		2.7030	3	.492	.453	2.6963	5	4.441	2.017	-.0067	4.468	4.052	-.246	.022	.018	.165	.076	.150	
71.46		2.7030	3	.492	.453	2.6960	5	4.183	1.903	-.0070	4.211	3.835	-.257	.022	.018	.156	.072	.142	
73.70		2.7234	3	.407	.425	2.7178	5	1.735	.852	-.0055	1.782	1.866	-.204	.022	.018	.065	.035	.068	
75.70		2.7234	3	.407	.425	2.7185	5	1.680	.830	-.0048	1.729	1.827	-.177	.022	.018	.063	.034	.067	
77.70		2.7393	3	.000	.354	2.7346	4	.716	.503	-.0047	.716	1.204	-.170	.022	.018	.026	.022	.044	
79.70		2.7393	3	.000	.354	2.7348	5	.704	.472	-.0045	.704	1.157	-.163	.022	.018	.026	.022	.042	
81.70		2.7393	3	.000	.354	2.7356	5	1.554	.779	-.0037	1.554	1.677	-.134	.022	.018	.057	.031	.061	
83.96		2.7393	3	.000	.354	2.7380	2	.428	.467	-.0013	.428	1.148	-.047	.022	.018	.016	.021	.042	
84.96		2.7393	3	.000	.354	2.7386	2	.212	.386	-.0008	.212	1.025	-.027	.022	.018	.008	.019	.037	
85.96		2.7393	3	.000	.354	2.7384	2	.410	.459	-.0009	.410	1.135	-.031	.022	.018	.015	.021	.041	
BODY	G	31.1060	1	3.860	4.351	30.9922	2	3.860	3.386	-.1137	5.460	10.807	-.366	.004	.009	.018	.018	.035	
AVG.	X	2.7261	51	13.993	1.990	2.7197	68	15.674	1.933	-.0064	21.011	5.438	-.234	.022	.018	.770	.102	.199	
	(G*X)/2												-.300	.013	.010	.385	.052	.101	
	G/X												156.45	16.4	12.7	515.4	68.5	134.2	

TABLE 4-11c
FTE-14 FUEL BODY METROLOGY DATA - FUEL BODY 3

		PRECISION:				PRECISION:													
		LENGTH = .00060				LENGTH = .00060													
		DIAMETER = .00030				DIAMETER = .00030													
		EQUIPMENT RANDOM ERROR:				EQUIPMENT RANDOM ERROR:													
		LENGTH = .00200				LENGTH = .00200													
		DIAMETER = .00035				DIAMETER = .00035													
CORE HEIGHT	OUTER DIAMETER	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN						
		IN X1	MTL NX1	MIL SX1	MIL EX1	IN X2	MTL NX2	MIL SX2	MIL EX2	IN X21	MIL SX21	MIL DX21	% UX	% EX	% RX	% SX	% EPX	% DX	
87.51		2.7400	3	.000	.354	2.7379	1	.530	.641	-.0021	.530	1.435	-.077	.022	.018	.019	.027	.052	
104.50		2.6900	3	.490	.453	2.6886	4	7.139	3.587	-.0014	7.156	7.086	-.053	.022	.018	.266	.134	.263	
106.85		2.6900	3	.490	.453	2.6863	4	2.399	1.250	-.0037	2.448	2.606	-.138	.022	.018	.091	.049	.097	
108.04		2.6900	3	.490	.453	2.6850	1	.530	.641	-.0050	.722	1.538	-.186	.022	.018	.027	.029	.057	
109.26		2.6900	3	.490	.453	2.6870	4	3.349	1.711	-.0030	3.385	3.470	-.110	.022	.018	.126	.066	.129	
111.20		2.6900	3	.490	.453	2.6869	4	2.163	1.137	-.0030	2.217	2.399	-.113	.022	.016	.082	.046	.089	
113.14		2.6900	3	.490	.453	2.6876	4	2.576	1.335	-.0024	2.622	2.764	-.090	.022	.018	.097	.052	.103	
115.08		2.6900	3	.490	.453	2.6882	4	2.982	1.532	-.0018	3.022	3.131	-.068	.022	.018	.112	.059	.116	
116.21		2.6900	3	.490	.453	2.6916	3	4.450	2.594	.0016	4.477	5.160	.061	.022	.018	.166	.098	.192	
BODY	0	31.0180	1	11.282	11.459	30.9990	2	11.282	8.225	-.0190	15.955	27.647	-.061	.004	.009	.051	.045	.089	
AVG.	X	2.6956	27	16.017	3.102	2.6895	29	17.001	3.176	-.0060	23.358	8.702	-.224	.022	.018	.866	.165	.322	
	(0+X)/2												-.142	.013	.010	.434	.065	.167	
	0/X												27.39	4.5	4.7	108.5	28.6	56.1	

TABLE 4-12a
FTE-15 FUEL BODY METROLOGY DATA - FUEL BODY 1

PRECISION:										PRECISION:									
LENGTH = .00060										LENGTH = .00060									
DIAMETER = .00030										DIAMETER = .00030									
EQUIPMENT RANDOM ERROR:										EQUIPMENT RANDOM ERROR:									
LENGTH = .00200										LENGTH = .00200									
DIAMETER = .00035										DIAMETER = .00035									
		PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN						
CORE	OUTER	IN	MIL	MIL	IN	MIL	MIL	MIL	IN	MIL	MIL								
HEIGHT	DIAMETER	X1	NX1	SX1	EX1	X2	NX2	SX2	EX2	X21	SX21	DX21	UX	EX	RX	SX	EPX	DX	
25.85		2.7392	3	.693	.534	2.7381	4	.648	.479	.0011	.949	1.406	-.039	.022	.018	.035	.026	.051	
26.85		2.7392	3	.693	.534	2.7372	3	.516	.462	.0020	.864	1.384	-.072	.022	.018	.032	.026	.051	
28.85		2.7392	3	.693	.534	2.7372	3	.432	.433	.0020	.816	1.347	-.074	.022	.018	.030	.025	.049	
30.85		2.7392	3	.693	.534	2.7370	5	.546	.429	.0022	.882	1.342	-.079	.022	.018	.032	.025	.049	
32.85		2.7392	3	.693	.534	2.7373	4	.591	.460	.0019	.911	1.382	-.069	.022	.018	.033	.026	.050	
34.85		2.7398	3	.624	.505	2.7375	5	.704	.472	.0023	.941	1.355	-.083	.022	.018	.034	.025	.049	
36.85		2.7398	3	.624	.505	2.7374	5	.638	.453	.0023	.893	1.330	-.086	.022	.018	.033	.025	.049	
38.85		2.7398	3	.624	.505	2.7370	5	.670	.462	.0027	.916	1.342	-.100	.022	.018	.033	.025	.049	
40.85		2.7398	3	.624	.505	2.7367	5	.760	.489	.0031	.983	1.378	-.112	.022	.018	.036	.026	.050	
42.85		2.7398	3	.624	.505	2.7359	5	.723	.478	.0039	.956	1.363	-.143	.022	.018	.035	.025	.050	
44.85		2.7398	3	.624	.505	2.7356	5	.511	.420	.0042	.807	1.287	-.152	.022	.018	.029	.024	.047	
46.85		2.7398	3	.624	.505	2.7349	5	.866	.524	.0048	1.068	1.426	-.177	.022	.018	.039	.027	.052	
48.85		2.7398	3	.640	.512	2.7348	5	.853	.519	.0050	1.067	1.429	-.184	.022	.018	.039	.027	.052	
49.97		2.7398	3	.640	.512	2.7355	3	.728	.549	.0043	.969	1.471	-.157	.022	.018	.035	.027	.054	
50.85		2.7398	3	.640	.512	2.7354	5	.878	.527	.0044	1.086	1.440	-.162	.022	.018	.040	.027	.053	
51.97		2.7398	3	.640	.512	2.7359	3	.291	.392	.0040	.703	1.263	-.145	.022	.018	.026	.023	.046	
54.96		2.7398	3	.640	.512	2.7370	3	1.040	.697	.0028	1.221	1.694	-.103	.022	.018	.045	.032	.062	
BODY	G	31.1050	1	3.536	4.066	31.0330	2	3.536	3.204	-.0720	5.000	10.146	.231	.004	.009	.016	.017	.033	
AVG.	X	2.7396	51	.602	.360	2.7365	73	1.177	.376	-.0032	1.322	1.021	-.115	.022	.018	.048	.019	.037	
	(G+X)/2												-.173	.013	.010	.025	.013	.025	
	G/X												200.64	41.4	32.4	85.1	36.1	70.7	

TABLE 4-12b
FTE-15 FUEL BODY METROLOGY DATA - FUEL BODY 2

PRECISION:					PRECISION:													
LENGTH = .00060					LENGTH = .00060													
DIAMETER = .00030					DIAMETER = .00030													
EQUIPMENT RANDOM ERROR:					EQUIPMENT RANDOM ERROR:													
LENGTH = .00200					LENGTH = .00200													
DIAMETER = .00035					DIAMETER = .00035													
		PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN					
CORE	OUTER	IN	MIL	MIL	IN	MIL	MIL	IN	MIL	MIL	%	%	%	%	%	%		
HEIGHT	DIAMETER	X1	NX1	SX1	EX1	X2	NX2	SX2	EX2	X21	SX21	DX21	UX	EX	RX	SX	EPX	DX
56.96		2.7288	3	.533	.469	2.7256	3	1.322	.841	-.0032	1.426	1.888	-.118	.022	.018	.052	.035	.069
57.96		2.7288	3	.533	.469	2.7248	3	.389	.419	-.0040	.660	1.232	-.147	.022	.018	.024	.023	.045
59.96		2.7288	3	.533	.469	2.7237	3	1.227	.792	-.0051	1.338	1.803	-.186	.022	.018	.049	.034	.066
61.96		2.7288	3	.533	.469	2.7234	5	1.719	.845	-.0054	1.799	1.895	-.197	.022	.018	.066	.035	.069
63.96		2.7288	3	.533	.469	2.7213	3	3.042	1.792	-.0075	3.089	3.630	-.276	.022	.018	.113	.068	.133
65.96		2.7037	3	.810	.586	2.6952	5	5.212	2.357	-.0084	5.275	4.761	-.312	.022	.018	.195	.090	.176
67.96		2.7037	3	.810	.586	2.6923	5	5.274	2.385	-.0113	5.336	4.813	-.420	.022	.018	.197	.091	.178
69.96		2.7037	3	.810	.586	2.6916	5	3.081	1.422	-.0121	3.186	3.015	-.447	.022	.018	.118	.057	.111
71.96		2.7037	3	.810	.566	2.6942	5	1.797	.877	-.0095	1.971	2.068	-.352	.022	.018	.073	.039	.076
73.96		2.7240	3	.494	.454	2.7153	5	2.321	1.096	-.0087	2.373	2.326	-.318	.022	.018	.087	.044	.085
75.96		2.7240	3	.494	.454	2.7160	5	2.165	1.030	-.0080	2.220	2.207	-.292	.022	.018	.082	.041	.081
77.96		2.7399	3	.432	.433	2.7320	5	1.285	.674	-.0078	1.356	1.570	-.286	.022	.018	.049	.029	.057
79.96		2.7399	3	.432	.433	2.7334	5	.694	.469	-.0065	.818	1.251	-.237	.022	.018	.030	.023	.046
80.96		2.7399	3	.432	.433	2.7333	3	.454	.440	-.0066	.627	1.210	-.241	.022	.018	.023	.023	.044
81.96		2.7399	3	.432	.433	2.7338	5	.704	.472	-.0061	.826	1.255	-.222	.022	.018	.030	.023	.046
82.96		2.7399	3	.432	.433	2.7339	3	.353	.408	-.0059	.558	1.166	-.217	.022	.018	.020	.022	.043
86.06		2.7399	3	.432	.433	2.7377	3	.760	.564	-.0022	.875	1.393	-.080	.022	.018	.032	.026	.051
BODY	0	31.1050	-1	3.889	4.377	30.9492	-2	3.889	3.403	-.1558	5.500	10.865	-.501	.004	.009	.018	.018	.035
AVG.	X	2.7262	51	13.654	1.971	2.7174	71	16.577	1.998	-.0088	21.604	5.502	-.323	.022	.018	.791	.103	.201
	(6+X)/2												-.412	.013	.010	.396	.052	.102
	6/X												155.04	11.7	9.1	379.9	49.7	97.3

TABLE 4-12c
FTE-15 FUEL BODY METROLOGY DATA - FUEL BODY 3

PRECISION:										PRECISION:									
LENGTH = .00060										LENGTH = .00060									
DIAMETER = .00030										DIAMETER = .00030									
EQUIPMENT RANDOM ERROR:										EQUIPMENT RANDOM ERROR:									
LENGTH = .00200										LENGTH = .00200									
DIAMETER = .00035										DIAMETER = .00035									
CORE HEIGHT	OUTER DIAMETER	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE		STRAIN							
		IN	MIL	MIL	MIL	IN	MIL	MIL	MIL	IN	MIL	MIL	UX	EX	UX	EX	EPX	DX	DX
103.06		2.6909	3	.490	.453	2.6814	5	3.498	1.603	-.0095	3.532	3.266	-.353	.022	.018	.131	.062	.121	
105.06		2.6900	3	.490	.453	2.6809	5	1.032	.580	-.0091	1.142	1.443	-.338	.022	.018	.042	.027	.054	
107.06		2.6900	3	.490	.453	2.6822	5	.813	.506	-.0078	.950	1.332	-.291	.022	.018	.035	.025	.049	
109.06		2.6900	3	.490	.453	2.6836	5	1.050	.587	-.0064	1.159	1.453	-.236	.022	.018	.043	.028	.054	
111.06		2.6900	3	.490	.453	2.6849	5	.573	.435	-.0051	.754	1.231	-.191	.022	.018	.028	.023	.046	
112.44		2.6900	3	.490	.453	2.6853	3	.451	.439	-.0047	.666	1.236	-.176	.022	.018	.025	.023	.046	
113.06		2.6900	3	.490	.453	2.6857	5	.650	.457	-.0043	.814	1.261	-.159	.022	.018	.030	.024	.047	
114.44		2.6900	3	.490	.453	2.6860	3	.404	.424	-.0040	.636	1.216	-.147	.022	.018	.024	.023	.045	
BODY	6	31.1060	1	3.860	4.351	30.9827	2	3.860	3.386	-.1253	5.459	10.805	-.403	.004	.009	.018	.018	.035	
AVG.	X	2.6901	24	.510	.366	2.6835	36	2.337	.524	-.0066	2.392	1.252	-.244	.022	.018	.089	.024	.047	
	(G*X)/2												-.323	.013	.010	.045	.015	.029	
	G/X												164.77	16.6	12.9	60.4	17.6	34.4	

TABLE 4-13
FTE-14 FUEL BODY METROLOGY SUMMARY

PRECISION:										PRECISION:									
LENGTH = .00030					LENGTH = .00030					LENGTH = .00030					LENGTH = .00030				
DIAMETER = .00030					DIAMETER = .00030					DIAMETER = .00030					DIAMETER = .00030				
EQUIPMENT RANDOM ERROR:										EQUIPMENT RANDOM ERROR:									
LENGTH = .00035					LENGTH = .00035					LENGTH = .00035					LENGTH = .00035				
DIAMETER = .00035					DIAMETER = .00035					DIAMETER = .00035					DIAMETER = .00035				

FUEL BODY	LENGTH DIAMETER LEN + DIAM ANISOTROPY	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN							
		IN G1 X1	MIL NG1 NX1	MIL SG1 SX1	MIL EG1 EX1	IN G2 X2	MIL NG2 NX2	MIL SG2 SX2	MIL EG2 EX2	IN G21 X21	MIL SG21 SX21	MIL DG21 DX21	% UG UX	% EG EX	% RG RX	% SG SX	% EPG EPX	% DGE DXX		
1	G	31.1000	1	1.202	2.340	31.0735	2	1.202	2.177	-.0264	1.700	6.264	-.085	.004	.009	.005	.010	.020		
	X	2.7393	36	.175	.352	2.7386	63	.728	.362	-.0008	.749	.989	-.028	.022	.018	.027	.018	.036		
	(G+X)/2 G/X												-.057	.013	.010	.014	.011	.021		
													299.54	244.6	193.3	268.9	197.6	367.4		
2	G	31.1060	1	3.860	4.351	30.9922	2	3.860	3.386	-.1137	5.460	10.807	-.366	.004	.009	.018	.018	.035		
	X	2.7261	51	13.993	1.990	2.7197	68	15.674	1.933	-.0064	21.011	5.438	-.234	.022	.018	.770	.102	.199		
	(G+X)/2 G/X												-.300	.013	.010	.385	.052	.101		
													156.45	16.4	12.7	515.4	68.5	134.2		
3	G	31.0180	1	11.282	11.459	30.9990	2	11.282	8.225	-.0190	15.955	27.647	-.061	.004	.009	.051	.045	.089		
	X	2.6956	27	16.017	3.102	2.6895	29	17.001	3.176	-.0060	23.358	8.702	-.224	.022	.018	.866	.165	.322		
	(G+X)/2 G/X												-.142	.013	.010	.434	.085	.167		
													27.39	4.5	4.7	108.5	26.6	56.1		
TEST ELEMENT AVERAGE	G	31.0747	3	40.736	23.522	31.0216	6	40.708	16.623	-.0531	57.590	56.453	-.171	.002	.002	.185	.093	.181		
	X	2.7230	114	20.372	1.940	2.7217	160	21.397	1.727	-.0014	29.544	5.091	-.051	.022	.018	1.085	.095	.187		
	(G+X)/2 G/X												-.111	.012	.009	.550	.066	.130		
													338.02	151.2	121.67	266.7	663.81	301.1		

TABLE 4-14
FTE-15 FUEL BODY METROLOGY SUMMARY

PRECISION:					PRECISION:				
LENGTH = .00030					LENGTH = .00030				
DIAMETER = .00030					DIAMETER = .00030				
EQUIPMENT RANDOM ERROR:					EQUIPMENT RANDOM ERROR:				
LENGTH = .00035					LENGTH = .00035				
DIAMETER = .00035					DIAMETER = .00035				

		PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN					
FUEL	LENGTH	IN		MIL	MIL	IN		MIL	MIL	IN	MIL	MIL	%	%	%	%	%	%
BODY	DIAMETER	G1	NG1	SG1	EG1	G2	NG2	SG2	EG2	G21	SG21	DG21	UG	EG	RG	SG	EPG	DG
	LEN + DIAM	X1	NX1	SX1	EX1	X2	NX2	SX2	EX2	X21	SX21	DX21	UX	EX	RX	SX	EPX	DX
	ANISOTROPY												V	EV	RV	SV	EPV	DV
													W	EW	RW	SW	EPW	DW
	G	31.1050	1	3.536	4.066	31.0330	2	3.536	3.204	-.0720	5.000	10.146	-.231	.004	.009	.016	.017	.033
	X	2.7396	51	.602	.360	2.7365	73	1.177	.376	-.0032	1.322	1.021	-.115	.022	.018	.048	.019	.037
1	(G+X)/2												-.173	.013	.010	.025	.013	.025
	G/X												200.64	41.4	32.4	85.1	36.1	70.7
	G	31.1050	1	3.889	4.377	30.9492	2	3.889	3.403	-.1558	5.500	10.865	-.501	.004	.009	.018	.018	.035
	X	2.7262	51	13.854	1.971	2.7174	71	16.577	1.998	-.0088	21.604	5.502	-.323	.022	.018	.791	.103	.201
2	(G+X)/2												-.412	.013	.010	.396	.052	.102
	G/X												155.04	11.7	9.1	379.9	49.7	97.3
	G	31.1080	1	3.860	4.351	30.9827	2	3.860	3.386	-.1253	5.459	10.805	-.403	.004	.009	.018	.018	.035
	X	2.6901	24	.510	.366	2.6835	36	2.337	.524	-.0066	2.392	1.252	-.244	.022	.018	.089	.024	.047
3	(G+X)/2												-.323	.013	.010	.045	.015	.029
	G/X												164.77	16.6	12.9	60.4	17.6	34.4
TEST	G	31.1060	3	4.022	2.349	30.9883	6	37.816	15.442	-.1177	38.029	30.615	-.378	.002	.002	.122	.050	.098
ELEMENT	X	2.7248	126	19.960	1.812	2.7184	180	22.065	1.681	-.0064	29.754	4.846	-.235	.022	.018	1.091	.091	.178
AVERAGE	(G+X)/2												-.307	.012	.009	.549	.052	.102
	G/X												160.98	15.9	12.4	749.1	65.7	128.7

TABLE 4-15
FTE-14 AND FTE-15 FUEL BODY STRAIN DATA

Fuel Element	Graphite Strain Measurements					
	Axial (%)	2 σ (%)	Radial (%)	2 σ (%)	Anisotropy	2 σ
FTE-14						
Body 1 (bottom)	-0.09	± 0.02	-0.03	± 0.04	3.00	± 3.87
Body 2 (middle)	-0.37	± 0.04	-0.23	± 0.20	1.56	± 1.34
Body 3 (top)	-0.06	± 0.09	-0.22	± 0.32	0.27	± 0.56
Total element average	-0.17	± 0.18	-0.05	± 0.19	3.38	± 13.01
FTE-15						
Body 1 (bottom)	-0.23	± 0.03	-0.12	± 0.04	2.01	± 0.71
Body 2 (middle)	-0.50	± 0.04	-0.32	± 0.20	1.55	± 0.97
Body 3 (top)	-0.40	± 0.04	-0.24	± 0.05	1.65	± 0.34
Total element average	-0.38	± 0.10	-0.24	± 0.18	1.61	± 1.29

TABLE 4-16
COMPARISON OF FTE-14 AND FTE-15 H-327 GRAPHITE STRAIN DATA WITH
OTHER TEST ELEMENT STRAIN DATA

Element	Irrad. Exposure (EFPD)	Element Average Graphite Strain Measurements (%)					
		Axial	2 σ	Radial	2 σ	Anisotropy	2 σ
FTE-3	133	-0.06	± 0.03	-0.06	± 0.04	1.02	± 0.83
FTE-14	317	-0.17	± 0.18	-0.05	± 0.19	3.38	± 13.01
FTE-4	449	-0.23	± 0.08	-0.17	± 0.04	1.38	± 0.60
FTE-15	517	-0.38	± 0.10	-0.24	± 0.18	1.61	± 1.29
FTE-6	645	-0.45	± 0.22	-0.24	± 0.04	1.92	± 0.98
FTE-5	897	-0.51	± 0.22	-0.28	± 0.04	2.05	± 0.84

TABLE 4-17a
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL BODY STRAIN

FUEL BODY	CORE HEIGHT	STRAIN %	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON		
			S (1-SIGMA) %	E (1-SIGMA) %	%	S (1-SIGMA) %	E (1-SIGMA) %	%	CALC/MEAS-1	S (1-SIGMA) Z (%)	E (1-SIGMA) SZ (%)	TEST1 D=Z/EZ	TEST2 D**2	
1	25.85	-.009			-.047	.013	.023		-118.44	5.18	8.79	-13.47	181.39	
	26.85	.005			-.051	.011	.021		-109.40	1.94	3.86	-28.34	803.15	
	27.85	.001			-.047	.013	.022		-101.80	.50	.85	*****	*****	
	29.00	-.004			-.029	.013	.022		-87.37	5.76	9.72	-8.99	80.88	
	30.85	-.014			-.022	.015	.023		-35.10	43.71	69.13	-.51	.26	
	32.75	-.032			-.022	.016	.024		45.72	108.60	162.01	.28	.08	
	34.70	-.055			-.015	.011	.021		278.39	273.07	542.04	.51	.26	
	36.85	-.083			-.015	.008	.020		465.92	326.71	772.70	.60	.36	
	39.00	-.112			.007	.025	.031		-1628.29	5294.92	6507.56	-.25	.06	
	41.00	-.141			-.026	.013	.022		450.01	272.17	474.64	.95	.90	
	43.00	-.164			-.022	.013	.022		668.42	443.62	773.64	.86	.75	
	45.00	-.193			-.026	.013	.022		654.99	373.60	651.52	1.01	1.01	
	46.90	-.214			-.029	.017	.025		631.20	422.13	618.69	1.02	1.04	
	48.85	-.232			-.044	.013	.022		430.27	153.08	266.93	1.61	2.60	
	50.85	-.258			-.044	.008	.020		489.24	113.40	268.16	1.82	3.33	
	52.85	-.286			-.051	.034	.038		460.40	369.77	419.48	1.10	1.20	
	53.85	-.301			-.026	.013	.022		1076.11	582.00	1014.95	1.06	1.12	
	54.85	-.315			-.044	.017	.025		618.38	276.51	405.24	1.53	2.33	
BODY AVERAGE					-.031	.016	.024		232.70	1278.20	1605.81	-8.82	853.96	
RMS/ERROR/TESTS		.113			.015	.004	.006		561.35	132.31	301.27	37.42	1.60	
2	57.96	-.400			-.048	.031	.036		740.62	550.83	637.03	1.16	1.35	
	58.96	-.401			-.066	.040	.043		507.78	364.15	400.65	1.27	1.61	
	59.96	-.401			-.095	.020	.027		321.23	86.57	117.98	2.72	7.41	
	61.80	-.407			-.128	.025	.031		217.16	61.82	76.34	2.84	8.09	
	63.80	-.429			-.169	.026	.032		154.42	39.99	48.45	3.19	10.16	
	65.70	-.559			-.085	.067	.070		568.47	529.82	548.98	1.04	1.07	
	67.70	-.673			-.203	.046	.049		230.68	74.20	79.93	2.89	8.33	
	69.70	-.684			-.248	.082	.084		175.04	91.35	93.59	1.88	3.53	
	71.66	-.591			-.259	.078	.081		128.06	69.06	70.91	1.81	3.26	
	73.70	-.552			-.206	.037	.037		164.27	42.19	48.38	3.48	12.09	
	75.70	-.524			-.180	.032	.037		191.45	52.38	60.08	3.19	10.16	
	77.70	-.428			-.172	.013	.022		149.17	18.56	32.12	4.64	21.57	
	79.70	-.428			-.164	.013	.022		160.39	20.25	35.06	4.57	20.93	
	81.70	-.446			-.135	.029	.034		230.32	71.42	83.97	2.74	7.52	
	83.96	-.478			-.047	.007	.019		908.09	155.09	413.88	2.19	4.81	
	84.96	-.493			-.026	.004	.018		1827.95	275.40	1390.55	1.31	1.73	
	85.96	-.507			-.033	.007	.019		1443.01	342.89	915.13	1.58	2.49	
BODY AVERAGE		.495			-.133	.040	.044		477.82	239.62	476.98	2.50	7.42	
RMS/ERROR/TESTS		.090			.073	.010	.011		481.25	116.72	58.12	115.68	10.31	1.62
3	87.51	-.413			-.077	.011	.021		438.95	74.08	147.01	2.99	8.92	
	104.50	-.407			-.052	.153	.154		681.68	2294.37	2310.95	.29	.09	
	106.85	-.352			-.138	.053	.056		156.04	97.94	103.75	1.50	2.26	
	108.04	-.325			-.186	.015	.024		74.70	14.25	22.40	3.34	11.12	
	109.26	-.294			-.112	.072	.074		165.25	170.37	175.90	.94	.88	
	111.20	-.247			-.115	.048	.052		114.61	90.17	96.45	1.19	1.41	
	113.14	-.199			-.089	.057	.060		122.83	141.92	149.17	.82	.68	
	115.08	-.150			-.067	.065	.068		124.63	219.13	227.66	.55	.30	
	116.21	-.122			.059	.097	.099		-305.22	335.30	341.26	-.89	.80	
BODY AVERAGE		.279			-.086	.075	.077		174.83	781.53	789.10	1.19	2.94	
RMS/ERROR/TESTS		.100			.064	.025	.026		253.07	84.36	260.51	263.03	3.57	1.88
ELEMENT AVERAGE					-.082	.043	.047		315.57	903.04	1127.01	-2.40	352.81	
RMS/ERROR/TESTS		.191			.071	.007	.007		498.52	75.16	136.14	169.90	15.91	1.37

TABLE 4-17b
FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL BODY STRAIN

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE				COMPARISON	
		STRAIN	S(1 SIGMA)	E(1 SIGMA)	STRAIN	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	EZ(%)	TEST1	TEST2
		%	%	%	%	%	%	Z(%)	SZ(%)	EZ(%)		0=Z/EZ	0=Z
1	25.85	-.021			-.040	.018	.026	-152.31	23.93	33.71	-4.52	20.42	
	26.85	-.010			-.073	.017	.025	-113.77	3.27	4.73	-24.05	578.51	
	28.85	-.012			-.073	.016	.024	-83.79	3.65	5.43	-15.44	238.29	
	30.85	-.035			-.080	.017	.025	-56.13	9.47	13.68	-4.10	16.84	
	32.85	-.062			-.069	.018	.026	-10.43	23.72	33.27	-.31	.10	
	34.85	-.091			-.084	.018	.025	8.54	23.23	32.94	.26	.07	
	36.85	-.120			-.088	.017	.025	37.22	26.14	36.55	.97	.93	
	38.85	-.151			-.102	.018	.025	47.31	25.89	36.71	1.29	1.66	
	40.85	-.186			-.113	.019	.026	64.51	28.07	38.43	1.88	2.82	
	42.85	-.217			-.142	.018	.025	52.20	19.20	27.23	1.92	3.68	
	44.85	-.245			-.153	.016	.024	59.79	16.24	24.05	2.41	5.79	
	46.85	-.271			-.179	.021	.027	51.75	17.58	23.31	2.22	4.93	
	48.85	-.293			-.182	.021	.027	60.65	14.23	24.14	2.51	6.29	
	49.97	-.311			-.157	.018	.025	98.40	22.70	32.19	3.06	9.34	
	50.85	-.330			-.161	.021	.027	105.54	26.51	35.17	3.00	9.01	
	51.97	-.354			-.142	.014	.023	146.63	24.04	39.65	3.75	14.05	
	54.96	-.417			-.102	.022	.029	304.51	88.71	114.37	2.70	7.28	
BODY AVERAGE													
		-.180			-.114	.018	.026	36.66	29.58	40.07	1.33	54.12	
RMS/ERROR/TESTS		.134			.042	.004	.006	103.45	25.09	7.17	9.72	5.50	1.62
2	56.96	-.491			-.117	.026	.032	318.89	93.08	113.39	2.81	7.91	
	57.96	-.499			-.147	.013	.022	240.69	29.88	51.65	4.66	21.72	
	59.96	-.516			-.187	.024	.030	175.95	36.01	44.87	3.92	15.33	
	61.96	-.533			-.198	.033	.038	169.30	44.76	51.10	3.31	10.98	
	63.96	-.552			-.275	.056	.059	100.85	40.90	42.99	2.35	5.50	
	65.96	-.720			-.314	.098	.099	129.17	71.19	72.43	1.78	3.18	
	67.96	-.809			-.422	.099	.101	91.81	45.25	46.01	2.60	3.98	
	69.96	-.801			-.448	.060	.063	76.98	23.91	25.01	3.16	9.98	
	71.96	-.681			-.351	.037	.042	93.84	20.63	22.96	4.09	16.71	
	73.96	-.670			-.319	.044	.047	109.63	28.56	30.95	3.54	12.55	
	75.96	-.624			-.294	.042	.046	112.50	30.20	32.93	3.42	11.67	
	77.96	-.526			-.288	.025	.031	82.37	15.92	19.59	4.21	17.69	
	79.96	-.532			-.237	.015	.024	124.24	14.46	22.36	5.56	30.88	
	80.96	-.538			-.241	.012	.022	123.44	11.51	20.31	6.08	36.93	
	81.96	-.548			-.223	.015	.024	146.22	16.91	26.16	5.59	31.24	
	82.96	-.558			-.219	.011	.021	154.87	12.96	24.68	6.28	39.38	
	84.04	-.589			-.080	.017	.025	633.49	153.96	225.64	2.81	7.88	
BODY AVERAGE													
		-.599			-.256	.046	.049	169.78	53.76	71.15	3.86	16.68	
RMS/ERROR/TESTS		.098			.096	.011	.012	130.24	31.59	13.04	17.26	15.90	1.62
3	103.06	-.527			-.353	.066	.068	49.16	27.85	28.91	1.70	2.89	
	105.06	-.480			-.338	.021	.028	41.94	9.00	11.85	3.54	12.53	
	107.06	-.429			-.290	.018	.026	47.91	9.34	13.23	3.62	13.10	
	109.06	-.376			-.238	.023	.030	57.90	15.32	19.58	2.96	8.74	
	111.06	-.317			-.190	.015	.024	66.98	13.62	21.16	3.17	10.02	
	112.44	-.276			-.175	.014	.023	57.66	12.81	20.98	2.76	7.61	
	113.06	-.258			-.160	.015	.024	61.09	15.56	24.21	2.52	6.37	
	114.44	-.217			-.149	.013	.023	45.75	12.76	22.10	2.67	4.29	
BODY AVERAGE													
		-.360			-.237	.029	.034	53.57	15.55	20.91	2.79	8.19	
RMS/ERROR/TESTS		.104			.076	.010	.012	8.07	2.85	5.50	7.39	7.90	1.94
ELEMENT AVERAGE													
		-.384			-.195	.034	.038	93.84	39.62	52.75	1.55	30.22	
RMS/ERROR/TESTS		.221			.100	.005	.006	123.15	19.00	6.11	8.14	10.06	1.38

TABLE 4-18a
FTE-14 SLEEVE-FUEL BODY GAPS
from Sleeve O.D.

CORE HEIGHT	SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP1		SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP2		DIFFERENCE GAP2-GAP1		RELATIVE CHANGE GAP2/GAP1 - 1	
	BOL	S.D	BOL	S.D	BOL	S.D	EOL	S.D	EOL	S.D	EOL	S.D	VALUE	S.D	VALUE	S.D
	IN.	IN.	IN.	IN.	MIL	MIL	IN.	IN.	IN.	IN.	MIL	MIL	MIL	MIL	%	%
7.16	2.7522	.0008	2.7230	.0204	14.60	10.21	2.7509	.0011	2.7230	.0204	13.97	10.21	-.63	14.44	-4.33	96.79
31.16	2.7522	.0008	2.7393	.0004	6.45	.45	2.7510	.0010	2.7387	.0005	6.16	.56	-.29	.72	-4.53	10.91
55.16	2.7522	.0008	2.7394	.0000	6.40	.40	2.7494	.0010	2.7382	.0008	5.58	.66	-.82	.77	-12.82	11.65
79.16	2.7522	.0008	2.7393	.0000	6.45	.40	2.7492	.0012	2.7348	.0007	7.20	.68	.75	.79	11.63	12.57
103.16	2.7522	.0008	2.6900	.0005	31.10	.47	2.7493	.0010	2.6886	.0071	30.34	3.59	-.76	3.62	-2.44	11.62
119.73	2.7522	.0008	2.7230	.0204	14.60	10.21	2.7479	.0010	2.7230	.0204	12.47	10.21	-2.13	14.44	-14.60	91.97

EOL SLEEVE DIA. = BOL SLEEVE I.D. + EOL SLEEVE O.D./BOL SLEEVE O.D.

FUEL BODY	SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP1		SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP2		DIFFERENCE GAP2-GAP1		RELATIVE CHANGE GAP2/GAP1 - 1	
	BOL	S.D	BOL	S.D	BOL	S.D	EOL	S.D	EOL	S.D	EOL	S.D	VALUE	S.D	VALUE	S.D
	IN.	IN.	IN.	IN.	MIL	MIL	IN.	IN.	IN.	IN.	MIL	MIL	MIL	MIL	%	%
1	2.7522	.0008	2.7393	.0002	6.45	.41	2.7502	.0013	2.7386	.0007	5.79	.73	-.66	.84	-10.18	12.73
2	2.7522	.0008	2.7261	.0140	13.05	7.01	2.7492	.0012	2.7197	.0157	14.75	7.86	1.70	10.53	13.03	85.50
3	2.7522	.0008	2.6956	.0160	28.30	8.02	2.7493	.0010	2.6895	.0170	29.89	8.52	1.59	11.70	5.62	42.44
ELEMENT AVERAGE																
X, SX	2.7522	.0008	2.7230	.0204	14.60	10.21	2.7497	.0012	2.7217	.0214	14.01	10.72	-.59	14.80	-4.06	99.43
EX		.0008		.0019		1.03		.0009		.0017		.96		1.41		9.46

EOL SLEEVE DIA. = BOL SLEEVE I.D. + EOL SLEEVE O.D./BOL SLEEVE O.D.

TABLE 4-18b
FTE-15 SLEEVE-FUEL BODY GAPS
from Sleeve O.D.

CORE HEIGHT	SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP1		SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP2		DIFFERENCE GAP2-GAP1		RELATIVE CHANGE GAP2/GAP1 - 1	
	BOL	S.O	BOL	S.O	BOL	S.O	EOL	S.O	EOL	S.O	EOL	S.O	VALUE	S.O	VALUE	S.O
	IN.	IN.	IN.	IN.	MIL	MIL	IN.	IN.	IN.	IN.	MIL	MIL	MIL	MIL	%	%
7.16	2.7522	.0008	2.7248	.0200	13.70	9.99	2.7476	.0011	2.7248	.0200	11.41	9.99	-2.29	14.13	-16.71	94.92
31.16	2.7522	.0008	2.7392	.0007	6.50	.53	2.7500	.0011	2.7370	.0005	6.49	.60	-.01	.80	-.08	12.27
55.16	2.7522	.0008	2.7398	.0006	6.20	.50	2.7516	.0011	2.7370	.0010	7.28	.74	1.06	.89	17.49	15.19
79.16	2.7522	.0008	2.7399	.0004	6.15	.45	2.7468	.0011	2.7334	.0007	6.72	.64	.57	.78	9.21	13.13
103.16	2.7522	.0008	2.6909	.0005	30.65	.47	2.7484	.0011	2.6814	.0035	33.51	1.83	2.86	1.89	9.32	6.21
119.73	2.7522	.0008	2.7248	.0200	13.70	9.99	2.7508	.0011	2.7248	.0200	12.99	9.99	-.71	14.13	-5.19	100.50

EOL SLEEVE DIA. = BOL SLEEVE I.D. + EOL SLEEVE O.D./BOL SLEEVE O.D.

FUEL BODY	SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP1		SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP2		DIFFERENCE GAP2-GAP1		RELATIVE CHANGE GAP2/GAP1 - 1	
	BOL	S.O	BOL	S.O	BOL	S.O	EOL	S.O	EOL	S.O	EOL	S.O	VALUE	S.O	VALUE	S.O
	IN.	IN.	IN.	IN.	MIL	MIL	IN.	IN.	IN.	IN.	MIL	MIL	MIL	MIL	%	%
1	2.7522	.0008	2.7396	.0006	6.30	.50	2.7508	.0014	2.7365	.0012	7.14	.90	.84	1.03	13.33	16.94
2	2.7522	.0008	2.7262	.0139	13.00	6.94	2.7468	.0011	2.7174	.0166	14.72	8.31	1.72	10.82	13.20	87.94
3	2.7522	.0008	2.6901	.0005	31.05	.47	2.7484	.0011	2.6835	.0023	32.46	1.29	1.41	1.37	4.53	4.44
ELEMENT																
AVERAGE																
X, SX	2.7522	.0008	2.7248	.0200	13.70	9.99	2.7492	.0022	2.7184	.0221	15.40	11.08	1.70	14.92	12.41	115.16
EX		.0008		.0018		.98		.0013		.0017		1.08		1.46		11.29

EOL SLEEVE DIA. = BOL SLEEVE I.D. + EOL SLEEVE O.D./BOL SLEEVE O.D.

TABLE 4-18b (Continued)

CORE HEIGHT	SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP1		SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP2		DIFFERENCE GAP2-GAP1		RELATIVE CHANGE GAP2/GAP1 = 1	
	BOL	S.D	BOL	S.D	BOL	S.D	EOL	S.D	EOL	S.D	EOL	S.D	VALUE	S.D	VALUE	S.D
	IN.	IN.	IN.	IN.	MIL	MIL	IN.	IN.	IN.	IN.	MIL	MIL	MIL	MIL	%	%
24.75	2.7522	.0008	2.7248	.0200	13.70	9.99	2.7448	.0005	2.7248	.0200	10.00	9.98	-3.70	14.12	-27.01	90.23
72.24	2.7522	.0008	2.7037	.0008	24.25	.57	2.7449	.0005	2.6942	.0018	25.35	.93	1.10	1.09	4.54	4.56
119.73	2.7522	.0008	2.7248	.0200	13.70	9.99	2.7489	.0005	2.7248	.0200	12.05	9.98	-1.65	14.12	-12.04	97.07
FUEL BODY	SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP1		SLEEVE DIAMETER		FUEL BODY DIAMETER		GAP2		DIFFERENCE GAP2-GAP1		RELATIVE CHANGE GAP2/GAP1 = 1	
	BOL	S.D	BOL	S.D	BOL	S.D	EOL	S.D	EOL	S.D	EOL	S.D	VALUE	S.D	VALUE	S.D
	IN.	IN.	IN.	IN.	MIL	MIL	IN.	IN.	IN.	IN.	MIL	MIL	MIL	MIL	%	%
2	2.7522	.0008	2.7262	.0139	13.00	6.94	2.7449	.0005	2.7174	.0166	13.75	8.29	.75	10.81	5.77	85.18

TABLE 4-19
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 1-1, 1-2, AND 1-3

FUEL STACKS 1-1,1-2, & 1-3 UC2 TRISO (23% FUEL VOL) & THC2 BISO (77% FUEL VOL)												
CALCULATED STRAINS BASED ON TEMPERATURES FOR FUEL STACK 1-1												
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=Z/EZ	TEST2 D**2
1	2	-1.489			-1.094	.182	.189	36.14	22.69	23.50	1.54	2.36
	6	-2.491			-2.164	.185	.191	15.10	9.85	10.18	1.48	2.20
	10	-2.841			-2.431	.150	.158	16.88	7.21	7.58	2.23	4.96
BODY AVERAGE												
		-2.274			-1.896	.173	.180	22.71	14.88	15.42	1.75	3.18
RMS/ERROR/TESTS		.573			.578	.100	.104	9.52	5.50	8.59	3.03	2.59
ELEMENT AVERAGE												
		-2.274			-1.896	.173	.180	22.71	14.88	15.42	1.75	3.18
RMS/ERROR/TESTS		.573			.578	.100	.104	9.52	5.50	8.59	3.03	2.59

TABLE 4-20
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-1 AND 3-1

FUEL STACKS 2-1 & 3-1 UC2 TRISO (23% FUEL VOL.) & THC2 BISO (77% FUEL VOL.)

FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN	S(1 SIGMA)	E(1 SIGMA)	STRAIN	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		%	%	%	%	%	%	Z(%)	SZ(%)	EZ(%)	D=Z/EZ	D**2
2	2	-2.442			-2.113	.122	.132	15.57	6.69	7.20	2.16	4.68
	4	-2.463			-2.340	.183	.190	5.30	8.26	8.54	.62	.38
	6	-2.469			-2.344	.110	.120	5.32	4.94	5.40	.99	.97
	8	-2.440			-2.440	.147	.155	-.02	6.03	6.34	-.00	.00
	10	-2.401			-2.119	.136	.144	13.32	7.28	7.72	1.72	2.97
BODY AVERAGE		-2.443			-2.271	.142	.150	7.90	6.73	7.13	1.10	1.80
RMS/ERROR/TESTS		.024			.132	.064	.067	5.73	2.56	3.01	3.19	2.21
3	2	-2.251			-2.317	.137	.145	-2.83	5.74	6.09	-.46	.22
	6	-1.979			-2.232	.118	.128	-11.33	4.69	5.07	-2.24	5.00
	10	-1.394			-1.772	.106	.116	-21.34	4.69	5.17	-4.13	17.06
BODY AVERAGE		-1.875			-2.107	.121	.130	-11.83	5.06	5.46	-2.28	7.43
RMS/ERROR/TESTS		.358			.239	.070	.075	7.56	4.37	2.92	3.15	2.59
ELEMENT AVERAGE		-2.230			-2.210	.134	.143	.50	6.16	6.55	-.17	3.91
RMS/ERROR/TESTS		.352			.197	.048	.051	11.54	4.08	2.18	2.32	1.94

TABLE 4-21

FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-2 AND 3-6

FUEL STACK 2-2 UC2 TRISO (27% FUEL VOL.) & THC2 TRISO (73% FUEL VOL.) FUEL STACK 3-6 UO2 TRISO (23% FUEL VOL.) & THC2 TRISO (23% FUEL VOL.)												
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=Z/EZ	TEST2 D**2
2	2	-1.005			-1.344	.163	.170	-25.21	9.06	9.46	-2.66	7.10
	4	-1.011			-1.308	.146	.154	-22.69	8.65	9.12	-2.49	6.20
	6	-1.013			-1.288	.149	.157	-21.32	9.09	9.57	-2.23	4.96
	8	-1.009			-1.179	.146	.154	-14.47	10.60	11.18	-1.29	1.68
	10	-.998			-1.248	.115	.125	-20.02	7.36	8.00	-2.50	6.27
BODY AVERAGE		-1.007			-1.274	.145	.153	-20.74	9.01	9.52	-2.24	5.24
RMS/ERROR/TESTS		.005			.056	.065	.068	3.58	1.60	4.03	5.00	2.21
3	2	-.952			-1.494	.099	.110	-36.30	4.21	4.69	-7.74	59.96
	6	-.873			-1.532	.279	.284	-43.01	10.39	10.55	-4.08	16.63
	10	-.696			-1.212	.270	.274	-42.61	12.76	12.97	-3.29	10.80
	BODY AVERAGE											
		-.840			-1.413	.231	.236	-40.64	9.81	10.02	-5.04	29.13
RMS/ERROR/TESTS		.107			.143	.134	.136	3.08	1.78	5.66	5.79	8.72
ELEMENT AVERAGE		-.945			-1.326	.182	.188	-28.21	9.32	9.71	-3.29	14.20
RMS/ERROR/TESTS		.104			.119	.064	.067	10.21	3.61	3.30	9.29	1.94

TABLE 4-22
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-3 AND 3-3

FUEL STACKS 2-3 & 3-3 UO2 TRISO (25% FUEL VOL.) & THO2 BISO (75% FUEL VOL.)													
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON		
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 %	S(1 SIGMA) %	E(1 SIGMA) %	TEST1 D=Z/EZ	TEST2 D**2	
2	2	-2.542			-2.115	.084	.097	20.21	4.78	5.52	3.66	13.41	
	4	-2.563			-2.113	.129	.138	21.30	7.41	7.92	2.69	7.24	
	6	-2.569			-2.001	.104	.115	28.40	6.70	7.39	3.84	14.76	
	8	-2.540			-2.136	.113	.123	18.91	6.30	6.86	2.76	7.60	
	10	-2.491			-2.016	.083	.097	23.55	5.10	5.91	3.98	15.86	
BODY AVERAGE		-2.541			-2.076	.104	.115	22.48	6.14	6.78	3.39	11.77	
RMS/ERROR/TESTS		.027			.056	.047	.051	3.33	1.49	2.75	3.03	7.57	2.21
3	2	-2.331			-1.984	.129	.138	17.53	7.66	8.18	2.14	4.59	
	6	-2.039			-1.806	.102	.113	12.86	6.37	7.06	1.82	3.32	
	10	-1.422			-1.535	.128	.137	-7.36	7.70	8.25	-0.89	.80	
BODY AVERAGE		-1.931			-1.775	.120	.130	7.67	7.27	7.85	1.02	2.90	
RMS/ERROR/TESTS		.379			.164	.069	.075	10.80	6.24	4.20	4.53	1.77	2.59
ELEMENT AVERAGE		-2.312			-1.963	.111	.121	16.93	6.59	7.20	2.50	8.45	
RMS/ERROR/TESTS		.376			.190	.039	.043	10.10	3.57	2.33	2.55	7.07	1.94

TABLE 4-23

FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 1-4, 2-4, AND 3-4

FUEL STACK 1-4 UC2 TRISO (22% FUEL VOL.) & THC2 BISO (78% FUEL VOL.)													
FUEL STACKS 2-4 & 3-4 (TH,U)O2 TRISO (55% FUEL VOL) & THC2 BISO (45% FUEL VOL)													
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON		
		STRAIN	S(1 SIGMA)	E(1 SIGMA)	STRAIN	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2	
		%	%	%	%	%	%	Z(%)	SZ(%)	EZ(%)	D=Z/EZ	D**2	
1	2	-1.272			-1.104	.078	.092	15.17	8.09	9.58	1.58	2.51	
	6	-2.134			-1.988	.096	.107	7.35	5.16	5.80	1.27	1.61	
	10	-2.350			-2.328	.098	.110	.95	4.26	4.75	.20	.04	
	BODY AVERAGE	-1.919			-1.807	.091	.103	7.83	6.06	7.02	1.02	1.39	
RMS/ERROR/TESTS		.466			.516	.052	.060	5.81	3.36	3.50	1.76	2.59	
2	2	-2.352			-2.089	.146	.154	12.59	7.88	8.30	1.52	2.30	
	4	-2.375			-2.316	.154	.161	2.52	6.81	7.14	.35	.12	
	6	-2.379			-2.486	.139	.147	-4.31	5.35	5.66	-.76	.58	
	8	-2.350			-2.347	.150	.157	.10	6.39	6.71	.01	.00	
	10	-2.321			-2.254	.128	.137	3.01	5.87	6.27	.48	.23	
	BODY AVERAGE	-2.355			-2.299	.144	.152	2.78	6.51	6.87	.32	.65	
RMS/ERROR/TESTS		.021			.129	.064	.068	5.55	2.48	2.91	.72	2.21	
3	2	-2.181			-2.232	.161	.168	-2.28	7.05	7.36	-.31	.10	
	6	-1.949			-2.055	.146	.154	-5.17	6.75	7.11	-.73	.53	
	10	-1.426			-1.683	.114	.124	-15.23	5.72	6.23	-2.45	5.99	
	BODY AVERAGE	-1.852			-1.990	.142	.150	-7.56	6.53	6.92	-1.16	2.20	
RMS/ERROR/TESTS		.316			.229	.082	.086	5.55	3.20	3.77	2.01	2.59	
ELEMENT AVERAGE		-2.099			-2.080	.131	.140	1.34	6.40	6.93	.11	1.27	
RMS/ERROR/TESTS		.377			.372	.039	.042	8.10	2.44	1.93	.35	1.79	

TABLE 4-24
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 1-5, 2-5, AND 3-5

FUEL STACK 1-5 UC2 TRISO (22% FUEL VOL.) & THC2 BISO (78% FUEL VOL.) FUEL STACKS 2-5 & 3-5 UO2 TRISO (21% FUEL VOL.) & THC2 BISO (79% FUEL VOL.)												
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) S2(%)	E(1 SIGMA) E2(%)	TEST1 D=Z/EZ	TEST2 D**2
2	2	-2.882			-2.509	.202	.207	14.90	9.24	9.50	1.57	2.46
	4	-2.903			-3.006	.238	.243	-3.40	7.65	7.81	-.43	.19
	6	-2.909			-2.827	.214	.220	2.91	7.81	8.00	.36	.13
	8	-2.880			-2.780	.178	.184	3.57	6.61	6.85	.52	.27
	10	-2.830			-2.743	.243	.247	3.15	9.12	9.30	.34	.11
BODY AVERAGE		-2.881			-2.773	.216	.222	4.23	8.15	8.35	.47	.63
RMS/ERROR/TESTS		.028			.160	.097	.099	5.92	2.65	3.64	1.05	2.21
3	2	-2.614			-2.607	.310	.314	.27	11.93	12.07	.02	.00
	6	-2.259			-2.459	.256	.261	-8.14	9.57	9.73	-.84	.70
	10	-1.568			-2.165	.230	.235	-27.55	7.71	7.88	-3.50	12.23
	BODY AVERAGE	-2.147			-2.410	.268	.272	-11.81	9.89	10.04	-1.44	9.31
RMS/ERROR/TESTS		.434			.184	.154	.157	11.65	6.73	5.71	2.49	2.59
ELEMENT AVERAGE		-2.606			-2.637	.237	.242	-1.79	8.84	9.02	-.24	2.01
RMS/ERROR/TESTS		.444			.244	.084	.085	11.54	4.08	3.13	.69	1.94

TABLE 4-25
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-6 AND 3-2

FUEL STACKS 2-6 & 3-2 UO2 TRISO (25% FUEL VOL.) & THO2 TRISO (75% FUEL VOL.)													
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON		
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=Z/EZ	TEST2 D**2	
2	2	-.733			-1.376	.164	.171	-46.70	6.34	6.61	-7.06	49.89	
	4	-.737			-1.232	.133	.141	-40.15	6.45	6.86	-5.85	34.22	
	6	-.739			-1.226	.275	.279	-39.77	13.50	13.71	-2.90	8.41	
	8	-.733			-1.225	.258	.262	-40.18	12.59	12.81	-3.14	9.84	
	10	-.726			-1.070	.283	.287	-32.13	17.96	18.22	-1.76	3.11	
BODY AVERAGE		-.734			-1.226	.231	.236	-39.79	12.21	12.45	-4.14	21.09	
RMS/ERROR/TESTS		.004			.097	.103	.106	4.62 2.07	5.46	5.57	9.26	2.21	
3	2	-.952			-1.304	.268	.272	-27.02	14.99	15.23	-1.77	3.15	
	6	-.873			-1.104	.288	.292	-20.91	20.63	20.92	-1.00	1.00	
	10	-.699			-1.222	.327	.331	-42.81	15.30	15.47	-2.77	7.66	
	BODY AVERAGE		-.841			-1.210	.295	.299	-30.25	17.17	17.41	-1.85	3.93
RMS/ERROR/TESTS		.106			.082	.171	.173	9.23 5.33	9.91	10.05	3.20	2.59	
ELEMENT AVERAGE		-.774			-1.220	.257	.262	-36.21	14.27	14.51	-3.28	14.66	
RMS/ERROR/TESTS		.083			.092	.091	.092	8.16 2.89	5.05	5.13	9.28	1.94	

TABLE 4-26
FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACK 1-1

FUEL STACK 1-1 UC2 TRISO (23% FUEL VOL.) & THC2 BISO (77% FUEL VOL.)

FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=Z/EZ	TEST2 D**2
1	1	-1.427			-1.461	.150	.158	-2.33	10.03	10.55	-.22	.05
	2	-2.035			-1.565	.093	.105	30.02	7.71	8.72	3.44	11.86
	3	-2.456			-2.029	.145	.153	21.03	8.62	9.10	2.31	5.34
	4	-2.751			-2.164	.149	.157	27.14	8.75	9.20	2.95	8.69
	5	-2.960			-2.324	.138	.146	27.33	7.56	8.02	3.41	11.63
	6	-3.108			-2.499	.164	.171	24.37	8.18	8.53	2.86	8.17
	7	-3.219			-2.706	.151	.159	18.98	6.65	6.99	2.72	7.38
	8	-3.304			-2.852	.114	.123	15.83	4.61	5.01	3.16	9.97
	9	-3.367			-3.051	.143	.151	10.34	5.19	5.47	1.89	3.57
	10	-3.416			-3.056	.114	.124	11.80	4.19	4.54	2.60	6.75
	11	-3.458			-3.012	.114	.123	14.82	4.33	4.70	3.15	9.93
BODY AVERAGE												
		-2.864			-2.429	.136	.144	18.12	7.16	7.62	2.57	7.58
RMS/ERROR/TESTS		.620			.548	.041	.043	9.00	2.71	2.16	8.52	1.79
ELEMENT AVERAGE												
		-2.864			-2.429	.136	.144	18.12	7.16	7.62	2.57	7.58
RMS/ERROR/TESTS		.620			.548	.041	.043	9.00	2.71	2.16	8.52	1.79

TABLE 4-27

FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-1 AND 3-1

FUEL STACKS 2-1 & 3-1 UC2 TRISO (27% FUEL VOL.) & THC2 BISO (73% FUEL VOL.)

FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=2/EZ	TEST2 D**2
2	1	-2.875			-2.152	.149	.156	33.61	9.23	9.71	3.46	11.98
	2	-2.890			-2.296	.115	.125	25.86	6.32	6.86	3.77	14.22
	3	-2.901			-2.304	.128	.137	25.94	7.00	7.48	3.47	12.01
	4	-2.909			-2.512	.124	.133	15.84	5.74	6.16	2.57	6.62
	5	-2.917			-2.632	.116	.125	10.83	4.87	5.28	2.05	4.21
	6	-2.919			-2.455	.119	.128	18.86	5.76	6.22	3.03	9.20
	7	-2.914			-2.403	.136	.144	21.26	6.85	7.27	2.92	8.55
	8	-2.907			-2.476	.123	.132	17.42	5.84	6.27	2.78	7.71
	9	-2.899			-2.482	.149	.156	16.83	6.99	7.35	2.29	5.23
	10	-2.889			-2.269	.140	.148	27.34	7.85	8.31	3.29	10.82
	11	-2.876			.055	.244	.249	*****	*****	*****	-.23	.05
BODY AVERAGE		-2.900			-2.175	.144	.152	*****	6934.58	7077.78	2.67	8.24
RMS/ERROR/TESTS		.015			.717	.044	.046	***** 462.06	2090.85	2134.03	8.87	1.79
3	1	-2.823			-2.409	.110	.120	17.16	5.36	5.86	2.93	8.58
	2	-2.793			-2.445	.092	.104	14.24	4.28	4.84	2.94	8.64
	3	-2.755			-2.270	.186	.192	21.36	9.95	10.28	2.08	4.32
	4	-2.707			-2.335	.111	.121	15.92	5.49	5.99	2.66	7.05
	5	-2.648			-2.381	.122	.131	11.21	5.69	6.12	1.83	3.35
	6	-2.575			-2.396	.186	.192	7.46	8.35	8.63	.87	.75
	7	-2.484			-2.169	.117	.127	14.53	6.20	6.71	2.17	4.69
	8	-2.364			-2.151	.122	.131	9.87	6.24	6.71	1.47	2.16
	9	-2.197			-2.042	.115	.125	7.57	6.05	6.57	1.15	1.33
	10	-1.974			-2.016	.126	.135	-2.09	6.14	6.58	-.32	.10
	11	-1.751			-1.875	.103	.114	-6.62	5.11	5.65	-1.17	1.37
BODY AVERAGE		-2.461			-2.226	.130	.139	10.06	6.44	6.87	1.51	3.85
RMS/ERROR/TESTS		.338			.180	.039	.042	7.92 2.39	1.94	2.07	5.01	1.79
ELEMENT AVERAGE		-2.680			-2.201	.137	.146	*****	4903.49	5004.75	2.09	6.04
RMS/ERROR/TESTS		.325			.523	.029	.031	***** 236.48	1045.43	1067.02	9.81	1.54

TABLE 4-28
FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-2 AND 3-2

FUEL STACKS 2-2 & 3-2 UC2 TRISO (27% FUEL VOL.) & THC2 BISO (78% FUEL VOL.)

FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) Z(%)	E(1 SIGMA) Z(%)	TEST1 D=Z/EZ	TEST2 D**2
2	1	-1.121			-.867	.192	.215	29.21	28.57	32.07	.91	.83
	2	-1.124			-.725	.171	.176	55.20	36.57	38.05	1.45	2.10
	3	-1.128			-.631	.192	.198	78.77	54.88	56.23	1.40	1.96
	4	-1.130			-1.061	.113	.123	6.57	11.37	12.38	.53	.28
	5	-1.133			-1.734	.137	.145	-34.69	5.15	5.47	-6.35	40.27
	6	-1.134			-1.204	.147	.155	-5.86	11.49	12.11	-.48	.23
	7	-1.132			-.729	.137	.146	55.27	29.20	31.03	1.78	3.17
	9	-1.127			-.223	.193	.200	405.46	438.34	452.37	.90	.80
	10	-1.124			-.490	.169	.176	129.29	79.18	82.44	1.57	2.46
	11	-1.121			-1.107	.138	.146	1.27	12.63	13.40	.09	.01
	BODY AVERAGE	-1.127			-.877	.161	.171	72.05	143.12	147.83	.18	5.21
	RMS/ERROR/TESTS	.005			.401	.051	.054	119.85	37.90	45.26	.57	1.83
3	2	-1.097			-.490	.201	.207	124.11	92.21	94.93	1.31	1.71
	3	-1.087			-.880	.216	.222	23.46	30.34	31.10	.75	.57
	4	-1.073			-.670	.188	.195	73.07	52.53	54.30	1.35	1.81
	5	-1.057			-1.076	.099	.110	-1.76	9.04	10.08	-.17	.03
	6	-1.037			-1.322	.132	.141	-21.57	7.83	8.34	-2.59	6.69
	8	-.983			-1.295	.133	.142	-24.08	7.79	8.30	-2.90	8.42
	10	-.889			-1.173	.129	.138	-24.23	8.35	8.93	-2.71	7.36
	BODY AVERAGE	-1.032			-.979	.162	.170	21.28	42.18	43.50	-.71	3.80
	RMS/ERROR/TESTS	.068			.303	.061	.064	53.13	20.08	15.94	1.88	2.01
ELEMENT AVERAGE		-1.088			-.919	.162	.170	51.15	113.06	116.77	-.19	4.63
	RMS/ERROR/TESTS	.064			.368	.039	.041	101.17	24.54	27.42	.77	1.62

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TABLE 4-29

FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 1-3, 2-3, AND 3-3

FUEL STACK 1-3 UC2 TRISO (22% FUEL VOL.) & THC2 BISO (78% FUEL VOL.) FUEL STACKS 2-3 & 3-3 UO2 TRISO (25% FUEL VOL.) & THO2 BISO (75% FUEL VOL.)													
FUEL BODY	FUEL ROD	STRAIN %	CALCULATED		STRAIN %	MEASURED		RELATIVE DIFFERENCE			COMPARISON		
			S(1 SIGMA) %	E(1 SIGMA) %		S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) S2(%)	E(1 SIGMA) EZ(%)	TEST1 D=Z/EZ	TEST2 D**2	
1	3	-2.087			-1.561	.113	.123	33.73	9.64	10.52	3.21	10.28	
	8	-2.851			-2.524	.117	.127	12.96	5.24	5.68	2.28	5.21	
BODY AVERAGE		-2.469			-2.042	.115	.125	23.34	7.76	8.45	2.74	7.75	
RMS/ERROR/TESTS		.382			.482	.081	.088	10.39	7.34	5.49	3.88	2.97	
2	1	-3.060			-2.037	.091	.103	50.26	6.70	7.60	6.61	43.67	
	2	-3.077			-2.104	.236	.255	46.21	16.38	17.72	2.61	6.80	
	3	-3.089			-2.177	.147	.154	41.89	9.56	10.07	4.16	17.31	
	4	-3.099			-2.051	.159	.166	51.10	11.71	12.25	4.17	17.42	
	5	-3.108			-2.176	.099	.111	42.83	6.52	7.26	5.90	34.77	
	6	-3.110			-2.045	.100	.111	52.07	7.43	8.27	6.30	39.67	
	7	-3.105			-2.160	.086	.099	43.72	5.71	6.56	6.66	44.39	
	8	-3.097			-2.185	.089	.102	41.75	5.78	6.59	6.34	40.18	
	9	-3.088			-2.164	.089	.101	42.67	5.85	6.67	6.40	40.94	
	10	-3.076			-2.065	.082	.096	48.91	5.92	6.89	7.10	50.41	
	11	-3.061			-1.970	.110	.120	55.43	8.65	9.46	5.86	34.33	
BODY AVERAGE		-3.088			-2.103	.125	.137	46.99	8.79	9.59	5.65	33.63	
RMS/ERROR/TESTS		.017			.070	.038	.041	4.56	1.38	2.65	18.72	1.79	
3	2	-2.965			-1.913	.128	.137	55.03	10.40	11.12	4.95	24.48	
	4	-2.867			-2.100	.091	.103	36.56	5.89	6.68	5.47	29.92	
	5	-2.800			-2.031	.093	.105	37.87	6.31	7.13	5.31	28.20	
	6	-2.717			-2.056	.124	.134	32.14	8.00	8.59	3.74	13.99	
	8	-2.480			-2.112	.104	.115	17.43	5.80	6.40	2.72	7.42	
	10	-2.052			-1.718	.092	.104	19.45	6.37	7.22	2.69	7.25	
BODY AVERAGE		-2.647			-1.988	.107	.117	33.08	7.31	8.02	4.15	18.54	
RMS/ERROR/TESTS		.306			.137	.043	.048	12.57	5.13	2.99	3.28	10.16	2.09
ELEMENT AVERAGE													
		-2.884			-2.060	.119	.130	40.11	8.24	9.01	4.87	26.14	
RMS/ERROR/TESTS		.324			.190	.027	.030	12.08	2.77	1.89	21.22	1.59	

TABLE 4-30
FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 1-4, 2-4, AND 3-4

FUEL STACK 1-4 UC2 TRISO (22% FUEL VOL.) & THC2 BISO (78% FUEL VOL.) FUEL STACKS 2-4 & 3-4 (TH,U)O2 TRISO (55% FUEL VOL.) & THC2 BISO (45% FUEL VOL.)												
FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) %	E(1 SIGMA) %	TEST1 D=Z/EZ	TEST2 D**2
1	2	-1.708			-1.407	.110	.121	21.39	9.51	10.41	2.05	4.22
	4	-2.279			-1.916	.117	.127	18.98	7.29	7.90	2.40	5.77
	6	-2.565			-2.213	.118	.128	15.91	6.20	6.71	2.37	5.63
	8	-2.726			-2.534	.107	.118	7.58	4.55	5.00	1.52	2.30
	10	-2.818			-2.773	.139	.148	1.62	5.11	5.41	.30	.09
	BODY AVERAGE	-2.419			-2.169	.119	.129	13.10	6.76	7.35	1.73	3.60
	RMS/ERROR/TESTS	.400			.478	.053	.058	7.40 3.31	3.02	3.29	3.87	2.21
2	1	-2.913			-2.306	.135	.143	26.34	7.38	7.84	3.36	11.30
	2	-2.929			-2.187	.115	.125	33.91	7.04	7.64	4.44	19.71
	3	-2.940			-2.125	.159	.167	38.38	10.38	10.85	3.54	12.50
	10	-2.928			-2.075	.103	.114	41.09	7.01	7.75	5.30	28.12
	11	-2.915			-2.357	.149	.156	23.70	7.81	8.21	2.89	8.33
	BODY AVERAGE	-2.925			-2.210	.134	.142	32.68	8.03	8.54	3.91	15.99
	RMS/ERROR/TESTS	.010			.106	.060	.064	6.71 3.00	3.59	3.82	8.73	2.21
3	2	-2.828			-1.963	.235	.254	44.03	17.22	18.62	2.36	5.59
	3	-2.789			-1.851	.159	.166	50.70	12.92	13.51	3.75	14.09
	4	-2.740			-2.092	.119	.128	30.96	7.43	8.02	3.86	14.90
	5	-2.680			-1.935	.186	.192	38.53	13.31	13.76	2.80	7.85
	6	-2.607			-2.152	.154	.161	21.14	8.67	9.08	2.33	5.42
	8	-2.397			-1.867	.159	.166	28.43	10.92	11.42	2.49	6.20
	10	-2.012			-1.971	.093	.105	2.09	4.84	5.45	.38	.15
	BODY AVERAGE	-2.579			-1.976	.163	.173	30.84	11.42	12.10	2.57	7.74
	RMS/ERROR/TESTS	.266			.103	.062	.065	14.90 5.63	4.32	4.57	6.80	2.01
ELEMENT AVERAGE		-2.634			-2.101	.143	.152	26.16	9.28	9.88	2.71	8.95
	RMS/ERROR/TESTS	.341			.294	.035	.037	13.87 3.37	2.25	2.40	11.19	1.62

TABLE 4-31

FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 1-5, 2-5, AND 3-5

FUEL STACK 1-5 UC2 TRISO (23% FUEL VOL.) & THC2 BISO (77% FUEL VOL.) FUEL STACKS 2-5 & 3-5 UO2 TRISO (21% FUEL VOL.) & THC2 BISO (79% FUEL VOL.)												
FUEL BODY	FUEL ROD	STRAIN %	CALCULATED		STRAIN %	MEASURED		RELATIVE DIFFERENCE			COMPARISON	
			S(1 SIGMA) %	E(1 SIGMA) %		S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) Z(%)	E(1 SIGMA) Z(%)	TEST1 D=Z/EZ	TEST2 D=Z/EZ
1	1	-1.283			-1.461	.100	.111	-12.16	6.01	6.69	-1.82	3.30
	3	-2.222			-1.574	.100	.111	41.21	8.97	10.00	4.12	16.99
	5	-2.688			-1.812	.143	.151	48.36	11.69	12.36	3.91	15.32
	7	-2.933			-2.256	.113	.124	30.00	6.54	7.12	4.21	17.76
	9	-3.073			-2.703	.143	.151	13.71	6.03	6.37	2.15	4.63
	11	-3.160			-2.497	.115	.125	26.53	5.85	6.35	4.18	17.47
BODY AVERAGE		-2.560			-2.050	.121	.130	24.61	7.82	8.46	2.79	12.58
RMS/ERROR/TESTS		.649			.465	.049	.053	19.76 8.07	3.19	3.45	6.84	2.09
2	1	-3.231			-2.630	.274	.291	22.83	12.81	13.57	1.68	2.83
	2	-3.248			-2.586	.185	.191	25.59	8.96	9.26	2.76	7.64
	11	-3.233			-2.512	.239	.257	28.73	12.23	13.19	2.18	4.74
BODY AVERAGE		-3.238			-2.576	.235	.250	25.72	11.46	12.16	2.21	5.07
RMS/ERROR/TESTS		.008			.049	.136	.144	2.41 1.39	6.62	7.02	3.82	2.59
3	2	-3.131			-2.218	.222	.227	41.18	14.13	14.46	2.85	8.11
	4	-3.029			-2.212	.224	.230	36.95	13.90	14.21	2.60	6.76
	6	-2.875			-1.314	.210	.216	118.86	34.99	35.90	3.31	10.96
	8	-2.632			-2.240	.398	.409	17.48	20.86	21.46	.81	.66
	9	-2.440			-2.212	.138	.146	10.32	6.89	7.30	1.41	2.00
	10	-2.185			-2.300	.231	.236	-5.00	9.55	9.75	-.51	-.26
BODY AVERAGE		-2.716			-2.083	.250	.257	36.63	19.11	19.62	1.75	4.79
RMS/ERROR/TESTS		.332			.345	.102	.105	39.94 16.31	7.80	8.01	4.28	2.09
ELEMENT AVERAGE		-2.758			-2.168	.205	.214	29.64	14.03	14.57	2.26	7.96
RMS/ERROR/TESTS		.524			.420	.053	.055	28.78 7.43	3.62	3.76	8.74	1.67

TABLE 4-32
FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD STRAIN - FUEL STACKS 2-6 AND 3-6

FUEL STACK 2-6 UO2 TRISO (25% FUEL VOL.) & THO2 TRISO (75% FUEL VOL.)
FUEL STACK 3-6 UO2 TRISO (23% FUEL VOL.) & THO2 TRISO (77% FUEL VOL.)

FUEL BODY	FUEL ROD	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	STRAIN %	S(1 SIGMA) %	E(1 SIGMA) %	CALC/MEAS-1 Z(%)	S(1 SIGMA) Z(%)	E(1 SIGMA) Z(%)	TEST1 D=Z/EZ	TEST2 D*2
2	1	-.931			-1.130	.284	.288	-17.66	20.68	20.98	-.84	.71
	2	-.934			-1.077	.307	.311	-13.24	24.76	25.07	-.53	.28
	3	-.937			-.828	.299	.303	13.16	40.83	41.37	.32	.10
	4	-.939			-1.031	.252	.257	-8.88	22.29	22.70	-.39	.15
	5	-.941			-1.098	.278	.282	-14.25	21.69	22.02	-.65	.42
	6	-.942			-.849	.323	.327	10.95	42.26	42.73	.26	.07
	7	-.940			-.932	.335	.338	.84	36.19	36.57	.02	.00
	8	-.939			-1.026	.323	.326	-8.50	28.77	29.09	-.29	.09
	9	-.937			-.802	.385	.388	16.91	56.10	56.55	.30	.09
	10	-.934			-.742	.296	.300	25.91	50.23	50.90	.51	.26
	11	-.931			-.894	.302	.306	4.14	35.21	35.66	.12	.01
BODY AVERAGE		-.937			-.946	.309	.313	.85	36.32	36.74	-.11	.20
RMS/ERROR/TESTS		.004			.127	.093	.094	13.82 4.17	10.95	11.08	.36	1.79
3	1	-.919			-1.134	.130	.139	-18.90	9.31	9.94	-1.90	3.62
	2	-.913			-1.098	.099	.110	-16.83	7.50	8.35	-2.02	4.06
	3	-.905			-1.421	.110	.120	-36.32	4.91	5.36	-6.77	45.83
	4	-.896			-.982	.121	.131	-8.82	11.26	12.13	-.73	.53
	5	-.885			-1.259	.129	.138	-29.71	7.21	7.70	-3.86	14.89
	6	-.873			-1.323	.100	.111	-34.05	4.99	5.55	-6.14	37.67
	7	-.857			-1.147	.100	.111	-25.26	6.51	7.24	-3.49	12.16
	8	-.837			-1.366	.102	.113	-38.68	4.60	5.09	-7.60	57.79
	9	-.809			-1.354	.093	.105	-40.24	4.09	4.62	-8.72	76.03
	10	-.768			-1.116	.078	.092	-31.21	4.83	5.69	-5.49	30.13
	11	-.727			-1.101	.107	.117	-33.94	6.40	7.04	-4.82	23.26
BODY AVERAGE		-.854			-1.209	.107	.118	-28.54	6.84	7.48	-4.68	27.81
RMS/ERROR/TESTS		.060			.135	.032	.036	9.53 2.87	2.06	2.26	15.54	1.79
ELEMENT AVERAGE		-.895			-1.078	.232	.237	-13.85	26.13	26.51	-2.40	14.01
RMS/ERROR/TESTS		.059			.185	.049	.050	18.89 4.03	5.57	5.65	11.24	1.54

TABLE 4-33
FTE-14 FUEL ROD METROLOGY DATA

PRECISION: LENGTH = .00100 DIAMETER = .00010 EQUIPMENT RANDOM ERROR: LENGTH = .00010 DIAMETER = .00060										PRECISION: LENGTH = .00100 DIAMETER = .00010 EQUIPMENT RANDOM ERROR: LENGTH = .00010 DIAMETER = .00010										
BODY HOLE	LENGTH DIAMETER LEN + DIAM ANISOTROPY	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN							
		IN	MIL	MIL	IN	MIL	MIL	MIL	IN	MIL	MIL	U	U	U	U	U	U	U	U	
		Y1	NY1	SY1	EY1	Y2	NY2	SY2	EY2	Y21	SY21	OY21	UY	EY	RY	SY	EPY	DY		
		X1	NX1	SX1	EX1	X2	NX2	SX2	EX2	X21	SX21	OX21	UX	FX	RX	SX	EPX	DX		
1 1	Y	2.5183	3	4.143	2.400	2.4597	3	15.658	9.042	-0.059	16.197	18.336	-2.330	.078	.006	.642	.371	.727		
	X	.6165	18	4.268	1.171	.6075	18	4.877	1.154	-0.009	6.481	3.223	-1.462	.032	.097	1.044	.265	.519		
	(Y+X)/2												-1.896	.055	.049	.613	.228	.447		
	Y/X												159.29	8.9	10.6	121.9	38.4	75.3		
1 4	Y	2.5123	3	2.677	1.558	2.4573	3	11.825	6.830	-0.055	12.124	13.730	-2.189	.079	.006	.482	.279	.546		
	X	.6150	18	1.887	.747	.6062	18	4.309	1.021	-0.009	4.704	2.479	-1.424	.032	.098	.763	.205	.401		
	(Y+X)/2												-1.806	.056	.049	.451	.173	.339		
	Y/X												153.76	9.0	10.5	89.1	29.5	57.8		
2 1	Y	2.4888	5	5.601	2.510	2.4336	5	2.156	.978	-0.055	6.002	5.260	-2.218	.079	.006	.236	.106	.208		
	X	.6149	30	3.496	.876	.6006	30	1.524	.296	-0.014	3.614	1.812	-2.325	.032	.097	.608	.147	.289		
	(Y+X)/2												-2.271	.056	.048	.326	.091	.178		
	Y/X												95.39	4.7	4.0	26.9	7.6	14.8		
2 2	Y	2.4960	5	3.226	1.452	2.4658	5	4.957	2.223	-0.030	5.914	5.204	-1.210	.080	.006	.236	.106	.208		
	X	.6165	30	3.026	.816	.6082	30	2.468	.462	-0.008	3.905	1.837	-1.337	.032	.097	.628	.150	.295		
	(Y+X)/2												-1.274	.056	.049	.336	.092	.180		
	Y/X												90.48	8.1	6.6	46.0	12.9	25.3		
2 3	Y	2.4846	5	2.941	1.325	2.4330	5	3.407	1.533	-0.052	4.501	3.971	-2.077	.080	.006	.180	.061	.158		
	X	.6136	30	1.868	.690	.6009	30	1.807	.345	-0.013	2.599	1.512	-2.076	.032	.097	.419	.124	.242		
	(Y+X)/2												-2.076	.056	.049	.228	.074	.145		
	Y/X												100.05	5.4	4.7	22.0	7.1	14.0		
2 4	Y	2.4952	5	4.446	1.995	2.4354	5	6.376	2.856	-0.060	7.773	6.828	-2.397	.079	.006	.309	.139	.272		
	X	.6165	30	2.913	.802	.6030	30	2.709	.505	-0.014	3.978	1.857	-2.200	.032	.097	.638	.151	.296		
	(Y+X)/2												-2.299	.056	.048	.354	.103	.201		
	Y/X												108.91	5.2	4.8	34.5	9.8	19.2		
2 5	Y	2.5004	5	5.005	2.244	2.4314	5	6.622	2.966	-0.069	8.301	7.290	-2.760	.079	.006	.329	.147	.289		
	X	.6181	30	5.665	1.196	.6009	30	2.428	.454	-0.017	6.163	2.507	-2.786	.032	.096	.974	.202	.396		
	(Y+X)/2												-2.773	.055	.048	.514	.125	.245		
	Y/X												99.04	4.0	3.4	36.6	8.9	17.5		
2 6	Y	2.5032	5	3.711	1.668	2.4796	5	5.572	2.497	-0.024	6.695	5.866	-.943	.080	.006	.267	.120	.234		
	X	.6212	30	6.297	1.297	.6118	30	1.807	.345	-0.009	6.551	2.630	-1.509	.032	.096	1.040	.213	.417		
	(Y+X)/2												-1.726	.056	.048	.537	.122	.239		
	Y/X												62.48	6.6	4.0	46.5	11.9	23.2		
3 1	Y	2.4837	3	14.183	8.191	2.4307	3	20.046	11.575	-0.053	24.556	27.793	-2.134	.080	.006	.982	.567	1.111		

TABLE 4-33 (Continued)

		X	.6154	18	2.643	.865	.6026	18	1.976	.476	-.013	3.300	1.936	-2.078	.032	.097	.529	.158	.310
		(Y+X)/2												-2.106	.056	.049	.558	.294	.577
		Y/X												102.69	5.4	4.8	54.0	28.4	55.6
3	2	Y	2.5037	3	6.041	3.493	2.4833	3	6.519	3.769	-.020	8.888	10.072	-.812	.080	.006	.354	.204	.401
		X	.6212	18	8.169	2.017	.6112	18	2.407	.576	-.010	8.517	4.111	-1.608	.032	.096	1.351	.333	.652
		(Y+X)/2												-1.210	.056	.048	.698	.195	.383
		Y/X												50.51	6.0	3.0	47.8	16.5	32.3
3	3	Y	2.4843	3	2.273	1.327	2.4400	3	3.504	2.032	-.044	4.176	4.757	-1.785	.080	.006	.167	.097	.190
		X	.6135	18	2.030	.767	.6027	18	2.568	.614	-.011	3.274	1.926	-1.766	.032	.097	.530	.158	.311
		(Y+X)/2												-1.775	.056	.049	.278	.093	.182
		Y/X												101.06	6.4	5.6	31.8	10.6	20.8
3	4	Y	2.4937	3	3.440	1.995	2.4433	3	5.083	2.941	-.050	6.137	6.966	-2.018	.079	.006	.245	.142	.278
		X	.6170	18	3.027	.932	.6049	18	3.195	.760	-.012	4.401	2.357	-1.961	.032	.097	.707	.193	.378
		(Y+X)/2												-1.990	.056	.048	.374	.120	.234
		Y/X												102.92	5.7	5.1	39.1	12.4	24.3
3	5	Y	2.5003	3	2.273	1.327	2.4430	3	4.196	2.431	-.057	4.772	5.427	-2.293	.079	.006	.190	.110	.216
		X	.6190	18	7.388	1.842	.6033	18	2.726	.650	-.016	7.875	3.828	-2.528	.032	.096	1.244	.308	.605
		(Y+X)/2												-2.410	.055	.048	.629	.164	.321
		Y/X												90.72	4.3	3.4	45.3	11.9	23.3
3	6	Y	2.5010	3	4.034	2.337	2.4710	3	3.778	2.190	-.030	5.528	6.278	-1.200	.079	.006	.220	.127	.249
		X	.6207	18	6.313	1.604	.6106	18	1.885	.455	-.010	6.589	3.269	-1.626	.032	.096	1.046	.265	.519
		(Y+X)/2												-1.413	.056	.048	.534	.147	.288
		Y/X												73.75	6.3	4.4	49.3	14.3	28.1
FUEL		Y	2.4969	54	10.412	1.421	2.4496	54	19.633	2.674	-.047	22.224	5.935	-1.694	.079	.006	.886	.121	.237
ELEMENT		X	.6170	324	5.139	.664	.6051	324	4.735	.281	-.012	6.988	1.414	-1.935	.032	.097	1.121	.115	.225
AVERAGE		(Y+X)/2												-1.915	.056	.048	.714	.083	.163
		Y/X												97.67	5.7	4.9	72.9	8.5	16.7

TABLE 4-34
FTE-15 FUEL ROD METROLOGY DATA

PRECISION:										PRECISION:									
LENGTH = .00100										LENGTH = .00100									
DIAMETER = .00010										DIAMETER = .00010									
EQUIPMENT RANDOM ERROR:										EQUIPMENT RANDOM ERROR:									
LENGTH = .00010										LENGTH = .00010									
DIAMETER = .00060										DIAMETER = .00010									
BODY HOLE		LENGTH DIAMETER LEN + DIAM ANISOTROPY	PRE-IRRADIATION				POST-IRRADIATION				DIFFERENCE			STRAIN					
			IN Y1 X1	MIL NY1 NX1	MIL SY1 SX1	MIL EY1 EX1	IN Y2 X2	MIL NY2 NX2	MIL SY2 SX2	MIL EY2 EX2	IN Y21 X21	MIL SY21 SX21	MIL DY21 DX21	Z UY UX V W EY EX RX RV RW SW	Z EY EX RX RV RW SW	Z EY EX RX RV RW SW	Z EY EX RX RV RW SW	Z EY EX RX RV RW SW	Z EY EX RX RV RW SW
1	1	Y	2.5171	11	6.457	1.951	2.4449	11	18.449	5.564	-.072	19.547	11.557	-2.868	.078	.006	.774	.234	.458
		X	.6156	66	2.896	.698	.6033	66	3.897	.490	-.012	4.855	1.671	-1.990	.032	.097	.783	.137	.266
		(Y+X)/2												-2.429	.055	.049	.551	.135	.265
		Y/X												144.12	6.3	7.0	68.8	15.4	30.1
1	3	Y	2.5025	2	1.965	1.408	2.4411	2	13.188	9.328	-.061	13.333	18.490	-2.452	.079	.006	.533	.377	.738
		X	.6137	12	2.363	.908	.6037	12	3.242	.941	-.010	4.012	2.564	-1.633	.032	.098	.650	.211	.414
		(Y+X)/2												-2.042	.056	.049	.420	.216	.423
		Y/X												150.09	7.8	9.0	68.0	30.2	59.1
1	4	Y	2.5056	5	2.419	1.094	2.4385	5	11.372	5.088	-.067	11.626	10.201	-2.676	.079	.006	.463	.207	.407
		X	.6141	30	2.552	.760	.6039	30	3.574	.660	-.010	4.392	1.973	-1.661	.032	.097	.711	.162	.318
		(Y+X)/2												-2.169	.056	.049	.424	.132	.258
		Y/X												161.13	7.9	9.5	74.4	20.1	39.4
1	5	Y	2.5088	6	3.379	1.358	2.4464	6	14.463	5.907	-.062	14.853	11.892	-2.490	.079	.006	.591	.242	.473
		X	.6149	36	2.779	.758	.6050	36	3.190	.541	-.010	4.230	1.825	-1.611	.032	.097	.663	.150	.294
		(Y+X)/2												-2.050	.055	.049	.452	.142	.279
		Y/X												154.57	8.0	9.3	75.1	20.8	40.7
2	1	Y	2.4892	11	2.474	.758	2.4355	11	16.362	4.935	-.054	16.548	9.786	-2.157	.079	.006	.664	.200	.393
		X	.6143	66	2.854	.695	.6006	66	5.533	.688	-.013	6.226	1.918	-2.194	.032	.097	1.009	.158	.309
		(Y+X)/2												-2.175	.056	.049	.604	.127	.250
		Y/X												98.32	5.1	4.4	54.4	11.5	22.6
2	2	Y	2.5002	9	5.100	1.705	2.4774	9	10.261	3.430	-.023	11.476	7.537	-.913	.080	.006	.458	.153	.300
		X	.6167	60	2.891	.707	.6114	60	3.632	.479	-.005	4.642	1.674	-.847	.032	.098	.750	.138	.270
		(Y+X)/2												-.860	.056	.049	.440	.103	.202
		Y/X												107.80	13.5	12.5	109.8	25.2	49.3
2	3	Y	2.4835	10	3.530	1.124	2.4300	10	2.904	.928	-.053	4.571	2.858	-2.153	.080	.006	.162	.058	.114
		X	.6133	66	2.105	.654	.6007	66	1.876	.252	-.013	2.820	1.373	-2.057	.032	.097	.454	.112	.220
		(Y+X)/2												-2.105	.056	.049	.245	.063	.124
		Y/X												104.67	5.5	5.0	24.8	6.4	12.5
2	4	Y	2.5004	5	3.500	1.574	2.4444	5	2.848	1.284	-.056	4.512	3.981	-2.240	.079	.006	.178	.080	.157
		X	.6164	30	2.842	.793	.6029	30	2.513	.470	-.013	3.794	1.807	-2.180	.032	.097	.605	.147	.268
		(Y+X)/2												-2.210	.056	.048	.317	.084	.164
		Y/X												102.71	5.1	4.6	29.8	7.8	15.4
2	5	Y	2.4970	2	1.900	1.924	2.4313	2	1.900	1.924	-.066	2.687	5.334	-2.631	.079	.006	.106	.108	.211

TABLE 4-34 (Continued)

		X	.6169	18	3.437	1.008	.6011	18	2.485	.594	-.016	4.242	2.294	-2.561	.032	.096	.676	.186	.365
		(Y+X)/2												-2.596	.056	.048	.342	.107	.211
		Y/X												102.73	4.4	3.9	27.4	8.6	16.8
2	6	Y	2.5029	11	3.311	1.007	2.4845	11	3.307	1.006	-.018	4.680	2.790	-.736	.080	.006	.186	.057	.111
		X	.6214	66	7.561	1.107	.6142	66	4.306	.539	-.007	8.702	2.414	-1.156	.032	.097	1.388	.196	.385
		(Y+X)/2												-.946	.056	.048	.700	.102	.200
		Y/X												63.66	8.6	5.4	78.1	11.9	23.3
3	1	Y	2.4938	11	2.785	.850	2.4399	11	4.124	1.250	-.054	4.976	2.964	-2.160	.079	.006	.196	.060	.118
		X	.6153	66	2.646	.683	.6012	66	2.409	.313	-.014	3.579	1.472	-2.293	.032	.097	.574	.120	.235
		(Y+X)/2												-2.226	.056	.048	.304	.067	.131
		Y/X												94.22	4.8	4.0	25.1	5.6	10.9
3	2	Y	2.4977	7	2.094	.805	2.4726	7	6.828	2.585	-.025	7.142	5.307	-1.004	.080	.006	.286	.108	.212
		X	.6169	42	2.914	.750	.6110	42	3.734	.585	-.006	4.736	1.864	-.955	.032	.098	.765	.153	.300
		(Y+X)/2												-.980	.056	.049	.408	.094	.184
		Y/X												105.18	11.9	10.8	89.4	20.3	39.9
3	3	Y	2.4855	6	2.920	1.202	2.4348	6	3.997	1.639	-.051	4.950	3.984	-2.041	.080	.006	.198	.081	.159
		X	.6131	36	2.122	.696	.6012	36	1.648	.292	-.012	2.687	1.481	-1.936	.032	.097	.433	.121	.238
		(Y+X)/2												-1.968	.056	.049	.238	.073	.143
		Y/X												105.40	5.9	5.3	25.7	7.8	15.3
3	4	Y	2.4973	6	2.738	1.129	2.4500	6	2.721	1.122	-.047	3.861	3.119	-1.893	.079	.006	.153	.063	.124
		X	.6169	42	3.127	.770	.6042	42	2.698	.428	-.013	4.130	1.727	-2.048	.032	.097	.662	.141	.276
		(Y+X)/2												-1.971	.056	.048	.340	.077	.151
		Y/X												92.43	5.3	4.4	30.8	7.1	13.8
3	5	Y	2.5004	5	4.455	1.999	2.4532	5	12.988	5.811	-.047	13.731	12.044	-1.887	.079	.006	.548	.245	.481
		X	.6181	36	4.956	1.021	.6044	36	3.391	.574	-.014	6.005	2.296	-2.220	.032	.096	.957	.186	.365
		(Y+X)/2												-2.053	.056	.048	.551	.154	.302
		Y/X												85.01	4.8	3.7	44.2	13.2	25.8
3	6	Y	2.4598	11	2.785	.850	2.4730	11	4.003	1.214	-.027	4.877	2.905	-1.073	.080	.006	.194	.059	.116
		X	.6195	66	2.150	.656	.6111	66	1.931	.258	-.008	2.890	1.381	-1.345	.032	.097	.463	.112	.220
		(Y+X)/2												-1.209	.056	.049	.251	.064	.124
		Y/X												79.79	7.8	5.8	31.0	8.0	15.7
FUEL		Y	2.4986	118	9.645	.894	2.4523	118	20.626	1.902	-.046	22.770	4.118	-1.851	.079	.006	.908	.084	.164
ELEMENT		X	.6163	736	4.233	.620	.6055	738	5.794	.236	-.011	7.176	1.300	-1.752	.032	.097	1.157	.106	.208
AVERAGE		(Y+X)/2												-1.802	.056	.049	.736	.068	.132
		Y/X												105.67	6.5	5.9	86.9	8.0	15.6

TABLE 4-35
FTE-14 FUEL ROD STRAIN SUMMARY

Body No.	Hole No.	Fuel Blend (%)	Axial Strain		Radial Strain		Anisotropy		Average Strain			Number of Samples, n	Relative Diff, C/M-1		Statistical Tests $\sqrt{n}D$	Test Results D^2/n
			Y (%)	+1 σ (%)	X (%)	+1 σ (%)			Calc. C (%)	Meas. M (%)	+1 σ (%)					
			Y/X	+1 σ												
1	1	TRISO/BISO (23/77)	-2.33	0.37	-1.46	0.27	159	38	-2.27	-1.90	0.23	3	0.19	0.145	1.35	1.81
1	4	TRISO/BISO (22/78)	-2.19	0.28	-1.42	0.21	154	30	-1.92	-1.81	0.17	3	0.06	0.100	0.61	0.37
2	1	TRISO/BISO (23/77)	-2.22	0.11	-2.33	0.15	95	8	-2.44	-2.27	0.09	5	0.07	0.043	1.76	3.09
2	2	TRISO/TRISO (27/73)	-1.21	0.11	-1.34	0.15	90	13	-1.01	-1.27	0.09	5	-0.20	0.056	-3.36	13.20
2	3	TRISO/BISO (25/75)	-2.08	0.08	-2.08	0.12	100	7	-2.54	-2.08	0.07	5	0.22	0.041	5.38	28.96
2	4	TRISO/BISO (55/45)	-2.40	0.14	-2.20	0.15	109	10	-2.36	-2.30	0.10	5	0.03	0.045	0.58	0.34
2	5	TRISO/BISO (21/79)	-2.76	0.15	-2.79	0.20	99	9	-2.88	-2.77	0.13	5	0.04	0.049	0.81	0.66
2	6	TRISO/TRISO (25/75)	0.94	0.12	-1.51	0.21	62	12	-0.73	-1.23	0.12	5	-0.41	0.058	-7.02	49.29
3	1	TRISO/BISO (23/77)	-2.13	0.57	-2.08	0.16	103	28	-1.88	-2.11	0.29	3	-0.11	0.122	-0.89	0.79
3	2	TRISO/TRISO (25/75)	-0.81	0.20	-1.61	0.33	51	17	-0.84	-1.21	0.20	3	-0.31	0.115	-2.66	7.10
3	3	TRISO/BISO (25/75)	-1.79	0.10	-1.77	0.16	101	11	-1.93	-1.78	0.09	3	0.08	0.055	1.54	2.36
3	4	TRISO/BISO (55/45)	-2.02	0.14	-1.96	0.19	103	12	-1.85	-1.99	0.12	3	-0.07	0.056	-1.25	1.57
3	5	TRISO/BISO (21/79)	-2.29	0.11	-2.53	0.31	91	12	-2.15	-2.41	0.16	3	-0.11	0.059	-1.82	3.32
3	6	TRISO/TRISO (23/73)	-1.20	0.13	-1.63	0.27	74	14	-0.95	-1.41	0.15	3	-0.33	0.072	-4.55	20.72

TABLE 4-36
FTE-15 FUEL ROD STRAIN SUMMARY

Body No.	Hole No.	Fuel Blend (%)	Axial Strain		Radial Strain		Anisotropy		Average Strain			Number of Samples, n	Relative Diff,		Statistical Tests $\sqrt{nD}$	Test Results D^2/n
			Y (%)	+1 σ (%)	X (%)	+1 σ (%)			Calc. C (%)	Meas. M (%)	+1 σ (%)		C/M-1	+1 σ		
							Y/X	+1 σ								
1	1	TRISO/BISO (23/77)	-2.87	0.23	-1.99	0.27	144	15	-2.86	-2.43	0.14	11	0.17	0.068	2.61	6.81
1	3	TRISO/BISO (22/78)	-2.45	0.38	-1.63	0.21	150	30	-2.47	-2.04	0.22	2	0.21	0.131	1.61	2.61
1	4	TRISO/BISO (22/78)	-2.68	0.21	-1.66	0.32	161	39	-2.41	-2.17	0.13	5	0.11	0.067	1.66	2.76
1	5	TRISO/BISO (23/77)	-2.49	0.24	-1.61	0.15	155	21	-2.56	-2.05	0.14	6	0.25	0.085	2.92	8.51
2	1	TRISO/BISO (27/73)	-2.16	0.20	-2.19	0.16	98	12	-2.90	-2.18	0.13	11	ND(a)	--	--	--
2	2	TRISO/TRISO (27/73)	-0.91	0.15	-0.85	0.14	108	25	-1.13	-0.88	0.10	10	0.33	0.079	4.16	17.33
2	3	TRISO/BISO (27/75)	-2.15	0.06	-2.06	0.11	105	6	-3.09	-2.11	0.06	11	0.46	0.042	11.15	124.39
2	4	TRISO/BISO (55/45)	-2.24	0.08	-2.18	0.15	103	8	-2.93	-2.21	0.08	5	0.33	0.048	6.79	46.08
2	5	TRISO/BISO (21/79)	-2.63	0.11	-2.56	0.19	103	9	-3.24	-2.60	0.11	3	0.25	0.053	4.67	21.80
2	6	TRISO/TRISO (25/75)	-0.74	0.06	-1.16	0.20	64	12	-0.94	-0.95	0.10	11	-0.01	0.104	-0.10	0.01
3	1	TRISO/BISO (27/73)	-2.16	0.06	-2.29	0.12	94	6	-2.46	-2.23	0.07	11	0.10	0.035	2.98	8.87
3	2	TRISO/TRISO (27/73)	-1.00	0.11	-0.96	0.15	105	20	-1.03	-0.98	0.09	7	0.05	0.097	0.53	0.28
3	3	TRISO/BISO (25/75)	-2.04	0.08	-1.94	0.12	105	8	-2.65	-1.99	0.07	6	0.33	0.047	7.08	50.13
3	4	TRISO/BISO (55/45)	-1.89	0.06	-2.05	0.14	92	7	-2.58	-1.97	0.08	7	0.31	0.053	5.82	33.90
3	5	TRISO/BISO (21/79)	-1.89	0.25	-2.22	0.19	85	13	-2.72	-2.05	0.15	6	0.33	0.097	3.37	11.33
3	6	TRISO/TRISO (23/77)	-1.07	0.06	-1.35	0.11	80	8	-0.85	-1.21	0.06	11	-0.30	0.035	-8.54	72.95

(a) Rod 11 is not considered reliable with -0.19 shrinkage.

TABLE 4-37
FTE-14 COMPARISON OF MEASURED AND CALCULATED FUEL ROD-FUEL HOLE GAPS

FUEL STACKS 1-1,1-2, & 1-3 UC2 TRISO (23% FUEL VOL) & THC2 BISO (77% FUEL VOL)
CALCULATED STRAINS BASED ON TEMPERATURES FOR FUEL STACK 1-1

FUEL BODY	CORE HEIGHT	GAP MIL	CALCULATED		GAP MIL	MEASURED		RELATIVE DIFFERENCE			COMPARISON	
			S(1 SIGMA) MIL	E(1 SIGMA) MIL		S(1 SIGMA) MIL	E(1 SIGMA) MIL	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=Z/EZ	TEST2 D**2
1	29.88	7.907			5.685	.579	.606	39.09	14.16	14.82	2.64	6.96
	39.82	9.865			9.477	.463	.496	4.09	5.09	5.45	.75	.56
	49.77	10.248			10.602	.434	.469	-3.34	3.96	4.28	-.78	.61
BODY AVERAGE		9.340			8.588	.496	.527	13.28	8.98	9.45	.87	2.71
RMS/ERROR/TESTS		1.025			2.103	.286	.304	18.50 10.68	5.19	5.45	1.51	2.59

TABLE 4-37 (CONTINUED)

FUEL STACKS 2-6 & 3-2 UO2 TRISO (25% FUEL VOL.) & THO2 TRISO (75% FUEL VOL.)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL	MIL	MIL	MIL	MIL	MIL	Z (%)	SZ (%)	EZ (%)	D=Z/EZ	D**2
2	60.99	7.805			11.690	.402	.450	-33.24	2.30	2.57	-12.94	167.32
	65.96	7.330			11.399	.401	.449	-35.69	2.26	2.53	-14.09	198.65
	70.93	7.267			12.499	.458	.501	-41.86	2.13	2.33	-17.97	323.01
	75.91	7.537			11.965	.355	.408	-37.01	1.87	2.15	-17.24	297.21
	80.88	7.746			12.224	.276	.341	-36.63	1.43	1.77	-20.70	428.29
BODY AVERAGE		7.537			11.955	.383	.433	-36.68	2.02	2.29	-16.59	282.90
RMS/ERROR/TESTS		.215			.387	.171	.194	2.81 1.26	.90	1.02	37.09	2.21
3	92.09	10.161			15.371	.552	.587	-33.90	2.37	2.53	-13.42	180.18
	102.03	10.176			14.204	.524	.562	-28.36	2.64	2.83	-10.01	100.25
	111.98	10.553			14.346	.558	.593	-26.44	2.86	3.04	-8.69	75.59
BODY AVERAGE		10.297			14.640	.545	.581	-29.56	2.63	2.81	-10.71	118.67
RMS/ERROR/TESTS		.181			.520	.314	.335	3.16 1.83	1.52	1.62	18.55	2.59

TABLE 4-37 (CONTINUED)

FUEL STACKS 2-3 & 3-3 UO2 TRISO (25% FUEL VOL.) & THO2 BISO (75% FUEL VOL.)

FUEL BODY	CORE HEIGHT	GAP MIL	CALCULATED		GAP MIL	MEASURED		RELATIVE DIFFERENCE			COMPARISON		
			S(1 SIGMA) MIL	E(1 SIGMA) MIL		S(1 SIGMA) MIL	E(1 SIGMA) MIL	CALC/MEAS-1 Z(%)	S(1 SIGMA) SZ(%)	E(1 SIGMA) EZ(%)	TEST1 D=2/EZ	TEST2 D**2	
2	60.99	10.546			11.826	.266	.334	-10.82	2.00	2.52	-4.30	18.51	
	65.96	10.128			11.818	.540	.576	-14.30	3.91	4.18	-3.42	11.72	
	70.93	10.081			12.151	.400	.448	-17.03	2.73	3.06	-5.57	31.03	
	75.91	10.298			12.201	.488	.528	-15.60	3.37	3.65	-4.27	18.26	
	80.88	10.432			11.626	.203	.286	-10.27	1.57	2.21	-4.65	21.63	
BODY AVERAGE													
		10.297			11.925	.400	.448	-13.61	2.85	3.20	-4.44	20.23	
RMS/ERROR/TESTS		.176			.218	.179	.200	2.65	1.18	1.27	1.43	9.94	2.21
3	92.09	10.061			11.535	.580	.614	-12.78	4.38	4.64	-2.76	7.59	
	102.03	9.501			11.035	.391	.440	-13.91	3.05	3.43	-4.05	16.42	
	111.98	8.684			10.185	.518	.555	-14.74	4.33	4.65	-3.17	10.06	
BODY AVERAGE													
		9.415			10.919	.502	.541	-13.81	3.97	4.28	-3.33	11.36	
RMS/ERROR/TESTS		.565			.557	.290	.312	.80	.46	2.29	2.47	5.76	2.59

TABLE 4-37 (CONTINUED)

FUEL STACK 2-2 UC2 TRISO (27% FUEL VOL.) & THC2 TRISO (73% FUEL VOL.)
 FUEL STACK 3-6 UO2 TRISO (23% FUEL VOL.) & THC2 TRISO (23% FUEL VOL.)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL	MIL	MIL	MIL	MIL	MIL	Z(%)	SZ(%)	EZ(%)	D=2/EZ	D**2
2	60.99	5.032			8.143	.520	.557	-38.21	3.94	4.23	-9.04	81.65
	65.96	4.570			8.785	.716	.744	-47.97	4.24	4.40	-10.89	118.66
	70.93	4.510			7.918	.617	.649	-43.04	4.44	4.67	-9.21	84.89
	75.91	4.770			8.026	.409	.456	-40.57	3.03	3.38	-12.01	144.26
	80.88	4.972			7.810	.410	.457	-36.33	3.35	3.73	-9.75	95.05
BODY AVERAGE		4.771			8.136	.548	.583	-41.23	3.84	4.11	-10.18	104.90
RMS/ERROR/TESTS		.208			.343	.245	.261	4.06	1.81	1.72	1.84	22.76
3	92.09	8.344			12.390	.305	.366	-32.65	1.66	1.99	-16.43	269.87
	102.03	8.359			12.931	.279	.344	-35.36	1.40	1.72	-20.54	422.00
	111.98	8.715			12.081	.522	.559	-27.86	3.12	3.34	-8.34	69.57
BODY AVERAGE		8.473			12.467	.384	.434	-31.96	2.19	2.45	-15.10	253.81
RMS/ERROR/TESTS		.172			.351	.222	.251	3.10	1.79	1.27	1.42	26.16

TABLE 4-37 (CONTINUED)

FUEL STACK 1-5 UC2 TRISO (22% FUEL VOL.) & THC2 BISO (78% FUEL VOL.)
 FUEL STACKS 2-5 & 3-5 UO2 TRISO (21% FUEL VOL.) & THC2 BISO (79% FUEL VOL.)

FUEL BODY	CORE HEIGHT	GAP MIL	CALCULATED		GAP MIL	MEASURED		RELATIVE DIFFERENCE			COMPARISON	
			S(1 SIGMA) MIL	E(1 SIGMA) MIL		S(1 SIGMA) MIL	E(1 SIGMA) MIL	CALC/MEAS-1 Z(%)	S(1 SIGMA) S2(%)	E(1 SIGMA) E2(%)	TEST1 D=Z/E2	TEST2 D**2
2	60.99	11.724			14.483	.603	.635	-19.05	3.37	3.55	-5.36	28.78
	65.96	11.322			15.500	.493	.532	-26.96	2.32	2.51	-10.75	115.46
	70.93	11.279			14.566	.552	.588	-22.57	2.93	3.12	-7.23	52.20
	75.91	11.482			15.483	.365	.417	-25.84	1.75	2.00	-12.95	167.71
	80.88	11.605			14.491	.517	.555	-19.92	2.86	3.07	-6.49	42.12
BODY AVERAGE												
		11.482			14.905	.512	.550	-22.87	2.70	2.90	-8.56	81.26
RMS/ERROR/TESTS		.167			.480	.229	.246	3.13 1.40	1.21	1.30	19.13	2.21
3	92.09	13.197			17.048	.570	.605	-22.59	2.59	2.75	-8.23	67.67
	102.03	12.576			16.231	.546	.582	-22.52	2.61	2.78	-8.10	65.64
	111.98	11.660			15.015	.409	.456	-22.34	2.11	2.36	-9.48	89.84
BODY AVERAGE												
		12.478			16.098	.513	.552	-22.48	2.45	2.63	-8.60	74.38
RMS/ERROR/TESTS		.631			.835	.296	.318	.11 .06	1.41	1.52	14.90	2.59

TABLE 4-37 (CONTINUED)

FUEL STACK 1-4 UC2 TRISO (22% FUEL VOL.) & THC2 BISO (78% FUEL VOL.)
 FUEL STACKS 2-4 & 3-4 (TH,U)O2 TRISO (55% FUEL VOL.) & THC2 BISO (45% FUEL VOL.)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL	MIL	MIL	MIL	MIL	MIL	Z(%)	SZ(%)	EZ(%)	D=Z/EZ	D**2
1	29.88	8.075			6.618	.200	.268	22.01	3.69	4.94	4.46	19.89
	39.82	9.523			9.627	.274	.327	-1.08	2.81	3.36	-.32	.10
	49.77	9.757			11.510	.290	.340	-15.23	2.14	2.51	-6.08	36.94
BODY AVERAGE		9.118			9.252	.258	.313	1.90	2.95	3.74	-.65	18.98
RMS/ERROR/TESTS		.744			2.015	.149	.181	15.35	8.86	1.70	1.12	2.59
2	60.99	8.951			9.984	.580	.614	-10.35	5.20	5.51	-1.88	3.53
	65.96	8.546			11.001	.699	.728	-22.32	4.94	5.14	-4.34	18.87
	70.93	8.500			11.559	.361	.413	-26.47	2.30	2.63	-10.06	101.24
	75.91	8.710			11.009	.609	.642	-20.88	4.38	4.61	-4.53	20.51
	80.88	8.847			11.034	.526	.564	-19.82	3.82	4.09	-4.84	23.44
BODY AVERAGE		8.711			10.918	.566	.601	-19.97	4.26	4.51	-5.13	33.52
RMS/ERROR/TESTS		.172			.512	.253	.269	5.31	2.38	1.90	2.02	11.47
3	92.09	8.227			10.952	.604	.636	-24.88	4.14	4.37	-5.70	32.48
	102.03	7.735			10.302	.467	.509	-24.92	3.41	3.71	-6.72	45.16
	111.98	7.012			8.369	.390	.439	-16.21	3.90	4.39	-3.69	13.62
BODY AVERAGE		7.658			9.874	.495	.534	-22.00	3.83	4.17	-5.37	30.42
RMS/ERROR/TESTS		.499			1.097	.286	.308	4.10	2.37	2.21	2.41	9.30

TABLE 4-37 (CONTINUED)

FUEL STACKS 2-1 & 3-1 UC2 TRISO (23% FUEL VOL.) & THC2 BISO (77% FUEL VOL.)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL	MIL	MIL	MIL	MIL	MIL	Z(%)	SZ(%)	EZ(%)	D=Z/EZ	D**2
2	60.99	9.643			11.951	.337	.392	-19.32	2.27	2.65	-7.29	53.20
	65.96	9.214			12.285	.547	.583	-24.99	3.34	3.56	-7.02	49.33
	70.93	9.165			12.110	.326	.383	-24.31	2.04	2.40	-10.15	102.94
	75.91	9.389			12.210	.383	.433	-23.10	2.42	2.73	-8.47	71.70
	80.88	9.533			11.693	.338	.393	-18.47	2.35	2.74	-6.74	45.40
BODY AVERAGE		9.389			12.050	.395	.443	-22.04	2.52	2.84	-7.93	64.51
RMS/ERROR/TESTS		.182			.210	.177	.198	2.65 1.19	1.13	1.27	17.74	2.21
3	92.09	8.894			11.235	.460	.502	-20.84	3.24	3.54	-5.90	34.76
	102.03	8.378			11.377	.313	.372	-26.36	2.03	2.41	-10.94	119.62
	111.98	7.650			10.235	.304	.364	-25.26	2.22	2.66	-9.49	90.08
BODY AVERAGE		8.307			10.949	.366	.418	-24.15	2.55	2.91	-8.77	81.48
RMS/ERROR/TESTS		.510			.508	.211	.241	2.38 1.38	1.47	1.68	15.20	2.59

TABLE 4-38
FTE-15 COMPARISON OF MEASURED AND CALCULATED FUEL ROD-FUEL HOLE GAPS

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL	MIL	MIL	MIL	MIL	MIL	Z(%)	SZ(%)	EZ(%)	D=Z/EZ	D+2
1	27.39	9.058			8.091	.576	.603	11.95	7.97	8.34	1.43	2.05
	29.88	10.558			8.758	.279	.331	20.55	3.84	4.55	4.51	20.38
	32.37	11.525			9.991	.512	.542	15.36	5.91	6.25	2.46	6.03
	34.85	12.130			10.383	.504	.535	16.83	5.68	6.02	2.80	7.82
	37.34	12.502			10.966	.466	.501	14.00	4.87	5.20	2.69	7.24
	39.82	12.713			11.466	.598	.624	10.87	5.78	6.03	1.80	3.25
	42.31	12.832			12.049	.517	.547	6.49	4.57	4.83	1.34	1.80
	44.80	12.898			12.874	.280	.331	.18	2.18	2.58	.07	.01
	47.28	12.927			12.891	.472	.505	.28	3.67	3.92	.07	.01
	49.77	12.931			12.891	.381	.420	.31	2.96	3.27	.09	.01
	52.26	12.864			12.891	.234	.294	-.21	1.81	2.27	-.09	.01
BODY AVERAGE												
		12.065			11.205	.454	.488	8.78	4.80	5.14	1.56	4.42
RMS/ERROR/TESTS		1.192			1.651	.137	.147	7.34	2.21	1.45	5.18	1.79

TABLE 4-38 (CONTINUED)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL		MIL	MIL		MIL	Z(%)	S2(%)	E2(%)	C=Z/EZ	D**2
2	58.50	11.196			11.334	.564	.599	-1.21	4.92	5.22	-.23	.05
	60.99	11.176			12.284	.350	.404	-9.01	2.59	2.99	-3.01	9.09
	63.48	11.144			12.775	.581	.615	-12.77	3.97	4.20	-3.04	9.26
	65.96	10.743			13.134	.524	.562	-18.20	3.27	3.50	-5.20	27.08
	68.45	10.535			13.317	.419	.465	-20.89	2.49	2.76	-7.57	57.27
	70.93	10.718			12.950	.304	.364	-17.23	1.94	2.33	-7.40	54.82
	73.42	10.905			12.364	.330	.387	-11.94	2.35	2.75	-4.34	18.83
	75.91	11.006			12.550	.343	.398	-12.31	2.40	2.78	-4.42	19.57
	78.39	11.249			12.264	.430	.475	-8.42	3.21	3.54	-2.38	5.67
	80.88	11.216			11.850	.278	.344	-5.35	2.22	2.74	-1.95	3.80
	83.37	11.146			4.175	1.328	1.343	166.95	84.89	85.86	1.94	3.78
BODY AVERAGE												
		11.003			11.731	.570	.604	4.51	25.76	26.09	-3.42	19.02
RMS/ERROR/TESTS		.232			2.450	.172	.182	51.66	15.57	7.77	7.87	11.34
3	89.60	10.104			10.523	.394	.442	-3.41	3.62	4.06	-.84	.71
	92.09	10.035			10.715	.376	.427	-6.35	3.29	3.73	-1.70	2.90
	94.56	9.921			11.582	1.036	1.055	-14.34	7.66	7.80	-1.84	3.38
	97.06	9.821			10.598	.459	.501	-7.34	4.01	4.38	-1.67	2.80
	99.55	9.731			10.782	.322	.379	-9.74	2.69	3.18	-3.07	9.41
	102.03	9.653			10.523	.708	.736	-8.27	6.17	6.42	-1.29	1.66
	104.52	9.563			10.140	.449	.492	-5.50	4.18	4.58	-1.20	1.44
	107.01	9.478			9.923	.382	.432	-4.49	3.67	4.15	-1.08	1.17
	109.49	9.259			9.990	.344	.398	-7.31	3.19	3.70	-1.98	3.92
	111.98	8.917			9.707	.404	.451	-6.14	3.82	4.27	-1.91	3.63
	114.47	8.574			9.248	.284	.348	-7.29	2.85	3.49	-2.09	4.37
BODY AVERAGE												
		9.558			10.339	.513	.551	-7.47	4.35	4.71	-1.70	3.22
RMS/ERROR/TESTS		.458			.599	.155	.166	2.76	.83	1.31	1.42	5.63

TABLE 4-38 (CONTINUED)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL		MIL	MIL		MIL	Z(1)	SZ(1)	EZ(1)	D=Z/EZ	D**2
2	58.50	5.236			6.434	.275	.340	-18.62	3.47	4.31	-4.32	18.70
	60.99	5.185			4.967	.601	.633	4.39	12.62	13.31	.33	.11
	63.48	5.130			5.325	1.036	1.056	-3.67	18.75	19.10	-.19	.04
	65.96	4.715			7.267	.327	.384	-35.25	2.91	3.42	-10.31	106.21
	68.45	4.481			8.392	.495	.535	-46.60	3.15	3.40	-13.70	187.69
	70.93	4.661			7.484	.594	.628	-37.72	4.95	5.22	-7.22	52.16
	73.42	4.853			5.525	.493	.533	-12.17	7.84	8.47	-1.44	2.06
	78.39	5.215			5.192	.960	.981	.44	18.58	18.98	.02	.00
	80.88	5.156			6.059	.705	.733	-14.24	9.96	10.38	-1.37	1.88
	83.37	5.152			7.442	.451	.494	-30.78	4.20	4.60	-6.70	44.83
BODY AVERAGE		4.981			6.409	.639	.670	-19.42	10.44	10.83	-4.49	41.37
RMS/ERROR/TESTS		.265			1.119	.202	.212	16.56	5.24	3.30	3.42	1.83
3	92.09	4.527			3.915	1.010	1.029	15.64	29.82	30.41	.51	.26
	94.58	4.474			5.648	1.144	1.162	-20.78	16.04	16.29	-1.28	1.63
	97.06	4.454			4.107	.978	.999	8.45	25.83	26.37	.32	.10
	99.55	4.468			5.732	.374	.425	-22.04	5.09	5.78	-3.82	14.56
	102.03	4.524			6.523	.380	.430	-30.64	4.04	4.57	-6.71	45.00
	107.01	4.769			6.282	.485	.525	-24.08	5.86	6.35	-3.79	14.40
	111.98	5.024			5.965	.431	.476	-15.78	6.09	6.72	-2.35	5.52
BODY AVERAGE		4.606			5.453	.755	.781	-12.75	16.59	17.01	-2.44	11.64
RMS/ERROR/TESTS		.158			.955	.285	.295	16.32	6.17	6.27	6.43	2.01

TABLE 4-38 (CONTINUED)

FUEL BODY	CORE HEIGHT	GAP MIL	CALCULATED			MEASURED			RELATIVE DIFFERENCE				COMPARISON	
			S(1 SIGMA) MIL	E(1 SIGMA) MIL	GAP MIL	S(1 SIGMA) MIL	E(1 SIGMA) MIL	ALC/MEAS-1 Z(1)	S(1 SIGMA) Z(2)	E(1 SIGMA) Z(2)	O-Z/EZ	D+Z		
1	29.88	10.137			8.299	.336	.380	22.14	4.94	5.59	3.96	15.70		
	34.85	11.312			9.783	.510	.540	15.64	6.02	6.38	2.45	6.01		
	39.82	11.724			10.774	.329	.374	8.82	3.32	3.78	2.33	5.45		
	44.80	11.838			11.833	.351	.393	.05	2.97	3.33	.01	.00		
	49.77	11.844			12.749	.291	.341	-7.10	2.12	2.48	-2.86	8.18		
BODY AVERAGE					10.688	.371	.411	7.91	4.12	4.55	1.18	7.07		
RMS/ERROR/TESTS		.647			1.555	.166	.184	10.49	4.69	1.84	2.03	2.64	2.21	
2	56.50	10.249			10.750	.301	.362	-4.67	2.67	3.21	-1.45	2.11		
	60.99	10.233			10.992	.328	.365	-6.90	2.78	3.26	-2.12	4.49		
	63.48	10.204			9.442	.798	.823	8.07	9.14	9.42	.86	.73		
	50.88	10.272			11.300	.313	.372	-9.10	2.52	2.99	-3.04	9.23		
	83.37	10.204			10.817	.467	.509	-5.66	4.07	4.44	-1.28	1.63		
BODY AVERAGE					10.660	.480	.520	-3.65	4.92	5.26	-1.41	3.64		
RMS/ERROR/TESTS		.026			.638	.215	.233	6.05	2.70	2.20	2.35	3.14	2.21	
3	92.09	9.786			9.280	.569	.603	5.46	6.47	6.86	.80	.63		
	94.58	9.675			7.938	.679	.708	21.87	10.43	10.87	2.01	4.05		
	97.06	9.575			10.263	.540	.577	-6.71	4.91	5.24	-1.28	1.64		
	99.55	9.485			9.472	.909	.931	.14	9.61	9.85	.01	.00		
	102.03	9.405			9.763	.514	.552	-3.67	5.08	5.45	-.67	.45		
	107.01	9.227			9.030	.568	.603	2.18	6.43	6.82	.32	.10		
	111.98	8.678			9.155	.329	.385	-5.21	3.40	3.99	-1.30	1.70		
BODY AVERAGE					9.272	.609	.642	2.01	7.03	7.39	-.02	1.23		
RMS/ERROR/TESTS		.341			.667	.230	.243	9.03	3.41	2.66	2.79	.64	2.01	

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TABLE 4-38 (CONTINUED)

FUEL BODY	CORE HEIGHT	CALCULATED		MEASURED		RELATIVE DIFFERENCE				COMPARISON	
		GAP MIL	S(1 SIGMA) MIL	GAP MIL	S(1 SIGMA) MIL	E(1 SIGMA) MIL	CALC/MEAS-1 Z(1)	S(1 SIGMA) Z(1)	E(1 SIGMA) Z(1)	TEST1 D-Z/EZ	TEST2 D+Z
1	32.37	11.322		9.566	.370	.411	18.36	4.58	5.08	3.61	13.05
	44.80	12.554		12.166	.402	.440	3.19	3.41	3.73	.85	.73
	BODY AVERAGE										
2	58.50	11.938		10.866	.387	.426	10.77	4.04	4.46	2.23	6.89
	60.99	.616		1.300	.273	.301	7.59	5.36	3.15	3.16	2.97
	63.48	12.188		11.559	.274	.340	5.45	2.50	3.10	1.76	3.09
	65.96	12.145		12.059	.562	.597	.96	4.71	5.00	.19	.04
	66.45	11.744		12.109	.643	.674	.30	5.33	5.58	.05	.00
	70.93	11.539		11.592	.522	.559	1.31	4.56	4.89	.27	.07
	73.42	11.743		12.017	.324	.381	-3.98	2.59	3.05	-1.21	1.70
	75.91	11.934		11.625	.347	.401	1.01	3.02	3.49	.29	.08
	78.39	12.014		12.200	.243	.316	-2.18	1.95	2.53	-.86	.74
81.68	83.37	12.258		12.225	.313	.372	-1.73	2.52	2.99	-.58	.33
	BODY AVERAGE										
	83.37	12.145		11.734	.243	.316	4.47	2.17	2.81	1.59	2.53
RMS/ERROR/TESTS				11.450	.223	.300	6.74	2.08	2.80	2.41	5.81
				11.034	.363	.415	10.07	3.62	4.14	2.43	5.92
3	92.09	12.010		11.782	.393	.442	2.04	3.38	3.81	.57	1.85
	97.06	.228		.356	.119	.133	4.02	1.21	1.15	1.88	1.79
	99.55	11.800		10.555	.487	.527	14.10	5.26	5.70	2.48	6.13
	102.03	11.691		11.055	.321	.379	6.74	3.10	3.66	1.84	3.38
	107.01	11.588		11.105	.307	.367	5.27	2.91	3.48	1.52	2.30
	111.98	10.675		10.922	.455	.498	6.10	4.42	4.84	1.26	1.59
BODY AVERAGE				10.772	.437	.481	5.29	4.27	4.70	1.13	1.27
				10.288	.345	.399	3.75	3.48	4.03	.93	.87
RMS/ERROR/TESTS				10.783	.398	.446	6.88	3.99	4.47	1.53	2.59
				.434	.163	.182	3.36	1.37	1.82	3.74	2.09

TABLE 4-38 (CONTINUED)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP	S(1 SIGMA)	E(1 SIGMA)	GAP	S(1 SIGMA)	E(1 SIGMA)	CALC/MEAS-1	S(1 SIGMA)	E(1 SIGMA)	TEST1	TEST2
		MIL	MIL	MIL	MIL	MIL	MIL	Z(1)	S2(1)	E2(1)	D=2/E2	D*2
1	27.39	8.769			8.408	.293	.342	4.30	3.63	4.25	1.01	1.02
	32.37	11.010			8.408	.293	.342	30.96	4.56	5.33	5.81	33.71
	37.34	11.912			9.691	.483	.515	22.92	6.13	6.53	3.51	12.31
	42.31	12.224			10.749	.253	.309	13.71	2.67	3.27	4.20	17.63
	47.28	12.320			11.533	.504	.535	6.82	4.67	4.95	1.38	1.90
	52.26	12.266			11.833	.239	.258	3.66	2.09	2.61	1.40	1.97
BODY AVERAGE												
		11.417			10.104	.361	.402	13.73	4.18	4.68	2.88	11.42
RMS/ERROR/TESTS		1.265			1.377	.147	.164	10.16	4.15	1.71	1.91	2.09
2	56.50	10.875			11.684	.477	.518	-6.92	3.80	4.13	-1.68	2.81
	66.99	10.866			11.467	.690	.719	-5.24	5.71	5.94	-.88	.78
	83.37	10.850			11.642	.438	.482	-6.80	3.51	3.86	-1.76	3.10
	BODY AVERAGE											
		10.864			11.597	.547	.583	-6.32	4.45	4.74	-1.44	2.23
RMS/ERROR/TESTS		.010			.094	.316	.336	.76	.44	2.57	2.73	2.49
3	92.09	13.056			12.403	.667	.697	5.26	5.66	5.91	.89	.79
	97.66	12.813			12.886	.579	.613	-5.57	4.47	4.73	-.12	.01
	102.03	12.549			10.369	.932	.954	21.50	10.92	11.17	1.92	3.70
	107.01	12.336			12.586	.765	.791	-1.97	5.96	6.16	-.32	.10
	109.49	12.049			11.986	.283	.347	.53	2.37	2.91	.18	.03
	111.98	11.615			12.903	.640	.671	-9.98	4.47	4.68	-2.13	4.55
BODY AVERAGE												
		12.412			12.189	.674	.703	2.46	6.22	6.46	.07	1.53
RMS/ERROR/TESTS		.460			.871	.275	.287	9.64	3.94	2.54	.17	2.09

TABLE 4-38 (CONTINUED)

FUEL BODY	CORE HEIGHT	CALCULATED			MEASURED			RELATIVE DIFFERENCE			COMPARISON	
		GAP MIL	S(1 SIGMA) MIL	E(1 SIGMA) MIL	GAP MIL	S(1 SIGMA) MIL	E(1 SIGMA) MIL	CALC/MEAS-1 Z(%)	S(1 SIGMA) S2(%)	E(1 SIGMA) E2(%)	TEST1 D=Z/EZ	TEST2 D**2
2	58.50	7.932			10.985	.464	.506	-27.80	3.05	3.32	-8.36	69.91
	60.99	7.884			10.877	.600	.632	-27.51	4.00	4.21	-6.53	42.61
	63.48	7.830			10.377	.878	.901	-24.55	6.38	6.55	-3.75	14.04
	65.96	7.356			10.427	.552	.587	-29.07	3.75	4.00	-7.27	52.92
	68.45	7.166			11.335	.394	.442	-36.79	2.20	2.47	-14.92	222.57
	70.93	7.348			9.835	1.116	1.136	-25.29	8.49	8.63	-2.93	8.59
	73.42	7.546			10.644	1.078	1.097	-29.11	7.18	7.31	-3.98	15.88
	75.91	7.658			10.944	.985	1.006	-30.03	6.30	6.43	-4.67	21.81
	78.39	7.918			9.444	1.576	1.589	-16.15	14.00	14.11	-1.14	1.31
	80.88	7.899			10.135	1.094	1.113	-22.07	8.41	8.56	-2.58	6.65
	83.37	7.843			10.119	.805	.830	-22.49	6.16	6.35	-3.54	12.53
BODY AVERAGE		7.674			10.466	.930	.952	-26.44	7.09	7.23	-5.43	42.62
RMS/ERROR/TESTS		.258			.534	.280	.287	5.07 1.53	2.14	2.18	17.99	1.79
3	85.60	3.421			5.888	.410	.457	-41.91	4.05	4.51	-9.29	86.37
	92.09	3.343			5.355	.383	.433	-37.57	4.46	5.04	-7.45	55.53
	94.58	3.256			5.863	.395	.443	-43.78	3.79	4.25	-10.30	106.19
	97.06	3.264			5.113	.610	.643	-35.78	7.67	8.07	-4.43	19.64
	99.55	3.310			6.038	.615	.647	-45.18	5.59	5.88	-7.69	59.09
	102.03	3.378			6.897	.421	.466	-51.02	2.99	3.31	-15.41	237.35
	104.52	3.447			5.788	.294	.356	-39.58	3.06	3.71	-10.65	113.51
	107.01	3.652			6.488	.414	.461	-43.71	3.59	4.00	-10.94	119.66
	109.49	3.801			6.047	.293	.356	-37.14	3.05	3.70	-10.04	100.85
	111.98	3.940			5.297	.281	.345	-25.62	3.94	4.85	-5.28	27.90
	114.47	4.079			5.355	.283	.347	-23.83	4.03	4.94	-4.83	23.29
BODY AVERAGE		3.546			5.830	.416	.462	-38.65	4.40	4.92	-8.76	86.31
RMS/ERROR/TESTS		.268			.515	.125	.139	7.75 2.34	1.33	1.48	29.04	1.79

TABLE 4-39
FTE-14 SUMMARY OF FUEL ROD POSTIRRADIATION EXAMINATION

Fuel Rod I.D. (a)	Fuel Type		Average Fuel Temp. (b) (°C)	EOL Fast Fluence (c) (10^{25} n/m ²) (E > 29 fJ)	Fissile Particle FI/MA (d) (%)	Fission Gas Release (e) Kr-85m (R/B)	Dimensional Change		Number of Broken Particles on Surface	Metallographic Examination							
										Fissile Particles				Fertile Particles			
	Fissile Particles	Fertile Particles					Length (%)	Diameter (%)		OPyC Failure (%)	95% Confidence Limits (%)	SiC Failure (%)	95% Confidence Limits (%)	OPyC Failure (%)	95% Confidence Limits (%)	SiC Failure (%)	95% Confidence Limits (%)
2-1-5	UC ₂ TRISO	ThC ₂ BISO	1313	1.45	24.5	2.62×10^{-4}	ND	ND	78	--	--	--	--	--	--	--	--
2-1-6	UC ₂ TRISO	ThC ₂ BISO	1283	1.45	24.3	3.75×10^{-4}	-2.41	-2.28	42	--	--	--	--	--	--	--	--
2-1-7	UC ₂ TRISO	ThC ₂ BISO	1251	1.44	24.0	1.08×10^{-3}	ND	ND	55	1.4	$0.0 \leq P \leq 7.5$	0.0	$0.0 \leq P \leq 5.3$	0.0	$0.0 \leq P \leq 1.8$	--	--
2-2-5	UC ₂ TRISO	ThC ₂ BISO	1289	1.45	24.5	4.92×10^{-5}	ND	ND	7	--	--	--	--	--	--	--	--
2-2-6	UC ₂ TRISO	ThC ₂ TRISO	1257	1.45	24.3	4.11×10^{-5}	-1.36	-1.21	18	2.4	$0.8 \leq P \leq 6.7$	3.9	$1.7 \leq P \leq 8.9$	(f)	--	(f)	--
2-2-11	UC ₂ TRISO	ThC ₂ TRISO	1133	1.36	22.3	7.55×10^{-5}	ND	ND	22	--	--	--	--	--	--	--	--
2-3-6	UO ₂ TRISO	ThO ₂ BISO	1286	1.45	24.3	ND	-1.81	-2.19	1	2.0	$0.7 \leq P \leq 6.1$	2.0	$0.7 \leq P \leq 6.1$	0.0	$0.0 \leq P \leq 1.4$	--	--
2-4-6	(Th,U)O ₂ TRISO (g)	ThC ₂ BISO	1291	1.45	24.3	ND	-2.73	-2.25	18	--	--	--	--	--	--	--	--
2-4-7	(Th,U)O ₂ TRISO (g)	ThC ₂ BISO	1251	1.44	24.0	5.02×10^{-5}	ND	ND	19	3.0	$1.0 \leq P \leq 8.4$	0.0	$0.0 \leq P \leq 3.7$	0.0	$0.0 \leq P \leq 3.1$	--	--
2-4-11	(Th,U)O ₂ TRISO	ThC ₂ BISO	1149	1.36	22.3	8.91×10^{-6}	ND	ND	2	--	--	--	--	--	--	--	--
2-6-5	UO ₂ TRISO	ThO ₂ TRISO	1280	1.45	24.5	3.18×10^{-5}	ND	ND	14	--	--	--	--	--	--	--	--
2-6-7	UO ₂ TRISO	ThO ₂ TRISO	1248	1.44	24.0	1.08×10^{-4}	ND	ND	15	2.0	$0.5 \leq P \leq 6.9$	0.0	$0.0 \leq P \leq 3.7$	0.0	$0.0 \leq P \leq 4.1$	12.8	$7.6 \leq P \leq 20.8$

(a) Fuel body - hole No. - fuel rod No. (No. 11 is at top).

(b) TREVER calculated.

(c) TREVER/GAUGE calculated.

(d) TREVER/GAUGE calculated.

(e) At 1100°C in TRIGA.

(f) Not determined because of ThC₂ hydrolysis.

(g) Th/U ratio = 1:1.

TABLE 4-40
FTE-15 SUMMARY OF FUEL ROD POSTIRRADIATION EXAMINATION

Fuel Rod I.D. (a)	Fuel Type		Average Fuel Temp. (b) (°C)	EOL Fast Fluence (c) (10 ²⁵ n/m ²) (E > 29 fJ)	Fissile Particle FIMA (d) (%)	Fission Gas Release (e) Kr-85m (R/B)	Dimensional Change		Number of Broken Particles on Surface	Metallographic Examination											
										Fissile Particles					Fertile Particles						
	Fissile Particles	Fertile Particles					OPyC Failure (%)	95% Confidence Limits (%)		SIC Failure (%)	95% Confidence Limits (%)	Total Coating Failure (%)	95% Confidence Limits (%)	OPyC Failure (%)	95% Confidence Limits (%)	SIC Failure (%)	95% Confidence Limits (%)	Total Coating Failure (%)	95% Confidence Limits (%)		
2-1-4	UC ₂ TRISO	ThC ₂ BISO	1467	2.00	37.4	9.33 × 10 ⁻³	-2.37	-2.65	3	--	--	--	--	--	--	--	--	--	--	--	--
2-1-5	UC ₂ TRISO	ThC ₂ BISO	1516	2.01	37.4	2.27 × 10 ⁻⁴	-2.60	-2.66	0	1.6	0.0 ≤ P ≤ 8.6	15.6 ^(ff)	7.5 ≤ P ≤ 26.5	0.0	0.0 ≤ P ≤ 5.5	0.0	0.0 ≤ P ≤ 1.6	--	--	--	--
2-2-4	UC ₂ TRISO	ThC ₂ BISO	1467	2.00	37.4	4.45 × 10 ⁻⁴	-0.82	-1.31	16	--	--	--	--	--	--	--	--	--	--	--	
2-2-5	UC ₂ TRISO	ThC ₂ TRISO	1516	2.01	37.4	6.65 × 10 ⁻⁴	-1.90	-1.57	14	4.4	0.1 ≤ P ≤ 12.1	14.7 ^(ff)	7.1 ≤ P ≤ 25.3	1.5	0.0 ≤ P ≤ 8.1	47.9	32.0 ≤ P ≤ 68.0	23.9	14.2 ≤ P ≤ 35.5	19.7	10.6 ≤ P ≤ 29.8
2-3-4	UO ₂ TRISO	ThO ₂ BISO	1467	2.00	37.4	1.26 × 10 ⁻⁴	-2.02	-2.08	26	--	--	--	--	--	--	--	--	--	--	--	
2-3-5	UO ₂ TRISO	ThO ₂ BISO	1516	2.01	37.4	4.58 × 10 ⁻⁵	-2.27	-2.09	3	--	--	--	--	--	--	--	--	--	--	--	
2-3-9	UO ₂ TRISO	ThO ₂ BISO	1408	2.02	36.2	2.63 × 10 ⁻⁴	-2.20	-2.13	5	1.8 ^(g)	0.0 ≤ P ≤ 10.1	1.8 ^(g)	0.0 ≤ P ≤ 10.1	1.8 ^(g)	0.0 ≤ P ≤ 10.1	0.0	0.0 ≤ P ≤ 1.6	--	--	--	--
2-4-3	(Th,U)O ₂ ^(h) TRISO	ThC ₂ BISO	1373	1.98	37.3	2.70 × 10 ⁻⁴	-2.40	-1.85	3	1.6	0.4 ≤ P ≤ 5.6	1.6	0.4 ≤ P ≤ 5.6	1.6	0.4 ≤ P ≤ 5.6	8.3 ⁽ⁱ⁾	4.7 ≤ P ≤ 14.2	--	--	7.5 ⁽ⁱ⁾	4.1 ≤ P ≤ 13.3
2-5-2	UO ₂ TRISO	ThC ₂ BISO	1339	1.96	37.0	4.70 × 10 ⁻⁴	-2.63	-2.54	2	27.9	21.3 ≤ P ≤ 35.6	2.7	1.1 ≤ P ≤ 6.8	1.4	0.4 ≤ P ≤ 4.8	1.6 ^(j)	0.3 ≤ P ≤ 4.4	--	--	--	--
2-6-4	UO ₂ TRISO	ThO ₂ TRISO	1467	2.00	37.4	3.39 × 10 ⁻⁵	-0.86	-1.20	2	--	--	--	--	--	--	--	--	--	--	--	
2-6-5	UO ₂ TRISO	ThO ₂ TRISO	1516	2.01	37.4	7.32 × 10 ⁻⁵	-0.63	-1.57	4	0.0	0.0 ≤ P ≤ 4.3	1.1	0.1 ≤ P ≤ 4.3	0.0	0.0 ≤ P ≤ 4.3	1.3	0.4 ≤ P ≤ 3.8	8.3	5.4 ≤ P ≤ 12.6	0.9	0.2 ≤ P ≤ 3.1
3-2-3	UC ₂ TRISO	ThC ₂ TRISO	1294	1.89	32.4	3.42 × 10 ⁻⁴	-0.75	-1.02	51	--	--	--	--	--	--	--	--	--	--	--	
3-3-3	UO ₂ TRISO	ThO ₂ TRISO	1294	1.89	32.4	5.87 × 10 ⁻⁵	ND	ND	19	--	--	--	--	--	--	--	--	--	--	--	
3-3-10	UO ₂ TRISO	ThO ₂ BISO	1252	1.04	21.7	1.70 × 10 ⁻⁵	-1.73	-1.70	ND	--	--	--	--	--	--	--	--	--	--	--	
3-6-10	UO ₂ TRISO	ThC ₂ BISO	1067	1.04	21.7	ND	-1.10	-1.14	ND	20.0 ^(k)	10.0 ≤ P ≤ 34.5	0.0	0.0 ≤ P ≤ 7.5	0.0	0.0 ≤ P ≤ 7.5	9.9	5.9 ≤ P ≤ 16.2	1.5	0.4 ≤ P ≤ 5.4	0.8	0.1 ≤ P ≤ 4.2

(a) Fuel body - fuel hole No. - fuel rod No. (No. 11 is at top).

(b) TREVER calculated.

(c) TREVER/GAUGE calculated.

(d) TREVER/GAUGE calculated.

(e) At 1100°C in TRIGA.

(f) Polishing damage.

(g) One particle on surface.

(h) Th/U ratio = 1:1.

(i) One production failure; 10 hydrolysis failures during the examination.

(j) Two production failures.

(k) All on surface, considered unloading damage.

TABLE 4-41
FTE-14 AND FTE-15 FISSION GAS RELEASE SUMMARY

Fuel Rod I.D.	Fraction of Total Thorium		Fraction of Defective SiC Coatings		Fraction of Kr-85m from Fissions		Thorium Contamination, G ($\times 10^{-4}$ gTh/gTh)	Calculated Fission Gas Release (R/B Kr-85m)				Expected Fission Gas Release, $H+I+J+K=L$	EOL TRIGA R/B Kr-85m, M	$\Delta R/B$, $M-L=N$	Pressure Vessel Failure Fraction	
	Fissile, A	Fertile, B	Fissile, C	Fertile, D	U-235, E	U-233, F		Defective Fissile		Fertile					Corrected, $N/(R/B)_f$	Uncorrected, $M/(R/B)_f$
								U-235, $H=CE(R/B)_f^{(a)}$	Th, $I=ACF(R/B)_f$	Defective $J=DBF(R/B)_f$	Th Cont. $K=FG(R/B)_f \text{ cont.}$					
FTE-14																
2-1-5	0.0	1.0	1.46×10^{-4}	0.0	0.76	0.24	0.37	5.88×10^{-7}	0.0	0.0	2.66×10^{-6}	3.25×10^{-6}	2.62×10^{-4}	2.59×10^{-4}	0.049	0.049
2-1-6	0.0	1.0	1.46×10^{-4}	0.0	0.76	0.24	0.37	5.88×10^{-7}	0.0	0.0	2.66×10^{-6}	3.25×10^{-6}	3.75×10^{-4}	3.72×10^{-4}	0.070	0.071
2-1-7	0.0	1.0	1.46×10^{-4}	0.0	0.77	0.23	0.37	5.88×10^{-7}	0.0	0.0	2.55×10^{-6}	3.14×10^{-6}	1.08×10^{-3}	1.08×10^{-3}	0.204	0.204
2-2-5	0.0	1.0	5.8×10^{-5}	1.0×10^{-3}	0.73	0.27	0.50	2.24×10^{-7}	0.0	1.43×10^{-5}	4.05×10^{-6}	4.27×10^{-6}	4.92×10^{-5}	4.49×10^{-5}	0.009	0.009
2-2-6	0.0	1.0	5.8×10^{-5}	1.0×10^{-3}	0.73	0.27	0.50	2.24×10^{-7}	0.0	1.43×10^{-5}	4.05×10^{-6}	4.27×10^{-6}	4.11×10^{-5}	3.68×10^{-5}	0.007	0.008
2-2-11	0.0	1.0	5.8×10^{-5}	1.0×10^{-3}	0.76	0.24	0.50	2.34×10^{-7}	0.0	1.27×10^{-6}	3.60×10^{-6}	3.83×10^{-6}	7.55×10^{-5}	7.17×10^{-5}	0.014	0.014
2-3-6	0.0	1.0	1.0×10^{-3}	0.0	0.70	0.30	1.70	3.71×10^{-6}	0.0	0.0	1.53×10^{-5}	1.90×10^{-6}	5.02×10^{-5}	4.83×10^{-5}	0.009	0.009
2-4-7	0.147	0.853	5.6×10^{-5}	0.0	0.76	0.24	0.78	2.26×10^{-7}	1.05×10^{-8}	0.0	5.62×10^{-6}	5.86×10^{-6}	8.91×10^{-6}	3.05×10^{-6}	0.001	0.002
2-4-11	0.147	0.853	5.6×10^{-5}	0.0	0.79	0.21	0.78	2.34×10^{-7}	1.20×10^{-8}	0.0	4.91×10^{-6}	5.16×10^{-6}	3.18×10^{-5}	2.66×10^{-5}	0.006	0.006
2-6-5	0.0	1.0	5.0×10^{-3}	2.1×10^{-3}	0.66	0.34	18.0	1.75×10^{-5}	0.0	3.78×10^{-6}	1.84×10^{-4}	2.05×10^{-4}	1.16×10^{-4}	0.0	0.0	0.022
2-6-7	0.0	1.0	5.0×10^{-3}	2.1×10^{-3}	0.67	0.33	18.0	7.46×10^{-6}	0.0	3.67×10^{-6}	1.78×10^{-4}	1.89×10^{-4}	1.08×10^{-4}	0.0	0.0	0.020
FTE-15																
2-1-4	0.0	1.0	1.46×10^{-4}	0.0	0.63	0.37	0.37	4.9×10^{-7}	0.0	0.0	4.1×10^{-6}	4.6×10^{-6}	9.53×10^{-5}	9.1×10^{-5}	0.017	0.018
2-1-5	0.0	1.0	1.46×10^{-4}	0.0	0.63	0.37	0.37	4.9×10^{-7}	0.0	0.0	4.1×10^{-6}	4.6×10^{-6}	2.27×10^{-4}	2.2×10^{-4}	0.041	0.042
2-1-9	0.0	1.0	1.46×10^{-4}	0.0	0.66	0.34	0.37	4.8×10^{-7}	0.0	0.0	3.8×10^{-6}	4.3×10^{-6}	2.29×10^{-5}	1.9×10^{-5}	0.004	0.004
2-1-11	0.0	1.0	1.46×10^{-4}	0.0	0.68	0.32	0.37	5.1×10^{-7}	0.0	0.0	3.6×10^{-6}	4.1×10^{-6}	3.06×10^{-5}	2.7×10^{-5}	0.005	0.006
2-2-4	0.0	1.0	5.8×10^{-5}	1.0×10^{-3}	0.59	0.41	0.50	1.8×10^{-7}	0.0	2.2×10^{-6}	6.2×10^{-6}	8.6×10^{-6}	4.45×10^{-4}	4.4×10^{-4}	0.083	0.084
2-2-5	0.0	1.0	5.8×10^{-5}	1.0×10^{-3}	0.59	0.41	0.50	1.8×10^{-7}	0.0	2.2×10^{-6}	6.2×10^{-6}	8.6×10^{-6}	6.65×10^{-4}	6.6×10^{-4}	0.125	0.125
2-3-4	0.0	1.0	1.0×10^{-3}	0.0	0.56	0.44	1.70	3.0×10^{-6}	0.0	0.0	2.2×10^{-5}	2.5×10^{-5}	1.26×10^{-4}	1.0×10^{-4}	0.019	0.024
2-3-5	0.0	1.0	1.0×10^{-3}	0.0	0.56	0.44	1.70	3.0×10^{-6}	0.0	0.0	2.2×10^{-5}	2.5×10^{-5}	4.58×10^{-5}	2.1×10^{-5}	0.004	0.008
2-3-9	0.0	1.0	1.0×10^{-3}	0.0	0.58	0.42	1.70	3.1×10^{-6}	0.0	0.0	2.1×10^{-5}	2.4×10^{-5}	2.63×10^{-4}	2.4×10^{-4}	0.045	0.050
2-4-3	0.147	0.853	5.6×10^{-5}	0.0	0.63	0.37	0.78	1.9×10^{-7}	1.6×10^{-8}	0.0	8.7×10^{-6}	8.9×10^{-6}	2.70×10^{-4}	2.6×10^{-4}	0.049	0.051
2-5-2	0.0	1.0	2.8×10^{-4}	0.0	0.49	0.51	0.05	7.3×10^{-7}	0.0	0.0	7.7×10^{-7}	1.5×10^{-6}	4.70×10^{-4}	4.7×10^{-4}	0.089	0.089
2-6-4	0.0	1.0	5.0×10^{-3}	2.1×10^{-3}	0.56	0.44	18.0	1.5×10^{-5}	0.0	4.9×10^{-6}	2.4×10^{-4}	2.6×10^{-4}	3.39×10^{-5}	-2.3×10^{-4}	0.0	0.006
2-6-5	0.0	1.0	5.0×10^{-3}	2.1×10^{-3}	0.56	0.44	18.0	1.5×10^{-5}	0.0	4.9×10^{-6}	2.4×10^{-4}	2.6×10^{-4}	7.32×10^{-5}	-1.9×10^{-4}	0.0	0.014
3-2-3	0.0	1.0	2.6×10^{-4}	2.2×10^{-3}	0.67	0.33	0.05	9.2×10^{-7}	0.0	3.8×10^{-6}	5.0×10^{-7}	5.2×10^{-6}	3.42×10^{-4}	3.4×10^{-4}	0.064	0.065
3-3-3	0.0	1.0	1.0×10^{-3}	0.0	0.65	0.35	1.70	3.5×10^{-6}	0.0	0.0	1.8×10^{-5}	2.2×10^{-5}	5.87×10^{-5}	3.7×10^{-5}	0.007	0.011
3-3-10	0.0	1.0	1.0×10^{-3}	0.0	0.82	0.18	1.70	4.3×10^{-6}	0.0	0.0	9.2×10^{-6}	1.4×10^{-5}	1.9×10^{-5}	3.0×10^{-6}	0.001	0.003

$(a)(R/B)_f = 0.0053$.

TABLE 4-42
FTE-14 AND FTE-15 FUEL KERNEL MIGRATION PREDICTIONS

Fuel Rod I.D.	Fuel Type		Irradiation Conditions			Kernel Migration					
						Fissile			Fertile		
			Fast Fluence (x 10 ²⁵ n/m ²)	Time-Averaged Mean Fuel Temp. (°C)	Peak Fuel Temp. (°C)	Calculated		Meas. Peak (μm)	Calculated		Meas. Peak (μm)
	Average (μm)	Peak (μm)				Average (μm)	Peak (μm)				
FTE-14											
2-1-5	UC ₂ TRISO	ThC ₂ BISO	1.44	1313	1534	21.6	28.3	ND ^(a)	52.0	68.4	ND
2-1-6	UC ₂ TRISO	ThC ₂ BISO	1.45	1283	1507	23.0	30.1	ND	55.5	72.9	ND
2-1-7	UC ₂ TRISO	ThC ₂ BISO	1.44	1251	1479	10.0	13.3	None	23.9	31.8	None
2-2-5	UC ₂ TRISO	ThC ₂ BISO	1.44	1289	1506	18.3	24.2	ND	44.1	58.3	ND
2-2-6	UC ₂ TRISO	ThC ₂ TRISO	1.45	1257	1478	13.9	18.3	None	33.2	44.1	None
2-2-11	UC ₂ TRISO	ThC ₂ TRISO	1.36	1133	1355	2.6	3.5	ND	6.0	8.2	ND
2-3-6	UO ₂ TRISO	ThO ₂ BISO	1.45	1286	1527	39.1	57.4	None	23.3	29.5	None
2-4-6	(Th,U)O ₂ TRISO	ThC ₂ BISO	1.45	1260	1486	43.3	56.2	14	41.0	53.8	None
2-4-7	(Th,U)O ₂ TRISO	ThC ₂ BISO	1.44	1229	1458	29.3	37.7	ND	17.5	23.4	ND
2-4-11	(Th,U)O ₂ TRISO	ThC ₂ BISO	1.36	1131	1355	16.7	21.1	ND	5.0	6.8	ND
2-6-5	UO ₂ TRISO	ThO ₂ TRISO	1.44	1311	1552	35.9	52.9	ND	19.4	24.5	ND
2-6-7	UO ₂ TRISO	ThO ₂ TRISO	1.44	1248	1493	29.2	42.3	None	10.4	13.2	None
FTE-15											
2-1-4	UC ₂ TRISO	ThC ₂ BISO	2.04	1255	1537	30.4	39.5	ND	73.3	95.7	ND
2-1-5	UC ₂ TRISO	ThC ₂ BISO	2.05	1296	1578	34.0	44.1	None	82.2	>100	15
2-2-4	UC ₂ TRISO	ThC ₂ TRISO	2.04	1235	1514	23.8	31.2	ND	57.2	75.3	ND
2-2-5	UC ₂ TRISO	ThC ₂ TRISO	2.05	1276	1556	26.3	34.5	None	63.4	83.3	None
2-3-4	UO ₂ TRISO	ThO ₂ BISO	2.04	1270	1572	60.8	90.0	ND	35.5	45.0	ND
2-3-5	UO ₂ TRISO	ThO ₂ BISO	2.05	1310	1612	62.2	92.5	ND	38.6	48.9	ND
2-3-9	UO ₂ TRISO	ThO ₂ BISO	2.02	1174	1472	39.7	56.3	None	9.7	12.4	None
2-4-3	(Th,U)O ₂ TRISO	ThC ₂ BISO	2.02	1151	1428	30.7	39.3	None	12.0	16.1	None
2-5-2	UO ₂ TRISO	ThC ₂ BISO	2.00	1163	1482	40.4	57.1	ND	22.5	30.2	ND
2-6-4	UO ₂ TRISO	ThO ₂ TRISO	2.04	1265	1562	59.9	88.3	ND	33.2	41.1	ND
2-6-5	UO ₂ TRISO	ThO ₂ TRISO	2.05	1305	1603	61.3	90.6	None	36.1	45.8	None
3-2-3	UC ₂ TRISO	ThC ₂ TRISO	1.78	1193	1438	6.0	7.8	ND	14.1	18.4	ND
3-3-3	UO ₂ TRISO	ThO ₂ BISO	1.78	1223	1483	38.1	57.6	ND	11.1	14.0	ND
3-3-10	UO ₂ TRISO	ThO ₂ BISO	1.04	1094	1270	14.9	23.9	ND	1.2	1.5	ND
3-6-10	UO ₂ TRISO	ThC ₂ BISO	1.04	1067				None			None

(a) ND = not determined.

TABLE 4-43
FTE-14 AND FTE-15 LOADING OF COATED PARTICLE SPINE SAMPLES

Distance from Reactor Bottom (mm)		Crucible Number ^(a)	Hole Number
FTE-14	FTE-15		
1135	1135	TS1	1, 2, 3, 4, 5, 6
1164	1166	TS2	1, 2, 3, 4, 5, 6
1196	1197	TS3	1, 2, 3, 4, 5, 6
1642	1645	TS4	1, 2, 3, 4, 5, 6
1851	1854	TS5	1, 2, 3, 4, 5, 6
1934	1937	TS6	1, 2, 3, 4, 5, 6
2377	2392	TS7	1, 2, 3 (empty)
2409	2424	TS8	1, 2, 3, 4, 5, 6
2441	2455	TS9	1, 2, 3, 4, 5, 6

FMB Batch Number ^(b)	Crucible Number - Hole Number	Prior Capsules
4252-01-070	3-4, 6-1	P13P
4252-00-010	1-5, 4-1, 5-1, 9-3	P13N, P13P
4262-00-050	1-2, 5-2, 9-4	P13N, P13P
4162-00-020	1-6, 4-3, 8-4, 5-3	P13P
4162-01-020	2-4, 6-4	P13P, P13N
4163-00-010	2-3, 6-3, 9-2	P13P
5466-37	3-3, 4-5, 5-5	P13N
4413-67	1-1, 7-1	P13L, P13M, FTE-1,2,3
4493-149	2-1, 4-4, 5-4, 8-5	FTE-1,2,3
4413-35	3-1, 8-1	P13L
4413-5	3-2, 7-3	P13L
4161-00-020	1-4, 8-2	P13N, P13P
4161-00-030	3-6, 4-6, 5-6, 8-3	P13N, P13P, FTE-14,15
4000-304	2-2, 6-2, 9-5	P13M
OR-1694	2-6, 6-6, 9-1	P13P
OR-1602	8-6	P13N
4423-89	2-3, 3-5, 4-2, 7-2	P13L
4413-127	2-5, 6-5, 9-6	FTE-1,2,3 spine and Thermal Performance Lab.

(a) All Type II crucibles.

(b) Fuel Materials Branch retrieval number.

TABLE 4-44
SUMMARY OF FTE-14 AND FTE-15 POSTIRRADIATION EXAMINATION OF THERMAL STABILITY SPINE SAMPLES

Fuel Test Element	Particle Batch Number(a)	Particle Type	Location(b)	EOL Avg Temp(c) (°C)	Fast Fluence(d) (E > 29 fJ/atom x 10 ²⁵ n/m ²)	FIMA(e) (%)	Fission Gas Release(f) (R/R Kr-85m)	Number of Particles in Sample		Stereo Examination		Metallography Examination(g)									
										OPyC Failure (%)	SIC Failure (%)	OPyC Failure (%)	95% Confidence Limits, P (%)	SIC Failure (%)	95% Confidence Limits, P (%)	Pressure Vessel Failure (%)	95% Confidence Limits, P (%)	Mixed Fission Products in IPyC (%)	95% Confidence Limits, P (%)	SIC Attack (%)	95% Confidence Limits, P (%)
								Stereo	Metallography												
FTE-14	4161-01-020	TRISO UC ₂ (VSM)	TS1-4	1282	1.3	--	--	--	91	--	--	0	0 ≤ P ≤ 4.2	0	0 ≤ P ≤ 4.2	0	0 ≤ P ≤ 4.2	0	0 ≤ P ≤ 4.2	0	0 ≤ P ≤ 4.2
	4161-01-030	TRISO UC ₂ (VSM)	TS3-6	1095	1.1	--	1.09 x 10 ⁻⁶	1056	86	0	0	0	3.0 ≤ P ≤ 4.5	0	0 ≤ P ≤ 4.5	0	0 ≤ P ≤ 4.5	19.0	9.0 ≤ P ≤ 27.0	0	0 ≤ P ≤ 4.5
	4161-01-030	TRISO UC ₂ (VSM)	TS5-6	1418	1.3	--	1.06 x 10 ⁻⁶	1026	91	0	0	0	0 ≤ P ≤ 4.2	3.2	1.0 ≤ P ≤ 8.5	0	0 ≤ P ≤ 4.2	95.0	85.0 ≤ P ≤ 100	4.4	1.0 ≤ P ≤ 10.0
	4161-01-030	TRISO UC ₂ (VSM)	TS4-6	1364	1.3	24.8	3.93 x 10 ⁻⁷	1049	19	0	0	0	0 ≤ P ≤ 22.0	5.3	0 ≤ P ≤ 25.0	0	0 ≤ P ≤ 22.0	100.0	80.0 ≤ P ≤ 100	47.0	24.0 ≤ P ≤ 71.0
	4161-01-030	TRISO UC ₂ (VSM)	TS8-3	1534	1.2	--	--	--	81	--	--	0	0 ≤ P ≤ 4.5	0	0 ≤ P ≤ 4.5	0	0 ≤ P ≤ 4.5	100.0	81.0 ≤ P ≤ 100	2.4	0 ≤ P ≤ 4.5
	OR-1694	TRISO UC ₂ (WAR)	TS2-6	1213	1.1	22.9	5.32 x 10 ⁻³	883	286	7.3	0	8.7	6.0 ≤ P ≤ 12.6	1.0	0.1 ≤ P ≤ 2.0	0	0 ≤ P ≤ 1.3	0	0 ≤ P ≤ 1.3	0	0 ≤ P ≤ 1.3
	OR-1694	TRISO UC ₂ (WAR)	TS6-6	1454	1.2	--	2.19 x 10 ⁻²	863	241	7.0	0.7	3.7	2.0 ≤ P ≤ 6.9	0	0 ≤ P ≤ 1.6	0	0 ≤ P ≤ 1.6	0	0 ≤ P ≤ 1.6	0	0 ≤ P ≤ 1.6
	4252-01-070	BISO ThO ₂	TS6-1	1325	1.2	--	4.54 x 10 ⁻⁵	221	40	0	--	0	0 ≤ P ≤ 9.0	--	--	0	0 ≤ P ≤ 9.0	--	--	--	--
FTE-15	4161-01-020	TRISO UC ₂ (VSM)	TS1-4	1294	1.7	--	--	--	97	--	--	0	0 ≤ P ≤ 4.0	0	0 ≤ P ≤ 4.0	0	0 ≤ P ≤ 4.0	0	0 ≤ P ≤ 4.0	0	0 ≤ P ≤ 4.0
	4161-01-020	TRISO UC ₂ (VSM)	TS8-2	1468	1.9	--	--	--	75	--	--	0	0 ≤ P ≤ 4.7	0	0 ≤ P ≤ 4.7	0	0 ≤ P ≤ 4.7	ND	--	1.3	0 ≤ P ≤ 7.2
	4161-01-030	TRISO UC ₂ (VSM)	TS3-6	1086	1.8	--	3.32 x 10 ⁻⁶	1043	53	0	0	5.7	1.0 ≤ P ≤ 16.0	7.5	4.0 ≤ P ≤ 18.0	5.7	1.0 ≤ P ≤ 16.0	32.1	20.0 ≤ P ≤ 46.0	0	0 ≤ P ≤ 6.5
	4161-01-030	TRISO UC ₂ (VSM)	TS4-6	1355	2.0	--	4.74 x 10 ⁻⁶	1048	42	0	0	4.8	0.3 ≤ P ≤ 16.6	21.4	10.7 ≤ P ≤ 37.0	4.8	0.3 ≤ P ≤ 16.6	100.0	77.0 ≤ P ≤ 100	21.2	10.7 ≤ P ≤ 37.0
	4161-21-030	TRISO UC ₂ (VSM)	TS5-6	1299	2.0	38.4	2.36 x 10 ⁻⁵	1060	44	0	0	0	0 ≤ P ≤ 7.9	9.1	2.5 ≤ P ≤ 23.0	0	0 ≤ P ≤ 7.9	100.0	81.0 ≤ P ≤ 100	18.5	8.4 ≤ P ≤ 33.0
	OR-1694	TRISO UC ₂ (WAR)	TS2-6	1207	1.8	33.8	1.23 x 10 ⁻²	844	59	7.4	0	13.6	6.0 ≤ P ≤ 25.0	0	0 ≤ P ≤ 6.0	0	0 ≤ P ≤ 6.0	0	0 ≤ P ≤ 6.0	0	0 ≤ P ≤ 6.0
	OR-1694	TRISO UC ₂ (WAR)	TS6-6	1418	2.0	--	1.57 x 10 ⁻²	841	45	6.5	0	4.4	0.7 ≤ P ≤ 15.2	2.2	0 ≤ P ≤ 12.0	2.2	0 ≤ P ≤ 12.0	0	0 ≤ P ≤ 7.7	0	0 ≤ P ≤ 7.7
	4252-02-070	BISO ThO ₂	TS6-1	1299	2.0	--	6.40 x 10 ⁻⁵	221	33	0	--	0	0 ≤ P ≤ 10.7	--	--	0	0 ≤ P ≤ 10.7	--	--	--	--

(a) Fuel Materials Branch data retrieval number.

(b) TS3-6 = thermal stability type II, crucible No. 3 - hole No. 6).

(c) TREVER calculated.

(d) GAUGE/FEVER calculated.

(e) Mass spectroscopy measured.

(f) At 1100°C in TRIGA reactor facility.

(g) Approximately 10% to 20% of the sample was examined.

TABLE 4-45
SUMMARY OF SiC THINNING RATES IN PEACH BOTTOM TEST ELEMENTS

Test Element	Spine Sample or Fuel Rod	FMB Batch I.D.	Mean Core Height (mm)	Max. SiC Attack (μm)	Real Time Operation (hr)	Max. Exp. Time-Weighted Temp. (°K)	RMS (°K)	SiC Thinning Rate (x 10 ⁻⁴ μm/hr)	
								Meas.	Calc.
GA Data									
FTE-5	TS3-5	4000-302	2028	4.0	24,832	NA ^(a)	NA	1.61	NA
FTE-5	2-5-7	4000-307	1776	1.7	24,832	1483	39	0.68	1.14
FTE-5	3-5-2	4000-307	2318	1.8	24,832	1460	31	0.72	0.75
FTE-6	TS6-5	4000-302	2684	4.0	18,358	NA	NA	2.18	NA
FTE-14	TS4-6	4161-01-030	1641	4.5	8,712	1720	46	5.16	44.83
FTE-14	TS5-6	4161-01-030	1851	10.0	8,712	1777	51	11.06	93.63
FTE-14	TS8-3	4161-01-030	2419	10.0	8,712	1877	61	11.06	305.93
FTE-14	2-1-7	4161-01-031	1865	5.0	8,712	1711	44	5.74	39.73
FTE-15	TS4-6	4161-01-030	1645	5.0	14,901	1746	70	3.36	63.10
FTE-15	TS5-6	4161-01-030	1845	15.0	14,901	1772	69	10.07	87.90
FTE-15	TS8-3	4161-01-030	2424	2.0	14,901	1826	66	1.34	170.00
FTE-15	2-1-5	4161-01-031	1733	9.0	14,901	1776	70	6.04	92.46
FTE-15	2-2-5	4161-01-031	1733	12.0	14,901	1755	69	8.05	70.86
FTE-15	2-1-9	4161-01-031	1987	4.0	14,901	1653	67	2.68	17.68
RTE-2	6-1-3	4000-307	2772	2.5	18,641	1466	51	1.34	0.84
RTE-4	4-7-3	4000-307	1982	5.0	9,931	1584	19	5.03	6.20
ORNL PIE Data									
RTE-1	3-6-6	4000-325	1746	5.0	18,358	1699	52	2.72	33.75
RTE-2	6-1-1	4000-307	2664	1.0	18,641	1464	52	0.54	0.81
RTE-2	Body 3 loose part.	4000-307	1460	5.0	18,641	1396	44	2.68	0.22
RTE-4	4-1-3	4000-309	1982	5.0	9,931	1584	19	5.03	6.20
RTE-5	3-5-6	4000-307	2550	5.0	24,832	1379	34	2.01	0.22
RTE-6	4-1-1	4000-307	1875	5.0	24,832	1473	28	2.01	0.95
RTE-7	5-5-5	4000-307	2483	1.5	6,474	1382	18	2.32	0.17
RTE-8	5-7-1	4000-307	2267	5.0	24,832	1443	25	2.01	0.55

^(a) NA = not applicable.

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