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May 2, 1988
Fort St. Vrain
Unit No. 1
P-88154

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, D.C. 20555

Attention: Mr. Jose A. Calvo
Director, Project Directorate IV

Docket No. 50-267

SUBJECT: Additional Information on FTE-2 Post Irradiation Examination

REFERENCES: (1) PSC Letter, Brey to Berkow, dated 7/18/86 (P-86468)

(2) PSC Letter, Brey to Berkow, dated 9/11/86 (P-86545)

Dear Mr. Calvo:

In a telephone conversation on March 25, 1988 among the staffs of Public Service Company of Colorado (PSC), General Atomics (GA), and the NRC, the post irradiation examination (PIE) reports for fuel element FTE-2 were discussed. These reports were submitted to the NRC in References 1 and 2. The NRC requested that PSC submit additional information summarizing the results of the PIE in the context of the Fort St. Vrain licensing basis and outstanding regulatory commitments.

The additional information, which summarizes the matters discussed in the telephone conversation, is enclosed. If you have any questions or comments regarding this information, please contact Mr. M.H. Holmes at (303) 480-6960.

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Very truly yours,

H.L. [illegible]
Nucl[illegible] Fuels

HLB/MHH:jw

Attachment

cc: Regional Administrator
ATTN: Mr. T.F. Westerman, Chief
Projects Section B

Mr. R.E. Farrell
Senior Resident Inspector
Fort St. Vrain

# FTE-2 POST IRRADIATION EXAMINATION
# ADDITIONAL INFORMATION

The results of the destructive post irradiation examination (PIE) of fuel test element FTE-2 were described in References 1 and 2. The FTE-2 PIE was conducted to fulfill two purposes regarding fuel examination.

The first purpose pertained to the performance of H-451 graphite under irradiation. Beginning with fuel Segment 9 (Cycle 4) in May 1984, the Fort St. Vrain (FSV) fuel elements originally fabricated with H-327 graphite were replaced with elements fabricated with H-451 graphite. General approval for use of H-451 graphite in FSV reload fuel segments was obtained from the NRC in 1979 as the result of a series of submittals to the NRC by General Atomics (GA). One of the requirements for use of H-451 listed in the NRC Safety Evaluation Report (Reference 3) was that PSC conduct destructive PIE on fuel test elements FTE-2, 4 and 6 to confirm that the performance of the H-451 graphite observed for these elements is consistent with the performance described in the GA submittals. Examination of these elements was required by the NRC because they were inserted into the core at the beginning of Cycle 2. Hence, they serve as lead irradiation assemblies and provide confirmation of graphite performance at intermediate exposures prior to the fuel in Segment 9 reaching those exposures.

The second purpose was to examine one of the 88 fuel rods in FTE-2 that contain FSV reference fuel particles. (The remaining fuel rods in FTE-2 contain a variety of experimental fuel particles which were, at the time of FTE-2 preparation, being considered for use in future HTGR applications.) Fuel particle examinations are conducted to confirm that particle coating failures are not excessive, that fuel kernel migration rates are consistent with those assumed in deriving the core thermal safety limit, and that no unanticipated coated fuel particle degradation is occurring.

The results of the PIE reported in References 1 and 2 indicate that the performance of FTE-2 in Cycles 2 and 3 was very good and consistent with expectations. The H-451 graphite and the FSV reference fuel particles were in very good condition.

## H-451 Graphite Performance

Reference 1, Section 1 (Item 1) notes that the H-451 graphite was in excellent condition with no observed cracks. The measured tensile strength and Young's moduli were found (Item 3) to be in agreement with the values given in the GA Graphite Design Data Manual. These values are the same as those presented in Reference 4, which transmitted to the NRC in one package the GA licensing documentation pertinent to use of H-451 graphite in FSV. Thermal expansivities were found (Item 4) to be about 19% lower than expected, but this deviation was noted to be conservative with respect to graphite stresses. Subsequent evaluation of the silicon carbide temperature monitors in FTE-2 resulted in the conclusion that the differences between the measured and predicted values of all H-451 graphite properties, including thermal expansitivity, was less than 10% at 650 degrees C (Reference 2).

Based on these results, it is concluded that the performance of the H-451 graphite in FTE-2 was consistent with the expected graphite behavior that served as the licensing basis for use of H-451 graphite in FSV reload fuel segments.

Fuel Particle Performance

As noted above, fuel particle examinations are conducted to confirm that particle coating failures are not excessive, that fuel kernel migration rates are consistent with those assumed in deriving the core thermal safety limit, and that no unanticipated fuel particle degradation is occurring. Fission product source items used as initial conditions in FSV accident analyses are derived by assuming a core average particle failure fraction of 5%, with up to 10% particle failure at the end of life of a fuel segment. Failure is defined as a breach of all four particle coatings.

Kernel migration is a phenomenon in which carbon in the particle buffer coating diffuses from the hot side of the kernel, through the kernel, to the cold side, resulting in migration of the kernel toward the particle coatings. Excessive kernel migration results in kernel-coating interaction and coating failure. Kernel migration rates increase with increasing temperature and thermal gradient. The kernel migration behavior of a coated fuel particle is an inherent characteristic of the fuel kernel material. The FSV Reactor Core Safety Limit (Technical Specification SL 3.1) is derived assuming that during normal reactor operation a kernel may migrate up to 20 microns (see Updated FSAR Section 3.6.8). Hence, particle examinations are conducted to ensure that kernel migration in excess of this amount has not occurred. The smallest kernel migration distance observable using metallographic techniques is 3 to 4 microns. Therefore, an observation of no kernel migration implies migration of less than 4 microns. Kernel migration is discussed in Section 3.6.7.6.2 of the Updated FSAR.

With regard to the performance of the FSV reference fuel particles in FTE-2, Reference 1, Section 1 notes (Item 9) that the reference fuel was in excellent condition. Small percentage failures (1.1% or less) for individual coating layers were observed (Item 10), but there were no cases of total coating failure. This performance is better than the 5% core average failure assumed in the FSV licensing basis.

No kernel migration was observed (Item 11) in the fuel particles. Thus, kernel migration was less than 4 microns during the two cycles that FTE-2 resided in the core. Based on linear extrapolation, kernel migration over six cycles of residency would be expected to be less than 12 microns, which is well within the assumptions made in deriving the core thermal safety limit. Linear extrapolation is conservative, since fuel temperatures generally tend to be higher in earlier cycles than in later cycles.

Limited chemical interaction was observed (Items 11 and 12) between the fuel kernels and some of the coatings in four of the 459 particles examined. This interaction occurs as a result of dispersion of the kernel material into the particle coatings during fuel manufacture. Kernel dispersion occurs as a result of a reaction between the kernels and hydrogen chloride gas generated during the SiC coating process. Control over the coating process minimizes this effect, and the fuel product specifications limit the amount of dispersion allowed in the final product. Accordingly, this phenomenon is not as limiting as kernel migration and is therefore not reflected in the core thermal safety limit.

Kernel-coating interaction resulting from kernel dispersion has been seen in a previous PIE and reported to the NRC (Reference 5). A larger amount of kernel-coating interaction was observed in Segment 2 fuel removed at the end of Cycle 2. However, QC records indicate that Segment 2 fuel exhibited kernel dispersion at the upper end of the range allowed by the fuel product specifications. It was, accordingly, anticipated that follow-on PIE inspections of fuel produced for later segments would show a reduction in kernel-coating interaction. This anticipation has been confirmed by the results of the PIE of FTE-2.

Based on these results, it is concluded that the performance of the FSV reference fuel particles in FTE-2 is very good and is conservative with respect to the fuel performance assumed in developing the licensing basis of Fort St. Vrain.

## References

1. PSC letter, Brey to Berkow, dated 7/18/86 (P-86468); Subject: "Destructive Examination of Fort St. Vrain Fuel Test Element FTE2," GA Document 908909, Issue N/C, 7/11/86.

2. PSC letter, Brey to Berkow, dated 9/11/86 (P-86545); Subject: "Thermal Diffusivity of H-451 Graphite and Temperature Monitor Analyses in FSV Fuel Test Element FTE-2," GA Document 908928, Issue N/C, 8/22/86.

3. NRC letter, Gammill to C. Fisher (GAC), dated 5/21/79 (G-79238); Subject: "Evaluation of Topical Report GLP-5588."

4. PSC letter, Lee to Collins, dated 12/2/83 (P-83391); Subject: "Technical Specification Amendment Request Regarding Fort St. Vrain Use of H-451 Graphite."

5. PSC letter, Brey to Collins, dated 1/3/84 (P-84001); Subject: "Metallographic Examination of a Fuel Rod from Segment 2 FSV Fuel Element 1-2415," (GA Document 906968, Issue A, 11/9/83).