PUBLIC SERVICE COMPANY OF COLORADO
P. O. BOX 840 · DENVER, COLORADO 80201

50-267

OSCAR R. LEE
VICE PRESIDENT

August 13, 1984
Fort St. Vrain
Unit No. 1
P-84275

Mr. E. H. Johnson, Chief
Reactor Project Branch 1
Nuclear Regulatory Commission
Region IV
611 Ryan Plaza Drive, Suite 1000
Arlington, Texas 76011

DOCKET NO. 50-267

SUBJECT: Response to NRC/LANL Concerns on Cracked Fuel Elements

REFERENCE: NRC Letter from E.H. Johnson to O. R. Lee Dated May 11, 1984 (G-84158)

Dear Mr. Johnson:

Please find enclosed forty (40) copies of the report, "Response to NRC/LANL Concerns Regarding Cracked Fuel Element Integrity." GA Technologies Inc. and Public Service Company of Colorado have reviewed the technical issues raised by LANL and have concluded that these issues pose no problems with regard to the performance of fuel elements with cracked webs at Fort St. Vrain.

This report fulfills part (1) of the requirement in your letter of May 11, 1984 (Reference 1).

If you have any further questions on this matter, please contact Mr. M. H. Holmes (303) 571-8409.

Very truly yours,

ORLee

O. R. Lee, Vice President
Electric Production

ORL/SH:pa
Attachment

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RESPONSE TO NRC/LANL CONCERNS REGARDING
CRACKED FUEL ELEMENT INTEGRITY

Introduction

The Los Alamos National Laboratory (LANL) report of April 30, 1984, "Fort St. Vrain Fuel Elements," presents a review of material submitted to the NRC by PSC regarding two Segment 2 fuel elements with cracked graphite webs. In the report summary, LANL concurs with PSC's information regarding the likely cause of the cracks and the low probability of extensive further cracking under normal operating conditions. LANL also concurs with PSC's position regarding the low probability of cracks affecting the integrity of the reactor fuel itself.

However, in its discussion of cracked fuel element integrity LANL raises two concerns associated with off-normal conditions:

1. The effects of the thermal stress field in combination with static or dynamic loading of the cracked element have not been addressed.

2. The effects of dynamic loading through the dowel-socket system on the stress field in the interior of the cracked element and on potential crack progression have not been addressed.

These LANL concerns are addressed in the following discussion.

Thermal Stress Field Effects

LANL expresses the concern that the static loading tests performed by GA on unirradiated H-327 graphite slabs with simulated cracks, "do not account for the presence of a strong, thermal stress field in the specimen, nor do they account for the possibility that the crack could reduce the strength of the element under dynamic loading conditions."

Calculations have been performed by GA in which the stress analyses of the cracked fuel element presented to the NRC on April 4, 1984, in Bethesda (Ref. 1) were perturbed by analytically imposing a static compressive load on the fuel element at the time of peak calculated stress. Crack configurations from zero to five cracked webs were assumed to exist. The pattern of these assumed cracks was the same as that observed for the three cracked webs in element 1-2415, or an extrapolation thereof (Ref. 1).

The maximum seismic load on a FSV fuel element during a Design Basis Earthquake (DBE) (0.1 g maximum horizontal ground acceleration) has been determined to be 1500 lb. This load is determined from the weights of individual fuel and reflector elements that can act upon a single element during a seismic event and from the 0.26 g maximum lateral acceleration experienced in the core during the DBE (Ref. 2). Accordingly, a 1500 lb static compressive load was used in these analyses.

The results of these calculations are summarized in Table 1. The table shows that the largest calculated increase in the peak in-plane stress/strength ratio resulting from imposition of a 1500 lb seismic load on the cracked element is 0.02. This increment is a minor perturbation on the stresses resulting from thermal and irradiation-induced strains. It is concluded from these analyses that imposition of the maximum seismic loads resulting from the DBE on the thermal and irradiation-induced stress fields in the cracked fuel element has a negligible effect on fuel element performance.

While the loading tests conducted on unirradiated H-327 graphite slabs and the calculations described above both involved imposition of static loads on the cracked fuel element, experimental evaluations of HTGR fuel element seismic strength have shown that fuel element performance under both static and dynamic loading conditions is essentially the same for relative impact velocities up to 120 in/sec (Ref. 3). Relative impact velocities in the HTGR core during a seismic event are less than 120 in/sec. These tests have shown that:

1. crack patterns resulting from static and dynamic loading are nearly identical,

2. strain behavior under static and dynamic loading, obtained from strain gage traces, is fundamentally the same, and

3. the magnitudes of the static and dynamic loads required to produce failure are the same (about 70,000 lb) and are much larger than the 1500 lb FSV DBE seismic load.

It is concluded, therefore, that analytical representation of fuel element seismic behavior by imposition of static compressive loads provides a valid approximation of fuel element performance under seismic (dynamic) conditions. This approximation is particularly valid in view of the large difference between the maximum DBE seismic load in FSV (1500 lb) and the loads required to produce fuel element cracking (70,000 lb).

TABLE 1

EFFECT OF FSV DBE SEISMIC LOAD ON CRACKED FUEL ELEMENT STRESS FIELD

	Peak In-Plane Stress/Strength Ratio	
Number of Cracked Webs	Without Seismic Load	With 1500 lb Seismic Load
0	0.70	0.70
3	0.90	0.91
5	0.69	0.71

Dowel-Socket System Loading

LANL contends that, "during a seismic event the Fort St. Vrain core (as currently constrained by the core restraint devices) will transmit dynamic loads primarily through the dowel pins and socket arrangement located on the ends of the fuel elements. This dynamic load transfer will produce a complex stress field in the interior of the element, and could subsequently cause cracks to further propagate, depending on the magnitude of loads being transmitted."

In fact, the behavior of the fuel elements under dowel-socket system loading is well characterized and has been a subject of previous PSC-NRC correspondence (Ref. 4) related to the core fluctuations investigaton. As explained in Reference 4, when the FSV dowel-socket system is loaded to its ultimate capacity, failure occurs in the sidewall of the element between either the socket or the dowel and the nearest face of the fuel element. (See Figure 1.) No failure occurs in the dowel pin itself. This sidewll failure typically initiates as two cracks at the base of the socket or dowel which, under continued application of the load, progress outward to the element edge to encompass a fragment that is about seven inches along the horizontal edge and three inches in the axial direction. Tests on FSV fuel element geometries (Ref. 5) have shown that this failure mode is the same for both static and impact loading conditions, with the dowel-socket system strength being somewhat higher under impact loading.

This failure mode indicates that, rather than being a complex stress field in the interior of the element, the stress field resulting from dowel-socket system loading is (1) a relatively simple stress cone, and (2) relatively localized at the end of the element with regard to stresses of sufficient magnitude to cause graphite failure.

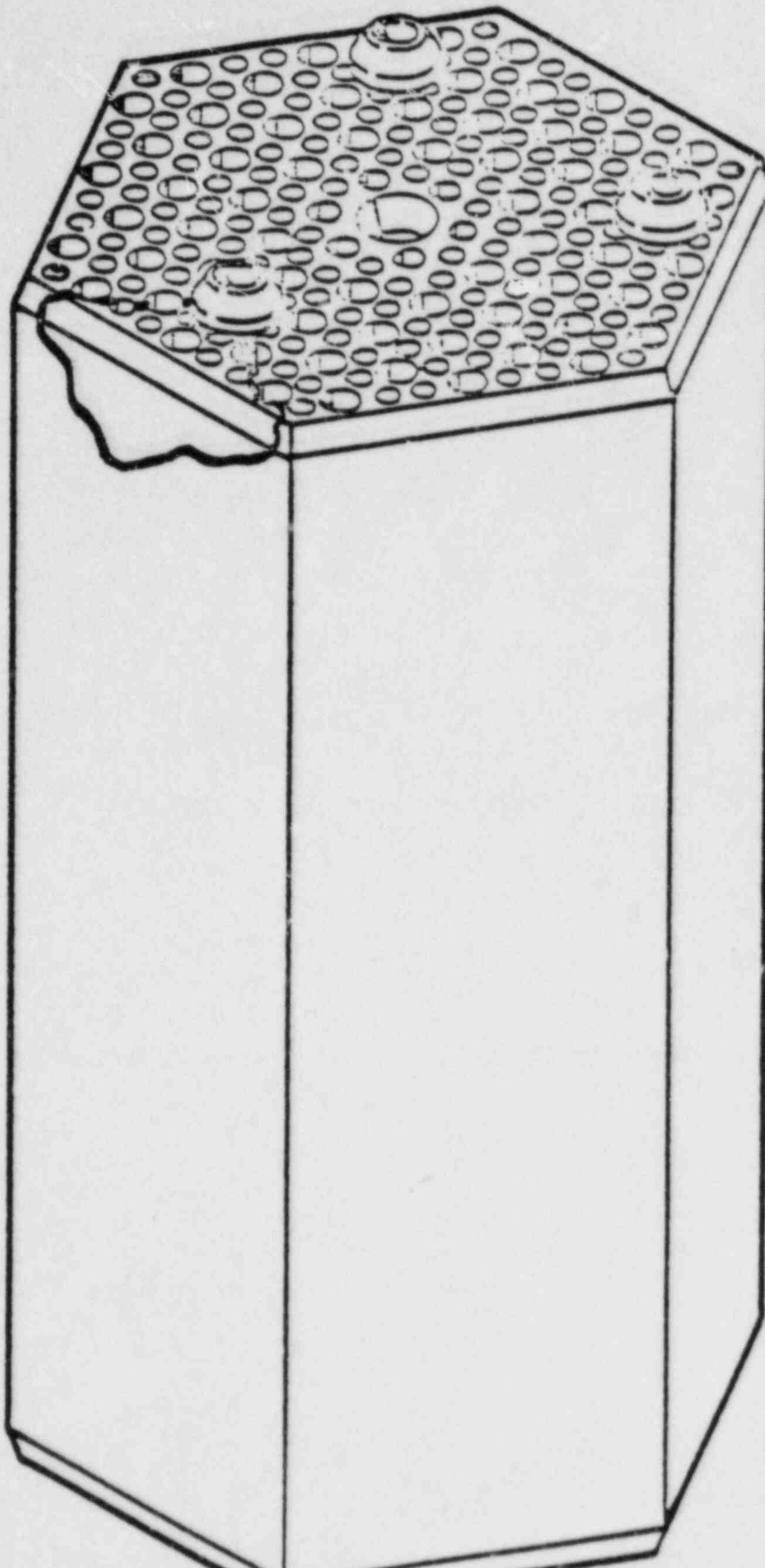

FIGURE 1: Typical Dowel/Socket Failure

It is possible that the presence of fuel element web cracks such as those seen in the Segment 2 fuel elements in the vicinity of the "B" face dowel might reduce the ultimate capacity of that one (out of three) dowel-socket system. It is unlikely, however, that the resulting localized stress field would produce any notable effect on the crack in the interior of the element. Therefore, extensive crack progression throughout the element is not expected to result from dowel-socket system loading.

<u>References</u>

1. Don W. Warembourg (PSC) letter to John T. Collins (NRC), "Fort St. Vrain Unit No. 1 Fuel Element Meeting," P-84104, April 6, 1984.

2. Response to AEC-DRL Question 5.6, Amendment No. 16 to Application of Public Service Company of Colorado for Construction Permit and Class 104 License for the Fort St. Vrain Generating Station, Docket No. 50-267, November, 1970.

3. L. Sevier, "LHTGR Graphite Fuel Element Seismic Strength," GA-A13920, April 30, 1976.

4. J. K. Fuller (PSC) letter to William Gammill (NRC), "Fort St. Vrain Operations and Oscillations Testing," P-78174, October 20, 1978.

5. Public Service Company of Colorado 330-MW(e) High-Temperature, Gas-Cooled Reactor Research and Development Program Quarterly Progress Report for the Period Ending June 30, 1966, GA-7314, September 1966, pp 29-31.