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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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Mr. George L. Wessman, Director
Plant Licensing Division
General Atomic Company
P. O. Box 81603
San Diego, California. 92133

Dear Mr. Wessman:

SUBJECT: REVIEW OF THORIUM-OXIDE AND URANIUM CARBIDE FUELS

We have completed our initial review of your document, "Safety Analysis Report: Use of UC_2 Fissile Fuel Particles in Fort St. Vrain Fuel Elements," Document Number GA-LTR-23, September 1978. We find this document acceptable for review and plan a review schedule parallel to that for the review of thorium oxide fuel, Document No. GLP-5640, June 1978. These reviews are now scheduled for completion by June 29, 1979.

The uranium carbide review will be administratively similar to the thorium oxide review and will require a fee based on actual cost up to a limit of $20,000. The fee will be payable at the completion of the review as described in my letter to you of January 3, 1979, pertaining to thorium oxide fuel. We will provide the Public Service Company of Colorado and the public document room in Greely, Colorado with a full set of documentation. It will be Public Service of Colorado's responsibility to make a separate application to us for loading the uranium carbide fuel described by your documentation into the Fort St. Vrain reactor.

In order to expedite the reviews for both fuels, this letter transmits the enclosure, "Lead Items for Review of ThO_2 and UC_2 Topical Reports." We have arranged with David Alperstein to discuss this material with you and General Atomic staff members on February 28 and March 1, 1979, prior to our development of first round questions.

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Please let us know if you have any questions.

Sincerely,

Themis P. Speis, Chief
Advanced Reactors Branch
Division of Project Management
Office of Nuclear Reactor Regulation

Enclosure:
As stated

cc: Mr. J. K. Fuller, Vice President
Engineering and Planning
Public Service Company of Colorado
P. O. Box 361
Platteville, Colorado 80651

Bryant O'Donnell, Esquire
Kelly, Stansfield & O'Donnell
990 Public Service Company Building
Denver, Colorado 80201

James B. Graham, Manager
Licensing and Regulation
East Coast Office
General Atomic Company
2021 K Street, NW.
Suite 709
Washington, D. C. 20006

Lead Items for Review of ThO_2

and UC_2 Topical Reports

I. ThO_2 Fuel Performance Data Base

The discussion of (a) irradiation test results and (b) fuel performance during a potential core heatup event (sections 4.2.3 and 4.4, respectively, of GLP-5640) is, in each case, rather brief. Perhaps the several references listed in GLP-5640 contain all that is needed as supplementary information. On the other hand, it might be possible to expedite the review if separate and more detailed discussion and analysis were provided of the overall data base for ThO_2 TRISO particle performance under normal and off-normal conditions. Thus, it would be helpful to have a summary presentation of the details of the irradiation tests and performance analyses, which would include the following:

1. Fuel test particle material parameters, such as kernel diameter, coating thicknesses, densities, anisotropy factors, etc.; differences between test material parameters and potential reload material parameters should be highlighted and discussed in terms of possible effects on performance.
2. Fabrication parameters should be discussed in terms of the precursors, methods, etc. that were used to produce the test particles as compared with the future reload particles and the effects of these fabrication parameters on fuel particle component structure and performance.

3. Test conditions, including numbers of particles tested versus number failed, method of failure detection, statistical significance of the test results, etc.
4. The analysis of the test results should include a discussion of the significance of the apparent lack of data on high exposure ThO_2 TRISO fuel particles (taking into account that the fraction of fissions in the fertile particles increases with time as more Th-232 is converted to U-233).
5. An attempt should be made to indicate the expected failure fraction for each potential failure mechanism, as was attempted for UC_2 TRISO and ThO_2 BISO particles in GA report GA-12971. The supporting data should be correlated with the predictions.
6. The relationship of the SiC tensile stress model to the irradiation test data base should be discussed. For example, for a given test sample, what was the calculated distribution of SiC tensile stresses, how many specimens (particles) failed in the sample, and what were the calculated tensile stresses in the failed particles? As a tie-in to the questions on fabrication parameters and particle coating structure and properties, what effect does SiC microstructure (grain size) and density have on strength, how are these parameters affected by fabrication, and what quality assurance procedures are used to ensure that the desired SiC structure and strength are obtained?

II. Gaseous Fission Product Release From ThO_2 TRISO Particles

The statement in GLP-5640 (p. 4-9) that gaseous fission product release from TRISO coated ThO_2 during core heatup is less than FSAR predicted values for ThC_2 particles seem inconsistent with the respective release-to-birth ratios (R/B) on page 4-7. Further information should be presented on the data base for the R/B values for each type of fuel particle. The way these values are used in the dose calculations should be discussed also.

III. Effect of Kernel Type on Steam-Graphite Reactions

It is indicated in GLP-5640 that, since the retention of barium and strontium (both known to catalyze steam-graphite reaction) is expected to be improved with ThO_2 kernels, the reaction rate of the core graphite will be reduced. There are no numerical values provided in the report discussion, however, and so it is not possible to determine the full ramification of this potential change in reactivity. For example, if less core graphite is reacted per unit time, does this result in greater oxidation of the core supports? If so, what is the potential safety significance? Moreover, within the core itself, a reduction in reactivity of the core graphite will not necessarily result in a reduction in total oxidation, but may merely shift the extent of oxidation from the top (colder) regions of the core to the bottom (hotter) regions. In addition, if the reactivity of the core graphite is, in fact, reduced significantly, there is a greater potential for hydrolysis of the carbide fissile kernels. These concerns should be addressed in sufficient detail to permit an assessment of their safety significance.

IV. Carbothermic Reduction of ThO_2

Although it is asserted in GLP-5640 that test results indicate that "the carbonaceous reduction of ThO_2 is not a performance consideration up to 2000°C, tests conducted at Brookhaven National Laboratory (reported in BNL-NUREG-50785) indicate that the "rate of reaction of UO_2 and ThO_2 with graphite becomes appreciable at 800°C to 1000°C and is very rapid above 2000°C." Some analysis and discussion of these apparently contradictory data or interpretation of data is desirable, particularly regarding its potential safety significance for the six events identified in Section 3 of GLP-5640.

VI. ThO_2 Kernel Migration

The most recent work on ThO_2 kernel migration (C. L. Smith, Nucl. Tech. 35, pp. 403-412) indicate that the migration is characterized by an incubation period that decreases with increasing temperature and burnup. What assurances are there then that the out-of-pile ThO_2 kernel migration measurements are not influenced (to a unknown degree) by removal from an irradiation out-of-pile and that the measurements out-of-pile do not provide false (low) indications of the rate in-reactor? Are there any decay processes that might affect the out-of-pile measurements, considering the period of time between the irradiation of the particles and the testing of the particles in an out-of-pile facility?

VII. SiC-Fission Product Interaction in TRISO-coated ThO_2 Particles

A fairly extensive data base exists which shows that the pressure vessel, SiC-tensile stress correlation breaks down at temperatures > 1500 - 1600°C. This is believed to be due to a chemical interaction between the SiC layer and fission products that have migrated out of the kernel to the inner surface of the SiC layer. The data that address this phenomenon in TRISO ThO_2 particles should be discussed, and the fraction of failures due to this mechanism should be predicted as a function of burnup and temperature.

VIII. Earlier review efforts (circa 1976) on HTGR fuel particle failure models and data culminated in an evaluation report NUREG-0111. In that report the TRISO UC_2 particle irradiation test data base, analyses, and coating failure models were critiqued, weaknesses were identified, and model modifications were suggested (see, in particular, section III of NUREG-0111). It would be helpful, therefore, to have a summary of the advances in the state-of-the-art regarding TRISO UC_2 particle testing and fuel failure model development that have been made since issuance of NUREG-0111. For example, what new evidence has been generated in support of (1) the SiC tensile stress and pressure vessel failure correlation and (2) the SiC fission-product-interaction failure rate at temperatures above 1500°C? What are the predicted failure rates for each identified potential failure mechanism as a function of particle age and temperature, and what specific data support the predictions?