FRAMATOME COGEMA FUELS

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Mr. Steven M. Matthews (Mail Stop O-9A1)
Vendor Inspection Section, Special Inspection Branch
Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, Maryland 20852-2738

Dear Steve:

Attached is a discussion of the results of some additional code benchmarking analysis that FCF undertook in response to your team's comments concerning "stressing the methods" with "T" and "L" fresh fuel configurations. The conclusion of the additional work is that the CASMO3/NEMO system continues to demonstrate a reliable capability for both heterogenous environments and power distribution gradients. CASMO3/NEMO can be applied to multiple burnable poison configurations, core reactivity calculations, local peaking with gradients, and gadolinia assembly control rod calculations with confidence.

This is being sent to you for your information and dissemination to the audit team and we would appreciate any comments you or the other team members may have concerning the results.

Very truly yours,

R. L. Gardner

R. L. Gardner
Manager, Quality
Framatome Cogema Fuels

IE09

IDER-13 vendor inspection

FRAMATOME
TECHNOLOGIES

Framatome Cogema Fuels
P.O. Box 11646, Lynchburg, VA 24506-1646
Telephone: 804-832-5000 Fax: 804-832-5167

(99900001)

Review of CASMO3/NEMO Capabilities

In discussions with the NRC audit team, FCF's lack of experimental benchmarks for the use of the CASMO3/NEMO code in "aggressive fuel management schemes" was characterized as a weakness. The configurations referred to were the "T" and "L" fresh fuel arrangements containing both gadolinia and LBP burnable poisons used in recent TMI and Crystal River III fuel cycles. It is FCF's belief that the code system has been sufficiently tested to reliably extend application to strongly heterogeneous environments (including Gd and LBP combinations) such as the "T" and "L" arrangements. In addition, operating experience suggests that there is no fundamental reason to avoid the configuration. For instance, cycles 8 and 9 at TMI utilized this type of arrangement without deviations in measured to predicted power distributions, failures, or the occurrence of DCP.

To further address the audit team concern, FCF initiated a study to obtain additional results comparing the NEMO/CASMO code system with experimental measurements for strongly heterogenous configurations. The scope of the study addressing reactivity effects as well as power distributions was as follows:

- Multiple burnable poison benchmarks
- Core reactivity benchmarks
- Local peaking benchmarks with gradients

Multiple Burnable Poison Benchmarks

Critical experiments with fuel containing gadolinia and control rods were modeled with CASMO3/NEMO. These critical experiments were performed using the core geometry as reported in the NEMO topical (BAW-10180A, Revision 1). The flooded active core is about 57 inches tall and comprises a 3 x 3 centered array of fuel assemblies surrounded by 2936 pins, about the same total number of pins as 22 fuel assemblies. These benchmark measurements are an extreme test for diffusion theory since the core is small and leakage is more important than in the typical large PWR cores. The cores also contain strong absorbers such as Ag-In-Cd pins, gadolinia rods, and B_4C rods as well as combinations of these absorbers.

The NEMO topical reports results with pin power measurements for the center assembly for two cores. The CASMO3/NEMO model for the new calculations employed the same modeling as used in the NEMO topical except that a fuel assembly quadrant pin power reconstruction model replaced a whole fuel assembly pin power reconstruction model, a 3-D model replaced the 2-D model, and the reflector model was refined. The quadrant pin power reconstruction model was needed to accurately represent the asymmetric assemblies (see Figure 1). A 3-D model was used because more accurate information was of interest beyond the central core region. The 2-D

model was focused on the center assembly pin powers, and a 3-D model was not required. A refinement of the reflector model was implemented because of the high leakage from the small core.

Core Reactivity Benchmarks

Calculations were performed for 17 core configurations. The agreement was excellent even though the configurations are small high leakage cores. Results were consistent and the standard deviation between the calculations and measurements was only 4.7 ppm.

The core configurations included rod worth measurements in assemblies with and without gadolinia (6 configurations with 4 wt.% gadolinia fuel pins and 2 configurations without gadolinia). Five configurations contained Ag-In-Cd poison and three contained B_4C poison. The mean of the control rod worth comparisons was -1.2% with a standard deviation of 3.1%. The statistics are similar to the data base of measurement versus NEMO comparisons of single control rod bank worths in current core designs. Based on these results, we conclude that the rod worth uncertainty for control rods inserted in fuel assemblies containing gadolinia is consistent with non-gadolinia fuel assemblies.

FCF's burnable poison design is B_4C in an Al_2O_3 matrix. The B_4C is the same poison material as for the control rod worth measurements. The results demonstrate excellent predictive capabilities by CASMO3/NEMO for the mixed poison configurations. The mean difference is about 1%. Differences ranged from -0.7% to +1.8%.

The ability of CASMO3/NEMO to predict gadolinia worths is also excellent. The gadolinia worth is defined by replacing fuel pins with gadolinia pins in the center assembly and in the 4 diagonally adjacent assemblies in the quadrant closest to the center assembly. The % deviation between the measured and predicted boron worth of gadolinia is between -0.7 and 1.3%.

Peaking near Gradients

Calculations were performed of two critical experiments to characterize power peaking accuracy in high flux gradient regions. Experimental measurements along the diagonal of the core (see Figure 1) were compared with the CASMO3/NEMO calculations. The same method was used as for the reactivity benchmarks. A necessary geometry approximation on the core periphery, while accurate for reactivity calculations, significantly affected the predicted powers near the periphery. For this reason, an additional NEMO model was used to bound the peripheral geometry of the critical experiment and the results were averaged.

One of the NEMO geometries for core 14 is illustrated in Figure 1. The geometry problem is that an interior core node structure representing fuel assemblies can not be matched with the core boundary configuration. Only a pin by pin type model could represent both without approximation. As illustrated in the figure, a little fuel is added in one region and removed in another to match up with interior nodes. The other NEMO model simply reverses the process, where fuel was added in the first model it is removed in the second. Because a commercial PWR has a uniform fuel assembly structure, this type of geometry problem does not occur in production applications.

The outer 4 pins were not included in the comparisons since they were very low in power and strongly affected by the leakage effects of the geometry approximations. The averaged results from the two models approximate the solution. The RPD values are normalized to the average of the pin powers for the center assembly for consistency with the measurements.

The following observations apply to both of the NEMO geometries. The center assembly pin power RPDs greater than 1.0 have a mean deviation of 0.4 % and a standard deviation of 1.1% and agree with earlier reported results. Since the powers are normalized to the center assembly rather than to the core average, the powers outside this assembly will reflect both local and global uncertainties.

The pin powers are provided in Tables 1 and 2. The CASMO3/NEMO codes produce more consistent results than the NULIF/PDQ codes. For instance, in core 5, CASMO3/NEMO yielded a standard deviation of 1.6% versus 4.2% for NULIF/PDQ. This trend continued with core 14, CASMO3/NEMO yielded a standard deviation of 2.0% versus 8.0% for NULIF/PDQ.

From these results it is concluded that even with sharp gradients CASMO3/NEMO will calculate accurate power distributions within quoted uncertainty bounds for high power locations even in extremely small cores. Similar calculations for the large PWR cores are less challenging because the leakage is much less.

Conclusion

Additional benchmark calculations have been performed to study the capabilities of the CASMO3/NEMO system in strongly heterogenous environments and power distribution gradients. The CASMO3/NEMO system continues to demonstrate a reliable capability for both the heterogenous environments and power distribution gradients. CASMO3/NEMO can be applied to multiple burnable poison configurations, core reactivity calculations, local peaking with gradients, and gadolinia assembly control rod calculations with confidence.

BACKGROUND OF FRAMATOME COGEMA FUELS (FCF)

Framatome Cogema Fuels, formerly B&W Fuel Company, is a 51%/49% partnership between two French firms - Framatome and Cogema. Framatome is a the world leader in design and construction of PWR nuclear islands and corresponding engineering services, fuel fabrication, and associated services. Cogema is the leading organization in the world for the nuclear fuel cycle, from natural uranium production to conversion, enrichment services, and spent fuel transportation, reprocessing, and recycling.

FCF serves its fuel and core component customers from engineering and manufacturing facilities in Lynchburg, Virginia, where production of nuclear fuel began over thirty years ago. To date, FCF has supplied over 9,000 fuel assemblies and 6,000 core components for Babcock & Wilcox and Westinghouse designed PWR plants. The FCF manufacturing facility combines the best of automation with the craftsmanship of experienced dedicated technicians.