UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION
BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of

DUKE ENERGY CORPORATION

(Catawba Nuclear Station, Units 1 and 2)

Docket No's. 50-413-OLA,
50-414-OLA

**REBUTTAL TESTIMONY OF DR. EDWIN S. LYMAN
REGARDING BREDL CONTENTION I**

Blue Ridge Environmental Defense League ("BREDL") hereby presents the following rebuttal testimony by Dr. Edwin S. Lyman regarding BREDL's Contention I.

Q. R-1: Have you read the testimony submitted by Duke Energy Corporation ("Duke") and by the U.S. Nuclear Regulatory Commission ("NRC") Staff on BREDL's Contention 1?

A.R-1: Yes, I have.

Q.R-2: Has the testimony of either Duke or of the NRC Staff caused you to reconsider your opinion regarding the validity of BREDL's safety contention I?

A.R-2: No, it hasn't. Contention I is based on the fact that the experimental database on the behavior of M5-clad MOX fuel under design-basis LOCA conditions is inadequate to resolve issues such as the impact of fuel relocation on MOX fuel. Neither the testimony of Duke nor the testimony of the NRC staff offers any experimental evidence to support their claims regarding the ability of the MOX LTAs to comply with 10 CFR § 50.46 criteria in the presence of relocation effects. Instead, Duke offers a single micrograph of an irradiated, reactor-grade MOX fuel pellet of unspecified burnup. Thus the testimony of Duke and the NRC Staff tends to support, rather than refute, BREDL's contention that the LOCA analysis in Duke's LTA LAR lacks adequate experimental support.

In fact, the NRC Staff testimony confirms several of the assertions that BREDL has made in the course of this proceeding. In response to Question 47, the Staff confirms that fuel relocation could cause the cladding temperature in the balloon to increase by several hundreds of degrees F. In response to Questions 38-39, the Staff also confirms the possibility that the amount of fuel that is relocated in MOX rods may be greater than the amount in LEU rods.

Q.R-3: In response to Question 42, NRC Staff witness Meyer states that "if fuel relocation has any effect, it would increase the temperature only in the ballooned

region of the fuel rod … the ballooned region is seldom the location of the calculated peak cladding temperature when relocation is ignored." Do you agree with this statement?

A.R-3: No. According to the results of the FR2 test series, fuel relocation has a significant impact on the clad temperature both at the ruptured, ballooned location on the fuel pin and at non-ballooned locations on the fuel pin. This can be seen from Figures 10 and 11 in Duke's testimony in response to Questions 46-47. For low-exposure fuel where relocation does not occur (Figure 10), the maximum temperature at the ballooned location is indeed about 200°F lower than the peak clad temperature, which occurs at a non-ballooned location. However, for high-exposure fuel where relocation does occur, the maximum clad temperature at the ruptured, ballooned location is about 300°F higher than the ruptured, ballooned location for the no-relocation case, and about 20°F lower than the peak clad temperature at the non-ballooned location. Therefore, I would expect from this data that fuel relocation in high-burnup fuel would have a substantial impact on the clad temperature not only at the ruptured location but also at the location where the peak clad temperature occurs.

This conclusion is also consistent with Exhibit C attached to my prefiled testimony, in which NRC states that "the fuel relocation effect on PCT may be significantly larger than that assumed in GS-92 [+46°F]" (Exhibit C, Attachment 4 at 5) and states that fuel relocation may have a +313°F impact on PCT. Exhibit C, Attachment 5 at 4.

While the phenomena involved in these processes are too complicated for simple back-of-the-envelope assessments, some observations can be made. According to the MOX LTA LAR at 3-43, the peak temperature at the hot pin rupture location is 1841°F. (Note that the Duke testimony in response to Question 154 is erroneous in stating that "the highest PCT at the rupture location in the LOCA calculations for Catawba described in the MOX fuel lead assembly license amendment request was approximately 1750°F …"). If the 313°F increase in clad temperature associated with fuel relocation with a filling ratio of 0.7 is added to this value, the resulting clad temperature at the rupture location is 2154°F. From Figure 11 in Duke's testimony, the PCT in a rod where relocation occurs appears to be about 20°F greater than the maximum temperature at the rupture location. Therefore, the peak clad temperature associated with an LEU rod with 0.7 filling ratio due to relocation could be as high as 2174°F --- a value with substantially less margin to the 10 CFR § 50.46 limit. Consideration of additional MOX effects, such as a greater filling ratio, could shrink this margin even further.

In addition to limits on PCT, the maximum clad oxidation must also be limited to less than 17%. Since the maximum clad oxidation typically occurs at the ruptured location, as a result of double-sided oxidation, a significant increase in clad temperature at the ruptured location due to relocation would result in a significant increase in maximum clad oxidation, with the potential to exceed the 10 CFR § 50.46 limit. The oxidation rate for M5 is substantially greater at 2174°F than at 1841°F.

Q.R-4: In response to Question 98, Duke's witnesses Harvey and Dunn state that the impact of fuel relocation on the increase of the heat source in the ballooned region is mitigated by the lower density of the relocated fuel compared to the original pellet density, so that only very high filling ratios are a cause for concern. Do you agree with this statement?

A. R-4: No. As the Staff testifies in response to Question 32, the diameter increase in the balloon can be as great as 100%, so the cross-sectional area can increase by a factor of 4. Therefore, if the entire area fills with fuel, the linear heat source would double for a filling ratio of only 50%. For the FR2 observed filling ratio of 0.615, the linear heat source would increase by a factor of 2.5. The significant impact of relocation on PCT and maximum clad oxidation for these filling ratios is demonstrated in Exhibit E attached to my pre-filed testimony.

Q.R-5: In response to Question 40, NRC Staff witness Meyer claims that, according to the results of recent high-burnup integral tests at Argonne National Laboratory ("ANL") "it appears that the small particles or fines are blown out of the burst opening when the rod depressurizes," implying that "there would be few or no small particles in the ballooned region" of the type that could make a difference in the relocated fuel mass in MOX fuel and LEU fuel. Does this test resolve your concern regarding the potentially more severe impact of fuel relocation with the MOX fuel LTAs?

A.R-5: No. First, the tests in question were performed on BWR fuel rods and not PWR fuel rods. The two types of fuel are sufficiently different that it is difficult to come to any conclusions about the behavior of PWR fuel rods during a LOCA from experiments on BWR rods. This is why ANL plans to repeat these tests using rods from the H.B. Robinson PWR. *See* NRC Staff Proposed Exhibit 3 at 32.

Second, BREDL's claim, confirmed by the Staff in response to Question 39, is that the excess fine particles generated in MOX fuel originates in the rim regions surrounding the plutonium agglomerates, which are distributed throughout the fuel pellet. The Staff provides no argument as to how fine particles generated near plutonium agglomerates but away from the periphery of the fuel rod would be selectively blown out of the burst opening, leaving only large particles. On the other hand, the rim material in LEU fuel is generated only around the circumference of the fuel pellets (Staff response to Question 39), and thus is adjacent to the clad and the burst opening. The apparent absence of fine particles in the vicinity of the burst opening does not provide evidence that fine particles escape from the fuel rod at circumferential locations away from the burst opening (in the case of LEU fuel) or from locations throughout the entire fuel rod cross-section (in the case of MOX fuel).

In fact, to the extent that the phenomenon observed in this test indicates that fine-grain rim material near the burst opening is blown out of the rod during depressurization of LEU fuel rods, the result only strengthens BREDL's contention that MOX fuel rods contain greater quantities of fine-grain material than LEU fuel and hence may be subject to more severe relocation effects.

Q.R-6: In response to Question 63, Duke's witnesses assert that the effect on Duke's LOCA analysis of using the LEU decay heat curve instead of the MOX decay heat curve is a conservatism of "up to 75°F on PCT." What is your opinion of this statement?

AR-6: While I agree that this is a conservatism, I would point out that the effect of using the LEU decay heat curve on PCT is considerably smaller than the effect of relocation on PCT, which could be on the order of several hundred Fahrenheit degrees. Both effects should be considered in any LOCA analysis involving MOX fuel, to ensure that any interactions between the two effects are properly accounted for.

Q.R-7: In response to Question 163, Duke's witnesses claim that BREDL is presenting a "chicken and egg" paradox by arguing that LOCA testing of irradiated MOX fuel rods is necessary to support the safety case for the MOX LTA program at Catawba. Is this a fair characterization of BREDL's position?

A.R-7: No, it is not. BREDL has pointed out that the necessary testing can be conducted with MOX fuel irradiated in Europe at European test facilities, of which there are several. The MOX LTAs that Duke proposes to load at Catawba are not merely incremental modifications of the LEU fuel that is in use at US reactors, but are radically different fuels with completely different microstructures. BREDL believes it would be irresponsible to use the Catawba station as a test reactor for these novel fuel assemblies. BREDL also notes that a loss-of-coolant accident at Catawba when MOX LTAs are present in the core would likely put an end to the MOX program in the United States. Thus it would be prudent to ensure that the likelihood of such an occurrence is low.

Q.R-8: Is this your entire rebuttal to the testimony of Duke and the NRC Staff?

A.R-8: No, these are just some initial observations, which I have been able to make in the relatively brief period of time available to prepare a written rebuttal. I am continuing to review their testimony.