Implications of ICET Program Results

The Integrated Chemical Effects Test (ICET) series were designed to determine if chemical by-products would form in representative post-LOCA sump pool environments. The observation that chemical by-products did form in each of the first three ICET environments implies that the consideration and evaluation of chemical by-products are important to ensure that the Generic Letter 2004-02 responses are sufficiently complete. The test results have implications with respect to chemical product formation, head loss consequences, and downstream effects which should be addressed. More detailed implications with respect to each of these areas follows.

<u>Chemical Product Formation</u>

The ICET results demonstrate that changes to one important environmental variable (e.g., pH adjusting agent, insulation material) can significantly affect the chemical products that form. For example, the types and nature of chemical products which formed in test #2 are substantially different than those in test #3 and the principal difference between these tests is the inclusion of Cal-Sil insulation material in test #3. Chemical products with varied quantities, consistencies, attributes and apparent formation mechanisms were found in each unique ICET environment. Therefore, it is not easy to predict how chemical effects in individual plant specific environments may differ from, or be represented by, the ICET results. It is therefore important to understand how individual plant conditions will affect chemical product formation. The ICET results indicate that containment materials (metallic, non-metallic, and insulation debris), pH, buffering agent, temperature, and time are all important variables that influence product formation. For environments not represented by the ICET set of tests, testing is recommended to determine formation of chemical products in plant-specific environments.

<u>Head Loss</u>

Since the ICET program objectives did not include measuring the head loss associated with chemical by-product formation, additional testing is recommended to understand the head loss consequences of these by-products. The most important consideration is the demonstration that net positive suction head (NPSH) margin exists in the presence of chemical by-products. Understanding the head loss associated both with ICET by-products and with by-products which may form in other plant-specific environments is important because of the variability in chemical product formation observed in the ICET program.

It is important to consider the effect of time when determining the head loss consequences resulting from chemical effects since it has been demonstrated to be important in the ICET environments. The quantity of the chemical by-products formed during tests 1, 2, and 3 generally increased as the testing time increased. However, early manifestation of chemical products is also an important factor in assessing head loss consequences since NPSH margins, without consideration of chemical effects, typically increase significantly with time. ICET test #3 exhibited the formation of white, neutrally buoyant material within 20 minutes after the initiation of this test.

Temperature related effects on chemical by-products is also an important consideration. Although the ICET series are conducted at constant temperature, the properties of the chemical by-product apparent during ICET test #1 were clearly temperature dependent. This material was not visible at the test temperature, but became visible and produced more total suspended solids as the temperature decreased from the test temperature to room temperature.

Additionally, metallic corrosion rates typically increase at higher temperatures which may increase the types and quantities of some of the chemical products compared to the ICET observations. For example, a greater aluminum corrosion rate is likely during the first day after a LOCA in plants with an environment similar to ICET Test #1 if containment pool temperatures are greater than the ICET test temperature (140°F). Therefore, temperature may influence the head loss related to chemical effects immediately after a LOCA (e.g., day 1). Temperature may also be a factor in the ability of by-products to be filtered out by debris beds. Therefore, it is recommended that the evaluation of head loss related to chemical effects for a given plant should account for the entire emergency core cooling system (ECCS) recirculation mission time and temperature profiles to determine the point of minimum NPSH margin. Additionally, it is recommended that the evaluation should determine the maximum chemical effect head loss during the entire recirculation mission time in light of expected uncertainties in the head loss characteristics of these materials.

It is important to note that the particle size associated with many of these chemical products (e.g., the ICET #1 by-product) is small, on the order of nanometers. This is a much finer particle than has been typically evaluated in head loss studies on fibrous and particulate PWR containment materials. However, particle agglomeration to a size that could be filtered was observed in ICET test #1. Because of the amorphous nature and size distribution of the ICET test #1 by-product, it is not expected that existing head loss correlations can be used to predict the head loss contributions due to chemical effects. However, as for fibrous and particulate containment debris, the flow rate at the sump strainer screen, and debris bed type and thickness may influence the head loss associated with chemical by-products. Therefore, it is recommended that the effect of these variables be considered.

Finally, at least one of the tests (ICET test #2) appeared to generate corrosion products that dislodged from the metallic coupons and fell into the test tank sediment. These corrosion products have different characteristics from precipitates or chemical products found in the fibrous insulation. There also is evidence of relatively large amounts of aluminum in the ICET test #1 sediment. Therefore, it is recommended that the influence of chemical by-products on the sediment characteristics, the ability of the sediment to transport to the sump strainer screen, and sediment contributions to head loss should also be addressed.

<u>Downstream Chemical Effects</u>

The possibility of chemical by-products to either form or be transported downstream of the sump strainer screen and affect the performance of downstream ECCS components is another important consideration. The quantity of the ICET #1 by-product increased as the temperature decreased and subsequent reheating up to the test temperature did not redissolve all of the by-product. It is therefore possible that additional chemical products could be produced at lower temperatures within the ECCS system, especially at the heat exchangers. If additional products can form, the rate at which excess chemical products are produced is important in order to evaluate the impact on the downstream components. It is recommended that the possibility of chemical by-products fouling the heat exchangers or transporting to the reactor core be evaluated. If the by-products transport, it is recommended that their impact on the ability of the ECCS water to cool the reactor core and the possibility that the material could travel back to the sump strainer screen through the LOCA break be addressed.

Blockage or wear of downstream components is another consideration. The flow meter in ICET test #3 stopped functioning after 8 days due to scale build-up on the pipe inner surface and the turbine blade edge which eventually impeded turbine rotation. As previously mentioned, metallic corrosion products appear to be evident in the sediment of ICET test #2. These findings imply that for similar chemical by-products, blockage or wear of close tolerance ECCS equipment (e.g., pumps, valves, offices, etc.) downstream of the sump strainer screen may be possible if the by-products are capable of being transported through the sump screen.