REQUEST FOR ADDITIONAL INFORMATION 708-5455 REVISION 2

3/1/2011

US-APWR Design Certification

Mitsubishi Heavy Industries

Docket No. 52-021

SRP Section: 15.04.06 - Inadvertent Decrease in Boron Concentration in the Reactor Coolant (PWR)
Application Section: 15.04.06

QUESTIONS for Reactor System, Nuclear Performance and Code Review (SRSB)

15.04.06-9

NRC would like additional justification of Equation (7) presented in response to RAI 15.4.6-5 (Reference 1). Equation (7) is given as the following:

$$N\_a/N\_0 = (keff\_O - 1)/((keff\_a - 1) = 10^{0.8}$$

where *N_0* is the initial neutron population, *N_a* is the neutron population when the source range high neutron flux alarm activates, *keff_0* is the initial effective multiplication factor of the reactor system at the beginning of the dilution event, and *keff_a* is the effective multiplication factor when the alarm setpoint is reached. The alarm is calibrated to activate when the neutron population reaches 0.8 decades above the initial neutron population.

Equation (7) is apparently based on the equilibrium neutron level *N* in a subcritical system:

$$N = S / (1 - keff)$$

where *S* is the source strength and *keff* is the effective multiplication factor. This equation describes the steady-state neutron population in a subcritical system with a fixed source of neutrons *S*. The concern with the use of this equation within Equation (7) is that Equation (7) neglects the lag time between when a positive reactivity insertion is made and when the system stabilizes to a new equilibrium neutron level. In other words: suppose a subcritical system with effective multiplication constant *keff_0* and an external neutron source *S* has reached equilibrium. The steady-state neutron population within such a system is given by:

$$N\_0 = S / (1 - keff\_0)$$

Then, a discrete reactivity addition of *delta_k* is introduced to the system. After a finite period of time *delta_t*, the system will settle to a new equilibrium population *N_new*:

$$N\_new = S / (1 - (keff\_0 + delta\_k))$$

As the system approaches criticality, this lag time *delta_t* corresponding to the time between when the discrete reactivity insertion *delta_k* is made and when the system settles into the new equilibrium neutron population can grow quite large. Therefore, removing effect of this lag time (as is apparently done in Equation (7)) would not be an accurate description of the neutron population as a function of the effective multiplication factor. In fact, by this logic, Equation (7) could be substantially non-conservative; the effective multiplication factor could be far closer to criticality than the source-range high-flux alarm would indicate.

This concern is highlighted for the operating fleet in the most recent *Transactions of the American Nuclear Society* (Reference 2).

In light of these concerns, NRC requests that MHI further justify the use of Equation (7) for describing the relationship between the source-range high flux alarm setpoint and the system effective multiplication factor.

References:

[1] UAP-HF-11006, "MHI's Revised Response to US-APWR DCD RAI No. 311-2347 Revision 1 (SRP 15.04.06)," January 14, 2011 (ML110190096).

[2] Bojduj, William, "Source Range Detector Response During Boron Dilution Accident at Shutdown," Transactions of the American Nuclear Society, Volume 103, No. 1, pp 517-518, November 2010.