Response to NRC's Request for Additional Information by the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16081-P-A, Addendum 2, "SVEA-96 Optima2 CPR Correlation (D4): Modified R-factors for Part-Length Rods" (TAC No. MD6383) (Non-Proprietary)

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Responses to Requests for Additional Information (RAIs) regarding WCAP-16081-P-A, Addendum 2, Revision 0, "SVEA-96 Optima2 CPR (Critical Power Ratio) Correlation (D4): Modified R-factors for Part-Length Rods" (Proprietary)

<u>NRC RAI 1a</u>

1. On page 1-1, the fifth paragraph states that: "As a result of the reevaluation of the FRIGG loop, it has been confirmed that the R-factor model utilized in Reference 1 could, in cases ... result in a non-conservative CPR prediction."

   Why would these part length rods go into dry out? Typically, dry out occurs just below the top spacer in full length rods. Please provide qualitative technical discussion in support of dry out, or Critical Heat Flux occurring in part-length rods of any size.

<u>Response to NRC RAI 1a</u>

Historically, the observation that a majority of Critical Power measurements indicate a dryout location either at the end of heated length or just below the top spacer is consistent with our FRIGG Loop testing experience. However, with improved spacer designs and numbers of spacers per assembly (decreased spacer axial separations), we have observed [

]^{a,c} Our experience is that the axial position of dryout depends mainly on axial power shape and coolant flow.

a,b,c

NRC RAI 1b

Why isn't this correction an issue with respect to Title 10 of the Code of Federal Regulation (10CFR) Part 21?

Response to NRC RAI 1b

Upon discovery, Westinghouse recognized the potentially non-conservative R-factor for the two-thirds length rods as an issue which could represent a condition adverse to nuclear safety with respect to 10CFR Part 21 and initiated its standard process for dealing with such an issue. This process involved:

1. Investigation of the cause of the fault,

2. Evaluation of the impact on all potentially affected plans and identification of the extent and consequences of the faulted condition, and

3. Establish whether or not the faulted condition represented a condition adverse to safety and whether or not it was reportable to the NRC.

In this case, this process was implemented as follows: Each plant operating, having operated, or scheduled to operate with reload quantities of SVEA-96 Optima2 fuel, for which the necessary nuclear design reload analyses had been completed, was evaluated to confirm the validity of the analyses performed with the D4.1.1 correlation.

The net impact on the R-factor was shown to be [

]^{a,c} It was demonstrated that the impact on margin to existing CPR limits was very minor relative to the existing margins to these limits.

The validity of the existing CPR limits was also evaluated. As discussed in Section 4 of Reference 2, either the proposed revision of the D4 correlation with an additive constant [

]^{a,c}.

The limiting slow transient in current U.S. SVEA-96 Optima2 applications is the Rod Withdrawal Error (RWE). The potential impact of the non-conservative R-factor additive constants on the RWE was also evaluated by repeating RWE calculations using the corrected R-factor additive constants and axial integration for the U.S plants evaluated. This evaluation demonstrated the continued validity of the current CPR limits.

Consequently, it was concluded that the faulted condition did not represent a substantial safety hazard, and that 10CFR Part 21 notification of the NRC was not required.

Corrected CPR evaluation software to apply the appropriate 2/3-length rod [

]^{a,c} described in Reference 2 has been provided to the utility for all U.S. SVEA-96 Optima2 applications.

NRC RAI 1c

The last sentence of this paragraph states that the full-length rods are "adequate". What does "adequate" mean in this context?

Response to NRC RAI 1c

Adequate R-factor treatment means that the current R-factor model applied to the full length rods is capable of correlating the probability of dryout as a function of the relative rod power and the sensitivity of each specific rod position to dryout (i.e. the additive constant) using the current axial weighting of the nodal R-factors which reflects the impact of local power for different axial levels.

NRC RAI 2

On page 2-1, the first three paragraphs of Section 2 provide a brief discussion of the R-factor axial dependence and the associated weighting factors. The third paragraph of this section also stated that: "... this non-conservative treatment is a consequence of the inherent difficulty of assigning a single additive constant to the two-third length rods which is adequate for all conditions." The cause of this non-conservative prediction is due to assigning a single additive constant value to both full- and part-length rods. Please confirm and explain.

Response to NRC RAI 2

The statements intended to reflect the fact that dependence of critical power on axial power shape is handled in the base formulation of the [

]^{a,c}

NRC RAI 3

On page 3-1, an issue is raised regarding the difference in the length of the fuel used at the FRIGG loop and the actual fuel. Please a provide table and/or list with the ratio between the FRIGG data and the SVEA-96 Optima2 data.

Response to NRC RAI 3

The lengths of the active fuel in the rods are tailored to assure compatibility with the reactor and to optimize performance while maintaining the applicability of the CPR correlation. The following table compares the active fuel lengths for the full-length and 2/3-length rods in different reactors using SVEA-96 Optima2 fuel with the FRIGG Loop test assembly dimensions:

[ ]a, b, c

NRC RAI 4

On page 4-1, the meaning of the second sentence is not clear to the NRC staff. Please provide additional explanation as to meaning and or implication of this sentence.

Response to NRC RAI 4

The second sentence on page 4-1 reads:

> "The D4 R-factor model does not allow the dryout sensitivity of a rod to be a function of its active fuel length relative to the full-length rod active fuel length since the R-factor is used in the CPR correlation to capture the relative rod power radial effects only and is assumed to be decoupled from the axial dependence."

The R-factor for each rod is given by Equation 5.2.2-1 of Reference 1. Equation 5.2.2-1 of Reference 1 [

]a,c

Therefore, the basis for this statement is that the sensitivity of each rod is given by the [

]a,c

The weighting procedure applied in the D4 correlation (i.e. reflected by WZ_z) provides [

]a,c.

NRC RAI 5

Pages 4-1 and 4-2 threat the subject of fast transients on part-length rods. Please provide a similar qualitative analysis for slow transients.

Response to NRC RAI 5

A "slow transient" is an event which proceeds sufficiently slowly that at any given time the core power distribution and hydraulic state predicted with a 3-D core simulator (e.g. POLCA7) is sufficiently accurate to evaluate the consequences of the event. The event is characterized as a series of steady state conditions. This approach is valid for a broad range of events since the fuel time constant is typically about 2.5 seconds for 10x10 fuel.

Consequently, slow transient evaluation is typically equivalent to analyzing the initial and most limiting (e.g. minimum CPR during the event) state points of the transient. Consequently, the R-factor from the limiting rod, independently of whether it is a part length or full length rod, is used automatically to evaluate CPR, and the possible jump of the limiting rod between the initial and final state points is correctly modeled by the R-factor model leading to a reliable transient CPR change.

NRC RAI 6

It is not clear to the staff from viewing Figure 4-1, whether it pertains to the D4.1.1 correlation, the D4 correlation with modified R-factors, or perhaps to both correlations. Please provide clarification. Also, additional study of Figure 4-1, indicates that the CPR for part-length rods is NOT permitted to approach the minimum critical power ratio value, due to the technical basis provide on pages 4-1 and 4-2 of Section 4. Is this a correct understanding?

Response to NRC RAI 6

Figure 4-1 is an illustration of the physical behavior of CPR for full-length and part-length rods during a typical fast transient and is not intended to reflect the actual CPR predictions of a specific CPR correlation. Figure 4-1 is an attempt to qualitatively show the behavior which we have observed actually occurs in a fast transient in a BWR and confirm that the behavior is consistent with physical expectations.

The initial minimum CPR may, as indicated in Figure 4.1, be determined by the CPR on a Part-Length rod. It is assumed that for this initial condition a fast transient occurs which is a typical reactor pressure increase resulting in a rapid power increase terminated by a reactor scram. During the reactor scram, the axial power shape is rapidly tilted upwards causing the power in the part-length rod to decrease much faster than it decreases in a full length rod resulting in a smaller transient CPR change in the part length rod than in the full-length rod. Since the transient power is substantially greater in the full length rod than the part-length rod, the minimum transient CPR in the bundle occurs in the full-length rod. When the scram rods are fully inserted the core power is greatly diminished leading to an increase in CPR. However, the minimum CPR will have occurred on the full-length rod. If the limiting transient is caused by a fast flow decrease, the actual dryout occurs close to the bundle exit due to total water film evaporation. The tendency for this effect to always occur at the core exit means it will occur on a full length rod.

This qualitative CPR behavior for the full length rod and the part length rod is shown in Figure 4-1. The figure also shows that if the bundle is initially limited by a part length rod, and during the transient the minimum CPR is on a full length rod, the transient CPR change would be the difference between the initial CPR of the part length rod and the transient minimum of the full length rod that also reaches the SLMCPR.

For a given minimum final CPR, the change in CPR during a fast transient is increased by an increase in initial CPR. Therefore, [

]^{a,c}

Supervision of the core minimum steady-state CPR will use the true CPR of the bundle based on both part length rod and full-length rod CPRs.

NRC RAI 7

In Section 5, on page 5-1, the second paragraph alludes to the change in CPR being "calculated conservatively for all cases...." What does this mean?

Response to NRC RAI 7

Figures 7.7, 7.8 and 7.9, of Reference 1 show that the BISON simulation of the FRIGG loop transients is conservative. This conclusion is based on the observation that in general the BISON simulated transients predict a minimum calculated CPR during the transients which is less than [

]^{a,c}

The initial minimum CPR (MCPR) during a fast transient occurred on a full-length rod in the vast majority of cases plotted in Figures 7.7 through 7.10 demonstrating that the fast transient CPR change is conservatively treated when the initial MCPR is on a full-length rod. [

]^{a,c}

Therefore, it is concluded that the change in CPR during fast transients will be conservatively calculated in all cases.

References

1. WCAP-16081-P-A, Revision 0, "10X10 SVEA Fuel Critical Power Experiments and CPR Correlation: SVEA-96 Optima2," March 2005.

2. WCAP-16081-P-A, Addendum 2, "SVEA-96 Optima2 CPR Correlation (D4): Modified R-factors for Part Length Rods," July 2007.