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RAIs for SPCB Additive Constants for ATRIUM-10 Fuel - EMF-2209(P) Revision 2, Addendum 1, Revision 0

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Question 1. **Section 3.0 of Chapter 3, on page 3-1 of the May 2008 submittal, provides a brief description of the adjustment needed to the voltage power provided to the part-length rods. Since a large number of tests were conducted for the development and validation of the SPCB correlation, one would expect an equivalent amount of voltage power applied to the part-length rods. Please provide a qualitative and quantitative technical basis as to how this issue was accounted for in your final determination of the adjusted additive constants, listed on page 2-1 of the May submittal.**

<u>Response 1:</u>

For each test in the ATRIUM-10 database that was used in the development of the SPCB correlation, the bundle powers as well as the rod powers and relative rod peaking factors at each axial level were re-computed using the method described below. The new local peaking factors were then used in the calculation of new f-effective values which were then used to determine the new additive constants using exactly the same methodology as was used previously.

The part length rods are constructed from full length rods by cutting off the un-needed portion. This assures that the part length rods and the full length rods will have the same axial power profile, within the length of the part length rods. To achieve the expected radial power across all the heated rods, the voltage drop must be equal across the heated length of all the test rods, meaning the part length rods must have the same overall voltage drop as the full length rods. To achieve the same voltage drop, the cut off portion of the part length rods is replaced by a compensation resistance located outside of the test vessel at the KATHY test facility. The current through the part length rods flows back through the rod and out to the compensation resistance through an insulated inner copper conductor that is [ ] .

The rod powers are computed based on the measured electrical resistances for each rod. For part length rods, the total rod resistance is the sum of the outer conductor resistance, R_O, the inner copper conductor resistance, R_{IC}, and the compensation rod resistance, R_E.

$$R_{T,i} = R_{O,i} + R_{IC,i} + R_{E,i} \tag{1}$$

For a full length rod,

$$R_{IC,i} = 0 \tag{2}$$

$$R_{E,i} = 0 \tag{3}$$

Note that the inner copper conductor resistance, R_{IC}, is composed of 3 parts. The first part consists of the length of conductor within the heated length of the bundle, the second part extends from the bottom of the heated length to the lower plate, and the third part is the length of conductor outside the pressure vessel (from the lower plate to the compensation bundle). The resistances associated with each part of the inner copper conductor are provided by the KATHY test facility and are determined based on the known lengths and a set of defined [ ] respectively, for each part.

An arbitrary voltage V_{ref} is used to compute the current and then the power (the exact value used is not important as it is normalized out).

From Ohm's law, the current in each rod, in Amperes, is calculated.

$$A_I = \frac{V_{ref}}{R_{T,I}} \times 1000 \tag{4}$$

From current and resistance, the power generated in each rod that is within the heated length of the test assembly is calculated. For a full length rod, the power generated is

$$Q_I = A_I^2 R_{O,I} \tag{5}$$

For a part length rod, the power generated in the outer conductor must be added to the power generated in that part of the inner copper conductor that is within the test assembly.

$$Q_I = A_I^2 \left(R_{O,I} + R_{IC,1} \right) \tag{6}$$

The total amount of power generated in the test assembly is

$$Q_T = \sum_{I=1}^{N_R} Q_I \tag{7}$$

If N_R is the total number of heated rods, then the normalized rod power factor is calculated

$$f_I^T = \frac{N_R Q_I}{Q_T} \tag{8}$$

The axial nodalization is then constructed according to the input with extra junctions added at the location of the end of heated length of the part length rods (in the general case, there can be more than one type of part length rod).

Now, for every rod, and for every axial volume k, the nodal power is calculated as.

$$Q_{i,k} = f_{z,i,k} Q_i \quad (9)$$

Where $f_{z,i,k}$ is the axial power profile for each rod type, corrected for the presence of the inner copper conductor in part length rods.

Equation (9) provides the three dimensional axial power distribution in the test assembly. For each axial plane k, the local peaking factor of each rod in the volume is calculated as.

$$f_{i,k} = \frac{N_k Q_{i,k}}{\sum_{i=1}^{N_k} Q_{i,k}} \quad (10)$$

Where N_k is the number of rods at axial level k.

The power deposited in each region of the assembly can be calculated. The average rod power factor for each rod in the lower part of the assembly (the fully rodded part) is calculated as

$$f_{L,i} = \frac{N_L \sum_{k=1}^{N_{LP}} Q_{i,k}}{\sum_{i=1}^{N_L} \sum_{k=1}^{N_{LP}} Q_{i,k}} \quad (11)$$

Where N_L is the number of rods in the lower part of the bundle.

Similarly, the average rod power factor for each rod in the upper part of the assembly (the part not containing part length rods) is

$$f_{U,i} = \frac{N_U \sum_{k=N_{LP}+1}^{N} Q_{i,k}}{\sum_{i=1}^{N_U} \sum_{k=N_{LP}+1}^{N} Q_{i,k}} \quad (12)$$

Where N_U is the number of rods in the upper part of the bundle.

An example of the impact the correction has on the local peaking factors associated with the bottom lattice (lattice extending from the bottom of the heated length to the end of the heated length of the part length rods) was provided in figures 3.1 and 3.2 in Reference 1. Note that the correction has no impact on the local peaking factors in the upper lattice.

Using the corrected radial and axial power distributions, as defined above, and the corrected bundle powers, new calculations were performed to determine the boiling transition values of f-effective (FEFF) for each test in the database. The boiling transition values are the values of f-effective which result in a CPR of 1.0 at the measured operating conditions. The new additive constants were then computed using the new data using exactly the methodology as was used previously. This methodology is described in Sections 2.3 and 2.5 of Reference 2.

Question 2. **The paragraph in Section 3.2 on page 3-2, attempts to explain the reason behind the higher bundle power reported in Reference 2/3. Did the error in the original calculation lye in assigning full length to the inner copper conductor instead of a ¾ length, which is the full heated length of the part length rod? Please provide additional clarification.**

Response 2:

As discussed in the Q1 response, the part length rod inner copper conductor is composed of 3 parts. The first part consists of the length of conductor within the heated length of the bundle, the second part extends from the bottom of the heated length to the lower plate of the test vessel, and the third part is the length of conductor outside the pressure vessel (from the outside of the lower plate to the compensation bundle).

The error in the previous calculation of the bundle power was that it included all of the power associated with the inner copper conductor. It did not exclude the power associated with the 2 parts of the inner copper conductor outside the heated length of the bundle (i.e. the part extending from the bottom of the heated length to the lower plate of the test vessel and the part extending from the lower plate to the compensation bundle).

References

1. SPCB Additive Constants for ATRIUM-10 Fuel, EMF-2209(P), Revision 2, Addendum 1, Revision 0, April 2008.
2. SPCB Critical Power Correlation, EMF-2209(P)(A), Revision 1, July 2000.