Request for Additional Information
Statistical Fuel Assembly Hold Down Methodology
BAW-10243P

1. With regard to the Monte Carlo propagation, Section 5.0 states that "if the normal distribution cannot be verified for a given uncertainty, the uniform distribution can be conservatively substituted for propagation." Describe the analytical normality tests performed on the measurements for each of the variables. Include in this discussion the means for verifying a statistically significant sampling size and treatment of any biases.

Response 1: The assumption of normality is arrived at in two ways. First, when data is present, the normal distribution is verified with the standard D prime test (ANSI N15.15, Reference 2 of the topical). The D prime test requires a sample size of at least 50. If the D prime value of the sample lies between the upper and lower D prime value for the given sample size, normality is assumed. If the D prime value does not match this criterion, further investigation is needed. Many times a highly peaked distribution (large negative kurtosis) will occur. In this case a normal distribution can also be justified since the standard deviation of such distributions is greater than that derived from non-parametric methods.

A second case arises mainly in the case of mechanical tolerances. Here absolute limits are specified. It is common practice to treat dimensional tolerances as normal around the specified value plus or minus three standard deviations (Note that +/- 3 standard deviations covers 99.73 percent of the data. Therefore the case of a tolerance of 100 +/- 3 inches would be treated as normal around 100 with a standard deviation of 1.

A uniform distribution, on the other hand, is usually necessary when a control variable is being propagated. For this situation maximum and minimum values of the variable are specified. When either limit is reached, action is taken to move the variable in the opposite direction until the opposite limit is reached (as in the case of a thermostat).

2. Section 10 states, "The method is illustrated with specific examples in Appendix B. In applications to different cores, some of the variables, their uncertainties and the method of determining the values will change. Variables and uncertainties may be added or deleted on a case by case basis."
   a. Please provide the supporting database or justification for each of the variables (e.g. basis of spring relaxation nominal and uncertainty values) in one of the Appendix B examples.
   b. Based on the above quote, the staff has concerns that the regulatory envelope around the statistical hold down (SHD) methodology is too broad and may be loosely interpreted in future applications. Please describe the method that will be employed to control the future application of the SHD methodology, especially deviations from the examples provided in BAW-10243P.

Response 2a: As stated in section 3.0 there are two classes of variables: mechanical and hydraulic. The eleven primitive variables are identified on page 9 in the paragraph following equation 6.

The mechanical variables will be discussed first. The first three variables identified below (CPD, FAH and FSH) are treated as a tolerance as discussed in the response to question 1 above.

CPD (Length between upper and lower core plate) - CPD is [ ] around [ ] inches with a standard deviation of [ ] inches.

FAH (Fuel Assembly Height) - FAH is [ ] around [ ] inches with a standard deviation of [ ] inches.

FSH (Free Spring Height) – FSH is [ ] around [ ] inches with a standard deviation of [ ] inches.

The next two mechanical variables were developed and justified in mechanical analyses. They are treated as simple mechanical tolerances.

TG (Thermal Growth) – TG is [ ] around [ ] inches with a standard deviation of [ ] inches.

SS (Spring Set) – SS is [ ] around [ ] inches with a standard deviation of [ ] inches.

The spring constant, SC is based on [ ] data as summarized below. It is described by a 5th order polynomial in spring depression (Figure 7-1) and is [ ] around its predicted value with a standard deviation of [ ] percent of the predicted value.

IG (Irradiation Growth) is conservatively assumed to be zero for this example. When a sufficient sample of fuel assembly growth data is obtained, it may be used in subsequent SHD analyses.

Finally (for the Mechanical Variables), the spring relaxation values are developed and justified in mechanical analyses for particular fuel assembly hold down spring designs. Spring relaxation at the end of the first cycle (EOC1) is [ ] around [ ] percent with a standard deviation of [ ] percent. Spring relaxation at the end of life (EOL) is [ ] around [ ] percent with a standard deviation of [ ] percent.

For the hydraulic variables, we find the following.

DW (Fuel Assembly Dry Weight) and VOL (Fuel Assembly Volume) are used with DEN (Coolant Density) to calculate the wet weight of the fuel assembly. DW and VOL are taken as nominal (see answer to question 7) with values of [ ] pounds force and [ ] cubic inches, respectively. DEN varies on a case by case basis (see Table 8-1).

LR (Hydraulic Lift Resistance) also varies on a case by case basis. Its nominal value is derived from the specific case LYNXT pressure drop (Table 8-1) and flow. The LR uncertainty is developed from the spacer grid form loss coefficient data shown on Figure 7-2 and summarized below. LR uncertainty is developed on page 14. Its values are a combined [ ] percent and [ ] percent on spacer grid resistance and nozzle/rod friction respectively.

Finally, the core flow uncertainties are taken from Reference 1 of the topical. The nominal values are plant specific and in the case of Q_{RCS} (RCS volumetric flow) is a conservative maximum value based on plant data. CFF (Core Flow Factor) is [ ] around [ ] with a standard deviation of [ ]. Q_{RCS} is [ ] around [ ] gpm with a standard deviation of [ ] percent ([ ] gpm).

<u>Response 2b</u>: The methodology has been constructed around the application of the uncertainties that arise in the variables found in the fundamental equation (Equation 1) below that has been used for computing net fuel assembly hold down force.

Net Fuel Assembly Hold Down Force = (Spring Depression)(Spring Constant)

+ Dry Weight of the Fuel Assembly

- Fuel Assembly Bouyancy Force

- Hydraulic Resistance Force of the Fuel Assembly

This equation has been used by Framatome ANP for deterministic calculations and contains all the axial forces acting on the fuel assembly. Whether a statistical hold down methodology or a deterministic hold down methodology is used, the impact of the uncertainties needs to be addressed in any fuel assembly hold down analysis. The SHD methodology provides a means of statistically accommodating uncertainties that avoids the overly-conservative compounding of uncertainties that can lead to excessive forces on the fuel assembly design that could potentially lead to distortion.

The eleven primitive variables defined in the topical report reflect a specific fuel assembly design application. As noted in Response 1, most of the uncertainties are associated with the mechanical calculation of the fuel assembly hold down spring forces (based on spring compression and spring constant). When a fuel design is changed such that the variables and uncertainties associated with spring depression and spring constant are affected, then new nominal and uncertainty values will be determined and incorporated into the fuel assembly hold down analyses. The same expectation applies for the hydraulic terms and the respective variables and uncertainties that are subject to change. For example, if the fuel design changes such that the hydraulic resistance, dry weight, and/or buoyancy force of the fuel design is affected, then new nominal and uncertainty values for these terms will be determined and incorporated into the fuel assembly hold down analyses. (These actions would be the same using the current deterministic methodology.)

3. Describe the connection between the SHD methodology used in the fuel mechanical design and the analysis of the Startup of an Inactive Reactor Coolant Pump transient event.

   Response 3: The SHD methodology would be used to compute the adequacy of the fuel assembly hold down spring system for keeping the fuel assembly engaged with the lower core plate. Analyses would be computed for both isothermal operation and for at-power operation. The most limiting isothermal operation condition typically occurs when the RCS pumps are activated at low temperatures.

   The analysis of a Startup of an Inactive Reactor Coolant Pump transient event is performed to address the nuclear excursion associated with the boron concentration assumptions.

4. Section 1.0 states that "the actual fuel assembly compressive forces during plant operation have been much greater than the calculated forces and, in some cases, may have contributed to observed fuel assembly distortion." Please provide any fuel assembly distortion data which has been collected to support this assertion.

   Response 4: A point of clarification should be made. The statement should be better phrased as "the actual fuel assembly compressive forces during plant operation have been much greater than the necessary forces and, in some cases, may have contributed to observed fuel assembly distortion."

   An operating plant has experienced an IRI (Incomplete Rod Insertion) event. Analysis of this event (reported to the NRC in LER 99-011-01CR, Three Mile Island, Unit 1) listed three independent contributors to bow with no explicit correlation to fuel assembly hold down. In order to reduce the observed distortions, Framatome decreased the hold down spring system load. The success of this action has been confirmed by the absence of any further IRI occurrences.

5. Have the governing hold down force equations, which have been previously applied deterministically, been reviewed and approved by the staff?

Response 5: The governing equations determining hold down force have not been reviewed and approved by the staff. However, they are identical in form for both the deterministic and statistical analyses. The difference in application is the propagation of uncertainties through the equations. The propagation of uncertainties technique was initially reviewed and approved by the staff for DNB analyses in BAW-10170P-A, "Statistical Core Design for Mixing Vane Cores" (Reference 1 of this topical).

6. In Section 7.1 and Appendix B, the core volumetric flow rate is discussed. Please describe how differences in local flow characteristics (e.g. inlet flow distribution, inlet flow uncertainty, cross-flow, increased flow along core shroud, etc.) are accounted for in the SHD methodology.

Response 6: The calculation of the term Hydraulic Resistance of the Fuel Assembly is performed by analyzing the core with a NRC approved crossflow thermal-hydraulic code, such as LYNXT and XCOBRA-IIIC. Local flow characteristics are captured in the thermal-hydraulic model of the core. The core is modeled with the plant-specific fuel cycle core configuration, or a bounding core configuration, to obtain the pressure drop across the various fuel assemblies. The model also includes a core inlet flow distribution applicable for the plant design.

7. Section 7.4 states, "The variability of the wet weight is extremely small, therefore, the fuel assembly wet weight value is a nominal value with no uncertainty." Please describe the manufacturing tolerances on fuel assembly components, including fuel loading, which may impact its overall weight.

Response 7: Wet weights of [ ] different Type B fuel assemblies were measured and recorded. Nine of these measurements were [ ] pounds force with the remaining [ ] being [ ] pounds force. From these data it is evident that the manufacturing tolerances on fuel assembly components, including fuel loading have a negligible effect on overall fuel assembly weight.

8. Section 8.0 states, "When examining a mixed core, or transition core, when multiple fuel designs reside in the core, the net hold down force determination is performed for each specific fuel design." In these situations, would the SHD methodology be applied to non-FANP fuel designs?

Response 8: If the FANP fuel designs could be shown to be limiting from a lift standpoint, the SHD methodology would not be applied to the non-FANP fuel designs. However, if the FANP fuel designs could not be shown to be limiting from a lift standpoint, the SHD methodology would be applied to the non-FANP fuel designs. In the later case, the non-FANP vendor or the utility would be required to furnish sufficient information on the non-FANP fuel design. If insufficient information on the non-FANP fuel design was not supplied in any necessary area, conservative assumptions in the SHD analysis would be required. These conservative assumptions could include uniform instead of normal distributions, deterministic treatment of some variables, conservative offsets of some variables, etc.

9. Section 8.0 states, "...the pressure drop prediction (based on the base design Case conditions) can confidently be adjusted for different flow rates by the square of the flow ratio within the propagation model." Please provide further discussion to justify this flexibility.

Response 9: With reference to equation 5 on page 8, Hydraulic Lift Pressure Drop (LPD) determines the upward lift force on the fuel assembly. LPD is equal to the fuel assembly hydraulic resistance (LR) times the square of the core volumetric flow rate (Q). LR is a function of the geometry (flow area and form loss and frictional components) and the coolant density. LR is determined from the base case LYNXT analysis. Its parameters are independent of the core volumetric flow rate (over the small range of propagation) and LDP is thus constant for any base case. Thus the LDP can be corrected for the small variations in core volumetric flow by the square of the ratio of the propagation Q to the base case Q. Note that this is only valid around any given base case. The LR for any different statepoint (full power versus the starting of the RCS pumps from the isothermal condition for instance) will not be a constant value. Further note that small variations in the inlet temperature (around a given base case) can be adjusted by a simple density ratio.