BAW-10133NP-A
Revision 1

Addendum 3

Grid Testing Methods Update

April 2009

BAW-10133NP-A
Revision 1
Addendum 3

Nature of Changes

Rev.	Item	Page	Description and Justification
0	1.	All	This is the initial release.

Contents

Tables

ABSTRACT

This topical addendum updates the faulted methods topical BAW-10133P-A, Revision 1, Addenda 1 and 2 for the addition of the Rapid Compression Test or Dynamic Crush Test to determine mechanical properties of fuel assembly spacer grids.

Siemens Topical Report XN-76-47(P)(A) (Reference 1), which includes a description of the dynamic crush test method, has been approved by the NRC for Siemens fuel designs.

Previous grid stiffness, damping, and crushing strength data was obtained using the Le Creusot (French) testing method, which is a progressive impact test. BAW-10133P-A, Addendum 1 (Reference 2) incorporates data generated from the Le Creusot method.

In this addendum, a brief review is made of the rapid compression and progressive grid impact test results. The differences in the results are discussed and explanations are made to show that the data obtained from the rapid compression testing method are adequate for performing the fuel assembly seismic and LOCA analyses with the methods outlined in Reference 2, which has been approved by the NRC.

1.0 Introduction and Background

Addendum 1 of BAW-10133P-A, Rev.1 provides refinements to the modeling of the spacer grids and the modeling of the hydrodynamic coupling. Addendum 2 provides the justification of higher damping values in fuel assembly seismic and LOCA analysis. As a consequence of these improvements, more realistic analysis results will be obtained. The NRC concludes that both addenda are acceptable for incorporation into the overall methodology for seismic and LOCA applications. The grid impact testing method in Addendum 1 was the Le Creusot (French) tests (progressive impact).

This topical addendum updates the faulted methods topical report BAW-10133P-A, Revision 1, Addenda 1 and 2 for the incorporation of the Rapid Compression Test (or Dynamic Crush Test) methods.

The Richland testing methods have been reviewed and approved by the NRC for licensing analyses. The Richland and Le Creusot test data for the same type of grids are compared and discussed. The results of the evaluations of the two methods on spacer grid seismic and LOCA impact loads are also presented to show that both of the testing methods are acceptable.

In this addendum, a brief review is made of the Richland and Le Creusot [ ] test results in comparison to the Richland and Le Creusot [ ] results. The differences in the results are discussed and explanations are made to show that the Richland grid impact testing results are applicable for the fuel assembly seismic and LOCA analyses using the analysis methods outlined in Reference 2.

2.0 Rapid Compression and Progressive Impact Test Methods

There are differences between the rapid compression and progressive spacer grid testing methods for finding through-grid stiffness and allowable crushing loads. A comparison of the rapid compression and progressive impact testing results is made for the Mark-BZ (15x15) and Mark-BW (17x17) spacer grid designs in this section. The intent of this comparison of the test results is to show that for all AREVA fuel designs, the Richland spacer grid testing methods produce data suitable for application to the core seismic and LOCA structural analyses.

The designs specifically covered in this analysis are:

- Mark-BZ Zircaloy-4 [ ]
- Mark-BW Zircaloy-4 [ ]
- Mark-BW M5 [ ]

The rapid compression and progressive impact testing methods used to define the ultimate strength and through grid stiffness are briefly summarized below.

<u>Rapid Compression Grid Crush Test (Richland Grid Crush Test)</u>

A dynamic crush test of the grid is performed using an MTS testing machine. A spacer grid filled with cladding and guide tube pieces is placed in the MTS load frame. The tests are conducted at 325^{0}C with a deflection to about [ ] The MTS testing machine is capable of delivering large velocities in the path of the ram, if necessary without requiring modification to the equipment. The spacer grids are loaded in a through-grid manner with the load applied across two opposite faces. The load is increased until the grid crushes. [

]

<u>Progressive Grid Impact Test (Le Creusot Dynamic Crush Test)</u>

A horizontal grid is secured on one face to a rigid anvil, with other faces free to move. The spacer grid is supported by four longer rods on the peripheral row adjacent to the anvil. Each grid is filled with empty fuel rod and guide tube segments. The test (at 325^{0}C) consists of a mass impacting the grid at the opposite face. The adjustable mass approximates that of an assembly span. The test progressively increases the impact velocity until grid instability takes place, which quantifies the grid behavior within the elastic range. The crush limit loads are found at the point of instability. Impact force, impact duration, pre-impact and post-impact velocity are measured during each impact. The stiffness and damping are determined from the impact energy data.

This testing method is also described in more detail in Reference 2.

2.1 Test Results

[ ]

2.2 Seismic and LOCA Analysis of Fuel Assembly

The maximum impact loads on the grids for the different grid type using the rapid compression and progressive impact grid test results are studied to show the applicability of the rapid compression grid test data to the analysis performed previously with the progressive impact grid test data. The intent of this study is to show that variations obtained in the fuel assembly impact loads are not significant and are well within acceptable range compared to the conservatism inherent in the fuel assembly seismic and LOCA analysis.

The Mark-B and Mark-BW spacer grid margins based on the empirical spacer grid properties provided in Tables 2.1.1 and 2.1.2 are studied. Except for the intermediate spacer grid and mid span mixing grid properties (if applicable), all other input to the core models remain the same as those used in the recent licensing analysis. The seismic and LOCA analyses cover varying number of adjacent fuel assemblies in order to determine the limiting core configuration for investigating the maximum horizontal impact loads. For the purpose of this study, the analysis is performed for the most limiting core configuration case and faulted case for the Mark-B and the Mark-BW fuel assemblies. The [ ] fuel assembly core model is the most limiting for the Mark-B fuel and the [ ] fuel assembly core model is the most limiting for the Mark-BW fuel.

For the Mark-B plants, two reactor types are analyzed, i.e., skirt-supported and nozzle-supported reactor vessels. Core flood and decay heat LOCA loads, and SSE seismic loads in the X and Z horizontal directions are applied. Of these three design cases, the highest loading condition is obtained for the SSE loads in the X direction for the skirt supported plant. So only this loading is considered for the study. The peak grid impact forces obtained for the Mark-B fuel assembly (Zircaloy-4) using the rapid compression grid test results are provided in Table 2.2.1.

For the Mark-BW fuel assembly the loads are analyzed for 2 Westinghouse designed plants – McGuire and Catawba. Of the [ ] design basis small line LOCA breaks, the highest loading condition for both the plants is obtained for the [ ] in the horizontal X direction. So the loadings are analyzed for these cases. The peak impact forces obtained for the Mark-BW fuel assembly (Zircaloy-4 and M5) using the rapid compress and progressive impact grid test results are provided in Table 2.2.2.

Table 2.1.1 Summary of Rapid Compression and Progressive Impact Test Results

Table 2.1.2 Number of Tested Grids

Table 2.2.1 Peak Spacer Grid Forces for Mark-B Fuel Assembly -Load Case – SSE-X Direction

2.3 Comparison of Grid Loads

The maximum impact loads on the grids for the different grid type using the Richland and Le Creusot test results are studied. The percent change in grid load margin in terms of normalizing to the Le Creusot result is presented in Table 2.3.1.

The effect of the differences in the grid properties obtained from the Richland and Le Creusot test results provides a less than [ ] variation in load a margin for both the Mark-B and Mark-BW designs. Thus, the grid loads obtained with both testing methods are acceptable.

Analytical approximations in fuel assembly mechanical response analysis arise from a nonlinear time history analysis. A margin to account for analytical approximations within a reasonable range is well accommodated in overall conservatisms used in the fuel assembly nonlinear analysis as specified in the faulted methods topical BAW-10133P-A, Revision 1, Addenda 1 and 2. Some of the most important conservatisms are described below.

[ ]

Table 2.3.1 %Change in Maximum Grid Impact Load Margin in terms of Normalizing to the Le Creusot Results

[ ]

2.4 Spacer Grid EOL Margins

As shown in Tables 2.2.1 and 2.2.2, the Mark-B (Zircaloy-4) and Mark-BW (Zircaloy-4 and M5) simulated EOL condition spacer grids were tested with the Richland and Le Creusot test methods. The margins to the lateral crush strength for the Mark-B grid with the Richland test data and the Le Creusot test data are [ ] and [ ] respectively. The margins to the lateral crush strength for the Mark-BW Zirc-4 for the McGuire plant with the Richland test data and the Le Creusot test data are [ ] and [ ] respectively. The margin to the lateral crush strength for the Mark-BW M5 for the McGuire plant with the Richland test data and the Le Creusot test data are [ ] and [ ] respectively.

Of these three cases, two cases resulted in higher margins and one case resulted in a lower margin with the Richland data when compared to the Le Creusot data. In general, the Richland data provide slightly higher initial margins due to higher grid strength obtained through the Richland testing. In the Richland testing the load is applied to the grid through a constant velocity until the grid fails, while in the Le Creusot testing, the load is applied through a moving mass, which is allowed to rebound. On successive impacts, in the Le Creusot testing, the mass is given a higher initial velocity until the grid fails. The crushing load in the Le Creusot testing method is obtained by applying the specified number of impact loadings, while in the Richland testing, the crush load is obtained by applying a constant velocity. It appears that a repeated increasing loading on the grid (until the grid fails) in the Le Creusot testing method is a contributor to the decrease in grid buckling load.

The grid typical buckling failure mode in both the Richland and Le Creusot tests is racking with a slight compression of the envelope. The guide tube positions are not altered in any of the tests.

3.0 Conclusion

Grid testing procedures of Le Creusot and Richland use different testing methods to find through-grid stiffness and crushing loads, which provide slightly different results. Both of the testing methods are considered adequate, because the data are comparable and both the testing methods realistically simulate the actual seismic and LOCA loadings on the fuel assembly spacer grid. Additional conservatisms as specified in the faulted methods topical report BAW-10133P-A, Revision 1, Addenda 1 and 2 will readily accommodate the differences in the Richland and Le Creusot test results.

In conclusion, the spacer grid impact testing procedures of both Richland and Le Creusot produce data suitable as input to the fuel assembly seismic and LOCA analysis approved in Reference 2.

4.0 References

1. XN-76-47 (P) (A), Combined Seismic-LOCA Mechanical Evaluation for Exxon Nuclear 15x15 Reload Fuel for Westinghouse PWR's, Exxon Nuclear Company, January 1982.

2. BAW-10133P-A, Revision 1 with Addendums 1 and 2, October 2000.