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EXHIBIT H

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Phenomenon Identification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burnup Fuel

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Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Specimen selection: Burnup	The amount of burnup to which the fuel rod used for the specimen was exposed. H(4) Fuel morphology (fragmentation, rim characteristics, bonding, etc.) is important. The nature of the bonding between the pellet and the cladding changes with the burnup increase. It will affect the potential for fuel relocation. The segment burnup level can determine the extent of pellet-cladding bonding and corresponding susceptibility to fuel relocation during ballooning and rupture. Fuel and rim-zone microstructure and the state of bonding with cladding are strongly influenced by fuel burnup. M(0) No votes. L(0) No votes. Fuel: Y(1): MOX agglomerates Clad: N Reactor: N Burnup: N K(1): Data PK(3): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Specimen selection: Fuel type (MOX)	Composition of the fuel, i.e., a specified MOX composition. H(2) May affect the amount of fine grain material after relocation. Fuel structure and mechanical properties are influenced by fuel type. M(1) The consequence of fuel fragments relocation (higher local decay heat and higher cladding temperature) could be more effective with MOX fuel than with UO2 fuel. Nevertheless the viscoplastic properties of the MOX should impair the fuel fragments relocation at high burnup. L(1) No significant differences in pellet-cladding bonding behavior or pellet cracking behavior are anticipated or have been observed with MOX fuel, and therefore no significant differences in relocation behavior are anticipated. Fuel: N Clad: N Reactor: N Burnup: N K(1): Data PK(2): Data, Judgement UK(1): Judgement

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Specimen selection: Alloy type	Composition or designation of the metal utilized in fuel-rod fabrication H(2) May affect burst (beta favoring or alpha favoring additions). Ductile burst and brittle failure by thermal shock and post-quench forces are influenced strongly by cladding alloy type. M(1) In general, compositional differences have not been observed to significantly affect cladding burst behavior. However, if significant differences in burst behavior occurred, the relocation characteristics could be similarly significantly altered. L(1) Data show no significant impact of alloy type on the balloon size that could influence the fuel fragments relocation. Fuel: N Clad: N Reactor: N Burnup: N K(2): Data PK(1): Data, Judgement UK(1): Judgement

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Specimen selection: Chemical and mechanical bonding	Chemical and mechanical bonding between the fuel pellet and the cladding prior to the test. H(4) Fuel morphology (bonding) is important. It will affect the potential for fuel fragmentation relocation. It is speculated that bonding could significantly affect the relocation characteristics by impeding pellet fragment movement. However, this effect has not been demonstrated. Major factor that influences fuel slumping and potential release of fuel particles upon burst and subsequent fragmentation. M(0) No votes. L(0) No votes. Fuel: N Clad: N Reactor: N Burnup: N K(0): No votes. PK(3): Data, Judgement UK(1): Lack of data

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Specimen selection: Cracking	Crack pattern and crack density of the fuel pellets prior to the test. H(2) Controls the rubble bed characteristics after relocation. Degree of fuel cracking directly influences the potential for fuel relocation and release. M(0) No votes. L(2) Beyond a given burnup the number of cracks is stable. In general the macroscopic fuel pellet cracking pattern develops early in life and does not change significantly with elevated exposures. Therefore, this contribution to fuel relocation susceptibility is not expected to be a dominant parameter during this test series. Fuel: N Clad: N Reactor: N Burnup: N K(1): Data PK(3): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During With or without blowdown	Determination of whether blowdown processes must be simulated in the test. H(0) No votes. M(1) During the blowdown phase of the LOCA transient, fuel stored energy is redistributed in the pellet and the clad. This redistribution produces a decrease of the pellet centerline temperature and increases the pellet rim and clad temperatures. Due to these temperature transients, the central part of the pellet will suffer a contraction while the rim and the clad will experience an expansion. These adverse effects could induce fuel mechanical stresses and fragmentation. The expansion and contraction inside the fuel pellet may affect bonding and fuel debris sizes. L(2) Vibration loads occurring during the blowdown phase may cause additional pellet fragment movement. In general, pellet fragments are relatively constrained within the fuel rod by the column geometry, as evidenced by characterization of fuel column geometry in hot cells. Therefore, this effect is not considered to significantly contribute to relocation susceptibility later during the cladding heatup and rupture phases. Fuel thermal contraction and cladding heatup during the blowdown phase increases the pellet-cladding gap and possibly facilitates pellet fragment relocation. Cladding heatup rate and temperature, either with or without a blowdown, are the primary factors that influence burst shape and dimensional changes. Fuel: N Clad: N Reactor: N Burnup: N K(0): No votes. PK(1): Data, Experience, Judgement UK(2): Judgement

Table D-1. PWR and BWR LOCA. Category D--Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Blowdown temperature transients for fuel and cladding	Simulation of the temperature response of the fuel and cladding during the blowdown phase of a large-break LOCA. H(2) Important parameters that influence cladding burst and dimensional changes. M(0) No votes. L(1) Pellet fragment movement. In general, pellet fragments are relatively constrained within the fuel rod by the column geometry, as evidenced by characterization of fuel column geometry in hot cells. Therefore, this effect is not considered to significantly contribute to relocation susceptibility later during the cladding heatup and rupture phases. Fuel thermal contraction and cladding heatup during the blowdown phase increases the pellet-cladding gap and possibly facilitates pellet fragment relocation. Cladding heatup rate and temperature, either with or without a blowdown, are the primary factors that influence burst shape and dimensional changes. Fuel: N Clad: N Reactor: N Burnup: N K(1): Data, Judgement PK(2): Data, Experience, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Pre- and post-burst test phases (2)	Look at the impact of fuel fragment relocation on the cladding temperature during the high temperature oxidation phase and the quenching phase. H(1) Data of fuel relocation determines the impacted phases. M(3) Needs in pile test to be prototypical (heating source should come from the fuel). If the objective is as speculated above, this test would help to characterize at which point in time the bulk of the relocation occurs. However, most rods that balloon also burst and it is not clear that a separation in time would significantly affect the LOCA performance (i.e., whether relocation occurs instantaneously to fill the ballooned region as opposed to instantaneous relocation on burst). Burst shape and dimensional changes are influenced by clad phase at the time of ballooning and burst. L(0) No votes. Fuel: N Clad: N Reactor: N Burnup: N K(1): Data, Judgement PK(3): Data, Calculation, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Internal pressure and moles of gas	The amount of gas in the rod upper plenum, for a given initial pressure in the test rod. H(3) Driving force for relocation, together with gravity. It is crucial to have a pressure evolution representative of a full-length rod. Internal gas pressure is the driving force for fuel fragments relocation. To be prototypical the amount of gas within the rod prior to the test has to be maintained constant. The internal pressure is a measured parameter, not an input data. Initial pressure is the primary factor that determines the burst temperature and shape and potential release of fuel particles from rim zone at burst. Plenum gas inventory is a secondary factor. M(1) If gas flow is the primary relocation mechanism, then an accurate simulation of that gas flow would be needed to obtain the most meaningful results. However, it is anticipated that similar relocation behavior would be obtained over a relatively wide range of gas flows. L(0) No votes. Fuel: N Clad: N Reactor: N Burnup: N K(0): No votes. PK(4): Data, Calculations, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Flow induced vibration	During ballooning and after burst, the fuel rod vibration induced by the flow can favour crumbling of the fuel pellet stack. H(0) No votes. M(2) Fuel column axial gaps have been observed to form and continue during normal reactor operation. This results suggests that fuel column shakeout is not likely with normal flow-induced vibration even over very extended periods. It is further noted that with cladding perforation, steam ingress will promote fuel pellet oxidation that has been observed, with failed fuel during normal reactor operation, to cause effective blockage within the fuel rod to preclude fuel downward fuel pellet fragment motion, again overriding the effects of flow induced vibration. Secondary driving force. L(2) Potential impact of rod vibration is expected to be small. Ballooning and burst occur after blowdown, and steam-flow-induced vibration during and after blowdown would be insignificant. Fuel: N Clad: N Reactor: N Burnup: N K(0): No votes. PK(2): Data, Judgement UK(1): Judgement

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Exterior rod constraints	Manner in which test specimen is constrained by surrounding rods to simulate potential in-reactor behavior. H(1) Prior ballooning experiments have shown that coplanar ballooning is not likely, and therefore balloons may not be constrained by adjacent ballooned sections. However, the constraints provided by adjacent non-ballooned rods can still provide a significant restriction on the amount of cladding ballooning and corresponding fuel relocation. M(1) Rod constraints during ballooning may affect the fuel distribution at the relocation site. L(2) The purpose of these tests is to analyze the separate effect of fuel fragment relocation. Exterior constraints influence ballooning shape to some extent. Fuel: Y(1): Most modern BWR fuel designs use part-length fuel rods resulting in zones where there is a significant gap between adjacent rods (because rods in certain lattice locations terminate at a lower elevation). This design feature may permit greater ballooning and relocation at those elevations. However, the fuel rods at those peculiar locations would correspondingly experience a circumferential temperature gradient, which is known to reduce the resulting burst strain. Clad: N Reactor: N Burnup: N K(0): No votes. PK(4): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Balloon size and burst size	Determination of the dimensions of the ballooned area and the cladding breach during the test. H(4) Affects the amount of relocated fuel in the balloon. The balloon and burst size represents the maximum potential volume for relocation. Directly influence the potential for fuel relocation, slumping, and release at and after burst. M(0) No votes. L(1) Balloon size and burst size are measured after the test. No need to measure it on-line Fuel: N Clad: N Reactor: N Burnup: N K(1): Judgement PK(2): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-During Length	Longitudinal dimension of the fuel rod segment to be tested. H(2) The driving force for fuel fragments relocation is the internal gas pressure in the plenum. For high burnup fuel rods the axial gas transport is significantly impaired. A short rod would favor the plenum gas participation The rod length has to be prototypical to avoid experimental bias. At the least, the length between two grids must be tested. M(1) The amount of fuel above the ballooned/burst section defines the potential fuel volume to be relocated. However, the size of the ballooned/burst region defines the maximum possible relocated fuel volume. Therefore, if the ballooned/burst location can be defined with reasonable certainty, sufficient length can be provided above that region to enable prototypic relocation. L(1) Length more than about 15 times of the pellet length (6 inches) is sufficient. Fuel: N Clad: N Reactor: N Burnup: N K(1): Calculation PK(3): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-PTE Granularity of dispersed material	Granularity of dispersed fuel fragments is measured to get relevant information on the fuel density in the relocated fuel fragments zone. H(3) The equivalent fuel density of the relocated fragments allows codes to simulate the local overheating of the cladding. Major factor that influences the potential for fuel relocation and release. M(1) Smaller pellet fragments would be expected to result in easier fuel movement and possibly a higher density of relocated fuel. However, pellet cracking patterns are established early in life and do not vary greatly with increased exposure, so a widely varied granularity of material, prior to dispersal, is not expected. L(0) No votes. Fuel: N Clad: N Reactor: N Burnup: N K(0): No votes. PK(4): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-PTE Thermography	Non-intrusive measurement of the temperature differences of the tested fuel rod. H(1) Provides the fuel distribution in 3D. M(0) No votes. L(2) Low added value Fuel: N Clad: N Reactor: N Burnup: N K(0): Data PK(2): Data, Judgement UK(1): Judgement

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-PTE Thermal diffusivity of rubble bed	Self defined. H(1) Output parameter. M(1) Probably difficult to do, but would be useful in quantifying the effective thermal properties of the rubble mass (This assumes that in the ballooned/burst region if the material is still there – it may be worthwhile to capture this just prior to burst although there may not be significant relocation at that time if gas flow is the primary relocation mechanism), otherwise this is best done analytically. L(1) No rationale provided. Fuel: N Clad: N Reactor: N Burnup: N K(0): No votes. PK(2): Data, Judgement UK(1): Judgement

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-PTE Strain profile of cladding as f(θ,z)	Measure the shape and the size of the ballooned area of the tested fuel rod. H(3) The purpose of this test is to assess the amount and characteristics of relocation. A determining aspect of that process is the amount of ballooning (free volume to which the fuel may relocate), and therefore this volume should be known in any assessment of relocation characteristics. Note that the circumferential variation of cladding strain should also be determined. Axial variation of clad circumferential strain is a parameter that directly influences the potential for fuel relocation and slumping. M(1) Will give some indications on potential impact of the balloon the shape (magnitude and extension) on the amount of relocated fuel. L(0) No votes. Fuel: N Clad: N Reactor: N Burnup: N K(1): Judgement, Calculation PK(3): Data, Judgement UK(0): No votes.

Table D-1. PWR and BWR LOCA. Category D– Separate Effect Testing (continued)

Subcategory (Test type)	Phenomena (Parameter)	Definition and Rationale (Importance, Applicability, and Uncertainty)
Simulation of fuel relocation	Conduct of Test-PTE Material balance (in-rod and dispersed)	Determination of the mass of fuel remaining within the tested fuel rod and the mass that left the fuel rod through the rupture. H(2) This is the primary result to be quantified in this test series, to be correlated with the ballooned region and burst size. It is the amount of lost material that is of interest as it could possibly contribute to such effects as flow blockage, etc. M(0) L(2) This information is covered by the local measurement of the fuel density. Fuel: N Clad: N Reactor: N Burnup: N K(1): Judgement PK(2): Data, Judgement UK(1): Judgement