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Subject: Transmittal of Westinghouse Electric Company Comments on Draft NUREG/KM-0013 [Docket ID NRC-2019-0043]

Westinghouse Electric Company (Westinghouse) appreciates the opportunity to comment on Draft NUREG/KM-0013, "Credibility Assessment Framework for Critical Boiling Transition Models." The enclosure of this letter contains a table of several editorial and technical comments. Westinghouse appreciates the NRC staff's consideration of the comments in the enclosure.

This submittal does not contain information proprietary to Westinghouse.

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This is a re-submittal of the file submitted May 22, 2019 with a change of address. Enclosure 1 remains unchanged from the initial submittal.

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Enclosure 1: Westinghouse Comments on NUREG/KM-0013

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Westinghouse Comments on Draft NUREG/KM-0013

Comment Number	Page Number	Line Number	Section Number	Section Title	Comment
1	1	3	1	Introduction	Consider clarifying in the critical boiling transition (CBT) definition that CBT occurs for heat transfer from the heated surface to the coolant.
2	1	15	1	Introduction	CBT cannot, by definition, occur at "the same thermal-hydraulic conditions". If the power is changed (increased) some thermal hydraulic (TH)-conditions will change and that is how CBT occurs. In order to obtain a well-defined measure of margin to CBT (such as critical power ratio (CPR) or departure from nucleate boiling (DNBR)) the fixed conditions must be defined as power increases.
3	1	20	1	Introduction	Consider adding the word "margin" at the end of the sentence such that it reads as follows, "… determine whether the proposed models can correctly predict CBT *margin*."
4	1	27	1	Introduction	Consider clarifying the application of CBT model assessment using this document. For example it could be clearly stated that this report may be used for light water reactors. State the applications.
5	1	31	1	Introduction	Consider clarifying that the report is meant as a Knowledge Management (KM) document for the NRC staff.
6	1	N/A	1	Introduction	Footnote 3. Consider replacing "evidence" with "analytical evidence," and deleting the footnote.
7	1	N/A	1	Introduction	On the topic of CBT, one of the reasons given for the additional term to refer to the boiling crisis phenomenon is the need to distinguish between the heat flux that causes the phenomenon to occur and the phenomenon itself. However, the document occasionally uses the phrase "CBT value," to refer to the "critical heat flux (CHF) value." Consider changing "CBT value" to "CHF value" where applicable.
8	3	3, 12	1.2	What Is Credibility?	Consider changing the word "credibility" for a Boolean-valued quantity as there is a significant rise in acceptance of Bayesian approaches in recent years, where the notion of "degree of belief" may be more appropriate. Additionally, claiming that all decisions are binary may be too general as there are many examples of non-binary decision-making in machine learning.
9	7	N/A	2.1	Literature Survey	Table 1. Consider adding the key works of Doroschuk, Kon'kov, Drescher, Köhler, Katto, and Becker to the table.
10	10	N/A	2.1.1	Technical References	Table 3. Please clarify the "Thermal Design Methodology" associated with WRB-1 and WRB-2 in 2013.
11	13	N/A	2.1.2	Regulatory References	Table 5. Please consider adding SRP Chapter 15 sections associated with the CBT models to the table as well as Regulatory Guide 1.70.

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Comment Number	Page Number	Line Number	Section Number	Section Title	Comment
12	15	7-9	2.2	Critical Boiling Transition Phenomena	Consider transient conditions where the heat flux could be affected by the cladding surface heat transfer.
13	15	34-35	2.2.1	Departure from Nucleate Boiling	Consider removing the following as it has not been verified “but is believed to be bubble crowding that prevents liquid from contacting the surface.”
14	16	6-7	2.2.2	Dryout	Consider changing “evaporation” to “film evaporation”. Consider that nucleate boiling may occur below the film when the film is thick.
15	16	16	2.2.2	Dryout	Consider that the film will probably breakup but not disappear slightly before dryout.
16	16, 17	38, 6-7	2.2.3, 2.3.1	Other Flow Regimes and Transitions & Critical Heat Flux Models	Consider replacing “film boiling” with “dispersed flow.”
17	17	8	2.3.1	Critical Heat Flux Models	In addition to inlet flow conditions, the system pressure should also be set.
18	17	11 & 21	2.3.1	Critical Heat Flux Models	The word “local” used in these two paragraphs does not seem to have the same definition, a clarification is needed.
19	17	21	2.3.2	Critical Power Models	Consider replacing “inlet conditions” with “boundary conditions.”
20	17	23-24	2.3.2	Critical Power Models	Consider the following change from, “the elevation of the location under consideration,” to "the distance between the elevation of the location under consideration and the elevation where nucleate boiling appears."
21	17	25	2.3.2	Critical Power Models	Consider the difficulty of defining the power increase for a fast transient (most anticipated operational occurrences (AOOs)). Typically, some form of artificial scaling of the steam quality profile is applied.
22	17	N/A	2.3.3	Semi-Empirical Modeling	Is this section on “Semi-Empirical Modeling” intended to cover the high resolution modeling approach based on Computational Fluid Dynamics (CFD) and/or the bid data approach based on machine learning and artificial intelligence? Consider clarifying.
23	18	N/A	2.3.4	Conservative vs. Non-Conservative Predictions	The wording seems to imply that CHF must decrease with decreasing mass flow. This may be expected when the *inlet conditions* are held constant (because of the resulting increase in local quality); however, it is not known to be true if the *local conditions* are held constant.
24	18	3 & 5	2.3.4	Conservative vs Non-Conservative Predictions	When the term “flowrate” is mentioned is “heat flux” what is intended?
25	18	11-13	2.4	Applying a Critical Boiling Transition Model	Code dependency is mostly relevant to the current PWR testing and analysis approach. For steady-state BWR application, the TH-relations involved are so fundamental that there is no code dependency.

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Comment Number	Page Number	Line Number	Section Number	Section Title	Comment
26	18	30	2.4.1	Applying a Critical Boiling Transition Model in a Pressurized-Water Reactor	Consider making a clear distinction between a “PWR assembly” and a “PWR test assembly.”
27	19	29-30	2.4.1	Applying a Critical Boiling Transition Model in a Pressurized-Water Reactor	Please clarify that other measures of margin to CBT are possible, besides DNBR.
28	19	41	2.4.1	Applying a Critical Boiling Transition Model in a Pressurized-Water Reactor	Please clarify what value should be used as “measured CHF” to evaluate the error.
29	20	3-4	2.4.1	Applying a Critical Boiling Transition Model in a Pressurized-Water Reactor	Consider rewording the following “a much more representative error of how the CBT model will be applied in practice”.
30	20	4-8	2.4.1	Applying a Critical Boiling Transition Model in a Pressurized-Water Reactor	Please clarify. Is the intended meaning here that quantities such as elevation or channel number should not be used as predictive variables in the model? That seems acceptable, but the wording does not make this clear. The measured CHF is not available in the real-world scenario, but it must be used in determining the model’s error. Perhaps what is meant is that the measured CHF at the predicted minimum margin location should be used, rather than at the actual measured location.
31	20	11	2.4.1	Applying a Critical Boiling Transition Model in a Pressurized-Water Reactor	Consider rephrasing, the meaning of the sentence is unclear.
32	20, 50	16-17, 37	2.4.2, 3.2.1.1	Applying a Critical Boiling Transition Model in a Boiling-Water Reactor & G2.1.1-Necessary Parameters	The text is incorrect, the following sentence is suggested “Most BWR methods consider a single 1D thermal-hydraulic channel per assembly, accounting for the power input from each rod individually.”
33	20	17-19	2.4.2	Applying a Critical Boiling Transition Model in a Boiling-Water Reactor	The text is incorrect. The reasoning behind BWR models can be described as follows: “Because of the fuel assembly channel (preventing crossflow between assemblies), full-size assembly tests can realistically capture the global thermal-hydraulic performance of BWR fuel assemblies without the need for local (sub-channel) analysis.”

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Comment Number	Page Number	Line Number	Section Number	Section Title	Comment
34	20	33-34	2.4.2	Applying a Critical Boiling Transition Model in a Boiling-Water Reactor	Consider mentioning that the inlet temperature is fixed.
35	21	6-7	2.5	Addressing Uncertainties and Errors	It is true that for most applications that a single global margin is sufficient for the entire assembly. But then CPR and critical quality should be evaluated only at the outlet. If local values of margin are calculated at all they need to be defined and linked to something that is measurable. Furthermore, for some applications there is a need to calculate cladding temperature, and then it is important to correctly predict the location.
36	21	14-15	2.4.3	Applying a Steady-State Model to Transient Conditions	Consider defining the application for transient conditions which answers the following questions: Shall the inlet mass flow or local mass flow be used (they are identical in steady-state but not for transients)? How is scaling power and quality artificially increased in the middle of a transient? How is boiling length defined during a transient?
37	24	15-16	3.1.1	G1.1-Credible Test Facility	Suggest rewording as follows "most CBT data used in the *U.S.* nuclear industry"
38	26	27	3.1.1.2	G1.1.2-Test Facility Comparison	Consider replacing "though" with "since" or "given that."
39	27	13-14	3.1.2	G1.2-Accurate Measurements	Consider clarifying the following: CP correspond to the directly measured assembly power (at dryout conditions).
40	31	9	3.1.2.2	G1.2.2-Statistical Design of Experiment	Suggest rewording from "changes in flow" to "changes in inlet flow and temperature."
41	32	21	3.1.2.3	G1.2.3-Data Fidelity	Clarify the following: "a reactor almost never operates at a steady state"
42	33	5-7	3.1.2.3	G1.2.3-Data Fidelity	Consider making a distinction between PWR and BWR data acquisition methods. For BWR, because of the relatively slow clad temperature increase, the state point is recorded immediately after identifying CBT. The loop is then driven to the next point by reducing the power or, most commonly, increasing the flow.
43	33	36	3.1.2.3	G1.2.3-Data Fidelity	Consider replacing "state point" with "transient initial conditions".
44	34	4-6	3.1.2.3	G1.2.3-Data Fidelity	The identification of CBT during a transient is often more complex than for steady-state. For instance, in the case of a power increase transient, the clad temperature can increase substantially (with power) before CBT has been reached. Consequently, it is often necessary to manually check all temperature traces to confirm, or not, the occurrence of CBT.

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Comment Number	Page Number	Line Number	Section Number	Section Title	Comment
45	34	9-10	3.1.2.3	G1.2.3-Data Fidelity	Even though the same transient is performed multiple times (with different initial power), it is generally not possible to determine the minimum power at which CBT occurs for transients in the same way as for steady-state. This is due to non-infinity small initial power steps, a small non-conservative bias is introduced, which must be properly handled.
46	34	11-14	3.1.2.3	G1.2.3-Data Fidelity	Rephrase for transient tests. A pre-determined sequence is run, which ensures (either by power reduction, flow increase or both) that the test assembly is not under CBT at the end of the transient.
47	35	N/A	3.1.2.4	G1.2.4-Instrumentation Uncertainty Impact	Table 12. For Levels 2 and 3, please clarify how the "minimal impact" should be quantified to meet NRC's expectation.
48	36	N/A	3.1.2.5	G1.2.5-Repeated Test Points	Table 13. Consider rephrasing the evidence of Level 3 as follows: "Multiple repeat *(> 1)* test points were taken over the test campaign at various input parameters *in order to provide evidence that the errors can be considered random and independent.* The variability in the resulting CHF or CP values was reasonably low." This adds clarification to "multiple" and incorporates the message on page 36 lines 22-24.
49	39, 41	4-5, 6	3.1.3.1, 3.1.3.2	G1.3.1-Equivalent Geometric Dimensions & G1.3.2-Prototypical Grid Spacers	Not only would a substantial amount of power be necessary for a full-size PWR fuel assembly, but it would still not be realistic due to the inaccurate representation of test channel walls and lack of consideration for assembly-to-assembly interactions in the PWR.
50	39	11-12	3.1.3.1	G1.3.1-Equivalent Geometric Dimensions	As a result of the small filament size, a much smaller amount of current is necessary for the indirectly heated rods, and hence the electromagnetic forces will be small.
51	39	N/A	3.1.3.1	G1.3.1-Equivalent Geometric Dimensions	Table 15. Please clarify the statement in Level 2 for PWR test assemblies as follows: "the vast majority of the components in the test assembly have equivalent geometric dimensions *in subchannel configuration*." Additionally consider incorporating lines 4 and 5 of this page which states that, 5x5 or 6x6 test assemblies are used for simulating the PWR fuel designs, since a full-size PWR fuel assembly test is not practical.
52	40	3	3.1.3.1	G1.3.1-Equivalent Geometric Dimensions	Consider the following grammatical change by replacing the word "understand" with "understood."
53	41	N/A	3.1.3.3	G1.3.3-Axial Power Shapes	Consider the three-field approach for dryout when determining the credibility of untested axial power shapes.
54	42	2 & 4	3.1.3.3	G1.3.3-Axial Power Shapes	Resistivity is usually understood to be a property of the material, not dependent on the length or cross sectional area of the sample.

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55	44	6-7	3.1.3.4	G1.3.4-Radial Power Peaking	It should be mentioned that in addition to testing a full range of R-factors, it is important to drive essentially every rod to dryout in order to make sure that a correct additive constant is obtained for every rod. In particular, one has to be careful to test and model part-length rods properly.
56	45	7	3.1.3.4	G1.3.4-Radial Power Peaking	In reading the content the following question arose. How can the assumption of symmetry be demonstrated (without peaking all rods)?
57	57	N/A	3.3.1	G3.1-Calculating Validation Error	This section can use more clarity. Is it possible to introduce concrete definitions and equations for the quantities being discussed (i.e., model error, model validation error, model application error)?
58	57	26	3.3.1	G3.1-Calculating Validation Error	Please clarify. Normally in applications, the power is known; it is the critical power which is unknown, because the reactor is operated at powers below CHF or CP.
59	58	7-10	3.3.1	G3.1-Calculating Validation Error	Please clarify. In either case (experiment or simulation), CBT happens at the interface of a rod and the coolant. A good experiment (with azimuthal TC's) can determine the subchannel, as well as the rod DNBR from CHF.
60	58	10	3.3.1	G3.1-Calculating Validation Error	Please clarify the following: "the simulation produces only one MDNBR value." In principle, the simulation could produce more than one node with the minimum DNBR. In practice, the simulation may produce only one such node because of minute numerical differences. However relying on a single node would be a weakness in the analysis process. There may be several nodes with minimum departure from nucleate boiling ratio (MDNBR) when meaningful differences are considered.
61	63	2-3, 10-11	3.3.2.1	G3.2.1-Identification of Validation Data	Please clarify. Lines 10 and 11 suggest that the scatter tends to be larger on data that was not used for training, and this is consistent with experience. However, lines 2 and 3 of the same page seem to imply the opposite.
62	70	9-11	3.3.3.1	G3.3.1-Indentifying Non-poolable Data Sets	It is not clear why the NRC staff discourage the use of tests for poolability for a larger number of tests (an example was given for 14 tests). If a failure of a test resulted in a higher standard deviation (smaller dataset), then this would be a conservative outcome of the higher DNBR limit.
63	72	N/A	3.3.3.2	G3.3.2-Identifying Non-conservative Subregions	Table 34. Consider changing the wording of the evidence for Level 1 & 2 from "Plots of each model input parameter versus the validation error" to "Plots of the validation error versus each model input parameter."
64	72, 73	N/A	3.3.3.2, 3.3.3.3	G3.3.2-Identifying Non-conservative Subregions & G3.3.3-Appropriate Trends	Table 34 & Table 35. The following question arose regarding Level 1 of Table 34: Should this be "Plots of the measured or predicted CBT values," rather than "Plots of the validation error"?