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NUCLEAR ENERGY INSTITUTE

August 14, 2019

Ms. Jane E. Marshall
Director, Division of Safety Systems (Acting)
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Comments on Draft Interim Staff Guidance on the Chromium-Coated Zirconium Alloy Fuel Cladding Accident Tolerant Fuel Concept

Project Number: 689

Dear Ms. Marshall:

On behalf of the nuclear energy industry, the Nuclear Energy Institute (NEI)[1] submits the attached comments on the draft Interim Staff Guidance (ISG) on the Chromium-Coated Zirconium Alloy Fuel Cladding Accident Tolerant Fuel Concept (ATF-ISG-01). NEI has been working with the Nuclear Regulatory Commission (NRC) to establish regulatory guidance that may be used by NRC staff reviewing industry applications involving chromium-coated zirconium alloy clad fuel products. The ISG also provides insights on staff expectations for vendor topical submittals for accident tolerant fuel (ATF). This ISG supplements the guidance in NUREG-0800, "Standard Review Plan." We appreciate the staff's early publication of the draft ISG and the opportunity to present our initial views of the document during the public meeting on August 6, 2019. The attachment represents our initial comments based on a short timeframe review.

While there are several areas of agreement, as noted in our comments, the attachment highlights key differences between industry's and NRC's expectation for how the ATF coated cladding applications should be assessed. Additionally, we would like to reiterate one main concern related to the inclusion of the manufacturing process into the ISG that was discussed in industry's presentation at the public meeting. Industry's concern is that the draft ISG significantly expands the traditional licensing scope and attempts to regulate the manufacturing process through fuel qualification. NUREG-0800 is a performance-based standard and the manufacturing process is not part of the current regulations. Furthermore, the coated cladding fuel concepts are not conceptually different from the current fuel products (same base substrate

[1] The Nuclear Energy Institute (NEI) is responsible for establishing unified policy on behalf of its members relating to matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include entities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect and engineering firms, fuel cycle facilities, nuclear materials licensees, and other organizations involved in the nuclear energy industry.

material with a 10-30 µm thick coating) and as such, the existing manufacturing oversight framework is considered to be adequate. Other NRC regulations and oversight, such as 10 CFR Part 50 Appendix B and vendor quality assurance inspections, are in place to review the manufacturing process. Therefore, manufacturing processes should not be included in the ISG as part of the staff's fuel qualification review.

Thank you for your consideration of our comments. We look forward to continue working with the NRC through the ISG publication process and industry's ATF activities as we work to deploy batch reloads by 2023. If you have any questions or require additional information, please contact me.

Sincerely,

Ben Holtzman

Attachment

c: Andrew Proffitt, NRR, NRC
Jason Drake, NRR, NRC
Josh Whitman, NRR, NRC
Dennis Morey, NRR, NRC
Robert Lukes, NRR, NRC
NRC Document Control Desk

Comment #	Location	Comment	Proposed Change
1	General	Although this ISG mainly focuses on the metallic chromium coatings on Zirconium based cladding, at some places NRC tried to include some discussion on chromium based ceramic coatings and emphasized their influence on the properties of underlying base cladding . This inclusion of discussion on ceramic coatings has only complicated the report and is not helpful, since many thermo-physical properties of the Cr-based ceramic coated cladding are expected to be significantly different than base cladding and requires substantial experimental data for developing models and licensing justification.	Industry recommends to remove discussion on Cr-based ceramic coatings and consider only metallic Cr-coating for this ISG. Or better explain how the ISG denotes information applicable to any coated cladding concept and where information is only relevant to a specific cladding concept.
2	General	If the ISG is intending to specifically denote the phenomena as being important for coating cladding concepts, the ISG should discuss the relative importance regarding the existing phenomena and new mechanisms. The current text equivocates the impact of all mechanisms such as defects and embrittlement. Defining importance or concentration of defects may allow for important issues to be more easily separated from the noise.	Please revise ISG text to be consistent with intent and if specifically denoting phenomena as being important for coating cladding concepts denote importance as per the PIRT report.
3	General	The use of 'chrome' and 'chromium' interchangeably in several places is incorrect. 'Chrome' refers to a method of industrial electroplating, not the element chromium	Please revise text to properly use chrome and chromium
4	Main Section Lines 23-26	Industry appreciates the ability to provide input on the ISG but what is the benefit in noting the feedback mechanism in the ISG itself?	Remove unnecessary text
5	Main Document References	The publication date for Reference 3 appears to be in error. The “ATF Project Plan” was published in September 2018, not September 2019.	Please revise text
6	Appendix A Lines 18-33	The ISG calls out that it is not attempting to set standards for review of any credit or benefit applicants may request, but many of the phenomena noted in Appendix C are specifically tied to benefits and not licensing criteria.	The ISG should clearly state whether it's denoting the specific content needed for a fuel topical report or providing additional guidance on how industry will need to realize prospective benefits.
7	Appendix A Lines 31-39	The confidence level to which the proposed property improvements must be demonstrated by the applicant to satisfy the NRC reviewer(s) is not explicitly stated in the document	Please include information related to the required confidence level.
8	Appendix A Lines 34-39	Industry agrees that benefits should be allowed when supported by data, but please indicate that the data must support the 'full operating domain.'	Please revise text as shown: "Finally, if an applicant wishes to take credit for coating behavior up to a certain burnup, or during certain accident conditions, it is necessary for the adherence of that coating to the substrate to have been ~~demonstrated to that burnup and during those conditions~~justified for the full operating domain."
9	Appendix A Lines 38-39	The structure of the sentence strongly implies that high burnup data is a requirement. This could have impacts on initial implementations and/or conditional topical approvals as the statement implies that coatings on the rods must be prototypical to demonstrate adherence at high burnup before batch loading and that it may not be possible to use all available data.	Please revise text as shown: "Finally, if an applicant wishes to take credit for coating behavior up to a certain burnup, or during certain accident conditions, it is necessary for the adherence of that coating to the substrate to have been ~~demonstrated to that burnup and during those conditions~~justified for the full operating domain."
10	Appendix A Lines 57-58	Industry agrees that SAFDLs can be addressed in multiple ways and that no specific testing requirements should be denoted.	None
11	Appendix A Line 70	What does the word “sufficiently” exactly mean?	Please clarify the expectation.
12	Appendix A Lines 67-72	The ISG text references PIRT Section 6.4.2 and states that the applicant should ensure the performance concerns referenced in the PIRT Section are addressed. The PIRT section states that all data (for some performance concerns) need to be provided from tubes that come from a qualified process. However, it does not provide any guidance to the reviewer as to what it means for a process to be “qualified.” The ISG should be clear that it is not regulation manufacturing processes nor should be requiring an applicant to get data from an approved/qualification process.	Please rephrase the ISG text to be clear that a manufacturing process doesn't require NRC qualification before data acquisition can begin.
13	Appendix A Lines 67-72	The ISG text references PIRT Section 6.4.2 and states that the applicant should ensure the performance concerns referenced in the PIRT Section are addressed. The PIRT section states that all data (for some performance concerns) need to be provided from tubes that are manufactured in a prototypic manner. However, it does not provide any guidance to the reviewer as to what it means for a process to be considered “prototypic.” The ISG should be clear that it is not regulation manufacturing processes nor should be requiring an applicant to get data from an approved/qualification process.	Please rephrase the ISG text to be clear that a manufacturing process doesn't require NRC qualification before data acquisition can begin.

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14	Appendix A Line 73-90	The ISG text discussing the current 50.46 regulatory limit (1204°C/17%ECR) is likely inappropriate and needs to be corrected. The referenced PNNL PIRT section 6.2.6 does not really talk about why 1204°C is not appropriate. The discussion on why 17% ECR may not be appropriate for a coated rod appears to be based on mix up of **calculated** ECR (that is regulated) with **measured** ECR (that is not regulated). The fact that there is a mis-match between calculated CP-ECR (or BJ according actual 50.46) and measured ECR is a reflection of the ATF effectiveness of the coating. The argument in ISG appears to be that for extended time at 1200°C (read this to mean for times far exceeding needed to reach the limit based on calculated CP/BJ-ECR, i.e. no longer in DBA space), the coated rod could be embrittled even though the measured ECR is low (because of ATF benefit); and because the embrittling mechanism is not understood this becomes a problem and so 17% ECR is not protecting the cladding. This argument only makes sense if 50.46 is based on **measured** ECR, but it is not. The current 50.46 regulatory limit, based on calculated ECR (CP or BJ) from time and temperature, actually continues to serve the purpose of protecting the cladding.	The section should be revised to state that current 50.46 regulatory limit (1204°C/17%ECR for uncoated cladding) can be applied on a conservative basis to coated cladding if supported by test data, and that if the applicant wishes to have a different licensing calculated ECR for the coated rod, then justification must be made. Moreover that no exemption to 50.46 would be needed in the former case, and an exemption would be needed in the latter option.
15	Appendix A Lines 97-101	Potential regulatory changes are introduced related to extensions of the existing fuel burnup limits. Such burnup limit extensions are currently being evaluated by the industry and were the subject of a 2018 workshop that included NRC staff. However, this comment seems inappropriate for the ISG since burnup limit changes were not within the review scope for the ATF PIRT.	Remove regulatory changes for increasing burnup limits from the ISG on coated cladding.
16	Appendix A Lines 113-115	"… may be to ignore the coating (for purposes of TM analyses) and use the properties of the underlying substrate" --> this wording carries the risk of not considering where the coating results in a changed behavior. It could be shown that the coating does not result in more than a negligible change, and thus use the model of uncoated cladding, but that is not ignoring the coating	"…may be to demonstrate that the coating will have a negligible impact on the property and use the properties of the underlying substrate."
17	Appendix A Lines 115-117	Industry appreciates that flexibility is provided for the applicant in addressing each damage mechanism	None
18	Appendix A Line 138	the use of the word "may" should be clarified to indicate that the described test data is one of many options to satisfy the data needs.	Revise text to indicate "…provides a list of test data that ~~may~~ could be used in code assessment."
19	Appendix A Lines 163-166	This statement pertains to geometric uncertainties resulting from fabrication. Presumably, this will also apply to uncertainties in coating thickness.	Please clarify the expectation.
20	Appendix A Lines 185-187	If cracking and delamination of the coating are ruled out by results from the LTA program and the surface roughness of the coated clad is shown to be similar to that for the un-coated clad, does the applicant need to do any CHF testing with coated cladding?	Please clarify the expectation.
21	Appendix A Lines 185-187 and Lines 246-248	The addition of a 30 µm thick coating to RFA fuel decreases the hydraulic diameter of interior sub-channels by less than 2% [1.7% for 30 µm and 1.1% for 20 µm]. This should have a negligible impact on the thermal-hydraulics. Additionally, the statement that "for AOOs and postulated accidents involving a decrease in reactor coolant flow … the presence of the chromium coating will not change the system's response …" implies NRC's recognition that the coating will have negligible impact on core thermal-hydraulics. Industry agrees that a 10-30 µm coating will have a negligible impact on T-H.	Please ensure consistency in ISG regarding treatment of coating impact on T-H. Specifically, whether the ISG is indicating this as an important area for an applicant to address because T-H scope is a topic in the traditional scope of licensing fuel topicals or because it's important to coated cladding applications
22	Appendix A Lines 221-226	This paragraph presumes that models (T-M, Nuclear physics and T-H) will be changed to capture the impacts of chroming coating. This does not acknowledge alternative approaches such as "ignore the coating" as discussed in Line 113 – 115.	Recommend to change each of the sentences to "…should be ~~captured~~ considered in the {fuel rod performance/nuclear physics / thermal hydraulics} ~~model~~ evaluation."
23	Appendix A, Lines 249-255	This section discusses many expected benefits relative to advertised features of a general product as opposed to providing guidance to review the material changes for a specific product submission, which may later result in benefits via the incorporation to analyses. A LOCA result, such as PCT, is the due to a wide variety of integrated properties and phenomena. A predicted PCT change should not be relied upon since it will be very plant and product specific. Additionally, the change in liberated hydrogen should be restricted to the reduced external surface reaction.	It is suggested the ISG focus only the material changes and their associated specific LOCA phenomena benefit, e.g. reduced external reaction with steam reduces energy release and oxygen generation and associated loss of ductility; reduced operational hydrogen minimizes hydrogen enhanced embrittlement; etc. Any change in results would be justified by the combination of changes, positive or negative, to the product.
24	Appendix A, Line 251	The text says that the parameters that are affected during LOCA are presented in the table below, however the draft does not contain a table listed below. This statement should be corrected or the table added.	Please provide table for review.

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25	Appendix A Lines 264-268	Statement indicates that the scope of work needed to complete the Chapter 15 demonstration increases significantly if the application is accompanied with (among other things) an increase in allowable fuel rod burnup or increased 235U enrichment. This is a “blanket statement” that needs to be clarified. The idea that the Chapter 15 Safety Analyses work would increase significantly is not consistent with how industry confirms safety analyses on a reload and bounding analysis basis. Only if the coated cladding implementation changes part of the bounding envelopes currently used by safety analyses would work then need to be addressed. However, the idea that a single parameter deviating from it’s non-coated value would automatically SIGNIFICANTLY increase the Chapter 15 safety analyses needs clarification.	NRC should explicitly define the additional scope needed to complete Chapter 15 analyses for coated cladding applications.
26	Appendix B Lines 32, 79, 83-84	Industry recognizes the importance of process controls in manufacturing but disagrees that the NRC should license specific manufacturing processes. The ISG and its application should focus on the critical material performance characteristics, regardless of the manufacturing process.	Statements concerning processing conditions and/or coating technique should be removed or re-written.
27	Appendix B, Lines 39-40	Suggest adding a caveat to the statement: "Table 5.1 in the PIRT report provides a summary of the tests that could be performed to quantify the material properties discussed below but should consider the updated text in the following sections."	Please revise text as noted.
28	Appendix B, Lines 59 - 85	Thermal expansion section - it is not clear what the NRC's expectations are. Are we supposed to justify the models/ show data? Address the stresses from thermal expansion mismatch? Something else?	Justification for thermal expansion models should be provided as well as a demonstration that thermal cycling does not lead to coating damage.
29	Appendix B, Lines 86-101	Industry believes that Cr-coated cladding will have an impact on emissivity by reducing oxide thickness – emissivity strongly correlates to oxide thickness, increasing with increased oxide until it stabilizes consistent with an ‘opaque’ surface.	Therefore the impact on emissivity values should be evaluated and accounted for in accident analyses - comment also provided to NRC for PIRT report section 5.1.3.
30	Appendix B Lines 131-146	The ISG says that the coating will not result in any improvement in the strength of the substrate, and is also assumed to have zero load bearing capability. This was not unequivocally stated in the PIRT. If supported by data, Industry wants to retain the ability to realize benefits in this area and so the ISG should not preempt them at this early stage.	Please remove statement "Generally, coating is assumed not to offer any load bearing capability."
31	Appendix B, Lines 173-185	The NRC does not state their expectations. Do they want FR growth data? Evaluation of strain mismatch and resulting stresses?	Verification of growth models with in-reactor data or a commitment to collect data can be used.
32	Appendix B Lines 199-202	In-reactor data is ‘recommended’ for oxidation rate, including cracked specimens. This does not seem necessary if only conservative oxidation benefits are claimed, and also does not seem necessary if other ex-reactor measures are taken to show that the cracks (if present) do not result in aggressive corrosion at edges.	Please revise text to indicate that if the coated cladding will be as good as or better than current fuel products for oxidation, and industry can provide supporting justification of this fact - it is conservative to use the current oxidation rate without additional test data.
33	Appendix B Lines 201-202	“…in-reactor data from rods with cracked coatings be evaluated to assess if there is aggressive corrosion at cracks or interfaces…” is more specific than necessary.	Revise text to state "…the interface between coated and uncoated regions in-reactor be evaluated to assess if there is aggressive corrosion at cracks or interfaces…”
34	Appendix B, Lines 236-245	Corrosion typically refers to the operational process, not the high temperature oxidation reaction. Additionally, while thinning of the cladding is important, high temperature steam oxidation results in diffusion of oxygen into the beta-substrate which is the mechanism for clad embrittlement. It is suggested that this section be clarified.	It is suggested that this section be clarified.
35	Appendix C	Most of the items in this section are not new failure mechanisms but rather performance characteristics which need to be accounted for in the current failure mechanisms. The exception is C.4.9 eutectic formation, which in fact is a new failure mechanism. Galvanic corrosion is a more specific example of corrosion that is required by NUREG-0800, S4.2 to be factored into the other fuel damage mechanisms, but could be treated as a new damage mechanism, since it conceivably could itself cause a fuel failure.	None
36	Appendix C Line 7	The word “siting” should be replaced with "citing"	Please replace text as noted.
37	Appendix C Lines 9-16	It is not clear how non-uniformity in coating thickness could lead to rod bow. The text may be confusing Rod Bow and Channel Bow in BWR applications.	Please clarify this section.
38	Appendix C Section C.2	There is no SAFDL listed for DNB or CPR? Should be included in this section and guidance provided.	Please add text as noted.
39	Appendix C Lines 53-67	There is too much presumption about what happens in Cr-coatings due to a crack in the initial, as-built coating. But this is only adverse if credit is taken for oxidation rate reduction post-ballooning during a LOCA.	This should be phrased so that the issue is addressed, but not assuming that there's an adverse consequence.

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40	Appendix C Line 66	In the same way NRC should not be licensing/regulation the specific manufacturing process, the inspection processes and controls should not be part of the licensing process. It is incumbent on the vendor to implement process controls that ensure material performance and properties are consistent with what is licensed.	Please remove text “it may be desirable to add crack detection criteria..”
41	Appendix C Lines 94-95	“Limits should be proposed that preclude environmental damage to the protective Cr2O3 layer…” can be written more generally.	Please revise text to “the impact of the coating and associated oxide layer on oxidation, hydriding, and crud should be predicted and evaluated.”
42	Appendix C Line 141	Reference to Appendix A is incorrect and should reference ISG Appendix B since the original PIRT text cross-references PIRT Section 5.1	Please revise as noted.
43	Appendix C, Lines 144 - 146	Appendix A lines 213 -216 refer to 10CFR50.46c and DG1327 as potential positive impact of the Cr-coatings related to these requirements. This is inconsistent with lines 144 - 146 which states that this ISG will only deal with current regulations and staff guidance.	It is suggested that this section be clarified.
44	Appendix C Line 151-152	For BWRs, this is not actually an accurate representation of dryout phenomena, nor is it actually articulated this way in NUREG-0800, Chapter 4.4.	Please revise the text "This thermal margin should not be exceeded for normal operation and AOOs." to be consistent with language currently in NUREG-0800.
45	Appendix C Lines 169-177	This failed to draw any parallels between the in-core Zr fuel rod and the ex-core Inconel heater rod differences. Is there an understanding that the performance of these two are the same, and that only a coating (whether on Zr or Ni-based alloy) may influence CHF? Also, CPR and CHF are not equivalent, and the physics may result in sensitivities not being the same between DNBR and CPR estimations for coated rods.	Industry requests that NRC review text for consistency.
46	Appendix C Line 181	Appendix A lines 181 – 194 appears to give applicants discretion to “appropriately account” for the impact of coatings on CHF, including the impact of coating degradation. In contrast, Appendix C appears to require CHF testing for each coating and assembly type rather than allowing discretion. In addition, Appendix C appears to cast doubt on the veracity of typical CHF testing using Inconel assemblies.	The two appendices should be reconciled so that applicants have a clear, crisp understanding of expectations.
47	Appendix C Line 195	Revise “impact on the uniform elongation relative to the reference Zr” with “impact on the pellet-cladding mechanical interaction relative to the reference Zr”.	Please revise as noted.
48	Appendix C Lines 197-199	If the alternate approach is followed and the current limits are concluded to be acceptable then RIA testing on irradiated material or a commitment to do so should not be required.	Please revise text to indicate that RIA testing is not required with acceptable justification.
49	Appendix C Lines 200-203	Industry believes that coated cladding will be as good as or better than current fuel products during an RIA, and as long as industry can provide supporting justification of this fact - it is conservative to use current RIA assumptions for a coated cladding RIA analysis. Assuming that all rods would fail creates unnecessary conservatism.	Please revise as noted.
50	Appendix C Lines 243-251	Rather than repeating the LOCA embrittlement testing program, including irradiated cladding tubes as proposed, a limited subset of testing on unirradiated and pre-hydrided tubes should be sufficient to confirm adequacy of the existing limits or reasonableness of a new set of conservative limits.	Please revise text to indicate there are additional methods of attaining test data.
51	Appendix C Section C.4	The subsections have statements about basing accident behavior using the term “based on”. This term should be revised to “with consideration of the potential impact”.	Please revise as noted.
52	Appendix C Lines 307-328	Coating cracking isn't a new failure mechanism; it does not inherently cause a cladding failure, but changes the behavior to be accounted for when evaluating other damage mechanisms	Cracking of the coating is not a failure mechanism itself and shouldn't be part of the ISG's performance criteria.
53	Appendix C Lines 329-357	Delamination is not a new failure mechanism itself; it does not inherently cause a cladding failure, except for the potential creation of debris, which affects other systems. It affects the fuel cladding response in the OTHER failure mechanisms and will be included in the performance assessment of the cladding when evaluating other failure mechanisms	Delamination is not a failure mechanism itself and shouldn't be part of the ISG's performance criteria.
54	Appendix C Line 331-332	“In general, ceramic coatings will be more susceptible to delamination than metallic coatings.” – this statement is not consistent with other places in the ISG where metallic and ceramic coatings are noted as being different in that this statement does not provide the reviewer references for the information.	Consider revising to state “Metallic and ceramic coatings may behave differently in this regard.” Or remove, as there is no specific assistance to the reviewer on the topic.
55	Appendix C Lines 386-391	An improvement would be to add that the interdiffusion could be ‘implicitly or explicitly’ considered in the development of SAFDLs. For example, if more limits on time-at-temperature are set such that interdiffusion does not become limiting, it would be implicitly covered and nothing further would be needed.	Please revise text to indicate "Cr-Zr interdiffusion should be considered either implicitly or explicitly in the development of limits on…"
56	Appendix C Lines 392-417	The current ISG text indicates that Cr-51 will cause the source term for ATF coated cladding to be worse than current fuel products. While Cr-51 is a radioisotope not currently present in current fuel products, the statement that the source term will be more limiting ignores the beneficial contributions the more robust accident tolerant attributes of the ATF fuel concept provide. The source term is unrelated to SAFDLs, safety, or the PIRT-defined damage mechanisms and performance concerns.	The ISG should direct the applicant to review the impact to source term holistically, and determine whether the ATF source term is more limiting source term or if the current source term values bound the ATF coated cladding source term. In many cases, the coated cladding application will be as good as or better than current fuel products, and if industry can provide supporting justification of this fact - it is conservative to use the current values without additional test data.

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57	Appendix C Line 403-406	The ISG assumes the impact of irradiation will have a negative impact on the strength and ductility of the coating; however, It could also improve properties as cladding/coating systems can be complex.	The ISG should simply advise the reviewer to consider the impact.
58	Appendix C Line 440	There are other methods for obtaining galvanic corrosion properties besides LTA examination.	Please revise text to consider the impact.
59	Appendix C Lines 441-449	Defects are not a new damage mechanism. They do not inherently cause a cladding failure, just as defects in current cladding do not inherently cause cladding failure. They are part of the properties in any cladding or coating and will be included in the performance assessment of the cladding when evaluating other failure mechanisms.	Defects are not a failure mechanism itself and shouldn't be part of the ISG's performance criteria.
60	Appendix C Lines 441-449	The quality assurance steps or processes associated with making the cladding should not be licensed as part of the product. Product licensing is based on components that are representative of typical manufacturing processes and the vendor quality control processes will be established to identify the presence of defects that would degrade the performance below the licensed performance level.	Statements concerning processing conditions and/or coating technique should be removed or re-written.
61	Appendix C Lines 450-456	The lowest temperature eutectic for the Cr-Zr system is noted as occurring at 1332 °C, which is noted beyond the current DBA temperature limit of 1200 °C. Is this being noted because it is an important finding for coated cladding that needs to be addressed even though it is beyond traditional licensing scope? Or is this being included for future applications where industry may try to extend the DBA temperature range?	Please clarify the expectation.