NRC Comments on the Susceptibility Assessment Criteria for Chloride-Induced Stress Corrosion Cracking (CISCC) of Welded Stainless Steel Canisters for Dry Cask Storage Systems. EPRI, Palo Alto, CA: 2015. 3002005371

While some general and specific comments and questions are provided herein, the comments and questions below are not intended to serve as the U.S. Nuclear Regulatory Commission's (NRC) comprehensive assessment of the subject EPRI report, but rather to provide specific comments and questions on the report in the areas that the NRC staff has identified for improvement.

NRC comments and questions on the EPRI report are as follows:

Comment Number	Report Section	Comment
1	General	This is a well written report that provides a useful description of the ISFSI and canister ranking criteria. While there are numerous comments and questions by the NRC staff, the NRC recognize that the approach described in this report is a result of a significant effort.
2	General	The approach described is clear and the existing limitations of information are accurately stated. The EPRI staff (and contractors) should consider identifying and prioritizing any additional information needed to refine and/or validate the approach to assess susceptibility.
3	1.1	Pitting and transition to SCC. This is an important consideration because it determines what size pits are of concern. Need a better understanding of what size pits can initiate cracking as a function of material condition (stress, strain, composition, potential mitigation methods such as peening).
4	1.1	See ML14274A030 for the Calvert Cliffs ISFSI license conditions on aging management programs. License Condition 23 states: *With respect to the aging management activities for the Dry Shielded Canister (DSC), as described in the "DSC External Surfaces Aging Management Program" in Attachment 2 to the Response to Fourth Request for Additional Information for Renewal Application (hereinafter referred to as Attachment 2), the licensee must perform the inspections at intervals not to exceed 5 years.*
5	1.4	Approach and statement on geographical variability: The primary sources of chloride containing salts identified includes bodies of salt water, cooling towers and salted roads. For most ISFSI sites, these are likely the only potential sources of chloride containing salts. A few sites may have to be in close proximity to other sources of chloride containing salts such as evaporation ponds and/or salt deposit storage areas that are generated from the evaporation ponds. Other sources may include naturally occurring geographical features such as dry lake beds and ephemeral lakes and industrial operations with emissions that contain chlorine and inorganic chloride salts such as secondary aluminum production (i.e., aluminum recycling). Guidance on assessing susceptibility to these less commonly encountered potential sources of chloride containing salts should be considered.
6	2.0	Statement on probability of CISCC and the effects of time stress and temperature: The statements on chloride and stress are simple enough but adding temperature to the discussion without details may add confusion. While correct, the statement on the effect of temperature are more

		complicated than indicated here. Perhaps either a qualifier on the temperature (i.e., when the surface is cool enough for the deposited salts to deliquesce in a given environment), or discuss temperature separately.
7	2.1	This section uses the term "material alloys." Suggest using either "alloys" since that is the proper term or being consistent with the opening paragraph in Chapter 6 specifically uses the term "austenitic stainless steel."
8	2.1.1	Statement on the effect of Mo additions is somewhat awkward. The important effects of the addition of Mo are increased resistance to localized corrosion and stress corrosion cracking.
9	2.1.2	Statement on annealing and stress relief treatments that can also desensitize material: The point of this statement is not clear. There are presently no annealing processes used in DCSS after canister fabrication. The statement is correct but it is misleading to include it here without indicating that annealing is not a common practice. A more detailed discussion should be considered on the temperature necessary for annealing, the distortion that would need to be managed at stainless steel solution annealing temperatures, and cooling rates necessary to avoid sensitization of grades that are not low carbon.
10	2.1.2	The term "oxygen cells" should be "oxygen concentration cell" but the real issue with crevices is more complicated than described in Section 2.2.2. Consider using the term "occluded region" and then maybe reference the work of A. Turnbull, "Chemistry Within Localized Corrosion Cavities," in Advances in Localized Corrosion, NACE-9, H. Isaacs, U. Bertocci, J. Kruger, and S. Smialowska eds., Houston, TX: National Association of Corrosion Engineers, pp. 359-373, 1990. Many other references are also available on the chemistry within pits, cracks, and crevices.
11	2.1.2	Statement on grinding welds: This is a significant factor and should be considered in detail. Many fabrication welds are subjected to grinding. The orientation of the grinding with respect to the orientation of the welds and the weld residual stresses may influence crack orientation.
12	2.2	Statement on residual stresses: The reference here is to a prior EPRI report. Suggest including a reference that has real data to support this statement on compressive stresses on the outer surface of a rolled cylinder. It is not clear whether the authors considered possible variations in fabrication processes that are used to construct canisters.
13	2.2	Statement on elevated WRS: Whether tensile WRS is "only" present parallel to the weld may be dependent on the definition of "elevated." While it is likely true that the highest tensile stresses run parallel to the weld, it has been shown in the recent work on the mockup from Sandia National Laboratories that tensile stresses are also positive perpendicular to the weld. Also the effects of weld repairs are not considered here.
14	2.2	Statement on KI increases: There is continuing discussion about the results of bent beam specimen tests conducted by CRIEPI and why these results were obtained. It is not clear whether this is real or an artifact of the test conducted. Several factors may be important including the limited cathodic

		surface area available and the applied stresses going through the specimen thickness
15	2.3.1	Statement on primary sources of chloride. The statement is accurate but the evaluation should consider location specific activities that may influence chloride deposition rates. See the specific comment to the approach in Section 1.4.
16	2.3.1	Statement on chloride accumulation and effects of canister orientation and overpack design: It is not clear if the statement on the overpack design being less important on chloride accumulation is an assumption, a modeling result, or something that is based on actual data. If actual data were used then the source of information should be cited. If it is an assumption, then that needs to be clearly stated.
17	2.3.2	Statement on majority of deposits being insoluble silicates: Can any statement be included here to indicate the possible (or known) source of the silicates? Earlier reports suggested much of the deposits were consistent with dust, pollen and concrete dust.
18	3	Statement on environmental parameters: Both Atmospheric Chlorides and Mean Absolute Humidity may be affected at the actual ISFSI site by local activities. For example, cooling towers are considered in the deposition of chlorides but are not considered in the potential effects on humidity. Other industrial activities may affect either chloride and/or humidity.
19	3	Statement on Mean Absolute Humidity: The approach used here based on the yearly mean absolute humidity may be appropriate. However, the yearly mean absolute humidity really cannot be used to assess crack growth. Was an approach for ranking sites based on the fraction of time when the AH > Specified Value considered? This would seem to be more appropriate for determining fraction of time where conditions exist for localized corrosion, CISCC initiation and CISCC growth compared to the yearly mean absolute humidity.
20	3.1	Saline cooling towers, What is the basis for defining low-saline cooling towers? Water with more than 250 ppm salt will taste salty and is typically used as the marker for a salt line in estuaries based on drinking water standards. Other definitions of brackish are 0.5 to 30 g of salt per liter.
21	3.2	Statement on local geography and prevailing winds reducing the concentration of chloride: The word "reduce" should be changed to "affect."
22	3.2.1	Statement on longer exposure to lower chloride aerosol concentrations: This is well supported and clearly should be an important factor in assessing susceptibility. Changes in elevation are also considered and known to affect chloride transport. What about humidity? Some models of chloride transport suggest that chloride transport is favored by low humidity conditions. It seems that the combination of humidity and prevailing wind conditions (i.e., seasonal variations) might be an important consideration. It is recognized that the combination of these factors is more challenging to incorporate than distance and elevation.

23	3.2.1	The comparison of distance from marine bodies of water to ISO-9223:2012 rankings is helpful.
24	3.2.2	It is unclear if cooling water chemistry includes consideration of additives that are commonly used to control scaling and microbial activity.
25	3.2.2	Agree with the statement on the generation of chloride aerosols and the relationship to the whitecaps but it is not clear that this was actually considered in the criteria. It appears to be based on distance to the shore.
26	3.2.2	How does the assessment of the predicted effects of cooling towers compare with actual data?
27	3.2.2	Cooling tower additives. This section specifically recognizes that anti-fouling agents are added to cooling water towers. It is unclear of the anti-fouling agents includes both biocides and additives to prevent scale formation. It seems (although not completely clear) that the chemistry and/or concentration of these additives is not considered in the adjustment factor. Where ranges of additive concentrations and chemistries considered in this assessment?
28	3.3	Use of NOAA data: The drawback to this approach is that the local humidity may be altered by site specific or near site conditions or activities. For example, if there are cooling towers present or large evaporation ponds or large cooling water ponds, the local humidity may altered compared to the information obtained at a NOAA site.
29	3.5	CISCC OpE and Rankings: An important practical question on the application of the susceptibility assessment, is how it will be used. Specifically, how will the values of the parameters be used to guide inspections? How will the assessment criteria be verified? What additional data is necessary to validate the approach developed here?
30	4.3	Deposition Factors. P. 4-8. *Deposition factors stop increasing with X_{Cl} for values greater than 5 because of the existence of OE indicating that initiation at a site with a Z_{ISFSI} of 10 can occur after about 10 years and because of the uncertainty associated with crack initiation at low chloride loads.* It is unclear why uncertainties about crack initiation at low chloride have an effect on the maximum value of X_{Cl}.
31	4.5	*Given the environmental factor results in Figure 3-1 from the flaw growth assessment [1], surfaces that are heated to more than 30°C above ambient do not deliquesce; surfaces more than 25°C above ambient do not deliquesce for enough of the year to cause substantial potential for CISCC.* The approach stated here is understandable but the formation of corrosion products on the surface may alter the total time where an aqueous phase may be in contact with the surface of the canister. In other words, the assessment criteria here might be a valid for an initial assessment of conditions but does not account for how changes to the deposit chemistry at the surface may affect the conditions where an aqueous phase could be present.

32	4.7	Summary statement on differentiating among canisters with the same rank. It is unclear if there could be a situation where there are multiple canisters with the same rank but with significantly different heat loads. Would the “longest duration of storage criterion” reliably select the canisters with the longest time at conditions (i.e., temperatures) where deliquescence can occur is a better criterion than total time in storage?
33	5.2	Please provide more details on how the ranking methodology and inspection results will inform aging management programs of other locations. Section 1.2 states that the objective of the report is to develop a set of criteria and associated ranking values to assess welded stainless steel canisters at the ISFSI with regard to the relative priority for inspections or other actions. The statement here seems to imply a greater use of the ranking methodology combined with inspection results. See also the comments in the report Section 3.5 on CISCC OpE and Rankings.
34	5.3	Statement on additional data: The statement is consistent with earlier statements in the report but it is not actual guidance on how the additional data should be used. What additional guidance is necessary to ensure that additional data will be used appropriately? Will additional guidance be issued on the use of additional data including the types of possible additional data listed here?
35	5.3	Atmospheric Chlorides: *It is noted that monthly wet candle measurements at the same location demonstrate that chloride levels may fluctuate over time (month-to-month and year-to-year) by more than a factor of 10 and can be significantly influenced by periodic weather events (e.g. hurricanes) [47]. Therefore, the measurement program should be performed for a minimum of one entire year, and the average value should then be used in the comparison.* Need to support only having one year of data. How are annual uncertainties accounted for if only one year of data is considered appropriate? The factor of 10 stated is a month to month or year to year variation and it is unclear if that would be deemed appropriate for uncertainty. The monthly and annual variations are probably more influenced by seasonal variations including surf conditions, wind speed and prevailing wind direction than periodic weather events such as hurricanes.
36	6	Table 6-1 and the chloride values affecting only initiation. There are other models suggesting that chloride concentration has an effect on growth rate. For Example: G. Nakayama and Y. Sakakibara, “Prediction Model for Atmospheric Stress Corrosion Cracking of Stainless Steel,” ECS Transactions, 50 (31) 303-311 (2013).
37	6.1	Z(ISFSI) truncation: The maximum value of Z_{ISFSI} is limited to 10 but as shown in Table 6-2 the maximum calculated value theoretically could be as high as 17. The basis for limiting Z_{ISFSI} to 10 as stated in Section 3.4 is because Z_{ISFSI} is used in the canister ranking assessment. The basis for limiting Z_{ISFSI} to a maximum value of 10 really is not well supported because a different parameter could be used in the canister ranking assessment based on the non-truncated value of Z_{ISFSI}. What is the maximum value (i.e., not the truncated value) of Z_{ISFSI} for existing sites in the U.S.? Is there value in not truncating the value of Z_{ISFSI}? Are there

		potential downsides to this approach such as possibly limiting sites that could be bounded by another site with a higher ranking?
38	6.2	*Canisters that have been transferred during storage between ISFSIs at different geographic locations are not considered by the criteria.* Why not? There should be adequate records to calculate ISFSI and canister factors.
39	6.3	*The criteria used to rank ISFSI and canister susceptibility are designed to provide a reasonable level of accuracy while using a level of precision that is congruent with the substantial uncertainty regarding the precise conditions that can lead to CISCC.* This statement identifies substantial uncertainty regarding the precise conditions that can lead to CISCC. While not explicitly stated, it is not clear if the statement is specific to initiation or whether it also considers propagation. There are considerable uncertainties in both the conditions for initiation and the effect of conditions on propagation rates. Some additional clarification would be helpful. In addition, any future considerations on updating the susceptibility assessment methodology should be added here.
40	A.2	Effects of penetration: Should indicate there is a regulatory compliance issue.
41	A.4	*Furthermore, limited data on the effect of chloride areal density on CISCC initiation and growth restricts the use of the chloride deposition model in deterministically calculating a time to initiation and when calculating growth rates.* See earlier comment on effects of chloride concentration on growth. It seems that this is an indication that more data is needed to resolve this uncertainty. Is that the case?
42	A.6.1	Residual stress analyses: Please consider the recent results from Sandia National Laboratories.
43	A.7.1	Flaw Size Tolerance: Is the critical flaw size the basis for defining failure? If so, what is the basis for that as a criterion? Penetration of the canister means that there is a penetration of the confinement barrier and confinement is one of the safety functions of the canister. Note also that most canisters are designed and licensed as "leaktight" per ANSI 14.5 (i.e., leakage rate less than 1E-7 ref cm3/second). If there is a penetration of the containment boundary then the boundary is not likely to be leaktight and the design basis is not maintained. Why is this not the definition of failure?
44	A.7.2	Crack Opening Area: Are loads from natural phenomena such as earthquakes considered? If so, include a description.
45	A.7.3	Helium Leakage: Are loads from natural phenomena such as earthquakes considered? If so, include a description.