Materials and Structural Evaluations
Not Acceptable RAI Responses
For GP-01 Revalidation Application to 2018 Ed. of IAEA SSR-6
Unresolved RAIs Needing Supplemental Information
For Aging Evaluation and Aging Management

RAI-M-6. RAI-M-6 requested the applicant to provide a complete evaluation of fatigue for the reusable package components for the 80-year period of use (and the 160 transports that are allowed during the 80-year period) that considers the combined effects of all applicable types of accumulated stress cycles in components during normal service conditions, including the following cycle types: (1) lifting cycles, (2) inner receptacle pressurization cycles, (3) vibration cycles, and (4) thermal stress cycles. The staff's more detailed description of the information needed for addressing the four cycle types is provided in the document including the original RAI.

If certain types of stress cycles are considered to be not applicable or negligible for certain components, the staff requested the applicant to justify and explain why they are not applicable or negligible.

Also, if such a complete fatigue evaluation cannot be performed, or if the fatigue evaluation cannot show adequate protection against fatigue failure, considering the combined effects of all applicable types of accumulated stress cycles in components, the staff requested that the applicant describes how periodic maintenance inspections of the package components will inspect for fatigue cracks in components, and describe the corrective actions that will be taken for any detected fatigue cracks, such as analytical flaw evaluation with follow-up inspections, repair/replacement of components with cracks, etc.

> ***RAI-M-6 is not yet resolved***. *The staff's comments on the applicant's response RAI-M-6 are as follows.*
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> > ***Issue (1), Lifting Cycles***. *The NRC staff determined that the applicant's response is generally acceptable, except for one issue: The staff noted that the applicant refers to alternating stress values in the fatigue analysis for rod bolts, which ignore the influence of any local stress-raising feature to accurately predict the behavior of the component, for example, at the discontinuity or change in cross section of the "member" (e.g., plate with a hole, bolt threads, etc.). The applicant should consider alternating stresses that account for stress increases at a local discontinuity by considering stress concentration factors in their fatigue calculation or provide rational for not considering it.*
> >
> > ***Issue (2), Inner Receptacle Pressurization Cycles***. *The NRC staff's comment is the same as the comment for Issue (1), Lifting Cycles regarding the fatigue analysis of the rod bolts. Specifically, in the fatigue analysis of the rod bolts, applicant should consider alternating stresses in the rod bolts that account for stress increases at a local discontinuity by considering stress concentration factors or provide rational for not considering it.*

Issue (3), Vibration Cycles*. The NRC staff does not agree with the applicant's response that 6400 cycles for lifting operations are also applicable to the fatigue analysis for vibration cycles that occur during transport operations. The package components could experience many vibration cycles from numerous vehicle transports by road during the 80-year service life and can significantly exceed 6400 cycles. As part of the evaluation, the applicant should address fatigue analysis for vibration cycles in more detail to show fatigue failure will not occur. If such a fatigue evaluation cannot be performed, or if the fatigue evaluation cannot show adequate protection against fatigue failure considering the combined effects, the applicant should describe proposed inspection methods, inspection equipment, and personnel qualification requirements for detection of fatigue effects like those requested in RAI-M-8.*

Issue (4), Thermal Stress Cycles*. The NRC staff needs much more elaborate rational for not considering the thermal stress cycles due to cyclical temperature fluctuations, rather than simply stating "appears as not significant".*

(See separate document related to the feedback on the structural evaluation.)

RAI-M-8. RAI-M-8 requested the applicant to provide a description of any national or international codes, standards, and/or other methods, programs, or procedures that are implemented to ensure that package maintenance activities (including visual inspections, screening and evaluation of visual indications, and corrective actions such as component repairs and replacements) are adequate to manage the effects of aging in metallic package components that would see long-term use, such that the package components are capable of performing their required safety functions throughout the period of use (i.e., the term of the certificate).

The staff requested that the descriptions requested address the following five criteria:

(1) inspection methods (e.g., bare metal visual exams and/or other types of nondestructive exams) for detection, characterization, and sizing of localized aging effects such as cracks, pits, and crevice corrosion;

(2) inspection equipment and personnel qualification requirements to ensure reliable inspections that can adequately detect and characterize indications of localized aging effects prior to component failure or loss of safety function;

(3) visual criteria for detection of aging effects such as early stage fatigue cracks and localized corrosion of stainless steel components, such as chloride-induced stress corrosion cracking, pitting, and crevice corrosion;

(4) surface cleaning requirements that are implemented to ensure that bare metal visual inspections of component surfaces are capable of detecting surface flaws, and for ensuring adequate removal of atmospheric deposits such as salts or other chemical compounds that may contribute to localized corrosion of stainless steel components;

(5) flaw evaluation methods (such as flaw sizing and flaw analysis methods) and associated flaw acceptance criteria that may be used to determine whether components containing flaws are acceptable for continued service.

The staff's more detailed description of the information needed (including examples) for addressing the five criteria above is provided in the RAI document.

RAI-M-8 is not yet resolved*. The NRC staff is using the guidance in the* ***IAEA Specific Safety Guide No. 6 (SSG-26), "Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material (2018 Edition)," (Rev. 1)*** *as a basis for determining whether the applicant's proposed evaluation of aging mechanisms and aging effects and the applicant's package handling and maintenance criteria are acceptable for meeting the applicable requirements of the* ***IAEA Specific Safety Requirements No. SSR-6, "Regulations for the Safe Transport of Radioactive Material (2018 Edition)", in particular paragraph 613A in the 2018 Edition of IAEA SSR-6 (Rev. 1)****.*

The NRC staff is using the specific guidance in the ***2018 Edition of IAEA SSG-26 (Rev 1), paragraphs 613A.1, 613A.3, 613A.4, and 613A.5*** *to inform its review of the applicant's proposed evaluation of aging mechanisms and aging effects and the applicant's use of the package handling and maintenance criteria as a basis for managing the effects of aging on package components.* ***Therefore, the applicant is referred to Paragraphs 613A.1, 613A.3, 613A.4, and 613A.5 in the 2018 Edition IAEA SSG-26 (Rev. 1) for general guidance on methods for complying with Paragraph 613A in the 2018 Edition of IAEA SSR-6 (Rev. 1)****.*

The staff's comments on the applicant's response to the five criteria of RAI-M-8 are as follows.

Criterion (1), Inspection Methods*. For this criterion the applicant stated that "localized aging effects, such as cracks, pits, and crevice corrosion are confirmed by the visual inspections during periodical voluntary inspections and package pre-shipment inspections."*

The NRC staff determined that the applicant's response to this criterion is generally acceptable for criterion (1), with the exception of several points:

The NRC staff noted that the description of the package handling and maintenance requirements, as described in Chapter III of the GP-01 Safety Analysis Report (SAR), do not include any visual inspections that are targeted for detection of localized corrosion effects, including pitting and crevice corrosion. (However, the staff noted that SAR Chapter III does include visual inspections for detection of "cracks" or "clefts" in the welds.) Therefore, the NRC staff requests the applicant to supplement or revise its package handling and maintenance instructions to include visual inspections that are targeted at detection of localized corrosion effects, including pitting and crevice corrosion, as well as cracks that may be formed by chloride induced stress corrosion cracking in stainless steel items or environmentally-assisted fatigue. As an alternative to SAR revisions, the staff requests that the applicant provide a reference to the sections of the applicant's own package handling and maintenance program documents (or other package operations, or quality assurance program documents) that contain requirements to perform visual inspections to detect localized corrosion effects such as pits, crevice corrosion, chloride-induced stress corrosion cracking, and environmentally-assisted fatigue.

Criterion (2), Inspection Equipment and Personnel Qualification Requirements. *For this criterion the applicant stated that "the following qualification requirements are required:"*

- *"Eyesight: Eyesight suitable for a Japanese license (6/20 both left and right eyes, 14/20 in both eyes);"*

- *"Trained in inspection methods and standards for package."*

The NRC staff determined that the applicant's response does not adequately address criterion (2). The staff is providing further detail on the information needed to address this criterion, as follows:

The eyesight requirement needs further explanation to address how it is applied to the performance of visual inspections of package components by inspection personnel, such that personnel have the visual capability to adequately detect and characterize localized aging effects, such as early stage cracks, pits, and crevice corrosion. The visual detection capability requirements and visual indication resolution requirements of applicable national or international codes and standards such as the ASME Boiler and Pressure Vessel Code (BPVC) Sections V and XI, applicable Japanese Industrial Standards (JIS), or applicable European Norm (EN) standards, and/or other methods, programs, or procedures should be described to support an adequate response.

Further, the response does not describe any equipment requirements for visual inspections such as requirements for lighting, magnification, cameras, or other visual aids. Such visual aids are often used by visual inspection personnel to help ensure adequate illumination, adequate visual resolution, and photographic records, as needed to adequately detect, characterize, evaluate, monitor, and trend localized aging effects, such as early stage cracks, pits, and crevice corrosion. Therefore, the staff requests that the applicant describe the equipment requirements for performing visual inspections to ensure that inspection personnel can adequately detect, characterize, and evaluate localized aging effects.

With respect to the applicant's statement, "Trained in inspection methods and standards for package", the staff understands this to mean that the applicant uses detailed national or international codes and standards such as the ASME Boiler and Pressure Vessel Code (BPVC) Sections V and XI, applicable Japanese Industrial Standards (JIS), or applicable European Norm (EN) standards, and/or other methods, programs, and procedures to ensure the needed qualification of inspection personnel and equipment to perform reliable visual inspections that can adequately detect and characterize indications of localized aging effects (such as early stage cracks, pits, and crevice corrosion) prior to component failure or loss of safety function. Therefore, the staff requests that the applicant provide a description of the requirements of the applicable codes, standards, methods, programs, and procedures that are implemented to ensure that visual inspections can adequately detect and characterize localized aging effects (such as early stage cracks, pits, and crevice corrosion). This should include a citation or reference for the applicable documents and a summary of the specific visual inspection qualification requirements.

Criterion (3), Visual Criteria for Detection of Aging Effects Such as Early Stage Fatigue Cracks and Localized Corrosion Effects Such As Chloride-Induced Stress

Corrosion Crackling, Pitting, and Crevice Corrosion. *For this criterion the applicant stated that "the use of stainless steel limits any risk of corrosion due to atmospheric conditions. Other potential chemical attacks appear not credible regarding use of the package." The applicant also stated that "the plates building the receptacles (inner and outer) are assembled by welds which are continuous and leaktight, ensuring the non-corrosion of the inner components".*

The NRC staff determined that the applicant's response does not adequately address criterion (3) for package component exposed to the outdoor air environment. The staff is providing further elaboration on the information needed to address this criterion, as follows:

Stainless steel transportation package components that are exposed to outdoor air may accumulate atmospheric deposits such as salts and other chemical compounds present in the atmosphere or present on road surfaces. Such deposits and chemical compounds, when mixed with rainwater or moisture, form aqueous electrolytes on the surfaces of the stainless steel that yield aggressive chemical agents (such as chlorides or other halides) that can chemically degrade the protective passive oxide layer on stainless steel surfaces. This can occur at vulnerable initiation sites such as tight creviced regions, leading to crevice corrosion, or at local pit nucleation sites where very small (and likely non-rejectable) local material defects, local microstructures, or local alloy composition may result in higher localized vulnerability to chloride attack of the protective passive oxide layer and localized de-passivation at that location leading to the formation of a pit.

Therefore, over time, such conditions and mechanisms can lead to localized breakdown of the passive oxide layer that normally protects the stainless steel surface from general corrosion. Over time, such local breakdown of the protective passive oxide layer often results in the formation of pits and crevice corrosion. If tensile stress is present, pits may act as initiation sites for chloride induced stress corrosion cracking. The material may also be susceptible to environmentally assisted fatigue cracking due to cyclical stress acting synergistically with the chemical effects of the aqueous electrolyte. Therefore, it is generally not possible to disposition such localized stainless steel aging affects as insignificant or not credible for an 80-year service life, or even an extended service life that is shorter than 80 years.

Therefore, the NRC staff determined that the package maintenance program should include visual criteria to look for localized aging effects such as early stage fatigue cracks and localized corrosion of stainless steel components exposed to the outdoor air environment. Localized corrosion effects include chloride-induced stress corrosion cracking, pitting, and crevice corrosion. In the RAI, the NRC staff provided specific examples of visual indications that may indicate potential localized corrosion of stainless steel components. These examples include the accumulation of atmospheric deposits such as salts, the buildup of localized corrosion products, rust-colored stains or deposits located around creviced regions, rust-colored stains or deposits located in and around pits, and surface discontinuities or flaws associated with the pits, crevice corrosion, stress corrosion cracking, and/or environmentally-assisted fatigue.

Therefore, the staff requests that the applicant provide a description of the visual criteria that are used to look for localized aging effects such as early stage fatigue cracks and localized corrosion (stress corrosion cracking, pitting, and crevice corrosion) of stainless steel components exposed to the outdoor environment. Except for the detection of *"cracks" or "clefts" in package welds, the staff noted that the current package handling and maintenance criteria described in SAR Chapter III do not include any these visual inspection criteria.*

<u>Criterion (4), Package Surface Cleaning Requirements to Facilitate Effective Bare Metal Visual Inspections and to Protect Against Localized Corrosion Effects</u>*. For this criterion the applicant stated that "The use of stainless steel avoids any risk of hidden defect under layer of protection (as for example painting used to protect carbon steel) and that before any control, surfaces are clean of any impurities before to perform the control." The applicant also stated that "Moreover, due to the simply design of the package, there is inaccessible external surface."*

The NRC staff determined that the applicant's response to criterion (4) does not provide sufficient information on specific surface cleaning requirements for package components. The staff noted that the description of the package handling and maintenance requirements in Chapter III of the SAR does not include surface cleaning requirements for package components. Therefore, the applicant should respond to this criterion by describing the specific surface cleaning requirements that are implemented as part of the package handling and maintenance requirements and provide references to the documents that contain these surface cleaning requirements. Further, the applicant should describe how the surface cleaning requirements are implemented to accomplish the following:

- *(i) Facilitate effective bare metal visual inspections that can adequately detect localized surface flaws that may be buried underneath dirt or atmospheric deposits, and*
- *(ii) Remove dirt and surface deposits that may contain salts or other chemical compounds that can contribute to localized corrosion of stainless steel components (such as pitting, crevice corrosion, and stress corrosion cracking). The periodic cleaning of surfaces to remove such surface deposits and chemical contaminates should be performed on a sufficient frequency (for example after every package transport and associated package unloading), and it should be of sufficient coverage that, with the performance of adequate visual inspections to look for localized aging effects, there is reasonable assurance that package components are not developing unacceptable service induced flaws or degradation, such as those associated with pitting, crevice corrosion, stress corrosion cracking, and environmentally-assisted fatigue.*

<u>Criterion (5), Flaw Evaluation Methods and Associated Flaw Acceptance Criteria to Determine Whether Components With Flaws Are Acceptable for Continued Service</u>*. For this criterion the applicant stated that "there are no specific standards for scratches. If deformation, cracks, or scratches that are found on visual inspection during periodical voluntary inspections or package pre-shipment inspections, they will be repaired, replaced, or disposed of on individual basis depending on their size and where they occur.*

The NRC staff determined that the applicant's response to criterion (5) does not provide sufficient information on flaw evaluation methods and associated flaw acceptance criteria to determine whether components with flaws are acceptable for continued service. Maintenance programs that are credited for managing applicable aging effects such as localized corrosion effects and fatigue during extended service periods (for *example, 20, 40, 60, or 80 years of service), need to have specific requirements for flaw evaluation and associated flaw acceptance criteria. If and when flaws are detected in safety-related components that are designed for long-term service, there needs to be specific criteria for characterizing the flaw, sizing the flaw, determining the root cause of the flaw, analyzing the flaw (to determine whether it could result in structural failure), and determining whether or not the flaw is acceptable for continued service.*

The staff noted that the applicant's response states that "deformation, cracks, or scratches…found on visual inspections…will be repaired, replaced, or disposed of depending on their size and where they occur". This seems to indicate that there are specific criteria and associated acceptance standards that are used to evaluating flaws or indications of localized aging degradation to determine whether components that have these indications are acceptable for continued service, or whether components with certain types or sizes of flaws require repair or replacement.

Many long-lived components for various design applications do not need to be immediately repaired or replaced just because there is a small flaw or a small amount of aging degradation. If the flaw or degradation is adequately evaluated and determined to be of a type and size that meets credible and conservative acceptance standards, accounting for flaw growth or increase in extent of degradation over a certain period of operation, then the component with the flaw may be acceptable for continued service during that operating period, provided that the size and characteristics of the flaw or degradation are tracked and monitored through documented and recorded inspections that are performed at an acceptable frequency over the approved operating period for the component with the flaw.

National and/or international codes and standards are often used by industry to determine the requirements for evaluation of flaws that are detected during component inspections and acceptance standards for determining whether long-lived components with flaws are acceptable for continued service. Examples of such codes and standards include the ASME Boiler and Pressure Vessel Code (BPVC), Section XI. In particular ASME BPVC Section XI Code Case N-860 provides criteria for evaluating indications of localized corrosion, characterization of flaws, sizing of flaws, analysis of flaws, and associated acceptance standards for welded stainless steel containments used for storage and transportation of spent nuclear fuel. Other applicable national or international consensus standards such as those in applicable Japanese Industrial Standards (JIS), or applicable European Norm (EN) standards may be used to determine criteria for evaluating visual indications of localized aging degradation, including requirements for characterizing, sizing, and analyzing detected flaws, and acceptance criteria for determining whether such flaws are acceptable for continued service.

Therefore, the staff requests the applicant describe and reference any national or international codes and standards, or other methods, programs, and procedures that are implemented for (i) evaluating flaws and indications of aging degradation (such as flaw characterization, flaw sizing, and flaw analyses methods), and (ii) flaw acceptance criteria to determine whether components containing flaws are acceptable for continued service.