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29 June 2017

Mr. Pierre Saverot
Spent Fuel Licensing Branch
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Spent Fuel Management
Mailstop EBB-3D-02M
11555 Rockville Pike
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Rockville, MD 20852

RE: Response to RAI Request for CoC number USA/9296/B(U)-96

Dear Mr. Saverot:

QSA Global, Inc. provides the following in response to Huda Akhavannik's letter dated 5 April 2017 requesting additional information in support of our 13 January 2017 amendment request for the Model 880 package designs.

1-1 *Clarify which jacket version is depicted on the licensing drawings and its importance to safety.*

As discussed in telephone conversation with NRC on 14 April 2017, the licensing drawings are dimensioned to cover all jacket options with variations in overall height noted as a range on the drawings. As discussed, the drawings indicate the jacket is "optional" which was intended to imply that the jacket is not important to safety (NITS). For clarification purposes, we have revised drawing R88000 to Revision X. This revision will list the jacket, jacket rivets, and sealant currently identified as "optional" on the drawing, as also "NITS" in the drawing BOM for these items.

As discussed on 14 April 2017, and as will be clarified in the attached SAR revision, the presence of the lithium-ion batteries and electronics in the Version 3 jacket will have no adverse impact on the package during normal or hypothetical accident conditions. The details associated with the batteries and electronics are not included on the descriptive drawings as they have no significant impact on the package integrity and are not expected to be installed/replaced by general users of the package.

QSA has decided to rescind its request to add Version 3 of the optional jacket to the Model 880SC package design. As such, we no longer request approval of drawing R880SC Revision F under the certificate, and request that reference for this package remain at Revision E of the drawing. The enclosed SAR Revision 12, has been updated to remove reference of the Version 3 jacket with the Model 880SC package design.

2-1 *Clarify the package weight for those packages that use jacket version 1 or 3.*

The maximum package weights, with the heaviest jacket attached, are specified on drawing R88000 Rev X on sheet 1 in the table column labelled "Maximum Total Package Weight with Jacket". Since the jacket's only significant impact on package compliance is how its weight impacts the overall final package weight, any version of the jacket is compliant to the drawings so long as the overall package weight does not exceed that specified on the drawing with the jacket attached, and the jacket meets the other dimensional specifications for the final package assembly on the drawing.

The 1 pound discrepancy noted when comparing weight increases for the Version 3 jacket to the jacketless versions of the different models is related to a rounding discrepancy correction made on the jacketless versions of the package, but which was not carried over in description of the package with jacket attached. When changed, the maximum values for the package with the jacket were not increased to accommodate slight variations in the base unit's mass which was corrected for the rounding issue. When we determined the maximum package weight for the packages with the Version 3 jacket, a uniform 3 pounds were added to each previous value listed in the "Maximum Total Package Weight with Jacket" column of the table on sheet 1 of drawing R88000.

This discrepancy has no effect on the NCT or HAC drop test results of the package since the overall maximum package weight for the heavier jackets (versions 2 and 3) were tested and found compliant under Test Report #1 for Test Plan 186, Revision 1 (Section 2.12.11 of the SAR) and Test Plan 216 Report Revision 0 (Section 2.12.19 of the SAR).

As noted in response to item 1-1, QSA no longer requests approval of the Model 880SC for use with the Version 3 jacket.

2-2 *Describe the performance of the Model 880SC with respect to the drop tests described for NCT and HAC, the puncture test as described under HAC and the cumulative damage as described under the HAC with jacket version 3.*

As noted in response to item 1-1, QSA no longer requests approval of the Model 880SC for use with the Version 3 jacket, so these questions are no longer applicable to this pending amendment request.

3-1 *Provide the lithium-ion battery test report and describe in the SAR the performance of the Model 880 package with jacket version 3 with respect to the thermal tests described for NCT and HAC.*

a) *Test Plan 216 was submitted to support use of jacket version 3 with respect to satisfying NCT requirements. In Section 3.2 of Test Plan 216, the applicant discusses the NCT testing for the new jacket version. In regards to the NCT Heat test, the applicant states that the test will not be performed because the new jacket will not change the previous evaluation in Test Plan 100. The tests in Test Plan 100 were performed on a Type A Model 880 package without a jacket and no thermal heat test was performed. In regards to the NCT Cold test, the applicant states that this test will not be performed because the new jacket will not change the previous evaluation in Test Plan 186. The tests in Test Plan 186 were performed on the Model 880 Pipeliner with a different jacket that did not include lithium-ion batteries and the thermal test was not performed. The applicant should describe in the SAR the performance of the Type B Model 880 package with the version 3 jacket including lithium-ion batteries with respect to the NCT heat and cold tests.*

Based on discussions with NRC staff on 18 April 2017, the expected increase in package temperature due to the battery pack presence was estimated to be ~ 2°C. Further measurements were made and documented in Technical Report 318 to determine the temperature rise to the package from the lithium-ion battery pack for NCT both when the battery cells are not charging during transport, and also when they are charging during transport. Results of the Model 880 when demonstrating compliance to the requirements of 10 CFR 71.43(g) with the package in still air (shaded), shows the maximum package temperature increases from 47°C to 50°C. Under the insolation conditions in 10 CFR 71.43(g), results for the Model 880 package with the Version 3 jacket showed no increase in the maximum package temperature from that previously assessed for the package.

In addition, the $LiFePO_4$ cells used in the Version 3 jacket comply with the requirements of United Nations "Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria", Sixth revised edition (2015) Part III, Section 38.3[1]. This includes testing to the T.2 Thermal test conditions. Under this test, test cells are stored for at least six hours at a test temperature equal to 72 ± 2°C, followed by storage for at least six hours at a test temperature equal to -40 ± 2°C. The maximum time interval between test temperature extremes is 30 minutes. This test is repeated until 10 total cycles are complete, after which all test cells are stored for 24 hours at ambient temperature (20 ± 5°C). The manufacture of the $LiFePO_4$ cells confirmed the Version 3 cells passed the 38.3 testing. To meet the testing under T.2, the cells must show no leakage, no venting, no disassembly, no rupture and no fire.

Based on the above analysis, under the NCT heat test and cold test requirements, this nominal temperature increase per battery cell will have no adverse impact on the package integrity or conformance and the battery cells will remain intact and undamaged when exposed to temperatures between 72°C to -40°C. The applicable sections of the SAR have been updated to reflect the temperature impact of the lithium-ion battery pack when the package is transported with the Version 3 jacket.

b) *Test Plan 216 was submitted to support use of jacket version 3 with respect to satisfying HAC requirements. On page 7 of Test Plan 216, the applicant states that the lithium-ion battery may be the only material used in the proposed jacket version 3 that may change the results of the original thermal test evaluation. The application then states, "the lithium-ion battery will be tested and/or evaluated at 800°C for 30 minutes separately in another report." Staff requests this lithium-ion battery test report. Additionally, the applicant should demonstrate the thermal performance of the package with jacket version 3 in order to demonstrate that the battery will not have a significant impact on the results of the original thermal test evaluation. This demonstration should include the effects of the preceding HAC tests (30 ft. drop, puncture, etc. on the damaged package/battery, followed by the 30 minute fire (and subsequent immersion). As part of evaluating the thermal tests, the effects of the flammable electrolyte jets should be considered and demonstrated to not lead to exceeding the melting temperature of any important to safety components and materials in the transport package. In SAR section 2.7.4, the applicant states that the July 2011 Fire Protection Research Foundation report in, "Lithium-Ion Batteries Hazard and Use Assessment", suggests that batteries that combust in a fire will produce small localized heat jets. The applicant states that these heat jets, "…are not expected to produce enough sustained heat to exceed the melding temperature of the stainless steel shell protecting the shield." The applicant should*

[1] United Nations "Recommendations on the Transport of Dangerous Goods – Manual of Tests and Criteria", Sixth Revised (2015).

demonstrate how the analysis in the Fire Protection Research Foundation report provides adequate evidence that the localized heat jets will not produce enough sustained heat to exceed the melting temperature of materials important to safety in the transport package.

As discussed during our conversation with NRC staff on 18 April 2017, the report referenced in Test Plan 216 was not generated. Evaluation of the battery pack cell performance under the thermal test conditions is provided as follows.

The battery pack cells, used in the Version 3 jacket, are comprised of four (4) Lithium iron phosphate ($LiFePO_4$) cathode cells with a graphite anode. This battery cell chemistry is safer than the typical lithium cobalt oxide composition. The $LiFePO_4$ cell materials also include copper, aluminum and a steel casing.

The $LiFePO_4$ battery pack cells, used in the Version 3 jacket, are designed with the following protective features:

- Vent seals which activate under high pressure build-up.
- A Current Interrupt Device (CID) which activates on excessive pressure due to an overcharge condition.
- A Shutdown separator which activates when the cells reach a temperature of 130°C as this temperature could melt the battery cell’s poly separator.

Under the HAC thermal test (800°C for 30 minutes), the individual cells contained within the battery pack would be expected to exceed the threshold temperature needed to exhibit thermal runaway. Typically, this would occur to cells exposed to temperatures in the 150°C - 260°C range which would allow melting of the cell separators.

As noted in The Fire Protection Research Foundation reference below[2], the severity of a cell thermal runaway event will depend upon a number of factors, including the cell state of charge (SOC), the ambient environmental temperature, the electrochemical design of the cell and the mechanical design of the cell. For any given cell, the most severe thermal runaway reaction will occur when the cell is at 100% SOC, or is overcharged, because the cell will contain maximum electrical energy. During a thermal runaway reaction for a fully (or overcharged) cell, a number of things occur:

1. Cell internal temperature increases for fully charged cells can reach temperatures in excess of 600°C (1,110°F), although $LiFePO_4$ cells are generally lower. This is also within the typical temperature range of 800°C – 1,000°C specified in DOT/FAA/TC-TN15/17[3].

   These temperatures are considered sufficient to cause hot surface ignition of flammable mixtures, but do not reach levels that will cause the melting of pure copper, nickel or steel. The shell of the 880 packages does not begin to melt until 1,400°C.

   The figure below shows an 18650 cell that underwent thermal runaway. Although the aluminium within the cell melted and the cell separator was consumed, the cell’s steel case and the copper current collector from the anode remained intact.

[2] Lithium-ion Batteries Hazard and Use Assessment Final Report, July 2011 Fire Protection Research Foundation.
[3] Fire Hazards of Lithium Batteries, DOT/FAA/TC-TN 15/17, February 2016.

An 18650 cell that has undergone thermal runaway.

2. Cell internal pressure increases for cylindrical designs will not cause appreciable swelling. In these cases, if sufficiently heated externally, the case wall may soften to allow bulging of the cell base.

3. Cell Venting. Cylindrical cells have venting mechanisms installed in their cap assemblies that activate when internal pressures are high (typically > 200 psi). CIDs contained in the cells activate to control the venting during thermal runaway.

4. Cell vent gases may ignite. This is dependent on the environment around the cell. The gases are not self-igniting and there must be sufficient oxygen in the surrounding environment to sustain combustion as well as an ignition source. During the thermal test, the battery pack is protected by the jacket and the 880 body weldment. Access to oxygen will therefore require combustion of the jacket material and breach of the battery pack case prior to accessing the individual LiFePO4 cells contained within the watertight case.

   Should conditions for ignition occur, the flames emanating from the battery pack cells will be highly directional (e.g., flames from 18650 cells are often described as "torch-like"). Since the battery pack cells are aligned parallel to the 880 body weldment, any flames that may be generated under the thermal test would also be oriented parallel to the 880 weldment and not be directed directly facing the body weldment. This will further minimize any temperature increase to the steel shell during the thermal test condition.

5. If thermal runaway occurs in one cell, it is likely to cause thermal runaway in adjacent cells. Under the thermal HAC testing, it is conservatively assumed that all (4) cells in the battery pack will undergo thermal runaway.

When evaluating the impact of the LiFePO4 cells contained in the Version 3 jacket of the Model 880 Series packages during the HAC, the worst case scenario would be for all cells in the battery pack to undergo thermal runaway during the thermal test of 10 CFR 71.73(a)(4). In this case, the expected package temperature exterior to the shell could be expected to increase to ~1,000°C. This temperature increase will be in localized to a small area surrounding and in contact with the individual battery pack cells that come into direct contact with the base of the shell. This value is below the melting point of 304L stainless steel of ~1,400°C. Based on this localized temperature increase of ~1,000°C, no failure or breach of the shell weldment will occur even if all cells in the battery pack undergo thermal runaway during the HAC thermal test.

As noted in Section 3.5.1 and supported by section 2.7.4.5 of the SAR, damage to the outer containment (shell), sufficient to impact the integrity of the depleted uranium shield, would require significant gaps in the shell (e.g. greater than 1.5 in^2) to allow ingress of oxygen inside the weldment, before pyrolization of the foam and subsequent oxidation of the depleted uranium shield could be induced. Based on the information related to Li-ion cells under thermal runaway conditions, the added heat generated by these cells will be insufficient to cause a breach of the 880 body weldment, and therefore, the Model 880 Series packages will retain their shielding integrity and containment during the HAC thermal test when assembled with the Version 3 jacket.

The SAR has been updated in Section 3 to reflect this additional information.

3-2 *Quantify in the SAR whether the lithium-ion batteries will have an effect on the package surface temperature.*

The applicant has requested to add an optional version 3 jacket with lithium-ion batteries without updating the thermal analysis or describing any added heat load from the batteries or any effect on the package surface temperature. The application should describe if there is any internal heat load associated with the batteries, and if so, demonstrate the effect of the added heat load from the lithium-ion batteries on the package surface temperature.

The thermal evaluation in Section 3.4.1.1 et. al. of the SAR has been updated based on our response to Question 3-1a).

3-3 *Identify in the SAR any established codes and standards applicable to the use of lithium-ion batteries in a transportation package.*

The applicant has requested to add an optional version 3 jacket with lithium-ion batteries without identifying any applicable codes and standards. The applicant should identify any codes and standards applicable for use of lithium-ion batteries in the transport package to provide staff with quality assurance of the lithium-ion batteries used.

Although the $LiFePO_4$ cells used in the Version 3 jacket comply with the requirements of UN 38.3 (see footnote reference 1 on page 3), this is standard for transport of lithium-ion cells and would be required of any battery/cell transported compliant to 49 CFR 173.185. As described in response to question 3-1(a) of this letter, the Version 3 jacket including the battery pack with the $LiFePO_4$ cells, is not important to the safety (NITS) or integrity of the Model 880 Delta, 880 Sigma or 880 Elite transport packages. We maintain that adding a requirement to the descriptive drawings for the $LiFePO_4$ cells to this established regulatory standard is unnecessary since it would complicate the drawing to address a requirement ensured under an existing, applicable regulation.

The document revisions associated with these changes are included as enclosures to this letter. Should you have any additional questions, or wish to discuss this response further, please contact me.

Sincerely,

e-Signed by Lori Podolak
on 2017-06-29 18:56:22 GMT

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e-Signed by Michael Fuller on 2017-06-29 19:08:34 GMT	June 29, 2017
RA/QA Approval	Date
e-Signed by Steve Grenier on 2017-06-29 19:08:19 GMT	June 29, 2017
Engineering Approval	Date

Enclosures:

- Lithium-ion Batteries Hazard and Use Assessment Final Report, July 2011 Fire Protection Research Foundation
- Fire Hazards of Lithium Batteries, DOT/FAA/TC-TN 15/17, February 2016
- SAR Revision 12
- List of Affected Pages
- Revision Description for the Model 880 Series SAR from Revision 11 to Revision 12

cc: ATTN: Document Control Desk
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