Chapter 3 – Thermal Evaluation

3.1 Correct the mass fraction of water in the calculations of hydrogen generation for both irradiated hardware and dewatered swarf.

The applicant calculates the mass fraction of water F_w by excluding the water mass from the total mass in the cask, but includes the water volume in the calculation of void volume, VOID, for both irradiated hardware and dewatered swarf in Attachment 3B of the application. The applicant is required to correct the equation for the mass fraction of water from $F_w = M_w / (M_L + M_H)$ to $F_w = M_w / (M_L + M_H + M_w)$, to make both the mass fraction calculation and the void volume calculation consistent.

This information is required by the staff to determine compliance with 10 CFR 71.35 and 71.43(d).

RESPONSE

The corrections have been incorporated. The examples have been removed from Chapter 3 and are now found only in Chapter 7.

3.2 Provide the basis for the determination that 2 gallons of water remaining in the cask cavity, after the cask is drained, is a conservative assumption for the evaluation of hydrogen generation.

The applicant assumes that the grooves in the cask cavity base and the drain port have a combined volume of less than 0.02 gallons after the package is drained. The applicant estimates a volume of 2 gallons if any additional water remains on the base to a depth of 0.5 inch, and then uses a total of 4-gallon water for the determination of hydrogen generation in the package containing irradiated hardware waste form.

The applicant is required to (i) validate the assumption that there are 2 gallons of water remaining in the cask cavity for hydrogen generation after the package is drained, and (ii) demonstrate that such assumption is conservative for the analysis (see also RAI No. 7.1).

This information is required by the staff to determine compliance with 10 CFR 71.35. and 71.43(d).

RESPONSE

Energy*Solutions* is confident that the design of the cask will result in very little water being retained in the cavity after draining. To ensure no more than 2 gallons of water is retained after draining, the following acceptance criterion is added to the acceptance requirements of Chapter 8:

> No more than 2 gallons of water may be retained in the cask cavity and drain port when the cask sits vertically on an essentially horizontal flat surface.

Meeting this acceptance criterion validates the assumption that no more than 2 gallons of water is retained in cask cavity.

Since the amount of hydrogen generated is directly proportional to the amount of water available for irradiation, see Eqns. 3-2 and 3-3 of Chapter 3 of the SAR, the use of 4 gallons of water in the irradiated hardware example gives a conservative value for the decay heat limit.

3.3 Correct the maximum normal operating pressure (MNOP) for a hot-day case with the ambient temperature of 100ºF.

The applicant used a cavity gas temperature of 225ºF in the calculation of the MNOP for a hot-day case with the ambient temperature 100°F, which is inconsistent with the maximum cavity temperature of 227.3°F listed in Table 3-3 of the application. The applicant is required to correct the MNOP with the exact cavity gas temperature from Table 3-3 for a hot-day case.

This information is required by the staff to determine compliance with 10 CFR 71.35, and 71.71.

RESPONSE

The correction has been made and incorporated into the revised Chapter 3.

3.4 Explain why the fire shield temperature (1331ºF), as reported in Table No. 3-1 and illustrated in Figure No. 3-8 of the calculation package TH-023, is significantly less than the ambient air temperature (1475ºF) during the fire transient for 30 minutes for HAC thermal analysis of the Model No. 3-60B package.

During the HAC fire test for the Model No. 3-60B package, staff found out that the fire shield temperature was reported as 1331ºF when the ambient temperature the package is exposed to is 1475°F. Figure No. 3-8 of the calculation package TH-023 indicates that the fire shield and inner shell temperature rises to 1331ºF, while the outer shell temperature rises to 353.3°F, a difference of almost 1000ºF. The NCT model results seem to indicate that there is little to no temperature gradient across the fire shield, outer shell and inner shell of the package, which would not be anticipated for this type of design. A detailed explanation on why the temperature is significantly below the fire temperature of 1475ºF should be provided.

This information is required by the staff to determine compliance with 10 CFR 71.71 and 71.73.

RESPONSE

The 3-60B cask fire shield is connected to the cask body in such a way that it provides an air gap between the cask body and itself. During the hypothetical fire test, the air gap provides a thermal barrier which impedes the transfer of heat from the fire-shield to the cask. The transfer of heat from the fire source to the cask takes place by a combination of two phenomena - radiation and forced-convection. The total heat-flow rate to the cask is a function of resistance provided by the air gap and the equivalent resistance of the radiation heat transfer between the fire shield and the cask outer shell. A large resistance will reduce the heat transfer rate and it will take a long time for the fire-shield to attain the same temperature as the fire environment.

The finite element model of the 3-60B cask appropriately incorporates both these heat transfer phenomena. The air-mass resistance has been incorporated by temperature dependent conductivity and radiation heat transfer has been incorporated by the referenced text book formula (Holman; Reference 3-2 of the SAR). ES, therefore, believes that the temperature predicted by the finite element model, i.e. 1331ºF is a reasonable result, which should be expected during the HAC fire test.

3.5 Provide clarification for the maximum allowable temperature of the seals listed in Table Nos. 3-1 and 3-2 of the application.

Section 3.2.2 of the application states that the seals are specified to be elastomer, 50 – 70 Durameter, temperature range of -40°F to 350°F. Table No. 3-1, "Summary of Maximum NCT Temperatures" and Table No. 3-2, "Summary of Maximum HAC Temperatures", list the maximum allowable temperature of the seals as 450°F, which is higher than the maximum specified in Section 3.2.2.

The applicant should clarify this discrepancy and specify a reference for the seal's maximum temperature.

This information is required by the staff to determine compliance with 10 CFR 71.43, 71.71 and 71.73.

RESPONSE

The maximum allowable temperatures listed in Tables 3-1 and 3-2 have been corrected to 350°F, which is consistent with Section 3.2.2 and the thermal analysis results shown in Tables 3-1 and 3-2 for the seals.

3.6 Clarify how the impact limiters affect the flow of heat into the package in the HAC model.

Section 5.0 of the calculation package No. TH-022 states that (i) the impact limiters are not modeled, (ii) the impact limiters support plates are modeled and, (iii) the outer surfaces of the impact limiter plates are not covered by foam but are considered to be totally insulated.

It is not clear how the heat migrates into the package through the impact limiter plates
during the HAC fire.

This information is required by the staff to determine compliance with 10 CFR 71.73.

RESPONSE

The calculation package TH-022 covers the NCT not the HAC fire. The HAC fire package is TH-023. Assuming that the comment, "*It is not clear how the heat migrates into the package through the impact limiter plates* *during the HAC fire*", pertain to TH-023; the ES response to this comment is as follows.

The heat input to the 3-60B Cask during the HAC fire is described in Section 3.0 of the SAR as follows.

"For the HAC fire the foam of the impact limiters is conservatively assumed not to provide any thermal insulation. In the structural analyses of the HAC drop and puncture drop conditions, it has been shown that after these tests, the casing of the impact limiter will be intact and remain attached to the cask body. Therefore, it is assumed that the fire directly hits the two ends of the cask through the 1/2" plate that form the casing of the impact limiters, in addition to the entire length of the fire-shield."

TH-023 mentions the above heat input process in various sections (e.g. radiation and forced convection). For more clarification the above paragraph will be added in Section 5.0 of TH-023.

3.7 Provide an analysis of the HAC fire with a radiation emissivity of 0.9 and an ambient temperature of 1475°F.

In the Calculation Package TH-023, the applicant assumes the emissivities of the fire shield and the environment to be 0.8 and 0.9 respectively, and derives an overall emissivity of 0.7347 by equation for radiation heat transfer between the fire shield and the environment.

10 CFR 71.73 requires a flame emissivity of at least 0.9 provided in the test when the specimen is fully engulfed in the fire, and a package surface absorptivity of at least 0.8 used in the calculation when the package is fully exposed to the fire.

To ensure package safety and compliance with 10 CFR 71.73, the model should implement the following requirements:

a) A package surface absorptivity of 0.8 or greater and an ambient temperature of 1475°F should be used in a 30 minute HAC fire calculation,

b) A uniform internal heat loading should be used for the temperature of the waste component.

c) The rest of the package calculation setups should remain the same as those in TH-023 for a 30-minute fire and its cool down (post-fire) phase.

An update of the calculation package TH-023 with new data, tables, and plots of HAC fire, including maximum material/component temperatures, maximum temperature difference through-wall results, nodal temperature distributions, and temperature transients of fire shield, O-ring, lead gamma shield, cavity bulk air, and inner and outer steel shells should be provided in responding to this RAI.

This information is required by the staff to determine compliance show compliance with 10 CFR 71.33 and 71.73.

RESPONSE

TH-023 in Section 5.3 (Radiation Modeling) includes the following paragraph.

"The regulations (Article 71.73 of Reference 2) require that an average environment emissivity coefficient of 0.9 must be used for HAC fire test. It also requires that for purpose of calculation, the surface absorptivity coefficient must be either that which the package may be expected to possess if exposed to fire specified or 0.8, whichever is greater. It is conservatively assumed in the analyses that the package has an absorptivity of 1.0. Therefore, an emissivity coefficient of 0.9 has been conservatively specified for all the elements that radiate heat to the environment. Form factor value of 1.0 is used and the area of the surface is automatically calculated by the computer program."

Therefore,

a) The HAC fire analysis uses surface absorptivity of 0.9 which is larger than that requested in this comment. The ambient temperature of 1475ºF has been used in the analysis (see Section 6.0 of TH-023).

b) Uniform internal heat loading has been used in the analyses. To envelop the maximum temperature on the cask inside wall surface as well as that on the waste container, ES has gone a step further than requested in this RAI. The waste has been simulated in two different ways (1) implicit internal heat load modeling, and (2) explicit internal heat load modeling. Please see Sections 5.5.1 and 5.5.2 for the detailed description of these simulations.

c) Since (a) and (b) are already addressed in the analyses, (c) does not apply.

Thus no updating of the analyses performed in TH-023 is needed. All the results requested in this RAI have been provided in TH-023. For reference their location is identified below.

Maximum material/component temperatures: Table 7.1 of TH-023 & Table 3-2 of the SAR.

Temperature transient of the requested components: Figures 9 & 10 of TH-023 and Figures 3-10 & 3-11 of the SAR.

Temperature transients of the cavity bulk air and waste: Figure 18 of TH-023

Nodal temperature distribution in the cask body at various time instants: Figures 11 through 17, Figure22 of TH-023 and Figures 3-12 of the SAR.

Nodal temperature distribution in the waste container: Figure 21 of TH-023.