Draft NUREG-2125 ACRS Comment Resolution Report

Resolution Table for ACRS Comments Received on NUREG-2125, Draft Report for Comment [ML12125A218]

Draft NUREG-2125 was presented to the NRC Advisory Committee on Reactor Safeguards (ACRS) Subcommittee on Radiation Protection and Nuclear Materials on Sept. 18, 2012 and to the full ACRS on Dec. 6, 2012. Verbal comments from the subcommittee and verbal and written comments from the full ACRS were received. The comments from these two groups are listed in separate rows in the Table below. The Table provides a comment response, and also identifies what changes, if any, that were made to Draft NUREG-2125 as a result of the comment. The final version of NUREG-2125 that incorporates the changes shown in this table is available from the NRC.

Commenter	Comment Number	Comment	Response	Change(s) made to Draft NUREG-2125
subcommittee	1	The report should more clearly state how freeway gridlock is included in the analyses	Gridlock is included via the use of urban rush-hour analyses that include a doubling of the traffic density and halving of the average truck speed.	The term gridlock was added to this footnote to Table 2.7 (emphasis added): During rush hour RADTRAN halves the truck speed and doubles the vehicle density to take into account traffic jams **and gridlock**. Detailed data for the actual traffic speed and density on a city by city basis is not available. The rush-hour collective dose is in addition to the urban (non-rush-hour) collective dose; both are included in the total. These two sentences were added in different places in section 2.3.3: RADTRAN assumes there is always a vehicle in the adjacent lane. and It is assumed that there is always a vehicle in the adjacent lane at the position of the cask and a vehicle in the same lane at the MIN distance from the cask.
subcommittee	2	The public summary of Appendix F should be given more prominence in the report.	The public summary has been moved to the front of the report immediately following the executive summary.	This was added at the end of the executive summary: A more complete plain-language summary of the report is given in the next section. . Appendix F and all references to it have been removed.

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subcommittee	3	The report should discuss criticality	A section on criticality will be added.	Section 5.6 was added: 5.6 Potential Criticality Spent fuel casks are required to demonstrate that they will remain subcritical following the hypothetical accident sequence of 10CFR71.73. In a transportation risk assessment, it must also be determined if the cask remains subcritical following more severe accidents. Because spent fuel casks are undermoderated (Elam et al., 2003) a criticality event requires the addition of moderator (water) into the cask. For water to get into the cask there must be a failure in the seals. In the accidents investigated in this study, only impacts into hard rock surfaces at speeds greater than 93 kph (60 mph) have the potential for failing the seals. Impacts into water at any speed cannot cause a seal failure. Therefore, for addition of moderator to be possible the cask would have to first impact a hard rock surface and then fall into a body of water. Even if the cask fell into a body of water after an impact caused the seal to fail, it would have to be in the right configuration for sufficient water to enter the cask that moderation is possible. The starting conditional probability for this is 4x10-10 accidents that produce a seal failure. The rail event tree does not provide any information about the probability of water, but the truck event tree gives 0.009 as the probability that there is water under a bridge. This is likely an over estimation of the chance that there is water near hard rock surface. Even if there is water present, the cask must rebound from the hard rock surface in such a way that it lands in the water. Then, if it lands in the water, the water must be deep enough to submerge the cask. Combined, the conditional probability that the cask gets flooded if there is a seal failure has to be less than 10-5. Even this is not a sufficient condition for there to be a criticality event. The fuel rubble must still be arranged in a manner that supports criticality. Given these extremely low probabilities, it can be deduced that a criticality event is not credible.

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subcommittee	4	Numbers like 10^{-9} are difficult to comprehend and how they are derived should be split into more understandable parts.	In the public summary we will attempt to pictorially represent the very low risk numbers.	Figure F-8 was added to the public summary along with this text: Figure F-8 provides a summary of all the accident probabilities and risks. The first pie chart shows that only about 1 in 1,000 trips will have an accident. The second pie chart shows that if an accident occurs, only about 1 in 2,000 accidents is more severe than the regulatory accident. The third pie chart shows that if an accident is more severe than the regulatory accident, only about 3 in 1,000,000 will result in either loss of gamma shielding or release of radioactive material.
ACRS	5	The report cites "Immersion under 0.9 meters of water. Casks carrying spent fuel also are require to withstand a nonsequential immersion in 200 meters (660 feet) of water for one hour." This is inconsistent with the regulations in 10 CFR 71.73. Please clarify the sources for all cask test requirements	The 200 meter immersion requirement is from 10CFR71.61	That section of the report was modified to read: (4) Immersion under 0.9 meters (3 feet) of water. Casks carrying spent fuel also are required to withstandIn addition, a nonsequential immersion in 20015 meters (66050 feet) of water for 1 hour. This paragraph was added after the section on sequential tests: In addition to the immersion test of 10 CFR 71.73, an undamaged cask carrying spent fuel is also required by 10 CFR 71.61 to withstand an external pressure of 2 MPa (290 psi) for a period of not less than one hour without collapse, buckling, or inleakage of water. This pressure is equivalent to an immersion in 200 meters (660 feet) of water.
ACRS	6	For all cask designs in which depleted uranium shielding is used, there is a potential for rapid degradation of the cask due to interdiffusion of the cask and shielding materials at the high temperatures that may encountered in the event of a prolonged fire. During such events the uranium can expand in volume due to phase changes and potentially damage cask and seal components. Depending on time and temperature, interdiffusion of iron and uranium can lead to the formation of Laves phases and possibly liquid eutectics and lead to accelerated penetration of the canisters. Provide a narrative and supporting test data and analyses showing that this phenomenon has been addressed and appropriately dispositioned. Additionally, your response should address the exothermic reactions that occur when Uranium forms intermetallic compounds with iron, chromium and nickel constituents of the spent fuel transportation canisters.	The peak temperature in the depleted uranium is below the temperatures where these phenomena occur.	The following was added at the end of section 4.4.3: The peak temperature in the DU gamma shielding is 406 degrees C (763 degrees F) as shown in Figure 4-40, well below the temperature where uranium goes through a crystal lattice phase change or the temperature where it can undergo intermetallic reactions (eutectic formation) with the stainless steel cask walls. In addition, a curve showing the temperature history for the hottest location of the DU was added to Figure 4-37 and Figure 4-40 was added showing the temperature distribution in the DU at the time of the peak temperature.
ACRS	7	The document should include a discussion of the systematic	All phenomena known to significantly affect a	The following was added at the end of

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		process used to determine what phenomena should be included in the analysis. The document should explicitly justify why certain phenomena, such as materials interactions, oxidation and associated different material properties of any oxides that could form, phase changes, corrosion, high burnup fuel, new cladding materials, etc., could be excluded.	cask's ability to provide thermal protection under hypothetical accident conditions, and under the historically severe transportation accident conditions studied, have been included in the analysis. This includes, but is not limited to all Part 71 and NUREG-1617 thermal analysis items. A review of literature and expert opinion elicitation has failed to identify any additional specific phenomena that would significantly affect a cask's ability to provide that protection. As far as the cited examples of phenomena are concerned, justification for their exclusion (as applicable) follows: • Material interactions: are already required to be analyzed, as stated in NUREG-1617. • Oxidation: Experience with thin stainless steel skins covering energy absorbing materials (these reach flame temperature very quickly during a fire) has shown there is insufficient oxidation to disrupt the ability of the skin to shield the energy absorbing material from the flames. Therefore, this phenomenon does not influence the response of the cask. • Oxides: Experience has shown that oxide layers that build up are not thick enough to significantly affect the thermal response of the casks. • Phase changes: Are considered in the analyses. Examples include melting of the neutron absorber material, lead melt, wood char, and carbon steel at the Curie temperature. The temperature of the DU is insufficient for the solid-solid phase change, but this possibility was investigated. Therefore, all of the phase changes that are important have been considered. • Corrosion: This is the same as oxidation. • High burn-up fuel: Only fuel satisfying the authorized contents in the Certificates of compliance is considered. Accordingly, fuel beyond 45 GWD is not considered in this report. However, by results would be expected to vary in direct relation to the higher burn-up fuel source term. This would in an increase in the risk results, but since the risk results are very low, it would not alter the conclusion that the transportation regulations	section 4.1: In addition, other thermally induced phenomena that could cause a degradation of the package are considered. These include the melting of lead in the Rail-Lead cask, solid/solid phase changes in the uranium in the DU-Truck casks, and rapid oxidation of the stainless steel in all of the casks. To make sure that all relevant failure mechanisms were considered, staff requested ORNL to perform a phenomena identification and ranking review of Draft NUREG-2125 (Smith et al., 2013). This review identified two additional phenomena, but concluded that the temperatures obtained by the casks were not sufficient for these phenomena to result in cask failure. The following was added above Figure 4-11: The non-uniform heating of a real fire leads to locations on the cask exterior, and especially on the impact limiter exterior, whose temperature is higher than 800 degrees C (1472 degrees F). The way the impact limiters were modeled in these analyses and conservatism in the CAFE code increase the maximum temperatures reported on the outer shell of the impact limiters. The peak temperature of this region shown in Figure 4-9 is above 1300 degrees C (2370 degrees F), a temperature where rapid oxidation of the thin stainless steel shell might be of concern. However, this extremely high surface temperature is an artifact of the conservative modeling process. That is, due to the boundary conditions specified for this simulation, the model over-predicts the temperature on this surface. In actual fire tests performed at Sandia and elsewhere throughout the world, rapid oxidation of thin stainless steel shells covering energy absorbing material has never been observed [Andersen et al., 1978, Pierce et al., 2003, Gelder and May, 2006]. The boundary conditions do have the intended effect of rendering the model conservative in that the high surface

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			provide adequate safety, even for high burn-up fuels - New cladding materials: Only certified cladding materials for the casks evaluated are considered. Further, all fuel is assumed to be failed in impact accidents, so the type of cladding is moot. There is no release from the cask in thermal accidents; so again, the type of cladding is moot.	temperature results in additional energy being imparted to the cask, thereby resulting in conservatively high peak temperatures throughout the cask.
ACRS	8	The document should include a list of applicable tests for validating phenomena relevant to these calculations (e.g., drop tests, fire tests, etc.). Identify the scale of such tests and any simplifications that could adversely affect the applicability of such tests for various types of canisters and relevant materials. The document should provide confidence that representative data are available for various cask designs or at least materials.	We agree, and this information was added.	This statement was added to the end of the second paragraph of section 3.2: The results from analyses using this type of code have been compared to results from both regulatory and high-speed impact tests. A recent Safety Analysis Report Addendum for the PAT-1 air transport package compared the very large deformations seen in full-scale testing of this package to those calculated using nonlinear explicit dynamics (Yoshimura et al., 2010). There have also been comparisons between full-scale regulatory drop tests of two spent fuel casks in Germany with explicit dynamic finite element analyses (Kishimoto et al., 2007, Musolff et al., 2007). These comparisons show good agreement between predicted and actual cask deformations. Appendix D includes a benchmark analysis of CAFE compared to an actual fire test and references other comparisons.
ACRS	9	List and justify simplifying assumptions invoked in the analyses. For example, Appendix D indicates that material properties are often limited to 726 °C or lower, despite the fact that the models predict much higher temperatures where these materials are located.	Rather than being separately listed, the assumptions that are critical to the report are included in the pertinent Chapters and Appendices to provide proper context. For example, the homogenization of the fuel region in both the impact and thermal calculations is discussed in Sections C.2.2, C.2.3, and D.3.1.2. The thermo-physical material properties are tabulated only to 1000 degrees K (726 degrees C) because data above this temperature shows considerable scatter, depending on source, and the important parameter for heat transfer is thermal diffusivity (=conductivity/(density*specific heat)), which for metals does not change much at high temperature.	The following paragraph was added just above section D.3.3.1: Only materials on the outside of the cask are expected to experience temperatures above 726 degrees C (1,340 degrees F). For all of the casks evaluated, the exterior layer is stainless steel. The important parameter for heat transfer through this stainless steel is thermal diffusivity, which is equal to the thermal conductivity divided by the product of density and specific heat. At high temperatures this value does not significantly change with increasing temperature. The value for thermal diffusivity of stainless steel used at 726 degrees C and above in these analyses was 5.26E-6 m^2/s. Recent measurements of thermal diffusivity of stainless steel at high temperature (Rempe

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				and Knudson, 2008) indicate a best fit for the thermal diffusivity at 1300 degrees C (2370 degrees F) is 5.8E-6 m^2/s, only 10% higher than the value used. Some of the data points given by Rempe and Knudson at high temperature are actually below 5.26E-6 m^2/s. Because of the large degree of scatter in the data for thermal diffusivity, a single analysis using a higher diffusivity (150%) was performed and resulted in only a couple of degrees difference in predicted temperature. Since the predicted temperatures are not near any of their respective limits, it was determined that the results were appropriate.
ACRS	10	The report does not make clear the difference between collective dose and collective dose risk.	A definition of collective dose risk will be added and consistent terminology will be used vis-à-vis collective dose and collective dose risk.	This sentence was added to the second paragraph of section 5.1: When the consequence to an entire population is considered, the accident risk is expressed as “collective dose risk,” and the units are person-Sv. This sentence was inserted into the first paragraph of section 6.2: The dose risk to a population (as distinct from the dose risk to an individual) is collective dose risk, which has units of person-Sv. This was added after the first use of the term collective dose risk in Appendix F: (the summation of dose to all exposed individuals times the probability of the accident) Throughout the entire report every use of the terms collective dose and collective dose risk were reviewed and changed as necessary so that collective dose does not refer to a probability weighted dose and collective dose risk does.
ACRS	11	The public summary of Appendix F should be given more prominence in the report.	Earlier versions of this report had the public summary in place of the executive summary. It was decided that this summary was too long to be at the front of the report so it was moved to Appendix F. A reference to the public summary will be added to the executive summary.	This was added at the end of the executive summary: A more complete plain-language summary of the report is given in Appendix F.