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Assessment of canister degradation processes in the regulatory review of SKB′s licence application for the construction and operation of a spent nuclear fuel repository in Sweden

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The Swedish Nuclear Fuel and Waste Management Company (SKB) has in 2011 submitted a licence application for a spent fuel repository at the Forsmark site in Sweden. The application is based on the KBS-3 concept consisting of three barriers; the copper canister, the bentonite buffer and the crystalline bedrock at about 500 m depth. In the SR-Site safety assessment SKB has in detail explored three fundamentally different reasons why canisters might fail to fulfil their prescribed containment function; due to i) isostatic loading, ii) corrosion failure in deposition holes where the buffer has been eroded, and iii) excessive shear loading in deposition holes affected by large earthquakes. The first case is regarded as a theoretical example, since canisters are designed and will be manufactured with significant margins to withstand even the most pessimistic loading conditions. However, for the second and third cases, a low likelihood of canister failures far into the future could not be excluded. The Swedish Radiation Safety Authority (SSM) has in 2018 completed a review of the SR-Site safety assessment with a statement to the Swedish Government. SSM agrees in broad terms with SKB's handling of the above mentioned cases. The Authority nevertheless recommended additional measures to further strengthening confidence in the robustness of the concept against those types of canister failures.
In this paper, we focus mainly on other conceivable reasons why the copper shell might fail: i) corrosion in anoxic pure water, ii) radiation-induced corrosion, iii) pitting corrosion, iv) stress corrosion cracking, iv) creep brittle failure, v) hydrogen embrittlement. SKB has provided justifications why none of these mechanisms are considered to be feasible, in the original application or as supplementary information. However, those mechanisms were brought up in the national consultation of SKB's application and by some of SSM's external experts. SSM has explored each of these mechanisms in three steps: i) assessment of state of knowledge for each mechanism, ii) assessment of the relationship between the hypothetical failure mechanism and the full range of in-situ conditions in deposition holes, iii) rough estimation of associated dose/risk consequences if failures should indeed occur. According to SSM's "what-if" assessments, the associated conditional consequences were estimated at worst to be small or modest, but it is nevertheless considered a high priority for SKB to avoid all conceivable reasons for potential early failure of the canisters. A resemblance with SKB's isostatic loading case is noted, since such failures could potentially occur in deposition holes in very tight bedrock conditions and with an intact buffer, which tend to mitigate dose consequences should failure occur. Further evaluation of copper creep mechanisms, localised corrosion mechanisms involving sulphide as well as the unsaturated phase in deposition holes, is recommended. SSM finally notes that, if needed, measures could be implemented to mitigate even hypothetical canister failures, such as the limitation of organic material involved in sulphide generation, and as far as possible restrict the required degree of creep deformation of the canister's copper shell.