CRA risk analysis

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Study into the effects of radiation exposure on seismic integrity claims for a neutron detector

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ABSTRACT
In order to assess without experiment whether a gas-filled neutron detector could continue to adhere to seismic qualification standards after suffering irradiation, mechanisms of damage were identified and compared to operating conditions. Operating conditions were given as 333-353 K temperature, 2 x 108 cm-2 s-1 fast flux (1.6 x 1017 cm-2 fluence) and 8 x 109 cm-2 s-1 thermal flux (6.3 x 1018 cm-2 fluence) equivalent to 2.5 x 10-5 displacements per atom (dpa). Appropriate seismic standards were suggested and the testing methods described. The major structural materials in the IN35D detector, aluminium, stainless steel and alumina ceramic, were characterised and alloy compositions produced. Radiation induced damage mechanisms were described for both thermal and fast flux and the particular mechanisms for each structural material identified. Peer-reviewed literature was consulted to predict the effect of radiation damage for a given fluence on mechanical properties relevant to seismic integrity such as yield stress, ultimate tensile stress, elongation and ductility. For aluminium, fluences of below 1021 cm-2 produced no noticeable changes in mechanical properties. Between 1021 and 1022 damage may occur if temperature is high enough. Above 1022 flux significant damage and changes in aluminium mechanical properties occurs. For stainless steel, a comparison to dpa was required and it was found that neutron damage below 1 x 10-3 dpa produce no noticeable effects. Finally, for alumina, a neutron fluence below 1021 cm-2 had no effect on mechanical properties. It was therefore decided that the minimum neutron fluence to produce noticeable changes in mechanical properties is, in all cases, at least an order of magnitude greater than the operating conditions for the detector, and even then an increase in temperature would be required to produce significant changes in ductility and fracture toughness to affect the ability of the device to adhere to seismic standards.

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