BURN BEHAVIOR OF A POLYURETHANE FOAM IMPACT LIMITER[1]

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ABSTRACT

Polyurethane (PU) foam, because of its capacity for energy absorption and thermal insulation, is used in impact limiters for radioactive materials transportation packaging. The burn behavior of a PU foam-filled impact limiter associated with the 10 CFR 71 Hypothetical Accident Conditions (HAC) fire is complex; it depends on the intrinsic properties of the PU foam, environment, and impact limiter geometry. Thermal degradation of PU foam can occur by pyrolysis (without oxygen) and/or by combustion (with flammable gases and oxygen). Depending on the impact limiter's geometry, which will affect chimney flow and jet flame, flames could reach high temperatures, potentially compromising the packaging's containment boundary.

We recently completed a study of the burn behavior of a PU foam-filled impact limiter. The packaging studied is a design for both the Mixed-Oxide Fresh Fuel Package and the Hanford Unirradiated Fuel Package, which have been certified for shipment by the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy, respectively. In this paper, the mechanisms of thermal degradation of PU foam are examined by reaction types and flame temperatures. Evidence suggests that for an air-tight impact limiter, the pyrolysis reaction dominates initially in the limiter enclosure. The pyrolysis generates a large amount of highly flammable gases, creating the conditions necessary for a subsequent combustion reaction near the vent holes where oxygen is present. The coupled heat release from the combustion of these flammable gases and oxygen drives the jet flames to burn at extremely high temperature.

We used the three-dimensional finite-element analysis code, ANSYS Mechanical, to model the packaging with the PU foam-filled impact limiters and compute the temperatures near the seal region of the containment boundary. The effects of various parameters on the package's thermal performance, including fire duration, chimney flow, burned-char thickness, and jet flame temperature, were examined. The results indicate that for the given impact limiter design under the simulated conditions, the O-ring seal temperature near the packaging containment boundary rose to varying degrees, but they did not exceed the seal temperature limit of 400°F (204°C). Some uncertainties with respects to burn conditions, such as existence and duration of smoldering fire, and their impacts on package safety were also discussed.

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