HEAT UP AND POTENTIAL FAILURE OF BWR UPPER INTERNALS DURING A SEVERE ACCIDENT

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ABSTRACT

In boiling water reactors, the steam dome, steam separators, and dryers above the core are comprised of approximately 100 tons of stainless steel. During a severe accident in which the coolant boils away and exothermic oxidation of zirconium occurs, gases (steam and hydrogen) are superheated in the core region and pass through the upper internals. Historically, the upper internals have been modeled using severe accident codes with relatively simple approximations. The upper internals are typically modeled in MELCOR as two lumped volumes with simplified heat transfer characteristics, with no structural integrity considerations, and with limited ability to oxidize, melt, and relocate.

The potential for and the subsequent impact of the upper internals to heat up, oxidize, fail, and relocate during a severe accident was investigated. A higher fidelity representation of the shroud dome, steam separators, and steam driers was developed in MELCOR v1.8.6 by extending the core region upwards. This modeling effort entailed adding 45 additional core cells and control volumes, 98 flow paths, and numerous control functions. The model accounts for the mechanical loading and structural integrity, oxidation, melting, flow area blockage, and relocation of the various components. The results indicate that the upper internals can reach high temperatures during a severe accident; they are predicted to reach a high enough temperature such that they lose their structural integrity and relocate. The additional 100 tons of stainless steel debris influences the subsequent in-vessel and ex-vessel accident progression.

KEYWORDS
upper internals, BWR, severe accident, MELCOR

1. INTRODUCTION AND BACKGROUND

Above the core of a boiling water reactor (BWR) are the upper internals (UIs), which consist of the shroud dome, steam separators and steam dryers. They condition the steam before entering the main steam lines. Steam separators are mounted onto the shroud dome, which is approximately 50 mm (2 in.) thick. The steam separators are formed by standpipes, each with a separator section. A device causes the flow to swirl, forcing the droplets in the steam to move towards the walls and be removed. The dryers force the steam through a convoluted flow path, further removing droplets from the steam. These features

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higher transfer of heat to the gases and much higher temperatures in the steam dome. Thus, a similar study of the upper internal response during severe accidents using the MAAP5.02 code may result in lower predicted upper internal temperatures.

Additional analysis using more rigorous modeling (i.e., finite elements) of UI structural integrity at elevated temperatures is recommended. The manner in which the UIs may slump and the subsequent impact on flow paths should be further investigated. These higher fidelity studies could provide guidance and form the basis for simpler modeling representations used in systems level codes such as MELCOR.

As noted, the relocation of 100 tons of additional material ex-vessel has the potential to impact the loads on containment. Future modeling using tools specifically designed to model melt spreading, and the long-term coolability of the core debris would provide insight into the potential impact.

Inspection and decommissioning of Units 1–3 at Fukushima Daiichi provide for a unique opportunity to understand the response of the UIs during severe accidents. Lower fidelity integral modeling (i.e., MELCOR), higher fidelity separate effects modeling (i.e., finite element for the structural response of the UIs and specialized codes for ex-vessel phenomena), and observations from inspections at Fukushima Daiichi could provide the technical basis for understanding the response and role of the UIs during severe accidents.

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