Thermal Evaluations for the HI-STORM UMAX Vertical Ventilated System

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Thermal Design Features Comparison with HI-STORM 100U

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- **Similarities**
  - Use of an insulated divider shell to guide ambient air from inlets to bottom of annular space between the MPC and the divider shell
  - Hot air exit from cavity is through an outlet vent in the overpack lid
- **Improvements**
  - Larger air flow passages (inlets, outlet, annular space between MPC and divider shell, between divider shell and container shell)
  - Air enters VVM cavity through four inlet vents
  - Thicker insulation on the divider shell
  - Use of baffle plates to direct the air flow from the ambient to the annular space between the MPC and the divider shell

Analyses Methodology

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- The analyses methodologies used are the same as those previously approved by USNRC for HI-STORM 100, HI-STORM FW and HI-STORM 100U.
- Same analyses codes are used (FLUENT and ANSYS).
- Analyses scenarios are the same as those previously evaluated.
- The decay heat in the MPCs loaded into the HI-STORM UMAX overpack are set to be equal to or less than the permitted values in above ground systems (HI-STORM 100, HI-STORM FW)
  - Fuel and component temperatures in the HI-STORM UMAX are lower than the above ground systems.
- Effect of wind is explicitly evaluated.

HI-STORM UMAX Maximum Permissible Heat Loads

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MPC Type		Heat Load Reduction Factor	HI-STORM UMAX Maximum Total Heat Load, kW
MPC-32		1.0	36.9
MPC-24		1.0	36.9
MPC-68		1.0	36.9
MPC-37	Short Fuel: L < 144 ”	0.95	44.70
	Standard Fuel: 144 ” ≤ L < 168”	0.95	44.70
	Long Fuel: L ≥ 168”	1.0	47.05
MPC-89		1.0	46.36

Acceptance Criteria

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- Fuel Integrity (ISG-11, Rev. 3) – Cladding Temperature Limit
  - > 752°F (400°C) (normal)
  - > 1058°F (570°C) (off-normal and accident)
- MPC & Cask Components
  - > All components must remain below their design temperature limits (HI-STORM UMAX FSAR Table 2.3.7)
- MPC pressures must remain below the design pressures (HI-STORM UMAX FSAR Table 2.3.5)

List of Thermal Analyses

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- Normal Long-Term Storage Condition
- Grid independency studies based on ASME V&V 20-2009
- Off-normal and accident condition for bounding MPC:
  - Off-normal Pressure
  - 50% inlet Duct Blockage
  - Off-normal Ambient Temperature
  - Extreme Ambient Temperature
  - 100% Duct Blockage
  - Fire Condition
  - Flood Condition
  - Burial under debris
- Wind effects evaluations for the bounding MPC

HI-STORM UMAX Thermal Model

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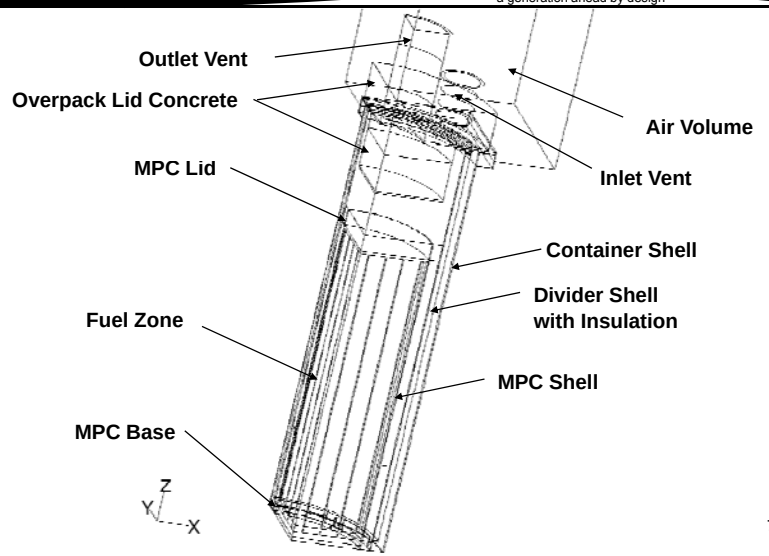

Normal Long-term Storage Temperatures for MPC-37

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Component	HI-STORM UMAX Temperature °C (°F)	HI-STORM FW Temperature °C (°F)
Fuel Cladding	362 (684)	375 (707)
MPC Basket	349 (660)	361 (682)
Aluminum Basket Shims	268 (514)	276 (529)
MPC Shell	235 (455)	246 (475)
Divider Shell	173 (343)	-
Overpack Lid Concrete	107 (225)	113 (235)

- The results reported above are for MPC-37 with short fuel.
- Fuel, MPC and Overpack temperatures are lower for HI-STORM UMAX.

Normal Long-term Storage Temperatures for MPC-32

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Component	HI-STORM UMAX Temperature °C (°F)	HI-STORM 100 Temperature °C (°F)
Fuel Cladding	366 (691)	388 (731)
MPC Basket	364 (687)	383 (721)
MPC Shell	217 (423)	231 (447)
Divider Shell	134 (273)	-
Closure Lid Concrete	89 (192)	120 (248)

- The results are reported for MPC-32 for the bounding scenario.
- Fuel, MPC and Overpack temperatures are lower for HI-STORM UMAX.

Temperature Contour for Normal Long-term Storage for MPC-37

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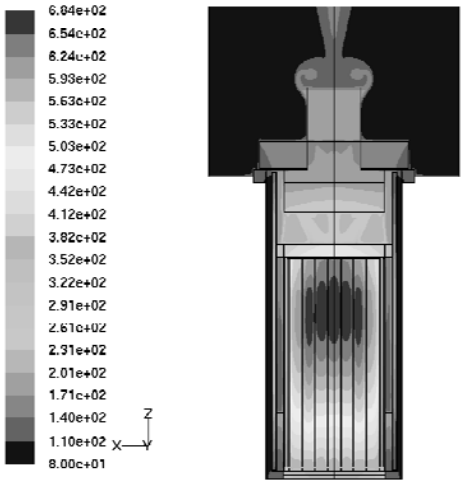

Contours of Static Temperature (f)

HI-STORM UMAX Wind Evaluation

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- **Potential Adverse Effects of Wind**
  - Decrease ventilation flow through HI-STORM UMAX flow passages
  - Increase air inlet temperatures for downstream HI-STORM UMAX modules on an ISFSI
- **Analyses**
  - Two separate thermal models to evaluate each of the above effects.
  - Conservatively, steady state conditions are evaluated.
  - Wind speed from 0 to 10 miles per hour

HI-STORM UMAX Wind Model to Evaluate Effect on Ventilation Air Flow

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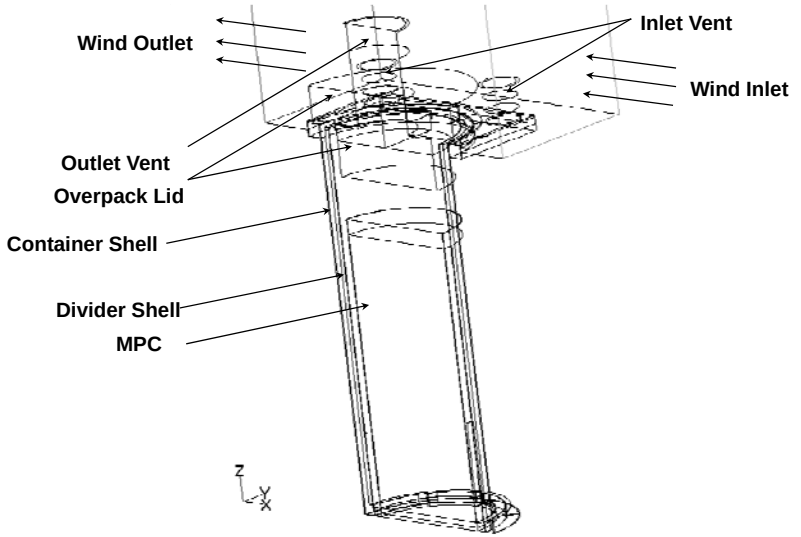

HI-STORM UMAX Wind Model to Evaluate Effect on Air Inlet Temperature

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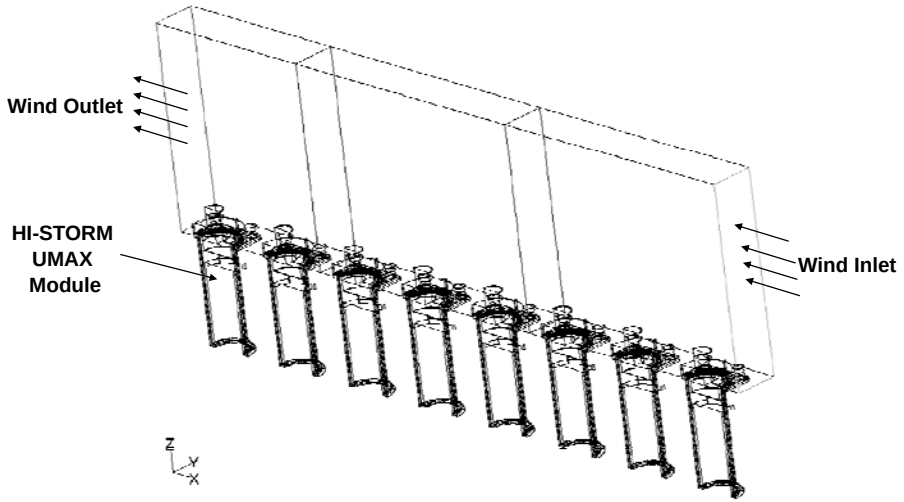

Effect of Wind on Fuel Cladding Temperature and Air inlet Temperature

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- **Effect of Wind on Fuel Cladding Temperature – Single Cask Model**

Wind Speed	Fuel Cladding Temperature °C (°F)
0 MPH	362 (684)
2 MPH	365 (689)
5 MPH	371 (700)
7 MPH	374 (705)
10 MPH	374 (705)

- **Cask Array Model**
  - **Maximum air inlet temperature increase due to wind: 6°C (11°F)**