

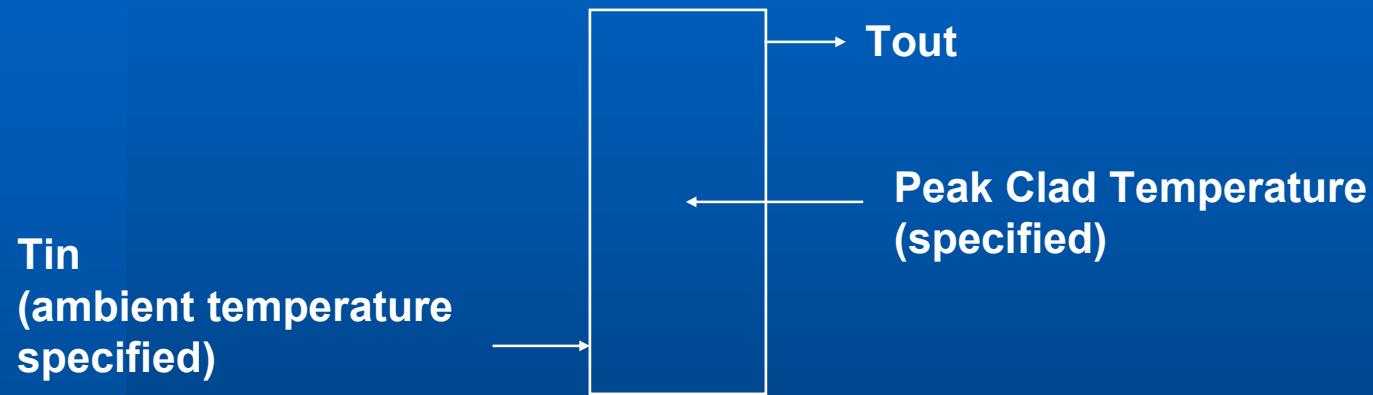
# HI-STORM 100U

## RESOLUTION OF REMAINING THERMAL ITEMS ON HI-STORM 100U

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- What is normal condition of storage ?



- The Thermal Capacity of the Cask is the Quantity of Heat it Can Reject for a Specified Ambient Temperature and a Specified Peak Cladding Temperature under Quiescent Steady State Conditions.

## PEAK CLADDING TEMPERATURE

- The Peak Cladding Temperature is Specified by the Regulator through National Lab. Reports, and Recently by ISGs.
- 1982 – Early 90s:
  - PNNL Report No: 6189 (Creep Based Formulation; Different Limit Depending on Fuel Age).
- Middle Period (Early 1990s – 2000)
  - Lawrence Livermore Report No: UCID-21181 (Diffusion Controlled Cavity Growth Model; different limit for fuel of different age).
- Recent Period (2000 – now) ; ISG-11
  - Peak Cladding Temperature  $\leq 752^{\circ}\text{F}$  (Same limit for all fuel of all ages).

## Treatment of Wind in Dry Storage System Thermal Evaluations

- The term “Normal Storage Condition” in the dry storage regulatory literature is a misnomer. It is essentially a reference condition. Steady-state analyses are performed with parameters assumed to remain constant.
- All dry storage applications on all dockets approved by USNRC have used quiescent ambient condition for thermal evaluations of normal long-term storage.
- In actual operations, the temperature field in the cask never reaches a true “steady-state” and is influenced by external conditions such as:
  - Ambient air temperature
  - Ambient air humidity
  - Ambient air pressure
  - Wind and presence of other casks
  - Presence of other structures

## Treatment of Wind in Dry Storage System Thermal Evaluations

- Wind is a “normally occurring” external condition. However, wind is a transient phenomenon, with varying directions and speed at all times.
- Time-varying phenomenon, such as wind, rain, etc. are not of steady state “genre” and should be defined as “Off-Normal Condition”.
- All Conditions that cause oscillation in the cask system’s thermal state are bundled as “off-normal condition” (another misnomer).
- Examples of off-normal condition parameters are:
  - Variation in the ambient temperature over short durations (3 days in the HISTORM FSAR)
  - Wind
  - Humidity changes
- The fuel cladding limit for the off-normal condition is 1058°F; i.e. 306°F above the “normal” condition limit. For this reason, off-normal conditions do not govern the thermal rating of a cask system.

## Treatment of Wind in Dry Storage System Thermal Evaluations

- The effect of wind has been analyzed in the “100U” by assuming that a given wind velocity vector persists for a long time to reach steady state.

### Effect of a Hypothetical Steady Unidirectional Wind

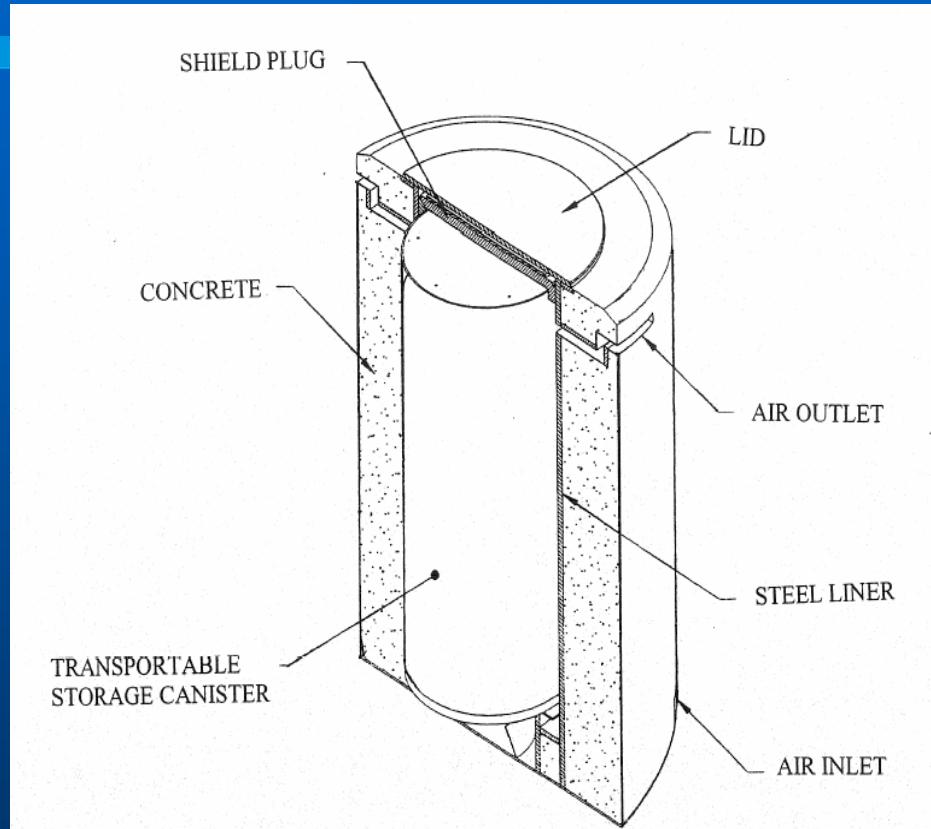
Wind Speed (mph)	Peak Cladding Temperature (PCT) (°F)
0	705
2.5	750
5	749
10	713
15	676

- Low magnitude wind increases the PCT as compared to the no-wind condition.
- The PCT at any wind speed is significantly lower than the allowable limits (752 F for no-wind condition and 1058 F for off-normal wind condition), i.e. wind does not govern.

## Treatment of Wind in Dry Storage System Thermal Evaluations

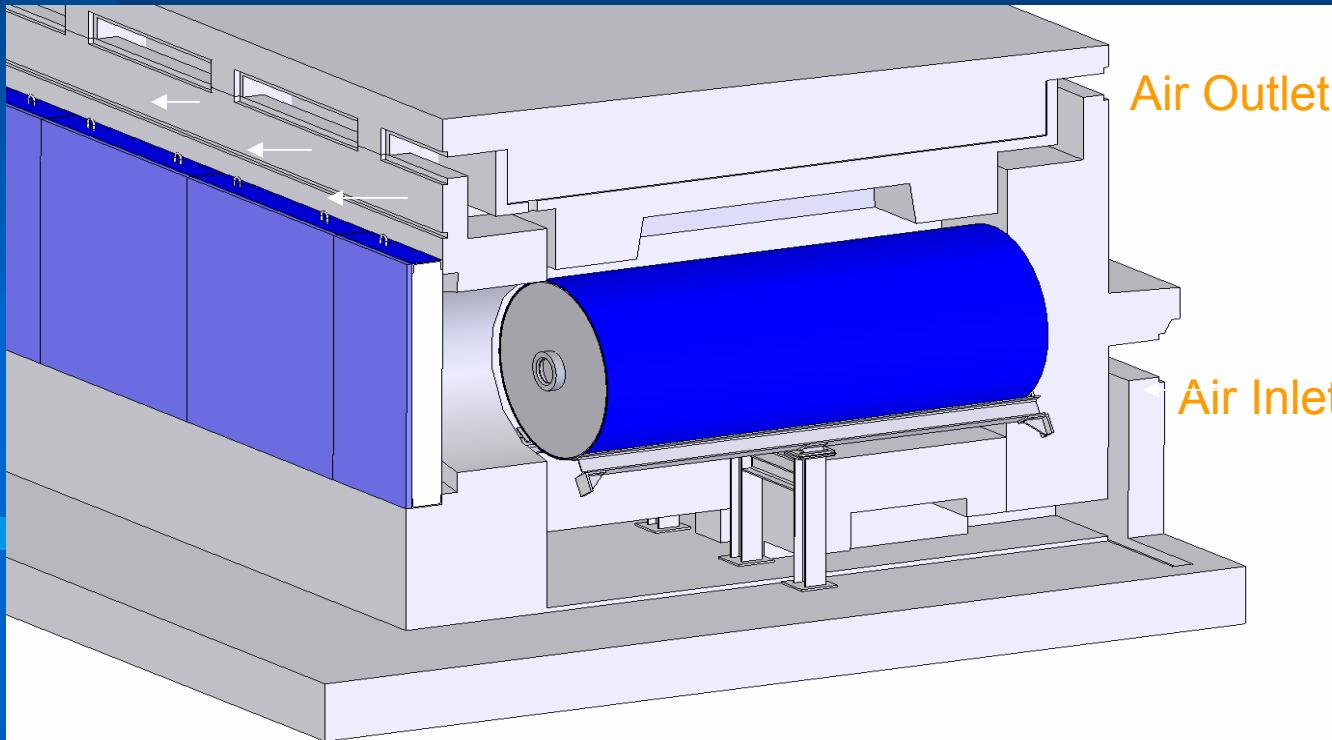
- Historically, the USNRC has not required the evaluation of wind in ventilated cask systems because of the large “delta” 306 °F available for the effect of transients such as wind.
- For this reason, the number and location of inlets and outlet ducts has never been a licensing issue in ventilated systems. As a result, several ventilated systems currently in use are extremely susceptible to the wind velocity vector.

## Treatment of Wind in Dry Storage System Thermal Evaluations



- Schematic of a typical NAC-UMS Storage System
- Two inlets and two outlets
- Inlets are 90-degrees rotated from the outlets.
- Air flow into an outlet will hinder natural circulation of air coming out of the outlet.

## Treatment of Wind in Dry Storage System Thermal Evaluations



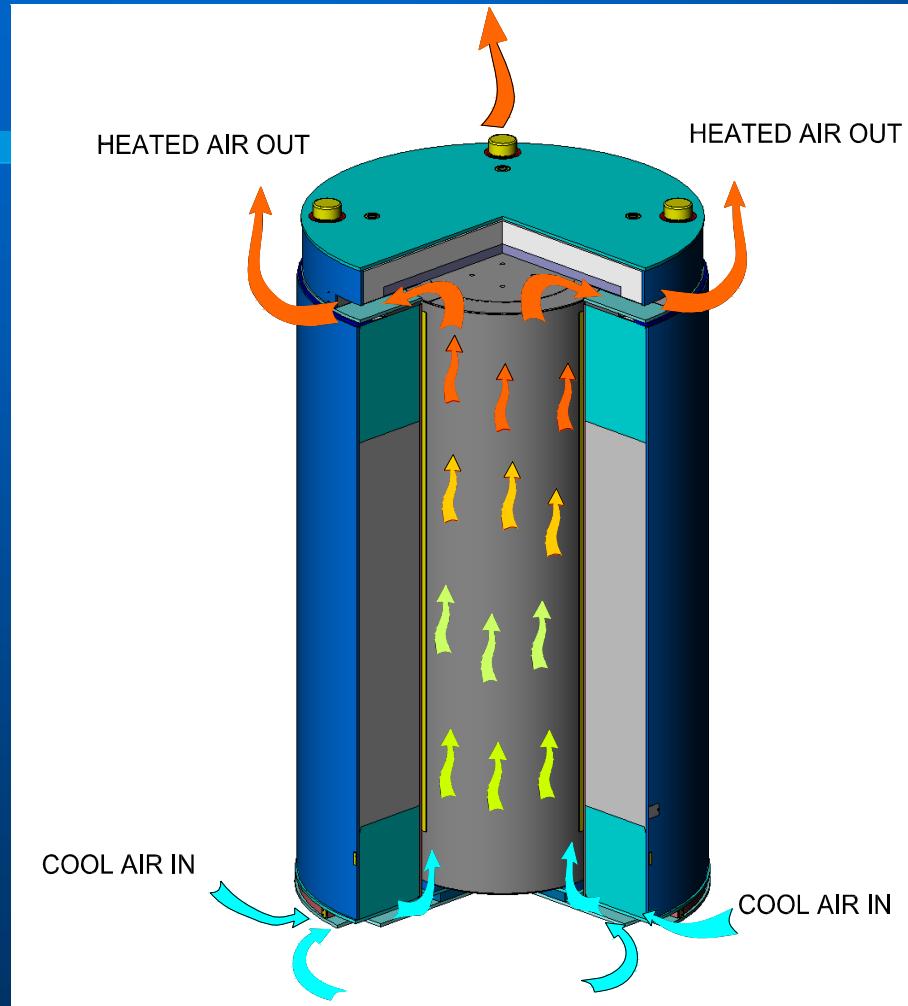
- Cut-Away View Of a NUHOMS Spent Fuel Storage Array
- Inlets on one side of the array and outlets on two-sides
- Air flow into the outlets will hinder natural circulation of air coming out of the outlet.

## Treatment of Wind in Dry Storage System Thermal Evaluations



**Array of NUHOMS Dry Storage Systems  
At A Power Plant ISFSI**

## Treatment of Wind in Dry Storage System Thermal Evaluations



- Schematic of a typical HI-STORM 100 System.
- Four inlets and Four outlets
- Air flow in a direction pointing at an outlet will hinder natural circulation of air coming out of that outlet as well as cooling air flow into the cask inlets.

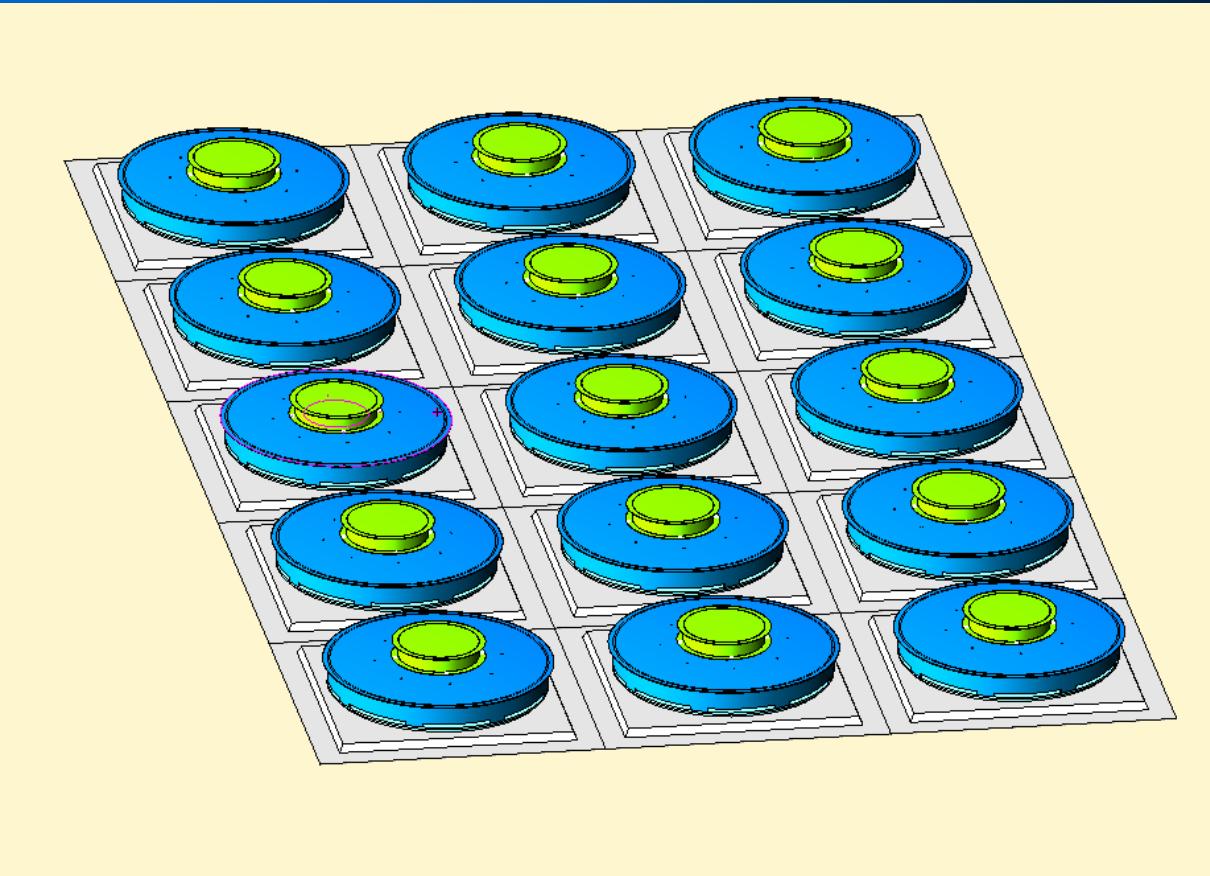
## Treatment of Wind in Dry Storage System Thermal Evaluations

- An array of aboveground system also creates a much more constrictive situation for air in-flow into the casks than 100U.



Array of HI-STORM 100 Systems At Hatch Power Plant ISFSI

## Treatment of Wind in Dry Storage System Thermal Evaluations

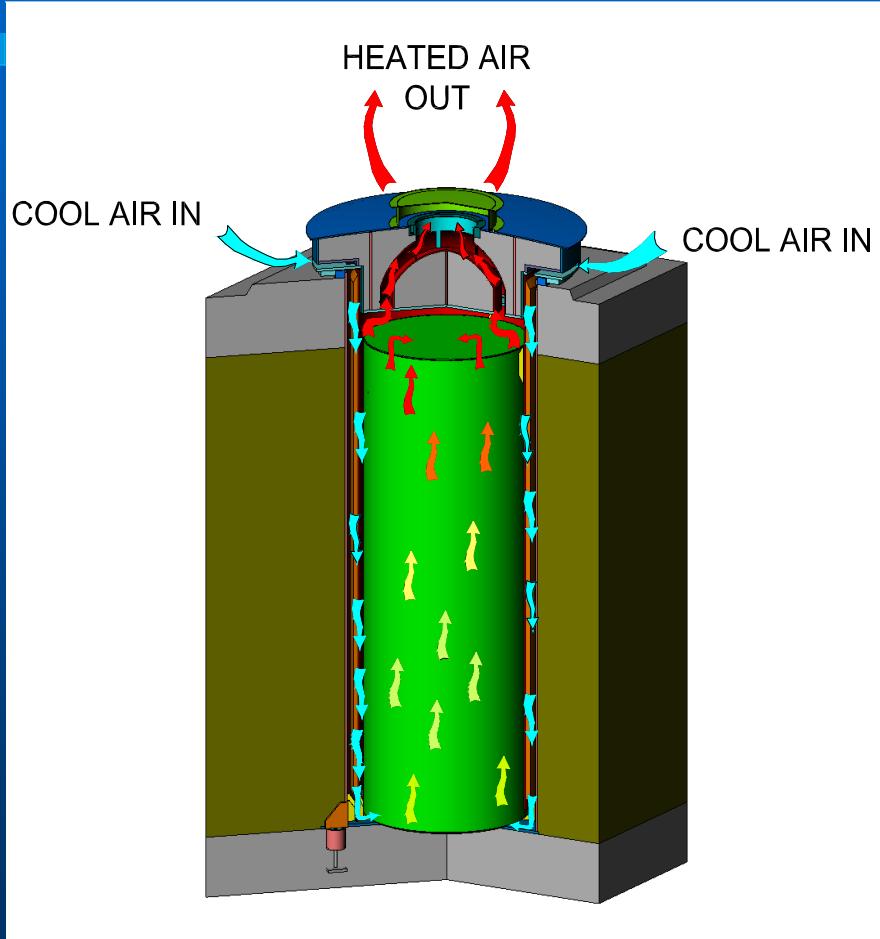


Typical Array of HI-STORM 100U Systems

## Treatment of Intermixing of Air Above VVMs

- How About The Risk of Inter-Mixing of Inlet and Outlet Air Streams ?

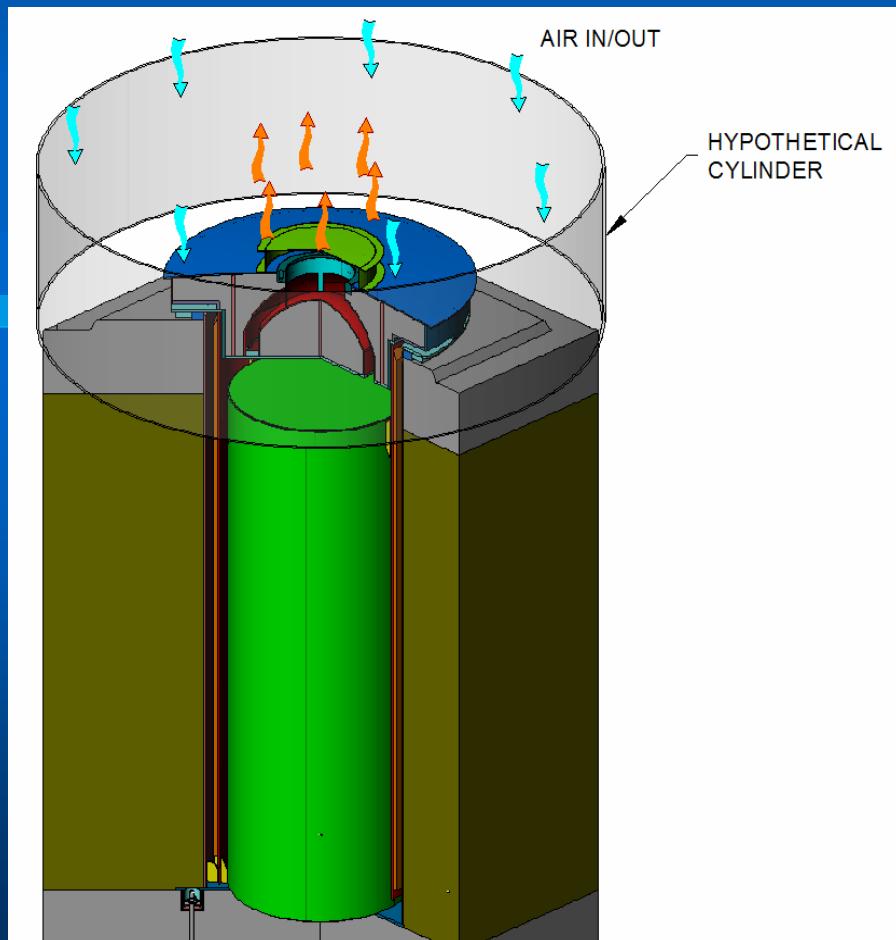
# Treatment of Intermixing of Air Above VVMs



- Schematic of a HI-STORM 100U System.
- All-Around (360 Degrees) inlets and outlets
- Sustained air flow in a fixed direction will affect natural circulation of air through the system.
- Recall that the top lid has been domed in “100U” to create an additional separation between the inlet and the outlet.

## Treatment of Intermixing of Air Above VVMs

- To maximize the potential for intermixing of inlet and outlet air in 100U, a single HI-STORM 100U with a hypothetical cylinder around the cask above the concrete pad has been considered.



## Treatment of Intermixing of Air Above VVMs

- To promote the mixing between the hot and cold streams, the ambient air and exiting air from the HI-STORM 100U cavity are artificially confined within the hypothetical cylinder.
- Use of a hypothetical cylinder around a cask to restrict air flow to the cask has been previously reviewed and approved by USNRC for HI-STORM 100 array and endorsed by PNNL when analyzing an array of 4000 casks.

# Conclusions

- Wind emphatically pertains to the transient thermal response of a cask & hence is a “Off-Normal” parameter.
- Potential for Intermixing of inlet & outlet airstreams has been conservatively modeled in the “100U” simulation.
- Analysis of a steady wind vector applied on a “100U” module shows variable effect depending on the magnitude of the wind velocity. The quantitative effect is not large enough to make wind as a governing condition for design.
- By physical reasoning, the effect of a large array of casks on the peak cladding temperature is expected to be stronger in above-ground systems. The “100U” ISFSI is wide open and unobtrusive to the wind.
- Due to interaction with NRC 3 years ago, the top lid design was modified from a flat to a domed surface to further separate the inlet and outlet ducts.