

# Preliminary Study on Passive Cooling of Instrumentation and Control Room Using PCMs

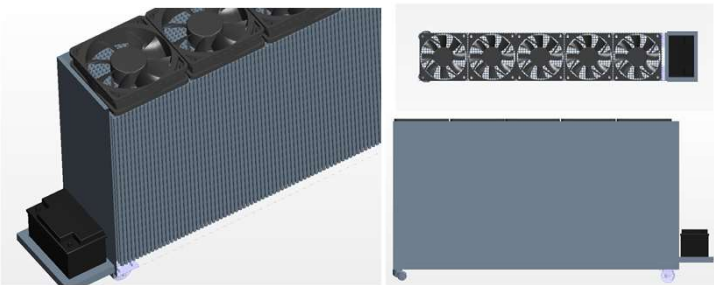
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## Introduction

- The role of the Passive Cooling Systems has become more significant since the Fukushima Daiichi nuclear power plant accident.
- The Westinghouse Corporation was first in applying the MCR passive cooling. It uses the thermal mass of concrete walls to provide temperature control. Metal heat fins are installed on the concrete walls to increase the surface area.
- However, passive cooling system for the MCR and Instrumentation & Controls (I&C) room has not been adopted in the APR1400.
- This is a preliminary study on the passive cooling of I&C Room using Phase Change Material(PCM).
- Mobile PCM cooler design was proposed. PCM cooler is stored in an air conditioned room with temperature maintained under melting temperature of PCM. PCM with melting temperature of 18 degrees Celsius (PureTemp18) was selected for design.
- When active cooling system fails. PCM cooler is moved to I&C room to absorb the heat from the computational equipment.



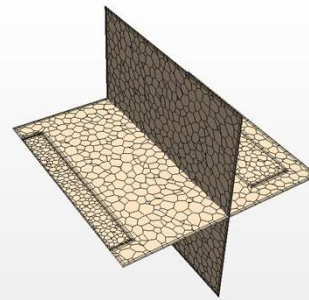
3D sketch of PCM Cooler

Schematic diagram of the PCM Cooler: top view (top), and side view (bottom)

- The PCM coolers use fans. The power supply is from a charged battery independent from the active power supply. The coolers are designed in modules and each module can cover the cooling of and I&C Room for 3 hours. By exchanging the module every 3 hours, the I&C room temperature can be maintained low for 72 hours.

## Design Parametres and CFD Modeling

- The Packaged Air Conditioning Unit (PACU) of APR1400 I&C room is 80 Btu/sec (84kW).
- Design objective was to match the PACU cooling power so that the system can replace the active cooling system in case of failure.
- Star CCM+ 2020.3. version was used for calculation.
- Since I&C room geometry and arrangement information is proprietary, an arbitrary room size of 1m x 1m x 1m was used with the PCM cooler as heat sink on one side and the server rack as heat source on the other.
- Adiabatic floor and wall conditions were used. Environmental pressure boundary was given on the top side.
- K-epsilon turbulence model was used to capture the turbulent air circulation.
- Segregated flow and segregated fluid temperature models were used.
- Constant volumetric heat source of 131.2kW/m<sup>3</sup> was given to the processors.
- Cooler was given -295.3kW/m<sup>3</sup> based on the geometry.
- Momentum source of 100N/m<sup>3</sup> was given in the cooler to model the fan and help the flow.

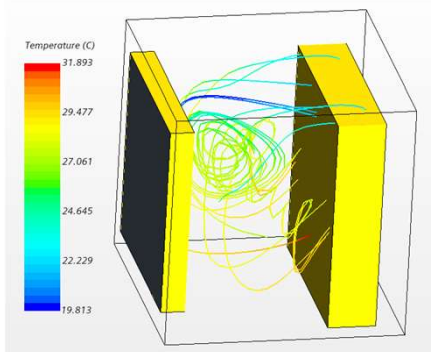


- 50,000 polyhedral meshes were used for calculation
- Steady state solution was obtained.

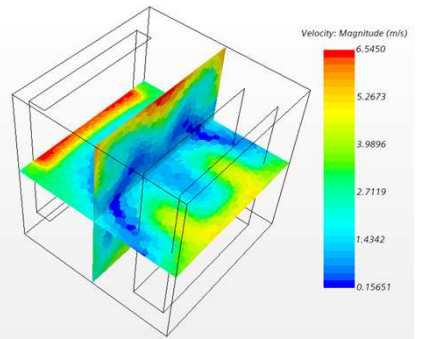
Cross sectional view of the mesh system

## Results & Discussions

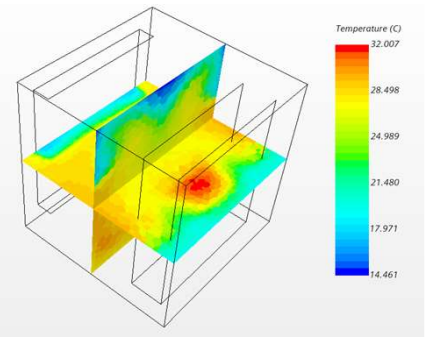
- Calculation ended when continuity, momentum, and energy residual all reached below 10<sup>-6</sup>.
- Results show a steady flow of air from between the cooler and servers.
- Temperature range is between 19 and 32 degrees Celsius.
- Maximum temperature is kept low in a reasonable range for computational equipment.
- Minimum temperature is just above 18 degrees which is the melting temperature of the heat sink.



Streamline of airflow from cooler (left) to server rack (right)



Cross sectional view of velocity



Cross sectional view of temperature

- Future Calculations will be done using the heat exchanger model of STAR CCM+ which does not specify the volumetric heat absorption but rather calculates the heat exchange depending on the temperature difference.
- More detailed information on the I&C room can help with more realistic calculation and results.

## Conclusion

- PCM coolers for the I&C room of APR1400 was suggested. Using CFD, the feasibility of cooler installation was studied. Room temperature is maintained well within reasonable range. More realistic modeling and results may be made possible if more detailed information on the I&C room geometry and equipment arrangement are acquired in the future.

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