Verifying the Cooling Capacity and Power Consumption of Thermoelectric Cooling Holders for Vaccine Storage

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Overview

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- The purpose of this paper was to verify the cooling capacity of different topologies of cooling system for the storage of vaccine in a portable solar powered vaccine carrier box for the use in Africa.

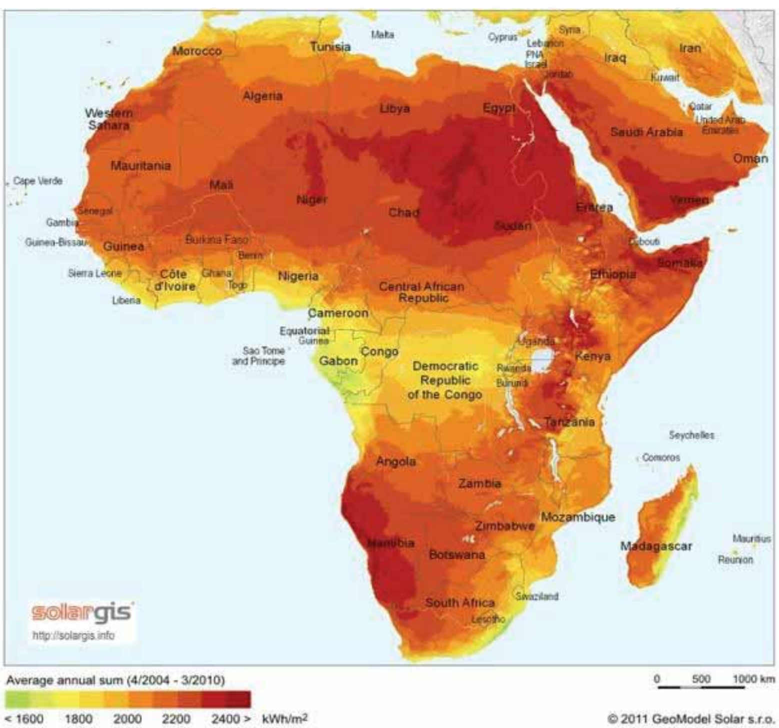
❖ The performance of the cooling holder is evaluated under normal operating conditions to determine if its cooling capacity is adequate

❖ Various simulations done in SolidWorks® and the temperature profile of different cooling holder topologies were evaluated

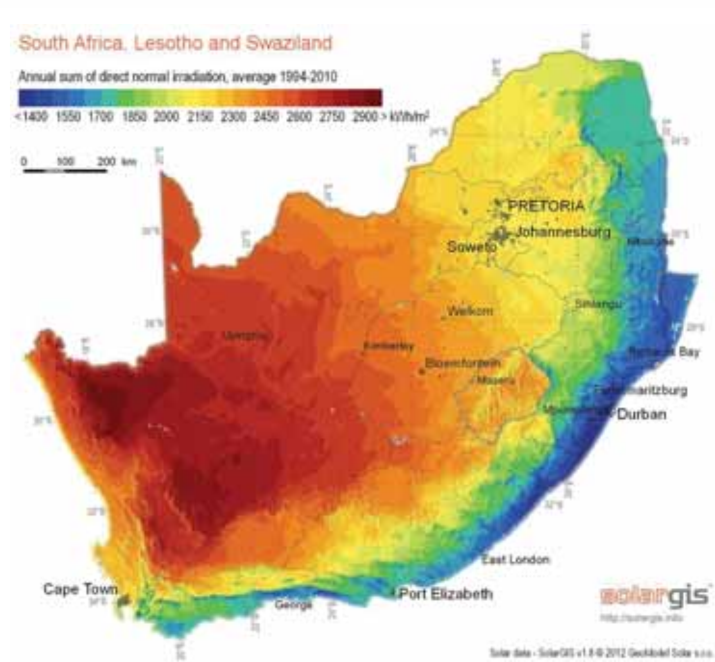
❖ The objective was to keep the power consumption to a minimum so that the cost of the power supply is kept as low as possible, but still providing enough cooling power for the refrigeration compartment

average annual solar radiation
falling on 1 m2 surface from 2004-2010, measured in kW/h

Average solar radiation in Africa



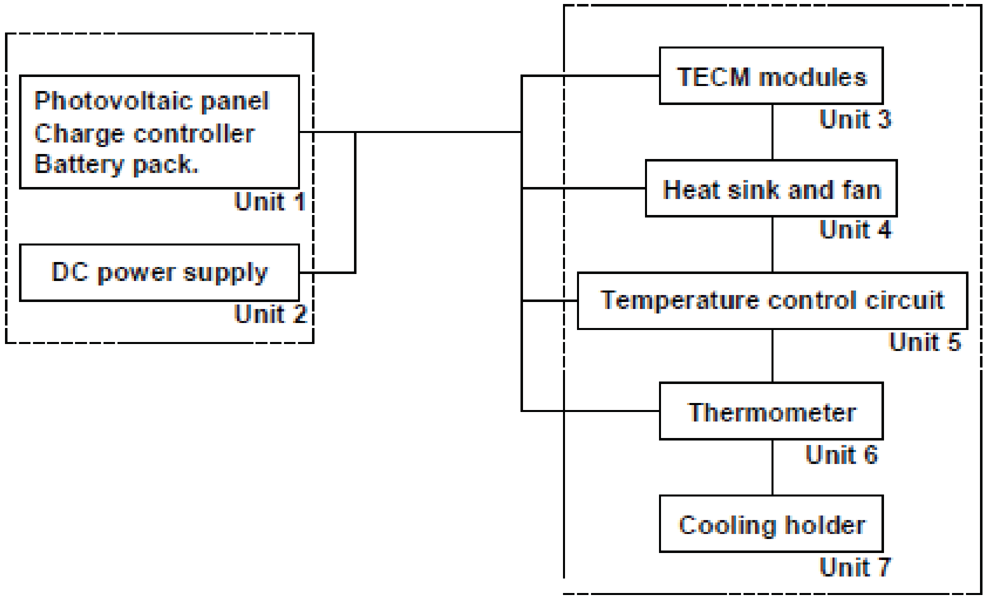
Average solar radiation in South Africa



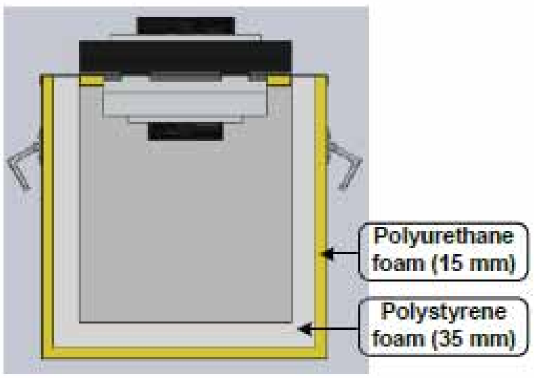
- There is more than 2000 kWh/m2 of energy available in the **mid region of Africa** and also **Potchefstroom** to generate power.

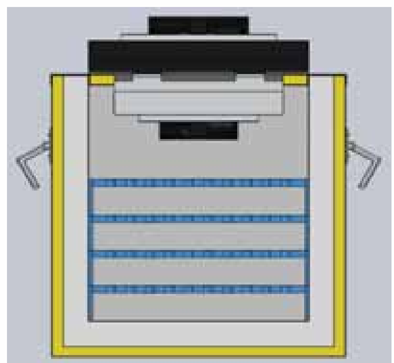
- This justifies the use of solar energy to power the cooling holder.

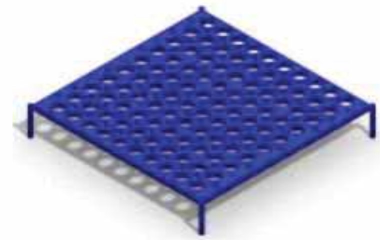
Design architecture

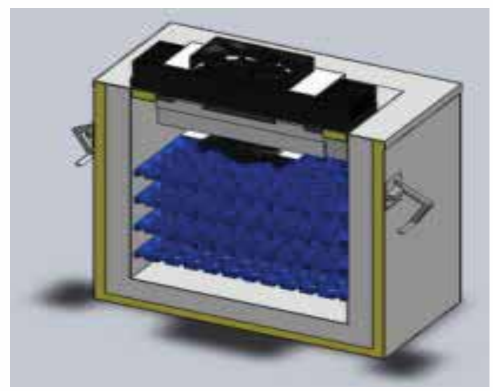


Vaccine storage shelf and
Position of vaccine storage shelves in cooling holder









The cooling holder consists of two layers of temperature isolation material, that is covered in a thin layer of metal sheet to protect it.

The temperature isolation material is:

- **polyurethane** foam with a thickness 15 mm
- **polystyrene** with a thickness of 35 mm,

400 vaccine bottles, 100 on each shelve. Each one of the vaccine bottles is able to store 20 ml of vaccine. This count up to a total of 8 litres of vaccine.

Prototype cooling holder with one TECM module (air cooling)

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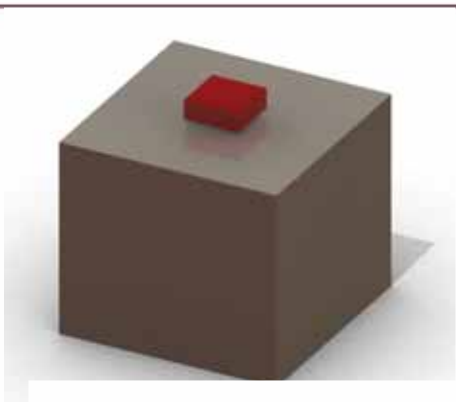
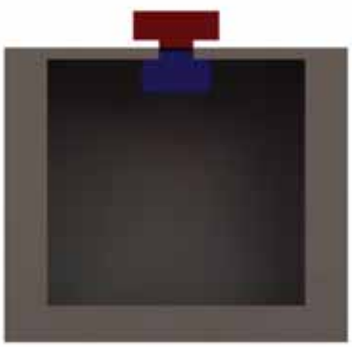
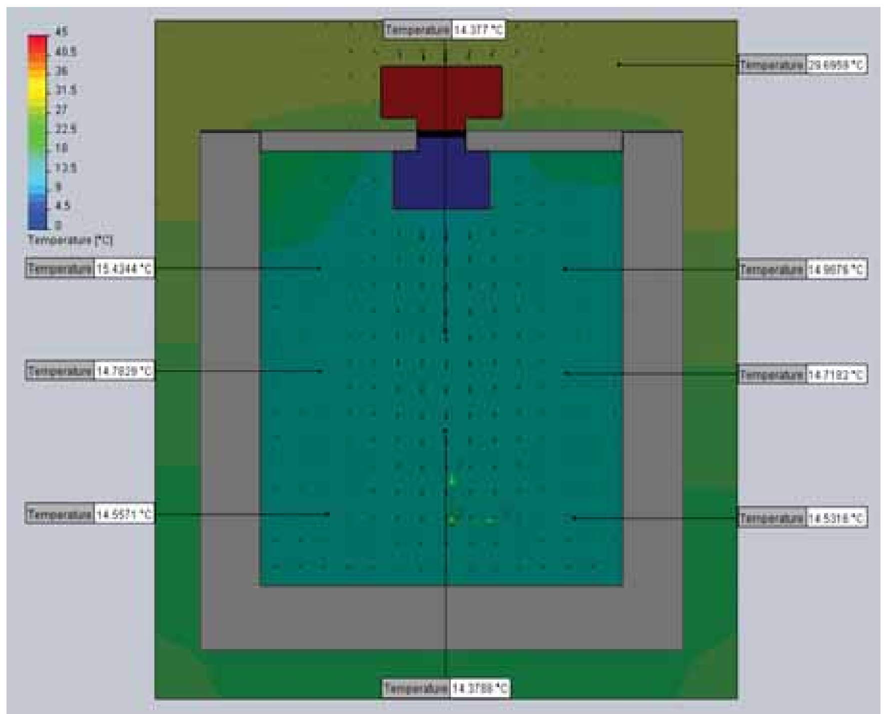




Temperature profile



- Air cooling type: by using a circulating fan on the cold side of the TECMs.
- TECM module has a heat sink on its hot surface and a cold sink on its cold surface, each with its own fan.
- one TECM is only capable of cooling from 32 to 15˚C.

Prototype cooling holder with two TECMs (air cooling)

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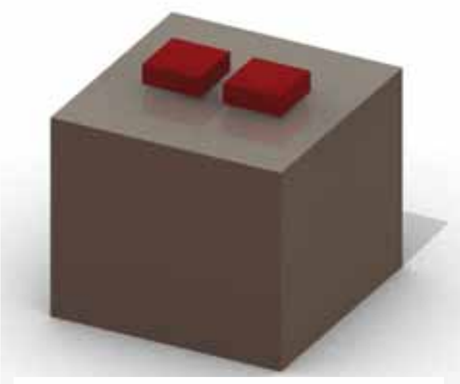
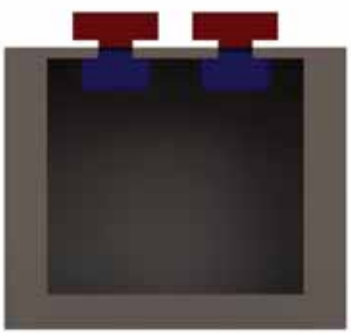
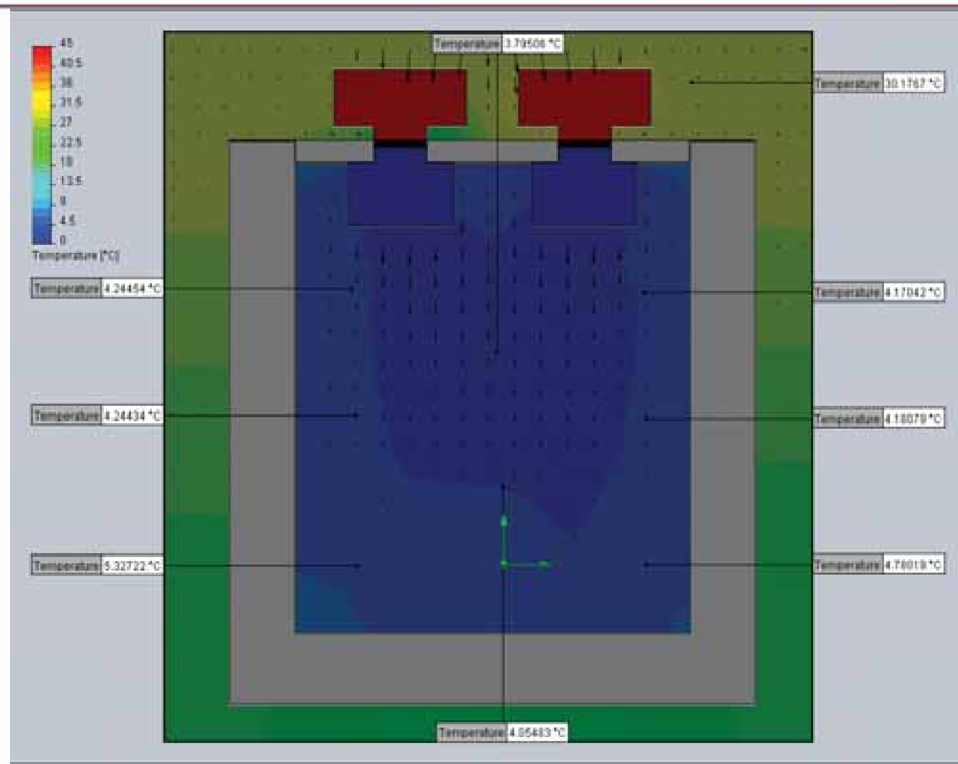
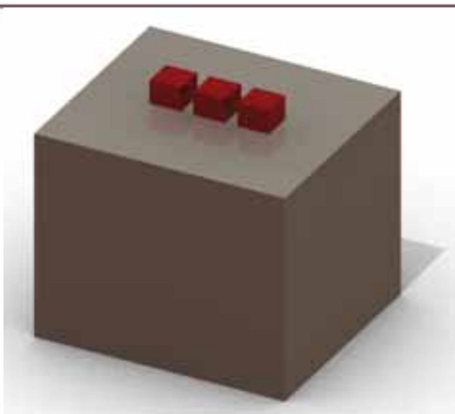


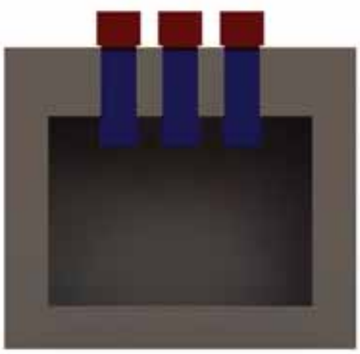


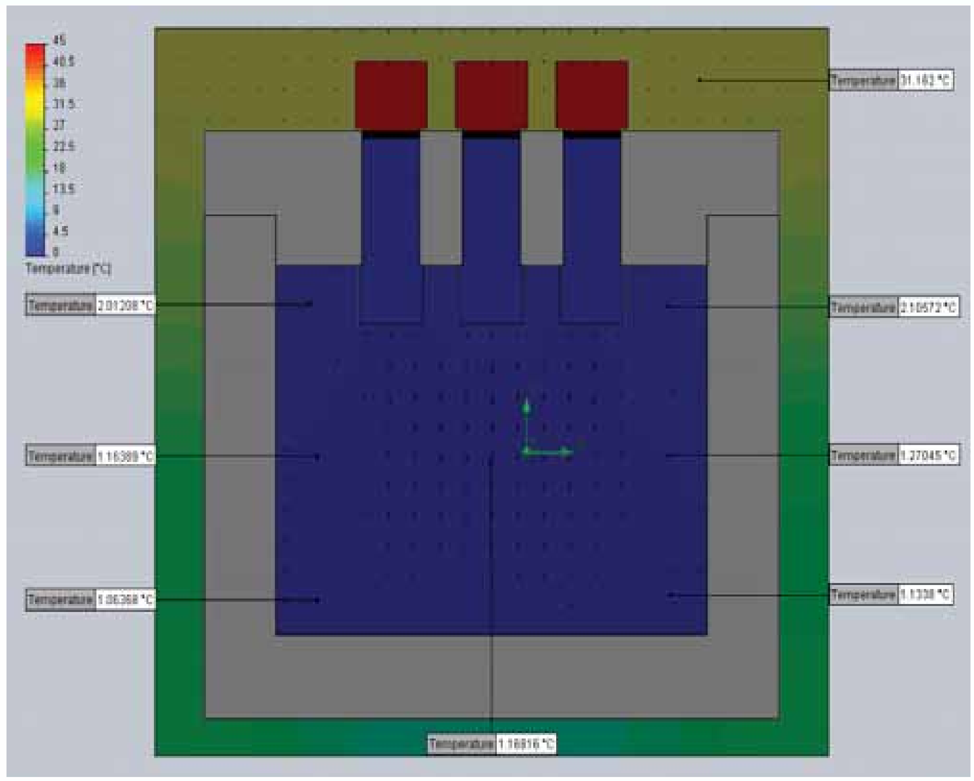


- two TECMs is enough to reduce the ambient temperature from 32 ˚C to 5 ˚C
- there is no cold point inside the refrigeration compartment that may have a temperature of less than 2 ˚C and cause harm to the vaccine.

Prototype cooling holder with three TECMs (air cooling)

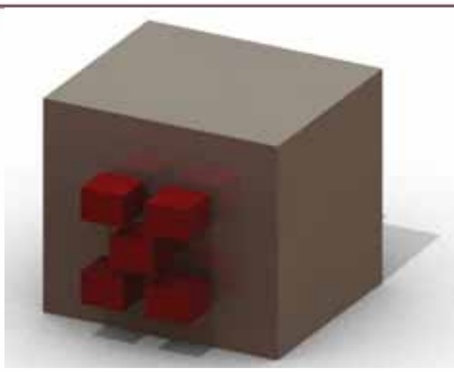


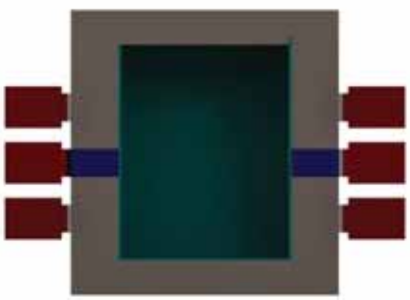


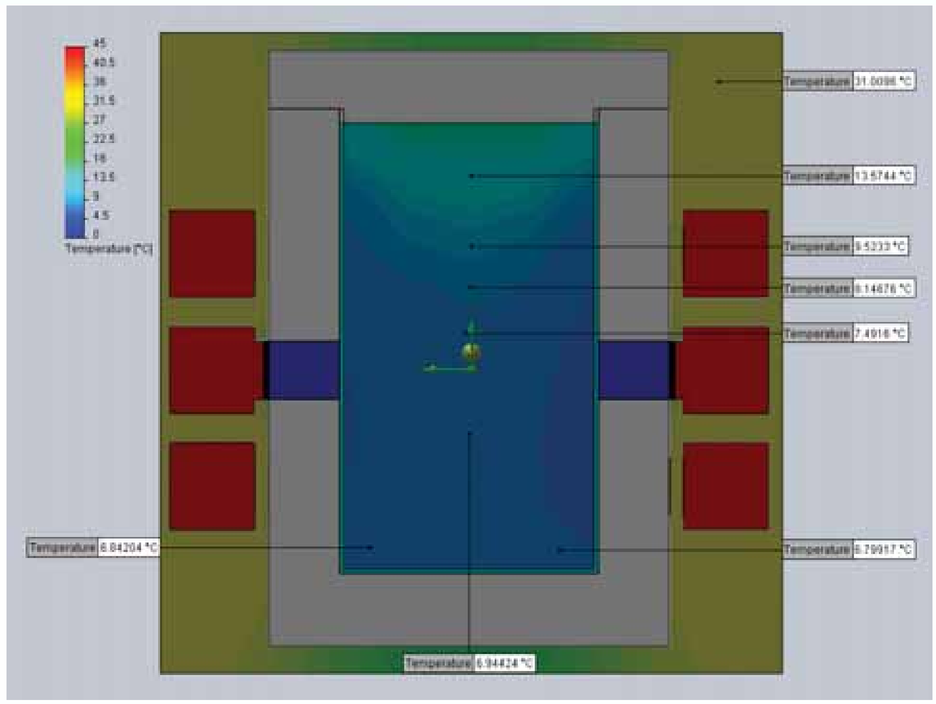


- Also meets the requirement of 5 ˚C inside the refrigeration compartment
- The energy consumption is higher than when using only two TECMs

Prototype cooling holder with ten TECMs (surface cooling)







- Surface cooling: TECMs cold surface are in direct contact with a thin metal plate on the inside of the refrigeration compartment
- TECMs have only a heat sink fan assembly on its hot surface.
- temperature profile shows us that a minimum of 10 TECMs are needed to reduce the temperature inside the cooling holder to 5 ˚C
- The temperature in the the cooling holder is also not uniform

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Number of TECM modules used	Power consumption	Voltage	Current
One	67.2 W	24 Vdc	2.8 A
Two	134.4 W	24 Vdc	5.6 A
Three	201.6 W	24 Vdc	8.4 A
Ten	672 W	24 Vdc	28 A

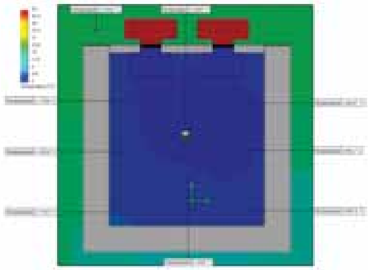
- each TECM has a power consumption of 67.2 W, with a voltage and current rating of 24 Vdc and 2.8 A respectively

- The increase in the total power rating causes an increase in the cost of the power supply.

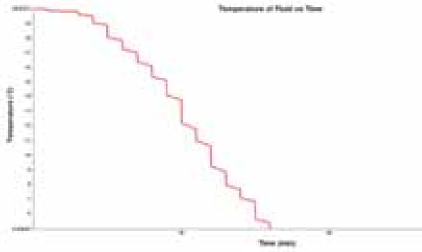
Case study

❖ The results for these simulations are illustrated in three different formats: a temperature profile format, graph format and table format.

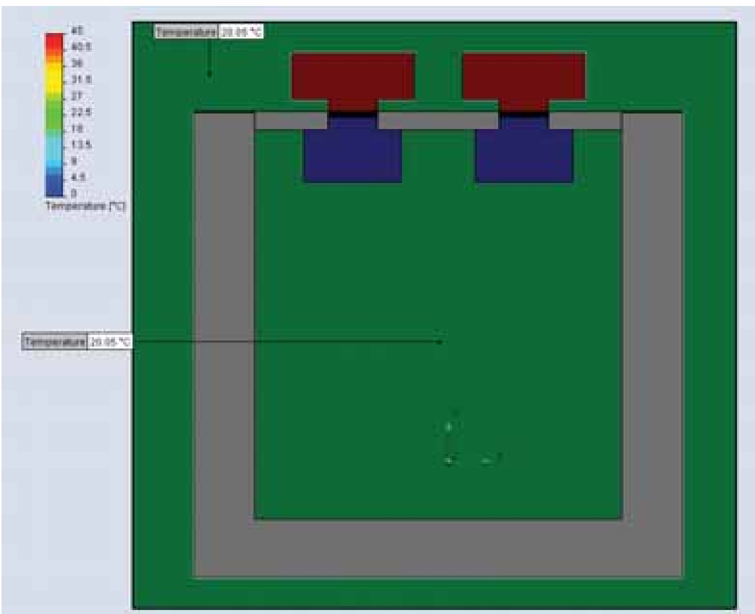
- The **temperature** profile gives a visual illustration of the temperature on the inside of the cooling holder. →



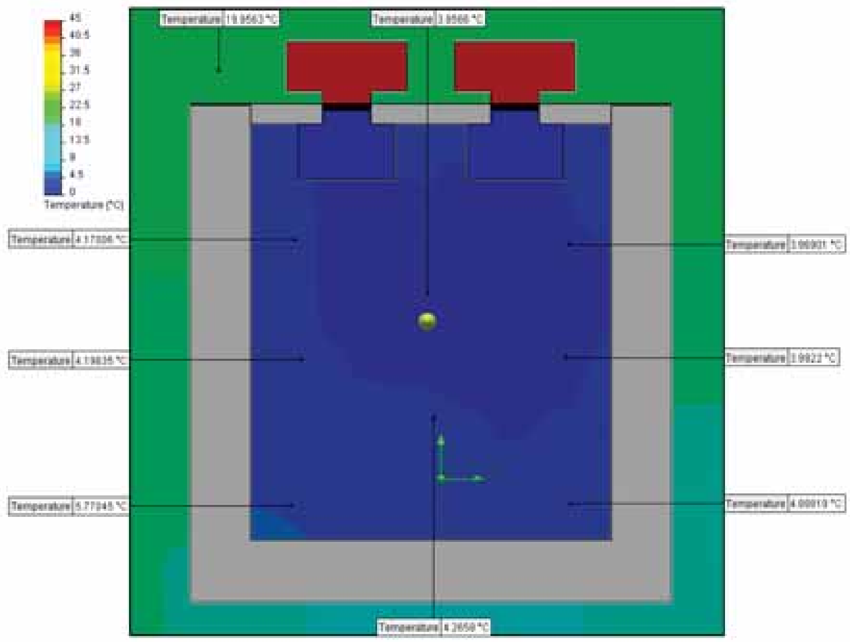
- The **graph** format illustrates the temperature at a specific time period and this also shows the amount of time that the cooling holder takes to reach 5 °C on the inside of the cooling holder. →



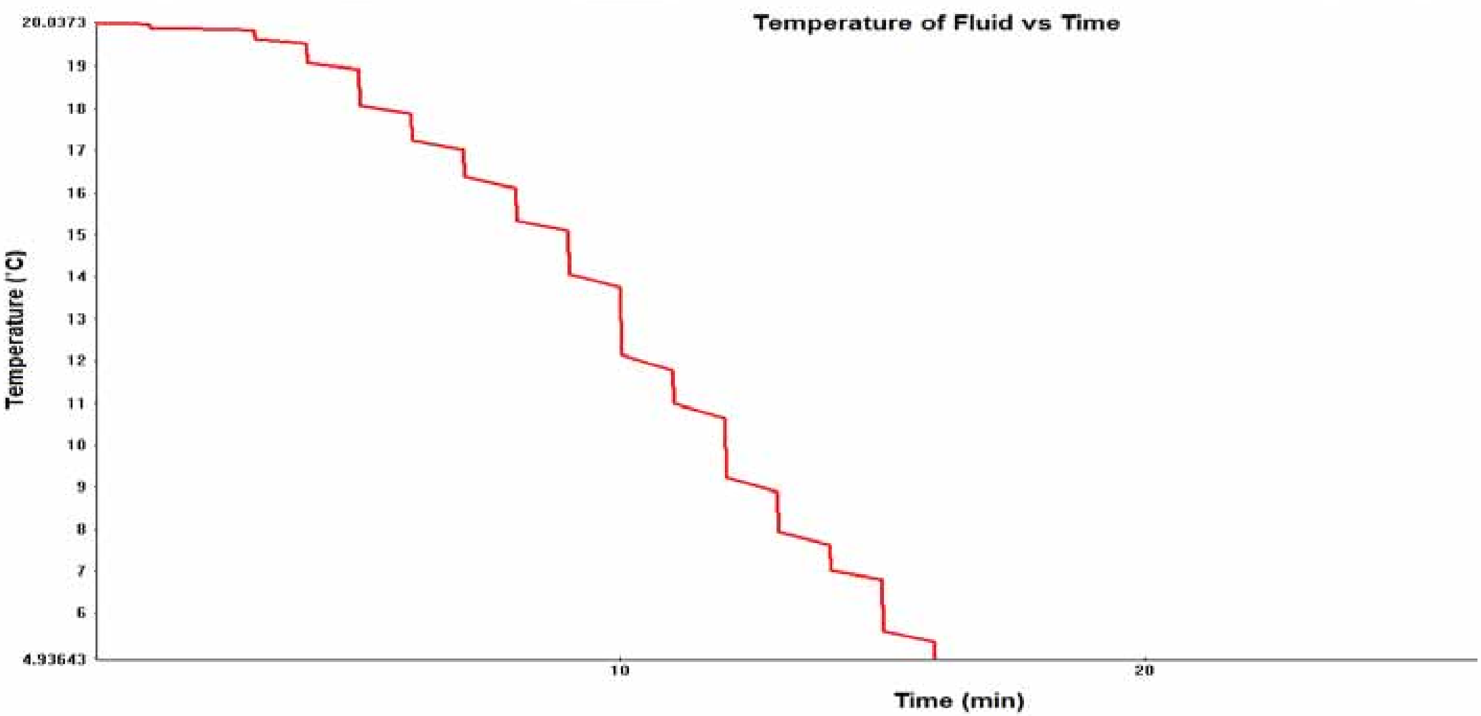
Temperature profile



Temperature profile; No-operation of TECMs at 20 ˚C

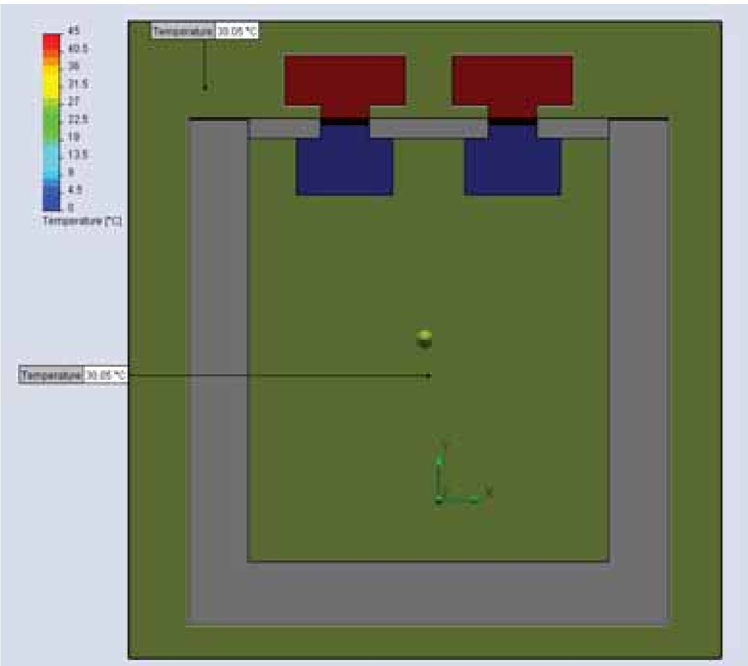


Temperature profile; Full operation of TECMs at 20 ˚C

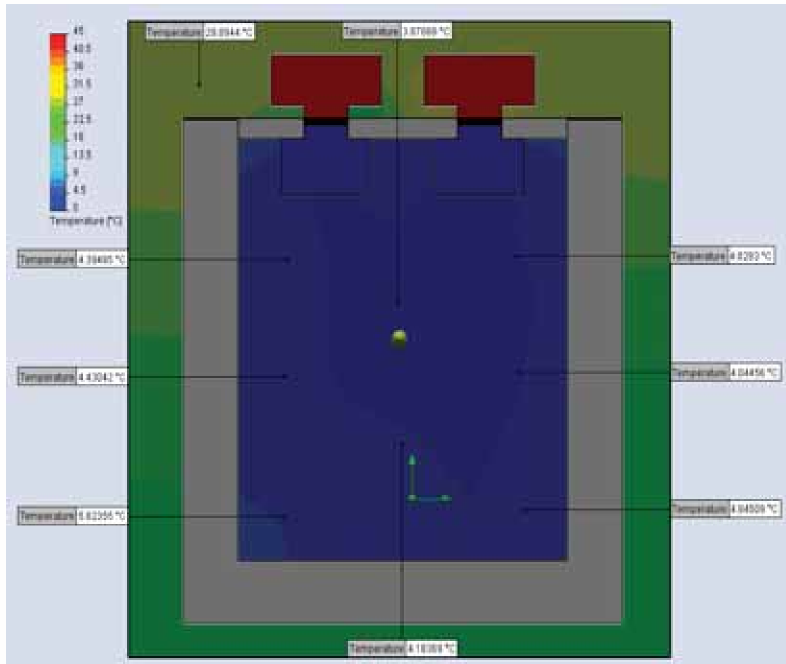


Time graph; Full operation of TECMs at 20 ˚C – 17min

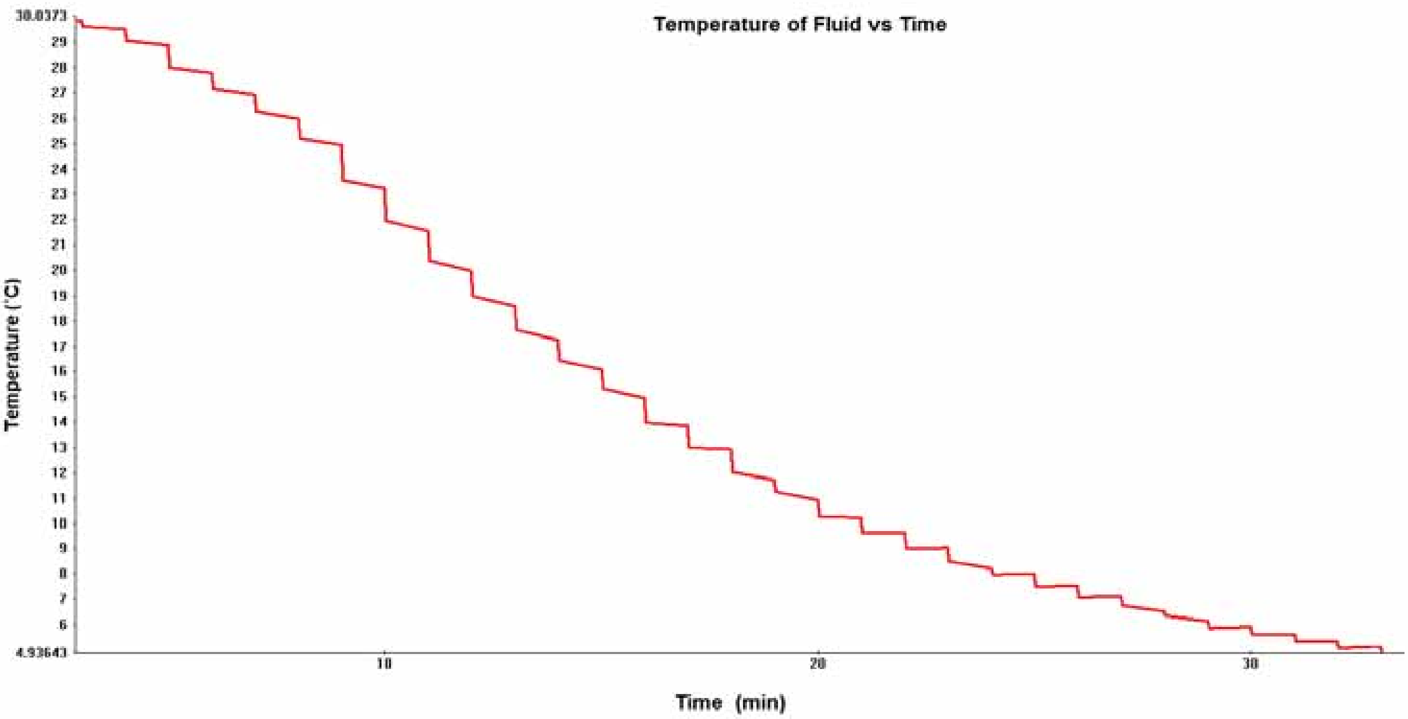
Temperature profile



Temperature profile; No-operation of TECMs at 30 ˚C

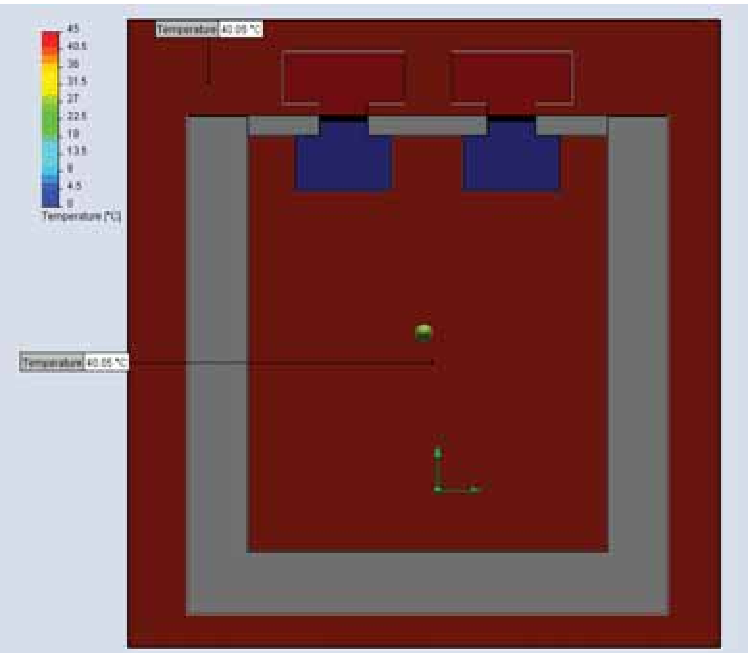


Temperature profile; Full operation of TECMs at 30 ˚C

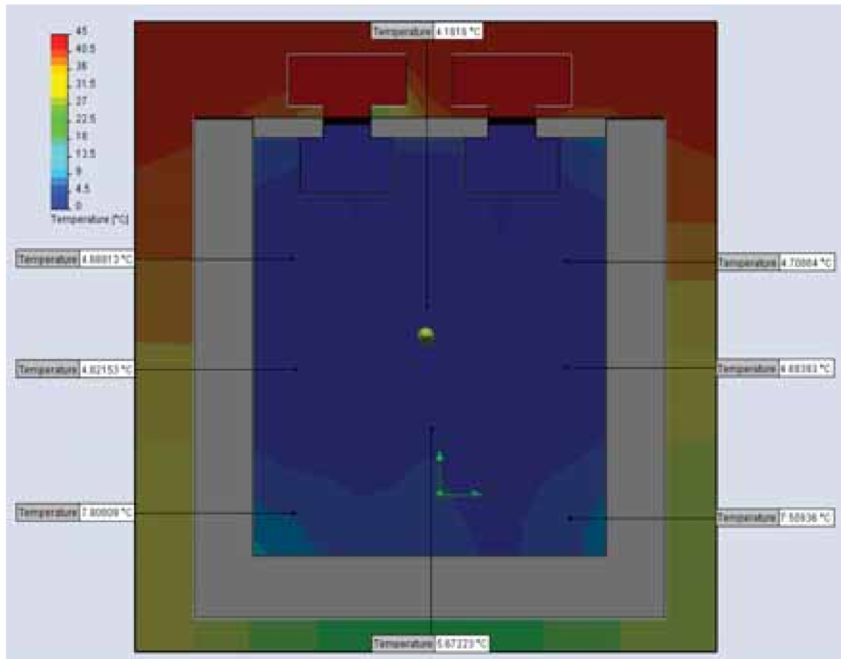


Time graph; Full operation of TECMs at 30 ˚C

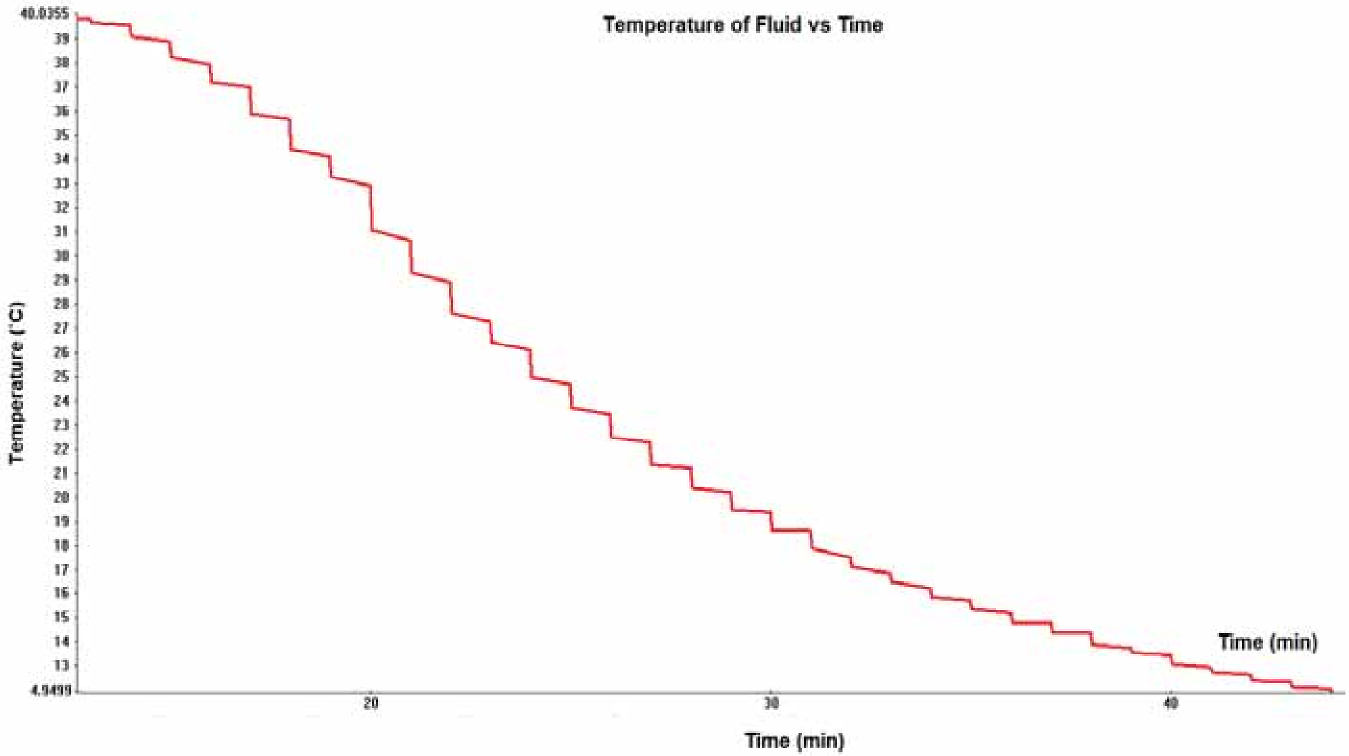
Temperature profile



Temperature profile; No-operation of TECMs at 40 ˚C



Temperature profile; Full operation of TECMs at 40 ˚C



Time graph; Full operation of TECMs at 40 ˚C

Actual constructed model and thermoelectric heat pumping assembly

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heat sink fan assembly

cold sink fan assembly

Conclusion

- The power consumption of different topologies of cooling system were verified
- The performance of the cooling holder was evaluated under normal operating conditions to determine if its cooling capacity is adequate.
- various temperature simulations that have done are discussed.
- The topology with two TECMs is the best topology for the cooling holder design, because it is able to cause a big temperature difference which is enough to cool the refrigeration compartment to 5 ˚C, whilst the ambient temperature is about 30 ˚C.
- This topology also consumes the least amount of power of all the topologies that have the necessary cooling capacity.

Thank you !