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SOLAR THERMAL ENERGY RESEARCH GROUP

Solar thermal storage in power generation using phase change material with heat pipes and fins to enhance heat transfer.

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Design philosophy and objectives

Use passive natural occurring phenomena to transfer heat:

- Design and test a modular PCS module.
- Determine the module's thermal characteristics experimentally.
- Develop a numerical model and validate it by comparing it to the module experiments.
- Use the results to design a PCS system for a power generation application.

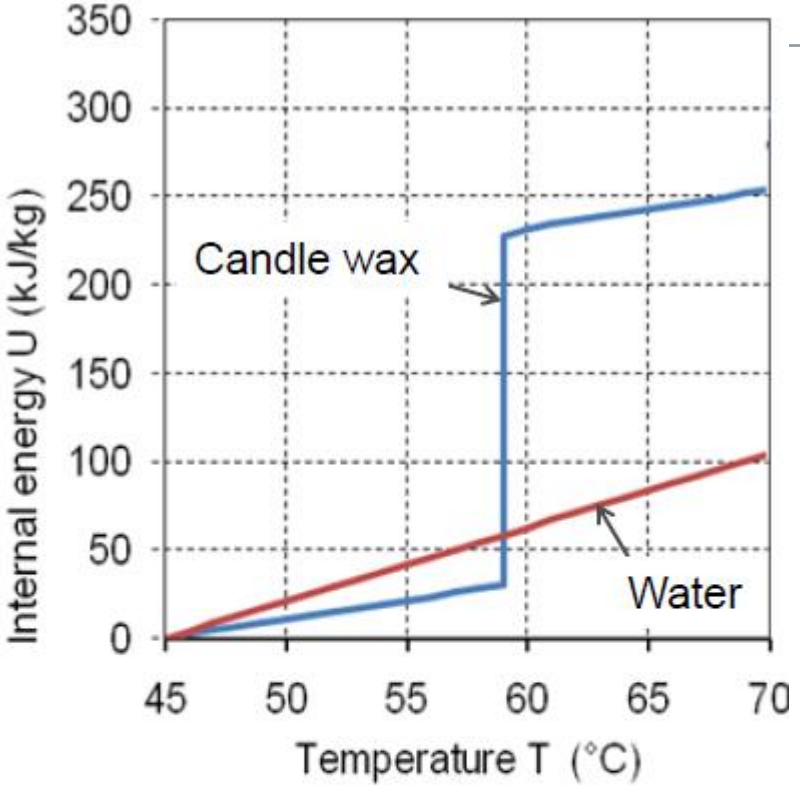
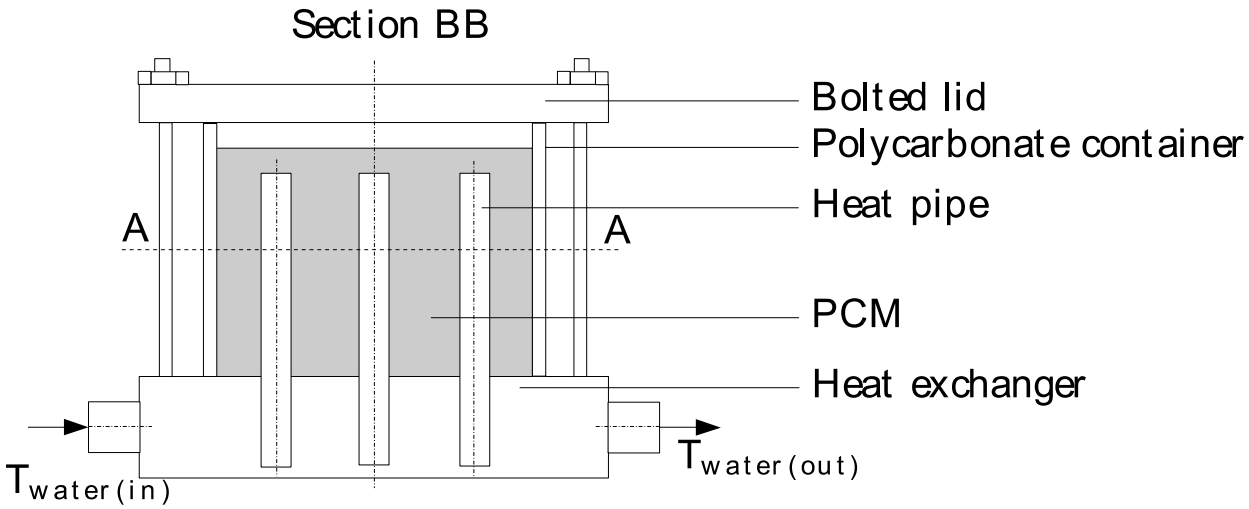


Fig 1. Internal energy of wax and water

Fig 2. Rectangular multichannel heat pipes

Background to phase change storage systems (PCS)



Different storage systems:

- Integral storage
- Indirect systems

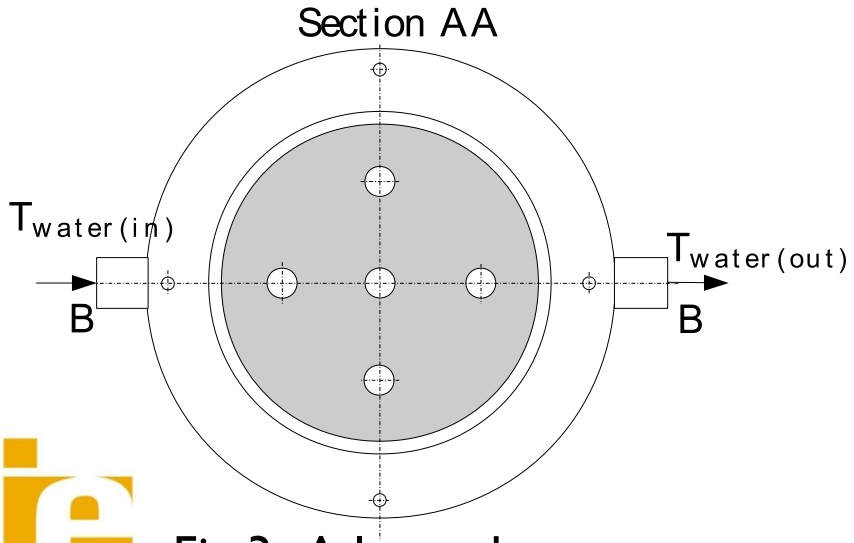


Fig 3. A latent heat storage test section (Robak *et al*, 2011)

Phase change storage system advantages

- Stores more heat across smaller temperature range,
- Saves on premium fuels and
- Increases system reliability and may improve energy performance.

Experimental setup

Experimental procedure:

- Measure temperatures and flow rates.
- Calculate energy balance of the components during the cycle.

Charge up phase

- Heat kettle water to 90°C
- Keep kettle water close to 90°C until all the wax has melted

Discharge phase

- Extract hot water from kettle
- Cool down wax container with heat exchanger

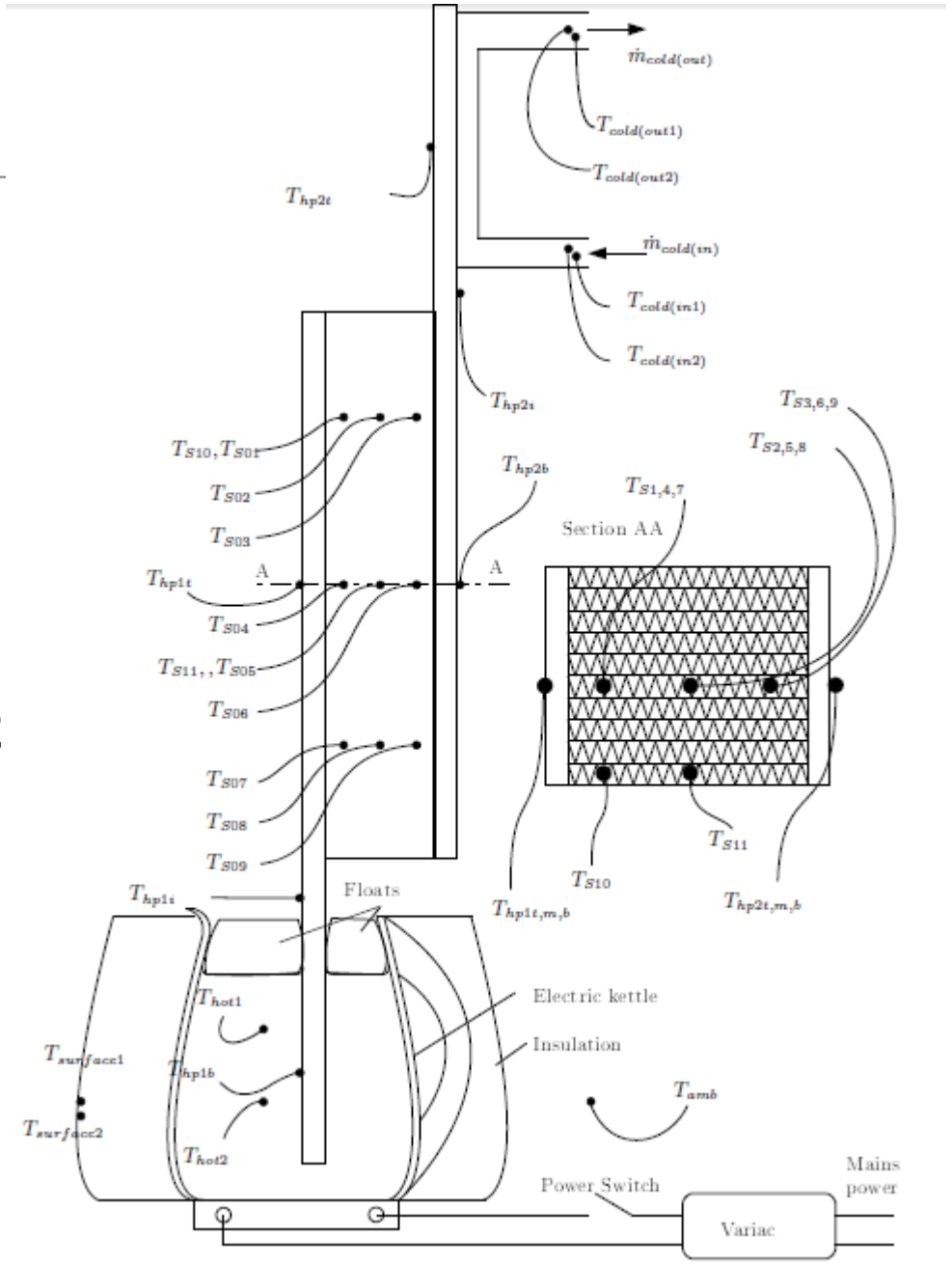


Fig 4. Experimental setup of the PCS module

Numerical thermal resistance model

- Keep track of the temperature and state (is it solid, mixture or totally liquid) in the control volumes.
- Change the length of wax as it melts and expands or solidifies and contracts.

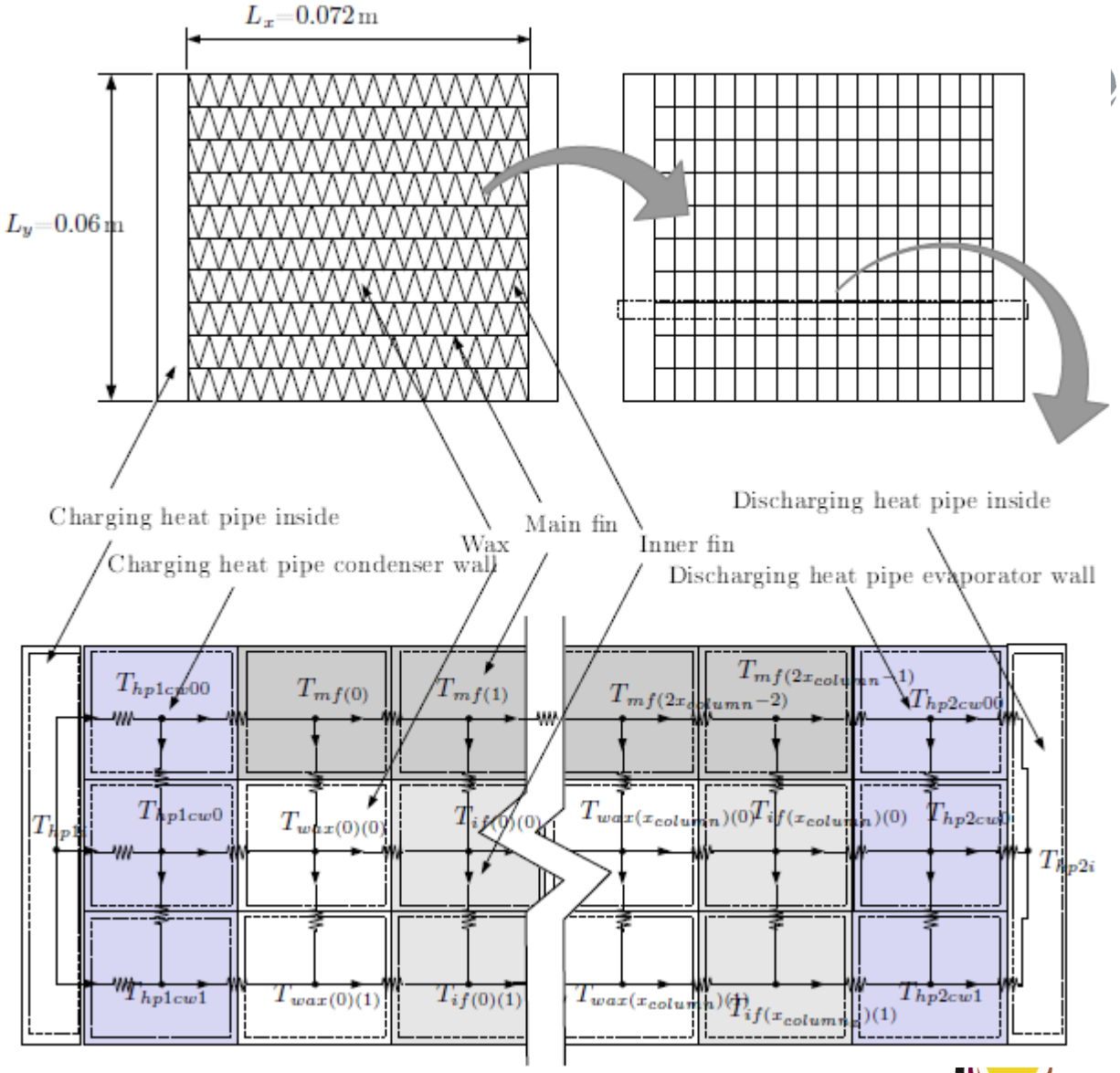
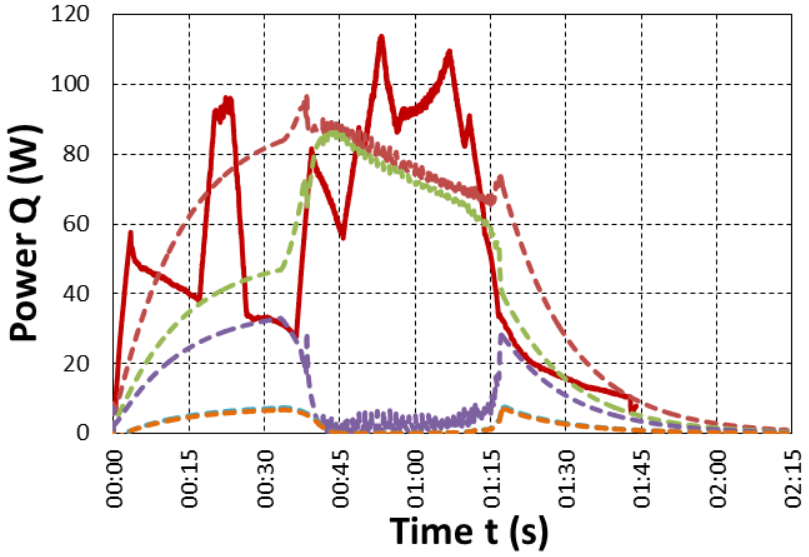
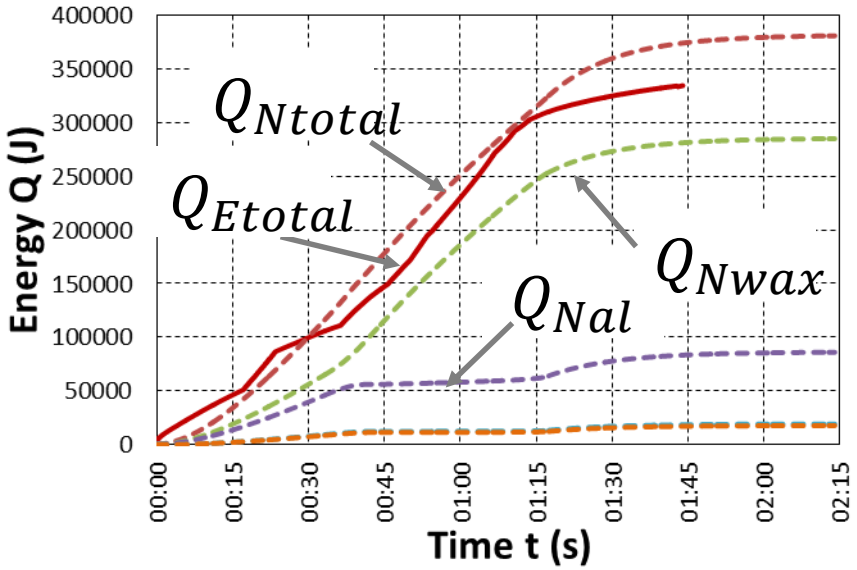


Fig 5. Thermal resistive diagram of PCS module

Power and energy response charge phase





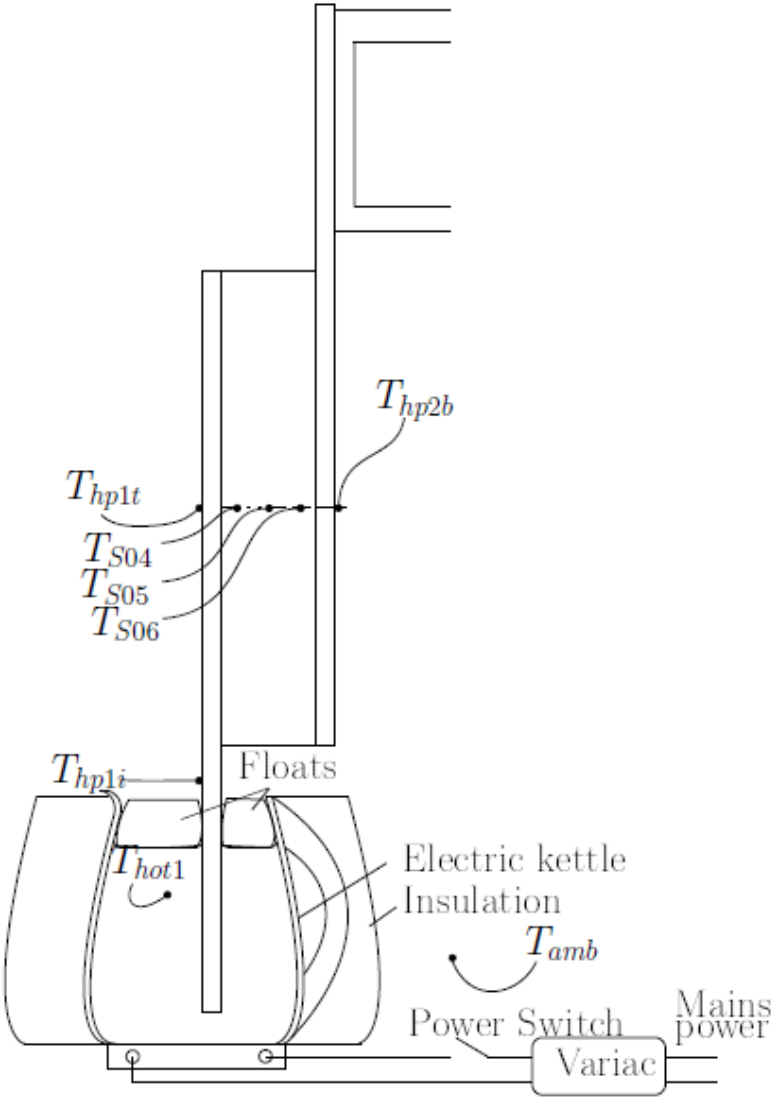
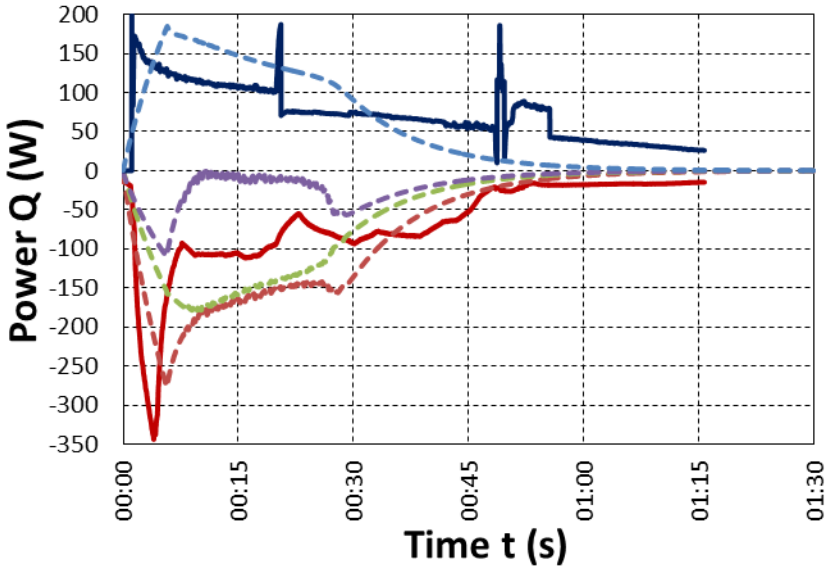


Fig 8. Experimental setup a

Fig 6-7. Power and energy response from the charge cycle.

Power and energy response discharge phase



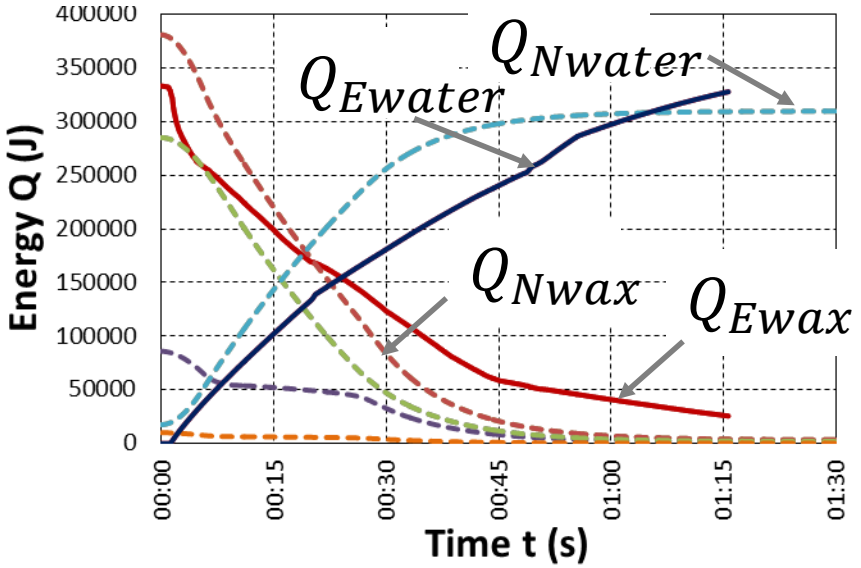


Fig 9-10. Power and energy response from the discharge cycle.

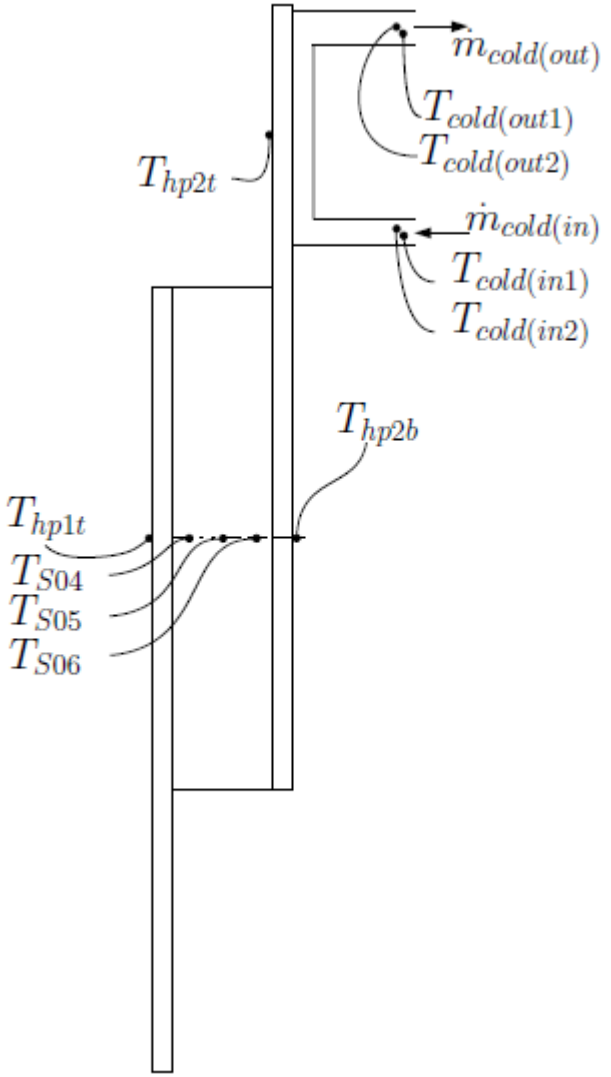


Fig 11. Experimental setup b

Concept development

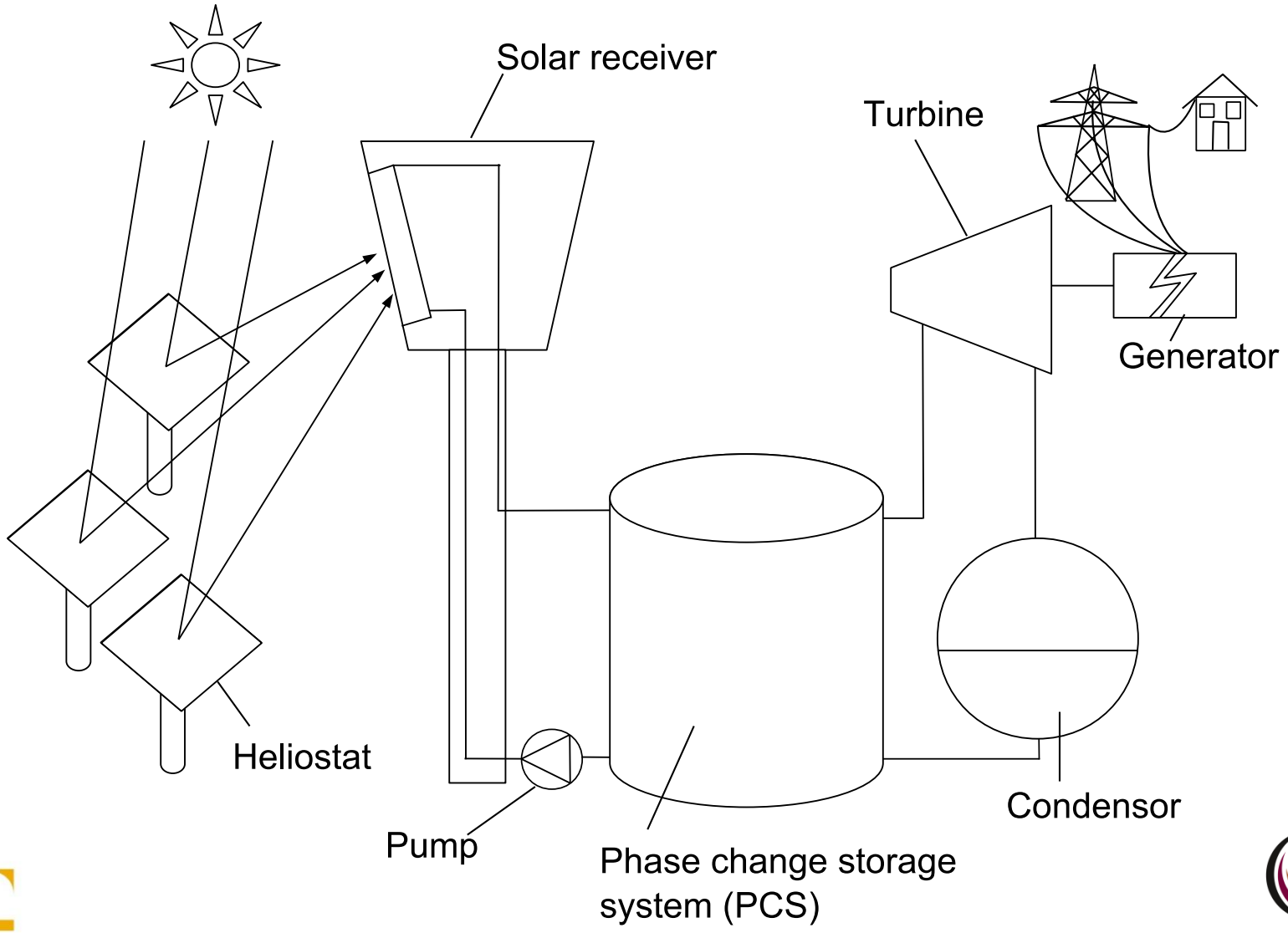


Fig 12. System layout of solar tower with latent storage

Temperatures during the summer solstice

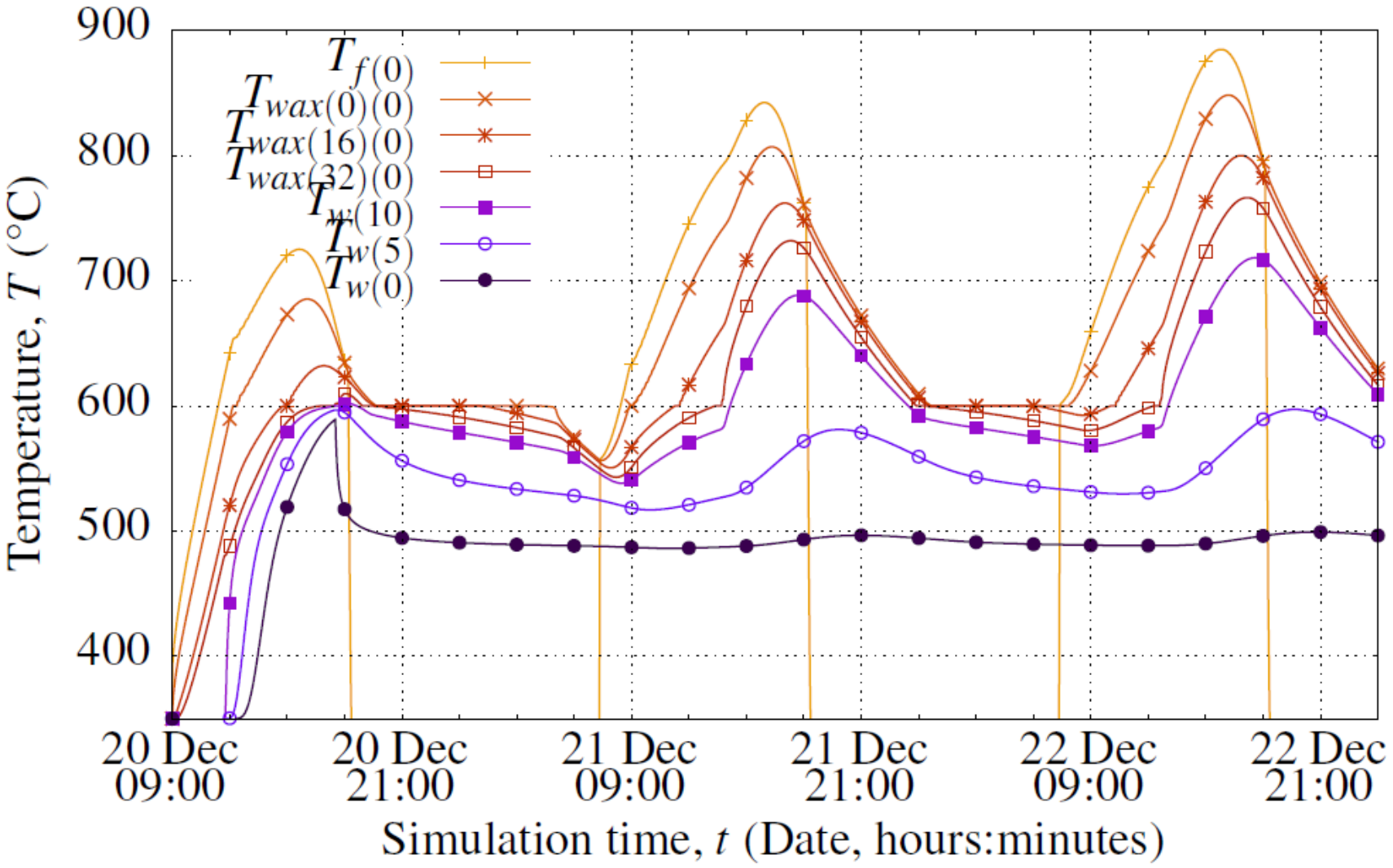


Fig 13. Temperature variation of the PCS system

Energy during summer solstice

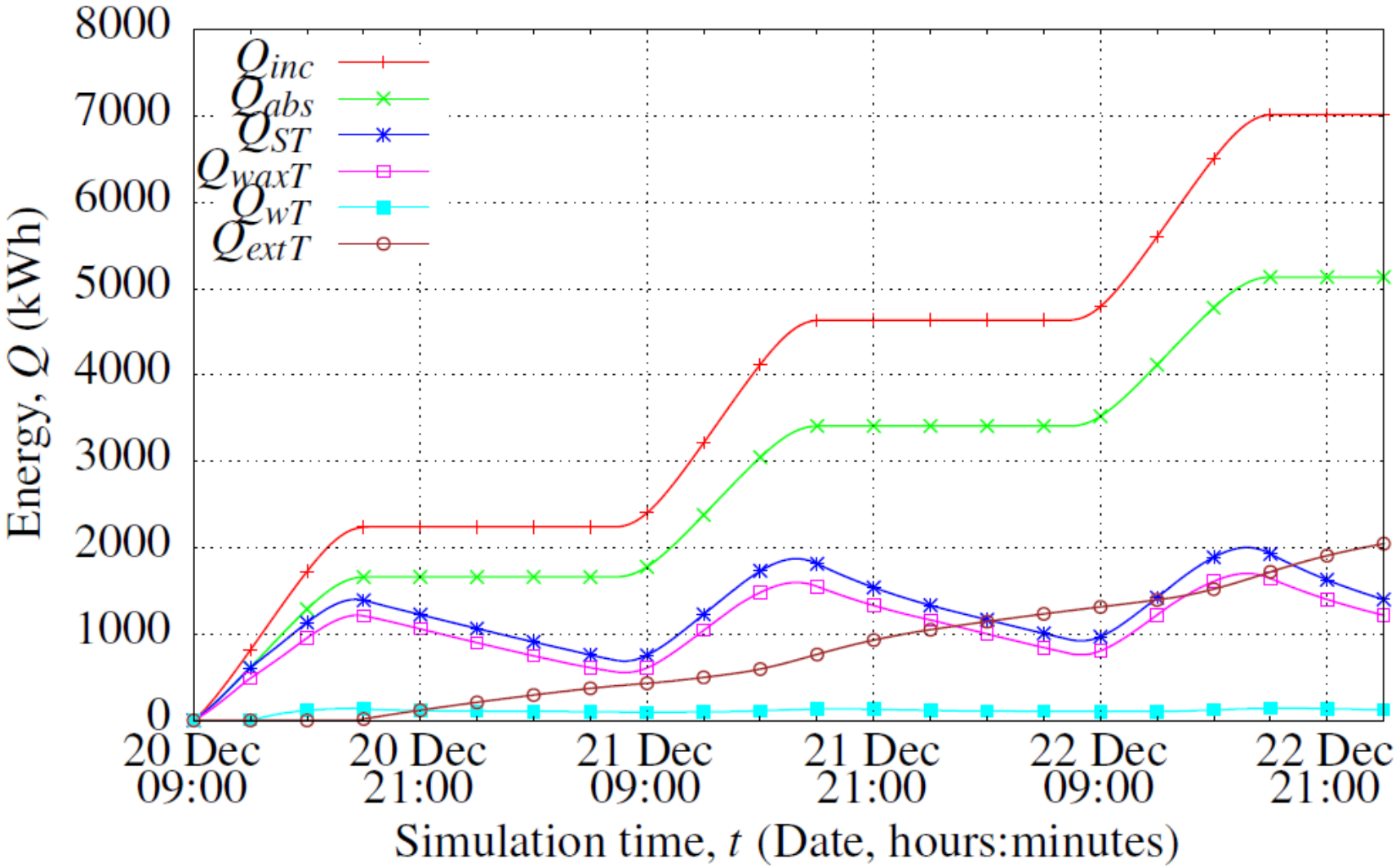


Fig 14. Energy variations during simulation

Power during summer solstice

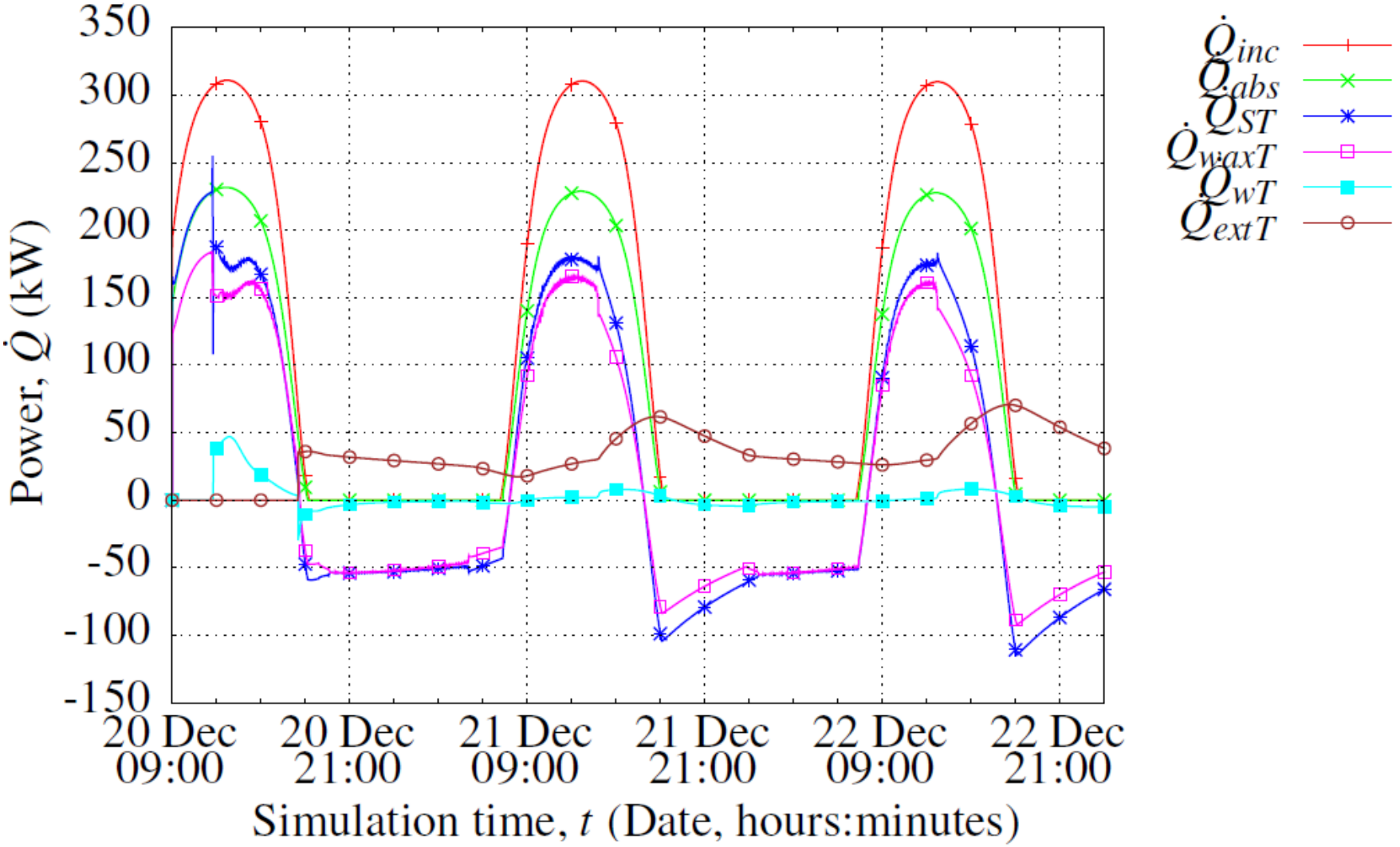


Fig 15. Power variation of the PCS system

Conclusions

- The numerical model correlates well with the experimental tests.
- Heat is quickly transferred into the wax during the charge phase and it can be quickly extracted due to the many finned heat paths.
- Heat pipes and fins are effective in transferring heat to and from the storage container.
- The numerical storage model was successfully used to simulate a power plant fitted to the Helio 100 field
- Power may be generated around the clock with the Helio 100 solar field or alternately it may be used as a small peaking station with the aid of a PCS system

All glory to my LORD Jesus Christ
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