FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

Absorption power cycle with aqueous salt solution for low temperature heat utilization

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INTRODUCTION AND STATE OF THE ART

Absorption power cycle (APC)

- Known as Kalina cycle, with water-ammonia fluid, partly commercialized
- Limited application due to technical issues and failures, limited experiments
- Many theoretical works predict benefit from temperature glide, propose complex configurations
- Suggested also combined power and cooling configurations

Water-LiBr working fluid

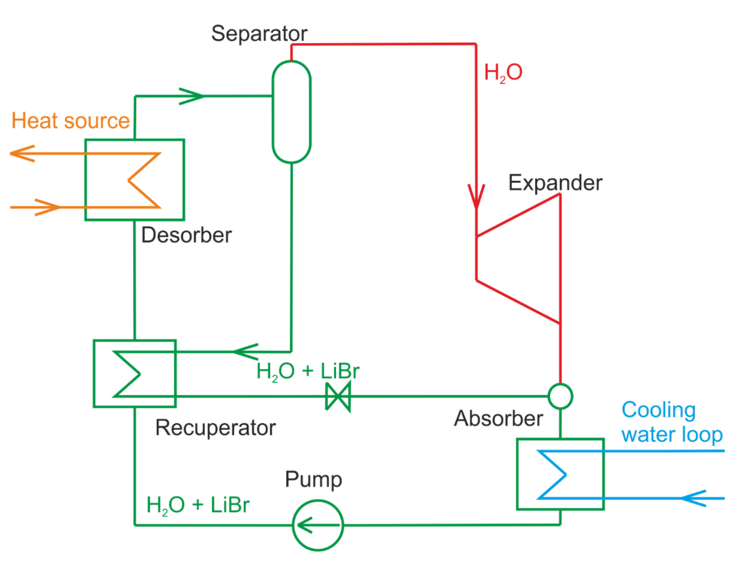
- Fluid common for absorption cooling, only few works suggest for APC
- **Limited literature** on prospect **in waste heat** (generally open loop heat source) utilization by salt APC, **no work on specific combined power & cooling system**
- **No experiments** with salt solution APC reported, limited on actual T glide
- Certain specifics compared to Kalina cycle – LiBr non-volatile, low pressures
  - **Turbines** appear as suitable expanders, at low T prospect of **3D print**

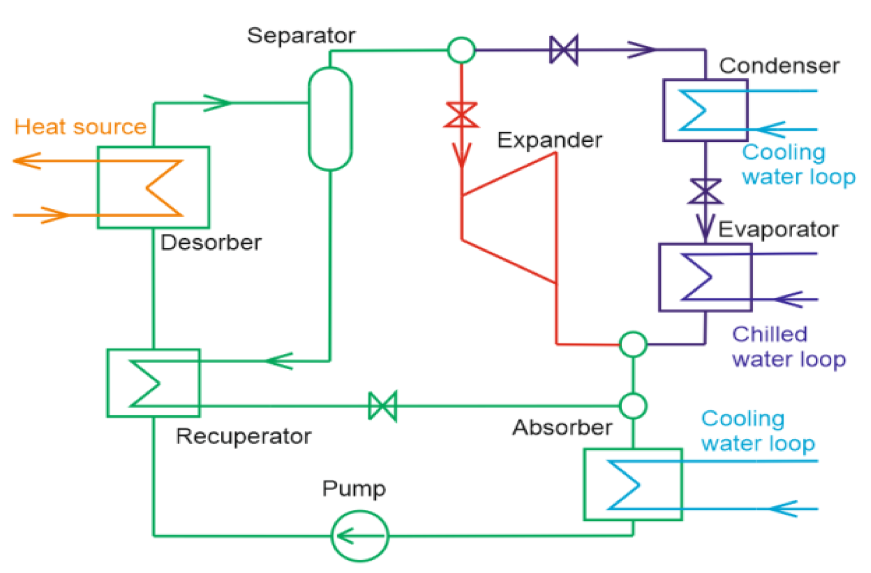
THESIS OBJECTIVES

- Focusing on salt solution APC
  - Find theoretical benefits and range of prospective applications
  - Upon the theoretical potential, prove technical feasibility of the APC by:
    - Designing and building APC as a proof-of-concept
    - Demonstration of operability of APC and its components, including turboexpander featuring additively manufactured components
    - Provide comparison between theoretical and real operation of key system's components, especially regarding temperature glide and expander feasibility
  - Based on system operation, suggest actual range of applicability and suggested heading of future salt solution APC development

METHODOLOGY & MODELS

- Standard heat and mass balance
- Implementation of fluid properties, HX calculation by elements due to T glide, iterative calculation of equation system in EES
- **Configurations:**
  - Focus on technical feasibility - simple
  - **APC** **APCC** (absorption power and cooling cycle)



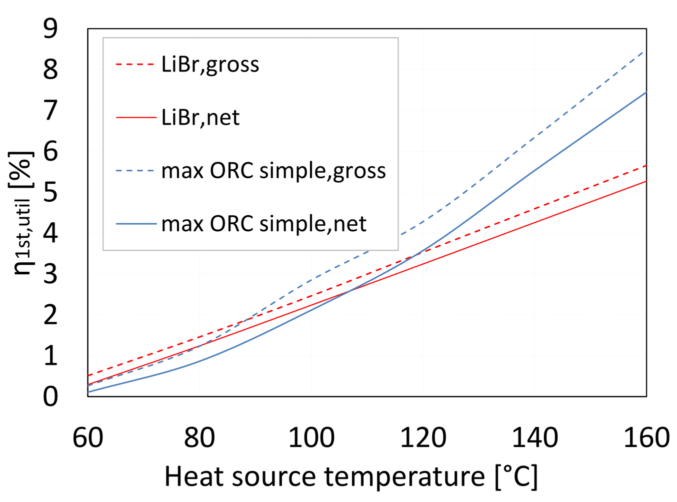


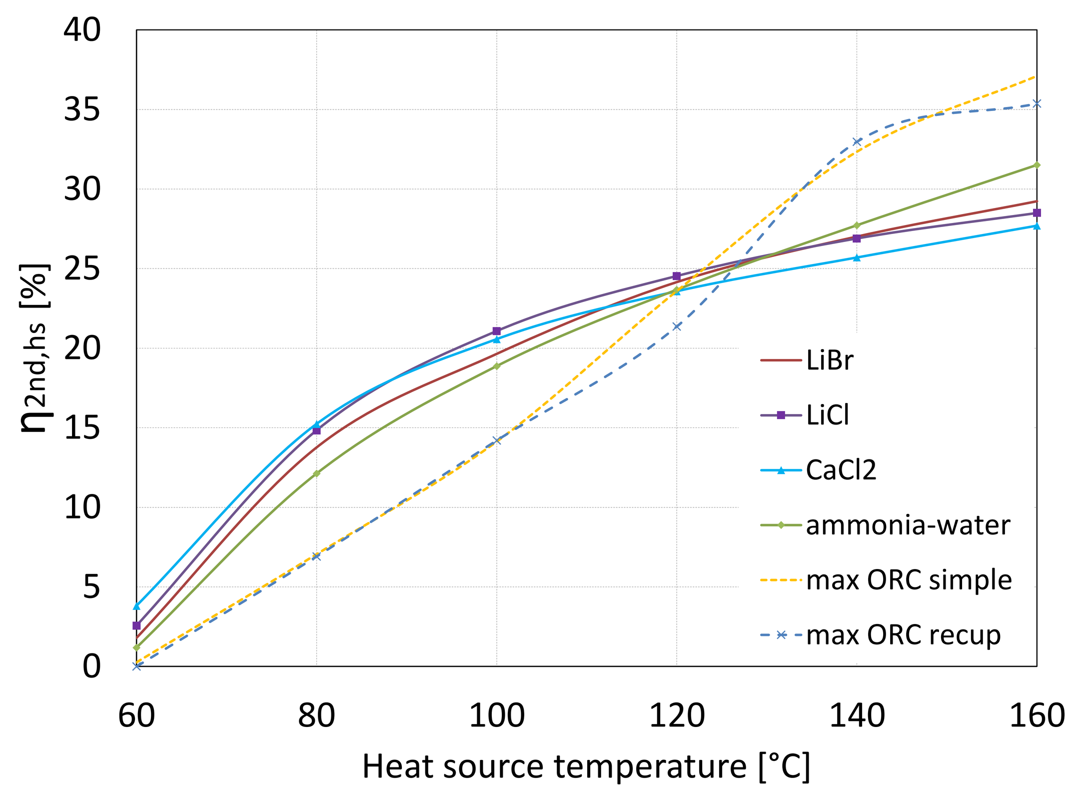
- Considered parasitic load – especially important for low T systems

- **Key performance indicators**
  - Cycle efficiency – not suitable for open loop heat source!
  - Utilization efficiency – includes cycle efficiency & ability for heat extraction
  - Energy & exergy efficiency, gross & net values

THEORETICAL APC INVESTIGATIONS

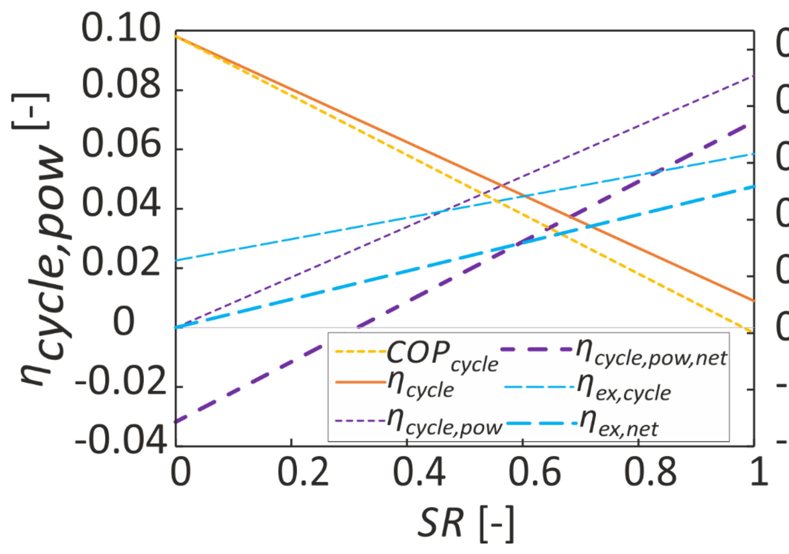
- Salt APC superior to ORC below 120°C heat source in WHR applications
- Salt APC slightly better than water-ammonia APC
- All salts similar performance
  - LiBr has most technical exp.
- Importance of gross vs. net W

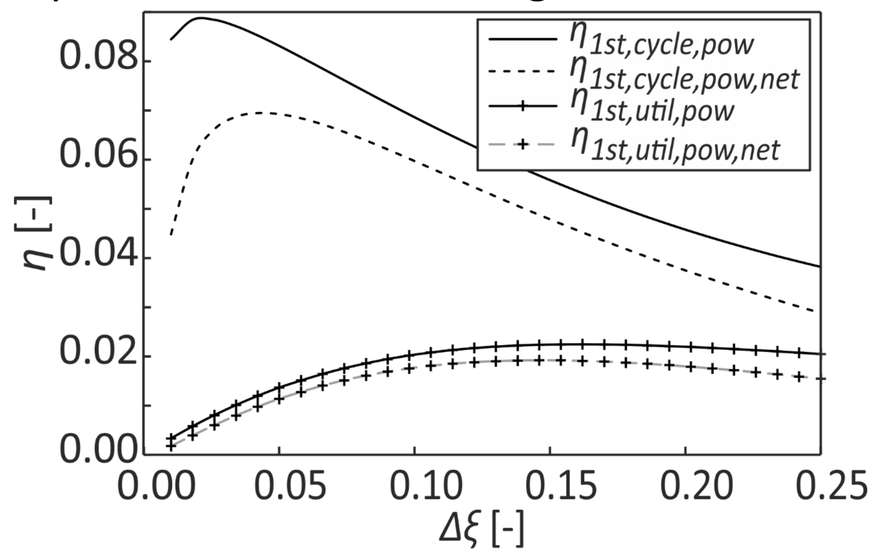




THEORETICAL APCC INVESTIGATIONS

- Flexible ratio between cooling and power (linear change in parameters)
- Comparable to ORC for W, superior to compression chiller for cold
- Optimal WHR power production at different parameters than cooling

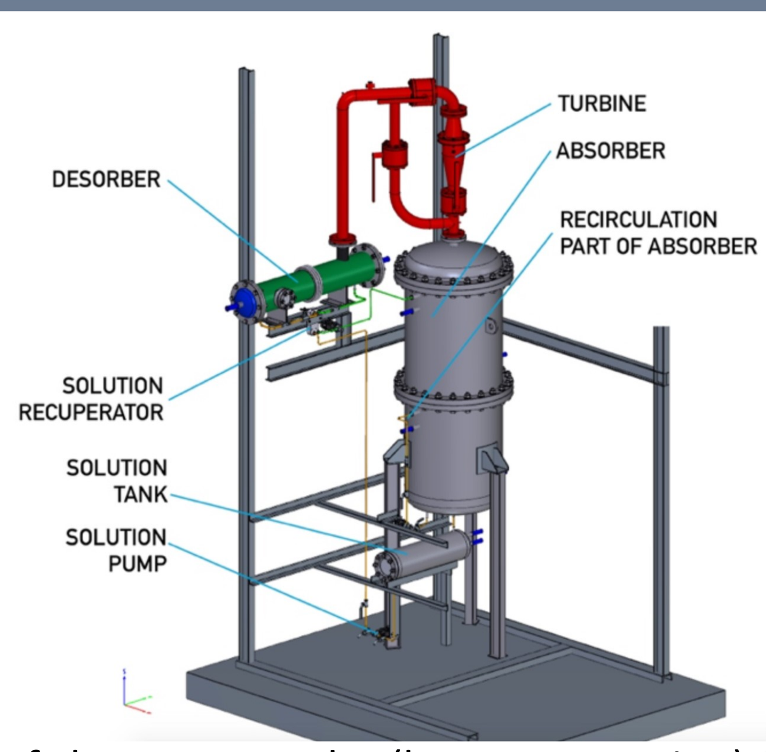




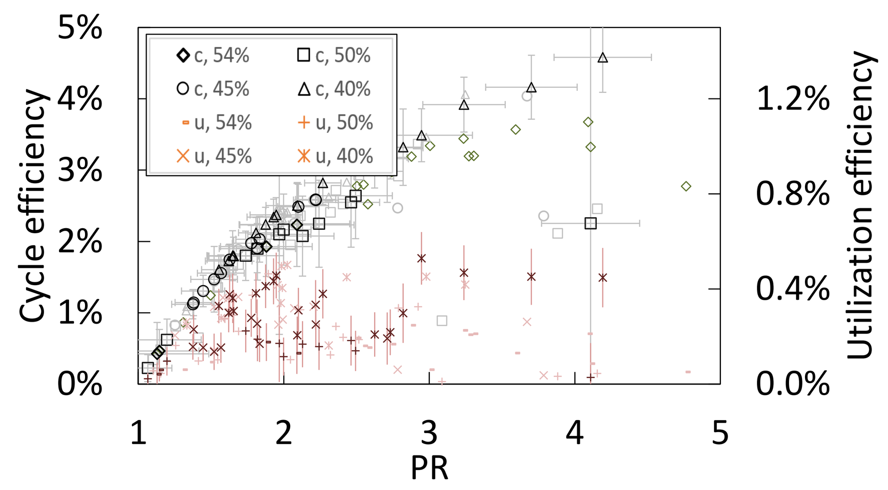
EXPERIMENTAL LiBr APC DEVELOPMENT

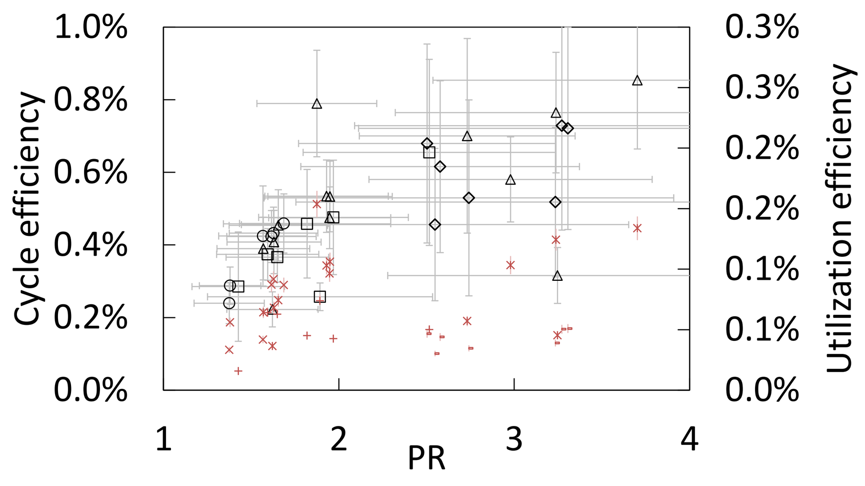
Proof of concept
20 kW_{th}, 300 W_{el} unit

- World 1st reported salt APC
- Expander – nylone 3D printed turbine

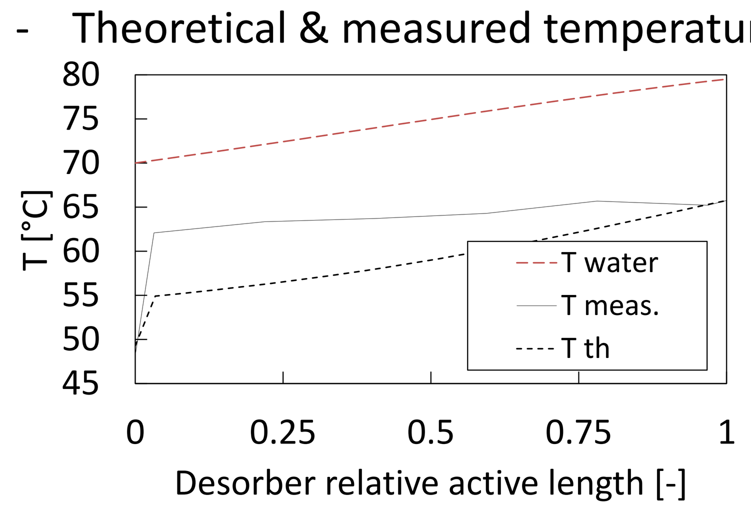


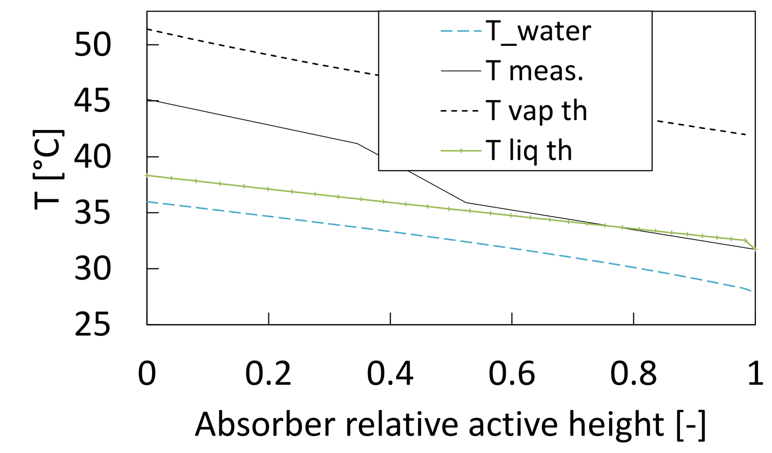
- Potential with state-of-the-art expander (bypass operation) & actual system efficiency



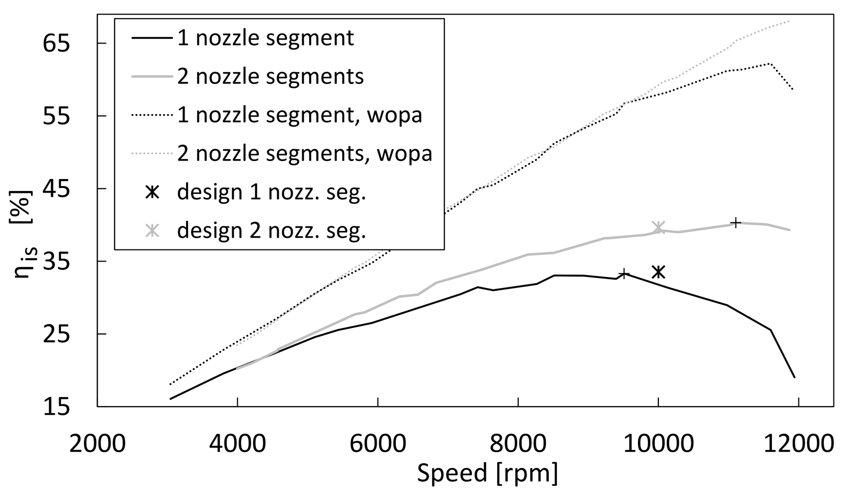


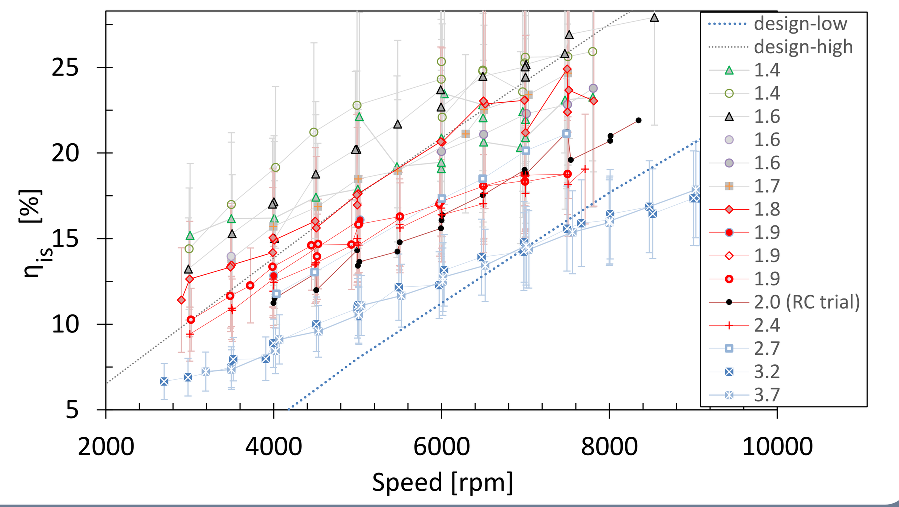
- Theoretical & measured temperature glide profiles for desorber & absorber





- Expander performance – trials with air turbine, comparison with models & APC low pressure vapour (mostly supersonic) turbine measured characteristics





CONCLUSIONS

- Evaluated prospects of salt APC and APCC, suitable for low temperature decentralized applications
- Built world's 1st reported LiBr APC system, investigated its real parameters
  - Temperature glide worse than predicted
  - Heat transfer better in desorber, worse in absorber
- 3D printed polymer turboexpanders, especially for APC, technically feasible, further performance optimization has prospect of higher efficiency

MAIN AUTHOR'S REFERENCES ON THESIS TOPIC

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