

SES 2019

Copenhagen, Denmark

10-11 September 2019

Performance analysis of a heat pump system providing district heating and cooling through gradual heating and cooling

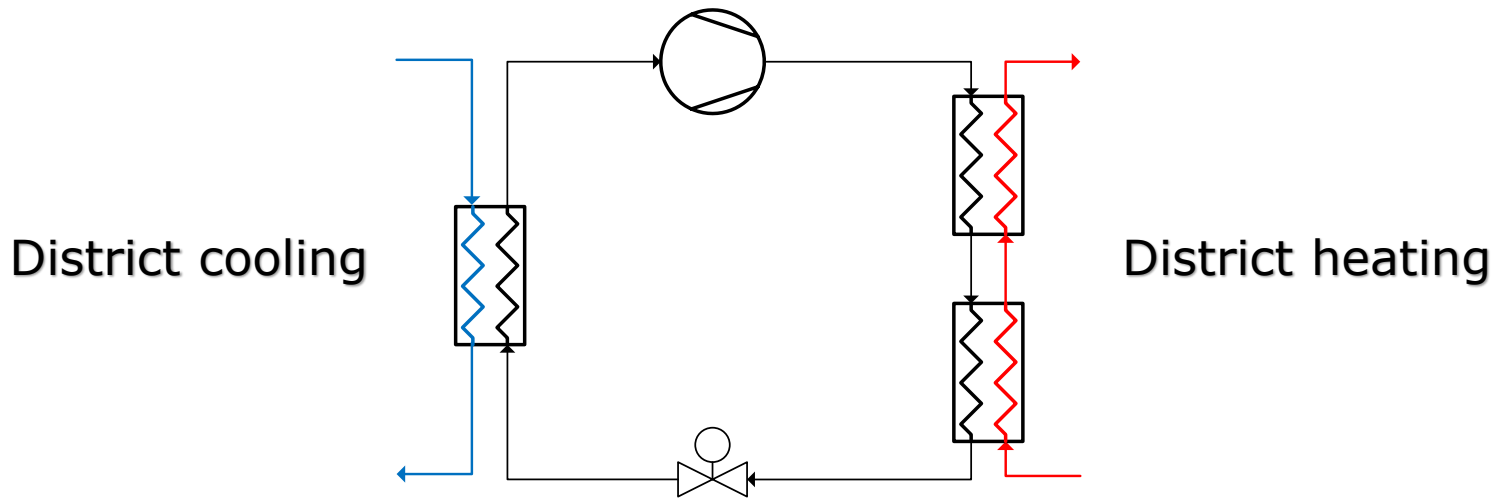
Presenter: R. Kofler

Co-authors: B.R. Kondakindhi, B. Elmegaard, C. Madsen, L.Olsen, W. B. Markussen

Introduction

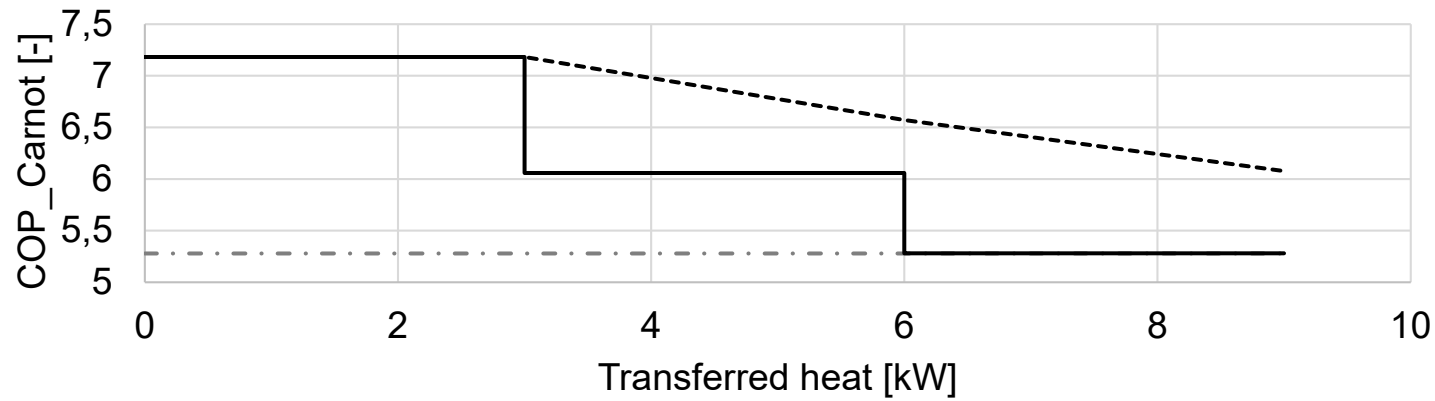
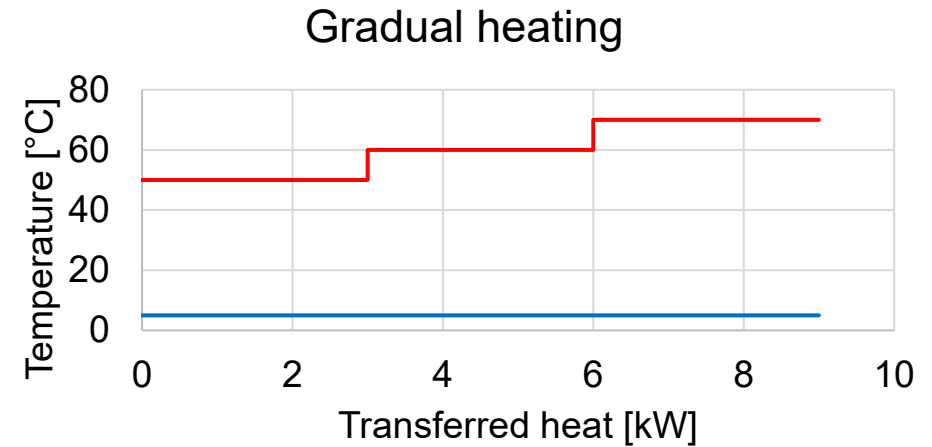
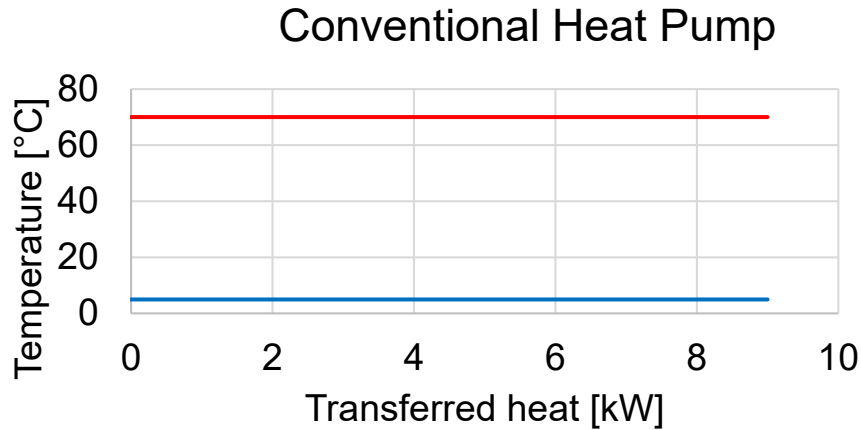


Power2
Heat/Cold



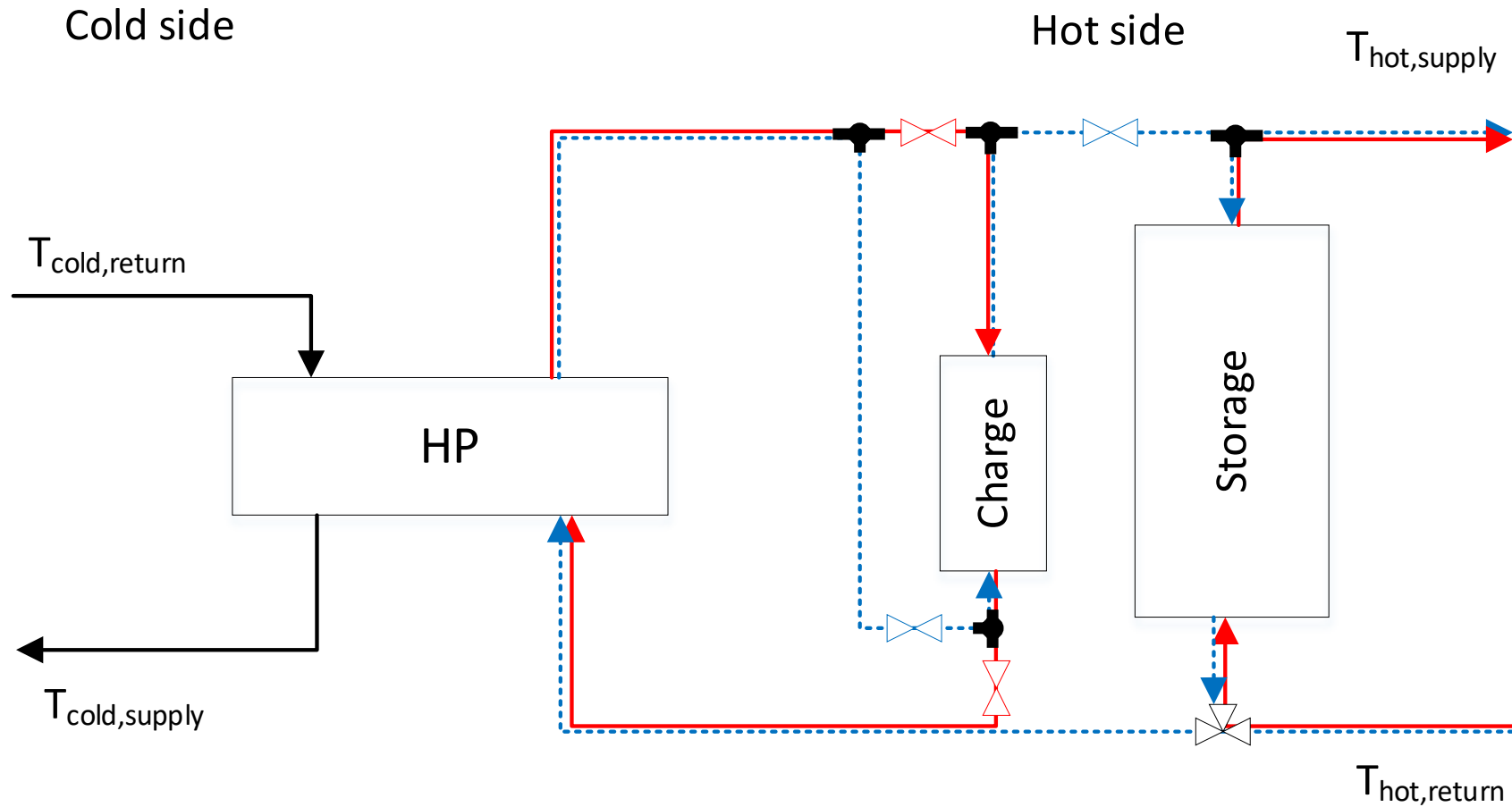
COP ↑↑↑
\$\$\$ ↓↓↓

Motivation gradual heating

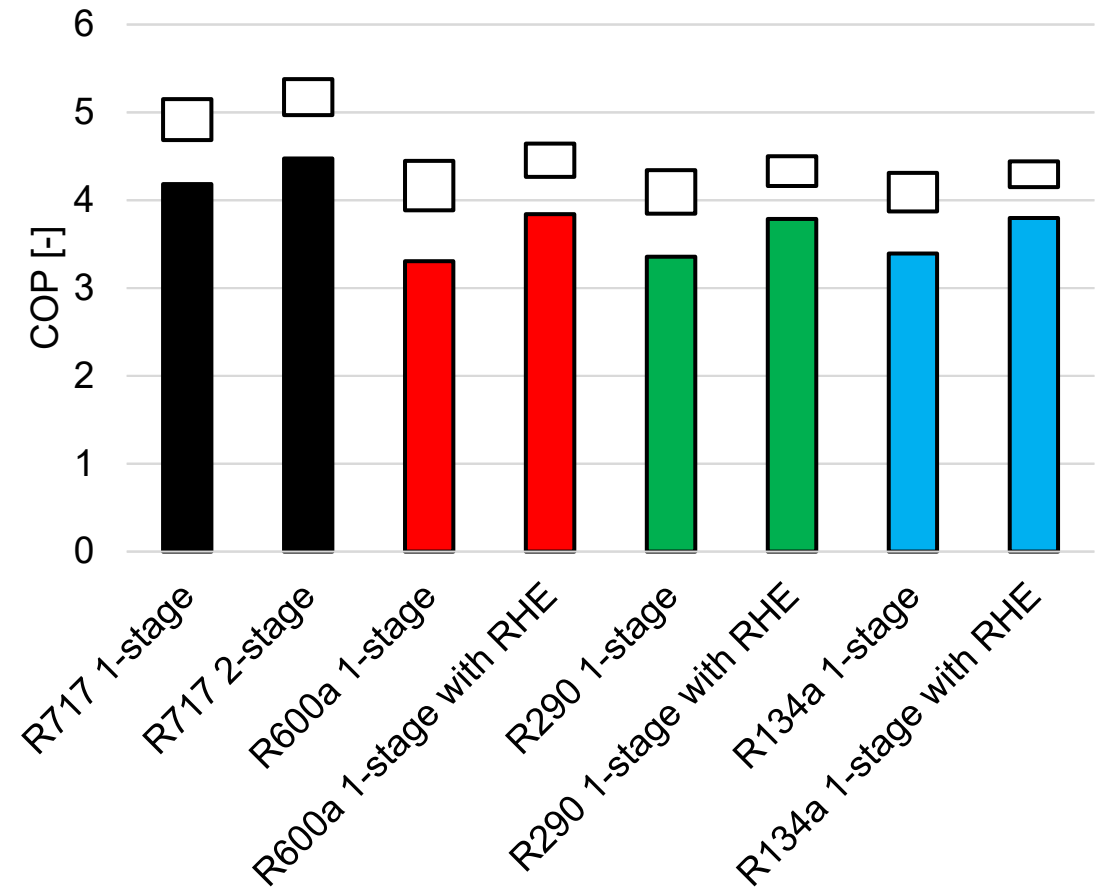
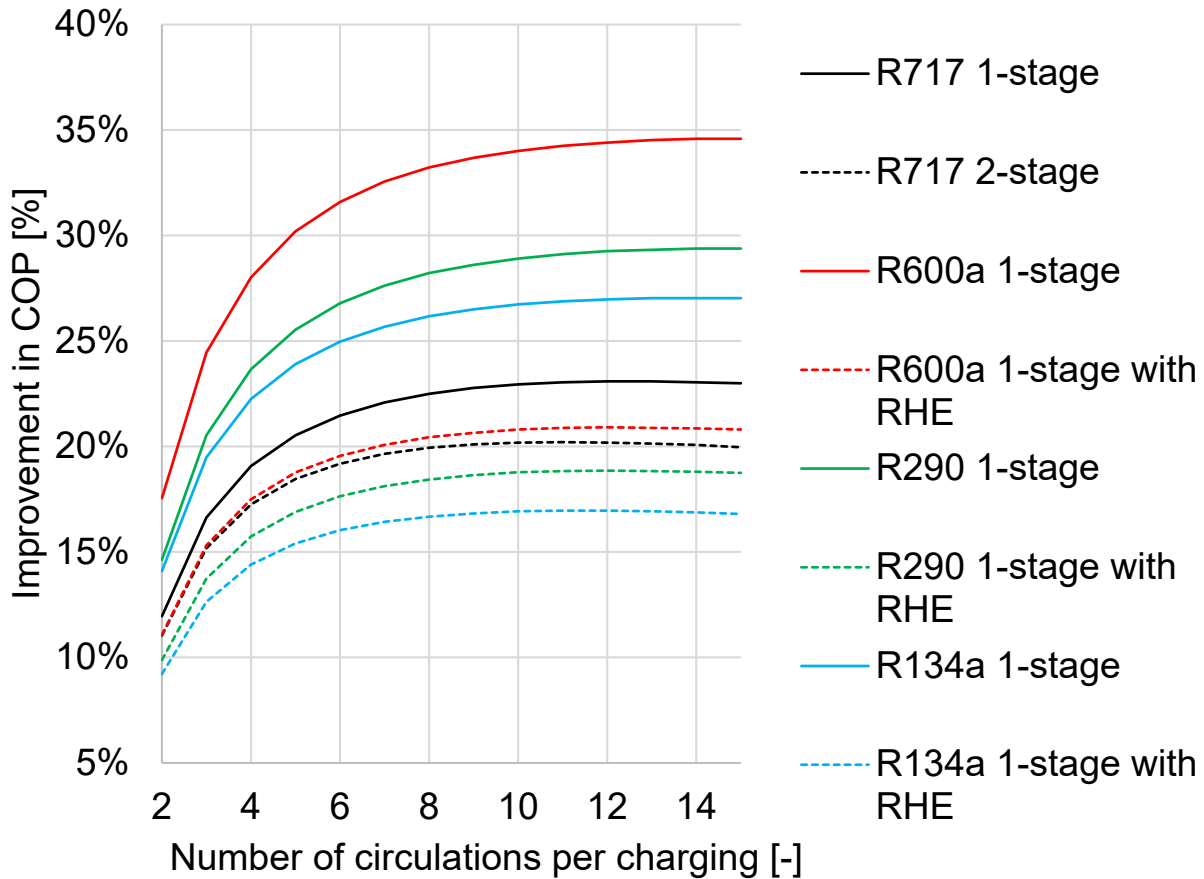


···· Conventional HP — Gradual heating - - - - Average gradual heating

Gradual heating with ISECOP system

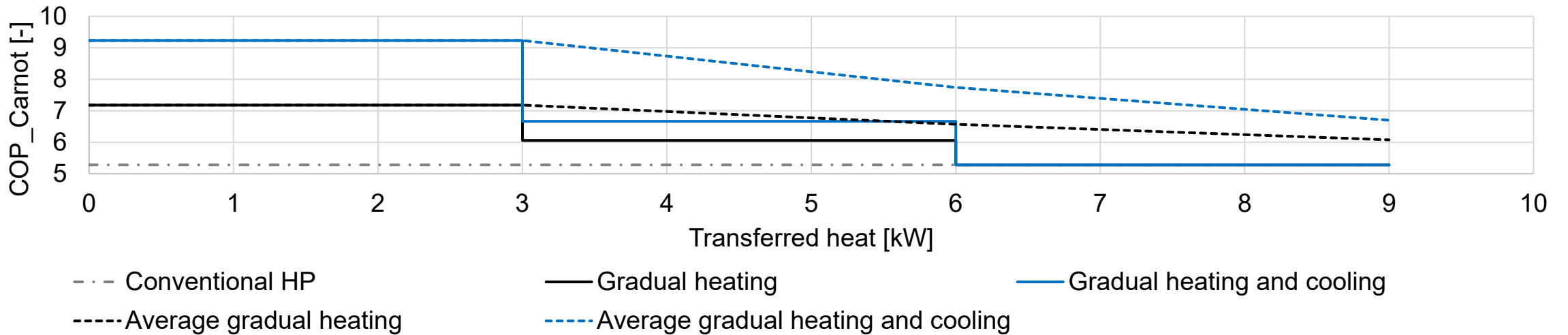
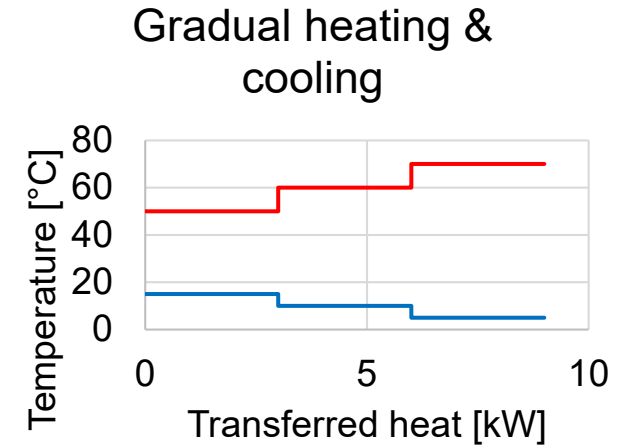
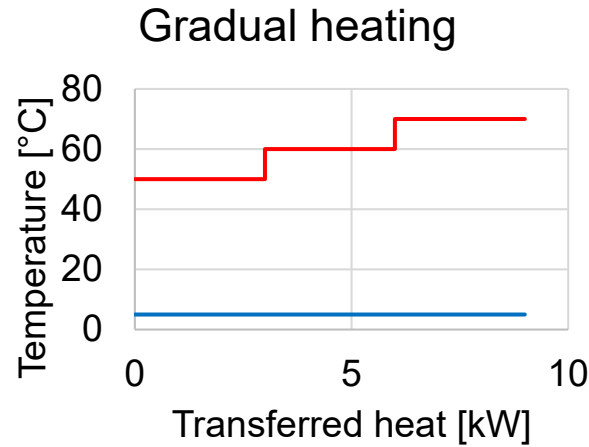
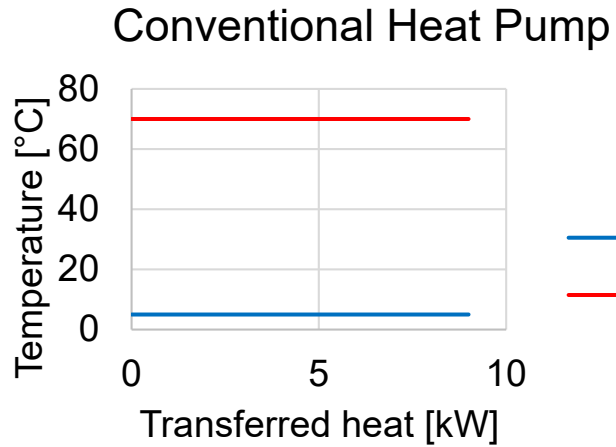


Results gradual heating

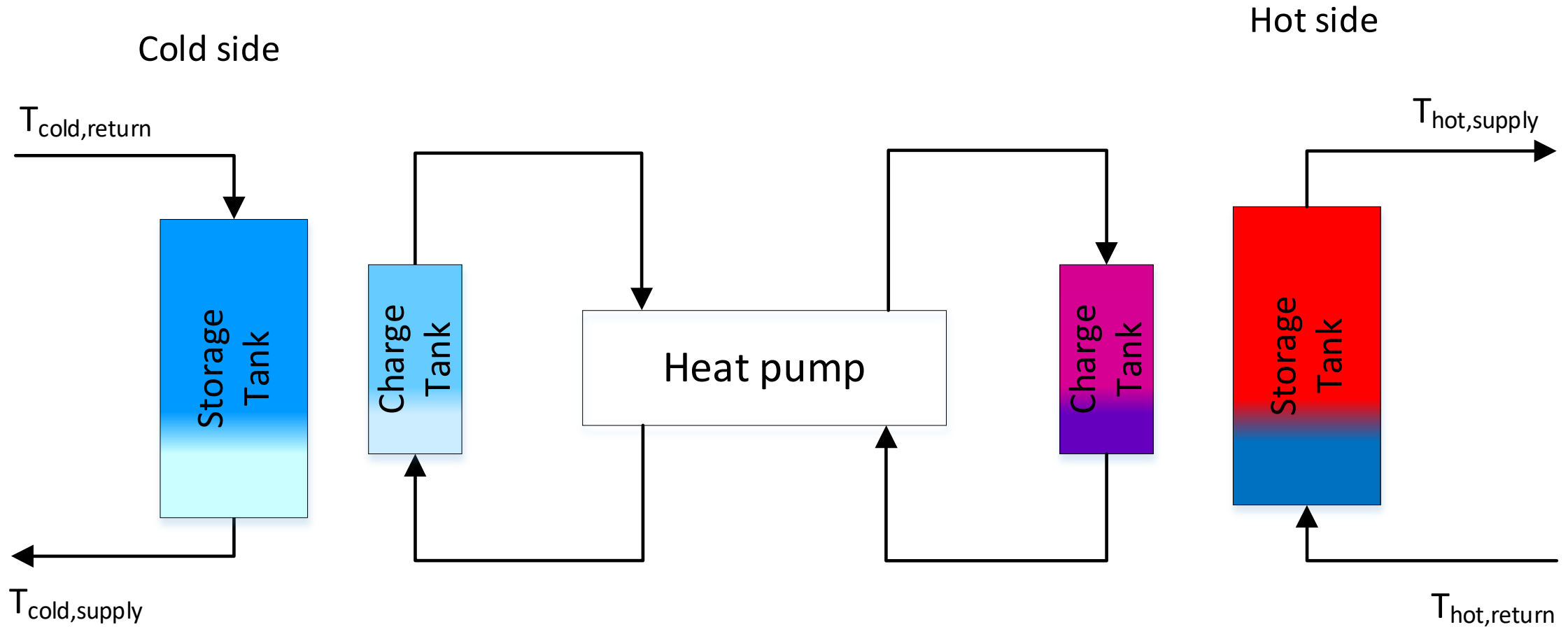


Kofler et al., 2019. Screening of heat pump performance improvements obtained through gradual heating using a tank system. Proceedings of the 25th International Congress of Refrigeration, International Institute of Refrigeration.

Motivation gradual heating & cooling

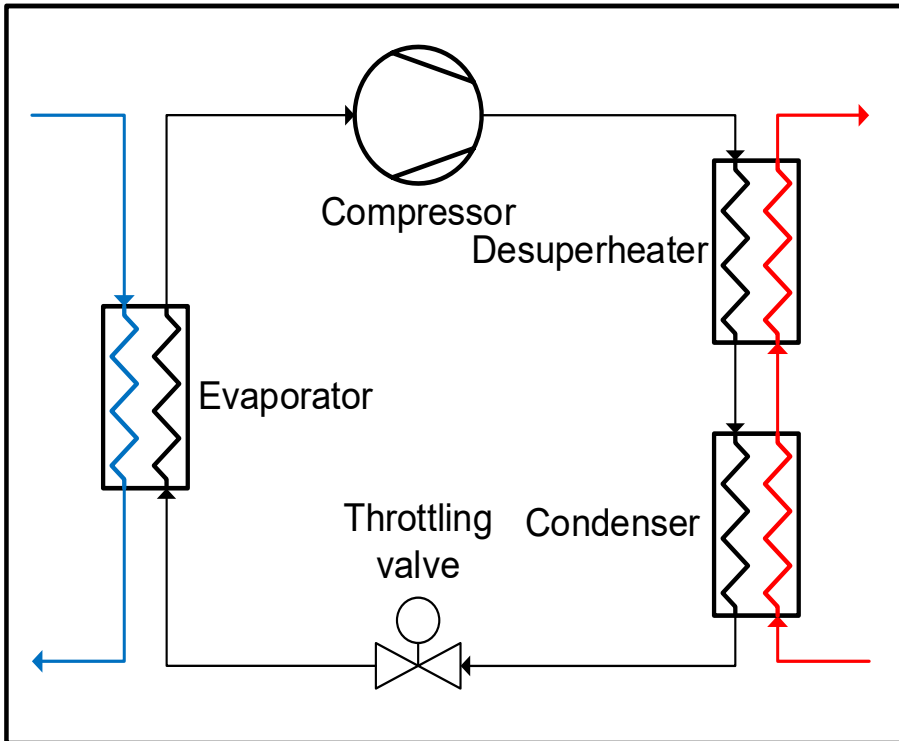


Gradual heating & cooling with ISECOP system



Case study

One-stage cycle



- Refrigerants:
 - Ammonia (300 kW)
 - R600a (10 kW)
- District heating
 - Return temperature 40 °C
 - Supply temperature 70 °C
- District cooling
 - Return temperature 15 °C
 - Supply temperature 8 °C

Simulation tool in EES

Evaporator Type

- Flooded Evaporator
- DEX

Internal Heat Exchanger With Subcooler

Compressor

Bock EX-HG 12F 60 4S

$V_S = 0,00006207 \text{ [m}^3\text{]}$
 $RPM = 7485 \text{ [min}^{-1}\text{]}$
 $f_Q = 0 \text{ [%]}$

Internal heat exchanger

$\eta_{RHE} = 0,6$
 $UA_{RHE} = \text{???? [kW/K]}$

Pump

$\eta_{is,Pump} = 0,8$
 $\Delta P_{CD} = 0,5 \text{ [bar]}$

Evaporator

$\Delta T_{min,EV} = 5 \text{ [K]}$
 $UA_{EV} = 1,233 \text{ [kW/K]}$
 $\Delta T_{SH} = 5 \text{ [C]}$

Condenser

$\Delta T_{min,CD} = 5 \text{ [K]}$
 $UA_{CD} = 0,9632 \text{ [kW/K]}$
 $UA_{Desup} = 0,1147 \text{ [kW/K]}$

Hot system

$N_{cycles} = 3$

Calculate V_{Tank} from t_{cycle} and $\dot{Q}_{Process,hot}$

$\dot{Q}_{Process,hot} = 10 \text{ [kW]}$
 $t_{cycle} = 300 \text{ [s]}$
 $V_{Tank} = 0,05383 \text{ [m}^3\text{]}$

Results

$COP_{total} = 4,113$
 $T_{ref,max} = 75,93 \text{ [C]}$
 $t_{Charge} = 900 \text{ [s]}$
 $\dot{m}_{water,hot} = 0,1794 \text{ [kg/s]}$
 $\dot{m}_{Water,regulate} = 0,05413 \text{ [kg/s]}$
Regulation = 30,17 [%]

Warnings

Compressor speed is higher than $1450 \text{ [min}^{-1}\text{]}$. Use a bigger compressor.

Buttons: Initialize, Calculate, Vary N_Cycle, Show plot, Save Inputs

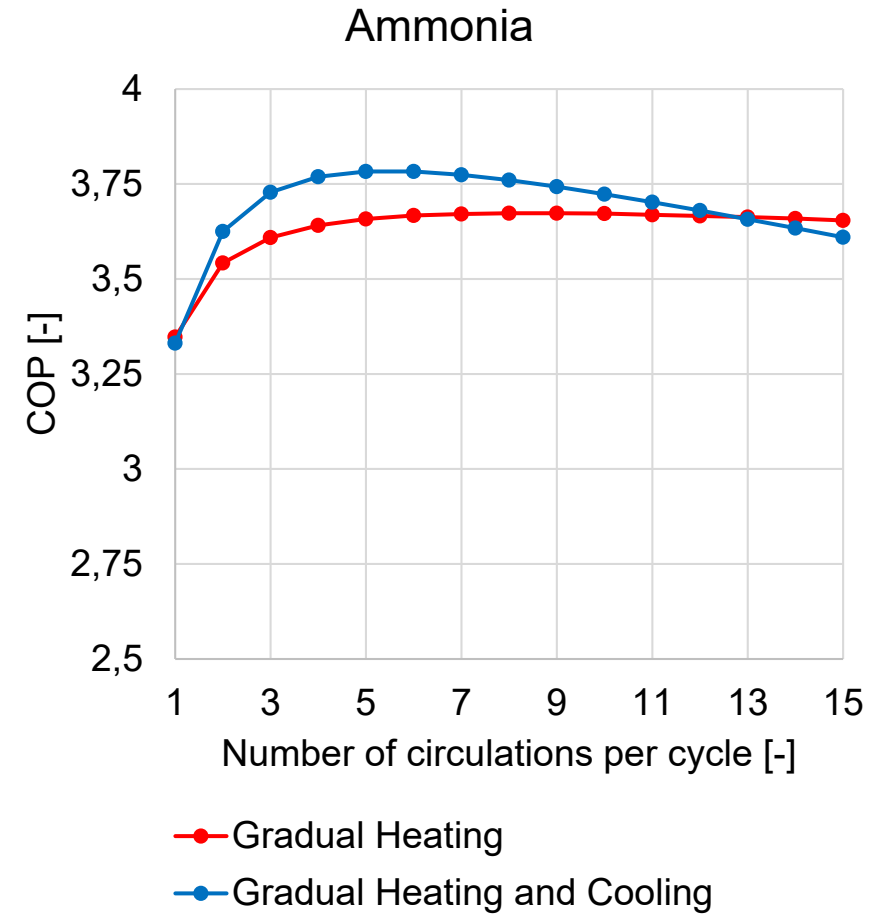
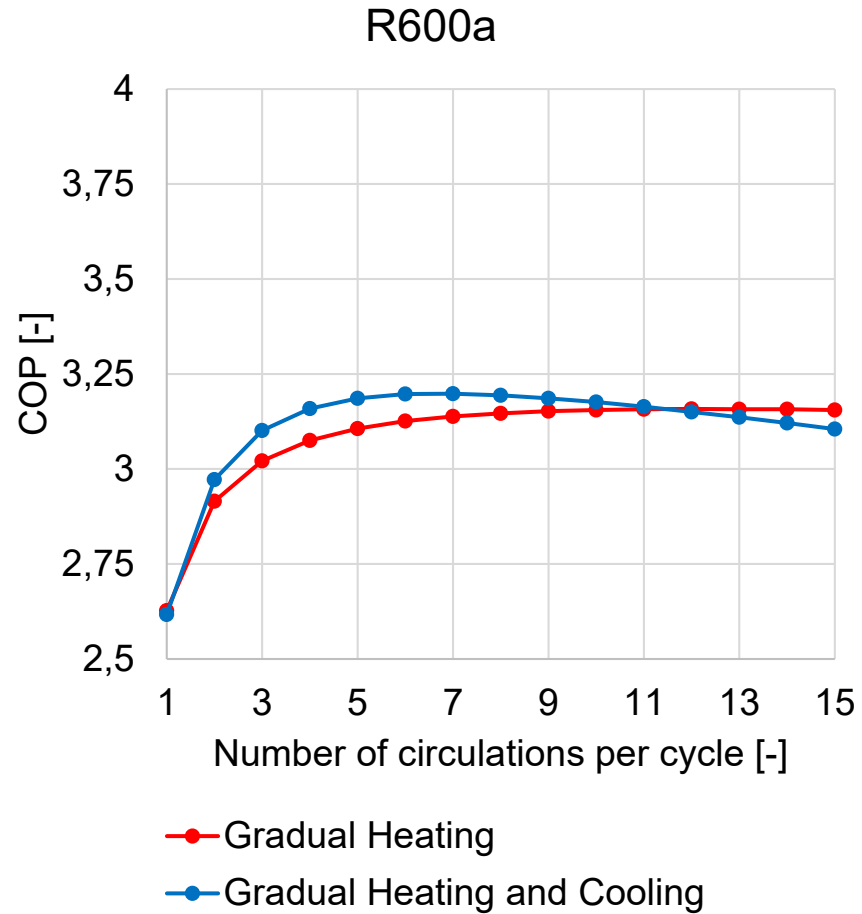
Parameters: $T_{cold,return} = 20 \text{ [C]}$, $T_{cold,supply} = 10 \text{ [C]}$, $T_{hot,supply} = 60 \text{ [C]}$, $T_{hot,return} = 20 \text{ [C]}$, $ref\$ = R600a$

Assumptions

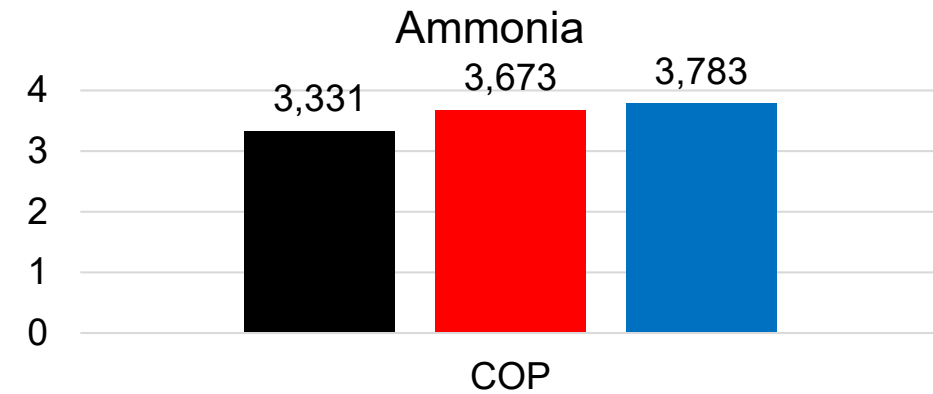
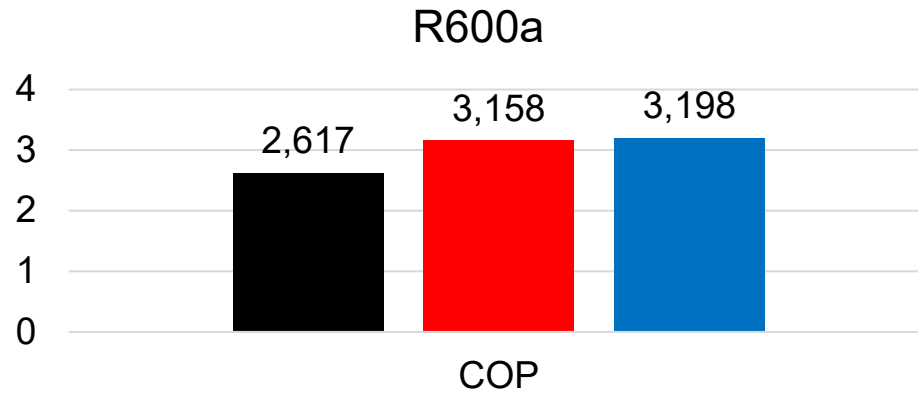
- Quasi-steady-state model
- Ideally stratified tanks without heat losses
- Same number of circulations through condenser and evaporator
- Constant water mass flow throughout the charging
- Constant compressor speed
- Constant UA-value for all HEX

Working fluid	R717	R600a
Compressor suction superheat [K]	0	5
Max. discharge temperature [°C]	180	180
Pinch point temperature difference [K]	5	5
Pressure drop in condenser and evaporator [bar]	0.5	0.5
Pump isentropic efficiency [-]	0.8	0.8
Compressor model	Sabroe HPX-708	Bock EX-HG 12P/60 4S

COP over N

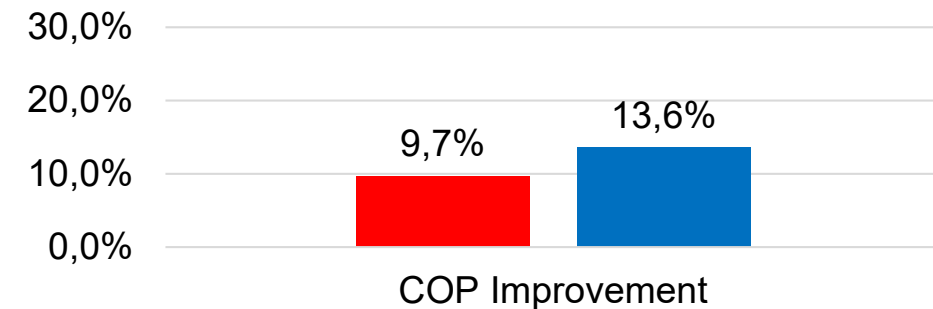
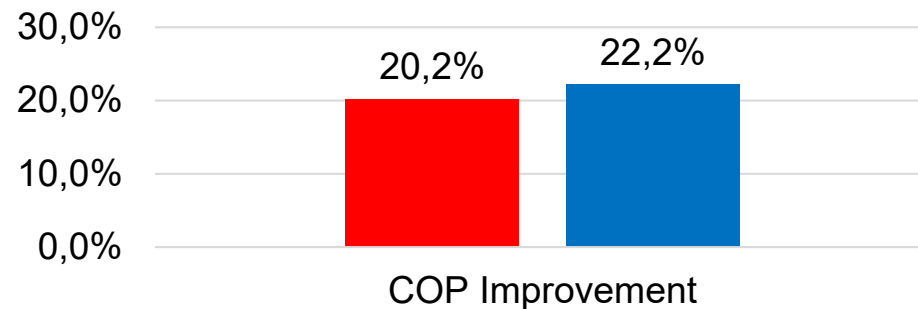


Maximum COP improvement

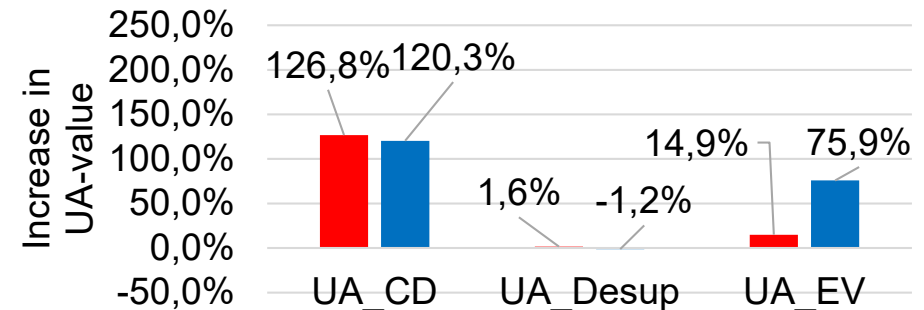
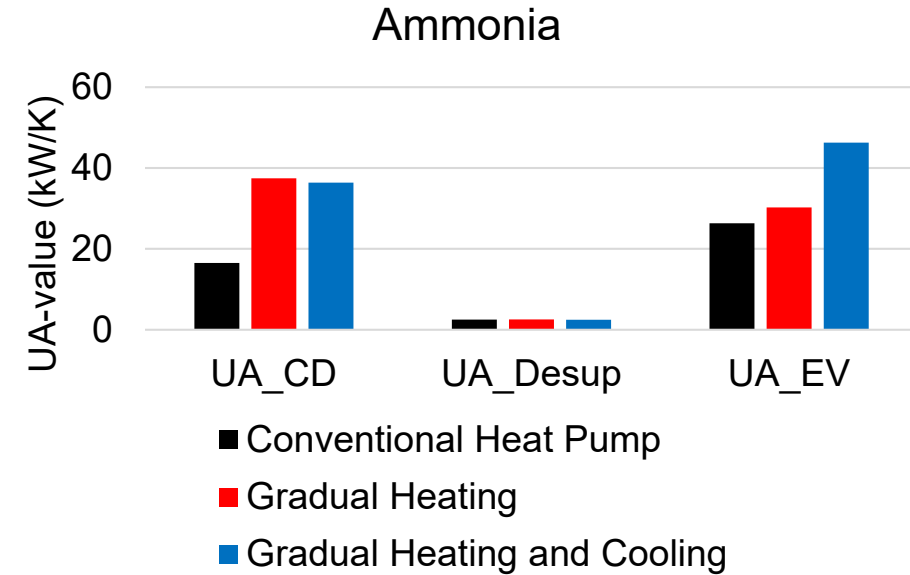
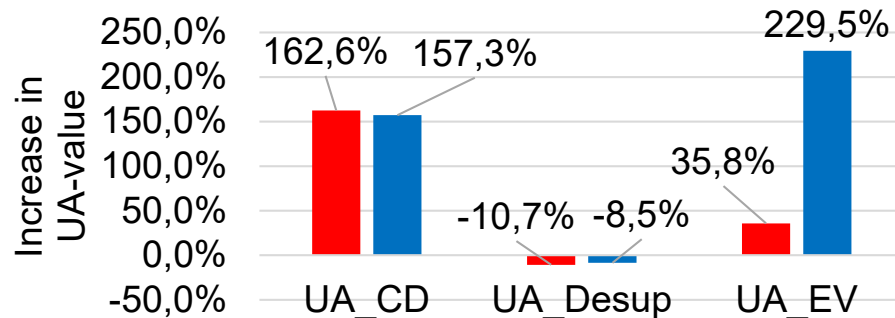
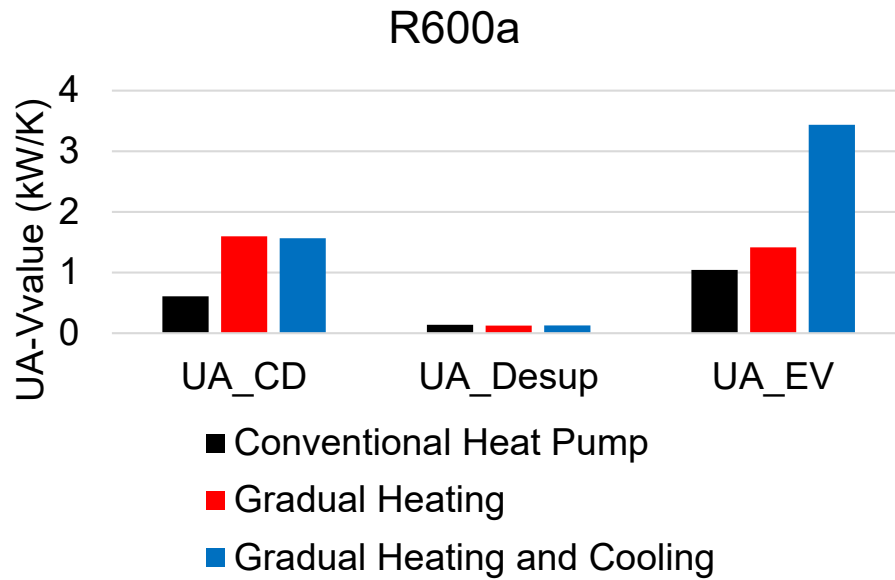


- Conventional Heat Pump
- Gradual Heating
- Gradual Heating and Cooling

- Conventional Heat Pump
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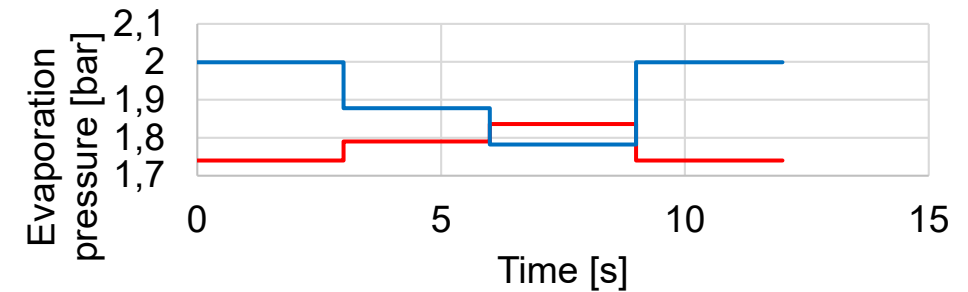
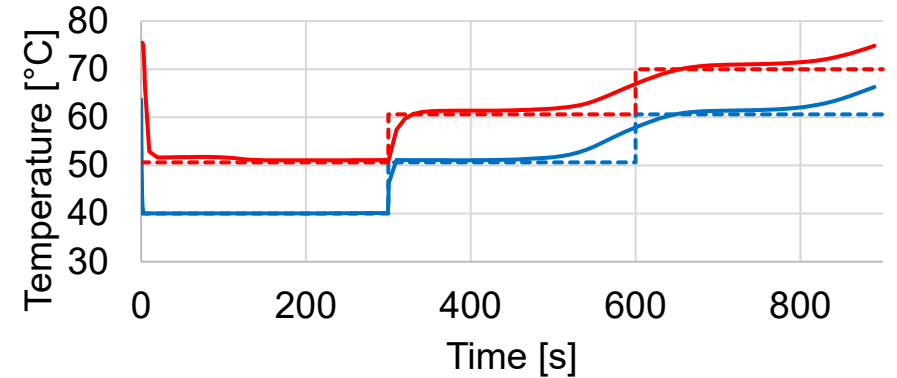
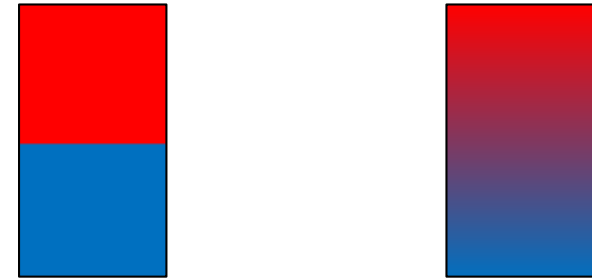


Influence on heat exchanger size



Discussion

- Neglected heat transfer, mixing and heat loss in tanks
- Dynamic behaviour of heat pump
 - Thermal inertia
 - Control strategy
- Sudden increase in evaporation pressure
 - Potential problem with condensation in suction line



— Gradual heating — Gradual heating and cooling

Conclusion

- Using the ISECOP system can improve the performance of a heat pump providing district heating and cooling
 - Gradual heating: 20.2 % (R600a) & 9.7 % (R717)
 - Gradual heating and cooling: 22.2 % (R600a) & 13.6 % (R717)
- Gradual heating and cooling leads to increase in evaporator size
 - Investment costs will be significantly higher than for conventional heat pump and gradual heating

Thank you for your attention!

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