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High-pressure control of an NH_3/H_2O absorption heat transformer: effects on useful heat output and COP

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Objectives

This study experimentally investigates the influence of a proportional electronic expansion valve on the high-pressure level of an NH_3/H_2O absorption heat transformer. In addition, the influence of the high-pressure level on both useful heat output and the coefficient of performance (COP) is analyzed.

Key data of absorption heat transformer

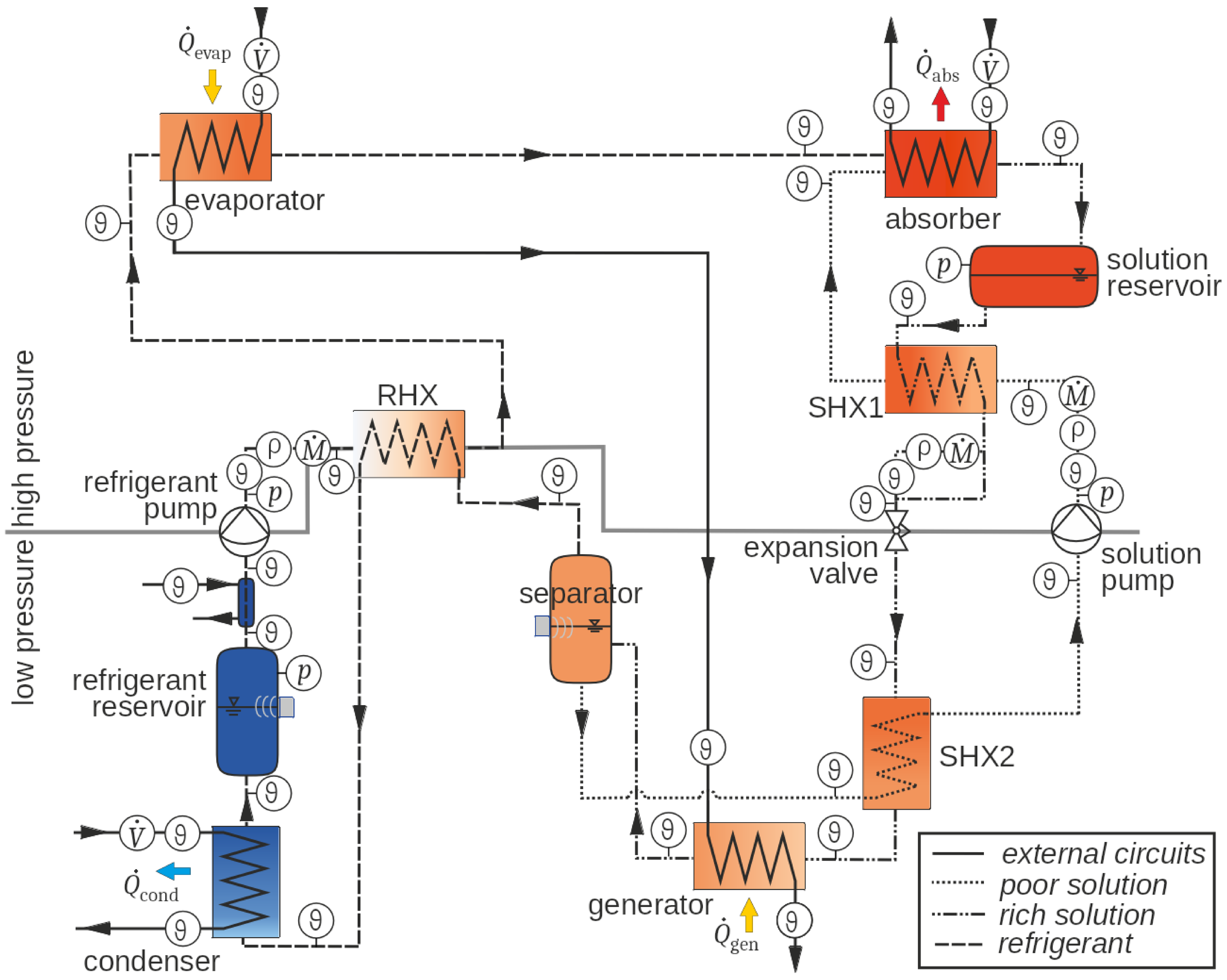
- Type: single-stage absorption heat transformer
- Working pair: NH_3/H_2O (ammonia/water)
- Useful temperature level: ≤120 °C
- Heat exchangers: plate heat exchangers (Alfa Nova HP27)
- Filling quantity: 9.8 kg with $\xi = 0.67$
- Expansion valve (EXV): electronic (Carel E2V24BSM00)
- Pumps: piston diaphragm pumps (Verder Hydra-Cell)

Performance parameters

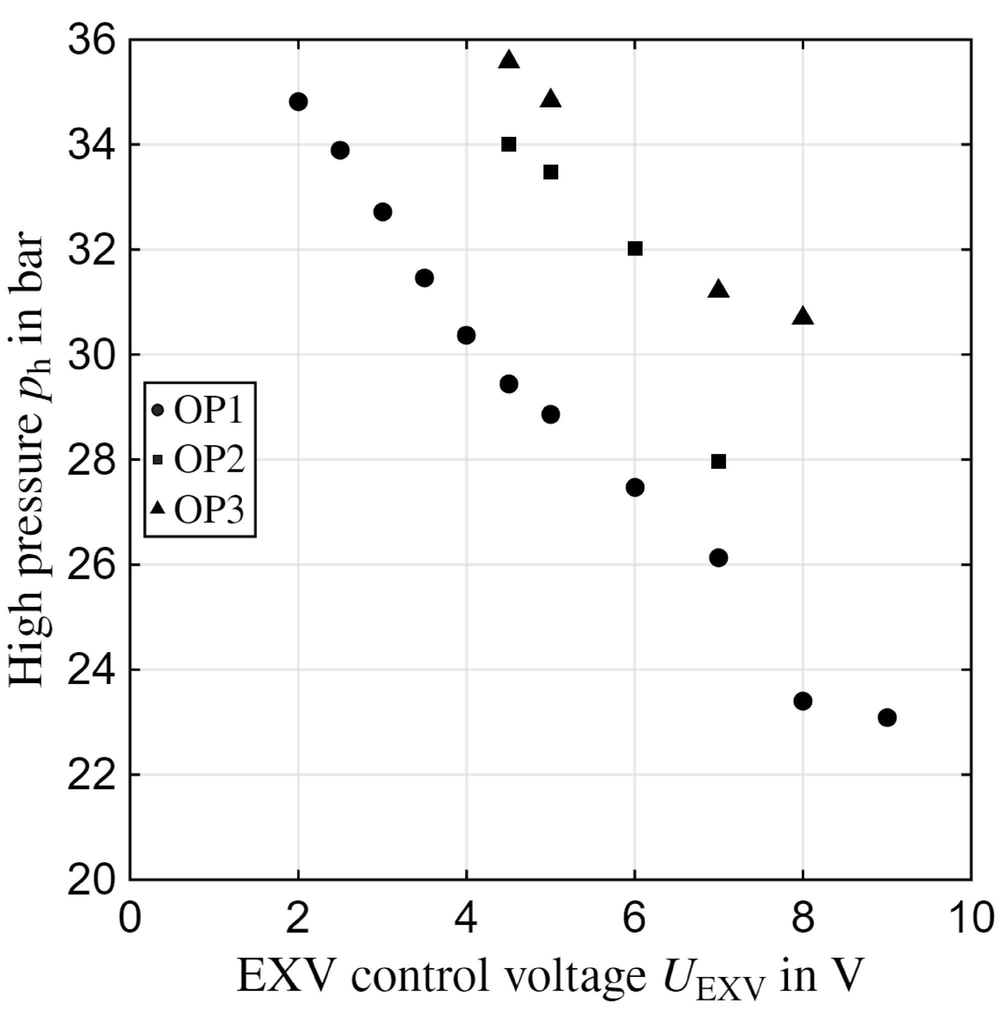
$\dot{Q}_{useful} = \dot{Q}_{abs}$ COP= $\frac{|\dot{Q}_{abs}|}{|\dot{Q}_{evap}|+|\dot{Q}_{gen}|}$

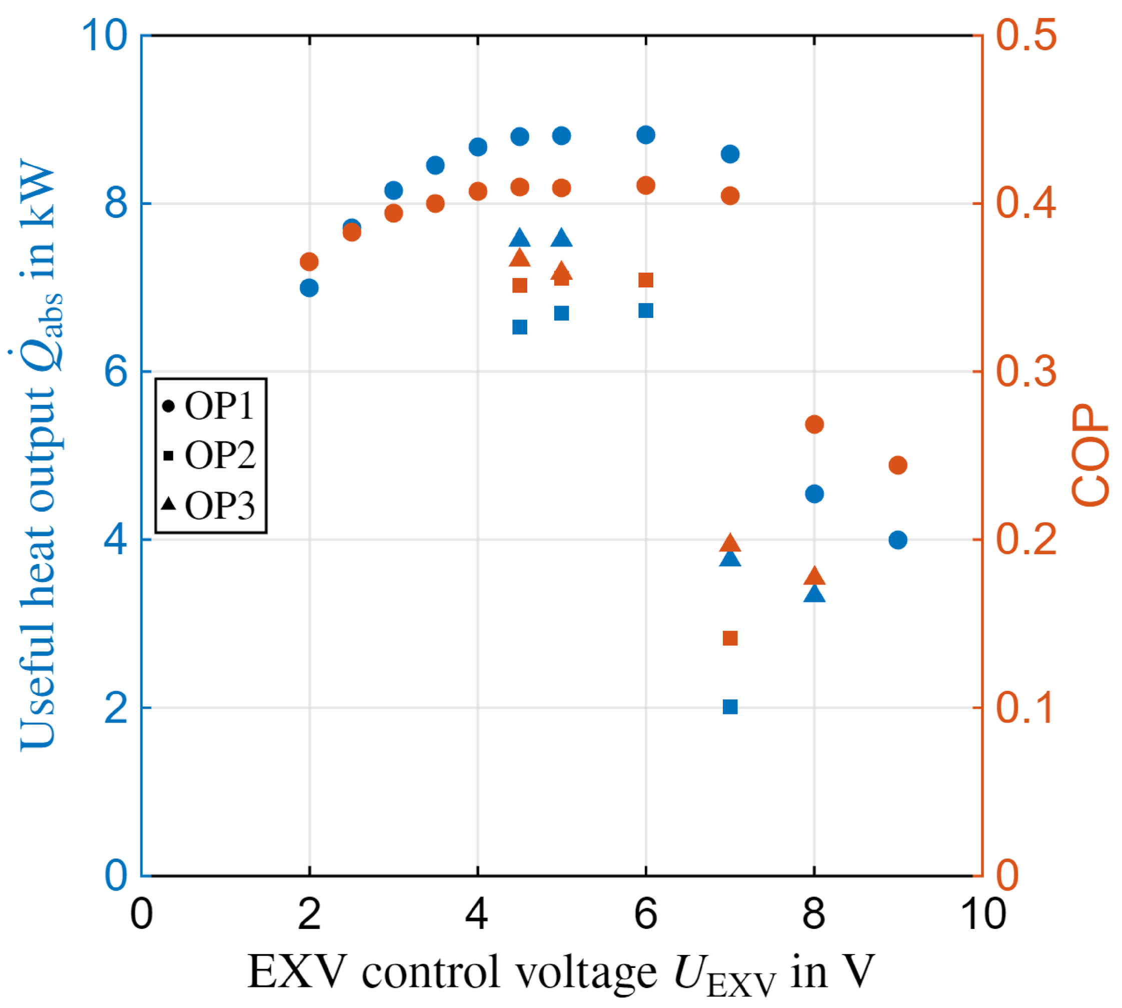
Operating points

OP	Recooling Condenser inlet	Driving heat Evaporator inlet	Useful heat Absorber outlet
OP1	$\vartheta_{ext,cond,in}$: 25 °C	$\vartheta_{ext,evap,in}$: 80 °C	$\vartheta_{ext,abs,out}$: 100 °C
OP2	$\vartheta_{ext,cond,in}$: 25 °C	$\vartheta_{ext,evap,in}$: 80 °C	$\vartheta_{ext,abs,out}$: 110 °C
OP3	$\vartheta_{ext,cond,in}$: 25 °C	$\vartheta_{ext,evap,in}$: 90 °C	$\vartheta_{ext,abs,out}$: 120 °C
OP1-3	$\dot{V}_{ext,cond} \approx 2000$ l/h	$\dot{V}_{ext,evap,gen} \approx 2000$ l/h	$\dot{V}_{abs,ext} \approx 1000$ l/h



Results: influence of high-pressure level





- High pressure p_h increases linearly with valve closure (U_{EXV} ↓) and increasing useful temperature level $\vartheta_{ext,abs,out}$ ↑
- Mass flow $\dot{M}_{rs}$ ↓, while $\dot{M}_{ref}$ = const. and $\dot{M}_{ps}$ ↓ → concentration ξ_{rs} ↑ → high pressure p_h ↑
- System performance is governed by a trade-off between incomplete absorption and evaporation:
  - For $U_{EXV} > 6$ V and thus $p_h < p_{h,opt}$ incomplete absorption ($x_{abs,out} > 0.09$ kg/kg)
  - For $U_{EXV} < 6$ V and thus $p_h > p_{h,opt}$ disproportionate decrease of vapor quality $x_{evap,out}$ → less refrigerant vapor available for absorption

→ This trade-off produces a characteristic curve with abrupt increase, broad plateau and subsequent drop-off for both useful heat output and COP

→ Maximum for useful heat output and COP occur at medium valve opening independent of operating conditions for $\dot{M}_{ref}$ = const.

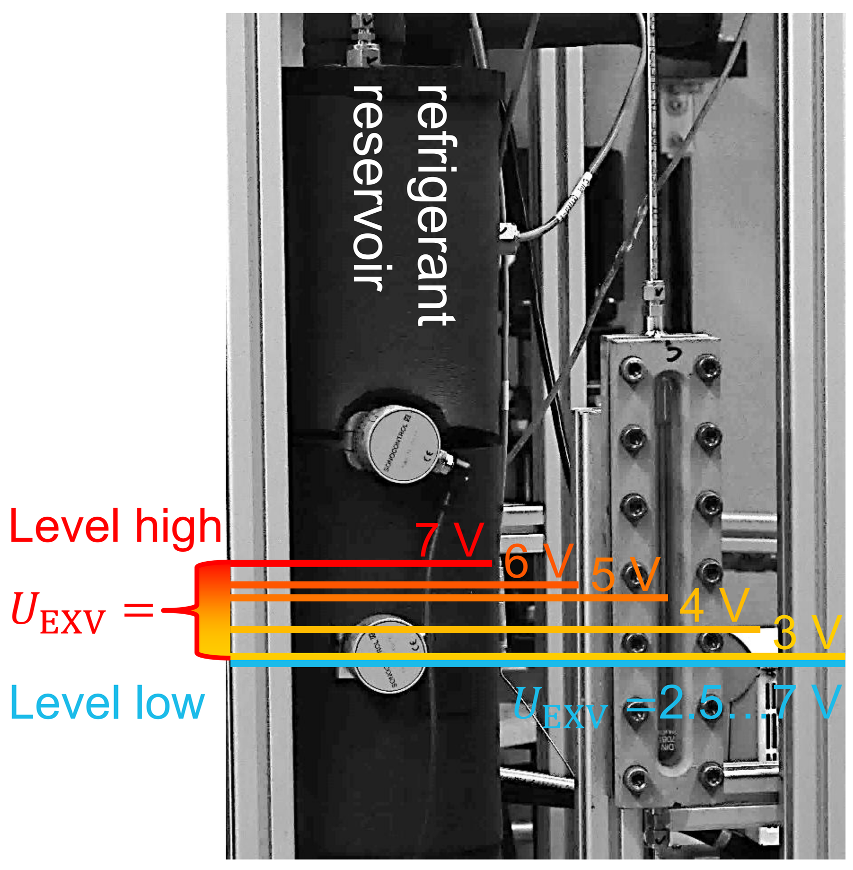
Results: influence of filling level in the refrigerant reservoir

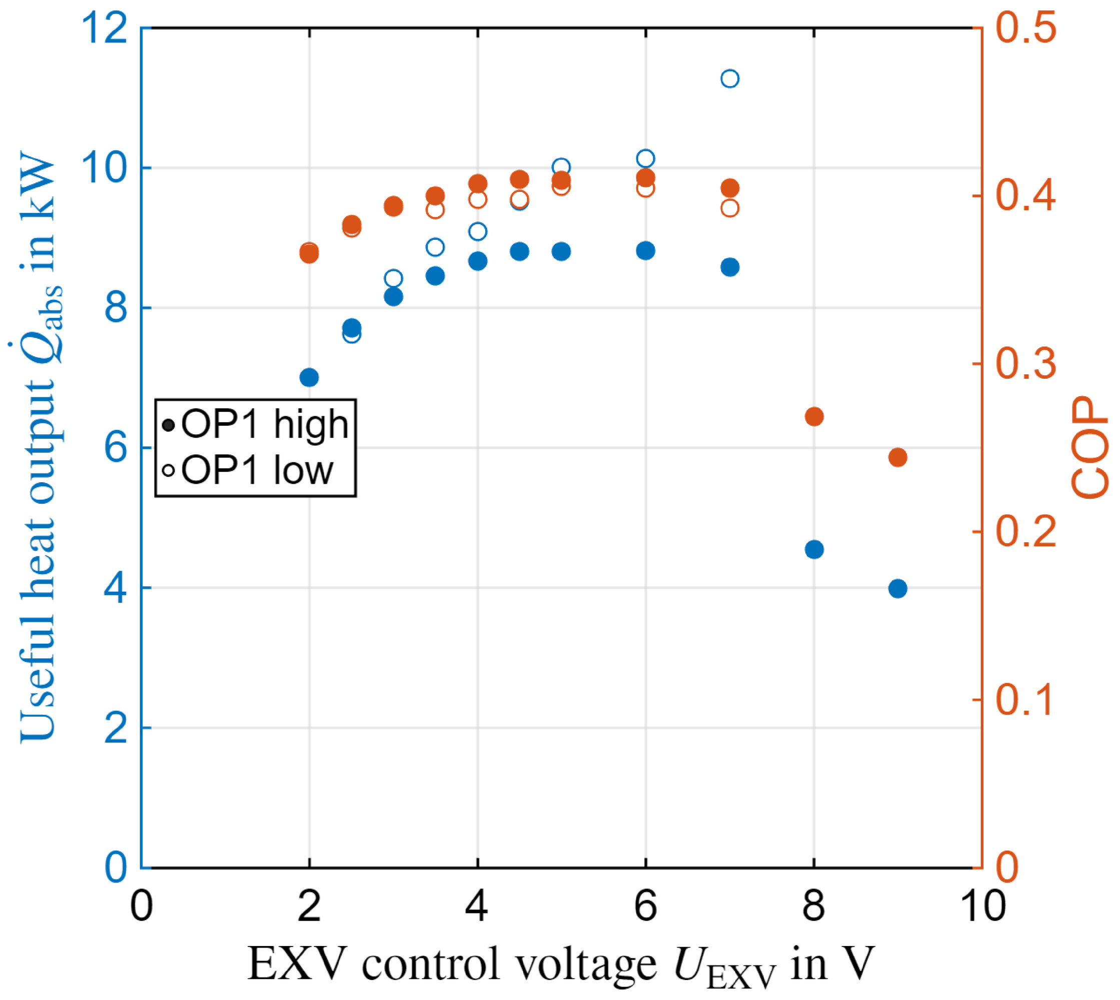
- Switching from filling level high to low increases the circulating refrigerant mass → concentration ξ_{rs} ↑ → high pressure p_h ↑
- Sensor position of refrigerant reservoir influences refrigerant mass flow $\dot{M}_{ref}$ as refrigerant pump controls for constant filling level
  - For level high: $n_{Pump,ref} = n_{min}$ → $\dot{M}_{ref}$ = const.
  - For level low: $n_{Pump,ref}$ ↑ → $\dot{M}_{ref}$ ↑

→ For level low the disproportionate increase in refrigerant mass flow $\dot{M}_{ref}$ dominates the trade-off between incomplete absorption and evaporation such that useful heat output increases when the valve opens

→ Maximum for useful heat output occurs at maximum valve opening for $\dot{M}_{ref} \neq$ const., while COP still occurs at medium valve opening

Filling level





Conclusions

→ The expansion valve controls the high pressure linearly and is an effective control variable

→ To maximize useful heat output, a medium valve opening for $\dot{M}_{ref}$ = const. and maximum valve opening for $\dot{M}_{ref} \neq$ const. is desirable

→ To maximize COP a medium valve opening is sufficient under all operating conditions

High-Temperature Heat Pump Symposium