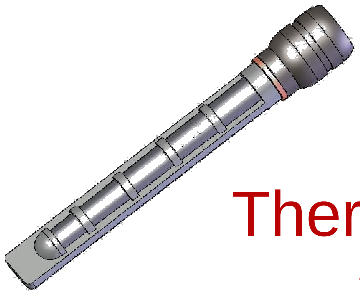
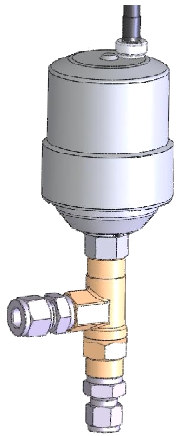
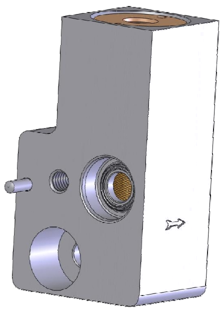
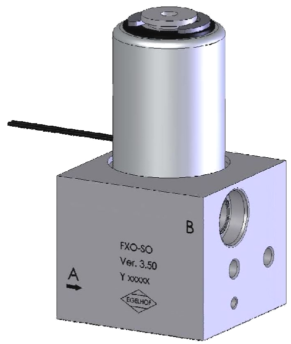




Thermostatic expansion valve for R744 with integrated safety features





Concept study
&
first experimental results

Aguilar, 31.01.2007

In Cooperation with:
Prof. J. Köhler, IFT TU Braunschweig

Index

1. Nomenclature

Abbreviation	Meaning
A_{eff}	Effective throttle area
COP	Coefficient of performance
hP	High pressure
IHX	Internal heat exchanger
MOP	Maximum operation pressure (of charge)
MOT	Maximum operation temperature (of charge)
opt.	Optimal (COP optimized)
Pc	Critical pressure
Tc	Critical temperature
TEV	Thermostatic expansion valve
Spec.	Specification
Δp	Pressure difference (at valve ports)
ρ	Refrigerant density at valve inlet

2. List of Requirements

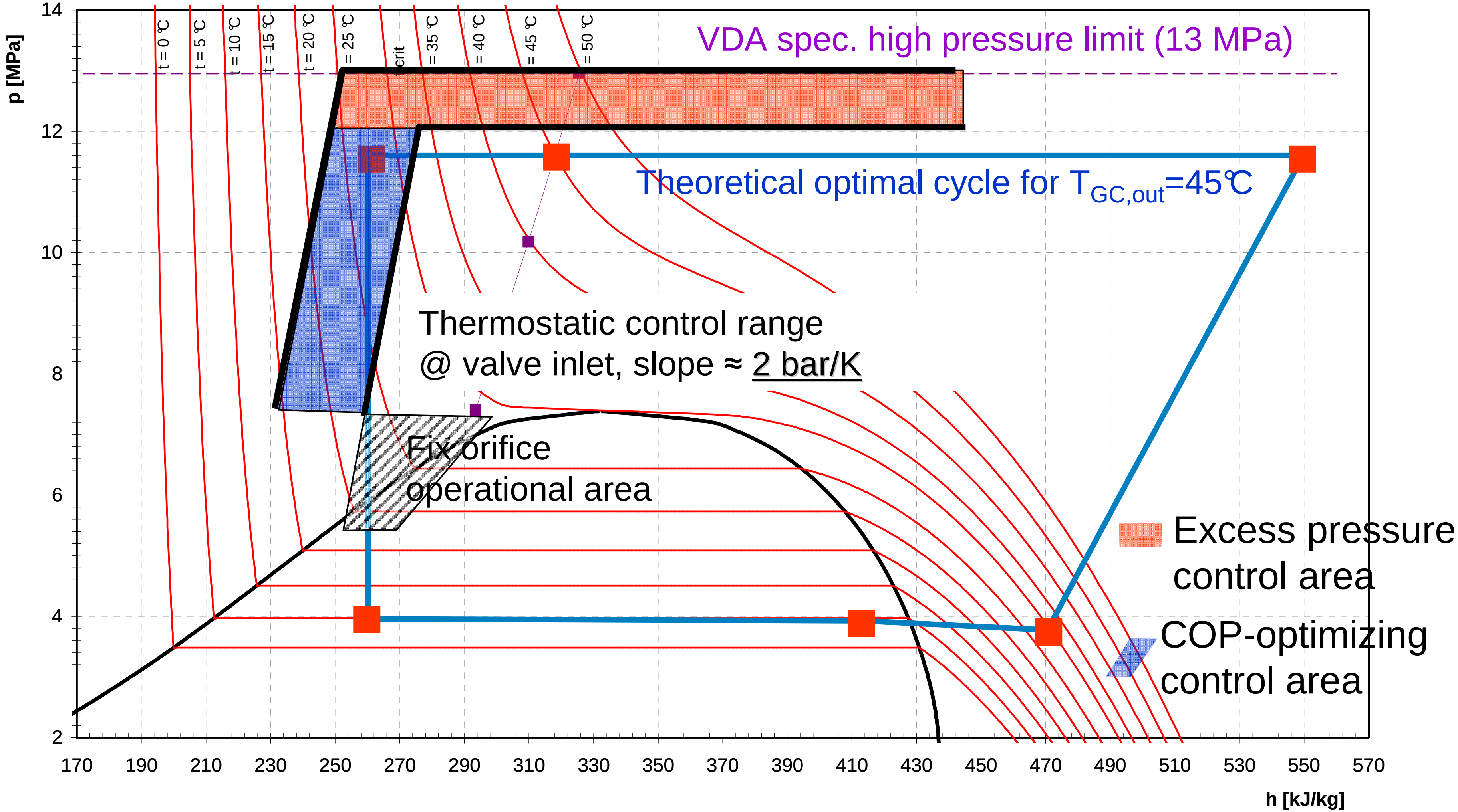
Requirement	Benchmark
Expansion of refrigerant	Isentropic expander
Compact design / Mass	Orifice
Easy to package	Δp valve
Maximal cooling performance during cool-down	Mechanically driven expansion valve
High pressure control at COP optimum	Electrically driven expansion valve
Excess pressure control	Mechanically driven expansion valve
System stability	Δp valve Thermostatic expansion valve
Noise	-
Costs	Orifice
Filtering	-

→ **New thermostatic control concept** (for cool-down performance, high pressure control at COP optimum, excess pressure control, system stability)

3. Characteristics & features

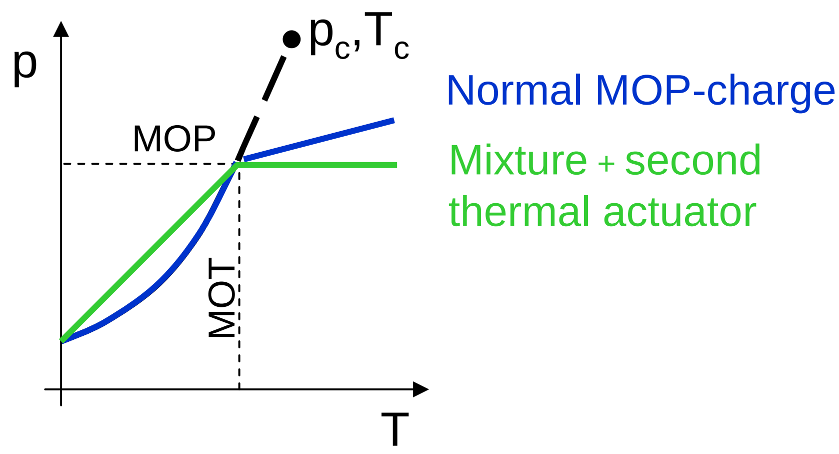
- Safety functionality when engine starts up – starting from high temperature and pressure levels (e.g. 50℃ / 8 MPa)
- High pressure control within a COP-optimized range for temperatures < 31℃ (at valve inlet)
- Adjustable orifice mode (throttle offset) for critical operational conditions (high pressure < 7.5 Mpa)
- Compact design & possibility of assembly close to the (main) evaporator
- No need for capillary tubes

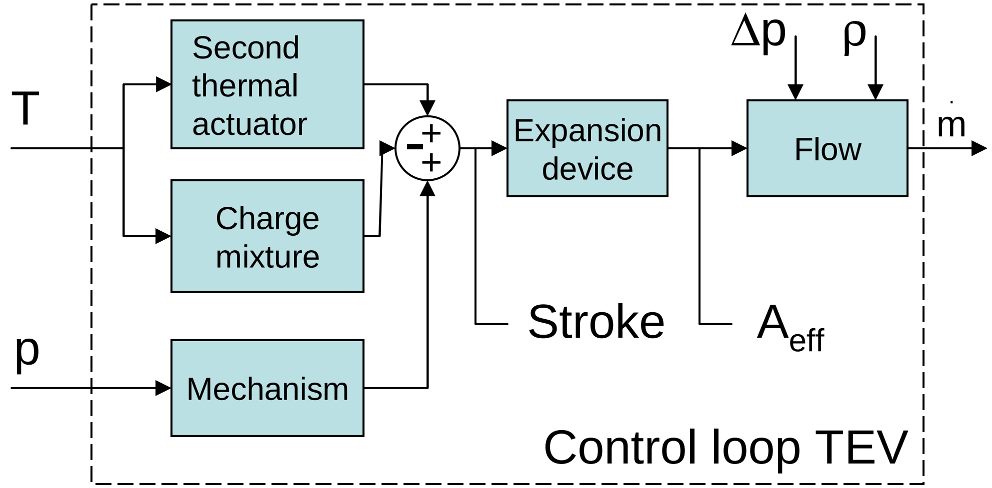
4. Function description



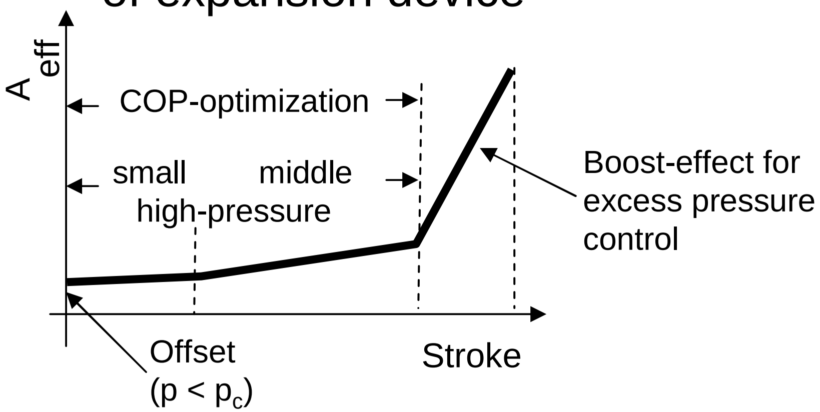
5. Components & properties

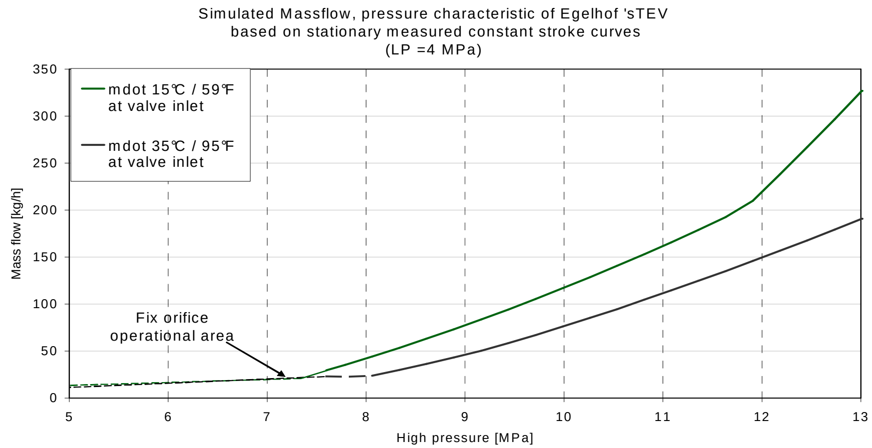
Power element





Operational ranges of expansion device





6. Experimental results
test description

1. Start-up behavior @ high environment conditions

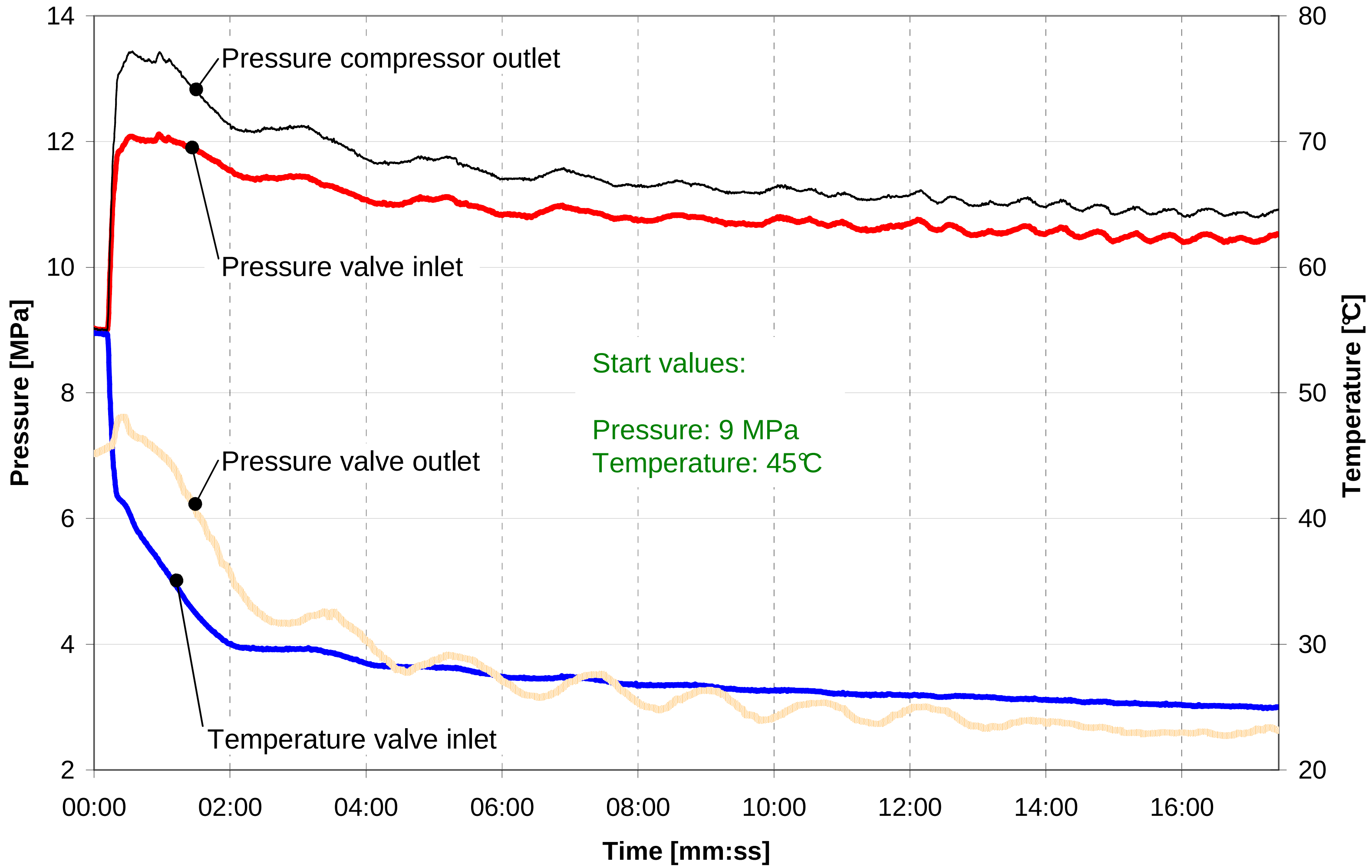
▪ Compressor speed:	1500 rpm
▪ Compressor volume:	33tfcb cc
▪ Environment start temperature:	≈ 50℃
▪ Equalized start pressure:	8 MPa
▪ HVAC:	max. cool-down

2. Stationary COP & high pressure control analysis

▪ Compressor speed:	1800 rpm					
▪ Compressor volume:	31 cc					
▪ Gas cooler air flow velocity:	2.8 m/s					
▪ Gas cooler air inlet temperature:	45,	40,	35,	30,	25,	20 ℃
▪ Evaporator (dry) air inlet temperature:	45,	40,	35,	30,	25,	20 ℃
▪ Evaporator air flow:	8.6,	7.6,	6.3,	5.2,	4.3,	3.4 kg/min
▪ Evaporator air outlet (target of HVAC):	5℃					

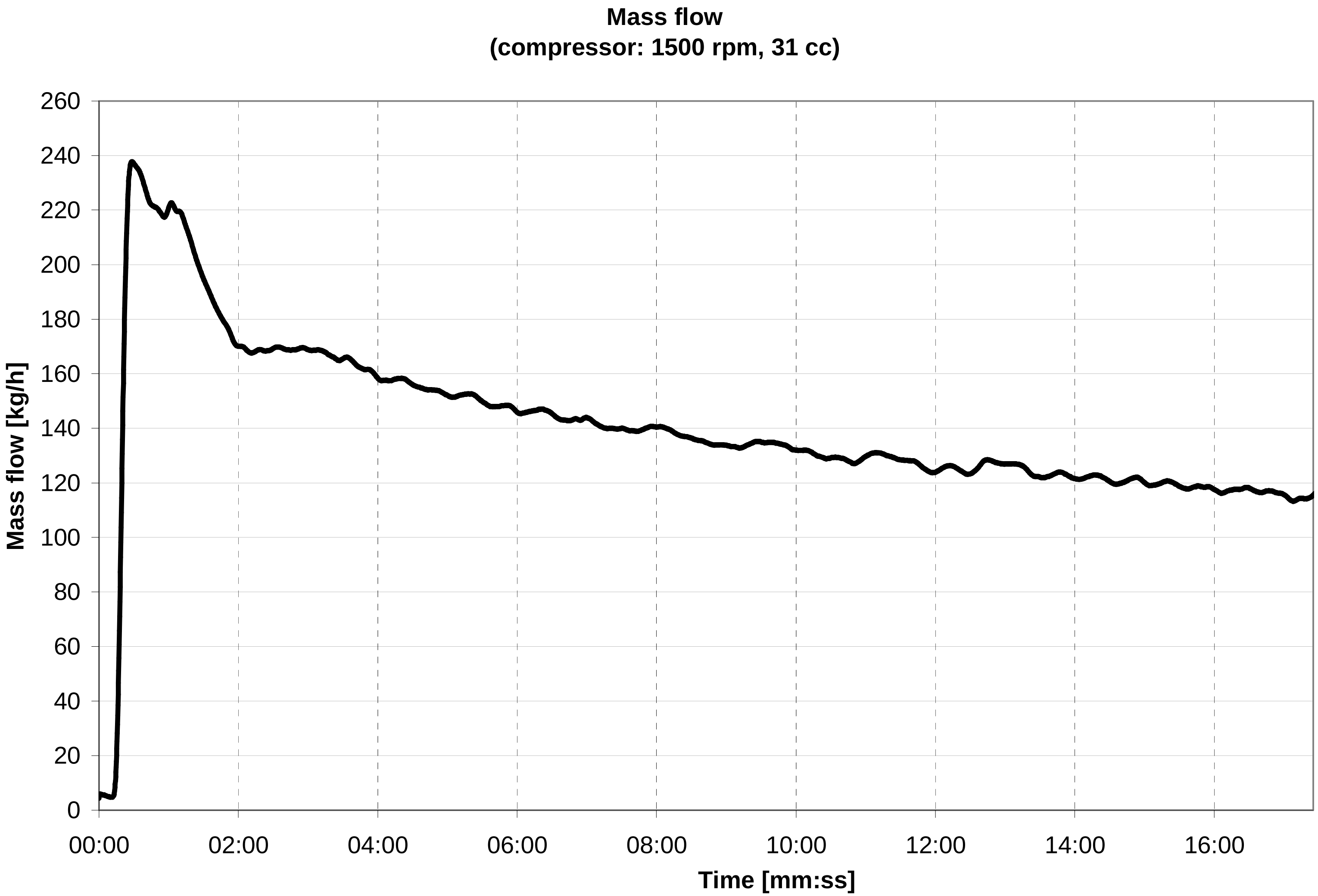
6. Experimental results
Start-up behavior (I)

Start-up behavior under high environment conditions

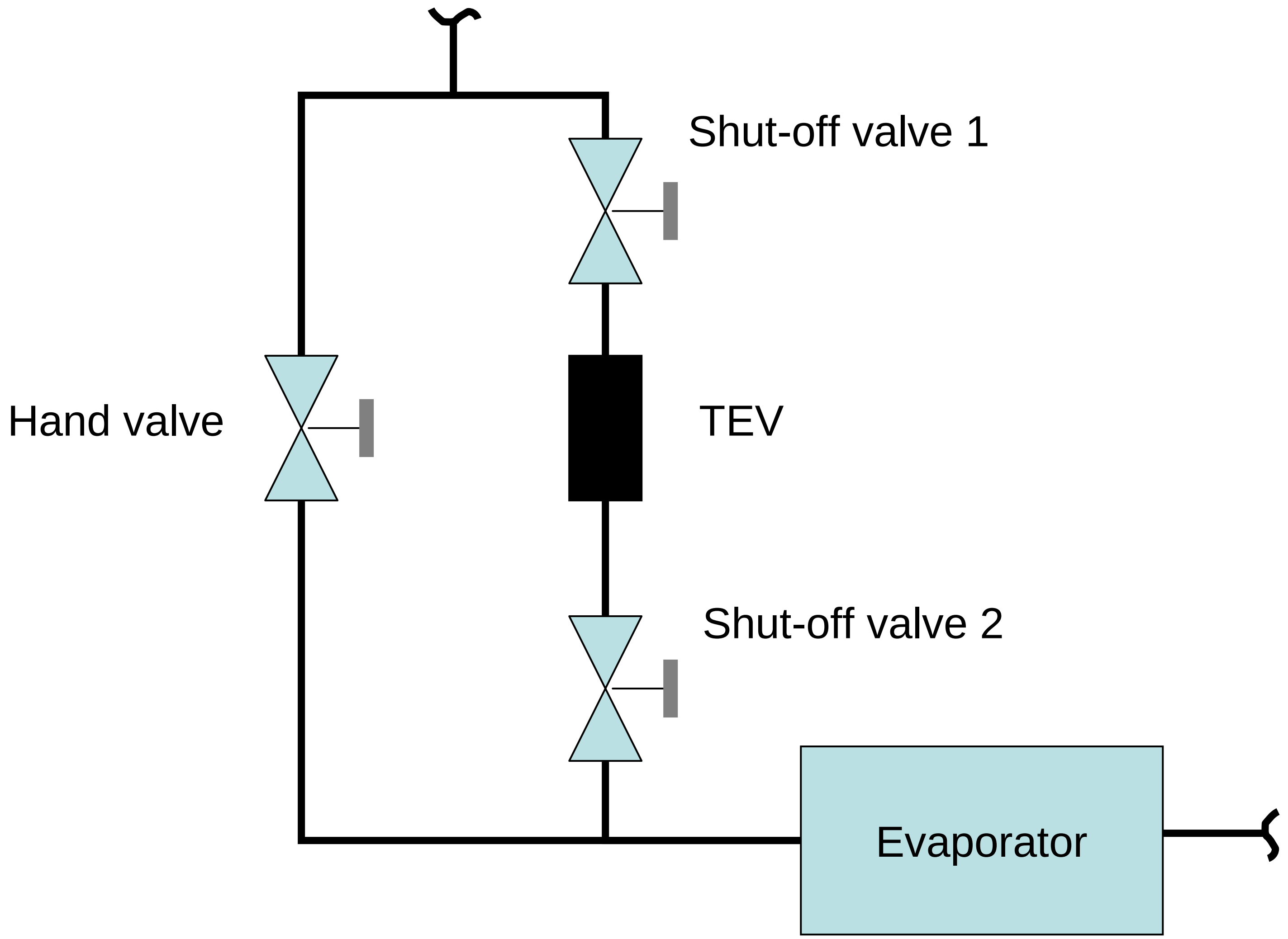


6. Experimental results
Start-up behavior (II)

EGELHOF REGELUNGSTECHNIK CONTROLS

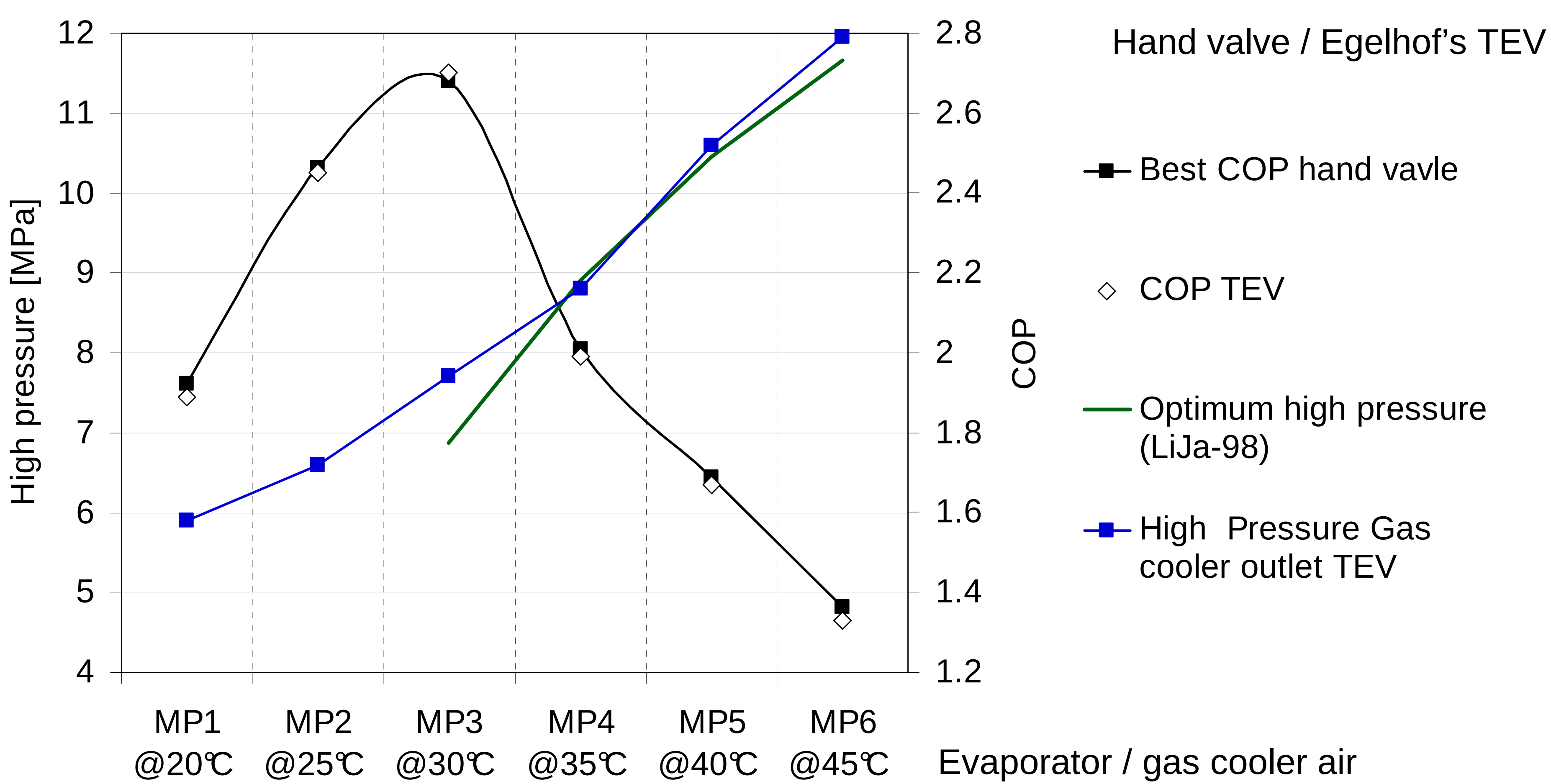


6. Experimental results
COP & high pressure control (I)

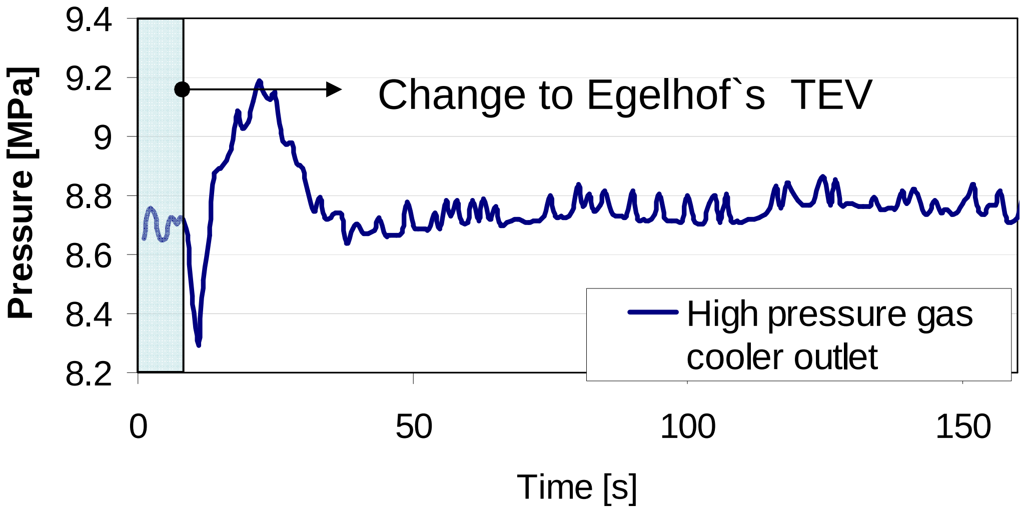


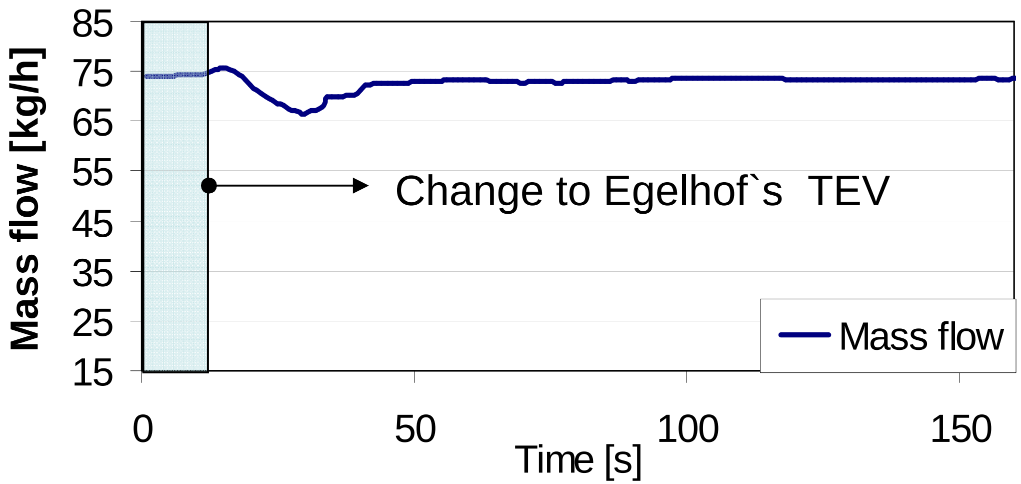
6. Experimental results
COP analysis (II)

High-pressure-Temperature diagram

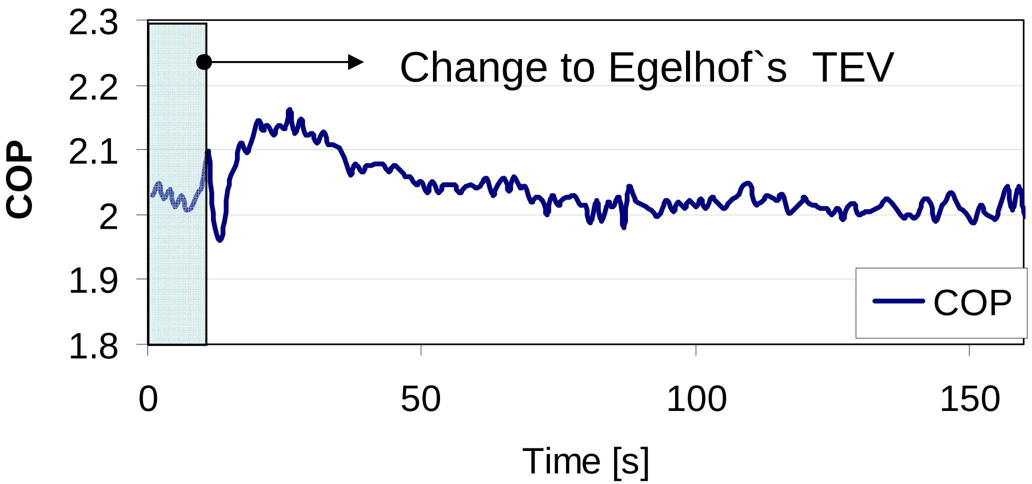


6. Experimental results
COP & high pressure control (III)





COP- optimal stationary cycle stage (operating with hand valve)



Environment temperature = 35℃ / 95℉

7. Conclusions

- Egelhof's TEV can be used to control the high pressure of an R744 refrigerant cycle within a pre-defined optimal range
- This control range is a result of the transfer of the optimal high pressure characteristic line at the gas cooler outlet to the valve inlet, and is highly dependent on the efficiency of the IHX
- The working behavior of the TEV is divided into three operational areas, which enable the valve to adapt its capacity to the cooling performance required. The three areas are: **fix-orifice**, **COP-optimizing** and **excess pressure**
- The set-up characteristics of these areas have to be adjusted according to the experimental results obtained for the target system, in order to guarantee correct functioning (COP optimization and safety)
- This adjustment can be done mechanically during valve assembly

7. Conclusions
TEV evaluation

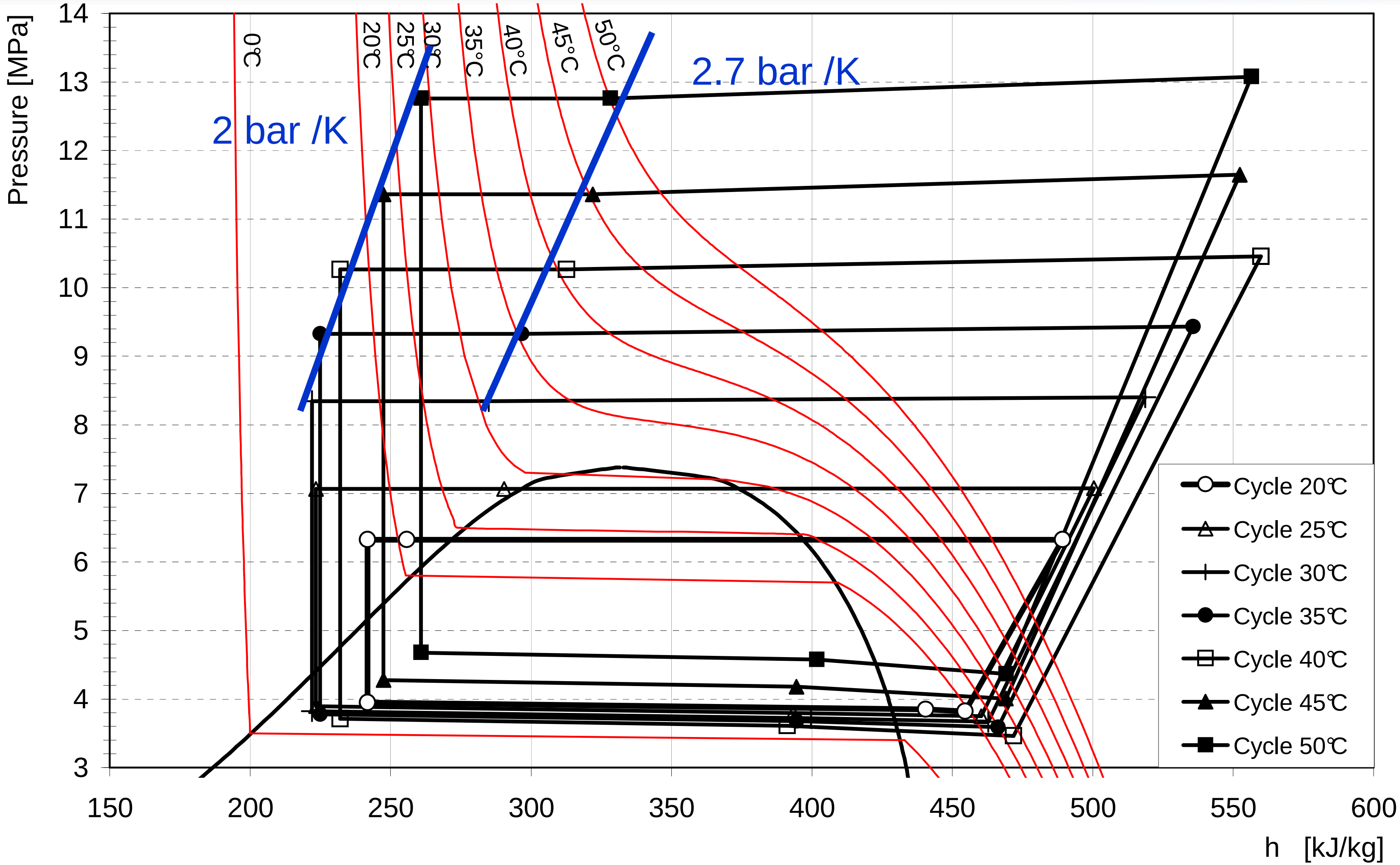
Requirement	TEV qualification
Expansion of refrigerant	-
Compact design / Mass	☺ ☺
Easy to package	☺ ☺ ☺
Maximal cooling performance during cool-down	☺ ☺ ☺
High pressure control at COP optimum	☺ ☺
Excess pressure control	☺ ☺ ☺
System stability	☺ ☺
Noise	t.b.d.
Costs	☹
Filtering	existing

7. Future steps

- Analysis of high pressure control on loss of refrigerant charge
- Analysis of valve behavior during load changes
- Mass and packaging optimization

Thanks for your interest!

Back up (I)


Pressure [MPa]
14
13
12
11
10
9
8
7
6
5
4
3
150
200
250
300
350
400
450
500
550
600
h [kJ/kg]
0°C
20°C
25°C
30°C
35°C
40°C
45°C
50°C
2 bar /K
2.7 bar /K
Cycle 20℃
Cycle 25℃
Cycle 30℃
Cycle 35℃
Cycle 40℃
Cycle 45℃
Cycle 50℃