# Ulster University
# Lot-NET Presentations

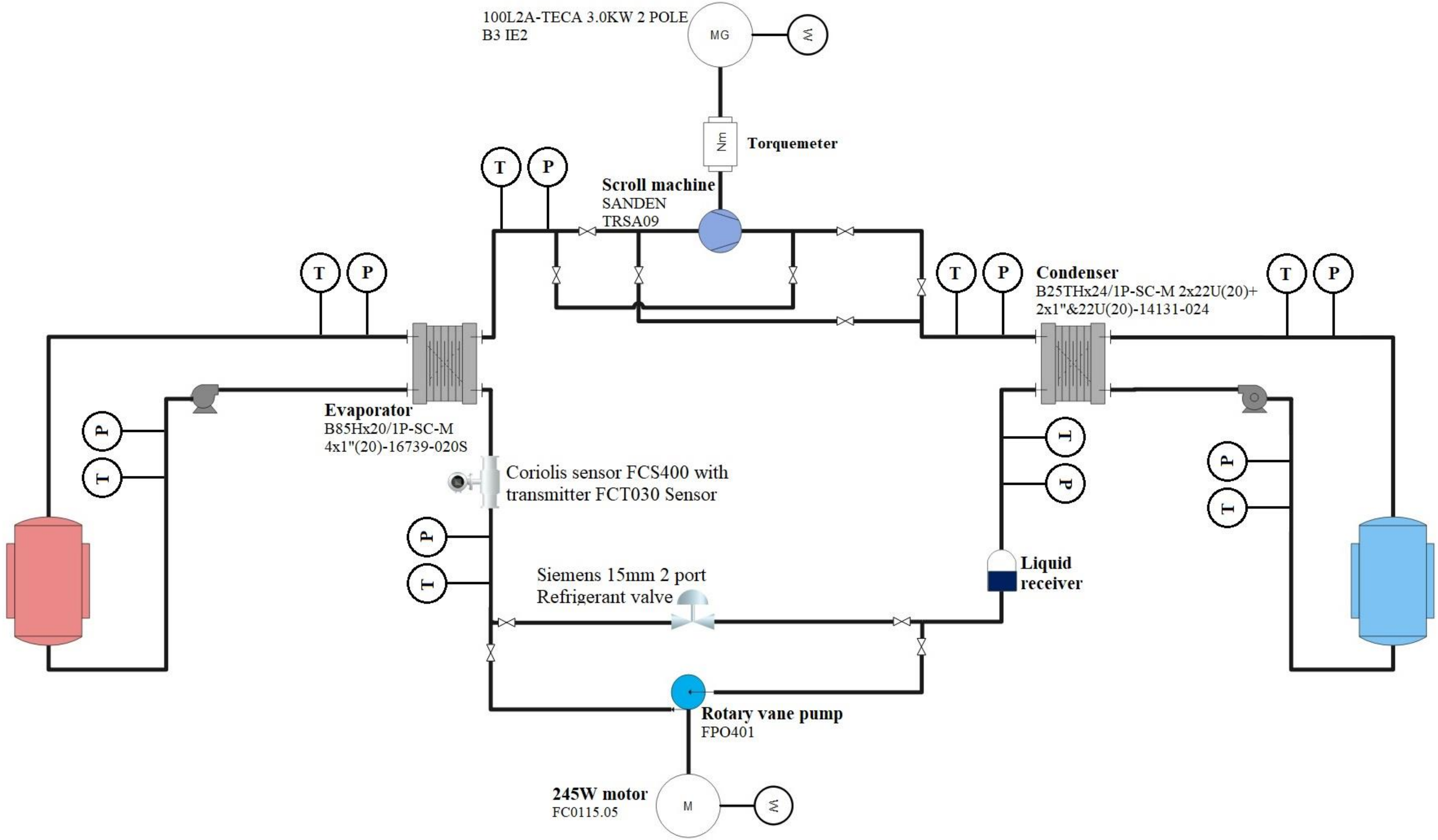
Prof. Neil Hewitt
Dr. Ming Jun Huang

Rahul V R
Adam Suliman
Dr Donal Cotter
Dr Shane Colclough
Marcio Novaes

# Reversible Heat Pump-Organic Rankine Cycle


**Supervisors**
Prof. Neil Hewitt
Dr. Ming Jun Huang

Rahul V R
PhD student
B00789593


100L2A-TECA 3.0KW 2 POLE
B3 IE2
MG
Nm
Torquemeter
Scroll machine
SANDEN
TRSA09
Condenser
B25THx24/1P-SC-M 2x22U(20)+
2x1"&22U(20)-14131-024
Evaporator
B85Hx20/1P-SC-M
4x1"(20)-16739-020S
Coriolis sensor FCS400 with
transmitter FCT030 Sensor
Siemens 15mm 2 port
Refrigerant valve
Liquid
receiver
Rotary vane pump
FPO401
245W motor
FC0115.05
M
T
P

# System description

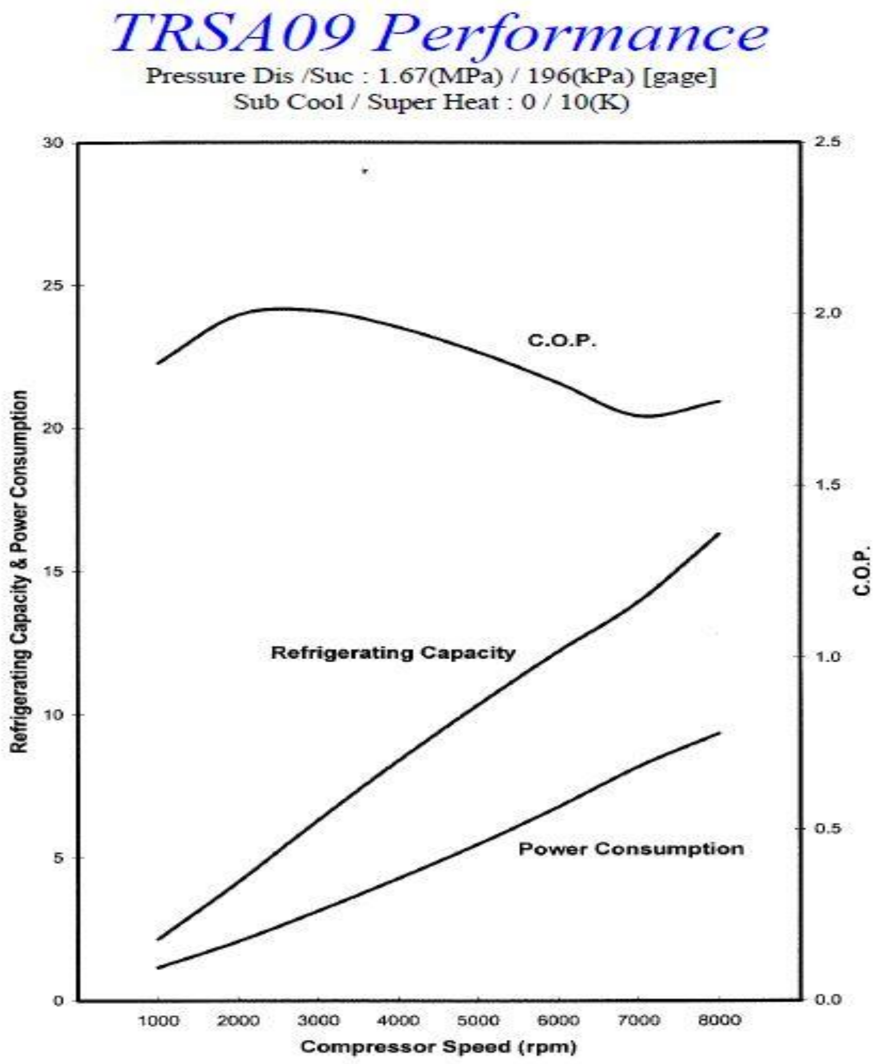
**ORC mode**

- Heat source temperature 90-120 C
- Condensing temperature 60-30C
- Evaporator heat transfer 13-7kW
- Condenser heat transfer 11-6kW

**HP mode**

- Evaporating temperature 70-90 C
- Condensing temperature 110-130 C
- Evaporator heat transfer 10-7kW
- Condenser heat transfer 8-12kW

# SANDEN TRSA09 modelling

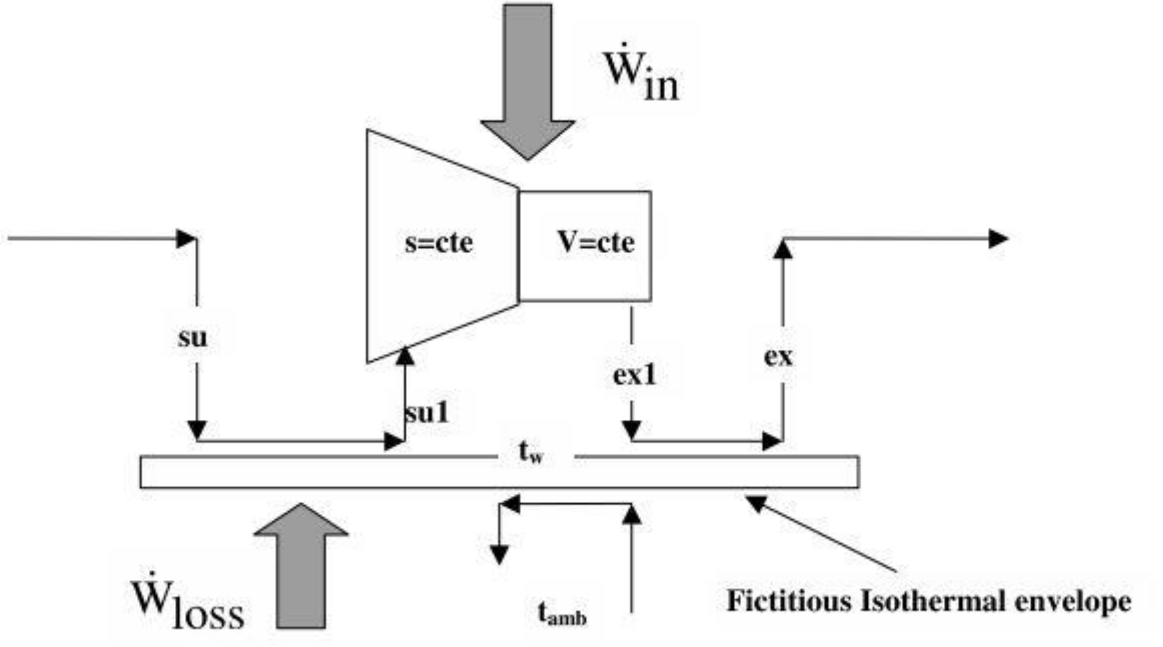



| Sl. No. | RPM | Power consumed (kW) | Mass flow rate (kg/s) | Exhaust temperature (K) |
|---|---|---|---|---|
| 1 | 1082.8 | 1.26 | 0.0195 | 372.18 |
| 2 | 1295.9 | 1.44 | 0.0231 | 369.97 |
| 3 | 1526.6 | 1.58 | 0.0272 | 366.45 |
| 4 | 1757.4 | 1.83 | 0.0311 | 367.03 |
| 5 | 1970.4 | 2.01 | 0.0348 | 366.12 |
| 6 | 2201.2 | 2.27 | 0.0388 | 366.72 |
| 7 | 2432.0 | 2.52 | 0.0432 | 366.61 |
| 8 | 2645.0 | 2.73 | 0.0475 | 365.89 |
| 9 | 2875.7 | 2.99 | 0.0518 | 366.11 |
| 10 | 3106.5 | 3.24 | 0.0558 | 366.38 |
| 11 | 3319.5 | 3.49 | 0.0598 | 366.61 |
| 12 | 3550.3 | 3.74 | 0.0639 | 366.82 |
| 13 | 3763.3 | 3.99 | 0.0678 | 367.06 |
| 14 | 3994.1 | 4.24 | 0.0716 | 367.40 |
| 15 | 4224.9 | 4.50 | 0.0755 | 367.70 |
| 16 | 4455.6 | 4.78 | 0.0795 | 368.13 |
| 17 | 4668.6 | 5.04 | 0.083 | 368.70 |
| 18 | 4899.4 | 5.36 | 0.0869 | 369.50 |
| 19 | 5130.2 | 5.61 | 0.0907 | 369.67 |
| 20 | 5343.2 | 5.90 | 0.0944 | 370.24 |
| 21 | 5574.0 | 6.22 | 0.0981 | 371.03 |
| 22 | 5787.0 | 6.51 | 0.1014 | 371.70 |
| 23 | 6017.8 | 6.80 | 0.1052 | 372.10 |
| 24 | 6248.5 | 7.12 | 0.1083 | 373.07 |

SANDEN TRSA09 performance with R134a as refrigerant

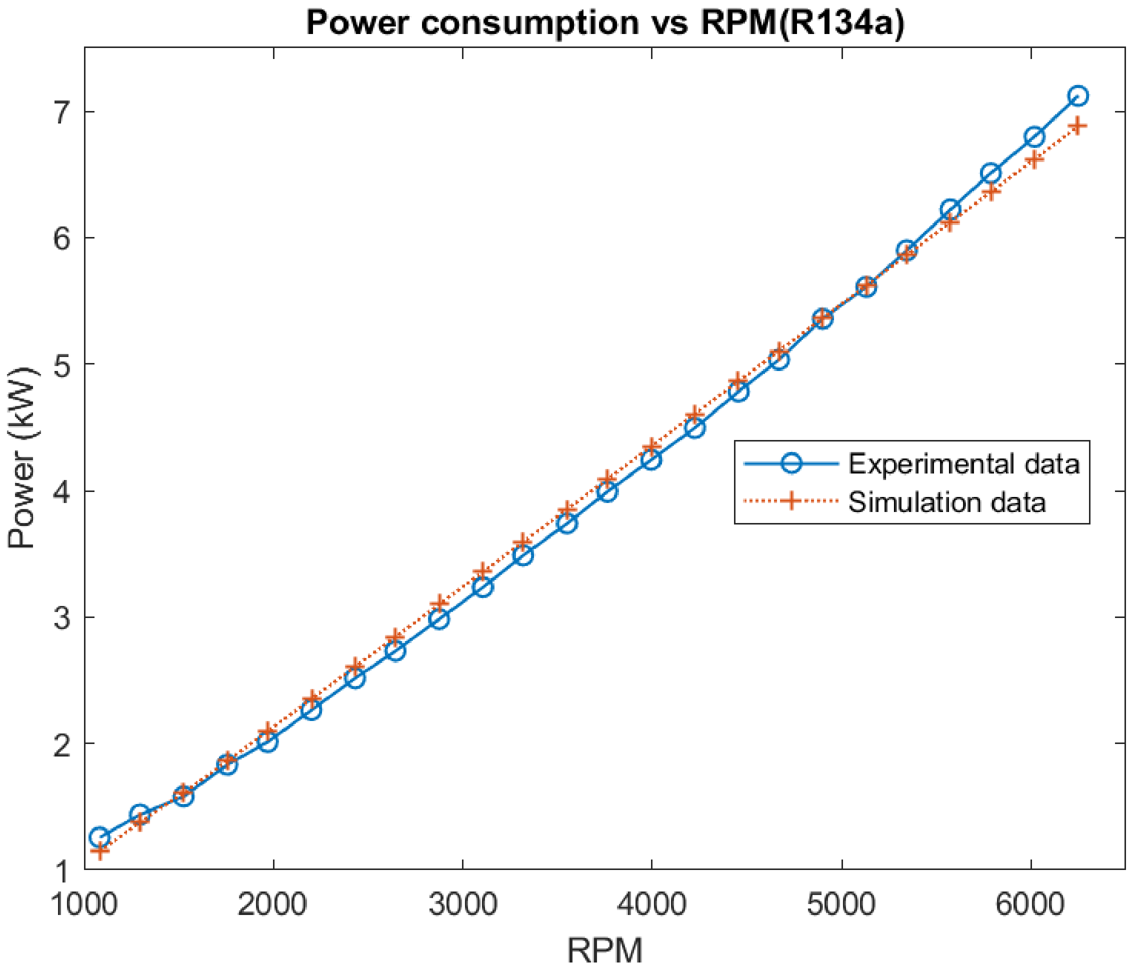
# Semi- empirical model of scroll compressor

- Heating of working fluid su – su1
- Isentropic compression  to adapted pressure su1 – ad
- Constant volume compression to exhaust pressure ad-ex1
- Cooling down of working fluid ex1-ex

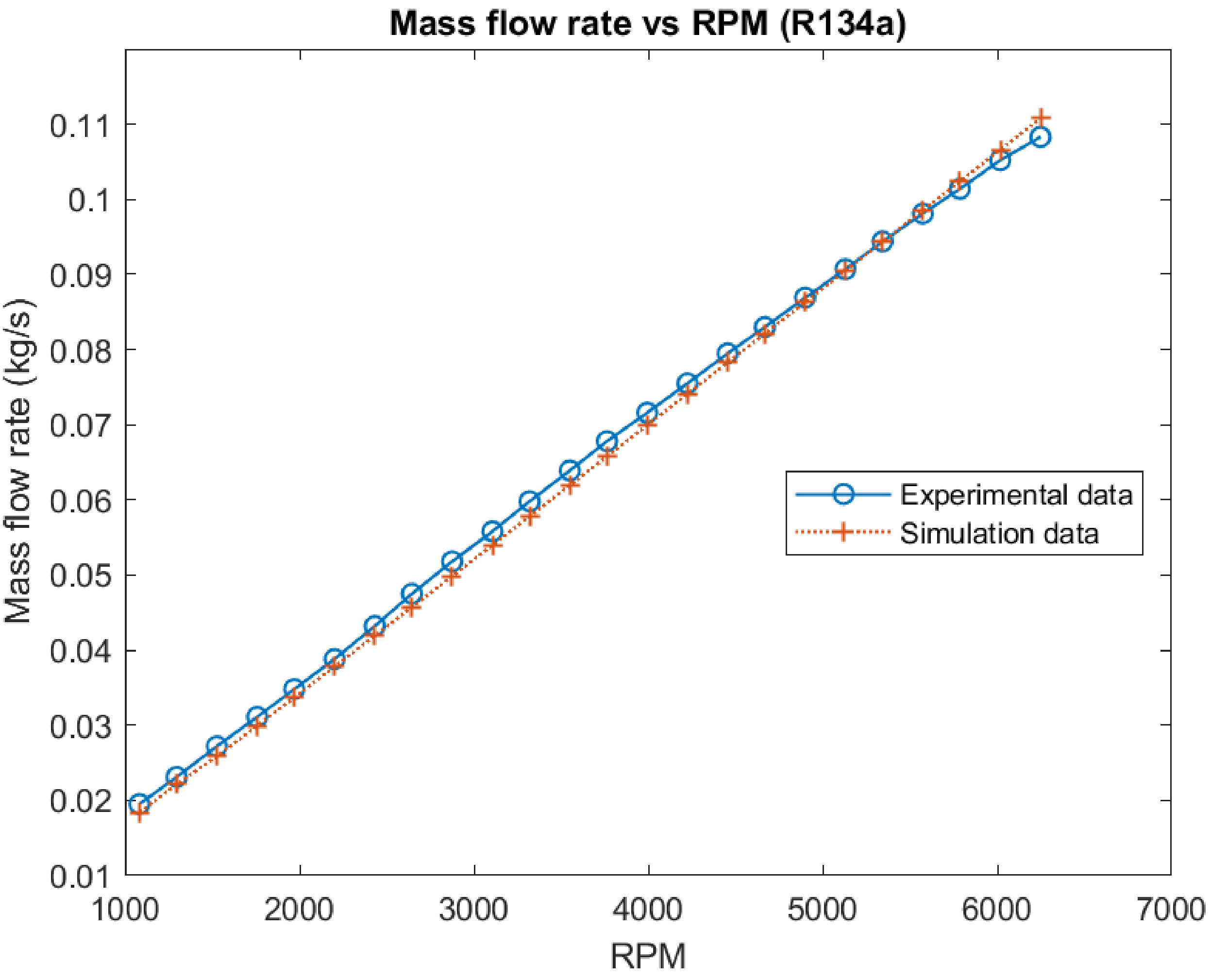


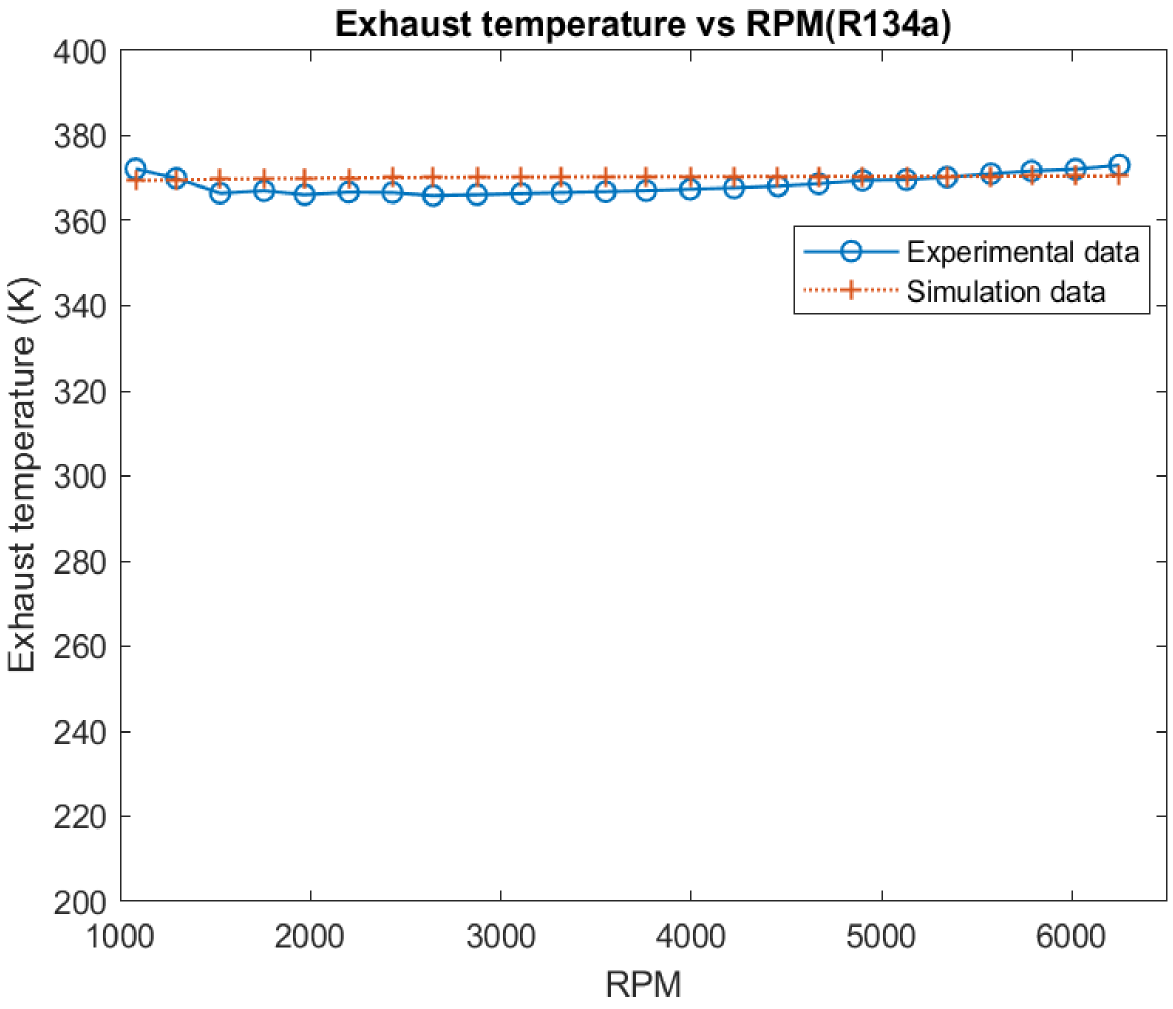

Semi empirical scroll compressor model (Winandy 2002)

- Model parameters calculated by minimizing an error function in MATLAB accounting for errors in prediction of mass flow rate, exhaust temperature and power consumption




The suction pressure is set as 196kPa (gauge pressure) and exhaust pressure is set at 1670kPa(gauge pressure) as specified in the datasheet provided.

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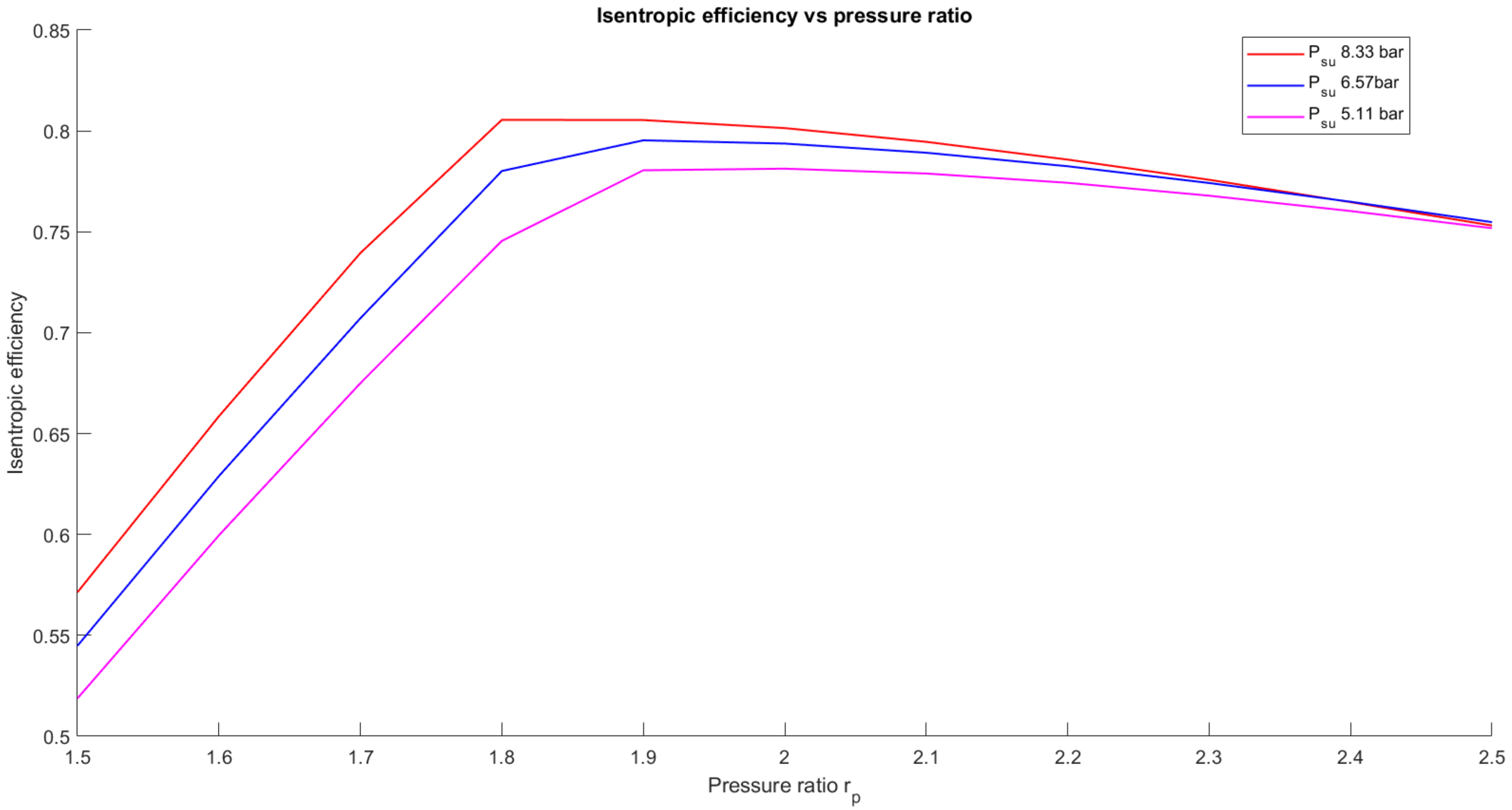
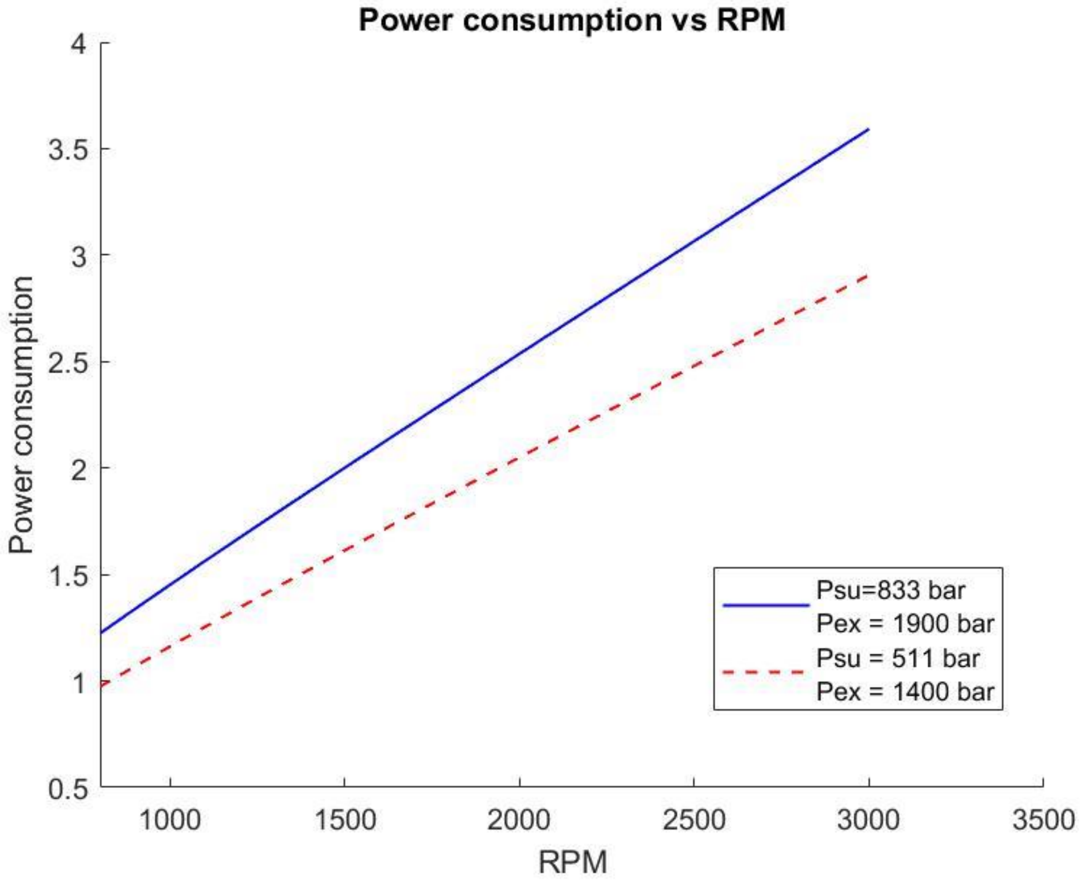
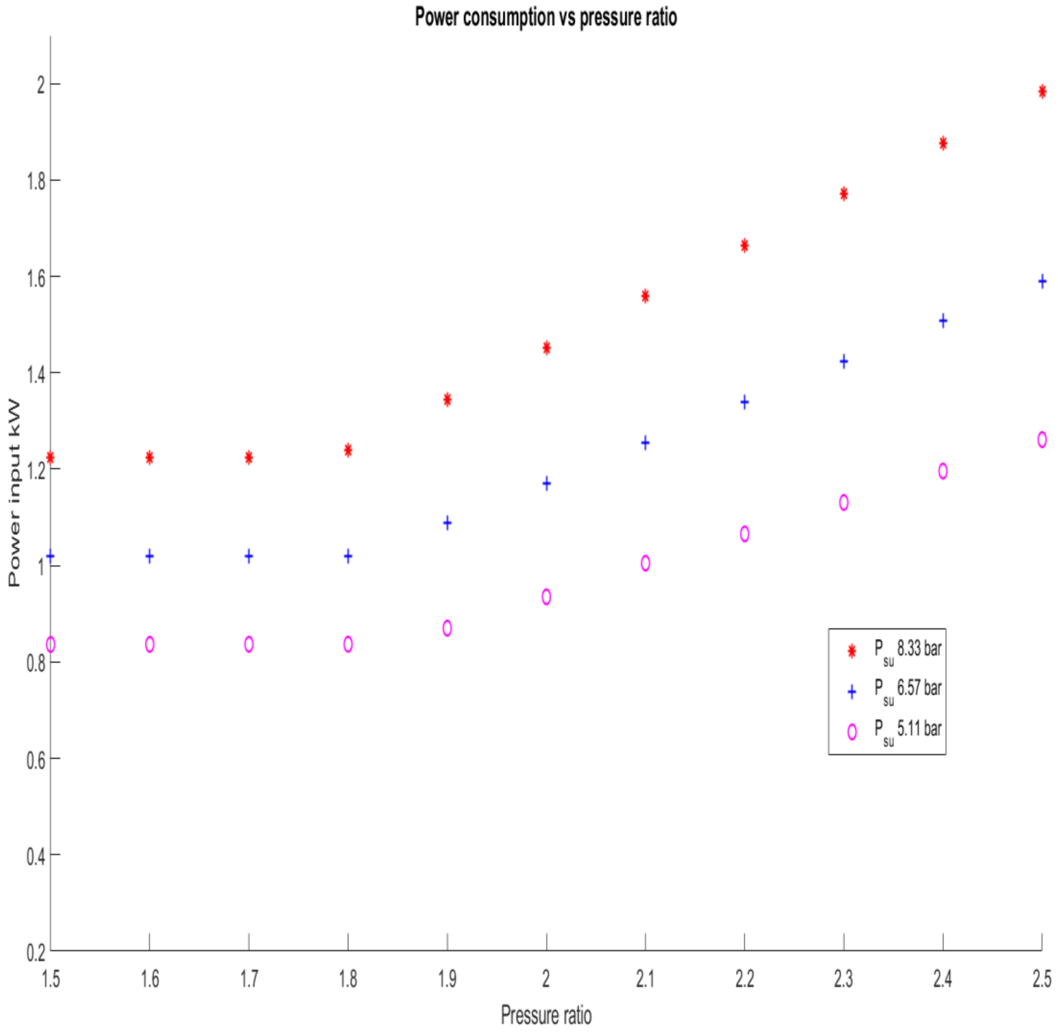



Isentropic efficiency vs pressure for SANDEN TRSA09 with R1233zd(E)
The parameters obtained for SANDEN TRSA09 with R134a is modified for R1233zd(E).

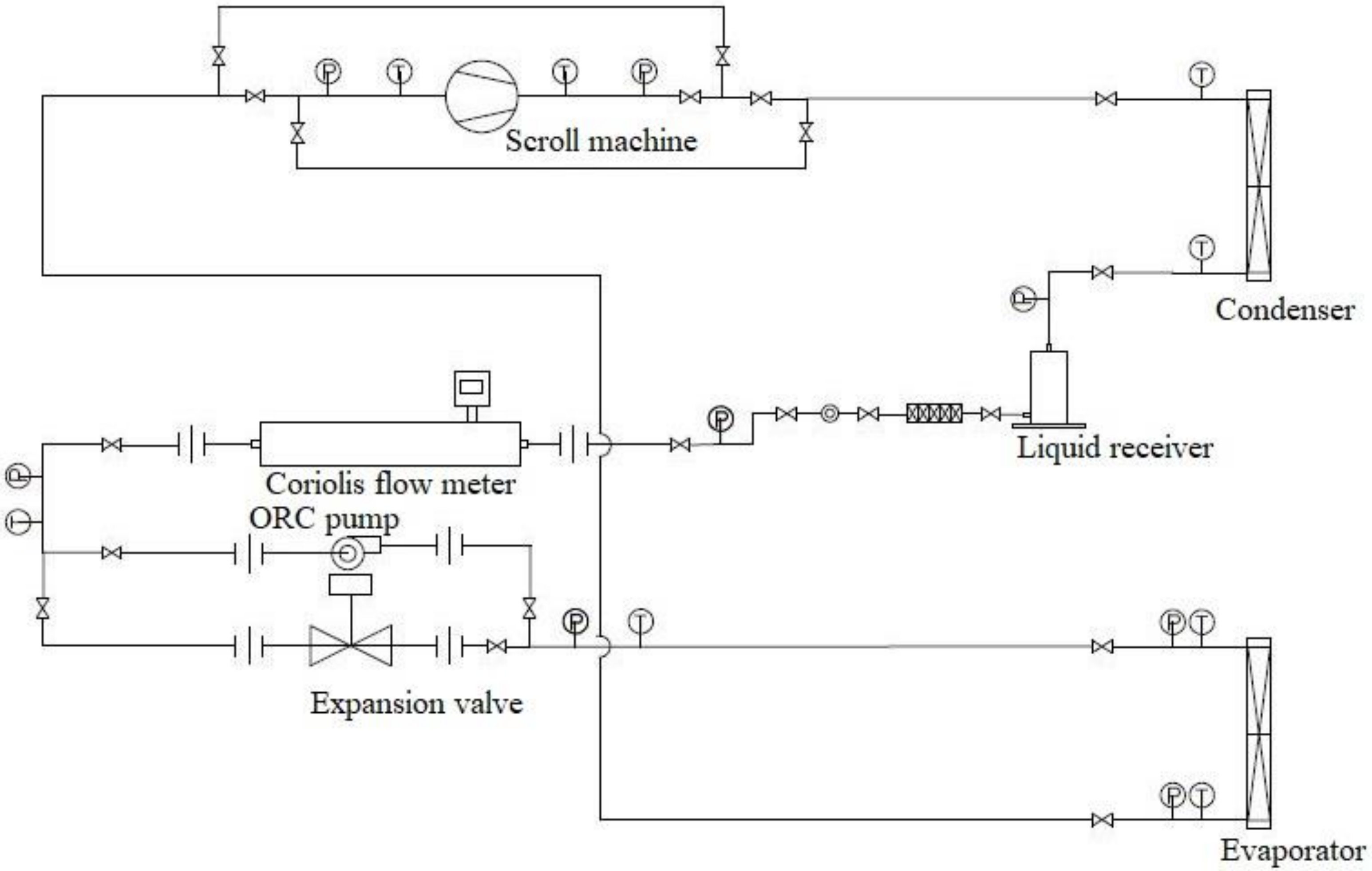



Power consumption vs RPM for SANDEN TRSA09 with R1233zd(E)

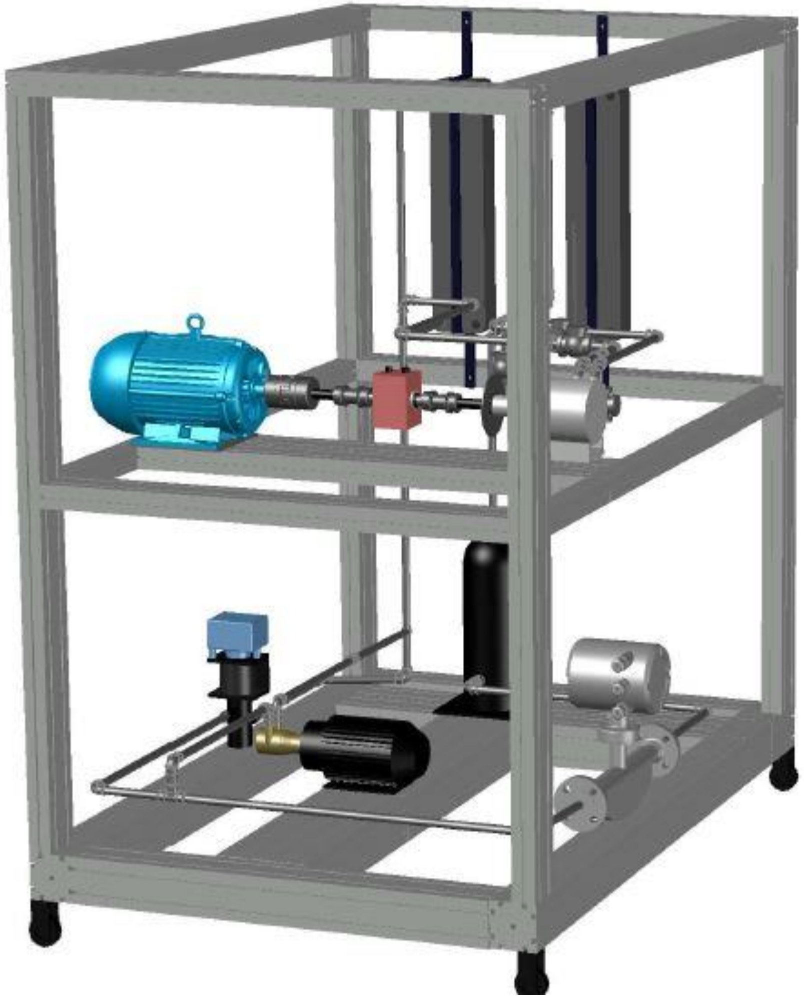



Power consumption vs pressure ratio for SANDEN TRSA09 with R1233zd(E)

# Schematic diagram of reversible HP-ORC system



# Reversible HP-ORC system



# Test rig construction in progress

# High Temperature Booster Heat Pump

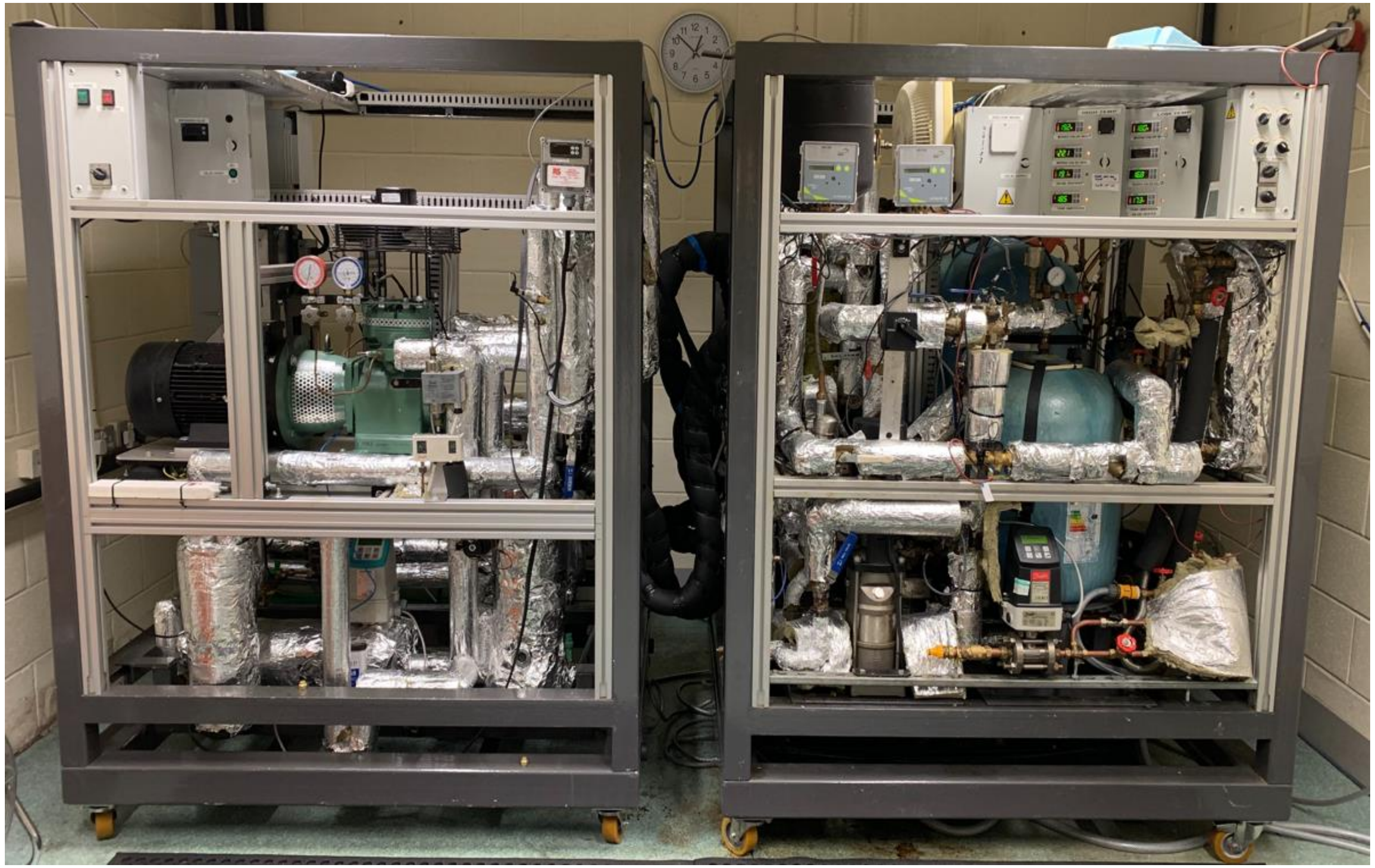

Supervisors
Prof. Neil Hewitt
Dr. Ming Jun Huang

Adam Suliman
PhD student

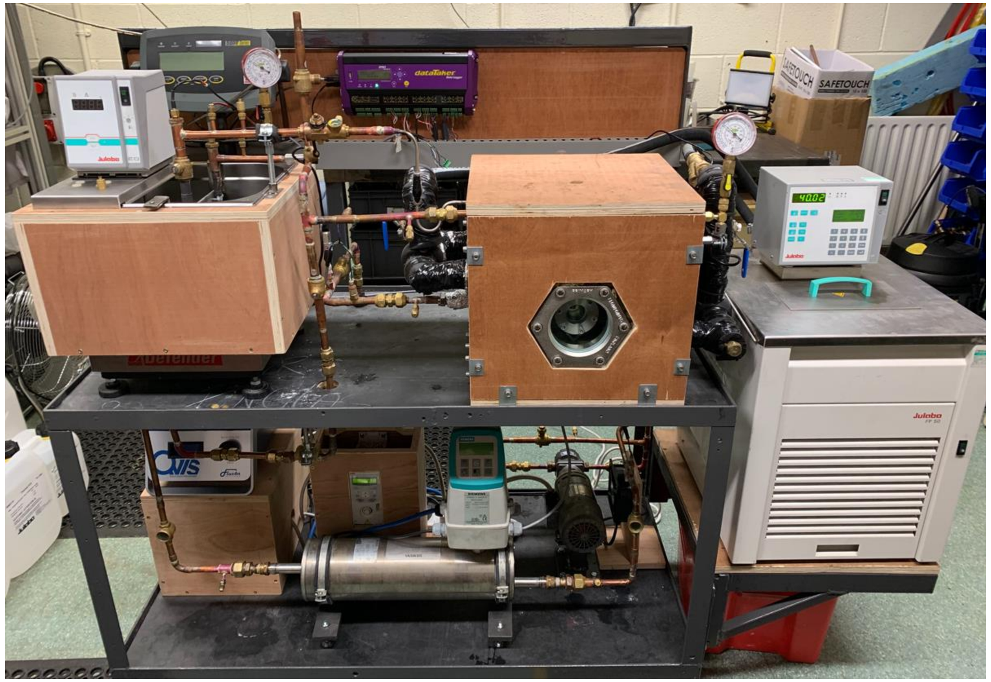
**Refrigerant-lubricant interactions at elevated temperatures and pressures.**

- Lubricant and refrigerant properties
- Testing campaign
- Sump temperatures – start-up and steady state
- Kinematic viscosity

# Experimental test-rigs

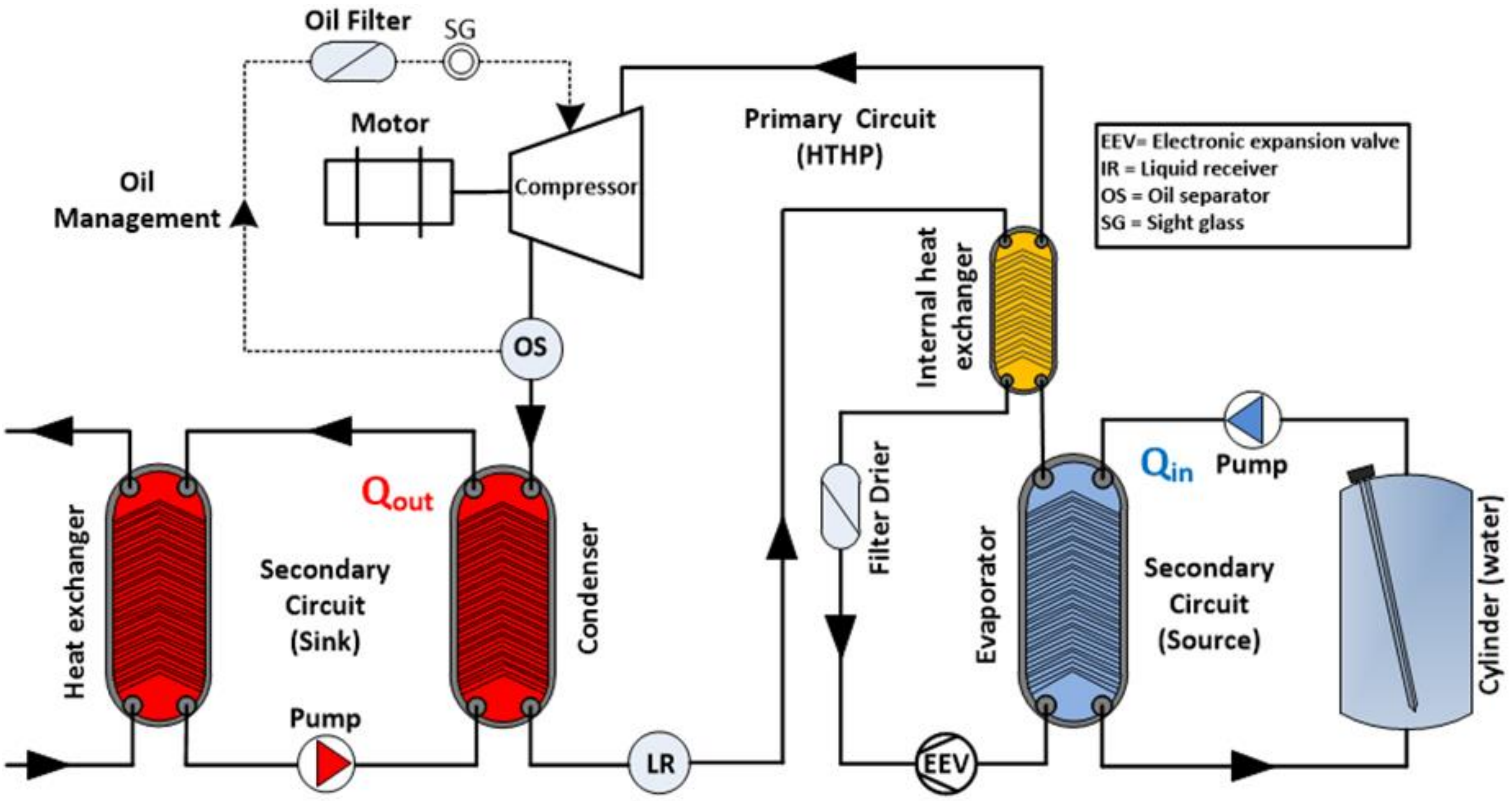


High temperature heat pump



Viscosity testing

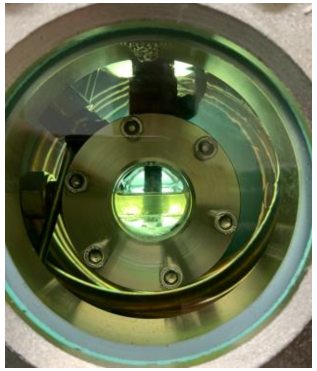
# HTHP circuit

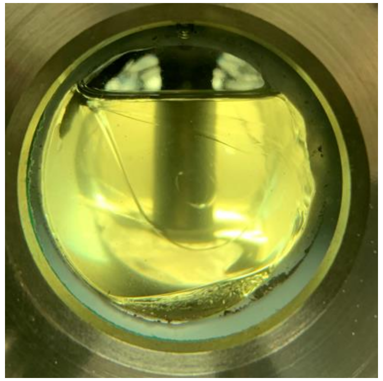


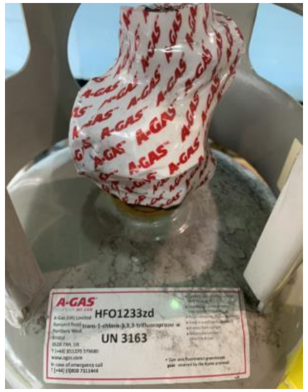

Basic schematic of HTHP circuit with oil management and secondary hydraulic circuits (source and sink)

# Lubricant and refrigerant properties

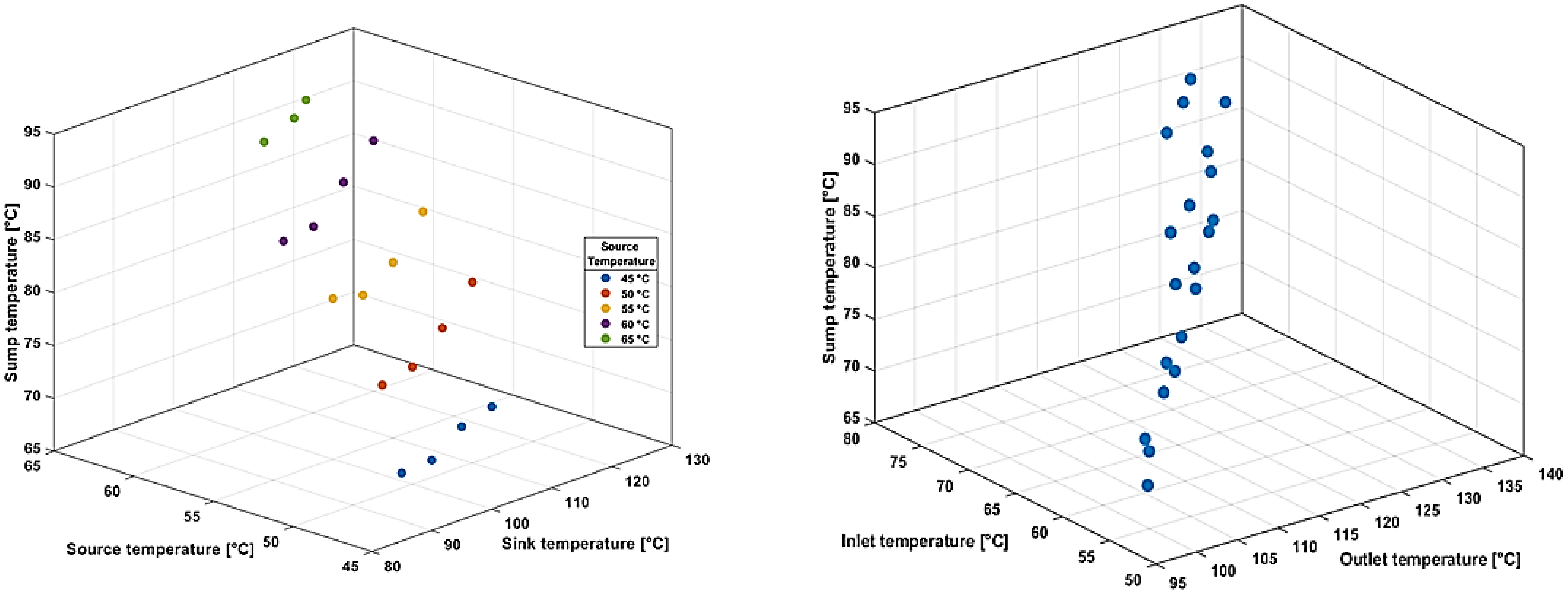
| Lubricant | | Refrigerant | |
|---|---|---|---|
| Group | Synthetic | Group | Isentropic (S) |
| Type | Polyol ester (POE) | Type | HCFO |
| Name | Reniso Triton SEZ 320 | Name | R1233zd(E) |
| Density | 1016 kg/m$^3$ | Critical temperature | 166.45 °C |
| Flash point | 278 °C | Critical pressure | 35.22 bar_g |
| KV at 40 °C | 301.0 mm$^2$/s | Normal Boiling Point | 18.26 °C |
| KV at 100 °C | 33.0 mm$^2$/s | ODP | 0.0003 |
| Viscosity Index | 148 | GWP | <1 |
| Pourpoint | -42 °C | Safety Group | A1 |



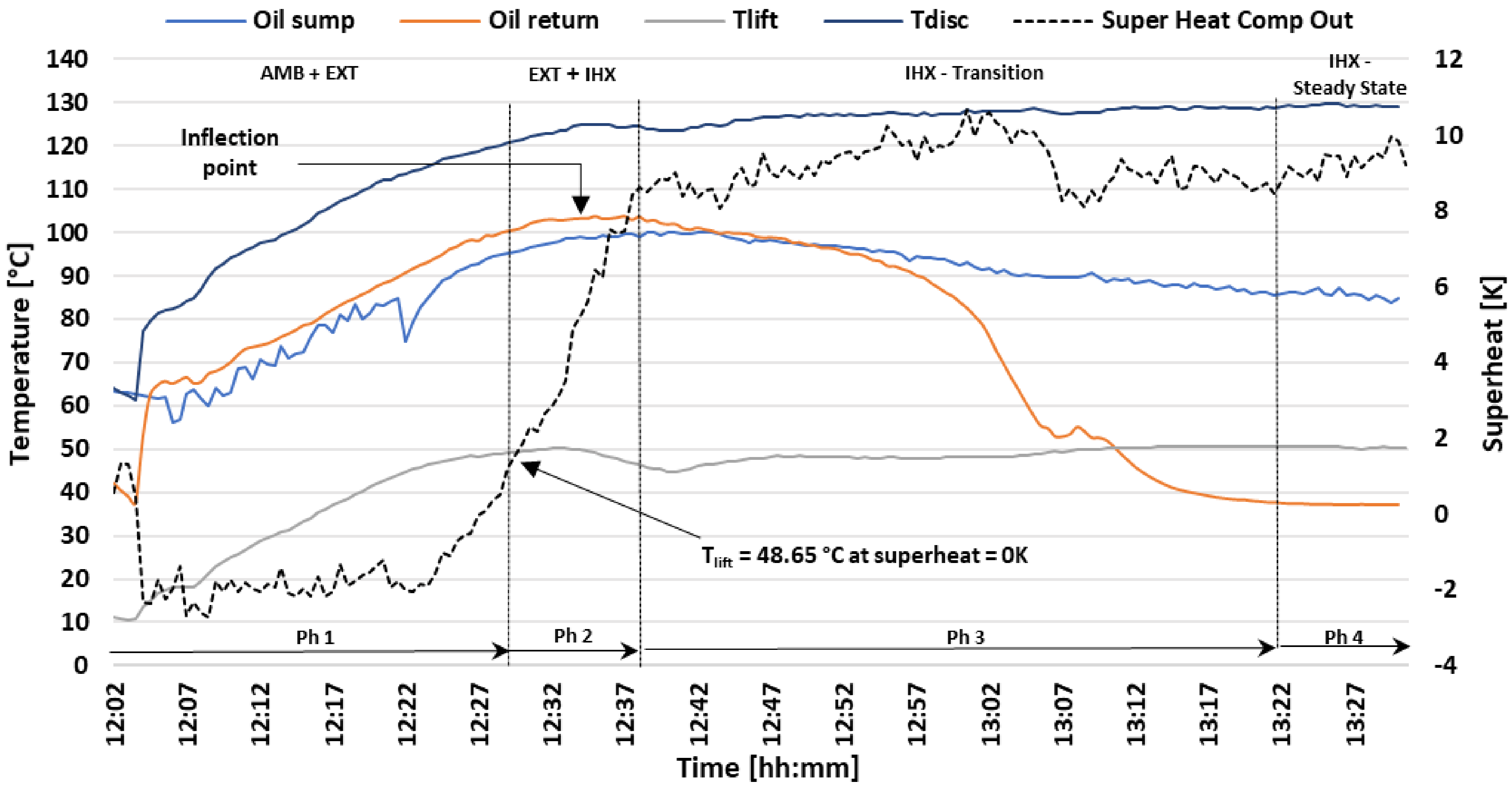



# Testing campaign



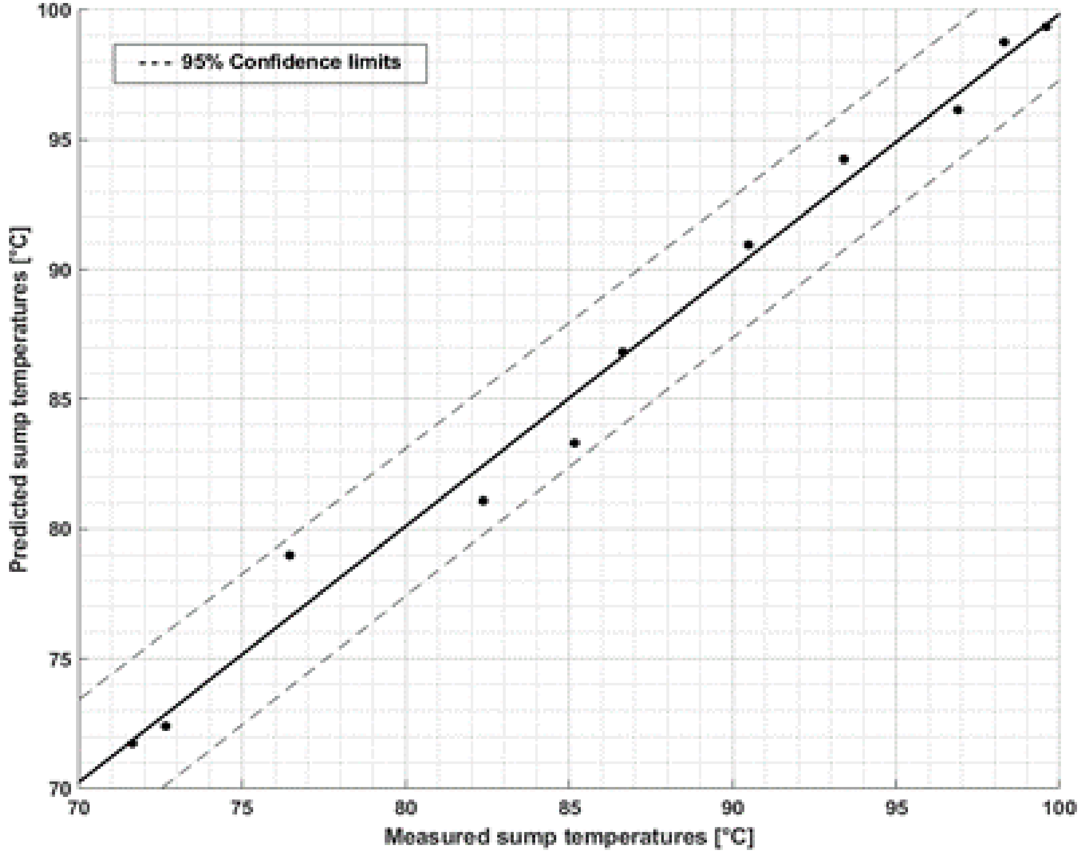

❑ (a) Plotted results for variables sink, source, and sump temperature during steady state testing. (b) Plotted results for variables outlet, inlet, and oil sump temperatures during steady state testing.

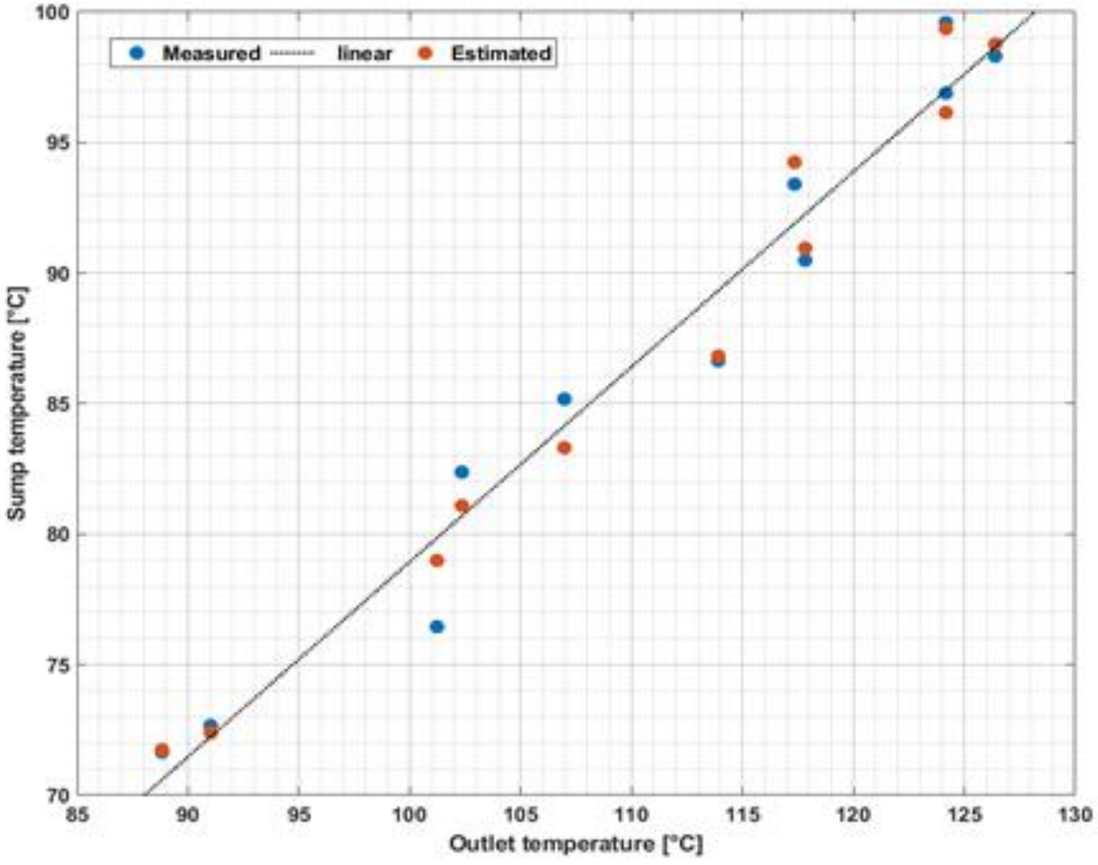
# Testing




- Transitions during start-up operations are shown (setpoints: Tsource 65°C and Tsink 115 °C), with four defined phases staged between idle and stable steady state conditions affecting oil management. Each stage is directly influenced by a combination of factors, including ambient heat (AMB), external heat sources (EXT), internal heat exchange (IHX).

# Sump temperatures at start-up




- (a) A plot showing oil sump pressure for steady state and start-up conditions. (b) A plot of the and oil kinematic viscosity on the logarithmic scale Vs. outlet temperature for steady state and start-up conditions

# Analysis

**Regression analysis**

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i \qquad i = 1, 2, 3 \dots n$$

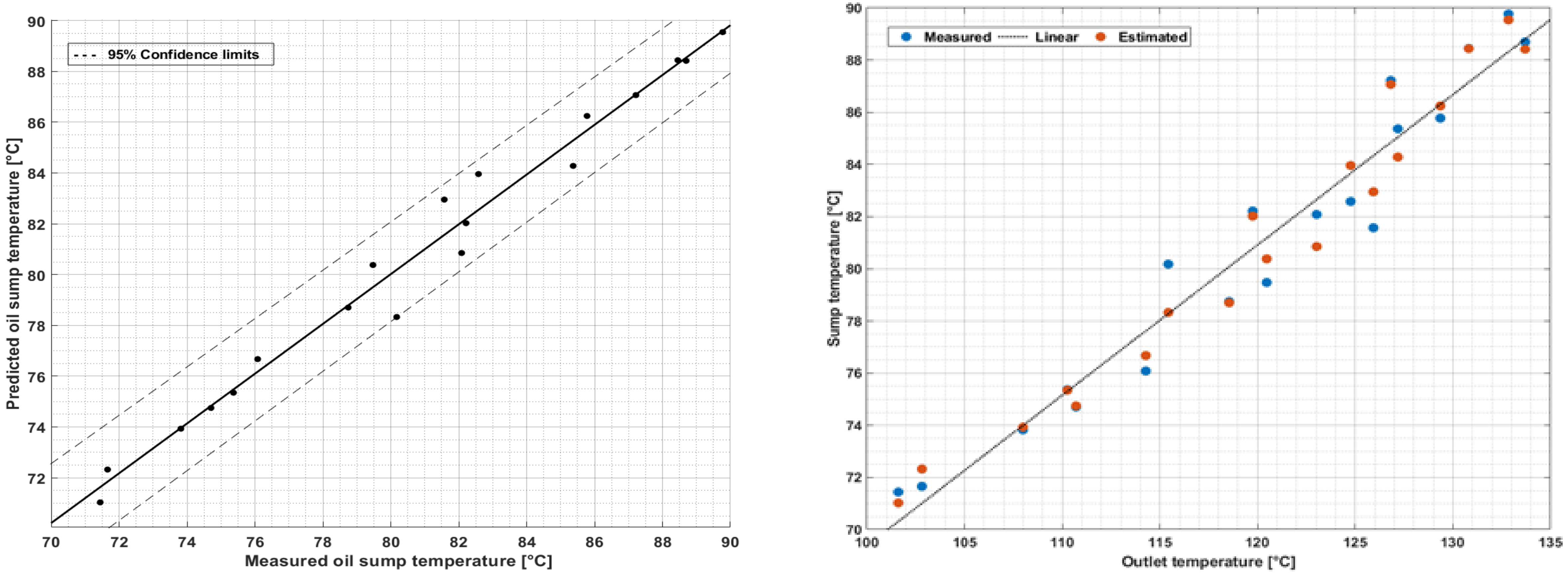
$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \dots . + \beta_n x_n + \varepsilon_i$$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_1 x_2 + \beta_5 x_1 x_3 + \beta_6 x_2 x_3 + \varepsilon_i$$

| Description | Coefficients ID | Coefficients Steady state | Coefficients Start-up |
|---|---|---|---|
| **(Intercept)** | β0 | 155.21 | 210.52 |
| **outlet** | β1 | -2.4516 | 7.6347 |
| **Inlet** | β2 | 3.5189 | -11.984 |
| **amb** | β3 | -6.0551 | -15.858 |
| **outlet: inlet** | β1,2 | -0.005005 | -0.024575 |
| **outlet: amb** | β1,3 | 0.098029 | -0.22406 |
| **inlet: amb** | β2,3 | -0.0728 | 0.61658 |

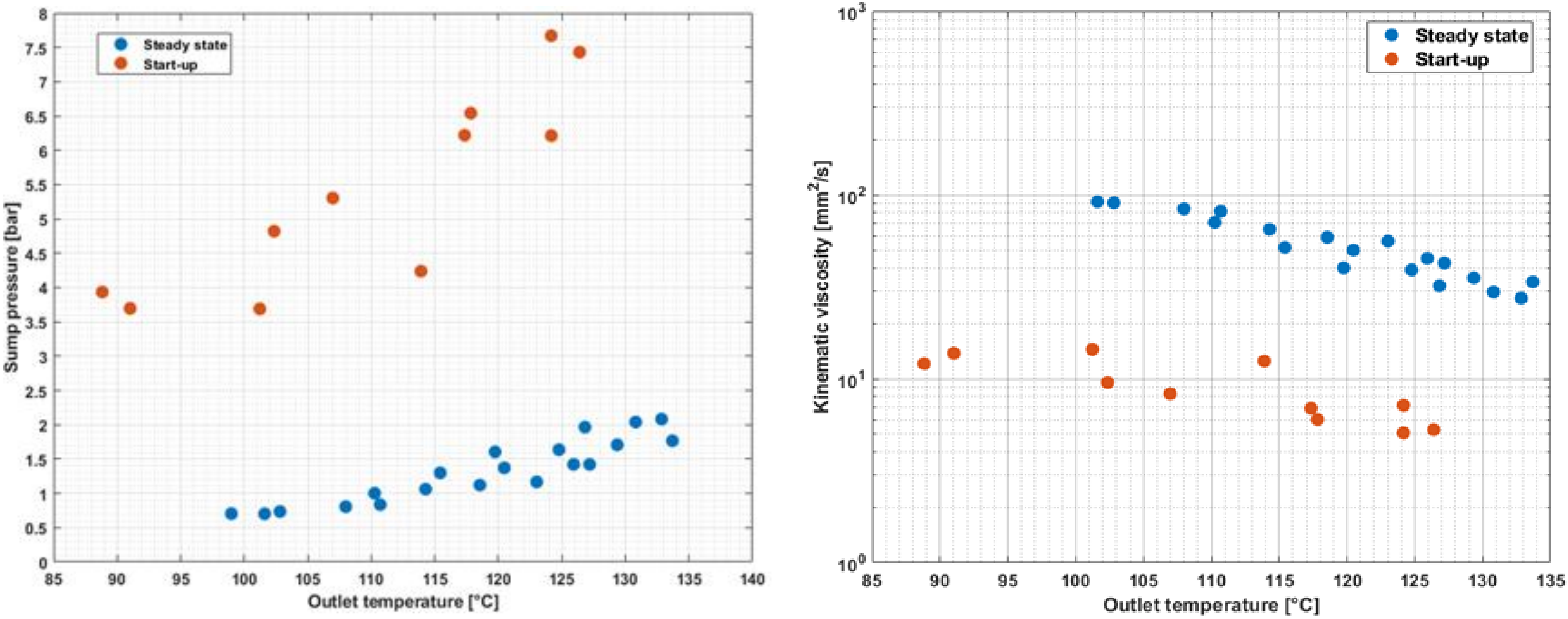
**Can extrapolation extent the range realistically in this work ??**

# Sump temperatures at steady state



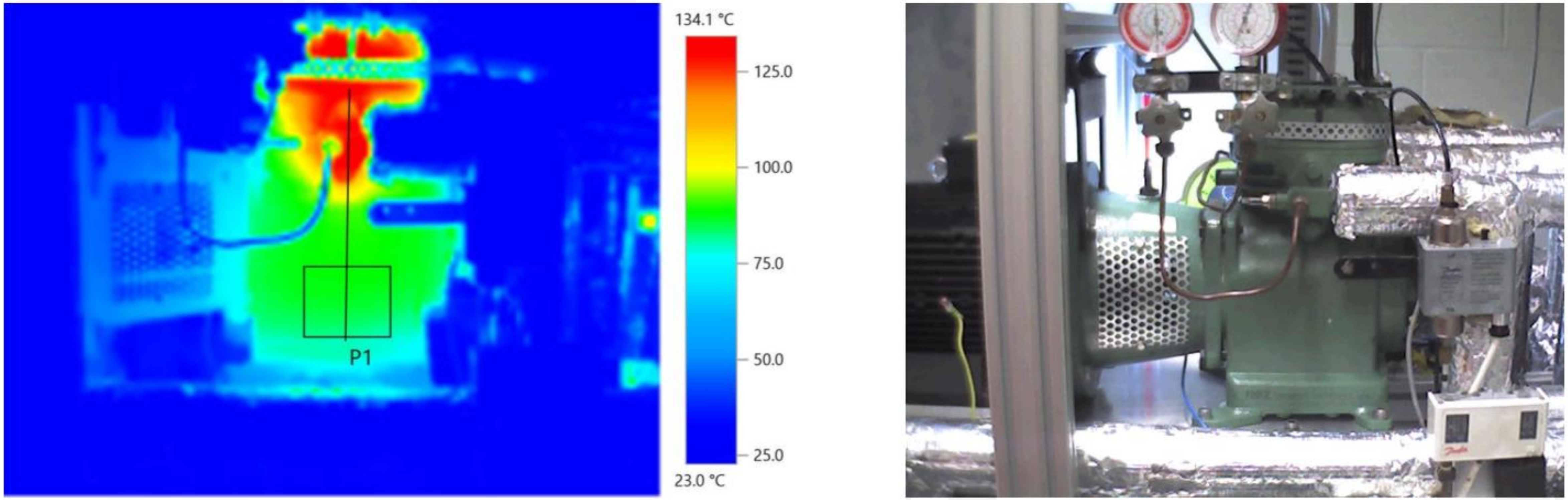

- (a) Comparison between measured oil sump temperature and predicted oil sump temperature derived using linear regression analysis dependant on outlet, inlet, and ambient temperatures. (b) Measured and predicted oil sump temperature corresponding to outlet discharge temperature.

# Oil Kinematic Viscosity



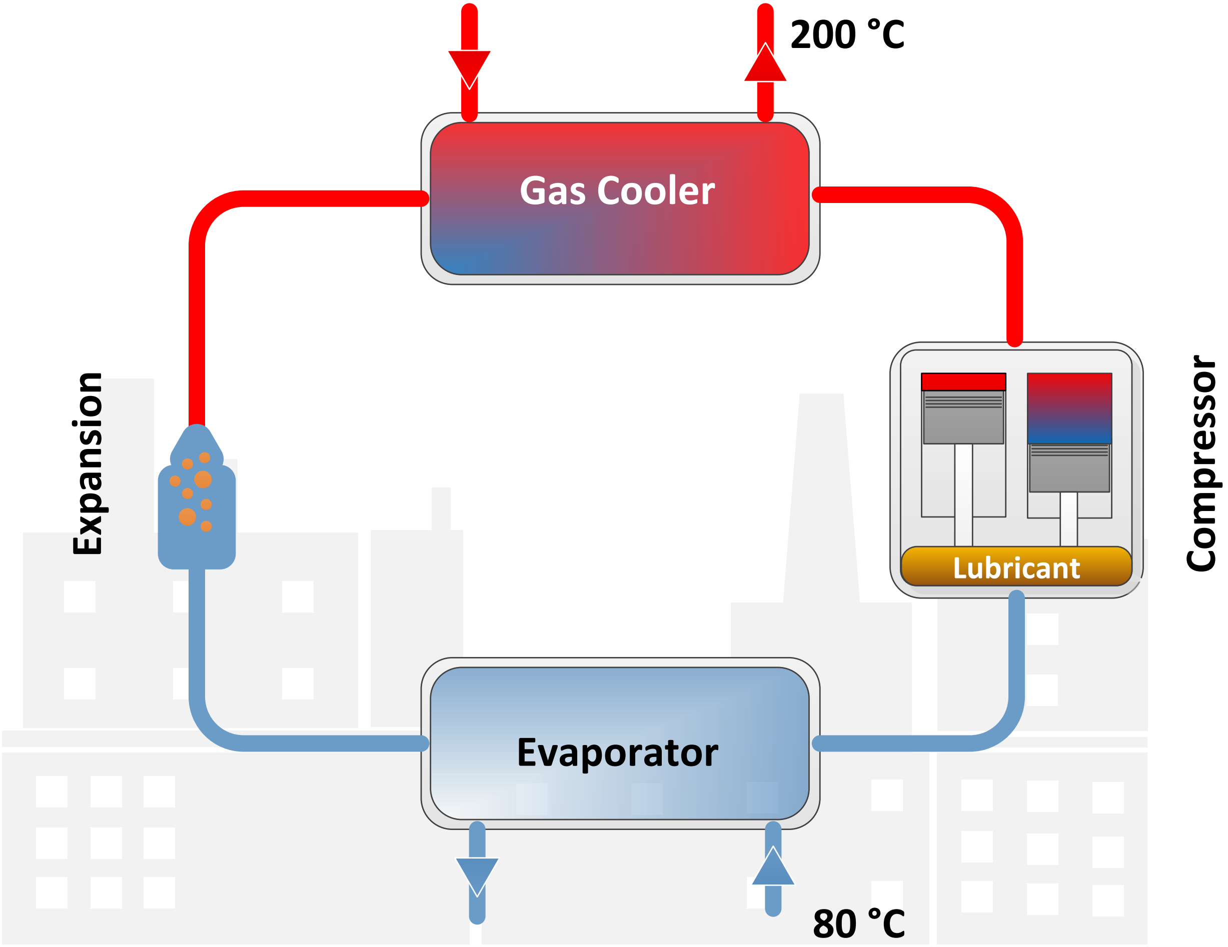

- (a) A plot showing oil sump pressure for steady state and start-up conditions. (b) A plot of the and oil kinematic viscosity on the logarithmic scale Vs. outlet temperature for steady state and start-up conditions.

# IR Thermography




(a) IR image of the compressor (discharge side profile), a rectangular section (P1) was analysed profiling the temperature at the sump; (b) Corresponding image of the Bitzer compressor.

Design and construction of VHTHP in conjunction with temperatures identified with other WPs.




**Basic heat pump cycle**

# Reference

PAPER ID: 1168
DOI: 10.18462/iir.rankine.2020.1168

**Theoretical Analysis of Transcritical HTHP Cycles with Low GWP HFO Refrigerants and Hydrocarbons for Process Heat up to 200 °C**

**Cordin ARPAGAUS, Frédéric BLESS, Stefan S. BERTSCH**

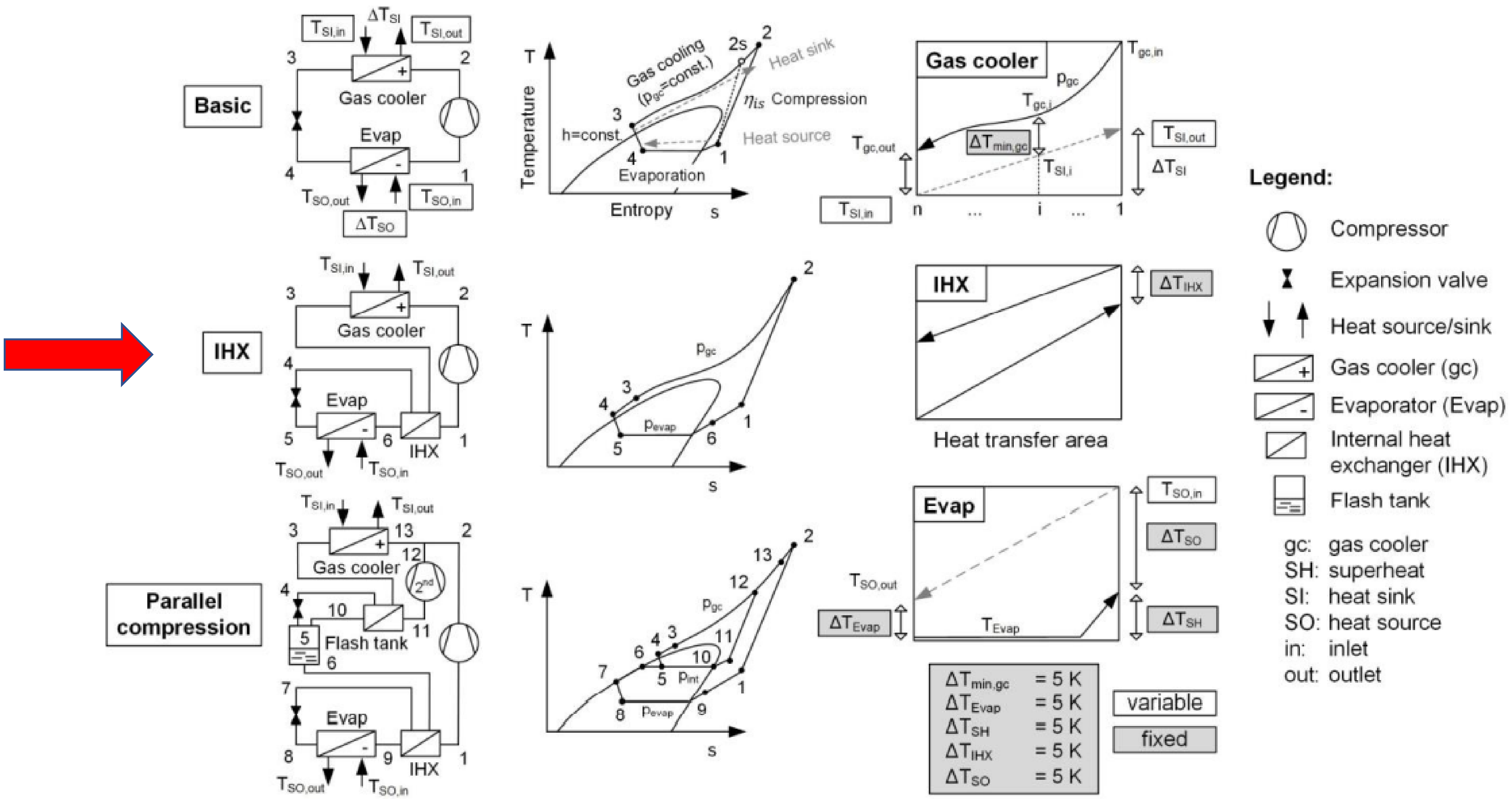



**Figure 1: Schematics of the investigated transcritical heat pump cycles with T-s diagrams and fixed approach temperatures in the gas cooler, IHX, and evaporator.**

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**Theoretical Analysis of Transcritical HTHP Cycles with Low GWP HFO Refrigerants and Hydrocarbons for Process Heat up to 200 °C**

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IHX cycle — Case study 1 (SI: 100 → 200 °C, SO: 80 → 75 °C)

| Refrigerant | $p_{gc}$ [bar] | COP [-] | $p_{ratio}$ [-] | VHC [kJ/m³] | $T_{gc,in}$ [C] | $T_{gc,out}$ [C] | η [-] | $\Delta T_{SH}$ [C] | $p_{evap}$ [bar] | $p_{int}$ [bar] | $p_{ratio,2nd}$ [-] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R601 | 35 | 3.3 | 12.3 | 2'968 | 204 | 105 | 0.53 | 5 | 2.8 | - | - |
| R514A | 37 | 3.5 | 10.1 | 3'883 | 209 | 105 | 0.55 | 5 | 3.7 | - | - |
| R1234ze(Z) | 46 | 3.4 | 6.9 | 6'187 | 219 | 105 | 0.55 | 5 | 6.7 | - | - |
| R1233zd(E ) | 44 | 3.4 | 8.6 | 4'936 | 207 | 106 | 0.54 | 5 | 5.1 | - | - |
| R1224yd(Z) | 52 | 3.4 | 9.0 | 5'395 | 205 | 105 | 0.54 | 5 | 5.7 | - | - |
| R245fa | 60 | 3.4 | 9.8 | 5'939 | 205 | 105 | 0.54 | 5 | 6.1 | - | - |
| R600 | 62 | 3.3 | 7.7 | 6'796 | 205 | 106 | 0.53 | 5 | 8.1 | - | - |

IHX cycle — Case study 2 (SI: 30 → 200 °C, SO: 30 → 25 °C)

| Refrigerant | $p_{gc}$ [bar] | COP [-] | $p_{ratio}$ [-] | VHC [kJ/m³] | $T_{gc,in}$ [C] | $T_{gc,out}$ [C] | η [-] | $\Delta T_{SH}$ [C] | $p_{evap}$ [bar] | $p_{int}$ [bar] | $p_{ratio,2nd}$ [-] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| R601 | 35 | 2.7 | 62 | 844 | 203 | 54 | 0.46 | 5 | 0.6 | - | - |
| R514A | 45 | 2.9 | 62 | 1'132 | 204 | 35 | 0.50 | 5 | 0.7 | - | - |
| R1234ze(Z) | 45 | 2.9 | 30 | 2'173 | 211 | 35 | 0.50 | 5 | 1.5 | - | - |
| R1233zd(E ) | 52 | 2.9 | 48 | 1'622 | 205 | 35 | 0.50 | 5 | 1.1 | - | - |
| R1224yd(Z) | 67 | 2.9 | 54 | 1'805 | 204 | 35 | 0.50 | 5 | 1.2 | - | - |
| R245fa | 79 | 2.9 | 65 | 1'872 | 205 | 35 | 0.50 | 5 | 1.2 | - | - |
| R600 | 83 | 2.9 | 40 | 2'681 | 204 | 35 | 0.49 | 5 | 2.1 | - | - |

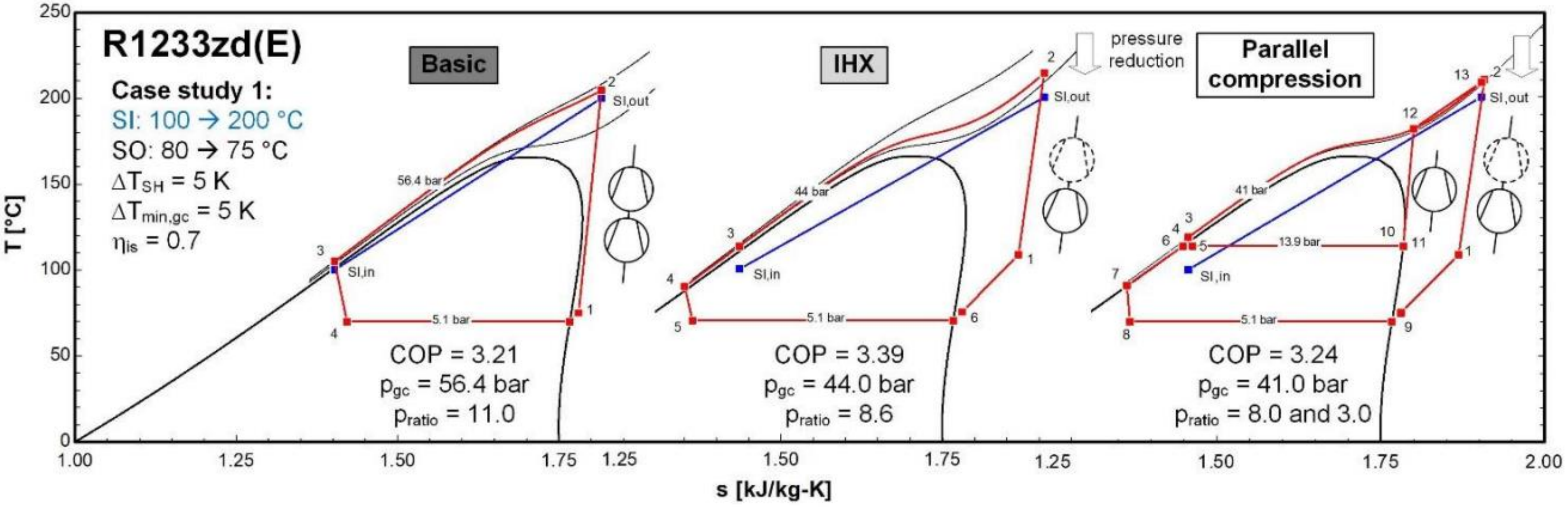
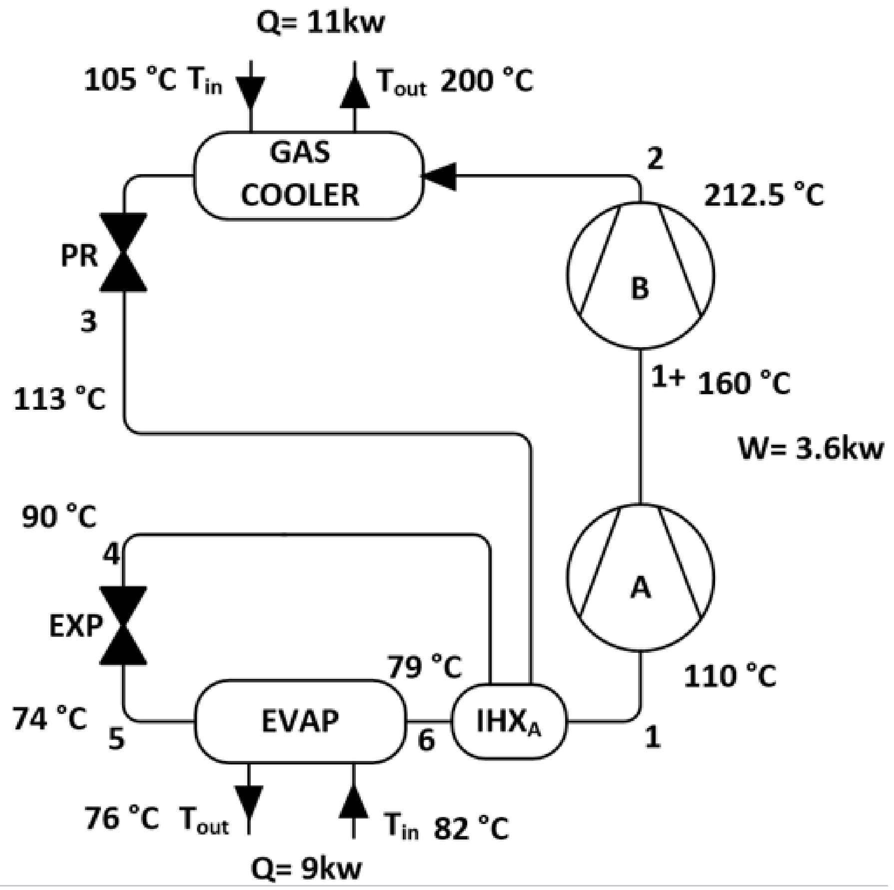


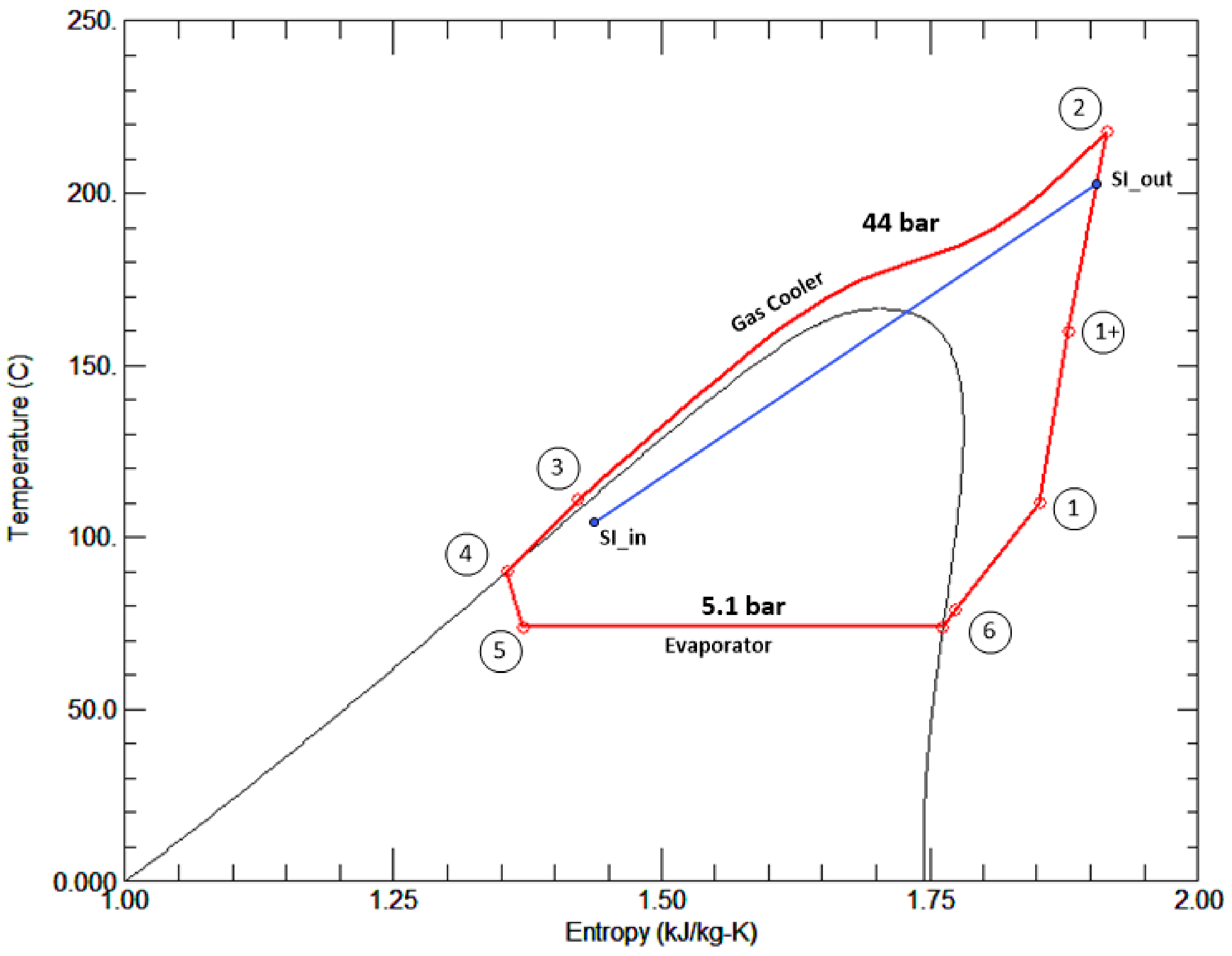

**Figure 4: Comparision of transcritical cycles with R1233zd(E).**

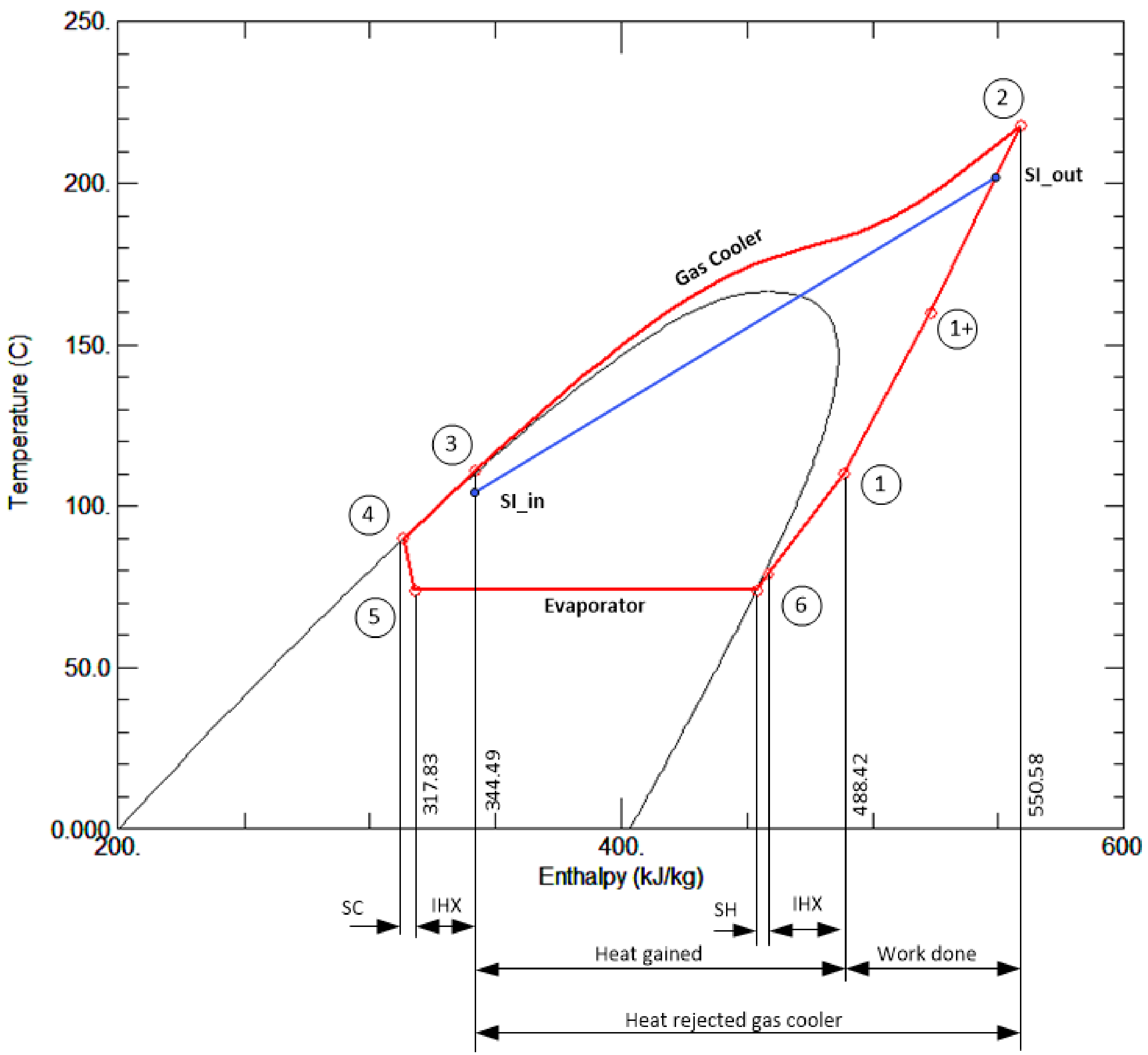
# Calculations & REFPROP details

| | Point | Temperature | Pressure | Density | Volume | Enthalpy | Entropy | Quality | Phase | GC secondary Temperature |
|---|---|---|---|---|---|---|---|---|---|---|
| | | °C | (bar_g) | (kg/m$^3$) | (m$^3$/kg) | (kJ/kg) | (kJ/kg-K) | (kg/kg) | | °C |
| Comp | 1 | 110 | 5.1 | 27.972 | 0.035749 | 488.42 | 1.8527 | Superheated | Gas | |
| | ↓ | 160 | 17 | 83.419 | 0.011988 | 523.07 | 1.8796 | Superheated | Gas | |
| Gas Cooler | 2 | 212.5 | 44 | 232.78 | 0.004296 | 550.58 | 1.8986 | Undefined | Supercritical | |
| | ↓ | 208 | 44 | 243.58 | 0.0041055 | 543.45 | 1.8839 | Undefined | Supercritical | 200.00 |
| | ↓ | 200 | 44 | 268.84 | 0.0037196 | 529.71 | 1.8551 | Undefined | Supercritical | 194.72 |
| | ↓ | 195 | 44 | 291.39 | 0.0034319 | 519.99 | 1.8344 | Undefined | Supercritical | 189.44 |
| | ↓ | 190 | 44 | 324.41 | 0.0030825 | 508.65 | 1.8101 | Undefined | Supercritical | 184.17 |
| | ↓ | 185 | 44 | 381.33 | 0.0026224 | 494.03 | 1.7783 | Undefined | Supercritical | 178.89 |
| | ↓ | 180 | 44 | 497.29 | 0.0020109 | 473.05 | 1.7322 | Undefined | Supercritical | 173.61 |
| | ↓ | 175 | 44 | 632.55 | 0.0015809 | 452.6 | 1.6869 | Undefined | Supercritical | 168.33 |
| → Constant pressure → | ↓ | 170 | 44 | 714.13 | 0.0014003 | 438.67 | 1.6556 | Undefined | Supercritical | 163.06 |
| | ↓ | 165 | 44 | 768.89 | 0.0013006 | 427.58 | 1.6305 | Subcooled | Liquid | 157.78 |
| | ↓ | 160 | 44 | 811.13 | 0.0012328 | 417.78 | 1.608 | Subcooled | Liquid | 152.50 |
| | ↓ | 155 | 44 | 846.22 | 0.0011817 | 408.74 | 1.587 | Subcooled | Liquid | 147.22 |
| | ↓ | 150 | 44 | 876.65 | 0.0011407 | 400.19 | 1.5669 | Subcooled | Liquid | 141.94 |
| | ↓ | 145 | 44 | 903.8 | 0.0011064 | 392.01 | 1.5475 | Subcooled | Liquid | 136.67 |
| | ↓ | 140 | 44 | 928.47 | 0.001077 | 384.11 | 1.5285 | Subcooled | Liquid | 131.39 |
| | ↓ | 135 | 44 | 951.22 | 0.0010513 | 376.43 | 1.5098 | Subcooled | Liquid | 126.11 |
| | ↓ | 130 | 44 | 972.43 | 0.0010284 | 368.93 | 1.4913 | Subcooled | Liquid | 120.83 |
| | ↓ | 125 | 44 | 992.36 | 0.0010077 | 361.59 | 1.473 | Subcooled | Liquid | 115.56 |
| | ↓ | 120 | 44 | 1011.2 | 0.0009889 | 354.39 | 1.4547 | Subcooled | Liquid | 110.28 |
| | ↓ | 113 | 44 | 1036.1 | 0.0009651 | 344.49 | 1.4294 | Subcooled | Liquid | 105.00 |
| IHX > Exp | 4 | 90 | 7.3212 | 1083.4 | 0.000923 | 313.38 | 1.3555 | 0 | Liquid | |
| Evap | 5 | 74 | 4.6518 | 164.25 | 0.0060883 | 317.83 | 1.3704 | 0.16 | 2-Phase | |
| | 5 | 74 | 4.6518 | 29.924 | 0.033418 | 453.98 | 1.7626 | 1 | Gas | |
| IHX | 6 | 79 | 5.1 | 31.989 | 0.031261 | 457.83 | 1.7695 | Superheated | Gas | |
| | ↓ | 110 | 5.1 | 27.972 | 0.035749 | 488.42 | 1.8527 | Superheated | Gas | |



# Calculations & REFPROP details



# Calculation based on design and REFPROP

| Initial Q Evap | Sec-Tevap | Sec-Tcond | ΔT lift | ΔT Ref Source | ΔT Ref Sink | Pgc | Pevap |
|---|---|---|---|---|---|---|---|
| kW | ° C | ° C | K | K | K | bar_g | bar_g |
| 4.0 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 4.5 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 5.0 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 5.5 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 6.0 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 6.5 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 7.0 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 7.5 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 8.5 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 9.0 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 9.5 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |
| 10.0 | 80.0 | 200.0 | 120.0 | 5.0 | 100.0 | 44.00 | 5.10 |

| h1 | h1+ | h2 | W= h2-h1 | $h2_{isen}$ | h3 | qc= h2-h3 | h4 | h5 | h6 | qr = h1-h4 | ṁ | Vol= ṁ/ρ | Q_comp | Q_gc | Q_evap | $QIHX_h$ | $QIHX_c$ | Q_loss | P_ratio | | $COP_{Ref}$ | $COP_{cond}$ | $COP_{carnot}$ | VHC GC | Isen η | vol η |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | kJ/kg | $kg/sec^{-1}$ | $m^3/hr$ | kW | kW | kW | kW | kW | kW | Comp1 | Comp2 | - | - | - | $kJ/m^3$ | % | % |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0229 | 3.11 | 1.4 | 4.7 | 4.0 | 0.71 | 0.70 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 98.0% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0257 | 3.50 | 1.6 | 5.3 | 4.5 | 0.80 | 0.79 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.7% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0286 | 3.89 | 1.8 | 5.9 | 5.0 | 0.89 | 0.87 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.5% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0314 | 4.28 | 2.0 | 6.5 | 5.5 | 0.98 | 0.96 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.2% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0343 | 4.67 | 2.1 | 7.1 | 6.0 | 1.07 | 1.05 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.0% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0371 | 5.06 | 2.3 | 7.7 | 6.5 | 1.16 | 1.14 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 96.7% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0400 | 5.45 | 2.5 | 8.2 | 7.0 | 1.24 | 1.22 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 96.4% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0428 | 5.84 | 2.7 | 8.8 | 7.5 | 1.33 | 1.31 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 96.2% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0486 | 6.61 | 3.0 | 10.0 | 8.5 | 1.51 | 1.49 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 95.7% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0514 | 7.00 | 3.2 | 10.6 | 9.0 | 1.60 | 1.57 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 95.4% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0543 | 7.39 | 3.4 | 11.2 | 9.5 | 1.69 | 1.66 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 95.2% |
| 488.4 | 523.1 | 550.6 | 62.2 | 532.0 | 344.5 | 206.1 | 313.4 | 317.8 | 457.8 | 175.0 | 0.0571 | 7.78 | 3.6 | 11.8 | 10.0 | 1.78 | 1.75 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 94.9% |

enlarge


| ṁ | Vol= ṁ/ρ | Q_comp | Q_gc | Q_evap | $QIHX_h$ | $QIHX_c$ | Q_loss | P_ratio | | $COP_{Ref}$ | $COP_{cond}$ | $COP_{carnot}$ | VHC GC | Isen η | vol η |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $kg/sec^{-1}$ | $m^3/hr$ | kW | kW | kW | kW | kW | kW | Comp1 | Comp2 | - | - | - | $kJ/m^3$ | % | % |
| 0.0229 | 3.11 | 1.4 | 4.7 | 4.0 | 0.71 | 0.70 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 98.0% |
| 0.0257 | 3.50 | 1.6 | 5.3 | 4.5 | 0.80 | 0.79 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.7% |
| 0.0286 | 3.89 | 1.8 | 5.9 | 5.0 | 0.89 | 0.87 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.5% |
| 0.0314 | 4.28 | 2.0 | 6.5 | 5.5 | 0.98 | 0.96 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.2% |
| 0.0343 | 4.67 | 2.1 | 7.1 | 6.0 | 1.07 | 1.05 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 97.0% |
| 0.0371 | 5.06 | 2.3 | 7.7 | 6.5 | 1.16 | 1.14 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 96.7% |
| 0.0400 | 5.45 | 2.5 | 8.2 | 7.0 | 1.24 | 1.22 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 96.4% |
| 0.0428 | 5.84 | 2.7 | 8.8 | 7.5 | 1.33 | 1.31 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 96.2% |
| 0.0486 | 6.61 | 3.0 | 10.0 | 8.5 | 1.51 | 1.49 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 95.7% |
| 0.0514 | 7.00 | 3.2 | 10.6 | 9.0 | 1.60 | 1.57 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 95.4% |
| 0.0543 | 7.39 | 3.4 | 11.2 | 9.5 | 1.69 | 1.66 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 95.2% |
| 0.0571 | 7.78 | 3.6 | 11.8 | 10.0 | 1.78 | 1.75 | 1.2 | 3.8 | 8.6 | 2.82 | 3.32 | 3.94 | 4957.39 | 70.2% | 94.9% |


-> Suggested compressor sizing = $4.5 m^3/h$

$Q_{gc}$ =6.5; $Q_{evap}$ = 5.5; COP =3.3

$P_{gc}$ = 44 bar_g; $P_{evap}$ = 5.1

-> Suggested compressor sizing = $7 m^3/h$

$Q_{gc}$ =10.6; $Q_{evap}$ = 9.0; COP =3.3

$P_{gc}$ = 44 bar_g; $P_{evap}$ = 5.1

# Thank you