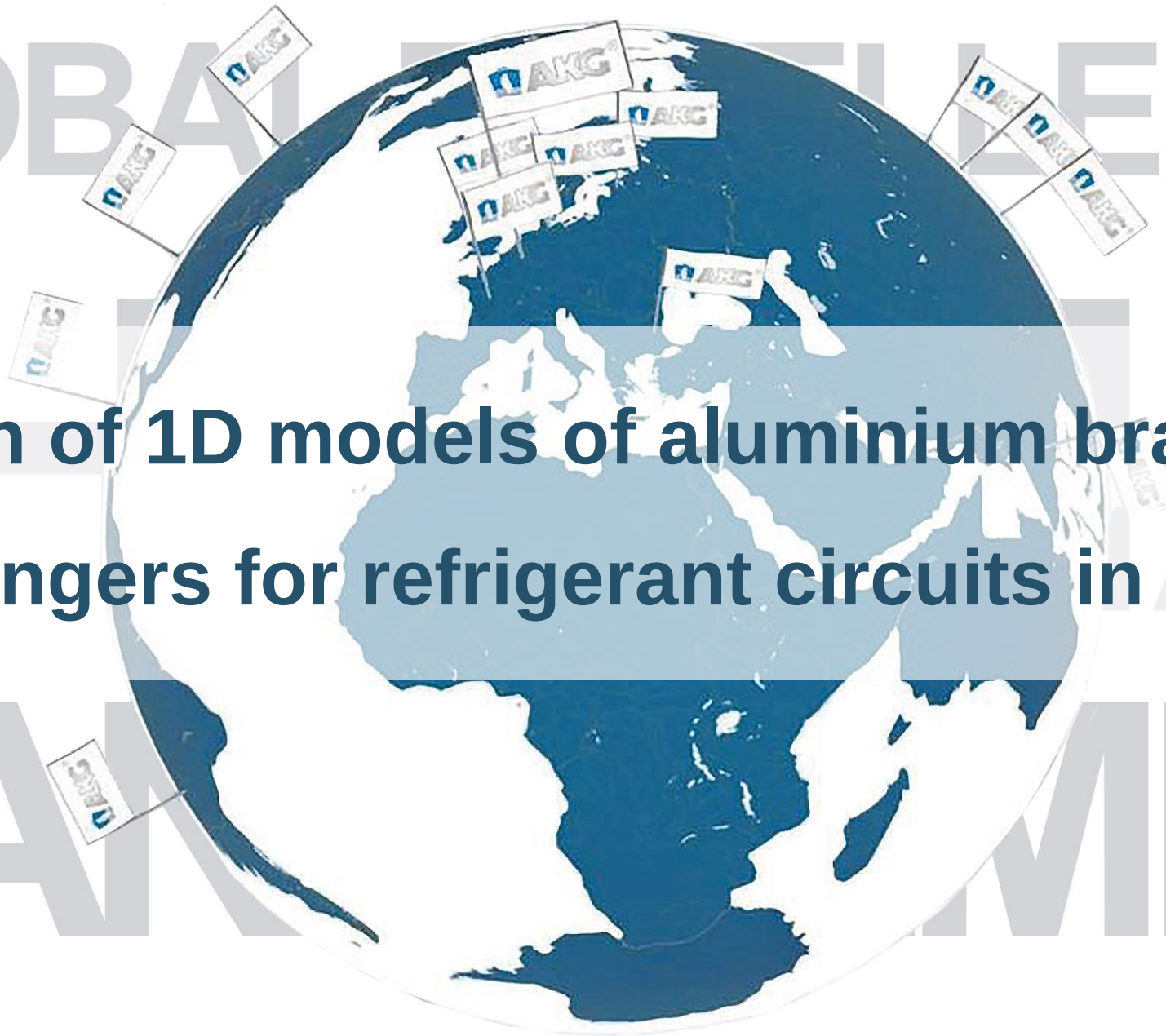


GLOBAL LEADERSHIP IN

**Validation of 1D models of aluminium brazed plate heat
exchangers for refrigerant circuits in KULI-HVAC**

MANAGEMENT



Founded **1919**



3,000 employees worldwide
(840 at HQ Hofgeismar)



11 Production plants



~402 Million Euro (2024)



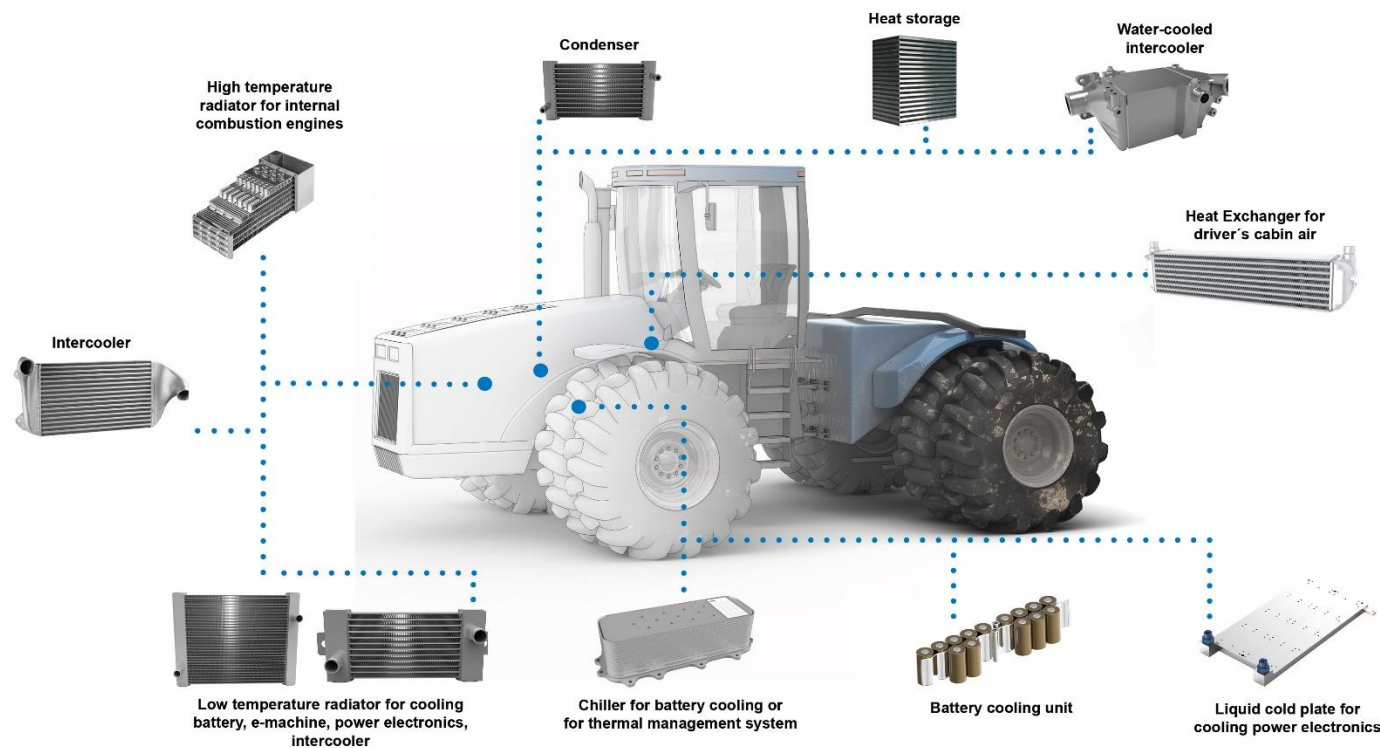
14 Sales companies



3. Generation
family owned business

Our Locations





High-Performance Heat Exchangers for

- Coolant/Water
- Oil
- Charge Air/Air
- Refrigerant
- Hydrogen and Various Gases
- Phase Change Material (PCM)

Manufactured from **Aluminum** and Plastic in

- Brazed
- Welded
- Glued Construction



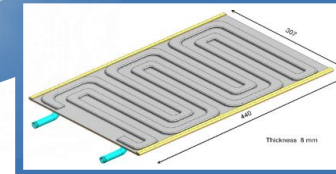
Components
and Cooling Systems



Refrigerant Circuit

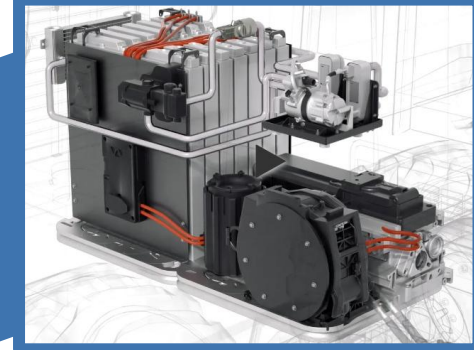


Patented
Innovations



Battery cooling

Full Thermal
Management
Systems



 **AKG Green**
Thermal Solutions.

READY TO DESIGN, DEVELOP and DELIVER TMS SYSTEMS for ALL DRIVETRAINS

The aim: Less effort for measurements rather calculated data with consistent accuracy

Question: **Which data basis leads to best 1-D models and is widely usable?**

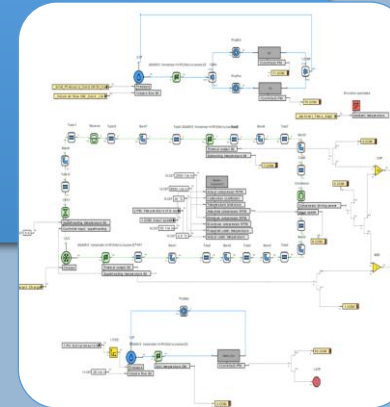
Components
and System
testing



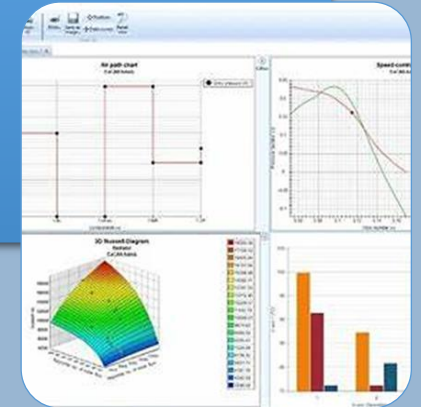
Component-
Level Design,
Calibration,
and Validation



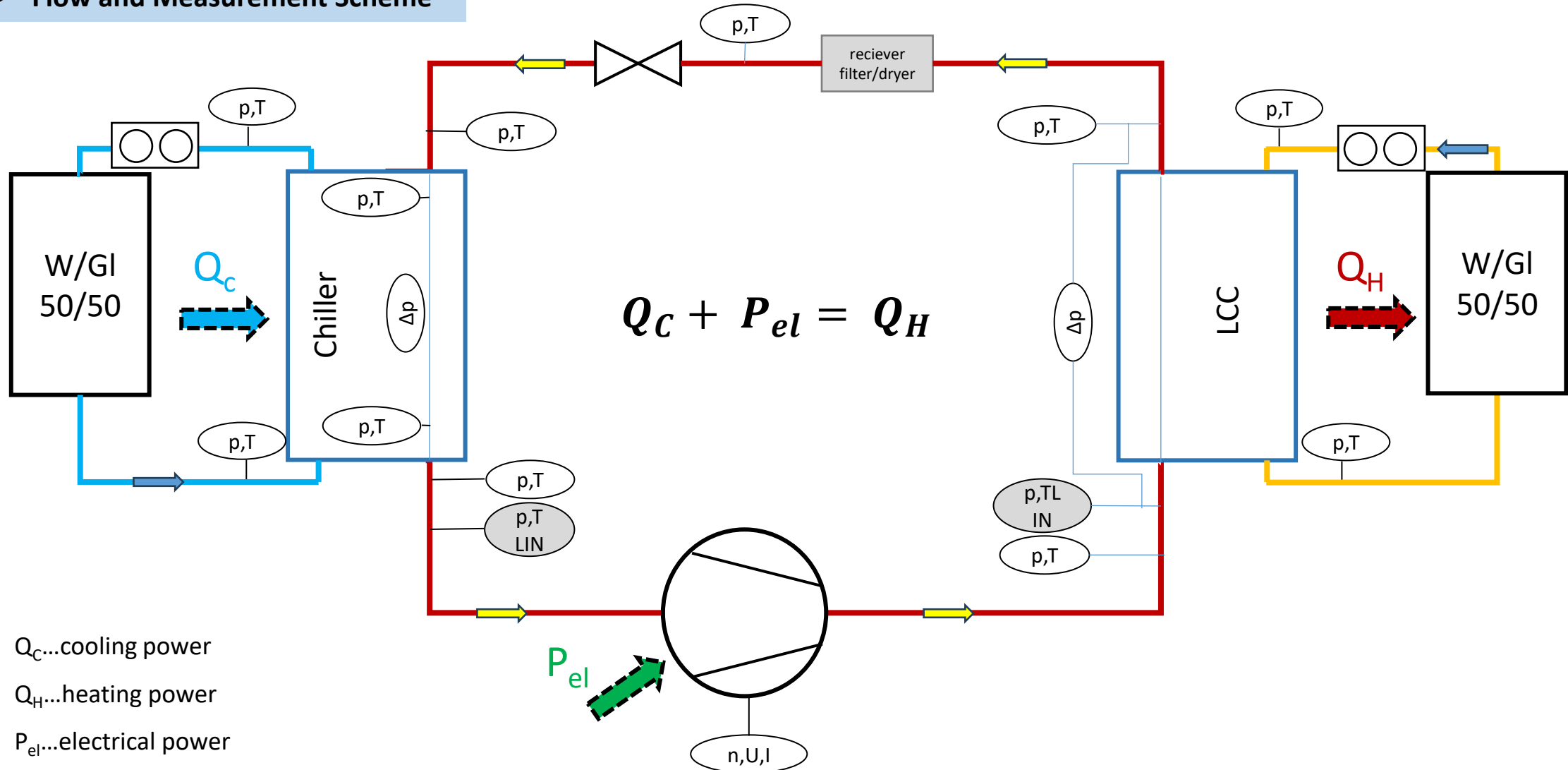
Creation of
Simulation
Model

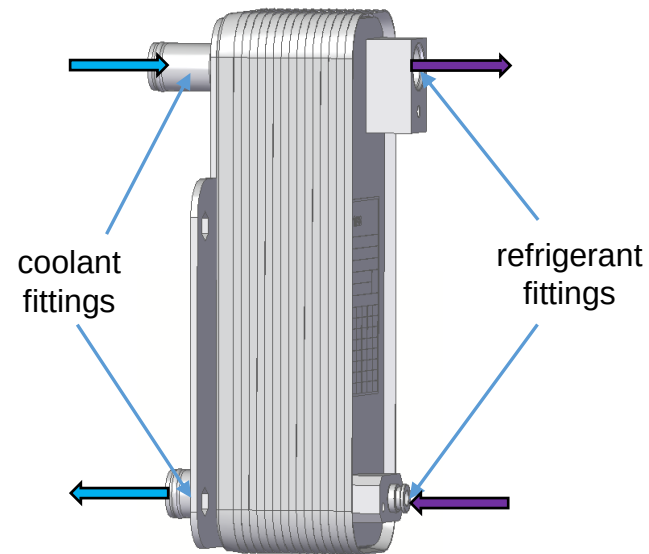


Evaluation
and Validation
of the
Simulation
Model



➤ Flow and Measurement Scheme

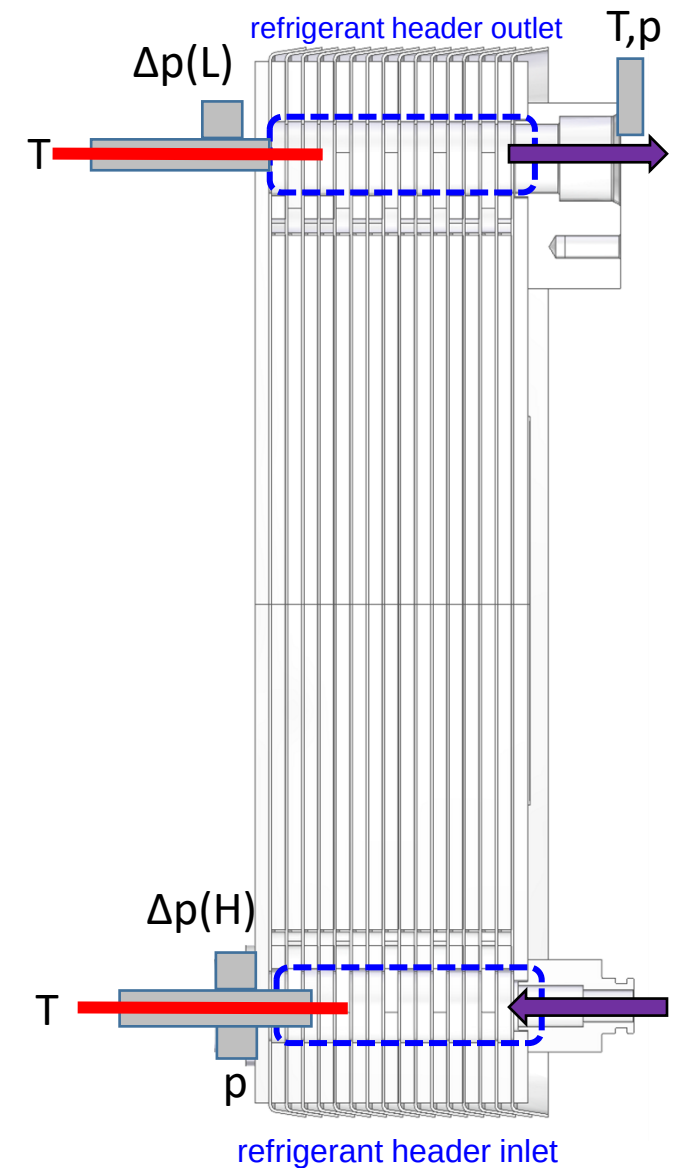
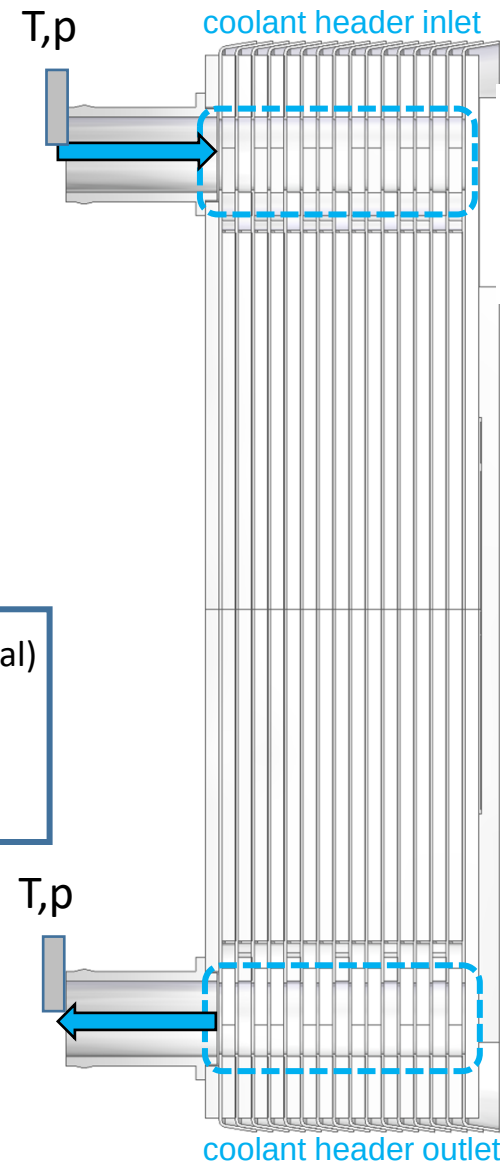


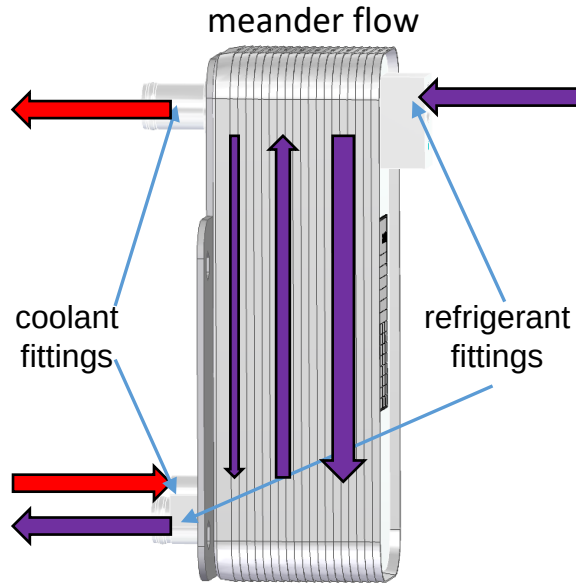


$\Delta p_{\text{core}} \rightarrow$ measured as $p_{\text{header,in}} - p_{\text{header,out}}$ (diff. pressure sensor – one signal)

$\Delta p_{\text{total}} \rightarrow$ measured as $p_{\text{header,in}} - p_{\text{out}}$ (2 pressure sensors)

$\Delta p_{\text{fitting}} = \Delta p_{\text{total}} - \Delta p_{\text{core}}$

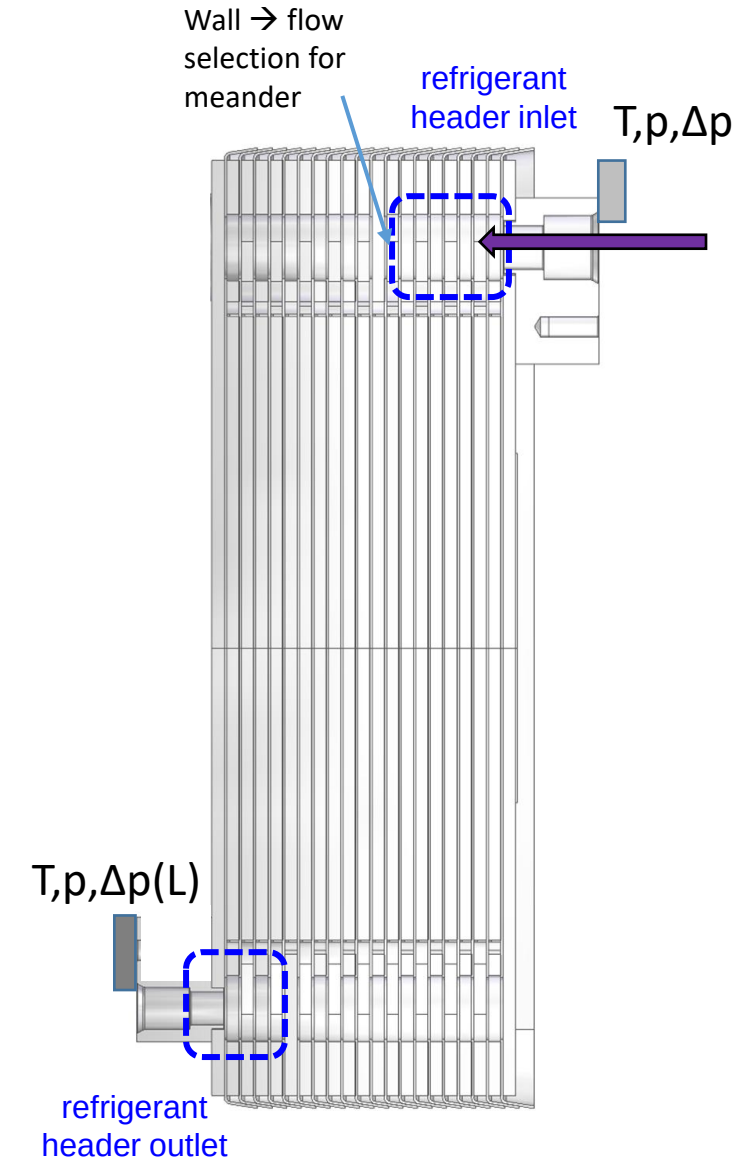
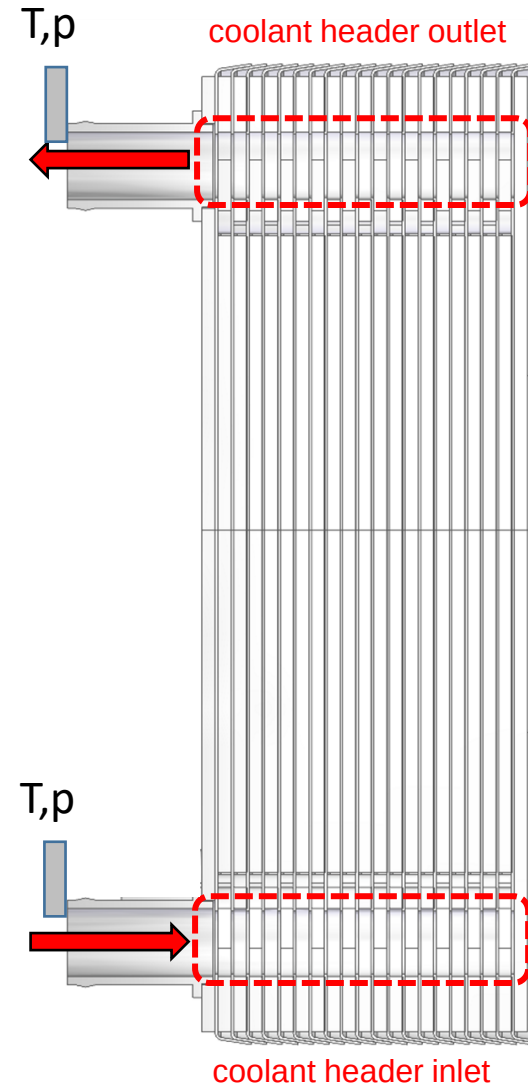




$\Delta p_{\text{core}} \rightarrow$ not possible to measure (meander)

$\Delta p_{\text{total}} \rightarrow$ measured as $p_{\text{in}} - p_{\text{out}}$ (2 pressure sensors + 1 diff. pressure sensor)

$\Delta p_{\text{fitting}} \rightarrow$ no result, but single phase $\rightarrow$ no problem to calculate



➤ Measurement Matrix 1 – coolant fixed

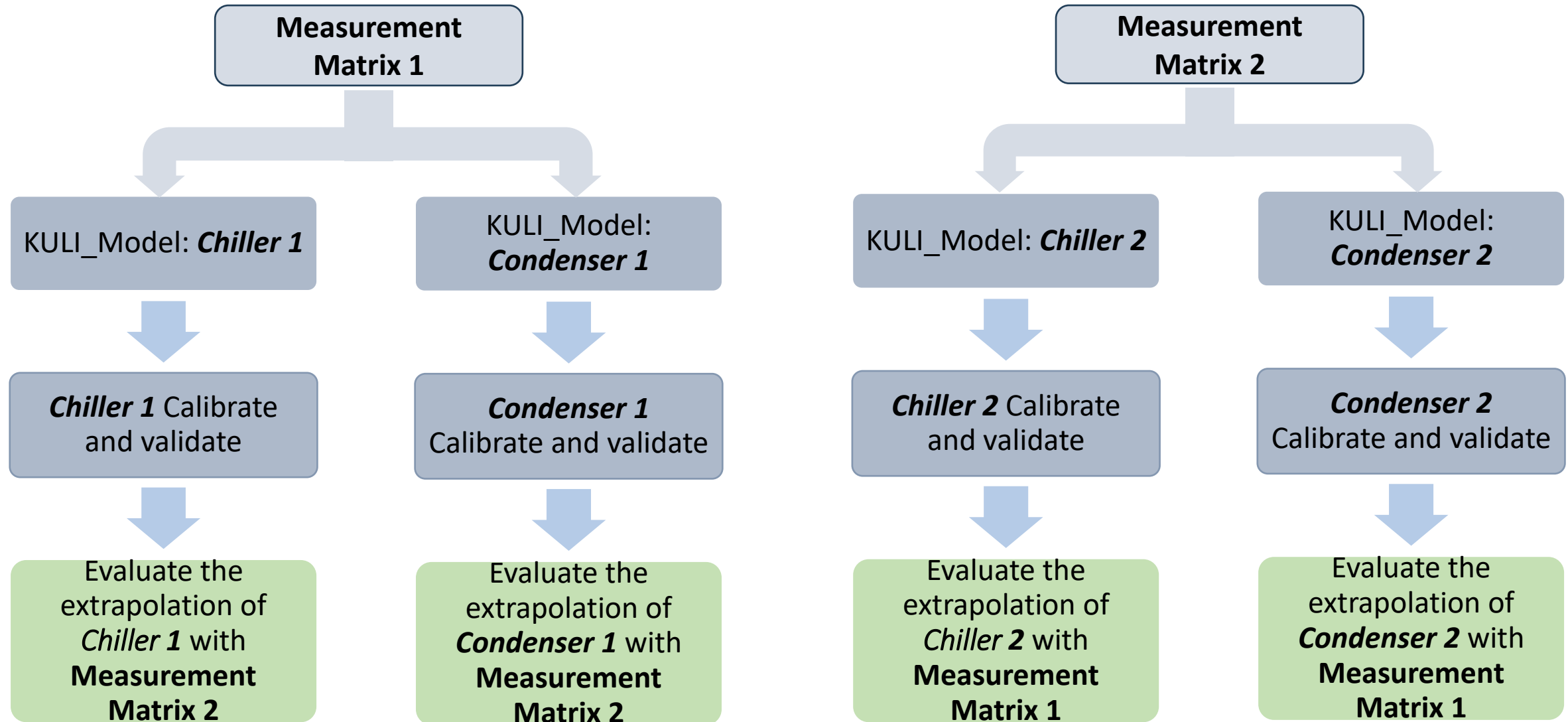
Chiller/Cond	SH10_30C_60C	SH10_30C_60C	SH10_30C_45C	SH10_5C_45C	SH10_5C_30C
V_flow_chiller [l/min]	14	28	14	14	14
T_cool_chiller_in [°C]	30	30	30	5	5
V_flow_cond [l/min]	23	49	23	23	23
T_cool_cond_in [°C]	60	60	45	45	30
SH [K]	10,0	10,0	10,0	10,0	10,0

- **Coolant fixed** (chiller, condenser)
 - flow rate
 - inlet temperature
- **Refrigerant with fixed superheating**

➤ Measurement Matrix 2 – refrigerant fixed

Chiller/Cond	SH10_30C_45C	SH10_5C_30C	SH5_5C_30C
T_cool_chiller_in [°C]	30	5	5
T_cool_chiller_out [°C]	25	0	0
p_in refr. Chiller [bar]	4,9	2,3	2,5
T_in refr. Chiller [°C]	13,7	-8,7	-6,9
p_in_cond_LIN [bar]	16,9	10,3	10,3
SH [K]	10	10	5

- **Coolant with fixed inlet and outlet temperature**
(chiller, condenser)
- **Refrigerant fixed**
 - Inlet pressure chiller
 - Inlet pressure condenser
 - Superheating



Same physical component for chiller KULI models and **same physical component** for the condenser KULI models.

➤ Chiller model with 40% pressure loss in the Tank

A/C plate heat exchanger [202504_ECS2025_Chiller1_with 40%_dp_tankkuliacphe]

FileTools

General dataConfigurationMeasured dataStatus

User

AKG

Date (0= current)

18.03.2025

Title

Chiller

Memo

Type

No.

Manufacturer

AKG Group

Series

Measrd. data file

Geometric data

Depth [mm]

231.1

Width [mm]

73.6

Height [mm]

58.2

Effective length [mm]

184.88

Metal thickness [mm]

0.6

Channel height

User defined

Both channels are equal

Inner flow [mm]

3

Outer flow [mm]

6

☐ Tanks volume inside [cm³]

☐ Tanks volume outside [cm³]

Parameter Calculation

Error inner pressure drop [%]

Min-20.301Mean value11.103Max37.6699

Error outer pressure drop [%]

Min-1.52133Mean value1.005Max2.11979

Error heat transfer [%]

Min-1.69671Mean value0.687729Max1.45356

Separation of eff. length

20

☒ Use quick calculation

Calibration OKCalibrate

Effective length

Height

Width

Depth

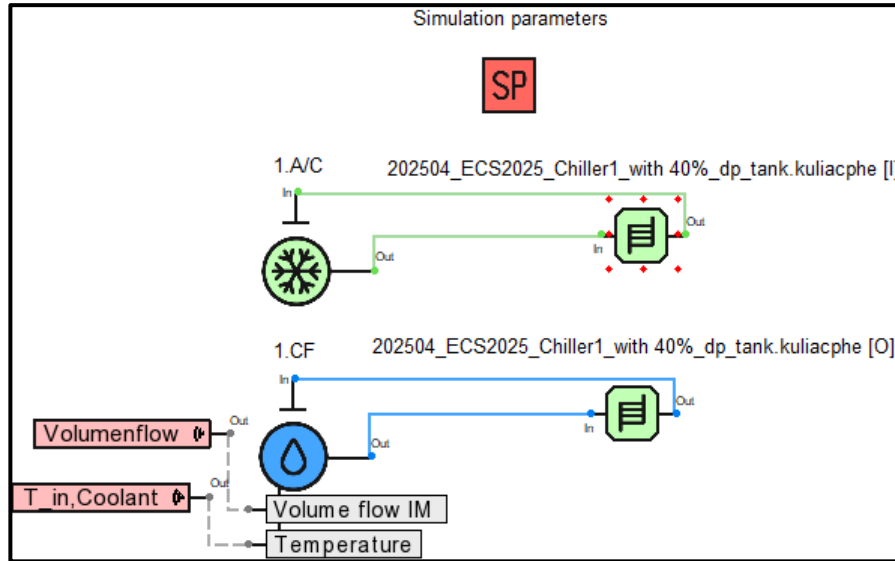
Chiller 1

Error inner pressure drop [%]	Min	-20.301	Mean value	11.103	Max	37.6699
Error outer pressure drop [%]	Min	-1.52133	Mean value	1.005	Max	2.11979
Error heat transfer [%]	Min	-1.69671	Mean value	0.687729	Max	1.45356

Chiller 2

Error inner pressure drop [%]	Min	-10.5206	Mean value	3.49025	Max	9.06178
Error outer pressure drop [%]	Min	-12.6784	Mean value	2.14635	Max	3.48281
Error heat transfer [%]	Min	-2.06508	Mean value	1.07877	Max	2.45482

➤ Test chillers against their calibration data and evaluate their extrapolation



General data Circuits / Air path Air side **SP** Simulation parameters

Type
☒ Steady state Associations
☐ Transient

Constant during simulation

Variable during simulation

Operating point [-]...	RPM Engine [1/min]...	Driving speed [km/h]...	Warm-up temperature [K]	Ambient pressure [hPa]...	Ambient temperature [°C]...	Air humidity [%]...	Comment	Calculate OP	A/C on	Volumenflow [l/min]...	T_in,Coolant [°C]...	Comp. Speed [1/min]...
1	1	80	0	1013	20	20		Yes	On	13.98	29.78	8498
2	2	80	0	1013	20	20		Yes	On	13.98	30.01	6499
3	3	80	0	1013	20	20		Yes	On	14	30.07	4499
4	4	80	0	1013	20	20		Yes	On	13.98	30.12	2499
5	5	80	0	1013	20	20		Yes	On	27.98	29.94	8498
6	6	80	0	1013	20	20		Yes	On	27.98	29.94	6499
7	7	80	0	1013	20	20		Yes	On	27.99	29.92	4499
8	8	80	0	1013	20	20		Yes	On	27.98	30.13	2499
9	9	80	0	1013	20	20		Yes	On	13.98	30.05	8498
10	10	80	0	1013	20	20		Yes	On	13.97	30.01	6499
11	11	80	0	1013	20	20		Yes	On	13.99	29.89	4499
12	12	80	0	1013	20	20		Yes	On	13.99	29.79	2499
13	13	80	0	1013	20	20		Yes	On	13.98	5.15	8498
14	14	80	0	1013	20	20		Yes	On	13.98	4.98	6499
15	15	80	0	1013	20	20		Yes	On	13.98	4.98	4499
16	16	80	0	1013	20	20		Yes	On	13.99	5.03	2499
17	17	80	0	1013	20	20		Yes	On	13.98	4.96	8498
18	18	80	0	1013	20	20		Yes	On	13.98	4.86	6498
19	19	80	0	1013	20	20		Yes	On	13.99	4.95	4499
20	20	80	0	1013	20	20		Yes	On	13.98	4.8	2499
21	21	80	0	1013	20	20		Yes	On	30.99	30.07	8498
22	22	80	0	1013	20	20		Yes	On	27.09	30.14	7499
23	23	80	0	1013	20	20		Yes	On	23.19	30.02	6499

Parameter variation

A/C circuit

File Tools

Type of circuit:
☐ Closed circuit (equalization)
☒ Open circuit (definition of inlet)

General data Outlet values

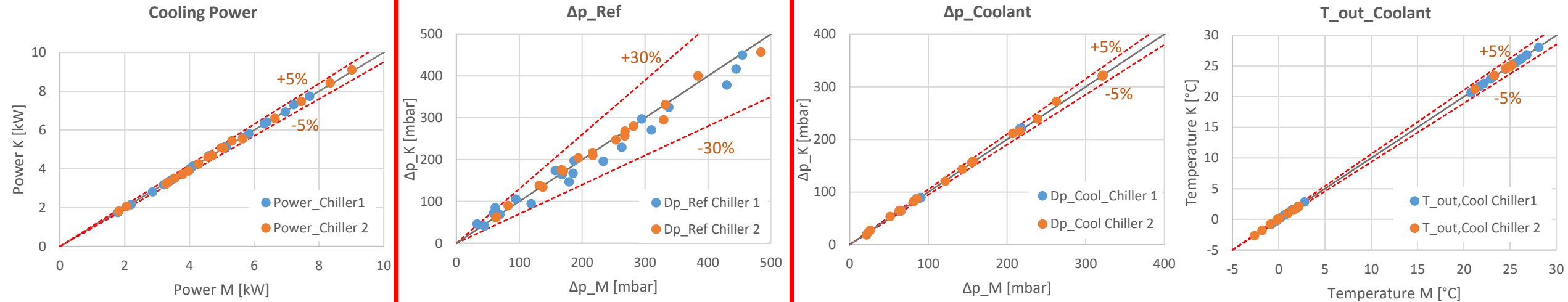
Unit kg/h bar kJ/kg

Compressor-speed [1/min]	Inner flow rate [kg/h]	Inlet pressure [bar]	Spec. inlet enthalpy [kJ/kg]
1	353.17	4.83	315.56
2	301.99	5.01	314.48
3	227.51	5.06	311.5
4	144.45	5.48	305.78
5	385.17	5.13	314.11
6	329.9	5.27	312.91
7	254.2	5.36	311.78
8	159.79	5.58	309.32
9	332.15	4.49	292.42
10	284.63	4.65	291.83
11	222.7	4.85	289.62
12	142.89	5.26	284.54

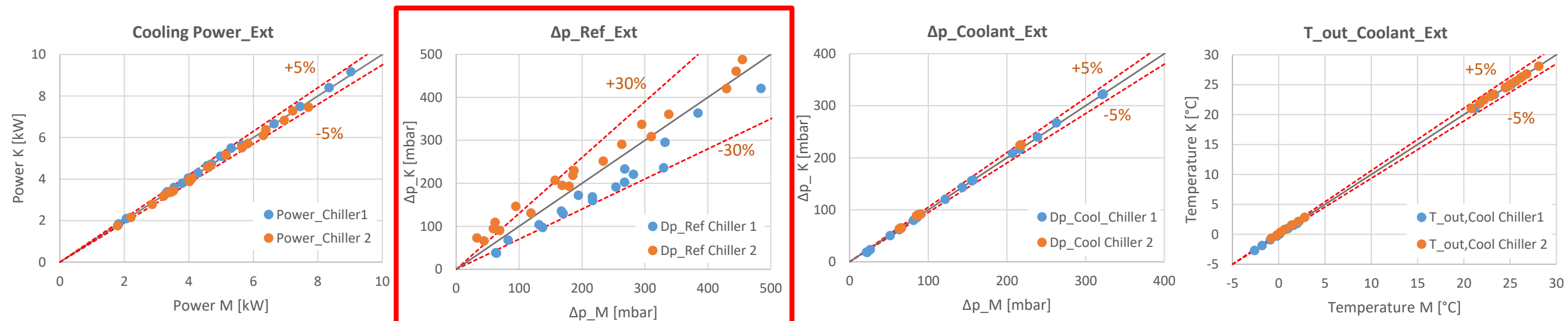
Compressor Speed
 Considered only if there is no compressor in circuit!
☐ Constant RPM
☒ RPM depends on
 Transmission ratio (Component / Reference) [-] ☒ RPM Engine 1

➤ Calibration data: Chiller 1 (with Matrix 1) and chiller 2 (with Matrix 2)

$K = K_{uli}$, $M = \text{Measurement}$



➤ Extrapolation : Chiller 1 (with Matrix 2) and chiller 2 (with Matrix 1)



➤ Condenser model with 40% pressure loss in the Tank

A/C plate heat exchanger [202504_ECS2025_Condenser1_with 40% dp_tank.kuliacphe]

File Tools

General data Configuration Measured data Status

User: AKG
Date (0=current): 18.03.2025
Title: Condenser with meander flow
Memo: Measurmentdata by const. Volumenflow , inlet Ter

Type:
No.:
Manufacturer: AKG Group
Series:
Measrd. data file:

Geometric data

Depth [mm]: 231.1

Width [mm]: 73.6

Height [mm]: 69

Effective length [mm]: 184.88

Metal thickness [mm]: 0.6

Channel height:
☐ User defined
Inner flow [mm]:
Outer flow [mm]:

☐ Tanks volume inside [cm³]:

Parameter Calculation

Error inner pressure drop [%]
Min: -22.8445 | Mean value: 10.1666 | Max: 25.1797

Error outer pressure drop [%]
Min: -0.784945 | Mean value: 0.267112 | Max: 0.863627

Error heat transfer [%]
Min: -3.91309 | Mean value: 2.34326 | Max: 2.74109

Separation of eff. length: 20

☒ Use quick calculation

Condenser calibrated

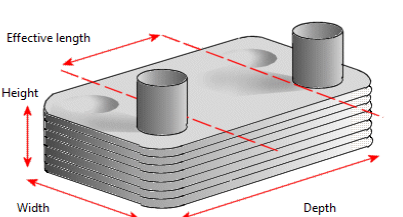
Calibrate

Effective length

Height

Width

Depth



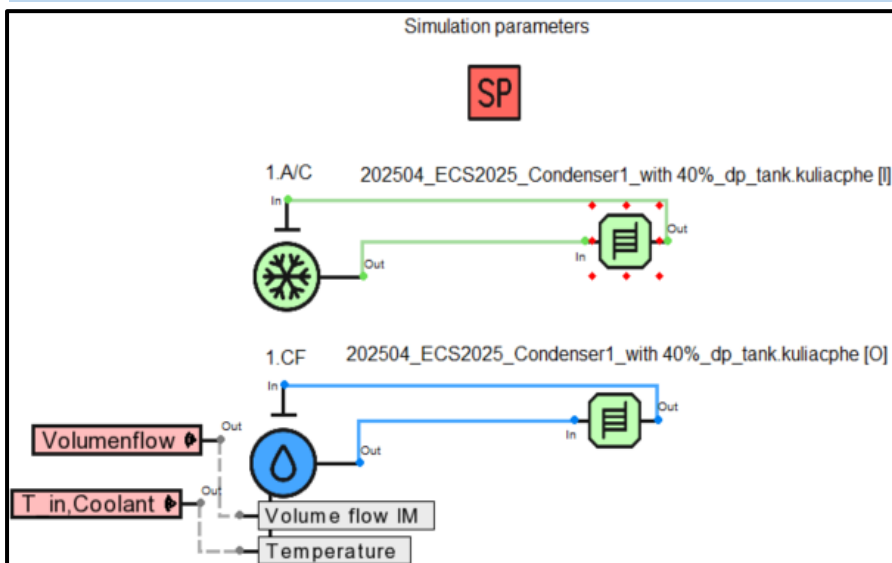
Condenser 1

Error inner pressure drop [%]	Min	-22.8445	Mean value	10.1666	Max	25.1797
Error outer pressure drop [%]	Min	-0.784945	Mean value	0.267112	Max	0.863627
Error heat transfer [%]	Min	-3.91309	Mean value	2.34326	Max	2.74109

Condenser 2

Error inner pressure drop [%]	Min	-28.4591	Mean value	12.0523	Max	20.7235
Error outer pressure drop [%]	Min	-1.52956	Mean value	0.713052	Max	1.41555
Error heat transfer [%]	Min	-3.46307	Mean value	2.39459	Max	4.7074

➤ Test condensers against their calibration data and evaluate their extrapolation



General data Circuits / Air path Air side SP Simulation parameters

Type

☒ Steady state ☐ Transient

Associations

Constant during simulation

Variable during simulation

Operating point [-]...	RPM Engine [1/min]...	Driving speed [km/h]...	Warm-up temperature [K]	Ambient pressure [hPa]...	Ambient temperature [°C]...	Air humidity [%]...	Comment	Calculate OP	A/C on	Volumenflow [l/min]...	T_in,Coolant [°C]...	Comp.Speed [1/min]...
1	1	80	0	1013	20	20		Yes	On	23.04	60.02	8498
2	2	80	0	1013	20	20		Yes	On	22.99	60	6499
3	3	80	0	1013	20	20		Yes	On	23.01	59.86	4499
4	4	80	0	1013	20	20		Yes	On	23	59.94	2499
5	5	80	0	1013	20	20		Yes	On	46.93	60.07	8498
6	6	80	0	1013	20	20		Yes	On	49.05	60.11	6499
7	7	80	0	1013	20	20		Yes	On	49.04	60.13	4499
8	8	80	0	1013	20	20		Yes	On	49.02	60.22	2499
9	9	80	0	1013	20	20		Yes	On	23	45.12	8498
10	10	80	0	1013	20	20		Yes	On	23.01	45.06	6499
11	11	80	0	1013	20	20		Yes	On	23.02	44.98	4499
12	12	80	0	1013	20	20		Yes	On	23	45.06	2499
13	13	80	0	1013	20	20		Yes	On	23.01	44.97	8498
14	14	80	0	1013	20	20		Yes	On	23.01	44.98	6499
15	15	80	0	1013	20	20		Yes	On	23	45.06	4499
16	16	80	0	1013	20	20		Yes	On	22.99	44.9	2499
17	17	80	0	1013	20	20		Yes	On	23	30	8498
18	18	80	0	1013	20	20		Yes	On	23	29.83	6498
19	19	80	0	1013	20	20		Yes	On	23	30	4499
20	20	80	0	1013	20	20		Yes	On	23	30	2499
21	21	80	0	1013	20	20		Yes	On	50.02	45.1	8498

Parameter variation

A/C circuit

File Tools

Type of circuit:

☐ Closed circuit (equalization)

☒ Open circuit (definition of inlet)

General data Outlet values

Unit

Compressor-speed [1/min]	Inner flow rate [kg/h]	Inlet pressure [bar]	Spec. inlet enthalpy [kJ/kg]
1	353.17	24.14	436.83
2	301.99	22.98	429.37
3	227.51	21.56	425.13
4	144.45	19.91	420.6
5	385.17	22.67	435.41
6	329.9	21.84	427.45
7	254.2	20.88	422.63
8	159.79	19.42	418.98
9	332.15	18.03	430.01
10	284.63	17.15	422.52
11	222.7	16.03	416.71
12	142.89	14.54	411.09
13	174.36	15.39	417.58

Compressor Speed

Considered only if there is no compressor in circuit!

☐ Constant RPM

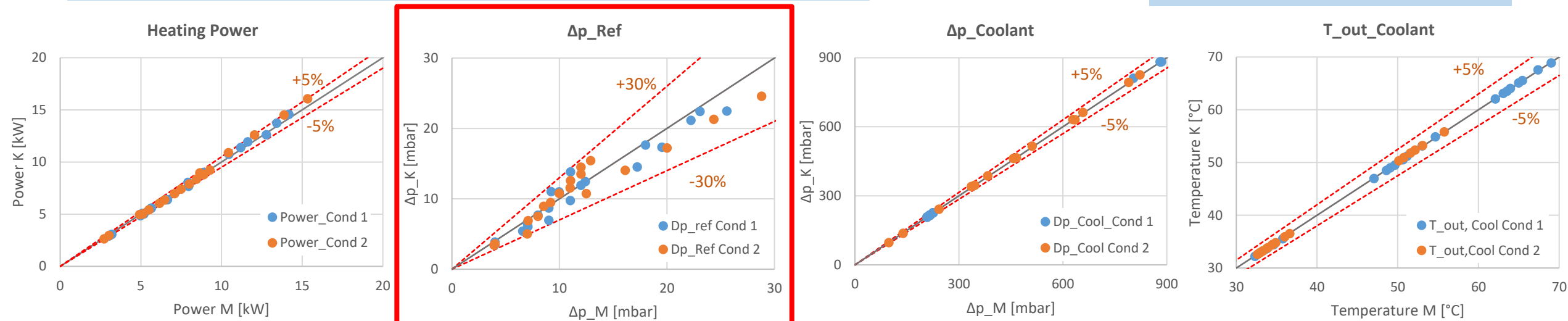
☒ RPM depends on

Transmission ratio (Component / Reference) [-]

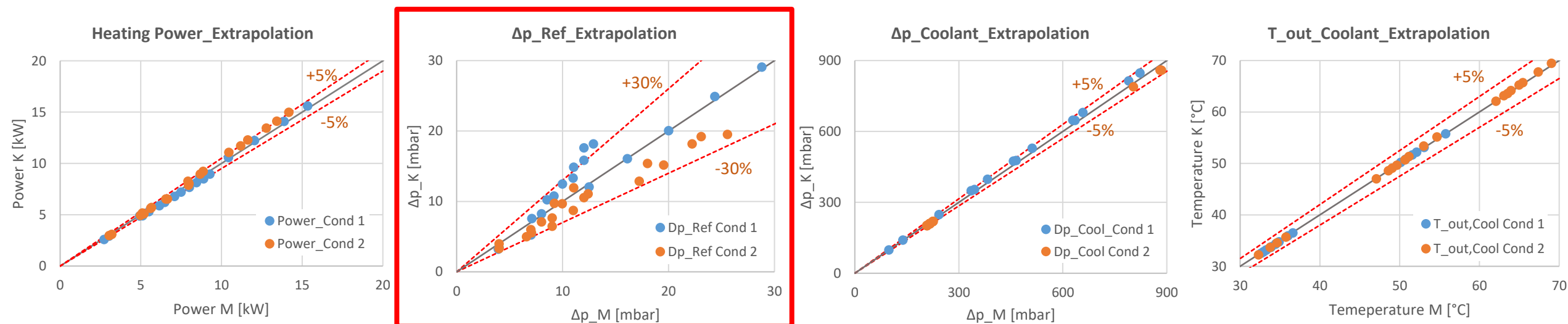
1

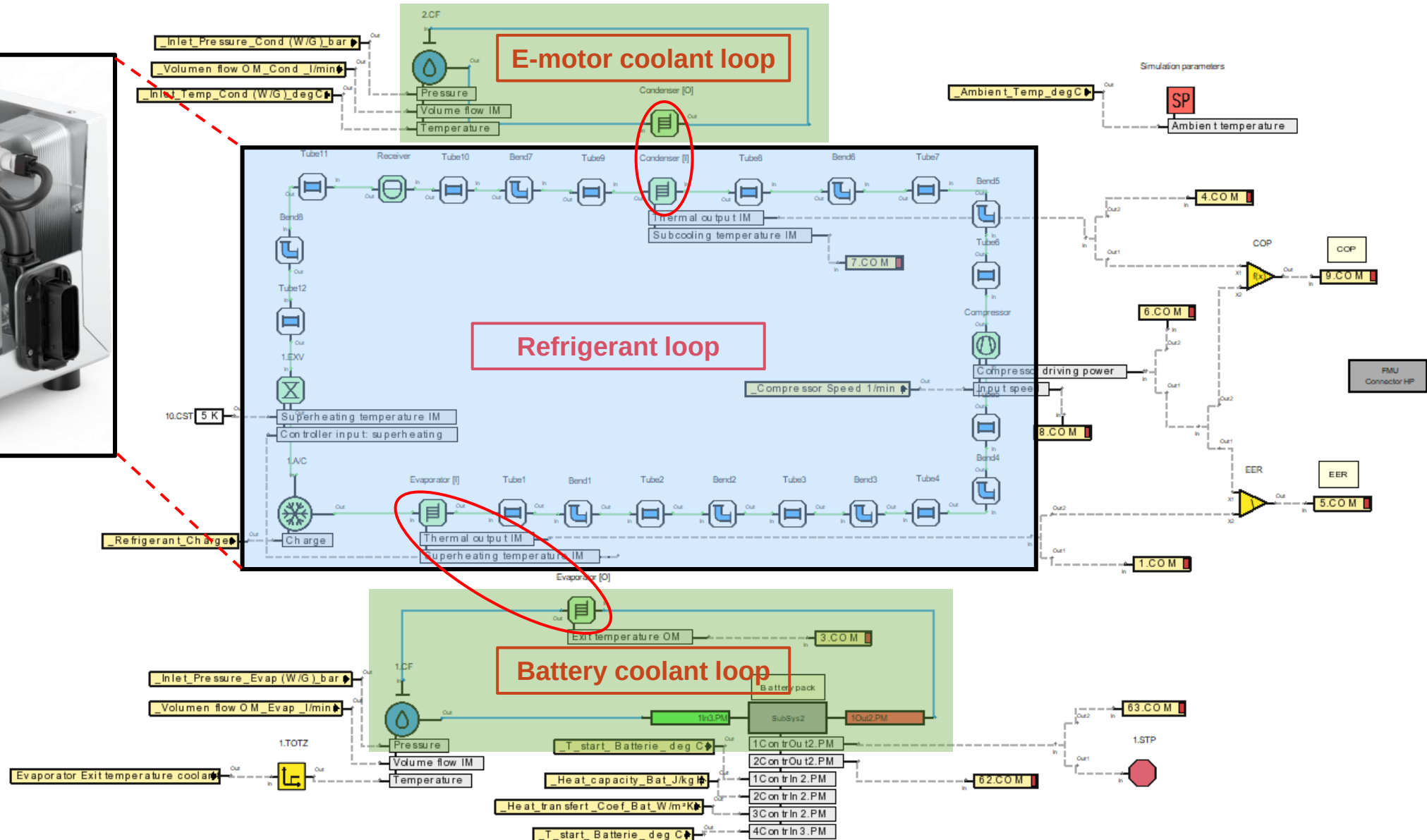
➤ Calibration data: Cond 1 (with Matrix 1) and Cond 2 (with Matrix 2)

$K = K_{uli}$, $M = \text{Measurement}$



➤ Extrapolation : Cond 1 (with Matrix 2) and Cond 2 (with Matrix 1)





➤ Application example of our aluminium brazed plate heat exchangers

- Compact Refrigerant Module
- Cooling Performance: 8kW @ 25°C Chiller out / 45°C Condenser in (Coolant)
- Refrigerant: R134a & R1234yf
- Chiller System and Heat Pump Application
- Easy integration into customer vehicles
- Integrated Controller (CAN J1939)
- AKG Software available



Please contact us for further information.

- The chiller and condenser can be accurately modeled in KULI as A/C plate heat exchangers.
- Both approaches show no significant difference in results.
- The models show good extrapolation capability within certain borders.
 - High deviation on refrigerant pressure drop (up to $\pm 30\%$ at certain operating points).
 - Further investigation required.
- The impact of the pressure loss deviation on the refrigerant will be further investigated at the system level.



Christian Djeufack
Simulation Engineer
christian.djeufack@akg-gruppe.de
+49 5671 883-1262



Dr.-Ing. Katerina Hatesuer
Project Manager
katerina.hatesuer@akg-gruppe.de
+49 5671 883-4624