SynErgy
Thermal Management

Mobilising the Industry for Thermal Management Module Development

Thermal Management Expo 2024, Stuttgart

Content

Company Profile - History

Founded
June 2016

1st Expansion
rented external office

VW eGolf with Heat Pump
April 2018

2nd Expansion
additional office space
June 2018

3nd Expansion
move to new office
Jan 2022

VW ID3 with R744 Heat Pump
Oct 2022

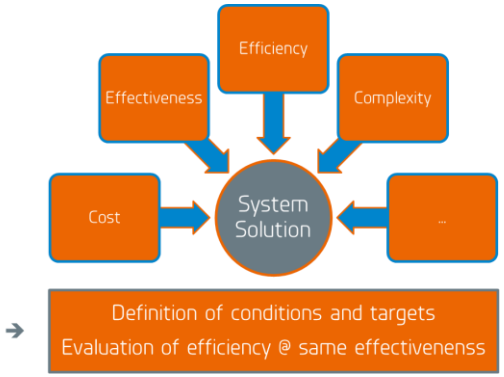
Sep 2016 | Oct 2017 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024

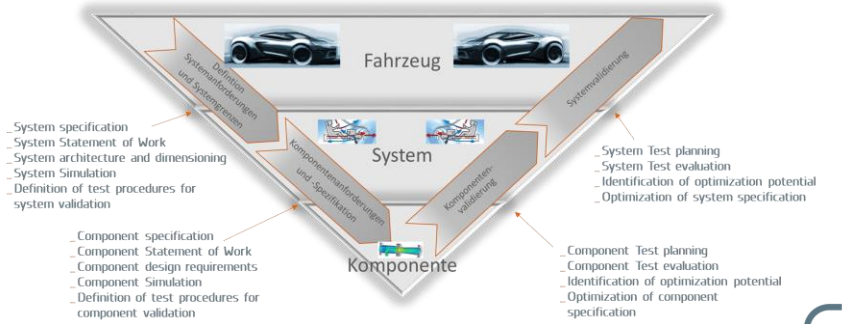
Company Profile – Founder

- Founded on 28th June 2016
- Owner and Managing Director: Dipl.-Ing. Marc Graaf
  Professional Profile:
  - Studied Mechanical Engineering, at the Aachen University of Technology
  - Specialized in Thermal Engineering / Heat Transfer Technology
  - > 25 years of professional experience in heat pump system development and automotive air conditioning systems with alternative refrigerants
  - Developed a thermal driven heat pump for residential heating (1997 – 1999)
  - Project Leader at an engineering service provider (1999 – 2002)
  - Manager Advanced Systems Development at an automotive supplier (2002 – 2016)
- > 20 Public presentations
- > 60 Patent applications

Portfolio – Main Topics

- Development of Heat Pump Systems and Thermal Management Systems for electrical Vehicles
- Integration of Batterie Conditioning into the Vehicle Thermal Management System
- Drive Cycle Analysis
- Development of Control Strategies for Thermal Management Systems
- Refrigerant System Design and Dimensioning of Components
- Design & Integration of Refrigerant Systems with alternative Refrigerants
- Top-down specification of component and subsystem Requirements





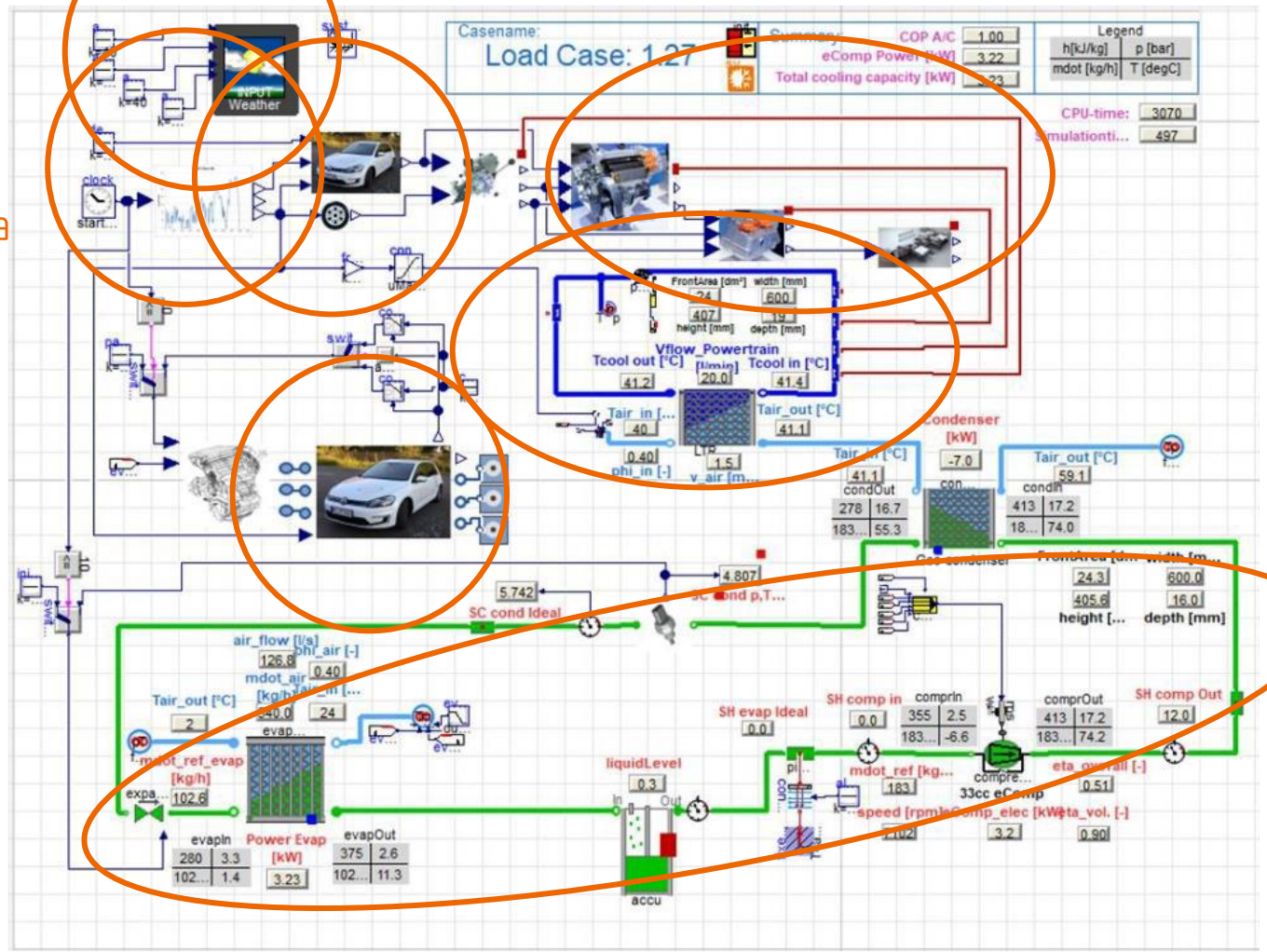
Thermal Vehicle Model

Weather model

Vehicle data
Drive cycle data

Cabin model

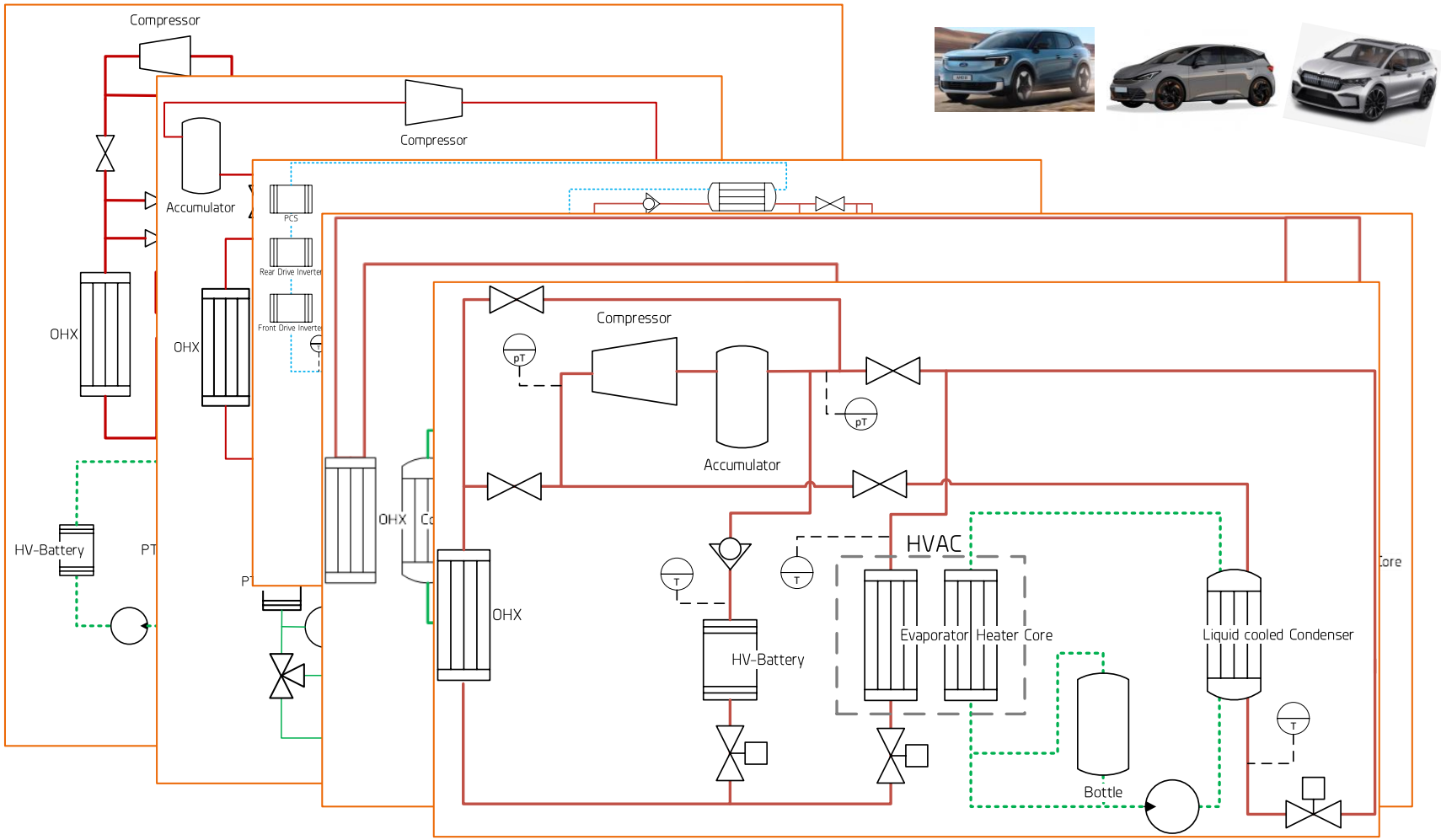
Refrigerant System Model



Powertrain

Coolant loop

TMS architectures – >15 architectures available



Cabin & vehicle Models – >80 applications available

Passenger cars, trucks, busses and off road applications

B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
Fahrzeug	Fahrzeug	Version	Stirnfläche	CW-Wert	Gewicht Masse Leergewicht [kg]	Batterie-kapazität [kWh]	maximale Antriebsleistung [kW] bei [1/min]	Drehzahl bei max Antriebsleistung	max Drehmoment [Nm]	WLTP Reichweite	Normverbrauch WLTP [kWh/100 km]	Reifengröße	Rollwiderstand cR PKW auf Asphalt	Fahrzeugklasse	Wärmepumpe erhältlich 06.2021	Fließschema (Bild kann vergrößert werden)
	Aiways U5				1825 [kg]	63,0 [kWh]	140 [kW]		315 [Nm]		16,3 [kWh/100 km]		0,011 bis 0,015	SUV	Nein	
	Audi e-tron	50 quattro	2,65 [m²]	0,27	2565 [kg]	95,0 [kWh]	300 [kW]		664 [Nm]		23,0 [kWh/100 km]	255/55 R19	0,011 bis 0,015	SUV	JA	
	Audi e-tron GT	GT 350 kW GT RS 440 kW	2,35 [m²]	0,24	2350 - 2420 [kg]	93,4 [kWh]	350 [kW] 440 [kW]	630 [1/min] 630 [1/min]		488 [Nm] 488 [km]	18,8 [kWh/100 km] 19,6 [kWh/100 km]	245/45R20	0,011 bis 0,015	Sportwagen	JA	
	BMW i3	i3 60 Ah i3 94 Ah i3s 94 Ah i3 120 Ah i3s 120 Ah	2,38 [m²]	0,29	1270 [kg] 1320 [kg] 1340 [kg] 1345 [kg] 1365 [kg]	22,0 [kWh] 33,2 [kWh] 33,2 [kWh] 42,2 [kWh] 42,2 [kWh]	125 [kW] 125 [kW] 135 [kW] 125 [kW] 135 [kW]	4800 [1/min] 4800 [1/min] 4800 [1/min] 4800 [1/min] 4800 [1/min]	250 [Nm] 250 [Nm] 270 [Nm] 250 [Nm] 270 [Nm]	260 [km]		155/70 R19	0,011 bis 0,015	Kleinwagen	JA	
	Citroen Berlingo Electric		2,90 [m²]	0,31	1605 [kg]	22,5 [kWh]	49 [kW]	1500 [1/min]	200 [Nm]	170 [km]	17,7 [kWh/100 km]	205/60 R16	0,011 bis 0,015	Kompaktklasse	NEIN	
	Citreon e-C4			0,28	1541 [kg]	50,0 [kWh]	100 [kW]	3700 [1/min]	260 [Nm]	350 [km]	16,6 [kWh/100 km]	215/60R17	0,011 bis 0,015	SUV	JA	
	Citroen C-Zero				1140 [kg]	14,5 [kWh]	49 [kW]	300 [1/min]	196 [Nm]	100 [km]	12,6 [kWh/100 km]	vorne 145/65 R15 hinten 175/55 R15	0,011 bis 0,015	Kleinstwagen	NEIN	
	Citroen E-Mehari				1573 [kg]	30,0 [kWh]	50 [kW]		166 [Nm]	195 [km]	20,0 [kWh/100 km]		0,011 bis 0,015	SUV	NEIN	
	DS Automotives DS 3 Crossback E-Tense				1600 [kg]	50,0 [kWh]	100 [kW]		260 [Nm]	320 [km]	17,8 [kWh/100 km]		0,011 bis 0,015	Kleinwagen	JA	
	e.GO Life First Edition	Life 20 Life 40 Life 60		0,27	1150 [kg] 1170 [kg] 1210 [kg]	14,5 [kWh] 17,5 [kWh] 23,5 [kWh]	20 [kW] 40 [kW] 60 [kW]			100 [km] 113 [km] 145 [km]	14,5 [kWh/100 km] 15,5 [kWh/100 km] 16,2 [kWh/100 km]		0,011 bis 0,015	Kleinstwagen	JA	
	Fiat 500 e			0,32		42,0 [kWh]	87 [kW]			300 [km]				Kleinstwagen	NEIN	
	Ford Mustang Mach-E	Standard Range AWD Standard Extended Range AWD Extended				75,0 [kWh] 75,7 [kWh] 98,9 [kWh] 98,8 [kWh]	190 [kW] 190 [kW] 210 [kW] 248 [kW]		415 [Nm] 565 [Nm] 415 [Nm] 565 [Nm]	450 [km] 420 [km] 600 [km] 540 [km]	16,5 [kWh/100 km] 17,9 [kWh/100 km] 16,5 [kWh/100 km] 18,1 [kWh/100 km]		0,011 bis 0,015	Sportwagen	NEIN	
	Honda e					35,0 [kWh]	110 [kW]			222 [km]	20,0 [kWh/100 km]			Kleinwagen		

Content

Development Trends - Legislation

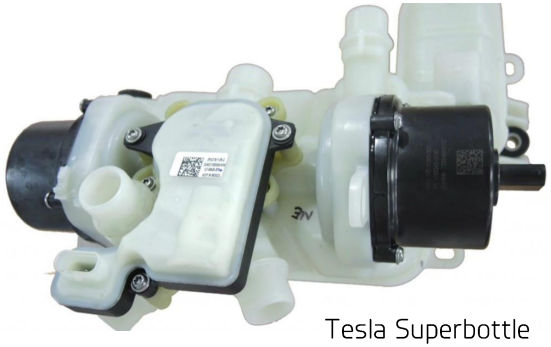
PFAS => R1234yf might be banned as refrigerant

Alternatives:

- R744: AC & HP systems are in production, very good HP performance
  Challenges:
  - higher system dynamics
  - challenge for efficient system control
  - lower performance and efficiency @high ambient temperature
- R290: very good refrigerant properties for AC & HP performance
  - flammable refrigerant
  - not allowed to use in direct system

Thermal Management Modules

_ Coolant systems:
Pumps, valves and expansion tanks are pre-assembled as module



Tesla Superbottle

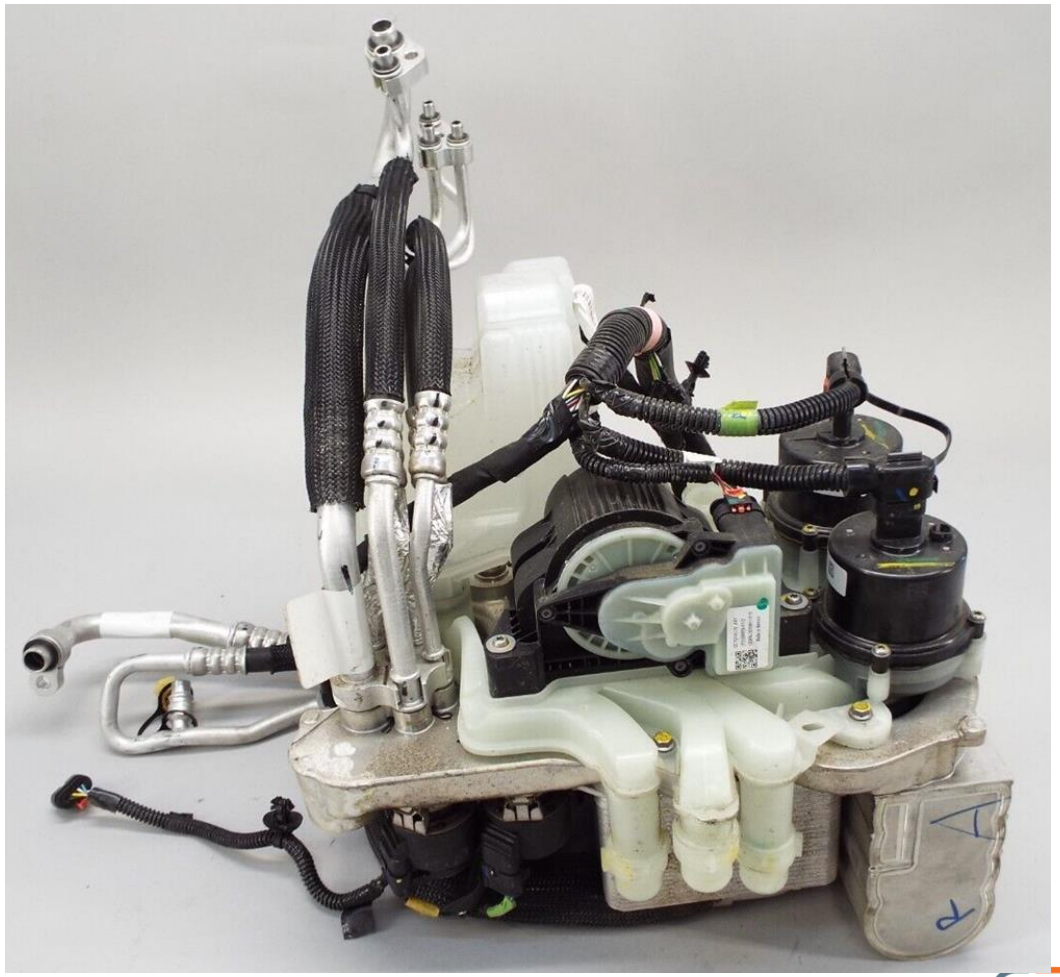
_ Refrigerant systems:
Valves, Heat exchangers and lines are pre-assembled as module

VW ID3

Thermal Management Modules

_ Coolant and refrigerant components are pre-assembled as module

Tesla Octovalve,Supermanifold



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Thermal Management Modules – Refrigerant

_ Complete Refrigerant Systems are being designed as module

_ Module can be pre-assembled, leak tested and charged

_ Module can be used with several refrigerants without impacting other components => preparation for PFAS ban of R1234yf

_ Easy to implement use of waste heat recovery at several positions in the vehicle (battery, E-Motors, etc.)

Some suppliers do not have a compressor in their portfolio and combine all aother components as module

Thermal Management Modules – Coolant

_ Coolant System cannot be implemented as total loop

_ Battery and drivetrain components need to be connected separately

_ Cooling Module and HVAC Heat Exchangers need to be connected separately

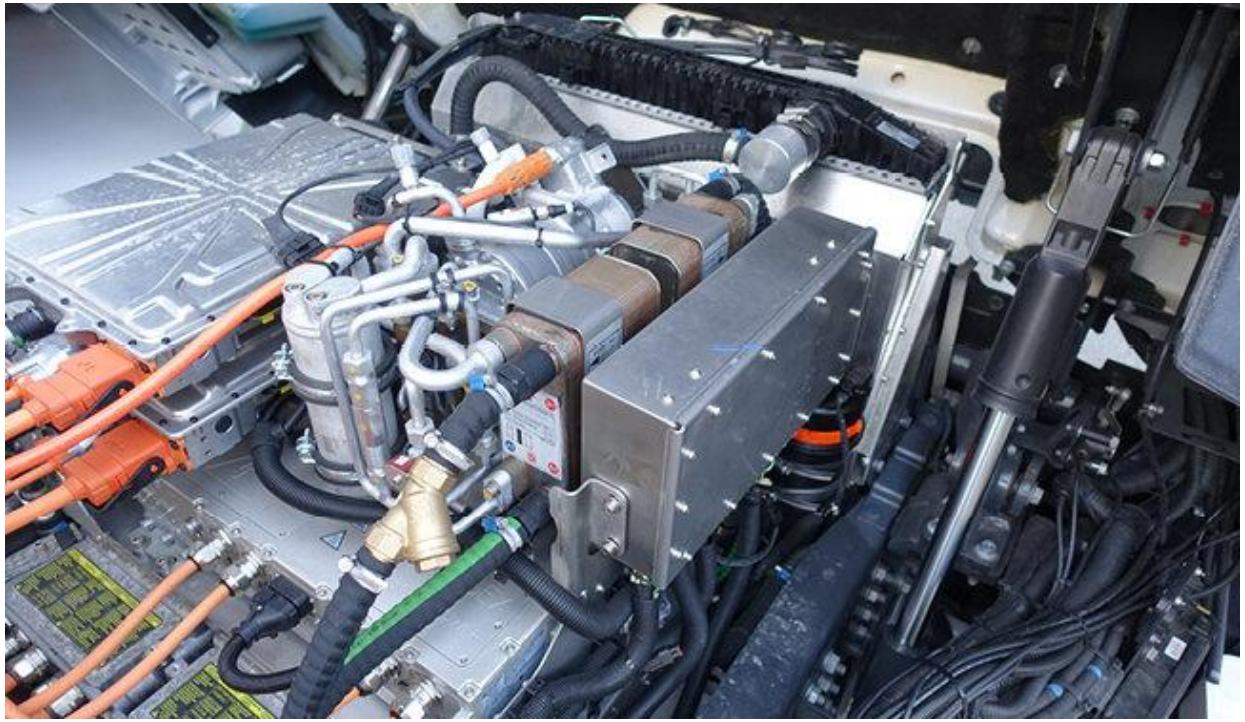
=> Coolant module can only contain pumps, valves and expansion tank

Tesla Superbottle

Thermal Management Modules – Advantages

Thermal Management Module:

- Module consists of complete refrigerant system
- System can be pre-assembled, leak tested and pre-charged at supplier
- Module can be used with different refrigerants (R1234yf / R290)
- System can be implemented independant from coolant archtecture



Rheinmetall Thermomodule

Thermal Management Modules – Disadvantages

Thermal Management Module:

- Indirect system has slightly reduced efficiency due to additional heat transfer resistance (refrigerant/coolant and coolant/air)

Sanhua Modular Concept

Summary

_ Modules are the current focus in cost reduction for Thermal Management Systems

_ Suppliers who have all components of one or more subsystems in their portfolio have advantages in developing and delivering subsystems as a module

_ For coolant systems, the supply of full functional submodules is not possible

_ For refrigerant systems, the supply of full functional pre-charged refrigerant modules can reduce cost and assembly time at the production line

_ Using an indirect refrigerant module gives the OEM the possibility when to introduce natural refrigerant, depending on legislative requirements (EU PFAS ban)

Thank you!

For your Interest!

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