Carbon Dioxide (R 744) as supplementary heating device

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- Fundamentals/Evaluation
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R744 Heat Pump

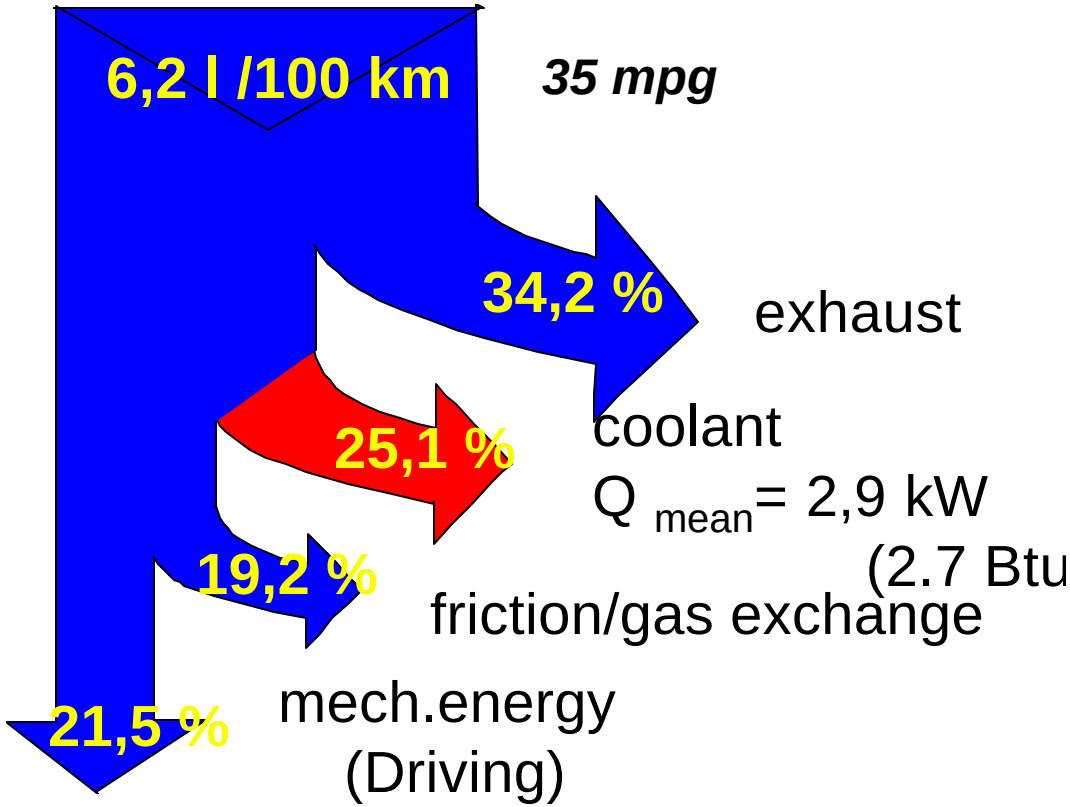
Motivation

Improved mileage needs efficiency gains of energy transformation in the engine

This effects engine heat and therefor reduced vehicle heating performance

Energy distribution for a mid size vehicle

- vehicle weight 1130 kg *(2400 lbs.).*
- 1.7 l DE Diesel engine
- Power 66 kW *(100hp)*
- ECE driving cycle
- average speed = 18,7 km/h *(12 mph)*



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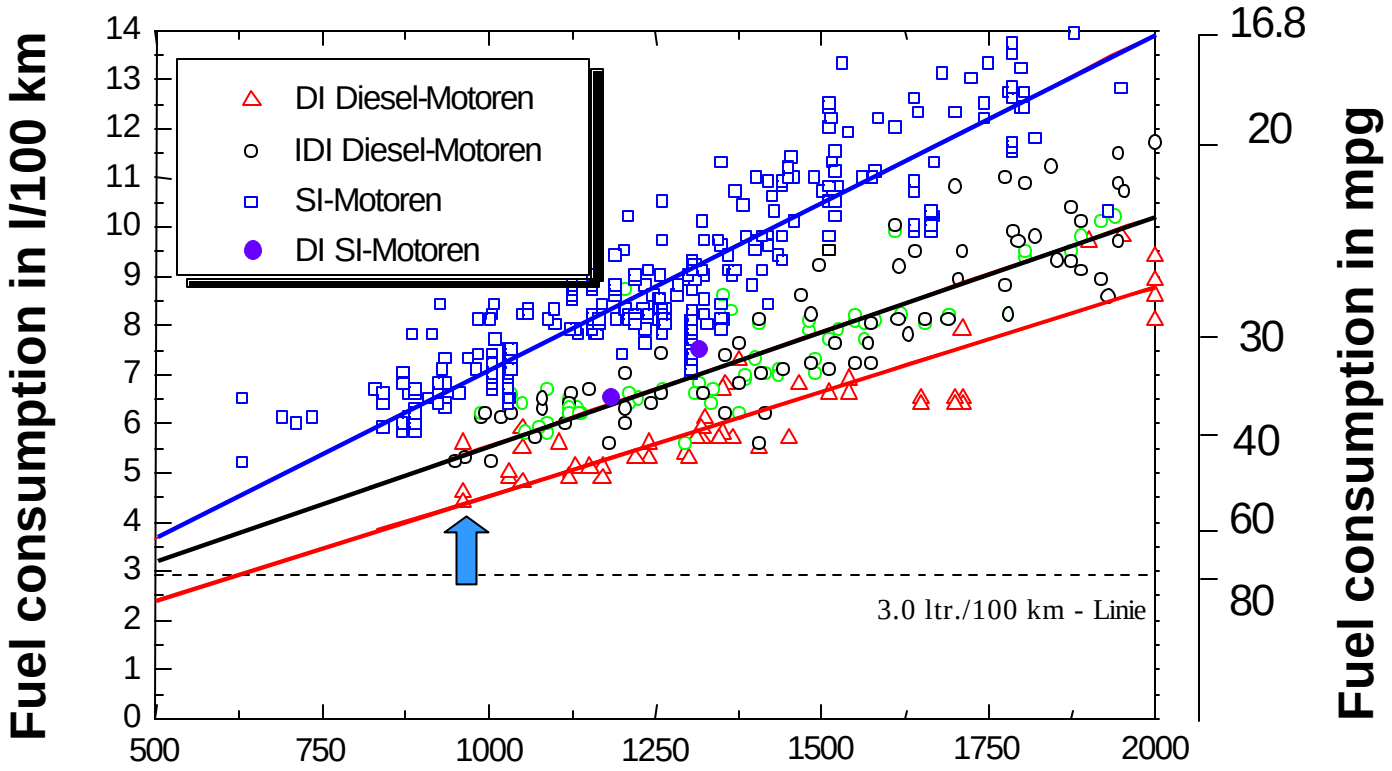
Fuel consumption and vehicle weight



Highly fuel efficient vehicles need a significar reduction of vehicle weight, aerodynamic dra powertrain losse and rolling resistance

DI Diesel = direct injection diesel engines
IDI Diesel = two section combustion diesel engines with vortex- or prechamber design
SI engines = spark ignition engines with external mixture formation
DISI- engines = direct injected spark ignition engines (internal mixture formation)

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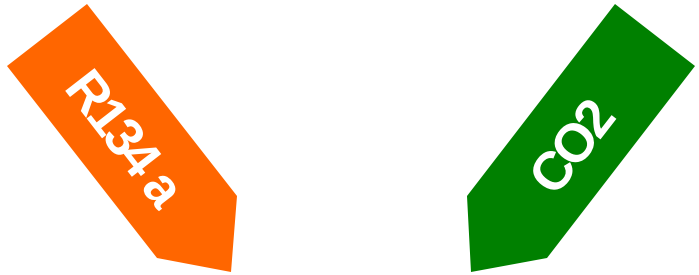
Refrigerant properties for AC and heat pump application



Thermodynamic properties	AC	☺	😐
	HEAT PUMP	😐	☺
Thermophysical properties	AC	😐	☺
	HEAT PUMP	☹	☺

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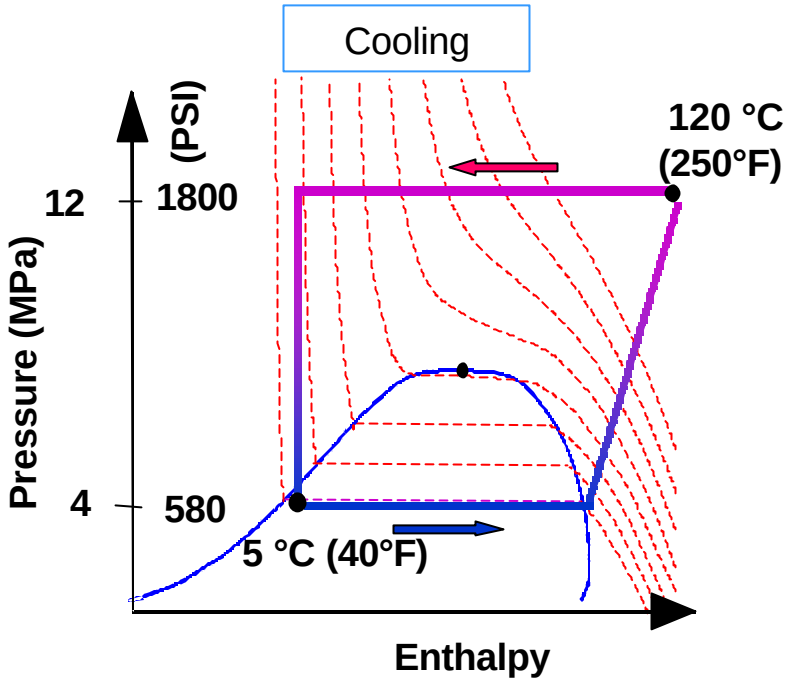
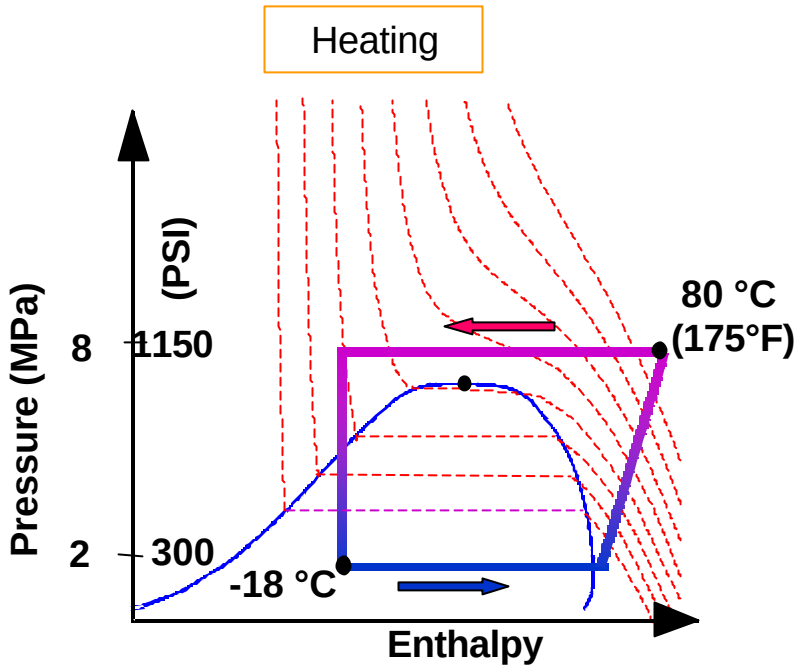
Heating with a CO2 AC-circuit



TASK 1

Overcome lack of heating in modern direct injection vehicle engines



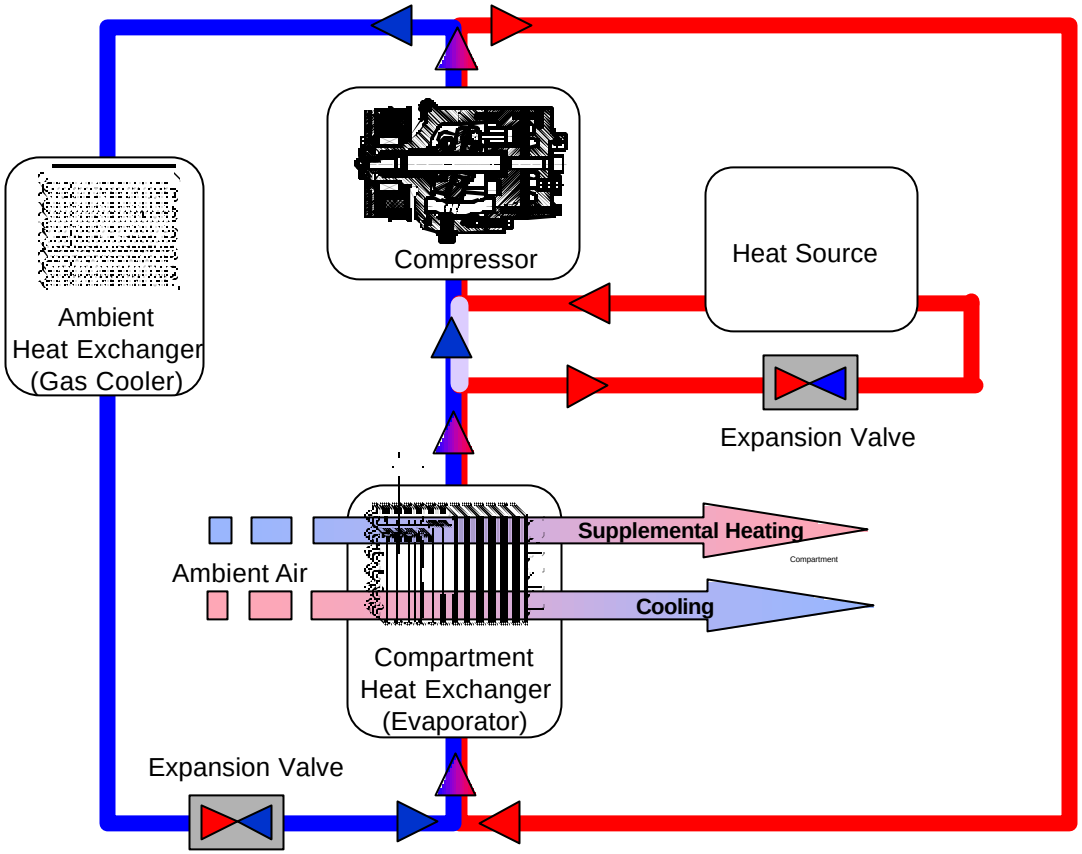
TASK 2

No need of supplementary heating units (cost reduction, fuel efficiency)

R744 Heat Pump

COOLING

HEATING



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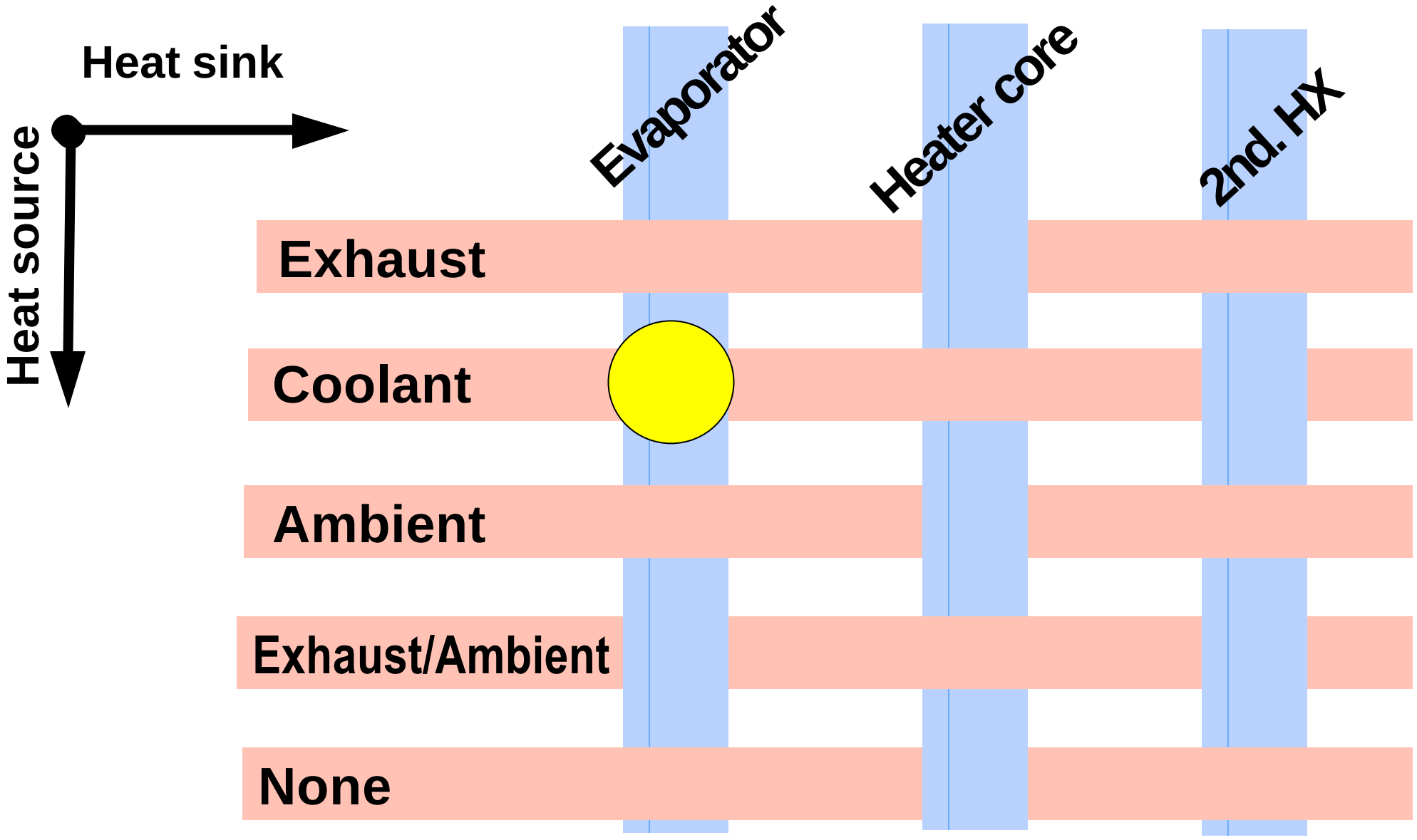

Points of Evaluation for a heat pump application in vehicle

Heat source

- costs
- capacity
- (dynamics, driving conditions, ambient condition)
- operation safety
- efficiency
- packging

heat sink

- costs
- capacity (dynamics)
- safety
- packging
- controllability
- dehumification
- operation safety
- hygienic aspects

History of Audi´s R 744 Heat Pump System

1998 First idea to build up a vehicle with R 744 Heat Pump System by using engine coolant as energy source in January

Order to Obrist Engineering to adopt an R 744 Heat Pump System to an Audi A4 1.6 ltr fuel engine in November

1999 Completed the installation of the Heat Pump System in August

First positive results in a road test in September

2000 Achieved the actual results in March

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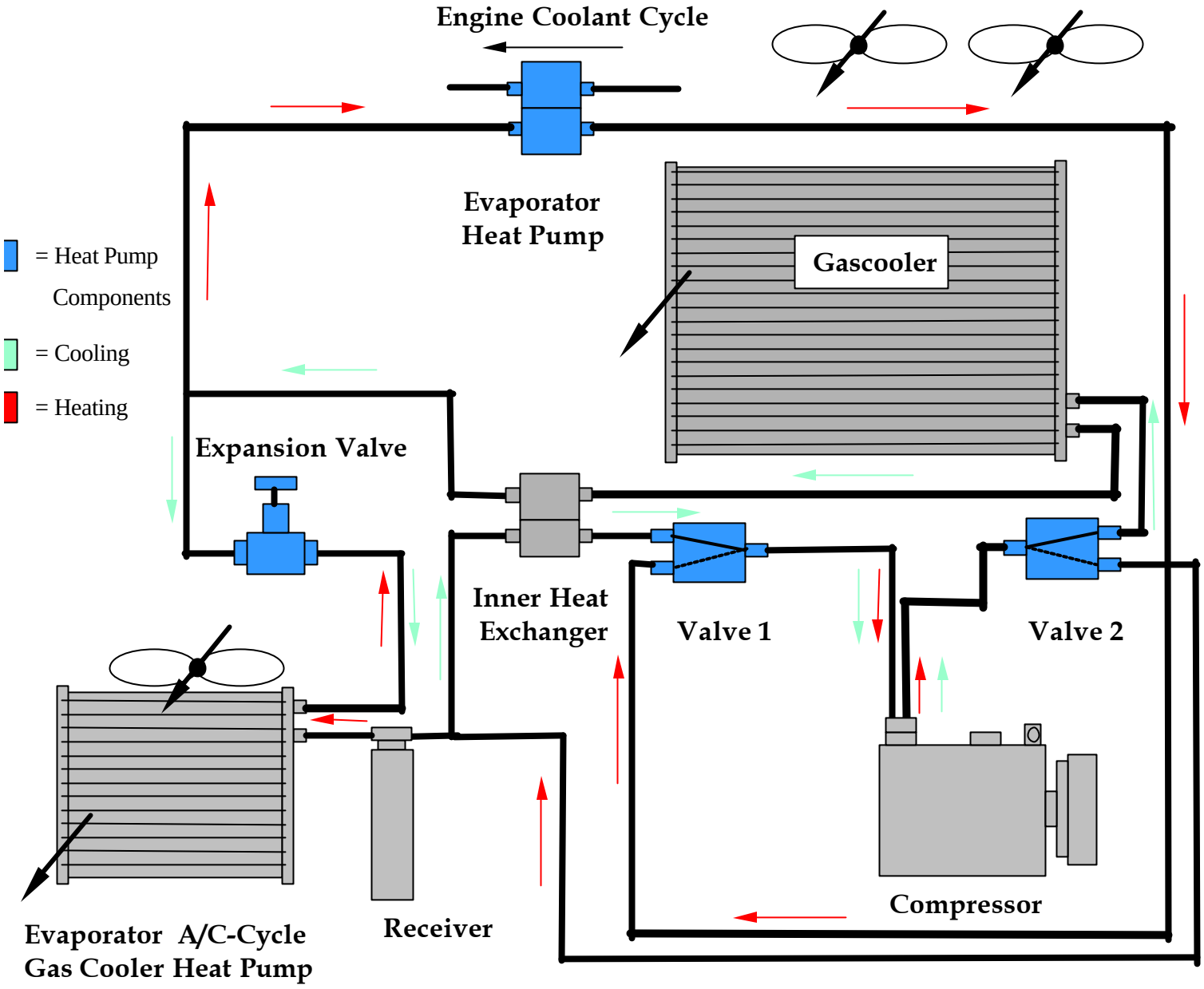

A/C- and Heat Pump Cycl

Engine coolant is use as energy source

Additional component are a heat exchanger and two valves to turn the operation mo

Expansion valve has to facilitate 2-way flov

Heating Performance Test

- **Ambient temperature:** **-20°C (-4°F)**
- **Driving conditions:** **20 mph, 3rd gear, 50 minutes**
  Idle, 10 minutes
- **Temperature Setting:** **max. warm**
- **Heater Blower:** **9V**
- **Air Distribution:** **Defrost Outlet**
  Foot Outlet

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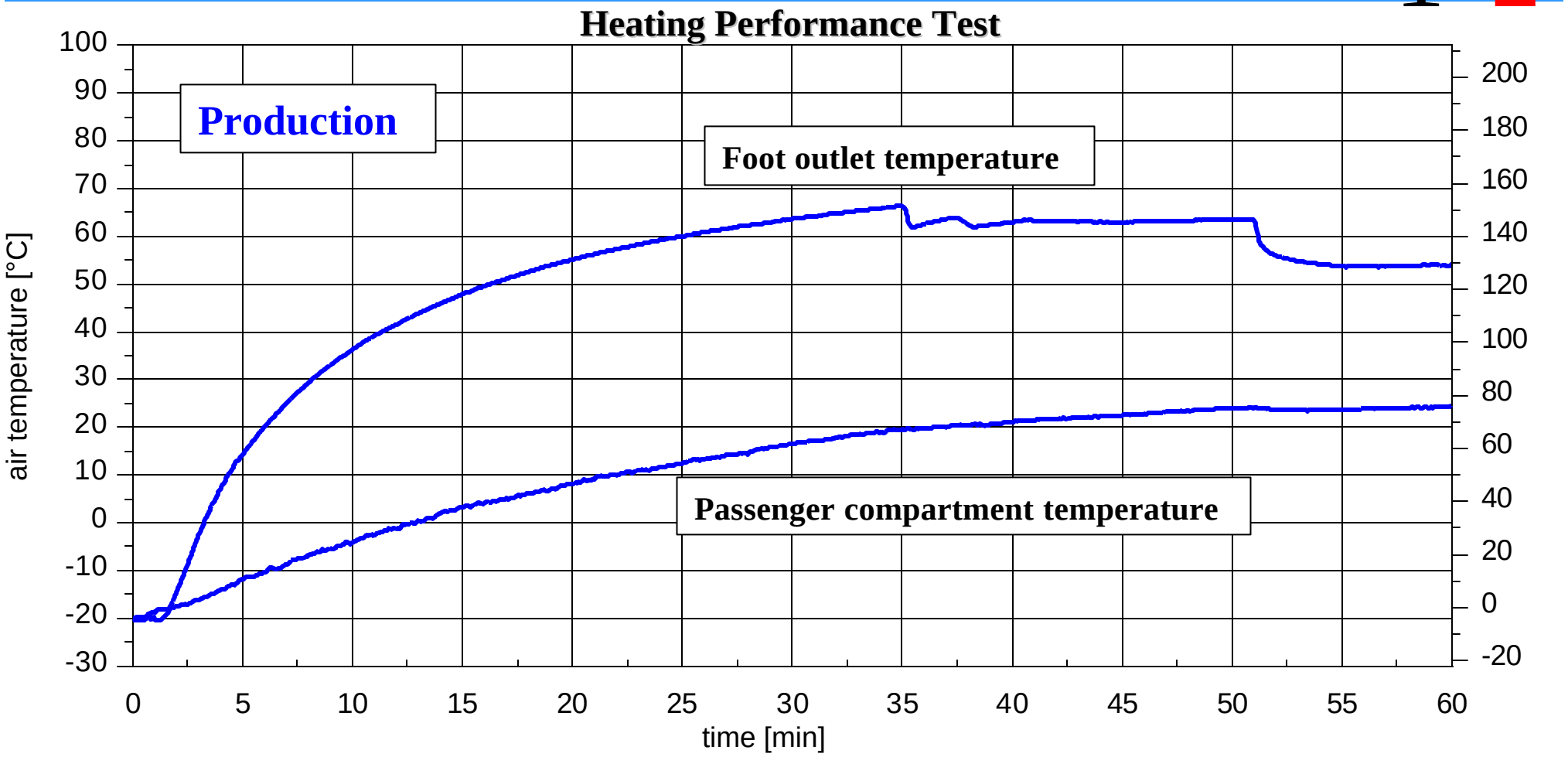

- **Decrease of foot outlet temperature of 10K under idling condition**
- **Heating performance of a production A4 1.6 ltr fuel engine**

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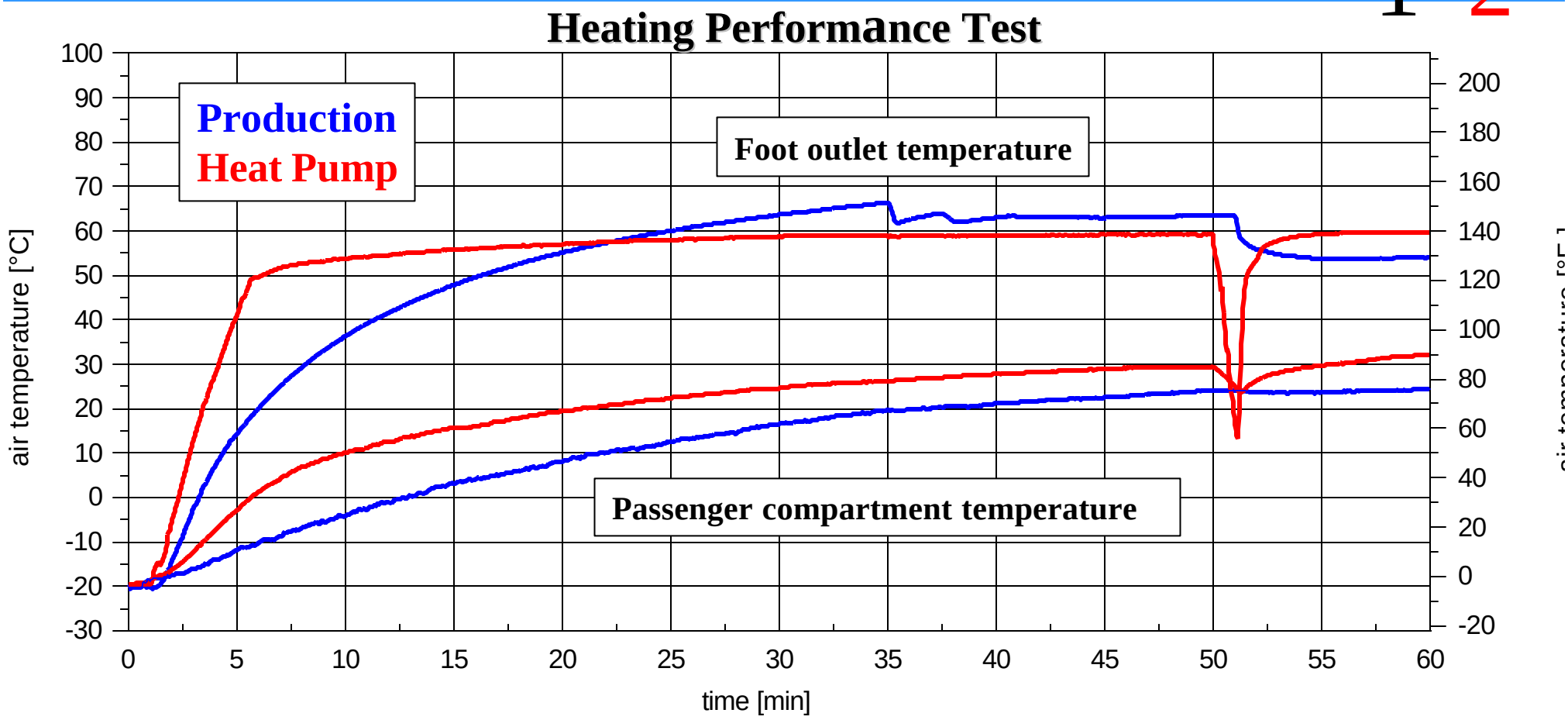

- Heating performance of a production A4 1.6 ltr fuel engine
- Decrease of foot outlet temperature of 10K under idling condition
- Heat Pump System operated without production heater core
- Significantly higher performance, even under idling conditions

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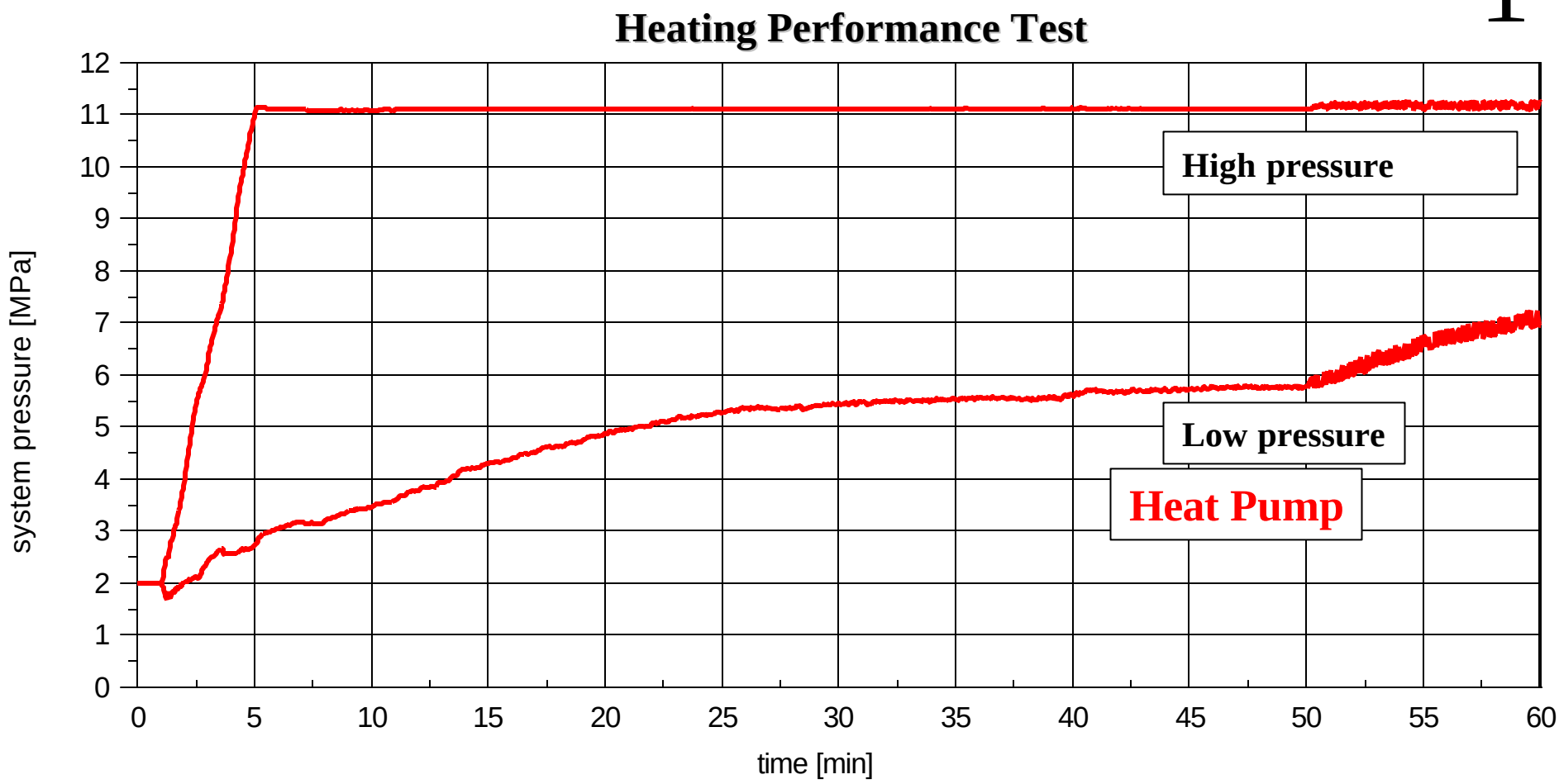

- Pressure curves of a Heat Pump System
- Discharge pressure control at 11 MPa
- Suction pressure increase according to engine coolant temperature increase

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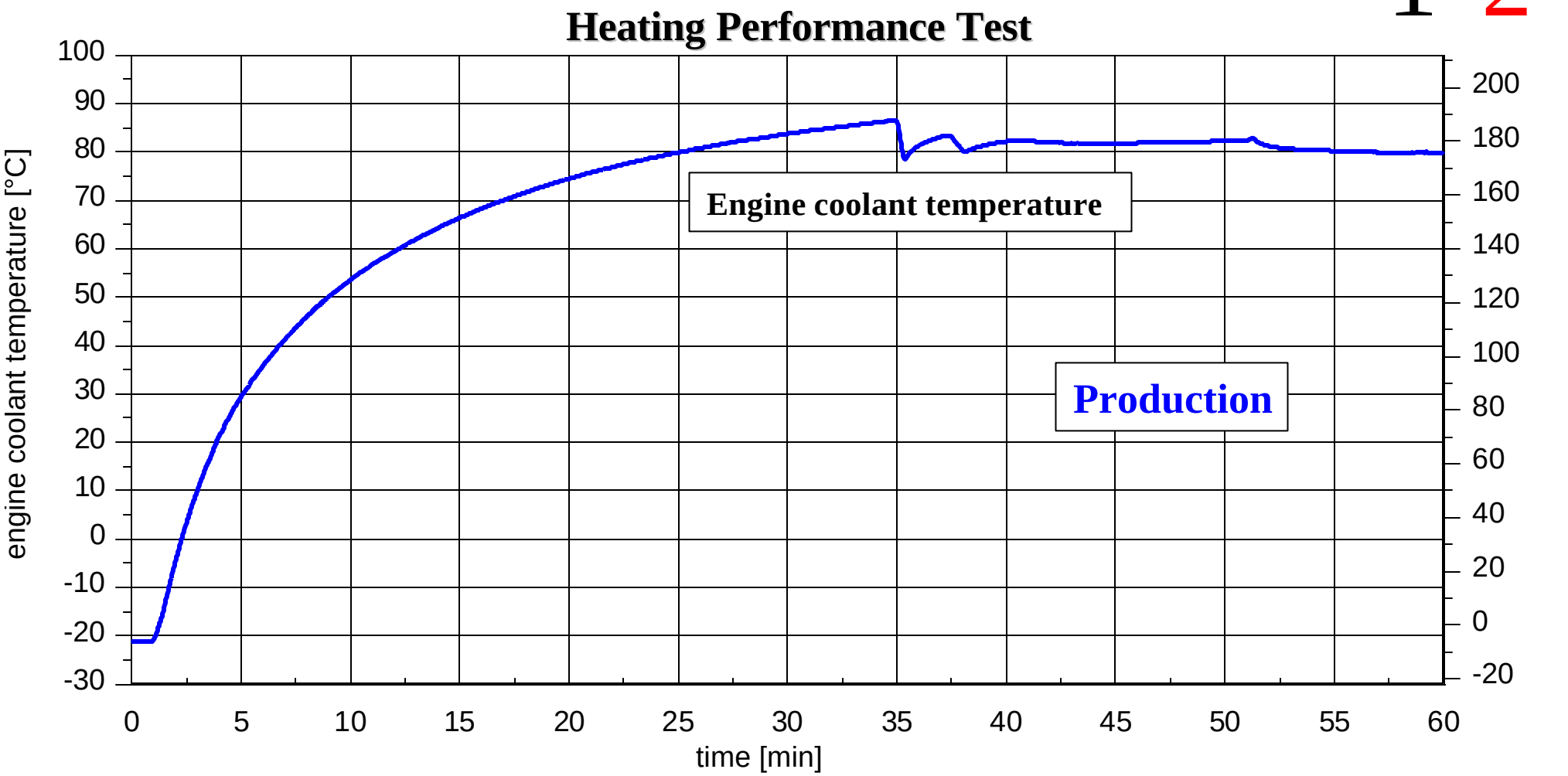

- **Engine coolant heat up of a production A4 1.6 ltr fuel engine**

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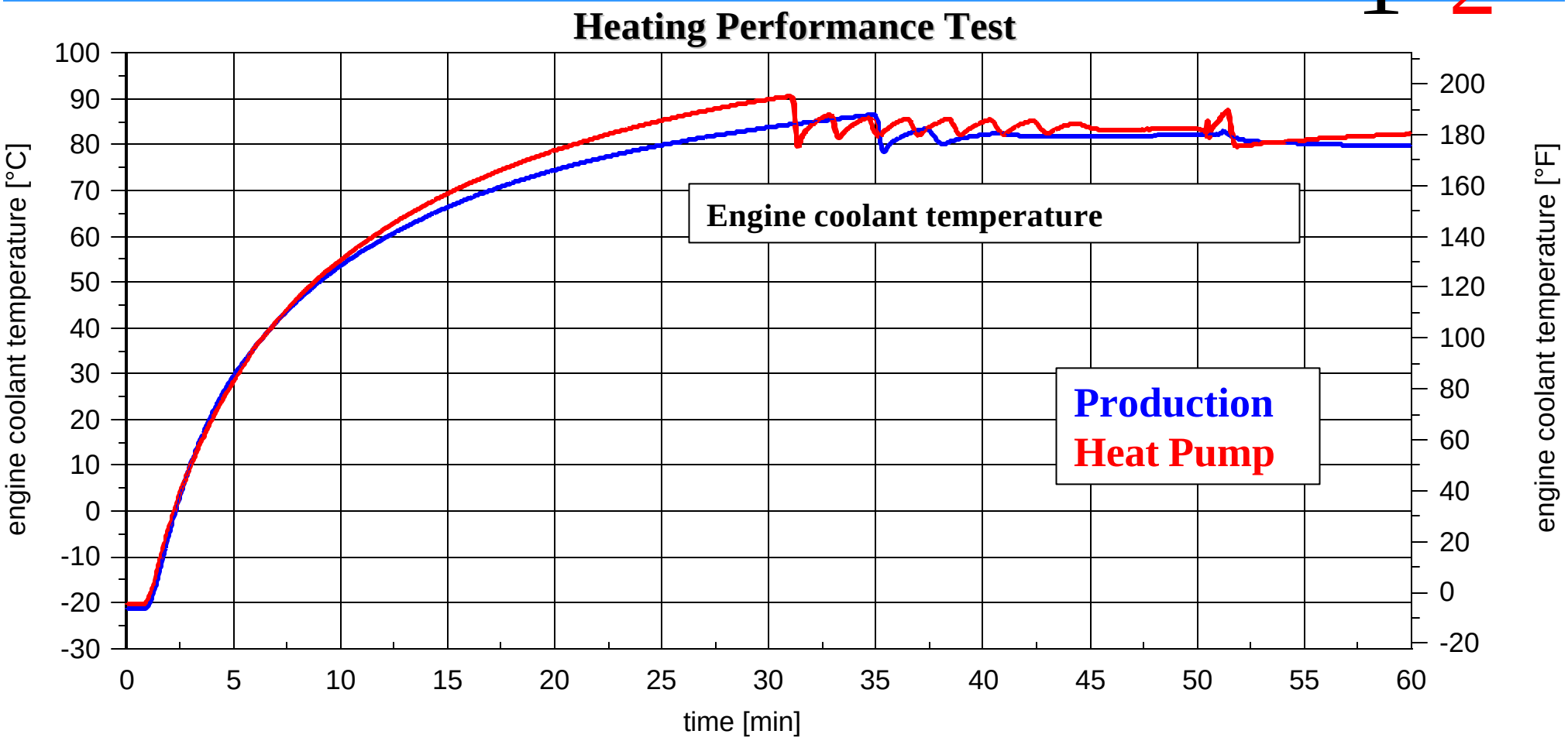

- Engine coolant heat up of a production A4 1.6 ltr fuel engine
- Engine coolant heat up with Heat Pump System
- Power consumption of compressor leads to a consistent energy balance in engine coolant system

Further Activities in 2000

- To build up a new A4 1.9 TDI (DIESEL) with an R 744 System that facilitates the operation of both - A/C and Heat Pump Cycle by actuating 2 valves
- To optimize the system in terms heating performance and efficiency
- To compare performance and efficiency of an R 744 Heat Pump System with conventional systems such as electrical, fuel or exhaust heaters

Conclusion / Outlook

High performance and dynamic even under low ambient temperatures, high outlet temperature level for passengers comfort

Expected high fuel efficiency with heatpump system

R744 is the right fluid for vehicle Heat Pump application