CO2 heat pumps applied to modern electric buses
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Different heat pump systems

Direct system air to air
• highest efficiency
• lowest safety level
• complex refrigerant circuit

CO2 heat pumps applied to modern electric buses
Different heat pump systems

Indirect system air to water

- lower efficiency
- higher safety level
- complex water circuit

![Diagram of CO₂ heat pump system]

CO₂ heat pumps applied to modern electric buses
Different heat pump systems

Double indirect system water to water

- lowest efficiency
- highest safety level
- complex water circuits
- most compact refrigerant circuit
- lowest refrigerant charge

double indirect system
Different heat pump systems

Simulation results

- Using compressor polynoms (EN 12900) from Bitzer
- Constant UA-values for all HX
- Constant pressure losses in lines and HX 50 kPa
- 2000 m³/h air inner HX
- 7300 m³/h air outer HX
- 2000 ltr./h water

Heating demand

- 11665 W
- 9203 W
- 6740 W
**Different heat pump systems**

Simulation results

- Using compressor polynomials (EN 12900) from Bitzer
- Constant UA-values for all HX
- Constant pressure losses in lines and HX at 50 kPa
- 2000 m³/h air inner HX
- 7300 m³/h air outer HX
- 2000 ltr./h water

Simulation results:

- Cooling demand:
  - 9303 W for direct CO₂
  - 11025 W for indirect CO₂
  - 11103 W for direct propane
  - 11103 W for indirect propane
Konvekta UL500 CO2 heat pump

- high efficiency
- natural refrigerant R744 / CO₂
- combines direct system air-to-air heat pump with indirect system heat transfer fluid for remote heating and cooling (driver) and waste heat collection
Konvekta UL500 CO2 heat pump system

- high efficiency
- natural refrigerant R744 / CO₂
- combines direct system air-to-air heat pump with indirect system heat transfer fluid for remote heating and cooling (driver) and waste heat collection
- separate HX-tubes and lines for heating and cooling circuit
- fast switching between both modes possible
Konvekta UL500 CO2 heat pump system

- Heating mode
Konvekta UL500 CO2 heat pump system

- Cooling mode
Konvekta CO2 heat pump – 1st and 2nd generation

1st generation
- Built up in 2012 (EURO championship in Poland)
- Direct system air-to-air heat pump with cold and hot water supply
- Using same HX-tubes for heating and cooling
- Using a reversing valve

2nd generation
- Change in 2015
- Change of the compressor type
- Direct system air-to-air heat pump with cold and hot water supply
- Using separate HX-tubes for heating and cooling
- Using not a reversing valve but fast switching solenoid valves

- Urban transport Klagenfurt STW 8,9m Solaris
  2 city tours of 100 km per day with recharging between the tours and over night

- Heating
  Hot water is supplied to convectors and to the driver's HVAC module.
  Hot air is supplied to the air ducts in the roof.

- Cooling
  Cold water is supplied to cool electric components and to the driver's HVAC module.
  Cold air is supplied to the air ducts in the roof.
Konvekta CO2 heat pump – 2nd generation SOP in 2019

• 2nd generation
  – Tested since in 2015
    ♦ Climatic chamber
    ♦ Field tests in public transport
    ♦ Oem winter test in Sweden
    ♦ Oem summer test in Spain
  – Tests with 4 compressor types of different manufacturers
  – Tests with frequency inverter
  – SOP in 2019 with 2 oems and 2 different compressor manufacturers
## Buses equipped with CO2 heat pump

- **Diesel buses with CO2 air condition**: 90
- **Electric buses with CO2 heat pump**: 260

### Cities with CO2 heat pump applications

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*Note: CO2 heat pumps applied to modern electric buses*
Electric bus heat up measurements

after 15 minutes:
- supply air 16°C
- return air 8,5 °C
- supply air driver 30 °C

after 30 minutes:
- supply air 20°C
- return air 17,5 °C
- supply air driver 43 °C
HVAC energy consumption of a city bus (simulated)

Darmstadt, 12m electric city bus with air condition and Diesel heater, 11 km/h average speed, 19 hours operation
HVAC energy consumption of a city bus (simulated)

Darmstadt, 12m electric city bus with air condition and electric heater (AC+PTC) versus reversible heat pump (AC+HP), 11 km/h average speed, 19 hours operation.
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