Mobile HVAC-System with CO_2 as Refrigerant

Results of Simulation and Measurements

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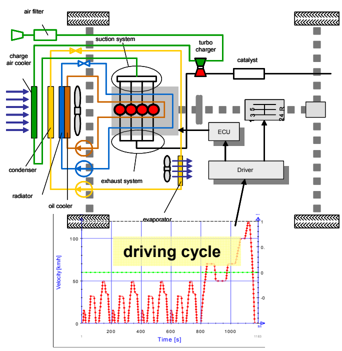

- ➢ HVAC-system is part of thermal network
- ➢ Influenced by / influences
  - underhood flow
  - engine operating point
  - fuel consumption, emissions
  - comfort
- ➢ Rarely running at steady-state operating conditions

HVAC-System

- (transient) simulation of the HVAC-system
- Supplementary heating
- Effect on vehicle
- Refrigernat CO_2

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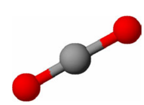
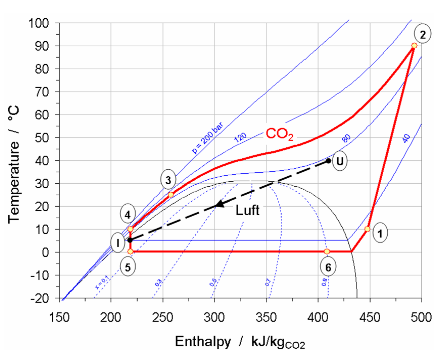
Introduction

Why CO_2?

- ➢ R134a-phase out due to high GWP (1300!)
- ➢ Most promising alternatives: CO_2 (Carbone Dioxid, R744), R152a



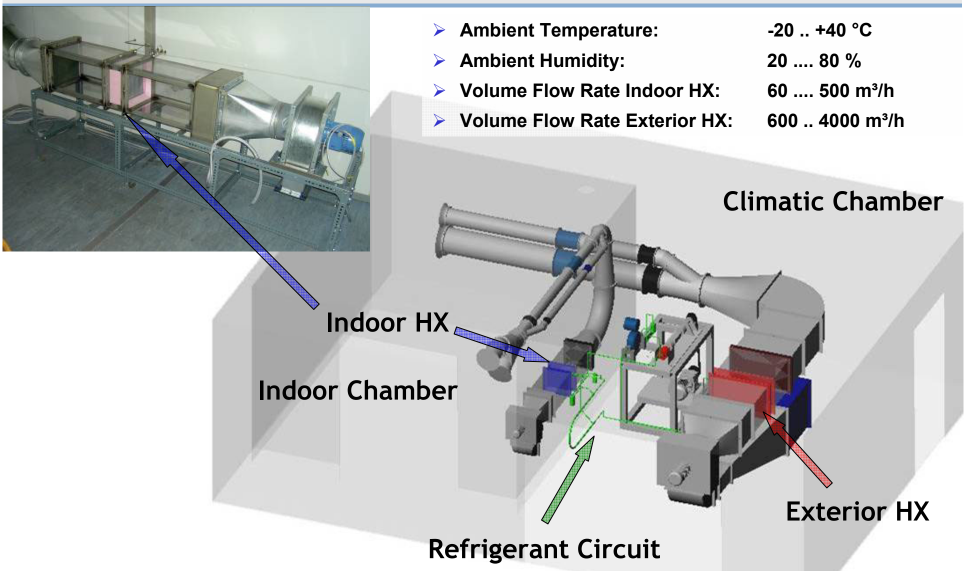
CO_2



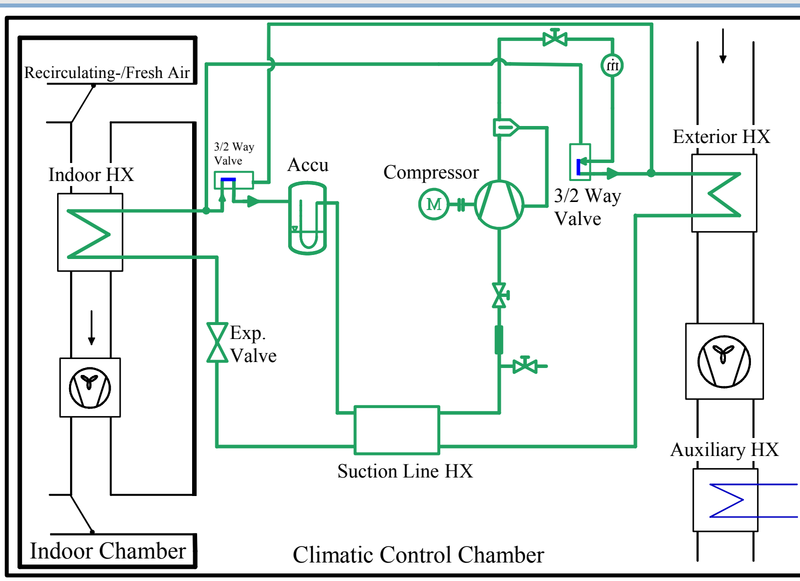
- ➢ Important differences to R134a
  - Critical point: 31.1°C / 73.8 bar
  - Supercritical refrigerant cycle (no condensation in „Condenser“)
  - High volumetric cooling capacity
- ➢ New components
- ➢ Different refrigerant circuit layout
- → Measurements & Simulations for circuit optimisation

HVAC Test Rig

- Ambient Temperature: -20 .. +40 °C
- Ambient Humidity: 20 .... 80 %
- Volume Flow Rate Indoor HX: 60 .... 500 m³/h
- Volume Flow Rate Exterior HX: 600 .. 4000 m³/h

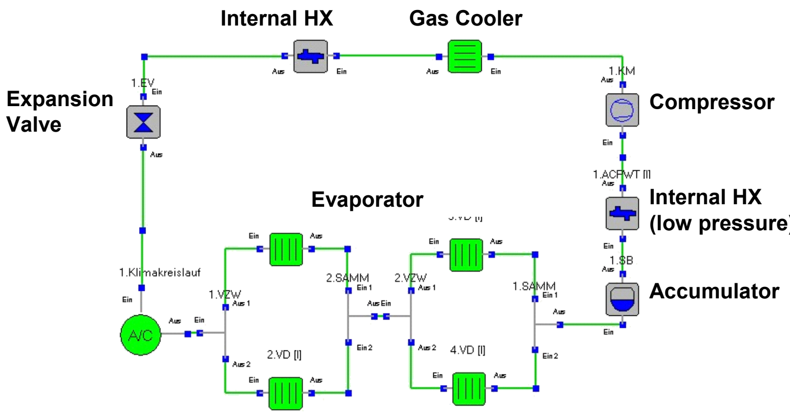


HVAC Test Rig



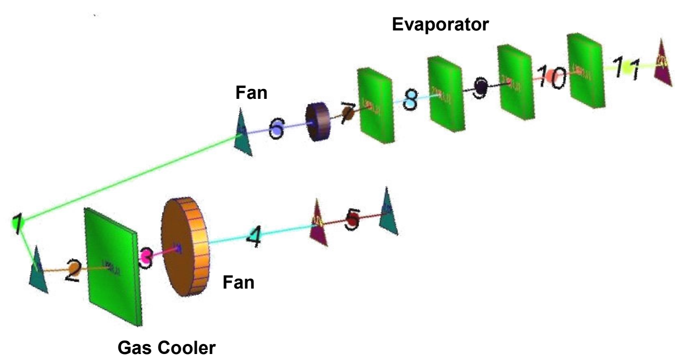
KULI-Simulations - Basics

Model of Refrigerant Circuit - AC



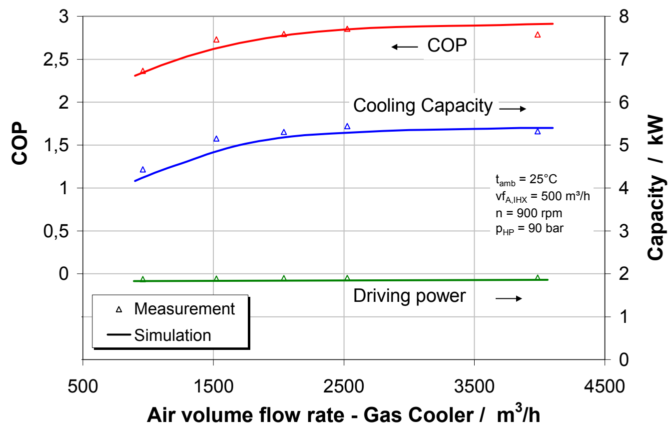
KULI-Simulations - Basics

Model of Air Side Flow



KULI Simulation – steady state

COP, Cooling Capacity and Driving Power vs. Gas Cooler Air Flow Rate



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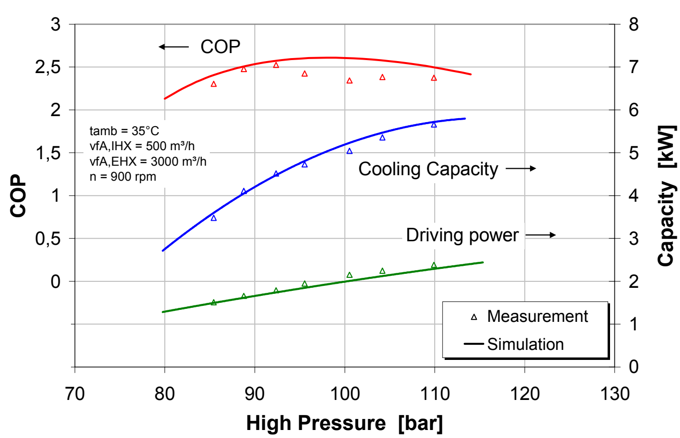
KULI Simulation - steady state

COP, Cooling Capacity and Driving Power vs. High Pressure



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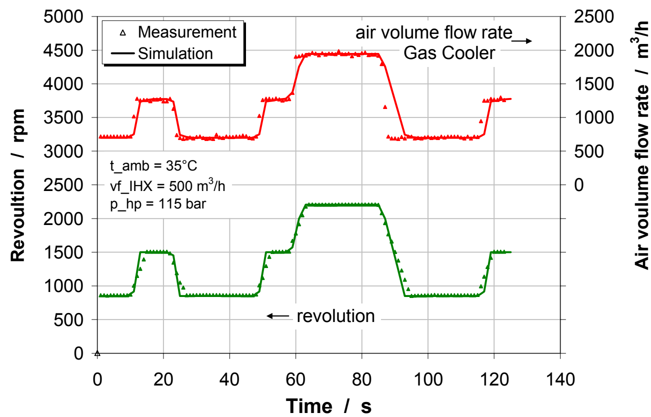
KULI Simulation – transient (quasi-steady state)

Driving cycle - Input variables



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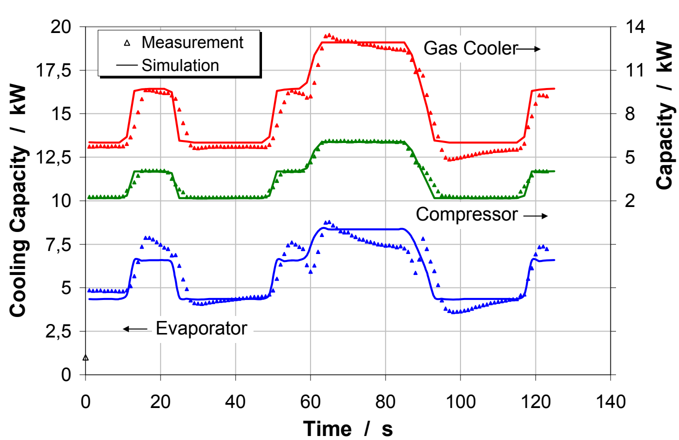
KULI Simulation – transient (quasi-steady state)

Driving cycle - Simulation vs. Measurement



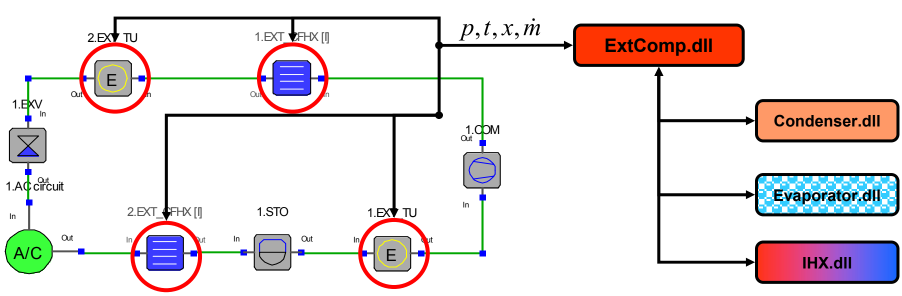
Advanced models

Requirements/Demands:

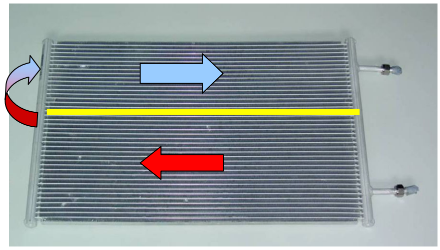
- Advanced geometry (modeling of various multi-pass geometry)
- Applicable for heating and cooling mode
- Transient behavior (structure warm-up)
- Airside coupling with CFD-simulation
  (non uniform airflow distribution)
- Implementation as External Component, coupling to KULI via enhanced COM-Interface

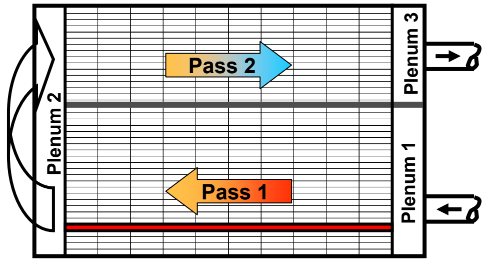
Coupling with KULI

- Geometry Data from ASCII-File
- Component Results available through KULI-Postprocessor
- Detailled calculation results written to Log-File

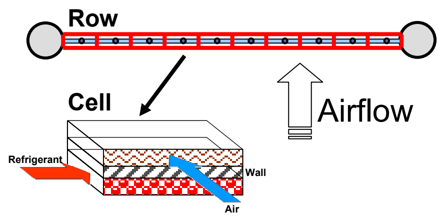


Gas Cooler Model





- Transient formulation of mass- and energy conservation for each cell
- Heat transfer & pressure loss equations for single- and 2-phase flow (evaporation & condensation)
- Arbitrary cell length for high resolution



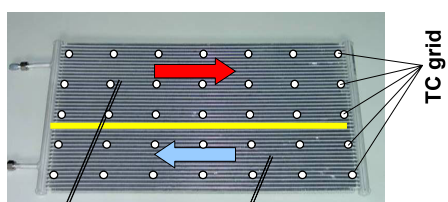
Gas Cooler – steady state

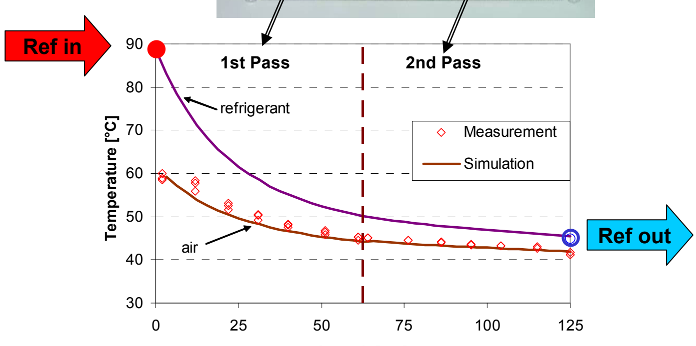
Measurement vs. Simulation

Inlet Conditions:
p_RefIn = 98 bar
T_RefIn = 89 °C
mf RefIn = 160 kg/h

T_AirIn = 37.6 °C
Vf_Air = 2030 m³/h

Rejected Heat:
Q = 5.9 kW

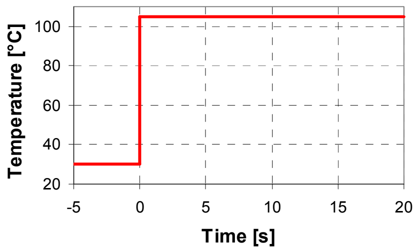




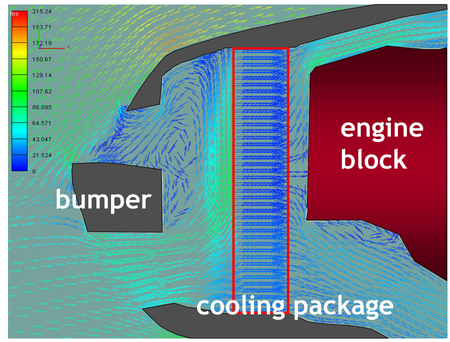
Gas Cooler – Warm Up

Gas Cooler warm up with / without consideration of thermal mass

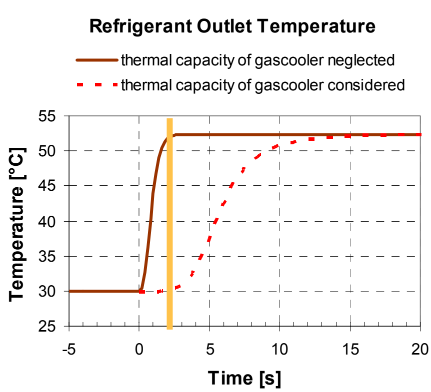
Refrigerant (CO_2) Inlet
- **p = 110 bar**
- **mf = 200 kg/h**
- **t = 30°C → 105°C**



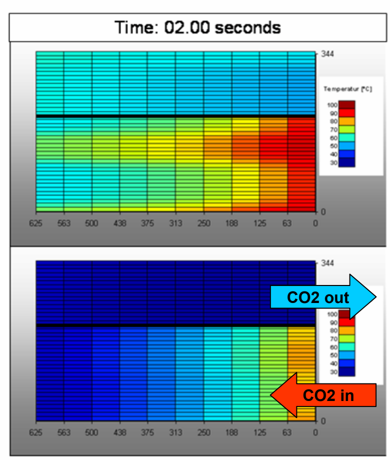
Air (uneven distribution)
- **Vf = 930 m³/h**
- **t = 30°C**



Gas Cooler – Warm Up

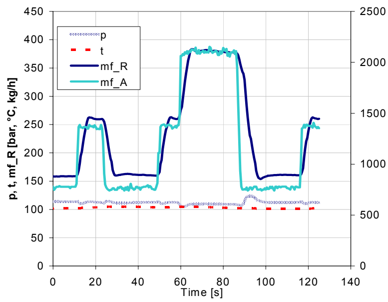


Surface temperature



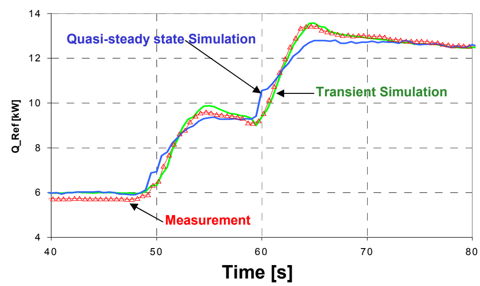
Advanced models – transient (Load Change)

Input variables



Gas Cooler heat rejection

$$\dot{H}_{Ref,in} - \dot{H}_{Ref,out}$$

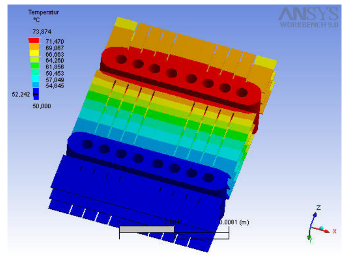


Summary

- Test rig for CO_2-HVAC system
- Influence of several system parameters investigated
- Good correlation of KULI simulation with measured data for steady state operation
- Advanced models
  - Simulation of component warm up
  - Gas cooler model: Good correlation with measurement data under transient conditions

Outlook

- **Further improvement of HX-models**
  (heat conduction, refrigernant distribution, oil …)
- **Transient cycle analysis for heating & cooling mode (with Advanced Component Models)**
- **Simulations & experiments for heat pump mode**
- **Different set-ups of hp**



Heat conduction in fins

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TUG Technische Universität Graz Erzherzog-Johann-Universität
FFG Österreichische Forschungsförderungsgesellschaft Austrian Research Promotion Agency
Kplus Kompetenzzentren-Programm
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