/// CO_2 as Refrigerant

Challenges in use in railway air conditioning

/// 2017/09/26 – Lutz Boeck

/// AGENDA

- **Motivation**
- **History – activities of FT in the past**
- **Challenges by using CO_2 in passenger railways**
  - Requirements for HVAC unit in railway application
  - Design and extreme conditions for different climatic zones
  - Performance & COP
  - Safety Concept
- **Field trail**
- **Conclusion**

/// MOTIVATION FOR CO_2 AS REFRIGERANT

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/// MOTIVATION

- **F-Gas-Regulation EU/517/2014 defines phase down**
  → but no limitation of current used refrigerants for railway sector
- **Influencing facts for moving forwards**
  - ☑ **FT environmental philosophy**
  - ☑ **Political decisions**
  - ☑ **Customer inquiries**
  - ☑ **Progress in other industry**
- **Enhancement of the internal know-how / preparation of the industrialization**
- **Project together with the NSB and SINTEF**
  Modification of a FLIRT HVAC-unit from R134a to CO_2

→ Ready for serial deliveries in 2020

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/// HISTORY

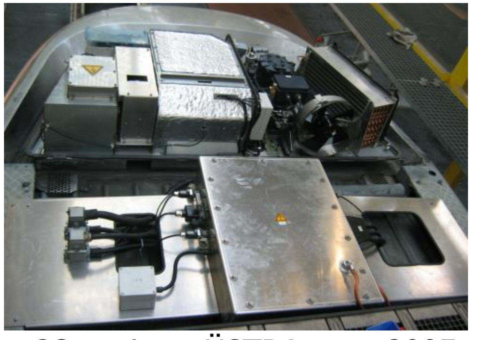
/// HISTORY OF CO_2 IN FAIVELEY

Retrospect

1995 First modification of existing compressors for CO_2-Application, implementation in a unit for lab test

2000 Development of test rig for CO_2 - lab test activities

2005 Development and construction of a drivers cab unit with CO_2
→ Tram Hannover ÜSTRA



CO_2 unit on ÜSTRA tram 2005

2005-2011 Successful operation

2014 Restart of activities
Study of different circuit layouts, potential suppliers, control strategies and safety concept

2015 Start of research project with SINTEF and NSB

First tram unit 1995

Component test rig 2005

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Lessons learned from projects - Cycle improvements

- high pressure control
- accumulator
- internal heat exchanger
- "Safe" evaporators
- minimization of refrigerant mass
- Heat pump function

All these features are now integrated in NSB demonstrator!

Roof installation on ÜSTRA tram 2005

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/// CHALLENGES

/// CHALLENGES FOR CO_2 IN RAILWAY

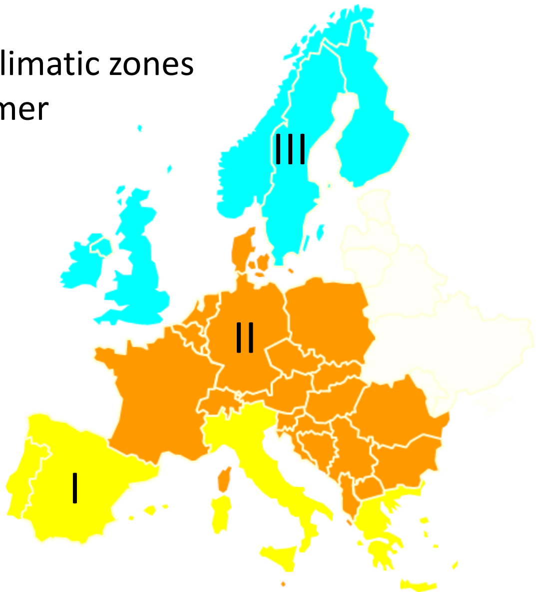
Railway specific requirements

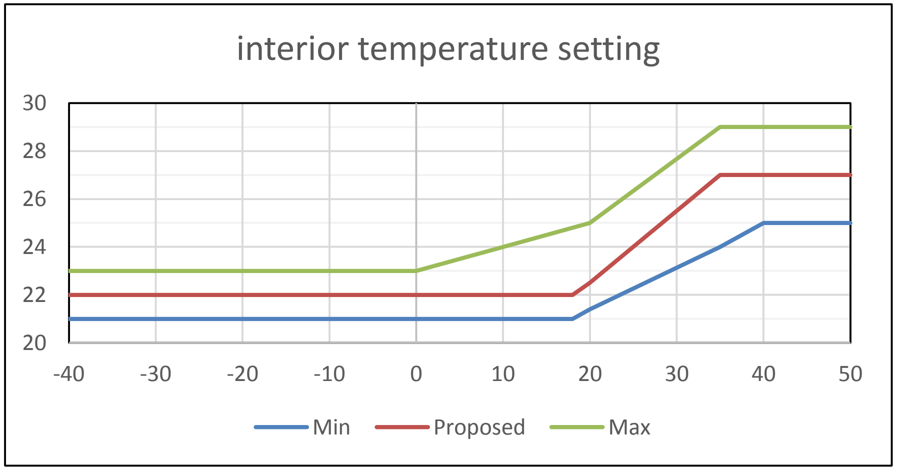
CO_2 unit shall fulfil similiar parameters as for R134a units as

- **Cooling capacity** (at design and extreme conditions)
- **Heating capacity** (down to -20° C)
- **Dimensions**
  (limited space for unit and components → large Δt on HX)
- **Weight**
- **Shock & vibration proof** (EN 61373:2011)
- **Energy consumption**
  (Peak, Efficiency, Yearly energy consumption)
- **Reliability**
- **Maintenance**
- **Safety**
- **Stillstand pressure (train parked without power)**

/// CHALLENGES FOR CO_2 IN RAILWAY

Design and extreme conditions for different climatic zones – EN 13129





Design conditions

Zone	Winter	Summer		
	Minimum exterior temperatures °C	Maximum exterior temperatures °C	Relative humidity [%]	Equivalent solar load (En) W/m²
I	−10	+ 40	40	800
II	−20	+ 35	50	700
III	−40	+ 28	45	600

Extreme conditions

Zone	Winter	Summer		
	Minimum exterior temperatures °C	Maximum exterior temperatures °C	Relative humidity %	Equivalent solar load (En) W/m²
I	−15	+ 45	30	800
II	−25	+ 40	40	700
III	−45	+ 33	30	600

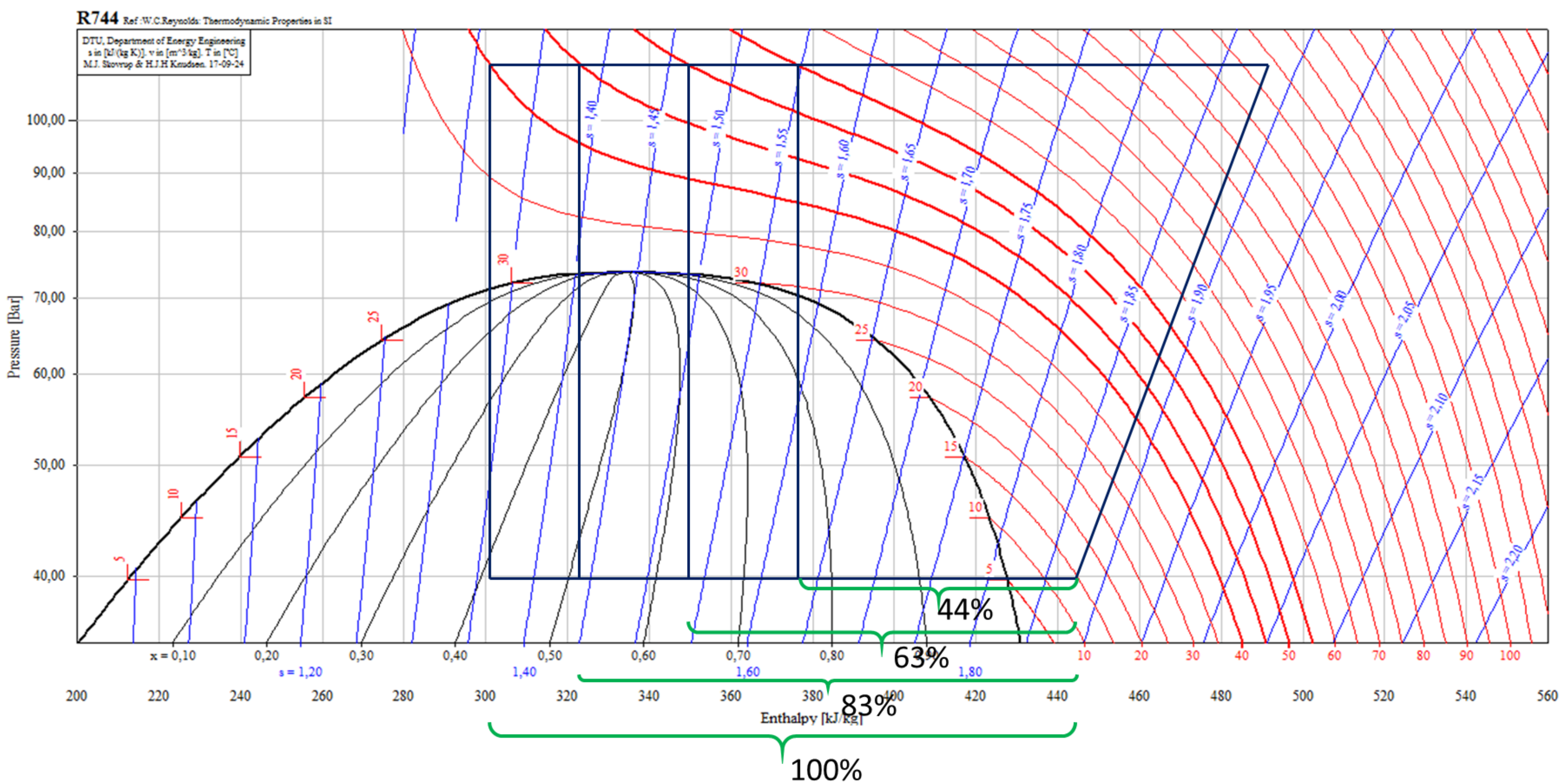
Operational limiting conditions

Zone	Summer		
	Maximum exterior temperatures °C	Relative humidity %	Equivalent solar load (En) W/m²
I	+ 50	25	800
II	+ 45	30	700
III	+ 38	25	600

/// CHALLENGES FOR CO_2 IN RAILWAY

Performance and COP – depending from ambient temperature

Reduction of cooling capacity depending from gascooler outlet temperature
40 / 45 / 50 / 55° C at given max. pressure



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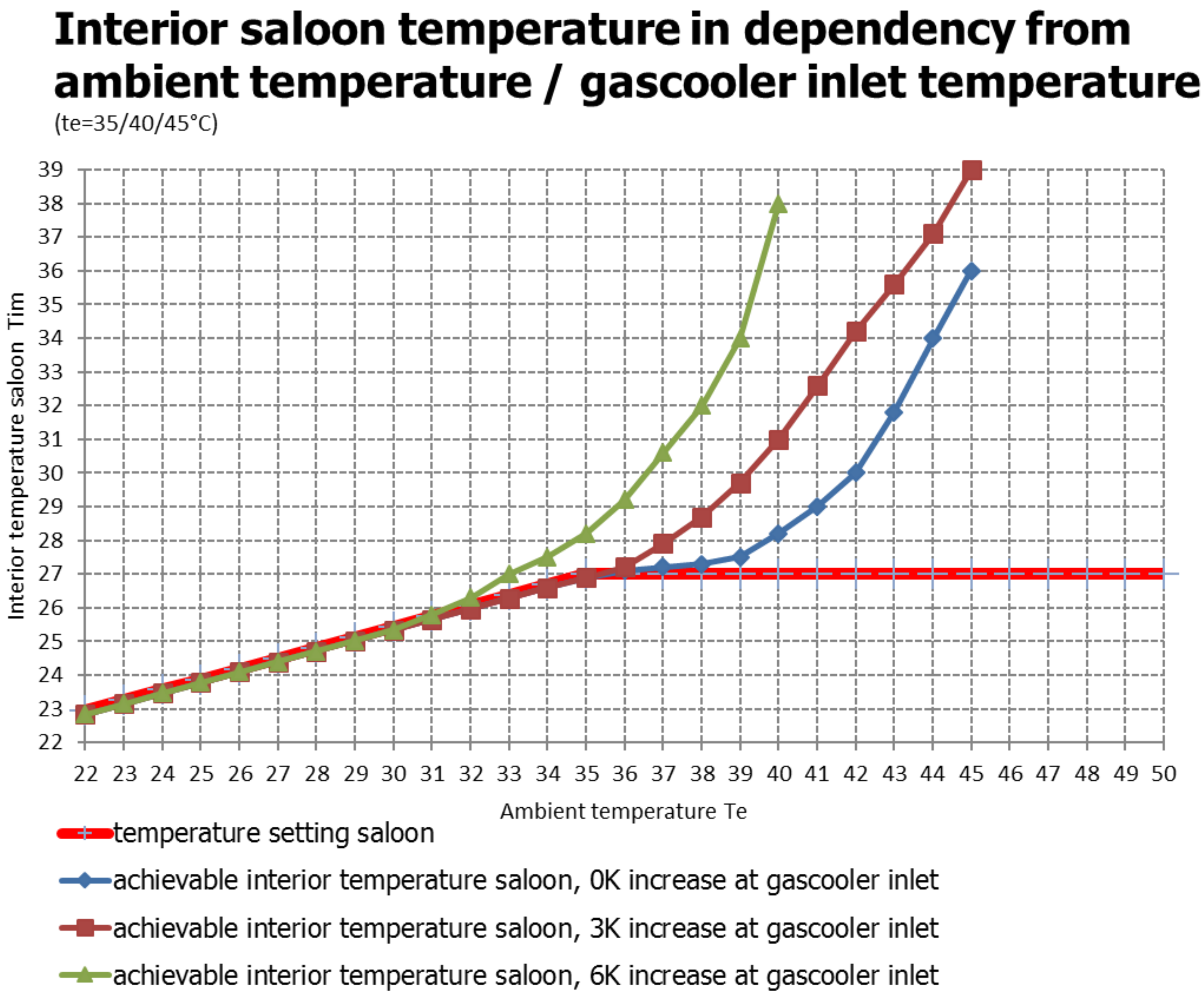
/// CHALLENGES FOR CO_2 IN RAILWAY

Design Conditions e.g. climatic zone II – EN 13129 / EN 14750



- very sensitive
- Significant

to be considered in design phase

/// CHALLENGES FOR CO_2 IN RAILWAY

Safety

CO_2 unit typically classified in Category II (I) PED 2014/68/EG

Safety concept at different stages on product life cycle required:

Manufacturer → safety concept for manufacturing and serial test
Car builder → safety concept for installation on train
Operator → safety concept for operation, maintenance and de-commissioning

→ Protection against hazards associated with:

- Physical and chemical characteristics of refrigerants
  - Refrigerant charge limitation
  - Machinery room requirements
- Pressures and temperatures occurring in the refrigerant cycle
  - Requirements for components and piping
  - Requirements for assemblies

VDB Guideline - R744-Klimaanlagen in Schienenfahrzeugen
Technische Auslegungsgrundlagen und Sicherheitsnachweise

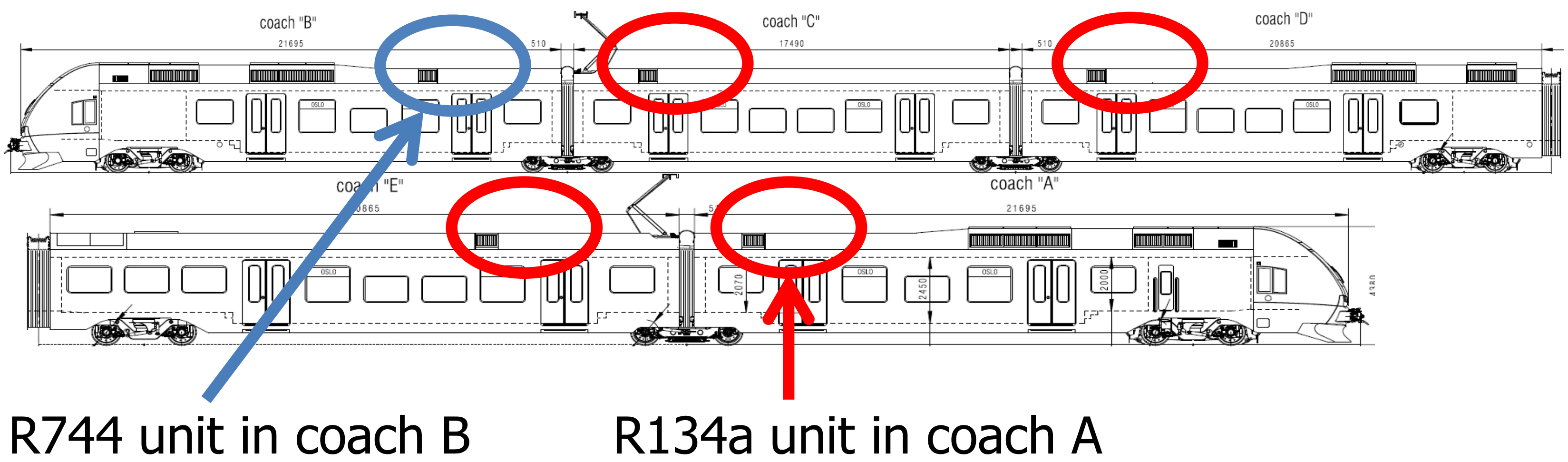
/// FIELD TRAIL

/// CHALLENGES FOR CO_2 IN RAILWAY

CO_2 unit for train – in service trial

Operation of a R744 unit under real service conditions

- Train of type „FLIRT“ at NSB network around Oslo in Norway
- Test period - 2017/18 → 12 Months
  → Evaluation of a complete cooling and heating cycle
- Data recording for R744 / R134a units on the train
  - operation of both systems under identical conditions
  → direct comparison possible



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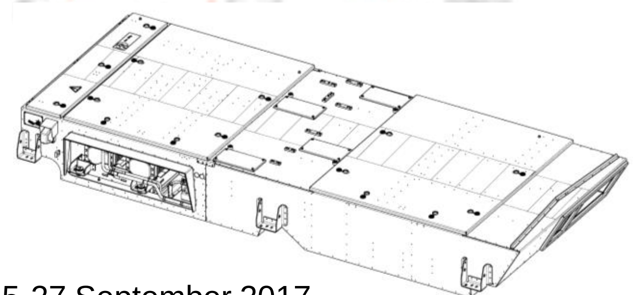
/// CHALLENGES FOR CO_2 IN RAILWAY

CO_2 unit for train – in service trial

- **Identical cooling / heating capacity in design points**
- **Similiar fresh air flow at the different operating conditions**
- **Identical dimensions, mechanical, electrical and air interfaces**
- **No modification of maximum electrical input power**
- **Increase of weight by max. 20% acceptable (Axle load)**

⬇

- **2 circuit system (Q_0=18 kW at design point 28˚ C/60%r.H)**
- **Changeover between cooling and heat pump operation**

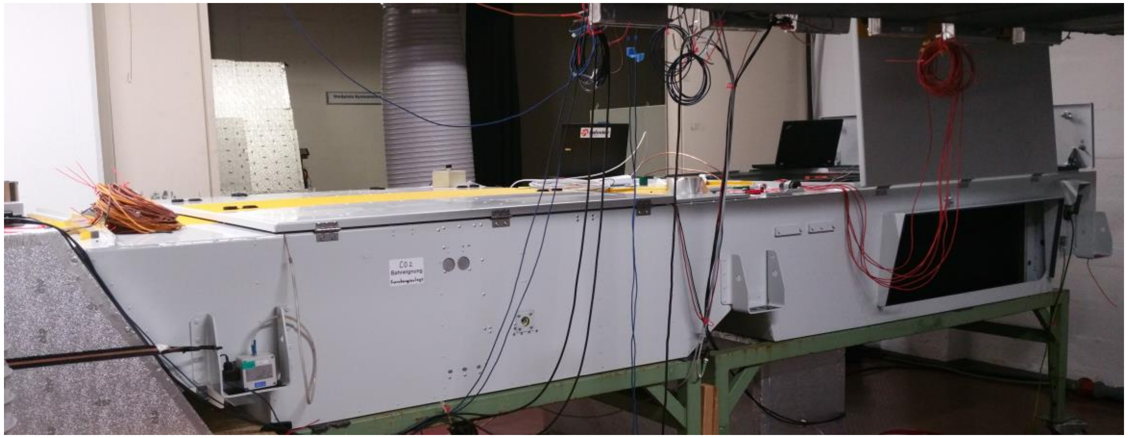


/// CHALLENGES FOR CO_2 IN RAILWAY

CO_2 unit for train – in service trial

Lab tests:

- Pressure test – HP=132 bar / LP=111 bar
- Shock and vibration
- Functional test safety devices
- Design point Heating / Cooling
- Extreme conditions Cooling
- Maximum conditions Cooling
- Part load conditions
- Changing conditions
- Changeover AC ↔ HP



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/// CHALLENGES FOR CO_2 IN RAILWAY

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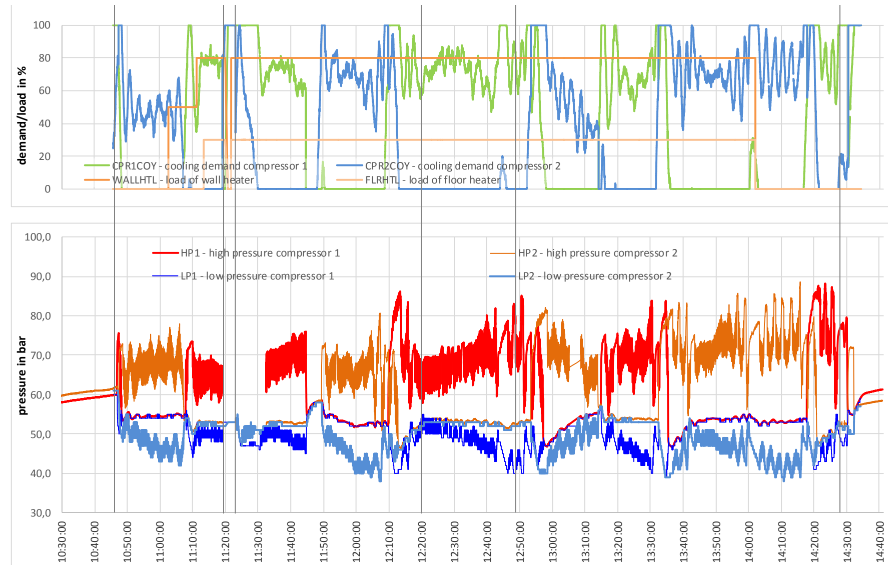
Field tests impressions



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/// CONCLUSION

/// CHALLENGES FOR CO_2 IN RAILWAY

Conlusion

CO_2 versus R134a unit

- Stronger reduction in cooling capacity at conditions above design point, more sensitive on performance degradation of HX
- More complex circuit layout → higher number of components
- Practical useable operating pressure limited due to stepwise arrangement of safety elements (3 steps)
- Management of standstill pressure – passive through Accumulator
- Weight level appr. 20% higher than R134a system (Accu, Comp.)
- Cost level significant higher
- Certification more expensive → Category II acc. PED 2014/68/EU
- Safety concept, especially for small rooms (DC, toilet)
- Control strategy different
- Power supply – adaption required
- Yearly energy consumption ??

/// CHALLENGES FOR CO_2 IN RAILWAY

Future / Potential for improvement / Tasks

- ✓ Solution for warm / extreme warm climatic zones
- ✓ Adaption of design points (to cover stronger reduction at high temp.)
- ✓ System design for heating and cooling (to compensate lower COP in cooling at high ambient conditions in yearly energy consumption)
- ✓ Design of HX for smaller temperature difference (dimensions, weight, air flow ↗)
- ✓ Increase of practical useable operating pressure
- ✓ Use of ejectors to compensate degradation in efficiency at high ambient conditions
- ✓ Management of stillstand pressure at hot and sunny days (no parking mode without power)
- ✓ Amplification of train power supply for climatic zone I
- ✓ Training of staff for maintenance and repair

Thank you for your attention.