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Refrigerants and refrigeration systems

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A study being conducted for DG ENTR by BIO Intelligence Service

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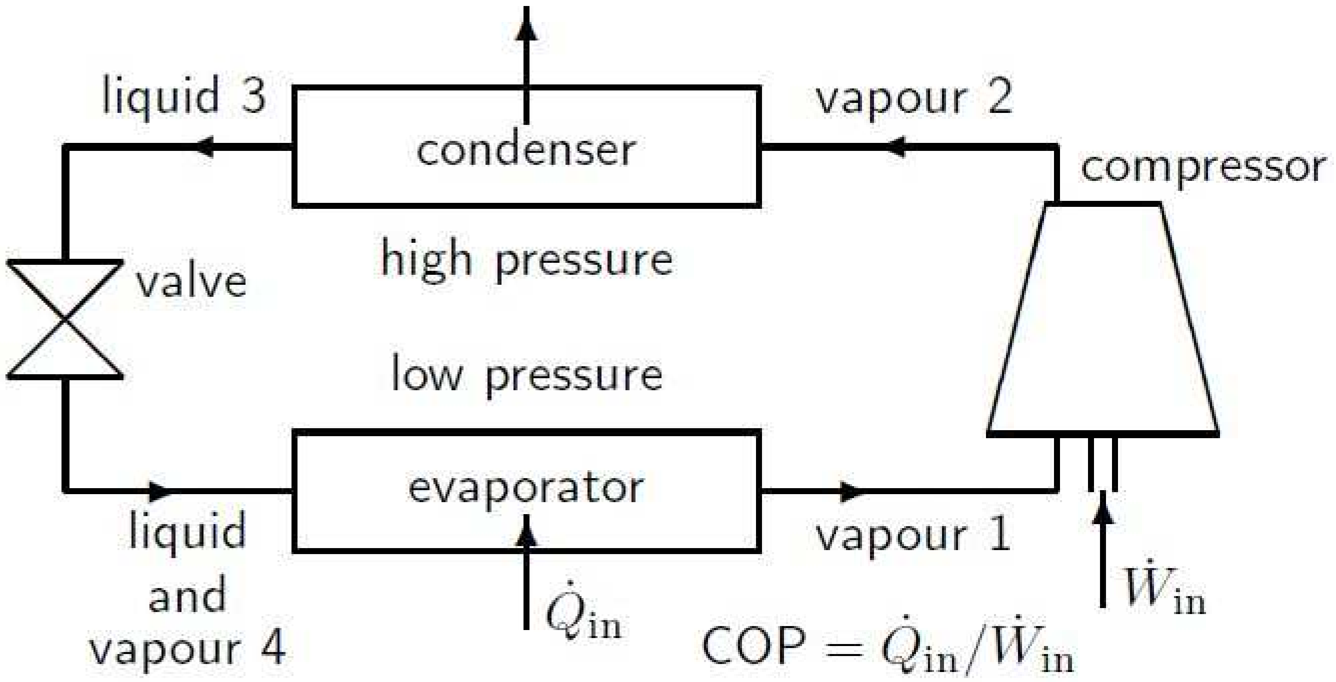
Agenda

10:00 – 10:20	**Welcome, explanation of the meeting structure and "Tour de table"**
10:20 – 10:30	**Short introduction to the Ecodesign Directive**
10:30 – 10:40	**Horizontal session: Progress update**
10:40 – 11:30	**Product focus: Walk-in cold rooms**
11:30 – 11:50	**COFFEE BREAK**
11:50 – 12:40	**Product focus: Service cabinets**
12:40 – 13:30	**Product focus: Blast cabinets**
13:30 – 14:20	**LUNCH BREAK**
14:20 – 15:10	**Product focus: Remote condensing units**
15:10 – 15:40	**Product focus: Chillers**
15:40 – 16:00	**COFFEE BREAK**
16:00 – 16:40	**Horizontal session: Refrigerants and Refrigeration systems**
16:40 – 17:30	**Conclusions, next actions to be taken and AOB**

Definition and operation

➢ Any compound used in a heat cycle that reversibly undergoes a phase change from a gas to a liquid.



International agreements

- Montreal protocol (1987): Ozone layer (substances with ODP)
- Kyoto protocol (1997): Climate change (substances with GWP)

Type	Refrigerant number(s)	Uses	Other issues
CFCs	*R12* *R505* *211*	*Widely used in most applications until 1990*	*Now **phased out** of production*
HCFCs	*R22* *R409a*	*Widely used in many applications. Not recommended for use after 1999*	***To be phased out** of production in 2015. Their use is also regulated increasingly strictly*
HFCs	*R134a* *R404a* *R407c*	*Started to be used in place of CFCs from about 1990*	*Different compressor oil needed, performance of some HFCs not as good as CFCs. Some reliability problems.*
HCs e.g. propane, iso-butane, propylene	R600a R290 R1270	R290 used in some industrial systems for decades. R600a now used in domestic systems.	Flammable, but are very good refrigerants with few changes needed to a CFC/HCFC system
NH_3 Ammonia	R717	Used in industrial systems since the birth of refrigeration	Toxic and flammable, reacts with copper
CO_2 Carbon dioxide	R744	Widely used before the 1950s, but superseded by halocarbons. Now being “rediscovered” as a primary and secondary refrigerant	Not yet widespread commercial use as a primary refrigerant, but an interesting prospect (high operating pressures requires special materials and construction)

Related EU Legislation:

- Regulation 1005/2009: Ozone Depleting Substances (recast) (CFCs, HCFCs, HBFCs)
  - prohibition
  - leakage prevention
- Regulation 842/2006: F-Gas (some HFCs, PFCs, SF6)
  - gradually prohibition of some applications
  - leakage prevention

Related standards:

- EN 378:2009 “Refrigerating systems and heat pumps. Safety and environmental requirements. Design, construction, testing, marking and documentation” → limits to refrigerant charge due to flammability
- ASHRAE Standard 34-2008: “Designation and safety classification of refrigerants”

Environmental impacts

- Production/distribution as any other product
- Use phase/End of life phase:
  - **O**zone **D**epletion **P**otential (CCl_3F=1)
  - **G**lobal **W**arming **P**otential (CO_2=1)
  - Importance on energy consumption (COP)
  - TEWI

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Environmental impacts

Refrigerant	Boiling point (°C)	Critical point (°C)[1]	Ozone depletion potential (ODP)	GWP, 100y	Safety classification (ANSI/ASHRAE 34)
R134a (hydrofluorocarbon)	-26	101	0.0	1410	A1
R404a (hydrofluorocarbon)	-46	72	0.0	3300	A1
R410a (hydrofluorocarbon)	-49	73	0.0	1890	A1
R407a (hydrofluorocarbon)	-43	82	0.0	1900	A1
R290 (propane)	-42	97	0.0	3	A3
R600a (isobutane)	-12	135	0.0	3	A3
R1270 (propylene)	-48	92	0.0	20	A3
ECP717 (ethane + ammonia)	-55	41.9	0.0	2	A2
R717 (ammonia)	-33	132	0.0	0	B2
R718 (water)	100	373	0.0	0	A1
R744 (carbon dioxide)	-78	31	0.0	1.0	A1
R152a (difluoroethane)	-24	113	0.0	122	A2
HFO-1234yf (hydrofluorooleofin)	-30	94	0.0	4	A2
HFO-1234ze(E) (hydrofluorooleofin)	-19	110	0.0	6	A2

[1] The temperature and pressure at which the liquid and gaseous phases of a pure stable substance become identical. Also called critical state.

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Comparison and applicability of alternative refrigerants (BAT):

Refrigerant	Service cabinets	Blast cabinets	Walk-in cold rooms	Chillers	Remote condensing units	Comments
CO_2 R744	✗	✓	✓	✓	✗	Not appropriate for small cold rooms. Used in large cascade systems, not in high ambient temperatures. Only applicable for remote blast equipment
Ammonia R717	✗	✗	?	✓	✗	Toxicity and corrosion issues
Propane R290	✓	✓	✗	✓	✓	May be used in small applications with small refrigerant charge
Isobutane R600a	✓	✗	✗	✗	✗	If hydrocarbons are to be used propane is more efficient option to choose
HFO R1234yf	✓	✓	✓	✓	✓	Used in the automotive industry
Water R718	✗	✗	✗	✓	✗	

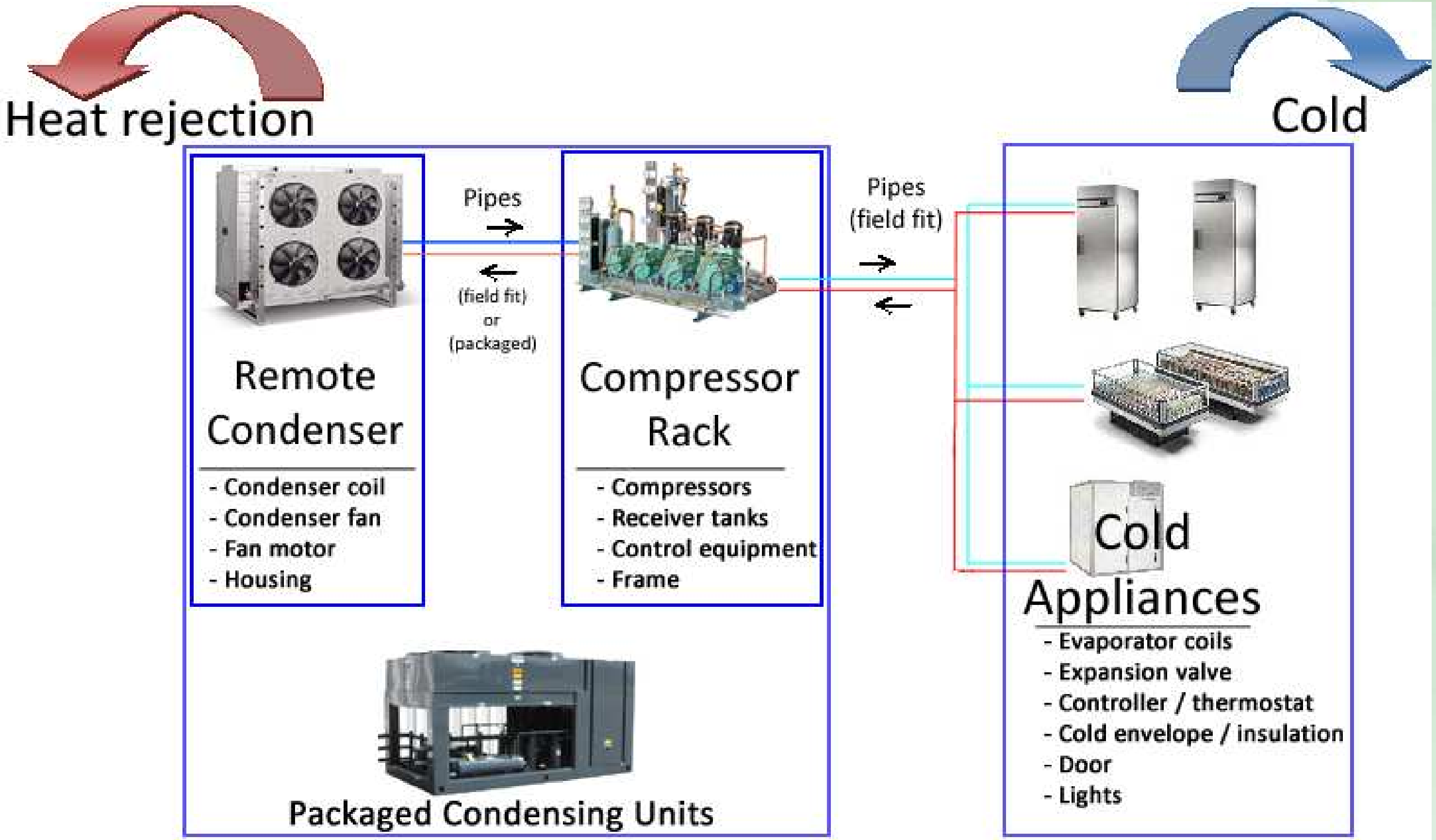
Questions to stakeholders

- COP and AEC of machines running alternative refrigerants

- Costs of using alternative refrigerants

- Leakage prevention/detection systems: costs and effectiveness

One or several remote refrigerating appliances connected together with one or several condensing units



Types of refrigeration systems

Configuration	Strengths	Weaknesses
Direct system	✓Good efficiency ✓Less components than indirect system ✓Lower investment cost than indirect system	✓Large refrigerant charges ✓Refrigerant leakages
Indirect system	✓Lower refrigerant charges ✓Simple and cheaper service ✓Use of natural refrigerants possible	✓Risk for low energy efficiency ✓Pump work ✓Risk of corrosion ✓Pipes need to be insulated
Distributed system	✓Good efficiency ✓Reduction of refrigerant circuit length => lower refrigerant charges ✓Less refrigerant leakages	✓No possibility to use natural refrigerants such as ammonia or HC ✓Noise
Cascade system	✓Lower refrigerant charges, less leakages ✓Simple and cheaper service ✓Natural refrigerants possible	✓Both medium and low temperature interact ✓Pump work ✓Risk of corrosion ✓Pipes need to be insulated

Main technical aspects

- Configuration of the system
- Refrigerant choice
  - Trade-off between performance limitations and impact of leaks
- Variable ambient conditions
- Construction and maintenance

Relevant EU standards

- There are no relevant EU performance test standards for refrigeration systems

Reference	Title
EN 378	Refrigerating systems and heat pumps – safety and environmental requirements
EN 12178:2003	Refrigerating systems and heat pumps - Liquid level indicating devices - Requirements, testing and marking
EN 13136:2001	Refrigerating systems and heat pumps - Pressure relief devices and their associated piping - Methods for calculation
EN 1861:1998	Refrigerating systems and heat pumps - System flow diagrams and piping and instrument diagrams - Layout and symbols
EN 12284:2003	Refrigerating systems and heat pumps - Valves - Requirements, testing and marking
EN 12900:2005	Refrigerant compressors - Rating conditions, tolerances and presentation of manufacturer's performance data

Environmental impacts

- **Indirect** = electricity consumption
- **Direct** = refrigerant leaks

Country	Year(s)	Annual refrigerant loss (%)
Netherlands	1999	3.2
Germany	2000-2002	5-10
Denmark	2003	10
Norway	2002-2003	14
Sweden	1993 1998 2001	14 12.5 10.4
United-Kingdom	1998	14.4

Source: IPCC/TEAP Special report, Safeguarding the Ozone layer and the Global Climate System, chapter 4, 2005

	Estimated average energy consumption (MWh/year)	Estimated average energy savings per product by 2020	Estimated total savings per year (TWh / year)
Compressors	22.9	5%	1.52
Condensers	19.1	3%	0.15

Possible energy savings

VDMA 24247 – Energy efficiency of refrigeration systems
Specifies measures for implementing the recommendations laid down in the position paper of the 'Forschungsrat Kaltetechnik e.V.'

- 40 % energy savings is possible with:
  - 10% : Efficient control, operation and design directive for refrigeration system
  - 12% : Reduction of effective temperature differences on heat exchangers
  - 3%: Use of highly efficient motors
  - 7% : Saving in the refrigeration need
  - 8% : System improvement, design in compliance with the annual temperature profile, heat recovery and further improvements

Improvement options

Technology	Energy savings (%)	Application
Trigeneration	20	Supermarket system
Liquid pressure amplification	Up to 20	All remote refrigeration systems
ECM/Variable speed compressor	15	All integral and remote systems
High-efficiency compressors	12	All integral and remote systems
Defrost optimisation	10	Freezers (should be operated on off-cycle)
Multi-evaporator systems	10	Freezers (indirect through removal of defrost heat load)

Non-quantified improvement options for refrigeration systems suggested by stakeholders include:

- Reducing pipe lengths to a minimum.
- Using electronic expansion valves.
- Reducing joints and potential leak points.
- Monitoring refrigerant levels to ensure efficient operation.
- Heat exchangers to collect waste heat produced by the central plants.