ATMO sphere EUROPE
solutions for europe
natural refrigerants
16-17 March 2015 in Brussels

Condensing Units with CO_2

seen in the light of the F-Gas and ECO design directives

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#1 *Agenda*

F-gas directive:

- Drivers and challenges for CO_2 refrigeration systems

ECO design:

- Status for implementation
- Requirements for CDUs
- Test results
- Comparison with HFC CDUs

Summing-up

#2 F-gas directive

Drivers and challenges for CO_2 refrigeration systems

- F-gas directive are targeting small commercial systems = CDUs
- Increased awareness of global impact from synthetic refrigerants
- Successful application of CO_2 in the supermarket sector, scaling down is an option
- Successful application of hydro carbon in display cabinets and similar appliances, scaling up is a challenge
- This leaves a window of opportunity open for CO_2 CDUs, but:
- Very competitive market
- Production numbers are climbing very slowly
- Production cost is high

#3 ECO design and background

- CDUs with CO_2 was seen by DTI to cover an important part of the Danish market after the introduction of the HFC ban in 2007
- Dorin announced CDU with CO_2 but it was never launched
- DTI tried without success to engage partners into a CDU demo project
- First CDUs placed on the market by Green & Cool, later Advansor
- ECO design draft from ENTR Lot 1 covering requirements for professional storage cabinets, blast cabinets, **condensing units** and process chillers was approved by the committee.

  Status: Not yet published (nor implemented).
- Support from the Danish EPA and Advansor made an ECO design test of a CO_2 CDU possible

#4

ECO design requirement excerpts

1. Requirements for energy efficiency

(a) From 1st of July 2015, the coefficient of performance (*COP*) and the seasonal energy performance ratio (*SEPR*) of condensing units shall not fall below the following values:

Operating temperature	Rated capacity P_A	Applicable ratio	Value
Medium	0.2kW< P_A < 1kW	COP	1.2
	1kw< P_A < 5kW	COP	1.4
	5kW < P_A < 20kW	SEPR	2.25
	20kW < P_A < 50kW	SEPR	2.35

#5

ECO design requirement excerpts

(b) From 1st of July 2018, the coefficient of performance (*COP*) and the seasonal energy performance ratio (*SEPR*) of condensing units shall not fall below the following values:

Operating temperature	Rated capacity P_A	Applicable ratio	Value
Medium	0.2kW< P_A < 1kW	COP	1.4
	1kw< P_A < 5kW	COP	1.6
	5kW < P_A < 20kW	SEPR	2.55
	20kW < P_A < 50kW	SEPR	2.65

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ECO design
Spreadsheet for calculating SEPR

declared refrigeration capacity	9,00	MT9 - CD380H

	degradation calculation							Ta	Sgc
	COP	Refrigeration demand (P_R) (=DC(full load)*Partload)	DC(Tref)	cop @ full cap	Cd (=degradation factor)	CR (=P_R/DC)	COPPL (=COP@full cap)*(1-Cd*(1-CR)		
COPA	1,36	9,00	9,15	1,36	0,25	0,98	1,35	32	35
COPB	1,67	8,07	9,94	1,67	0,25	0,81	1,59	25	32
COPC	2,26	6,73	10,36	2,26	0,25	0,65	2,06	15	22
COPD	3,83	5,40	6,20	3,83	0,25	0,87	3,71	5	12

(yellow)	Need to be filled in
(blue)	Automatically filled in
(pink)	Bin of Strassbourg
(green)	Cd (use default set value)

	j	Tj (°C)	hj	partload%	refrigeration demand	COPPL	Ph*Tj	PH*Tj/COPD(
	1	-19	0,08	60%	5,40	3,71	0	0
	2	-18	0,41	60%	5,40	3,71	2	1
	3	-17	0,65	60%	5,40	3,71	3	1
	4	-16	1,05	60%	5,40	3,71	6	2
	5	-15	1,74	60%	5,40	3,71	9	3
	6	-14	2,98	60%	5,40	3,71	16	4
	7	-13	3,79	60%	5,40	3,71	20	6
	8	-12	5,69	60%	5,40	3,71	31	8
	9	-11	8,94	60%	5,40	3,71	48	13
	10	-10	11,81	60%	5,40	3,71	64	17
	11	-9	17,29	60%	5,40	3,71	93	25
	12	-8	20,02	60%	5,40	3,71	108	29
	13	-7	28,73	60%	5,40	3,71	155	42
	[illegible]	-6	39,71	60%	5,40	3,71	214	58
	15	-5	56,61	60%	5,40	3,71	306	82
	16	-4	76,36	60%	5,40	3,71	412	111
	17	-3	106,07	60%	5,40	3,71	573	155
	18	-2	153,22	60%	5,40	3,71	827	223
	19	-1	203,41	60%	5,40	3,71	1.098	[illegible]
	20	0	247,98	60%	5,40	3,71	1.339	361
	21	1	282,01	60%	5,40	3,71	1.523	411
	22	2	275,91	60%	5,40	3,71	1.490	402
	23	3	300,61	60%	5,40	3,71	1.623	438
	24	4	310,77	60%	5,40	3,71	1.678	453
D	25	5	336,48	60%	5,40	3,71	1.817	490
	26	6	350,48	61%	5,53	3,54	1.939	548
	27	7	363,49	63%	5,67	3,38	2.060	610
	28	8	368,91	64%	5,80	3,21	2.140	666
	29	9	371,63	66%	5,93	3,05	2.205	723
	30	10	377,32	67%	6,07	2,88	2.289	794
	31	11	376,53	69%	6,20	2,72	2.334	858
	32	12	386,42	70%	6,33	2,56	2.447	958
	33	13	389,84	72%	6,47	2,39	2.521	1.054
	34	14	384,45	73%	6,60	2,23	2.537	1.140
C	35	15	370,45	75%	6,73	2,06	2.494	1.210
	36	16	344,96	76%	6,87	2,02	2.369	1.175
	37	17	328,02	78%	7,00	1,97	2.296	1.167
	38	18	305,36	79%	7,13	1,92	2.178	1.134
	39	19	261,87	81%	7,27	1,87	1.903	1.016
	40	20	223,90	[illegible]	7,40	1,83	1.657	907
	41	21	196,31	[illegible]	7,53	1,78	1.479	831
	42	22	163,04	85%	7,67	1,73	1.250	721
	43	23	141,78	87%	7,80	1,69	1.106	656
	44	24	121,93	88%	7,93	1,64	967	590
B	45	25	104,46	90%	8,07	1,59	843	530
	46	26	85,77	91%	8,20	1,56	703	452
	47	27	[illegible]	93%	8,33	1,52	596	391
	48	28	[illegible]	94%	8,47	1,49	479	322
	49	29	[illegible]	96%	8,60	1,46	373	256
	50	30	31,02	97%	8,73	1,42	271	191
	51	31	20,21	99%	8,87	1,39	179	129
A	52	32	11,85	100%	9,00	1,35	107	79
	53	33	8,17	100%	9,00	1,35	74	54
	54	34	3,83	100%	9,00	1,35	34	25
	55	35	2,09	100%	9,00	1,36	19	14
	56	36	1,21	100%	9,00	1,36	11	8
	57	37	0,52	100%	9,00	1,36	5	3
	58	38	0,40	100%	9,00	1,36	4	3
						total	55.327	22.844
							SEPR	2,42

Climate data Central Europe

Load and COP calculation

Calculation of energy needed and consumed

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ECO design
Spreadsheet for calculating SEPR
MT9 with actual data from DTI Lab

declared refrigeration capacity	9,00	MT9 - CD380H

	degradation calculation							
	COP	Refrigeration demand (P_R) (=DC(full load)*Partload)	DC(Tref)	cop @ full cap	Cd (=degradation factor)	CR (=P_R/DC)	COPPL (=COP@full cap)*(1-Cd*(1-CR)	° C
COPA	1,36	9,00	9,15	1,36	0,25	0,98	1,35	32
COPB	1,66	8,07	8,13	1,66	0,25	0,99	1,66	25
COPC	2,53	6,73	7,01	2,53	0,25	0,96	2,51	15
COPD	3,83	5,40	6,20	3,83	0,25	0,87	3,71	5

	j	Tj (°C)	hj	partload%	refrigeration demand	COPPL	Ph*Tj	PH*Tj/COPDC
	49	29	43,35	96%	8,60	1,48	373	251
	50	30	31,02	97%	8,73	1,44	271	188
	51	31	20,21	99%	8,87	1,40	179	128
A	52	32	11,85	100%	9,00	1,35	107	79
	53	33	8,17	100%	9,00	1,35	74	54
	54	34	3,83	100%	9,00	1,35	34	25
	55	35	2,09	100%	9,00	1,36	19	14
	56	36	1,21	100%	9,00	1,36	11	8
	57	37	0,52	100%	9,00	1,36	5	3
	58	38	0,40	100%	9,00	1,36	4	3
						total	55.327	20.895

SEPR	2,65

Input data

Output data

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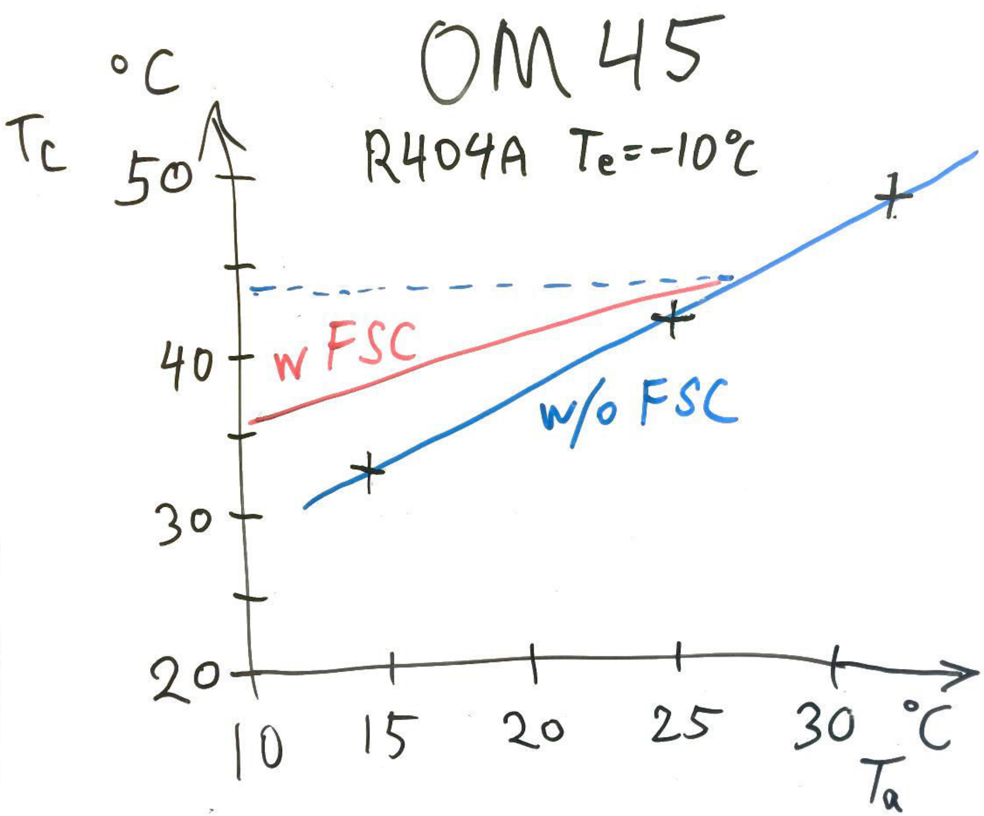
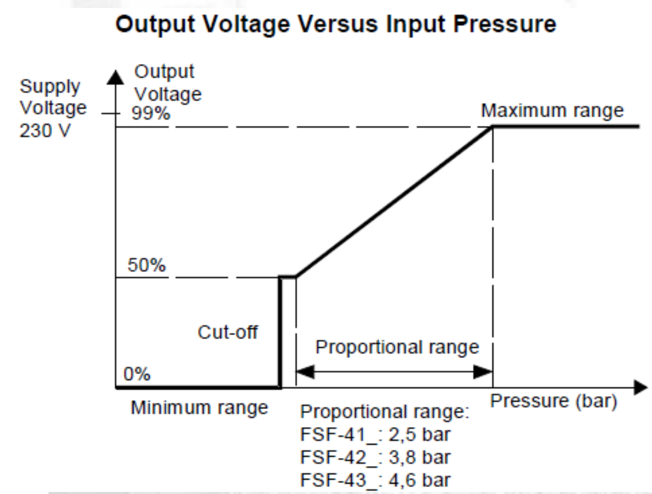
#8 ECO design

Copeland OM 45 with Alco Fan Speed Control, Standard Setting

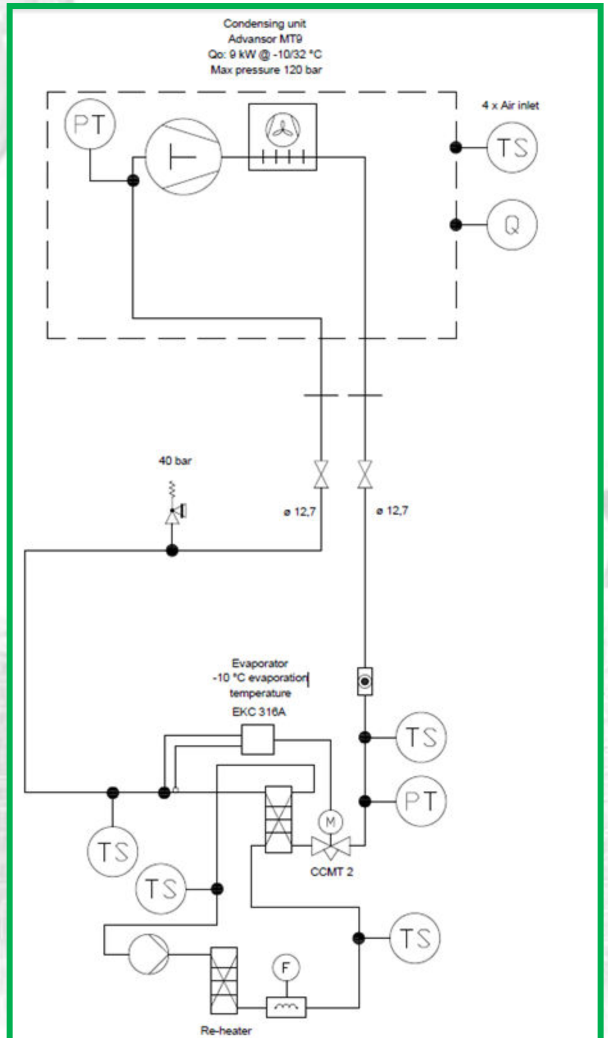




#9

ECO design

Advansor XXS MT9 in test at DTI Lab



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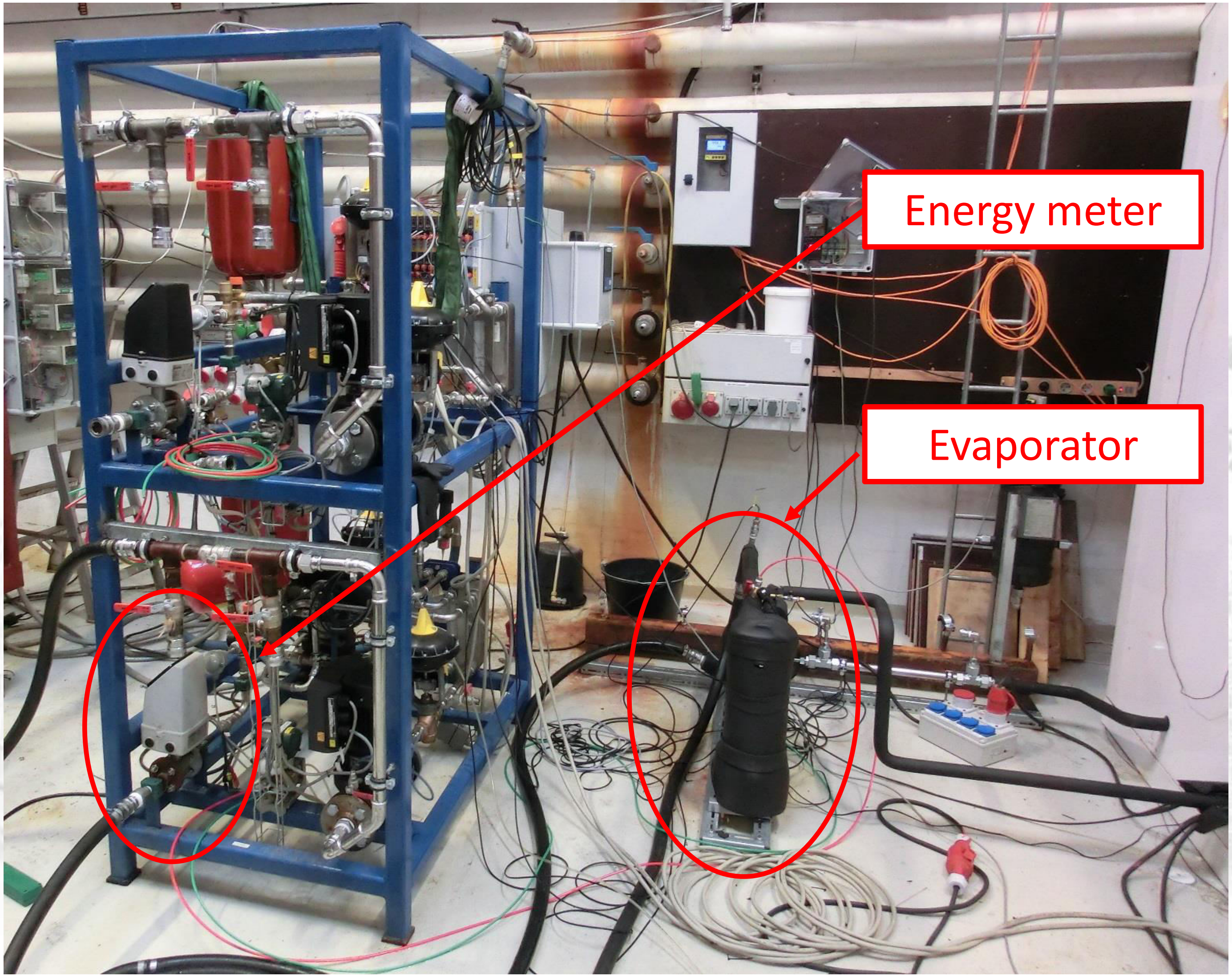
#10

ECO design

Test rig for measuring load at DTI Lab



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#11

ECO design

Comparing SEPR for CDUs

CDU Unit Approximately 9 kW nominal	SEPR	Modulating	EXV needed	Sound level	Comment
	-	-	-	dB(A)	-
Limit 2015	2,25				ECO Design criteria
Limit 2018	2,55				ECO Design criteria
XXS MT9 CO2	**2,65**	**X**	**X**	**45**	**Lab Tested**
XXS MT9 CO2	3,07	X	X	45	Calculated/ potential for optimising
OM-45	2,87		X	46	Price optimized on/ off
OM-45 FSC	2,22			46	d.o. with standard fan speed control setting
ZXDE-060E	3,28	X		41	High end product modulating digital scroll
ZXME-060E	3,49		X	41	High end on/ off

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#12 Summing-up

- 1st generation CO_2 CDU exceeds ecodesign requirements
- Compressor and gas cooler design/ airflow can be improved
- Potential to match best in class
- Generally ecodesign put much needed pressure towards designing and commissioning energy efficient systems
- Consistent testing methods and protocols are available adopting procedures from heatpump SCOP testing

- There is business potential!

Let us aim at the kindling interest invoking a self-reinforcing effect, increasing production numbers, lowering production cost, increasing sales and so forth…

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Thank you very much!

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