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natural refrigerants

11-12 October 2011 in Brussels

MAYEKAWA

Presented by Jan Boone, MAYEKAWA

MAYEKAWA Europe nv/sa

LINE-UP NATURAL 5

FIELD CASE STUDY OF INDUSTRIAL PLANT OPERATING WITH NATURAL REFRIGERANTS

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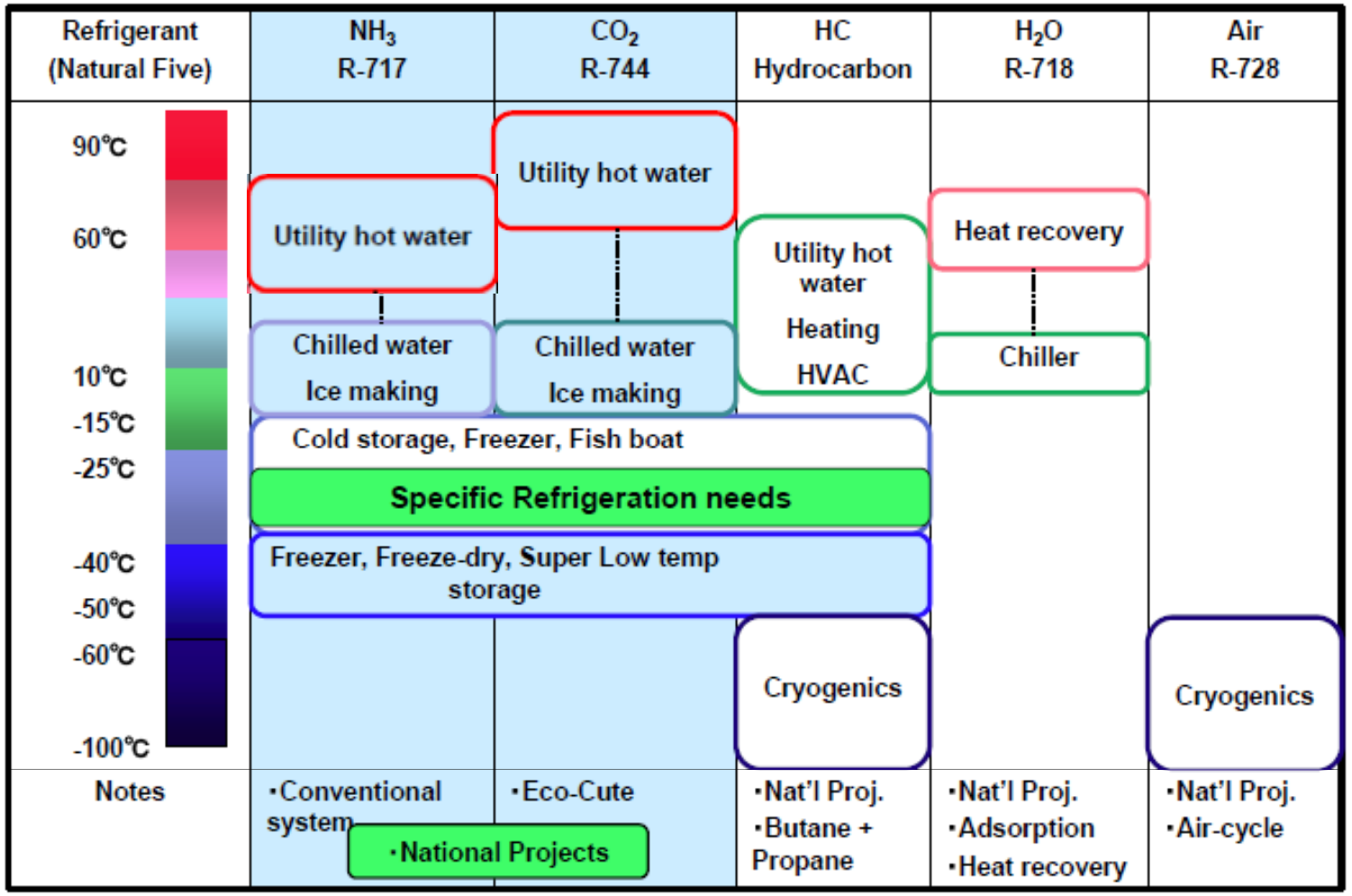
"Natural Five" Refrigerants and Product Solutions



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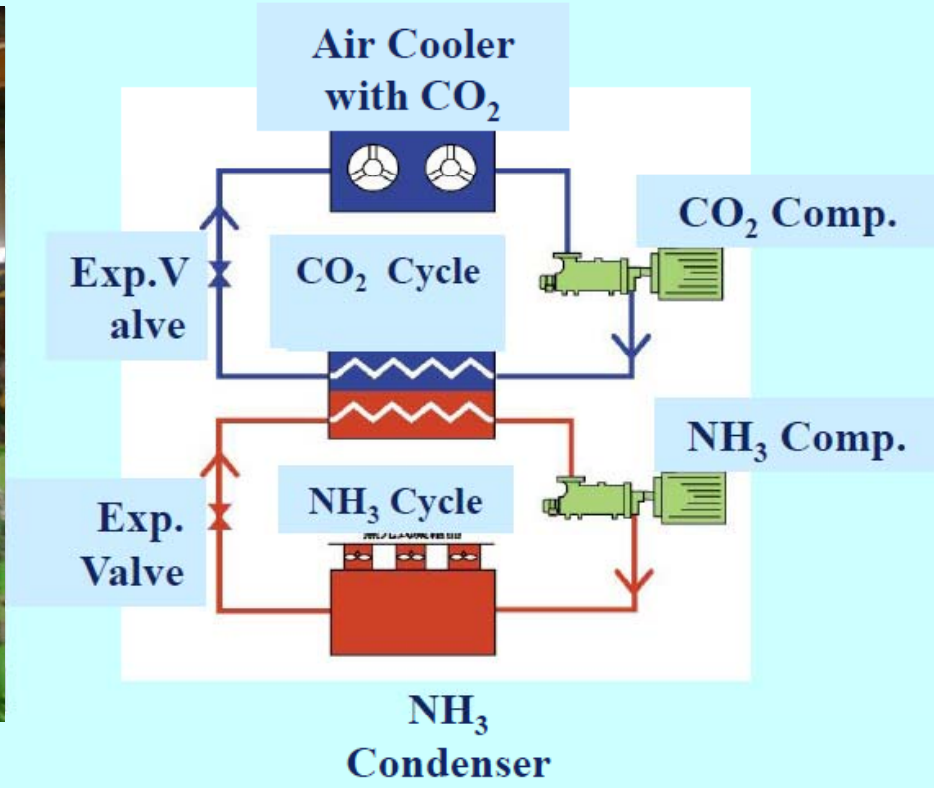
CO2/NH3 CASCADE COMPRESSION REFRIGERATION



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FIELD CASE

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INTRODUCTION

Starting point, need? **2900kW -51°C** **-12°C** **-51°C** **-35°C** **+10°C** **+55°C** **+35°C** **+12->14°C**	**The contractor Cofely Refrigeration bv received the request from his customer to convert & increase the refrigeration size of the plant, in use with refrigerant R22 since 1997, in capacity and freezing temperature from 1300kW at -42°C to 2900kW at -51°C.** **The new plant is to be used for processing meat which is frozen during the process, operating 24hrs/day per workweek by using :** **chilling in the process working rooms requiring -12°C,** **product freezing :** **plate freezers(4x550kW), quick freezing tunnel (1x600kW) and a spiral freezer(1x600kW) requiring -51°C,** **freezing in stores requiring -35°C.** **The freezers need to be defrosted by using the CO2 hot gas from the plant.** **In addition heat recovery is required to obtain hot water for :** **the process(55°C),** **floor-/office-/loaddock-/expedition room heating(35°C),** **bottom floor freezingrooms (12-14°C),**
TC<Twb+10°C	**and** **condensing temperature must not exceed 10°K above wetbulb-temperature (authority requirement)**

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->INTRODUCTION

Why natural refrigerants -51°C	For the temperature of -51°C CO2 is the most suitable refrigerant for direct use on the low temperature system applied in a cascade system with NH3 as refrigerant only used for the high temperature cascade side.
Which choice & why <2000kg NH3	CO2 for low temperature side used for direct cooling on the freezers. Most suitable NF. NH3 for high temperature side for cascade purpose only as the customer's environmental licence did not allow more than 2000kg NH3 in the plant. NH3 is standard application for Cofely Refrigeration bv.
Timeframe 2003 idea Re-built & Extend 10-2004->6-2005	In 2003, the idea came up to re-build the plant by re-using the installed compressors and to extend the plant capacity with lower process temperatures by using CO2 as NF. Plant extension had to be executed from October 2004 till June 2005, Starting with the convertion of the F250VLD units into N250VLD for use with NH3 in May 2005.

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->INTRODUCTION

Steps to get the project running	**Plant stop was scheduled from wk35-2004 to wk25-2005.** **Plant erection was done in 5 phases.** **Phase 1 : modification of R22 plant to NH3 (from wk18 to wk23-2005)** **Phase 2 : installation of CO2 equipment (from wk49-2004 to wk10-2005)** **Phase 3 : start-up of C5 & C6 (from wk10-2005 to wk14-2005)** **Phase 4 : start up of C7 (wk16-2005)** **Phase 5 : start-up of C8 & C9 (wk18-2005 to wk20-2005)** **Full production from wk25-2005**
Funding, partner : other organisation	Yes NOVEM (ROB-program : reduction-plan other greenhouse gases-Reductieplan Overige Broeikasgassen) Funding in terms of reduction of greenhouse gases (program management is done by Ministry of VROM and execution is in hands of NOVEM in NL) EIA (Energy investment deduction) VAMIL (free writing off) MIA (environment investment deduction)

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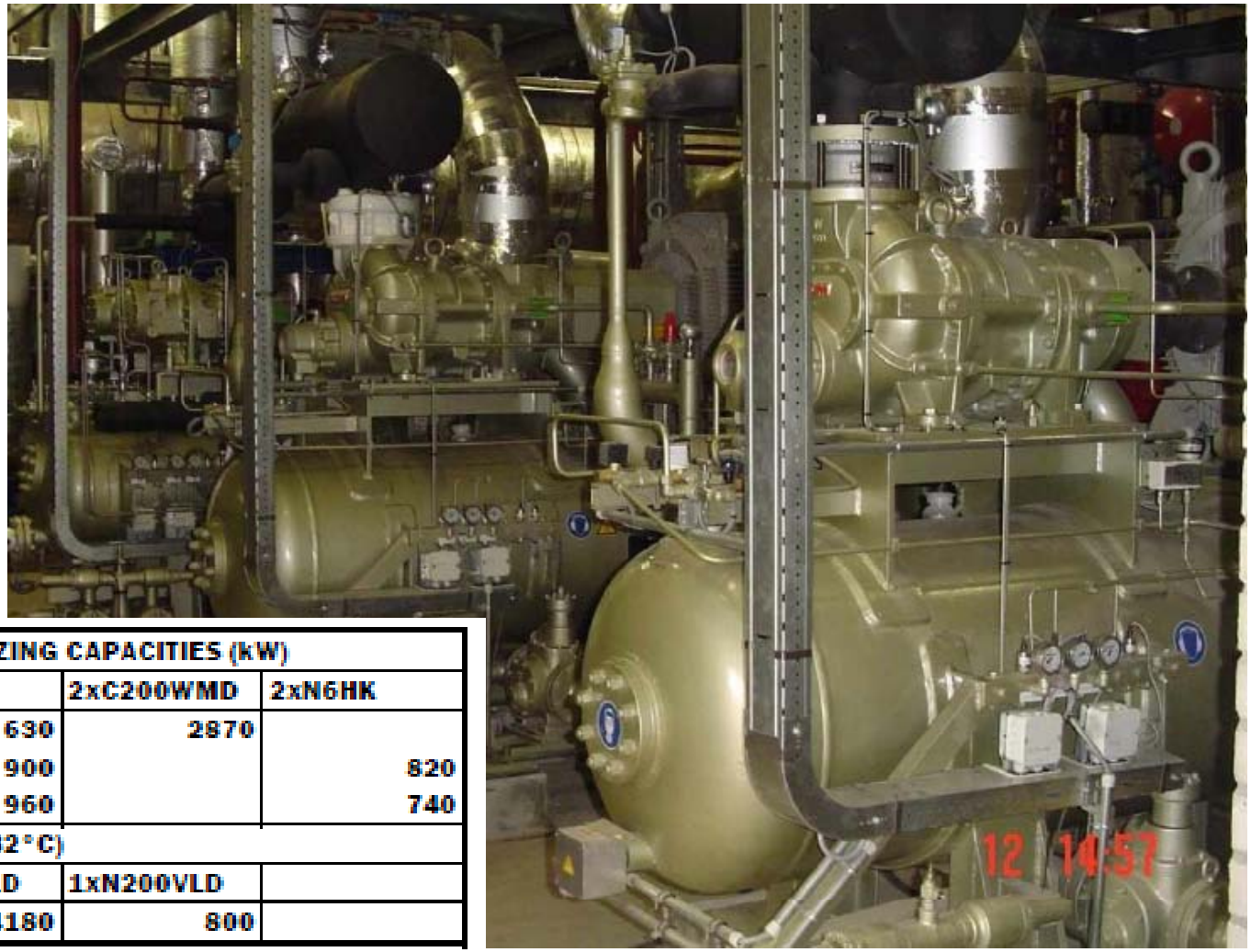

LOW TEMPERATURE SIDE : FREEZING CAPACITIES (kW)			
CO2 LIQUID T°(°C)	1xGH160	2xC200WMD	2xN6HK
-51	630	2870	
-41	900		820
-31	960		740
HIGH TEMPERATURE SIDE (TC = 32°C)			
NH3 TE (°C)	3xN250VLD	1xN200VLD	
-18	4180	800	

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COMPRESSOR OPERATING PARAMETERS															TESTS DONE										
CUSTOMER															FILE NAME										
PLANT															SHEET NO							5			
MYCOM SO NO						27127-1									ISSUED BY							JAN BOONE			
UNIT NO						7									DATE							UNTILL 15/4/2005			
COMPRESSOR						GH160S									REVISION NO							0			
TC	°C	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	
PD	BARG	23,29	24,01	24,74	25,48	26,24	27,02	27,82	28,63	29,45	30,30	31,16	32,04	32,93	33,85	34,78	35,73	36,70	37,68	38,69	39,72	40,76	41,83	42,91	

TE	PS	PRESSURE DIFFERENCE : DISCHARGE PRESSURE - SUCTION PRESSURE																							
°C	BARG																								
-31	12,80	10,49	11,21	11,94	12,68	13,44	14,22	**15,02**	15,83	16,65	17,50	18,36	19,24	20,13	21,05	21,98	22,93	23,90	24,88	25,89	26,92	27,96	29,03	30,11	
-32	12,34	10,95	11,67	12,40	13,14	13,90	14,68	15,48	16,29	17,11	17,96	18,82	19,70	20,59	21,51	22,44	23,39	24,36	25,34	26,35	27,38	28,42	29,49	30,57	
-33	11,89	11,40	12,12	12,85	13,59	14,35	15,13	15,93	16,74	17,56	18,41	19,27	20,15	21,04	21,96	22,89	23,84	24,81	25,79	26,80	27,83	28,87	29,94	31,02	
-34	11,45	11,84	12,56	13,29	14,03	14,79	15,57	16,37	17,18	18,00	18,85	19,71	20,59	21,48	22,40	23,33	24,28	25,25	26,23	27,24	28,27	29,31	30,38	31,46	
-35	11,02	12,27	12,99	13,72	14,46	15,22	16,00	16,80	17,61	18,43	19,28	20,14	21,02	21,91	22,83	23,76	24,71	25,68	26,66	27,67	28,70	29,74	30,81	31,89	
-36	10,60	12,69	13,41	14,14	14,88	15,64	16,42	17,22	18,03	18,85	19,70	20,56	21,44	22,33	23,25	24,18	25,13	26,10	27,08	28,09	29,12	30,16	31,23	32,31	
-37	10,20	13,09	13,81	14,54	15,28	16,04	16,82	17,62	18,43	19,25	20,10	20,96	21,84	22,73	23,65	24,58	25,53	26,50	27,48	28,49	29,52	30,56	31,63	32,71	
-38	9,80	13,49	14,21	14,94	15,68	16,44	17,22	18,02	18,83	19,65	20,50	21,36	22,24	23,13	24,05	24,98	25,93	26,90	27,88	28,89	29,92	30,96	32,03	33,11	
-39	9,42	13,87	14,59	15,32	16,06	16,82	17,60	18,40	19,21	20,03	20,88	21,74	22,62	23,51	24,43	25,36	26,31	27,28	28,26	29,27	30,30	31,34	32,41	33,49	
-40	9,04	14,25	14,97	15,70	16,44	17,20	17,98	**18,78**	19,59	20,41	21,26	22,12	23,00	23,89	24,81	25,74	26,69	27,66	28,64	29,65	30,68	31,72	32,79	33,87	
-41	8,68	14,61	15,33	16,06	16,80	17,56	18,34	19,14	19,95	20,77	21,62	22,48	23,36	24,25	25,17	26,10	27,05	28,02	29,00	30,01	31,04	32,08	33,15	34,23	
-42	8,32	14,97	15,69	16,42	17,16	17,92	18,70	19,50	20,31	21,13	21,98	22,84	23,72	24,61	25,53	26,46	27,41	28,38	29,36	30,37	31,40	32,44	33,51	34,59	
-43	7,98	15,31	16,03	16,76	17,50	18,26	19,04	19,84	20,65	21,47	22,32	23,18	24,06	24,95	25,87	26,80	27,75	28,72	29,70	30,71	31,74	32,78	33,85	34,93	
-44	7,64	15,65	16,37	17,10	17,84	18,60	19,38	20,18	20,99	21,81	22,66	23,52	24,40	25,29	26,21	27,14	28,09	29,06	30,04	31,05	32,08	33,12	34,19	35,27	
-45	7,31	15,98	16,70	17,43	18,17	18,93	19,71	**20,51**	21,32	22,14	22,99	23,85	24,73	25,62	26,54	27,47	28,42	29,39	30,37	31,38	32,41	33,45	34,52	35,60	
-46	7,00	16,29	17,01	17,74	18,48	19,24	20,02	20,82	21,63	22,45	23,30	24,16	25,04	25,93	26,85	27,78	28,73	29,70	30,68	31,69	32,72	33,76	34,83	35,91	
-47	6,69	16,60	17,32	18,05	18,79	19,55	20,33	21,13	21,94	22,76	23,61	24,47	25,35	26,24	27,16	28,09	29,04	30,01	30,99	32,00	33,03	34,07	35,14	36,22	
-48	6,39	16,90	17,62	18,35	19,09	19,85	20,63	21,43	22,24	23,06	23,91	24,77	25,65	26,54	27,46	28,39	29,34	30,31	31,29	32,30	33,33	34,37	35,44	36,52	
-49	6,10	17,19	17,91	18,64	19,38	20,14	20,92	21,72	22,53	23,35	24,20	25,06	25,94	26,83	27,75	28,68	29,63	30,60	31,58	32,59	33,62	34,66	35,73	36,81	
-50	5,82	17,47	18,19	18,92	19,66	20,42	21,20	22,00	22,81	23,63	24,48	25,34	26,22	27,11	28,03	28,96	29,91	30,88	31,86	32,87	33,90	34,94	36,01	37,09	
-51	5,55	**17,74**	18,46	19,19	19,93	20,69	21,47	**22,27**	**23,08**	23,90	24,75	25,61	26,49	27,38	28,30	29,23	30,18	31,15	32,13	33,14	34,17	35,21	36,28	37,36	
-52	5,28	18,01	18,73	19,46	20,20	20,96	21,74	22,54	23,35	24,17	25,02	25,88	26,76	27,65	28,57	29,50	30,45	31,42	32,40	33,41	34,44	35,48	36,55	37,63	
-53	5,02	18,27	18,99	19,72	20,46	21,22	22,00	22,80	23,61	24,43	25,28	26,14	27,02	27,91	28,83	29,76	30,71	31,68	32,66	33,67	34,70	35,74	36,81	37,89	
-54	4,78	18,51	19,23	19,96	20,70	21,46	22,24	23,04	23,85	24,67	25,52	26,38	27,26	28,15	29,07	30,00	30,95	31,92	32,90	33,91	34,94	35,98	37,05	38,13	
-55	4,54	18,75	19,47	20,20	20,94	21,70	22,48	23,28	24,09	24,91	25,76	26,62	27,50	28,39	29,31	30,24	31,19	32,16	33,14	34,15	35,18	36,22	37,29	38,37	

TC	°C	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	
PD	BARG	23,29	24,01	24,74	25,48	26,24	27,02	27,82	28,63	29,45	30,30	31,16	32,04	32,93	33,85	34,78	35,73	36,70	37,68	38,69	39,72	40,76	41,83	42,91	

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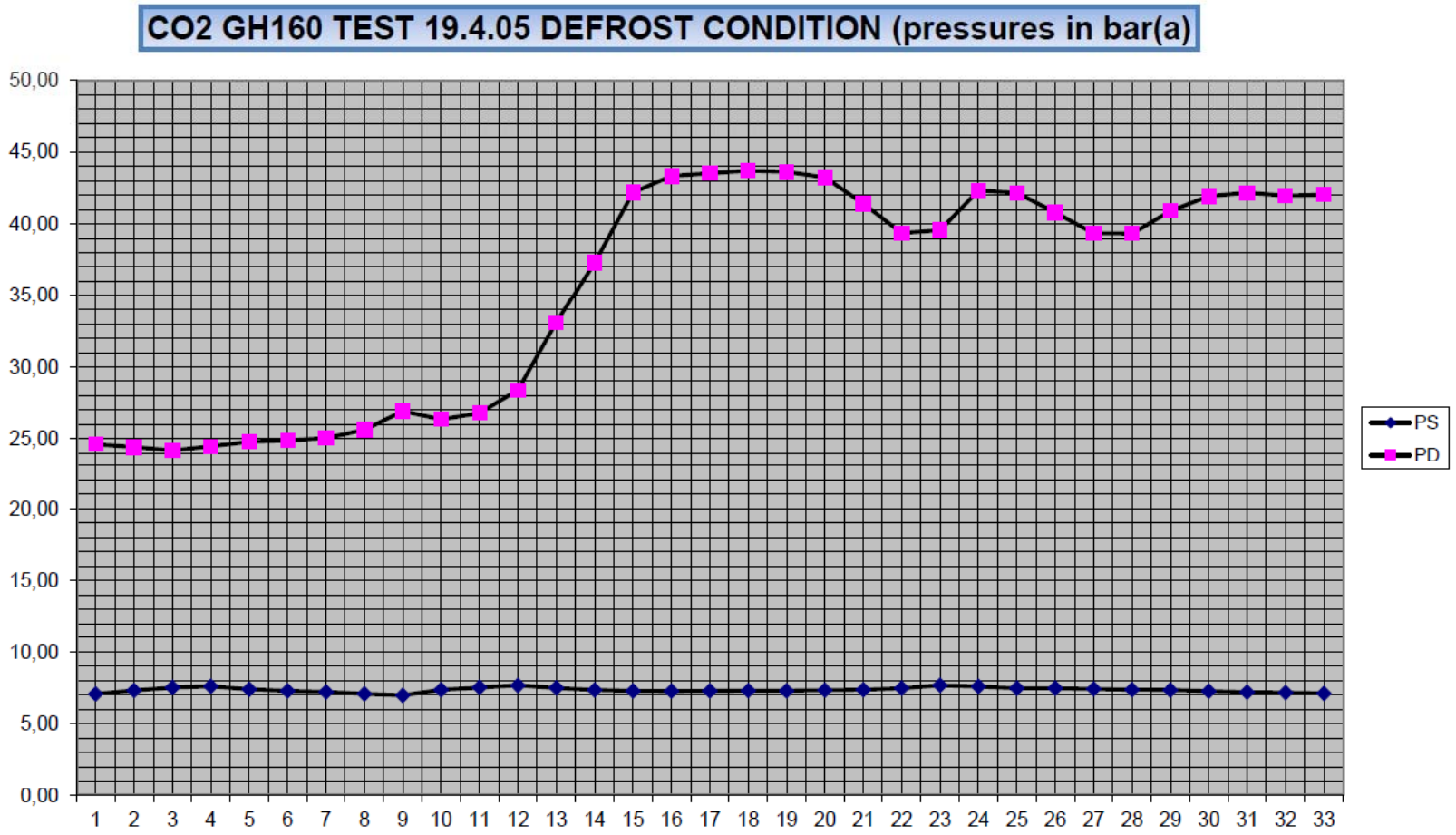
CO2 GH160 TEST 19.4.05 DEFROST CONDITION (pressures in bar(a)
50,00
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
PS
PD

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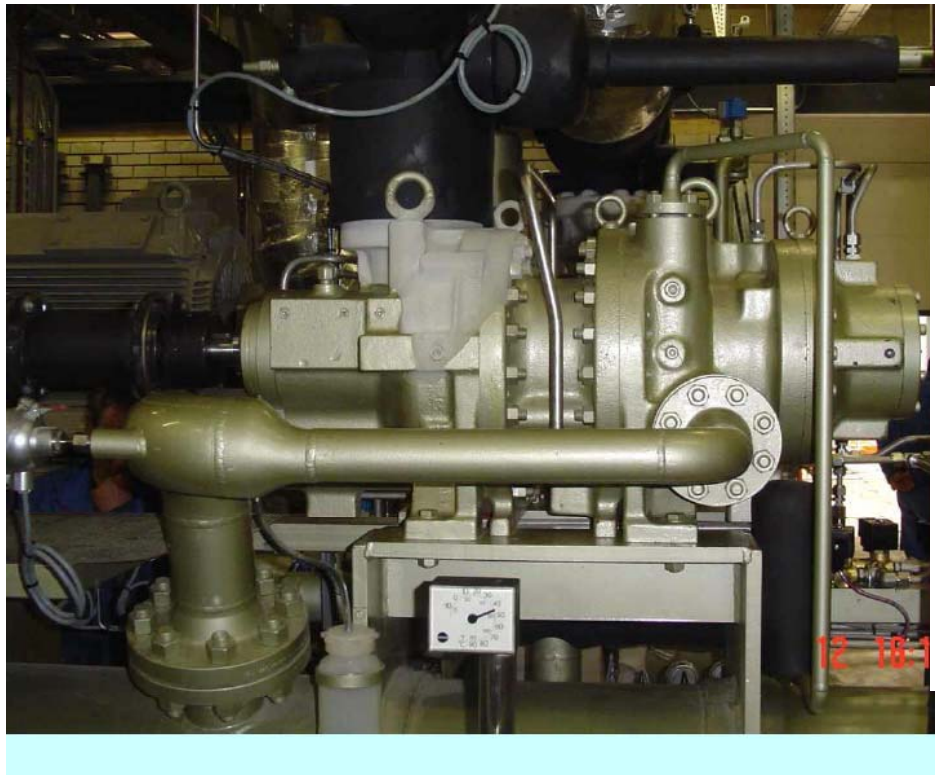

OVERVIEW INSTALLED COMPRESSORS :					
natural	type	unit	date	hours**	
CO2	C6HK	C5	2005	49027	
CO2	C6HK	C6	2005	2666	
CO2	GH160	C7	2005	41144	
CO2	C200VMD	C8	2005	30878	
CO2	C200VMD	C9	2005	3762	
NH3	N250VLD	C1	1997	61301	*
NH3	N250VLD	C2	1997	39812	*
NH3	N250VLD	C3	1997	38133	*
NH3	N200VLD	C4	2005	54928	

* : Incl. F250VLD use 1997->2005

**: 5-10-2011

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EFFICIENCY ANALYSIS

design

CO2/NH3 CASCADE		RT	BKW	THR	COPc-each	COPc-total
TE=-51°C	TC=+32°C	kW	kW	kW		
CO2 LS	GH160	629	184	813	3,4	
	C200VMD	1100	311	1411	3,5	
	C200VMD	1191	330	1521	3,6	
	total	2920	825	3745	3,5	1,61
NH3 HS	N250VLDx2	2760	723			
	N250VLDx1	987	268			
	total	3747	991		3,8	

average

CO2/NH3 CASCADE		RT	BKW	THR	COPc-each	COPc-total
TE=-51°C	TC=+25°C	kW	kW	kW		
CO2 LS	GH160	629	184	813	3,4	
	C200VMD	1100	311	1411	3,5	
	C200VMD	1191	330	1521	3,6	
	total	2920	825	3745	3,5	1,75
NH3 HS	N250VLDx2	2820	626			
	N250VLDx1	927	214			
	total	3747	840		4,5	

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->EFFICIENCY ANALYSIS

Difference planned & actual results if occured?	
If yes, why were there differences? TC:32->25°C 90600€	For the main freezing load of 5 days 24hrs operation : Average condensing temperature on the NH3 cascade compressors is reduced from design value of 32°C to 25°C, this means a compressor absorbed power reduction of 151kWh or 906 MWh based on 6000hrs operation per year. (COP-c increase of 8,7%) This represents an energy saving for the customer of 90600 € (based on 0,10€/kWh) Heat recovery results ?
How is the process of measuring efficiency?	The freezing equipment is operating following load programs which must be covered by the refrigeration plant, which was fullfilled. Per type of compressor 1 machine is equipped with frequency convertor for speed control at part-load operation in order to keep the best COPc

COST ANALYSIS

COSTS INVOLVED & POSSIBLE COST SAVING OR HIGHER SPENDING FOR THIS PROJECT.	This installation represents for Cofely Refrigeration bv a value of approx. 4.000.000 €.
Estimated price difference to conventional system	The comparison with synthetic refrigerant R507 has been considered. Cofely Refrigeration bv concluded that this solution was much more expensive than the choosen CO2/NH3 concept.

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->COST ANALYSIS

Savings or potential savings because of existing or pending regulation	At the completation and the acceptance of the new CO2/NH3 plant, TNO reported that the CO2/NH3 plant is significantly more efficient than a comparable plant with R507. The calculated savings amount to 23% on energy, resp. 49% on CO2 equivalent emmission at that time. In addition the plant is equipped with following energy-saving options : -heat recovery -high efficiency electrical motors -hot gas defrosting -frequency controllers -energy-saving condensors

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->COST ANALYSIS

Potential savings in the future **70-80°C hot water**	**As the process needs hot water at temperature level of 70 to 80°C there is great interest to add hot water overcompression heat pumps with operation during the cheaper night-time power price and to buffer hot water for use during the production process.** **There is plenty of heat rejected from the high stage NH3 cascade plant (over 4 mW per hour during week-production days) which can be used as heat source for the heat pumps.**
Did forecast succeed/expectations were met?	The customer is absolutely happy with the plant.

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BARRIERS & SOLUTIONS

WHAT BARRIERS WERE WE FACING WITH THIS PROJECT & HOW SOLVED ?	
Technical problems or availability of systems, components, engineers?	As this plant was one of the first in Europe realised, supply and availability of high pressure components has been one of the faced bottle necks. Thanks to the customer who gave full confidence and made strong investment in this new technology to Cofely-GDF Suez it was possible to succeed and realise this plant with success !
Psychological barriers from customer:management?	Not as customer fully relied on the capability Cofely Refrigeration.
Safety problems, legilative barriers?	The plant/system was build fully in compliance with CE-PED.
Short term cost differences?	Not

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LESSONS LEARNED

WHAT HAS BEEN LEARNED FROM THE PROJECT & HOW CAN THIS BE APPLIED TO OTHER PROJECTS USING NR.	
What will you do different in the future?	For the refrigeration plant, the customer will go for the same solution as demonstrated by this field case which is already running 6 years with full satisfaction !
What can you apply to the next project?	With the next plants where hot water is needed in the process, neccessary important energy savings should be inplemented by installing hot water high pressure compression heat pumps with NF NH3 by recuperating the condensor heat from the cascase NH3 high stages which is available in great quantities.

FUTURE PLANS

Have you planned or do you know about similar projects?	
What are your recommendations for the planning, design etc. Of NR systems ?	Continue in the same line. The Cofely group has more than 60 CO2 plants in operation which have been installed since 2001!

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ACTION PLAN

IDEAS OF CONCRETE ACTIONS TO GET NATURAL REFRIGERANTS FASTER TO EUROPE :	
1.1. What are the concrete actions already done ?	Mayekawa only promotes natural refrigerants since the beginning of this century.
1.2. Or/and planning to do ?	
2.1. what kind of actions needed to expand NR systems, for : Technology, Training, Safety, Policy, Standards, Regulation, Market, Costs, End-users.	Unlimited development ongoing. With each new product:system neccessary trainings are also made available. Suppliers of refrigeration accessories (EN378 qualified) should make more products available for high pressure/big size duty. Mayekawa still have too often to rely on expensive accessories designed for oil and gas industry.

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CONCLUSION

NATURAL REFRIGERANTS
FASTER TO EUROPE :

THIS PROVEN FIELD EXAMPLE SHOWS THAT THE SUCCESS OF THE NEW TECHNOLOGY IS MUCH DEPENDING ON THE QUALITY OF THE PREPARATIONS DONE ON BEFOREHAND FOLLOWED BY THE INSTALLATION AND COMMISIONING WITH OPTIMAL FINE TUNING, FROM COOPERATION BETWEEN ALL PARTIES INVOLVED :

MANUFACTURER : MAYEKAWA JAPAN/ MAYEKAWA EUROPE
CONTRACTOR : COFELY REFRIGERATION & END-USER.

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THANKS FOR YOUR ATTENTION!

Thanks to the Contractor of the plant in the fieldcase : COFELY REFRIGERATION bv(NL) Mr.Willy van Leeuwen (willy.van.leeuwen@cofely-gdfsuez.nl)

Presented by Jan Boone, MAYEKAWA

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WORLDWIDE
- 35 countries / 121 offices
- 8 production plants

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EN/09/2011