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

Trans critical R744 for Food Industry

Freezing units -40° C

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

#1

SUMMARY

- **THE PROJECT**
- **REFRIGERATION EQUIPMENT**
- **HEAT RECOVERY**
- **MAIN INFORMATION**
- **PIPING AND PICTURES**
- **COMPARISONS**
- **CONCLUSIONS**

<u>Preliminary remark</u>; The aim is not to oppose naturals refrigerants (NH3 et CO2), but TO SHOW THAT CO2 TC IS A POTENTIAL ALTERNATIVE, taking into account investment, running costs, safety, maintenance team skills, local regulations …

#2 THE PROJECT

- **1 Low temperature cold room for raw (and final products) at -25° C**
- **Some positive cold room to elaborate product at + 8° to +10° C**
- **1 cooking line needing 1.5 ton/hour of vapor**
- **2 Spiral freezers for ‘’meat pallets” called « Bouchons »** (*Based on Chicken or Pork Meat with Reunion Island typical spices (combava) wrapped in rice leaf)*
- **2 Medium temperature platforms with multi head weighers at -2° C**
- **1 conditioning room at + 12 ° C**
- **1 Low temperature ‘’buffer” cold room for day production at -20° C**
- **1 loop for 2.6 m3/h sanitary water**

#3 Refrigeration Equipment

- **First CO2 TC unit**
  - **Booster TC unit with pumped CO2**
    - *Refrigeration for 2 Spiral freezers (1 700 kg/h unit.)*
  - **Heat recovery**
    - *For Sanitary water and water boiler heating up*
- **Second CO2 TC unit**
  - **Booster TC unit with Direct expansion CO2**
    - *For Glycol cooling to ice storage accumulator system*
    - *For DX to L.T. cold room air coolers*
  - **DAY and NIGHT running conditions**
    - *DAY : CO2 DX Refrigeration of ''Buffer'' L.T. cold room*
    - *NIGHT : CO2 DX Refrigeration of L.T. main cold room and Glycol cooling to Ice production in accumulator*
- **ICE accumulator**
  - Chilled water +1/+3° C for positive cold rooms

#4 First Unit

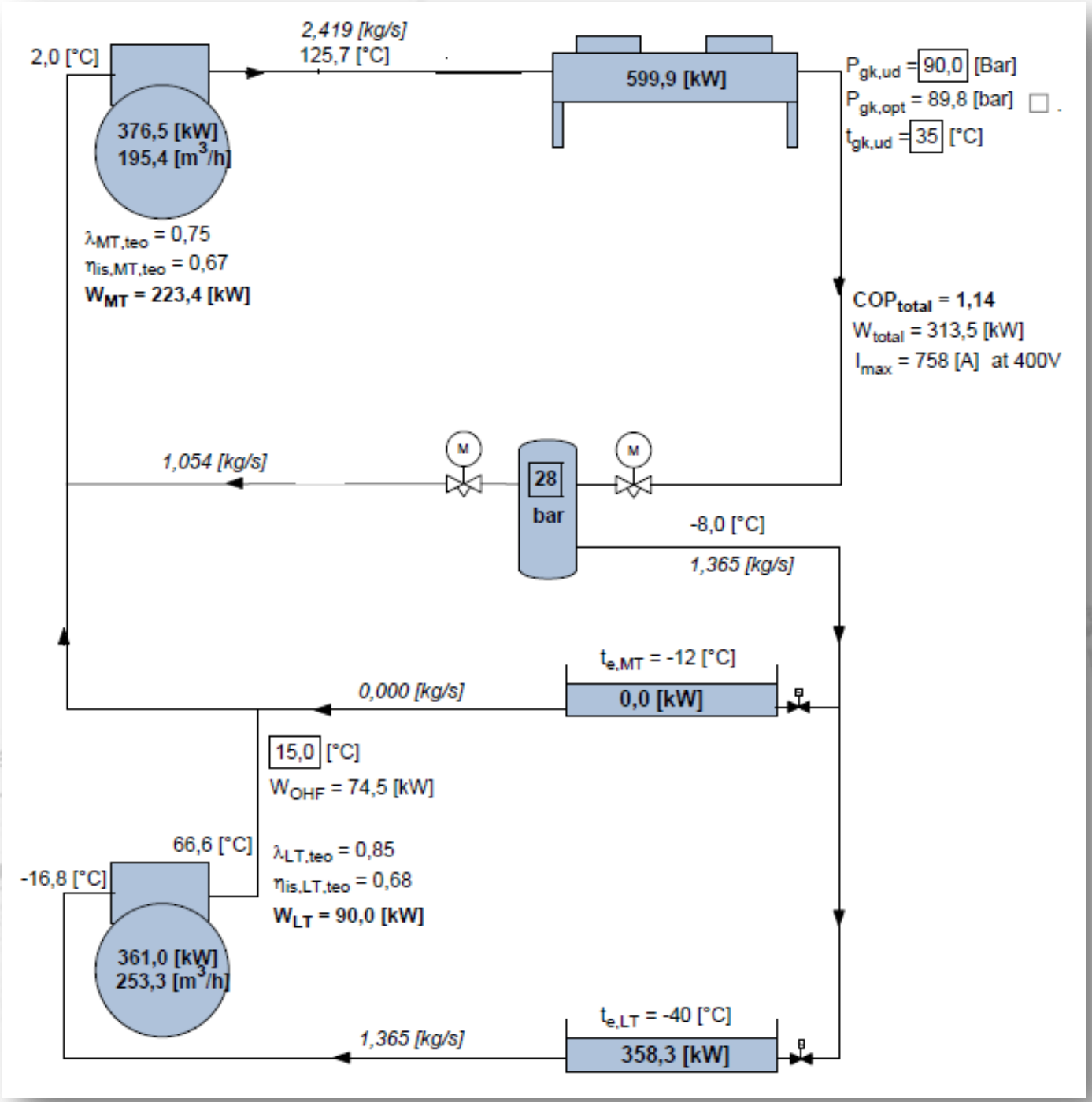
- **First unit booster CO2 TC**
  - MT level -12° C
  - Intermediate load 0 kW
  - LT level **- 40 ° C**
  - Low Temp load **358 kW**

- **8 semi hermetic Bitzer compressors on M.T. (1 with inverter)**
- **5 semi hermetic Bitzer compressors on L.T. (1 with inverter)**
- **1 low pressure vessel**
- **2 R744 refrigerant pump with variable flow**
- **1 heat recovery plate exchanger**
- **1 desuperheater**
- **1 H.C. resilient cooler**
- **1 gaz cooler**
- **CO2 charge : 1300 kg**

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

#5

First Unit
(32° C ext.)



#6 Second Unit

- **Second unit booster CO2 TC** **with Day/Night mode**

	DAY	NIGHT
Mode		
MT level	-12° C	- 8° C (-2/-6 Glycol)
Intermediate load	0 kW *	155 kW
LT level	- 29 ° C	- 33 ° C
Low Temp load	20 kW	70 kW

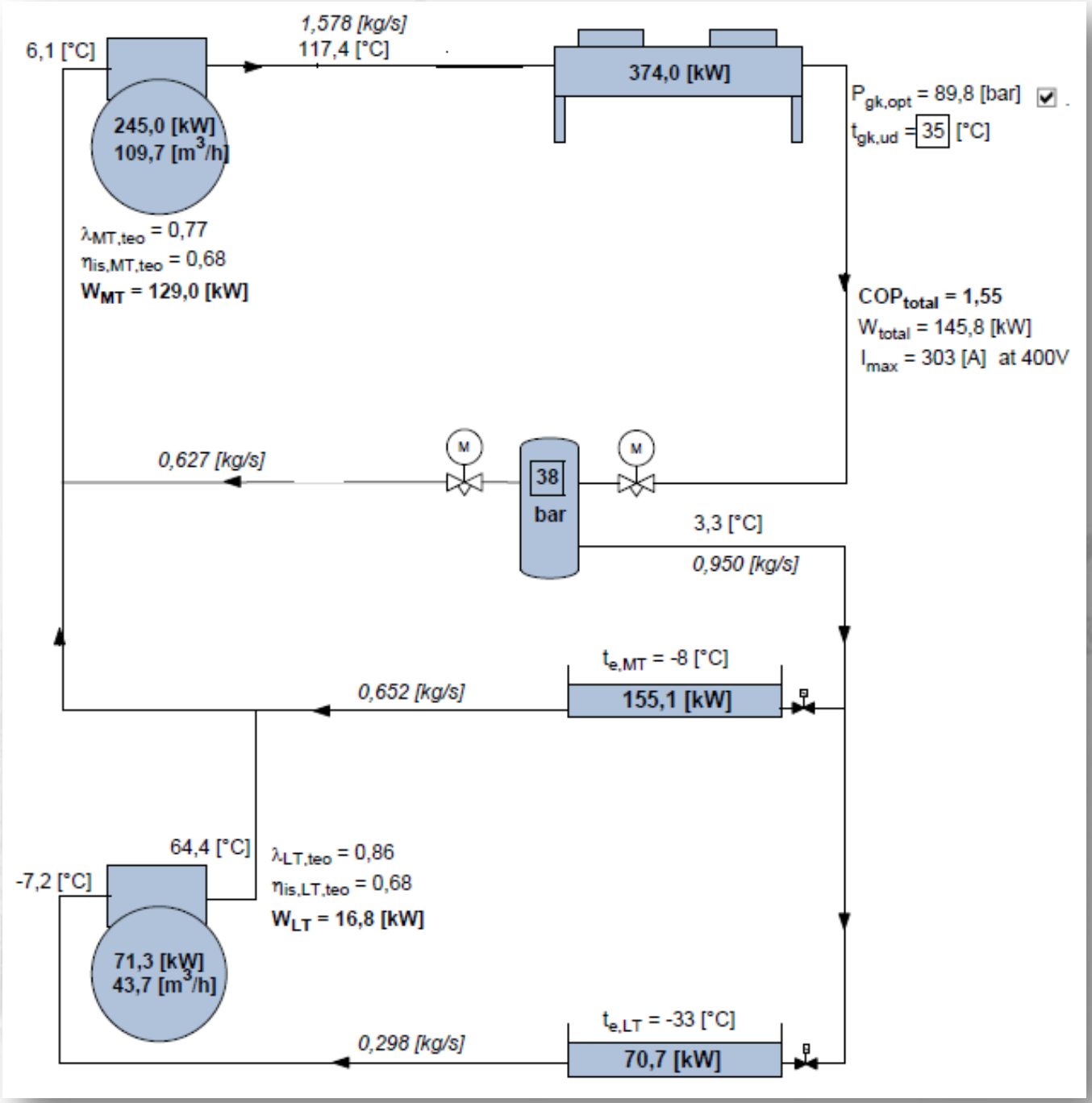
* *Can assist ice bank in case of more load requested*

- **5 semi hermetic Bitzer compressors on M.T. (1 with inverter)**
- **3 semi hermetic Bitzer compressors on L.T. (1 with inverter)**
- **1 liquid line to M.T. expansion valve on glycol plate exchanger**
- **1 liquid line to L.T. expansion valve on air coolers (Cold rooms and platforms)**
- **1 desuperheater**
- **1 gaz cooler**
- **CO2 charge : 250 kg**

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

#7

Second Unit :
32° C ext.



❑ HEAT RECOVERY SYSTEM

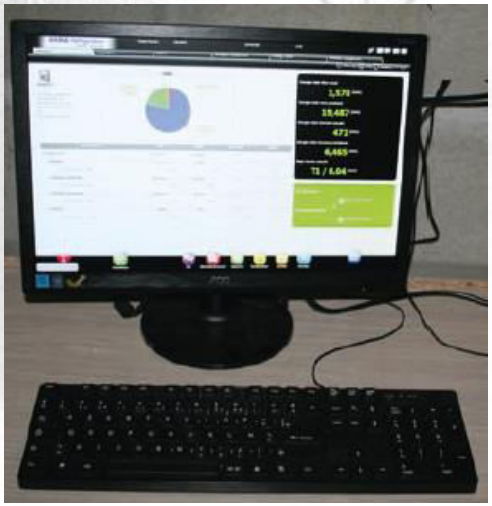
- ❑ 100% pre heating of water from +17 to +85° C for the vapor boiler.
- ❑ 100% of sanitary water heating: 2.6 m3/h to ° 65° C
- ❑ Water heating for vapor production is done on line as vapor (cooking) is needed continuously and at the same time as freezing
- ❑ heated sanitary water is accumulated on storage tank; the water is used partly for product but mainly for cleaning all conveyors and process machines

❑ SET of INSTRUMENTATION, MESURING and PROCESS CONTROLS

- ❑ Programmers for each room for day/night operation
- ❑ Counter of energy recovered from ice accumulator
- ❑ Electricity measurements on main consumers

(main supply line, racks, production, distribution …)

- ❑ Gas and water consumptions
- ❑ Remote and monitoring control system
- ❑ Energy management



#9 Main information

- **OWNER/INVESTOR :** **ASIA FOOD Reunion Island**
- **PLANT :** **France : Le Mans (72)**
- **CONSULTANT REFRIGERATION :** **AF Consulting**
- **CONTRACTOR :** **AXIMA REFRIGERATION GDF SUEZ**
- **SPECIFIC SUPPLIERS :**

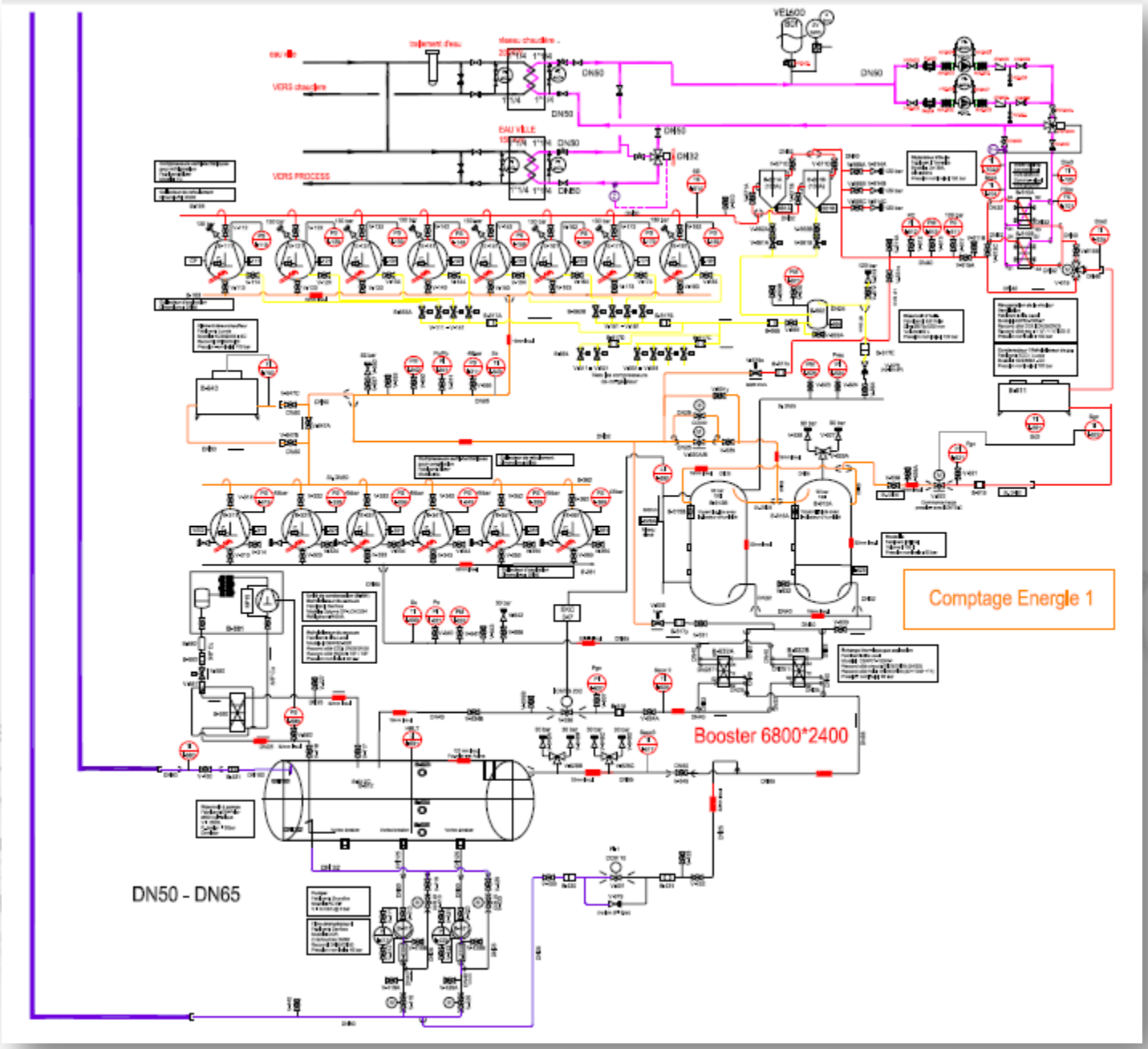
ADVANSOR (DK)	**for CO2 TC units**
FAFCO (CH)	**for ice accumulator**
BITZER (D)	for TC compressors
DANFOSS (DK)	for TC units control
SINOFREEZE (CH)	for Spiral freezers
CAREL (IT)	for Cold room control
ALFA LAVAL (S)	for CO2 plate exchangers
LUVATA (IT)	for Gas coolers
CONTARDO (IT)	for air coolers

ATMOsphere EUROPE
solutions for europe
natural refrigerants

16-17 March 2015 in Brussels

#10

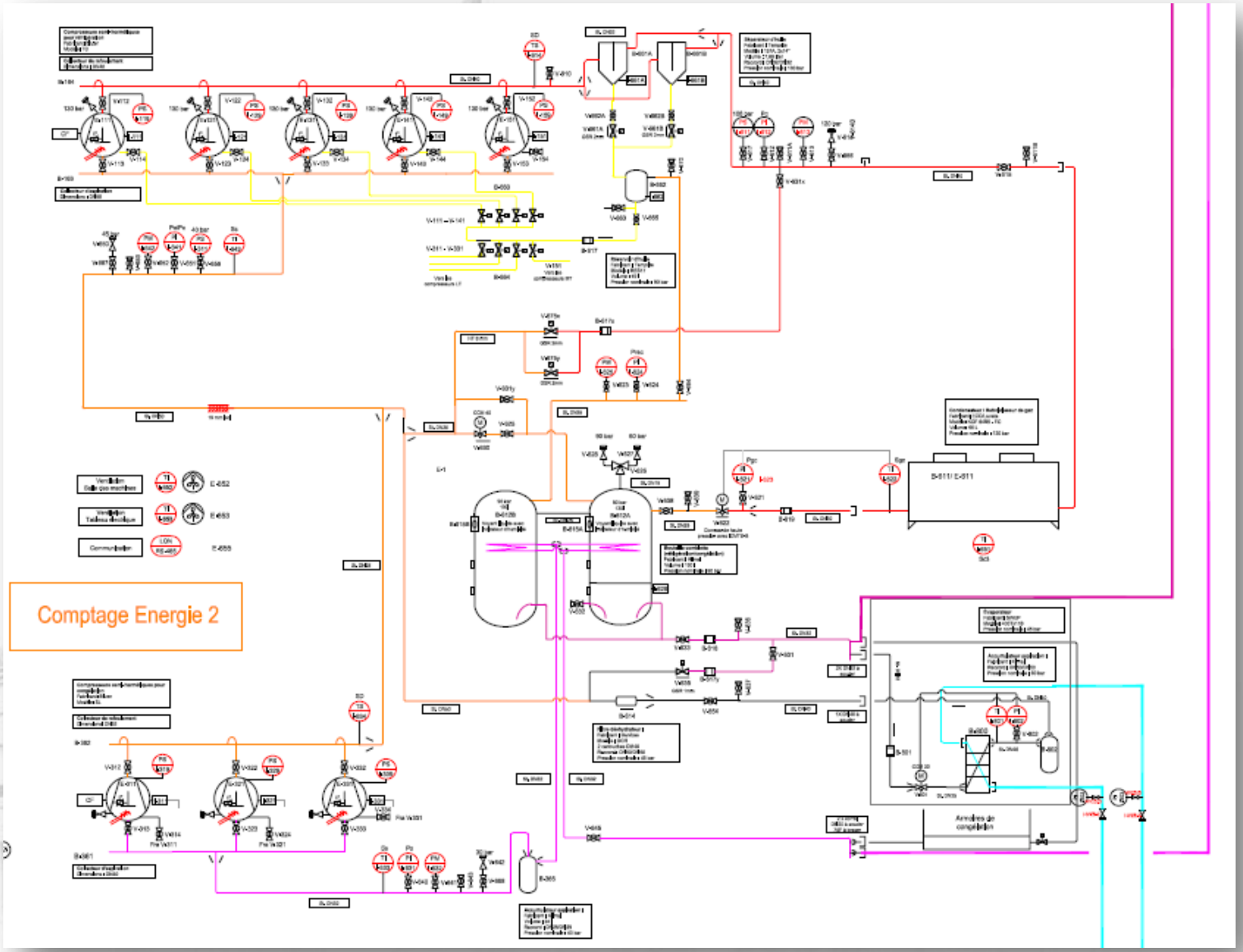
R744 TC Pumped Booster Rack



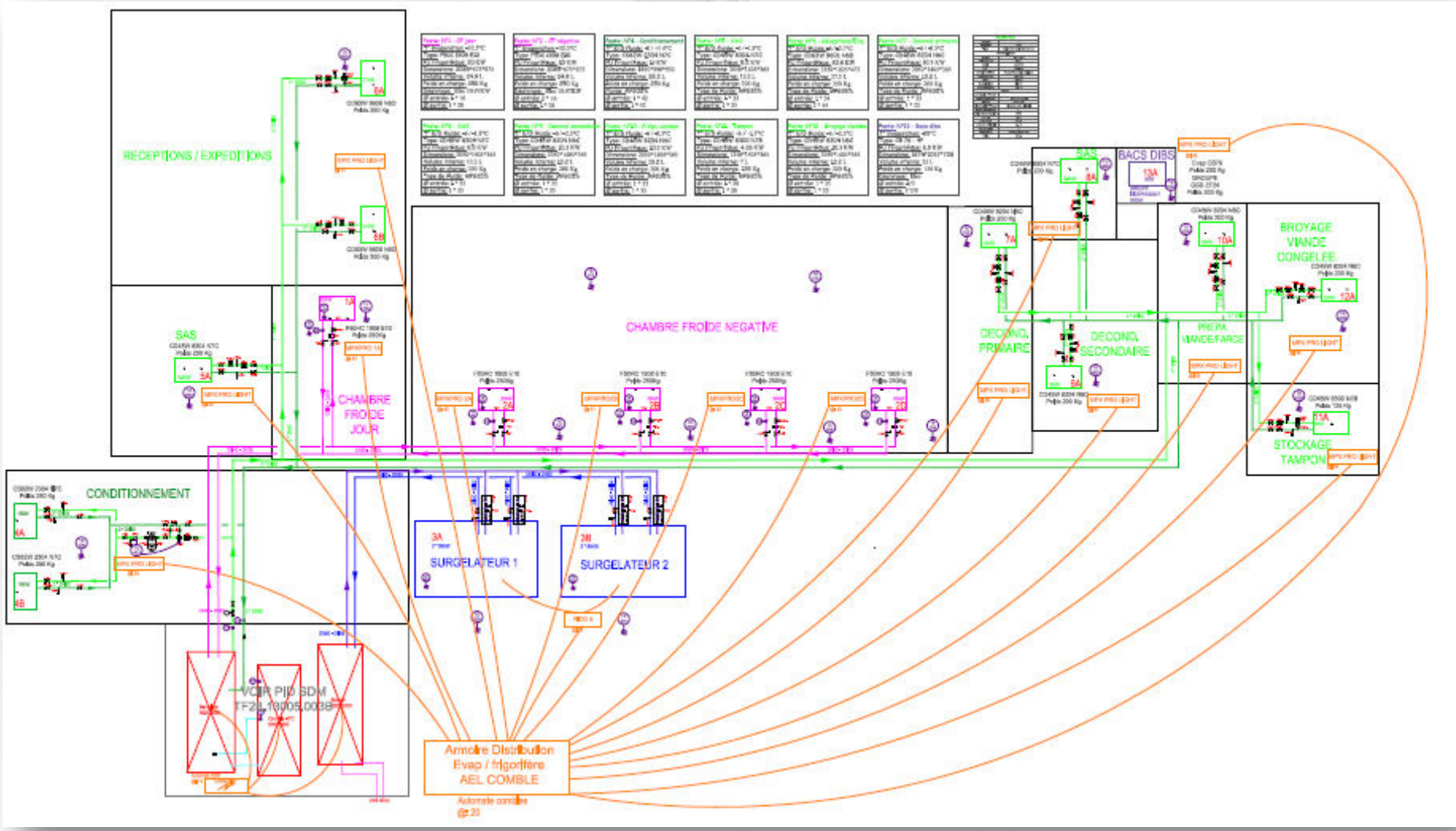
ATMOsphere EUROPE
solutions for europe
natural refrigerants
16-17 March 2015 in Brussels

#11

R744 TC DX Booster Rack



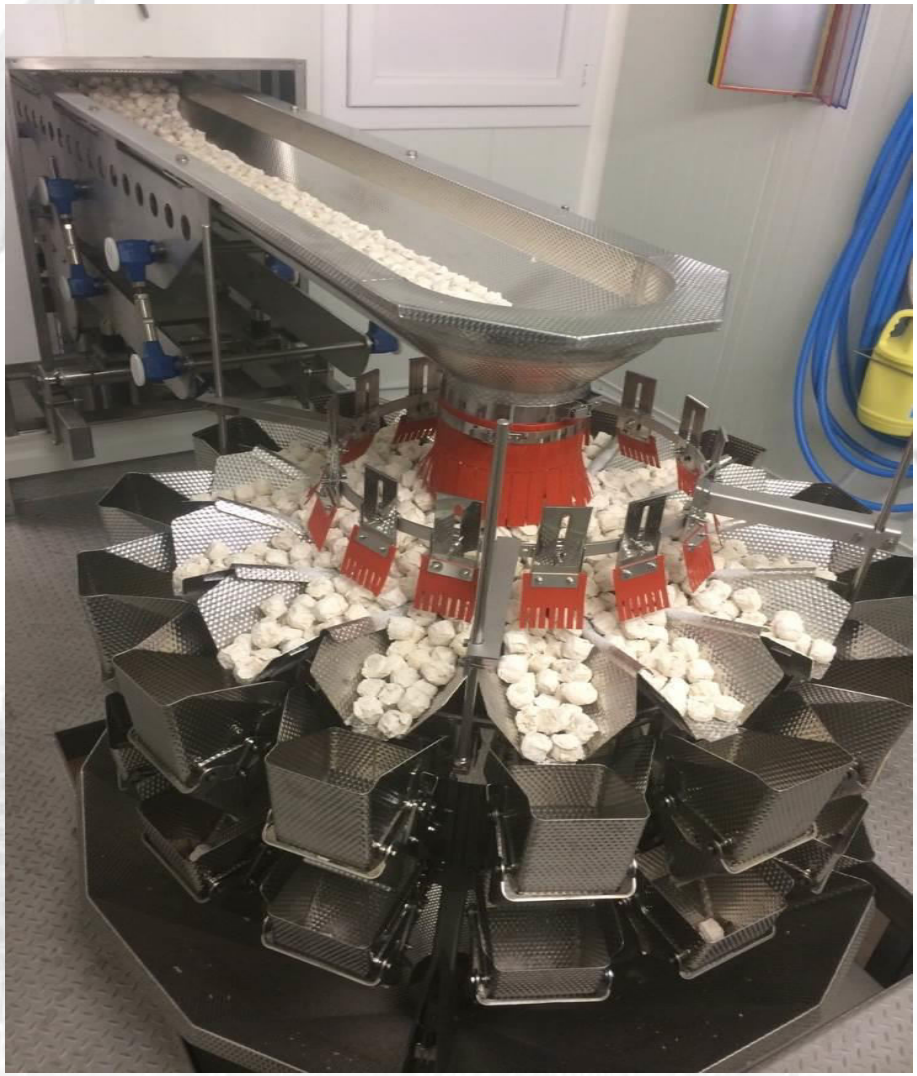
#12 Main diagram



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

#13

The product : ‘’Bouchons” in the Multi heads Weigher



The factory built end of 2013

The platform is cooling by DX CO2 from LT suction line of the Rack at -2° C

#14

The pumped R744 Rack

LT Vessel and inverter pumps side

Compressors and Liquid receivers side

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

#15

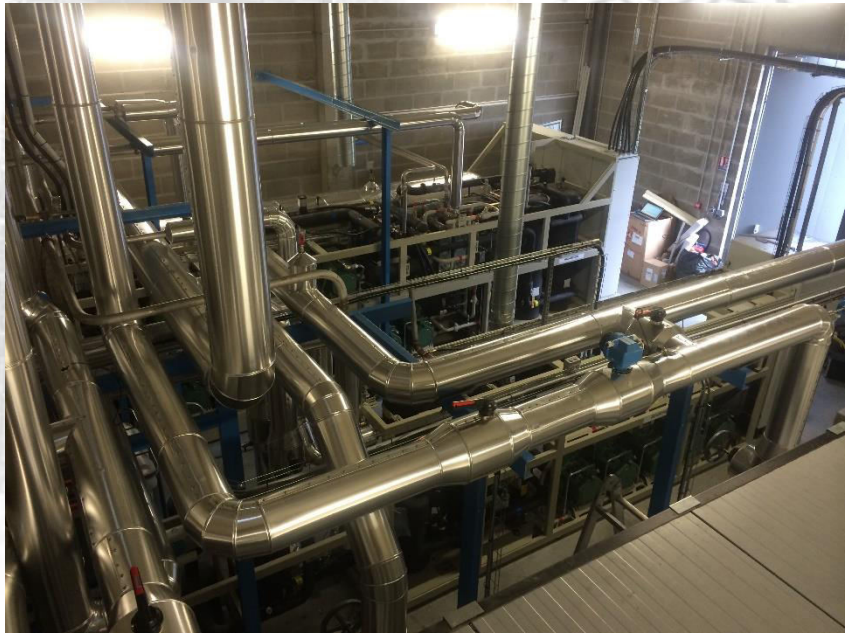
Piping- Ice Storage – Gas cooler – Rack TC

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

#16

Loft piping CO2 & Chilled water

The overall Machines room



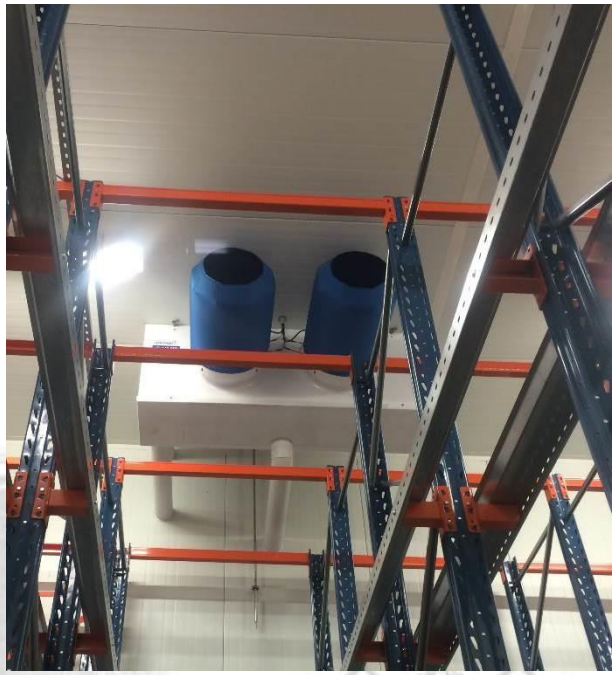
ATMOsphere EUROPE
solutions for europe
natural refrigerants
16-17 March 2015 in Brussels

#17

Refrigeration users

Freezer regulation equipment

Chilled water cold room



Cold Room regulation equipment

#18 Solutions Comparison

H.F.C. SOLUTION ?

- Witch refrigerant for low temperature and pumped circulation ?
- R404A/R507 ? -> G.W.P. !!
- High refrigerant cost
- Carbon tax ? Not yet in France but …
- Leak Rate !
- Short sustainability

AMMONIA SOLUTION ?

- Refrigerant charge above 1 500 kg introduce declaration process in France
- Plant less than 10 meters from neighbor !
- Safety for working peoples and products during storage and production
- Equipment's for safety, detection, alarms …
- Qualify the plant every 5 years
- Costs of NH3 distribution piping (see following tables)
- Costs of water for condensation (make up, treatment , controls)

CASCADE (HYBRID) SOLUTION CO2/NH3 ?

- Less NH3 and No ammonia in rooms
- But still ammonia outside. Either evaporative (Water !) either air condenser (less performance and higher risk)

CASCADE (HYBRID) SOLUTION CO2/H.F.C. ?

- One solution when Ammonia is problem face to regulation and/or price
- Flooded reliable system with high amount of R134a then Problems of H.F.C …

#19 Solutions Comparison

SOLUTION CO2 TC

- Good COP considering local ambient conditions, nights running time, accumulation facility
- Lower cost for distribution piping
- No need of water for condensation
- Important potential of heat recovery until 100% of discharged HP heat
- Evaporators compacts, lights, performants and quick to defrost
- Plant servicing open to more suppliers
- Less stress for plant handling
- More simple refrigerant management
- More product and personal safety
- Good compromise investment/running costs !

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

#20 Solutions Comparison

Informations	R404 A	NH3	NH3/CO2 cascade	R134a/CO2 flood cascade	TC Booster CO2
	commercial compressors	Industrial compressors	Industrial & commercial compressor	Industrial & commercial compressor	Commercial compressor
	Pumped and DX	Pumped + Glycol	Pumped CO2 + Glycol	Pumped CO2 + Glycol	Pumped and DX
	Air condenser	Evaporative condenser	Air condenser	Air condenser	Air condenser
French and European regulation	Very restrictive	Restrictive	Not so restrictive	Not so restrictive	No restrictive
	YES F-Gas	YES NH3 > 1500 kg (FR)	YES NH3 > 150 kg	YES F-Gas	
	HIGH GWP	YES evaporative system (FR)	No evaporative system	GWP > 150 but cascade R134a	
		YES HP liquid outside (FR)		No evaporative system	
Sustainability	Very Short	Good	Good	Short	Good
Maintenance costs	Very High	High	Medium	Medium	Low
	Leak integrity	Mechanic maintenance	Mechanic maintenance	Mechanic maintenance	Medium skill
	Refrigerant cost	Water treatment	High skill	Refrigerant cost	
	Leak Rate/High amount	Water consumption		Leak Rate/High amount	
	Carbon tax ?	High skill		Carbon tax ?	
				High skill	
Water consumption	NO	YES	NO	NO	NO
Running costs (Maintenance, energy, heat recovery)	150 %	130 %	120 %	110%	100%
Investment	100 %	140 %	160 %	120 %	108 %
Refrigeration effciency	117 %	100 %	107 %	110 %	105 %
Heat recovery potential	Limited	Medium	Medium	Limited	Good
T.E.W.I.	+ 2 800%	1	+ 7%	+ 670 %	+ 5%

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

#21 Solutions Comparison : Piping

Base 250 kW	Vapor -10°C			Vapor -40°C		
	CO2	NH3	R507	CO2	NH3	R507
Vaporization heat kJ/kg	258.6	1297	170	435.3	1389	191.5
Specific volume of vapor m3/kg	0.014	0.42	0.043	0.038	1.55	0.13
Mass flow kg/s	0.967	0.193	1.47	0.574	0.18	1.305
Vapor volume flow m3/s	0.014	0.081	0.063	0.022	0.28	0.17
Ratio of vapor volume flow	1	5,8	4,5	1	12,7	7.7

#22 Conclusion

The CO2 TC SOLUTION WITH PUMP CIRCULATION IS OF COURSE A MUCH BETTER SOLUTION THAN ANY H.F.C. ALTERNATIVE

BUT ALSO

AN INTERESTING ALTERNATIVE TO USUAL AMMONIA SOLUTION

As soon as:

- Evaporating temperature is low between -35 to – 54° C
- Distribution piping is important
- Heat needed at high temperature level
- Maintenance team is not so skilled
- Local regulation and constraints for ammonia are important
- Weather condition are suitable for average good efficiency

WAYS OF IMPROVEMENT

- Compress separately the « flash gas » witch can represent 40% of the mass flow M.T.
- Study some solution on DX similar to flooded solution with ejector
- Find sub cooling sources
- Follow the evolution of compressor to bigger ones

EUROPE ATMOsphere

solutions for europe

natural refrigerants

16-17 March 2015 in Brussels

THANKS FOR YOUR ATTENTION

Mr Vincent RIVET
afconsulting@sfr.fr
+33 (0)6 62 47 07 01