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Solutions for Europe
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CO_2 refrigeration in warm climates

Efficiency improvement

enJECTOR®
enEX Leading in refrigeration

Enex srl

DRAVA

ELBA

NEVA

AIRHEAT/ GEOHEAT

MORE THAN 300 UNITS PRODUCED – CO_2 AS THE ONLY REFRIGERANT - INSTALLED IN 15 COUNTRIES

REFRIGERATION CONCEPTS:

- SINGLE STAGE
- 2-STAGE SIMPLE INTERCOOLER AND OPEN FLASH TANK
- BOOSTER
- CASCADE
- HEAT PUMPS: TAP WATER HEATING (WATER/WATER AND AIR/WATER)

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Evolution of CO_2 refrigeration

PERIOD	PHASE	DESIGN SOLUTION	COUNTRY
1994 -1997 1998 1999	From idea to prototypes	 First installation cascade First installation of a refrigeration transcritical system	--
2000 -2004	Pioneer installations	Multicompressor 1 stage Multicompressor 2 stage with intercooler	Italy Switzerland Northern Europe
2005 -2009	CO_2 only solution becomes widly accepted. Optimized components available	- Economizer - Booster - 2 stage Open Flash Tank	Northern Europe United Kingdom Switzerland
2010 -2012	Focus on reliability	No new design solutions	Pilots plants in central/southern Europe
2013 - ?	Search for Resilience/Reliability/Efficiency Improved design?	Expansion work recovery?	All Europe?

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Today

A) CO_2 ESTABLISHED ALTERNATIVE TO HFCs IN COMMERCIAL REFRIGERATION

B) MORE THAN 1300 SUPERMARKETS INSTALLED IN EUROPE*

C) STILL LIMITED TO NORTH AND MID EUROPE

* Shecco, 2012, Study on supermarket refrigeration system with transcritical R744 units

Needs

1. MOVE SOUTH THE APPLICATION BORDER-MAKE THE USE OF CO_2 SYSTEMS CONVENIENT IN WARMER CLIMATES
2. IMPROVE OVERALL EFFICIENCY OF CO_2 PLANTS
3. MAKE CO_2 ECONOMICALLY COMPETITIVE THROUGH MASS PRODUCTION ALLOWED BY A MUCH LARGER MARKET

Development Objectives

A) REFRIGERATION SYSTEM WITH CO_2 AS THE ONLY REFRIGERANT

B) HIGHER EFFICIENCY THAN CO_2 STATE-OF-THE-ART SYSTEMS

C) SIMPLE DESIGN

D) SUITABLE FOR WARM CLIMATES

E) COST EFFECTIVE, SUITABLE ALSO FOR SMALL SHOPS /PETROL STATIONS/HORECA

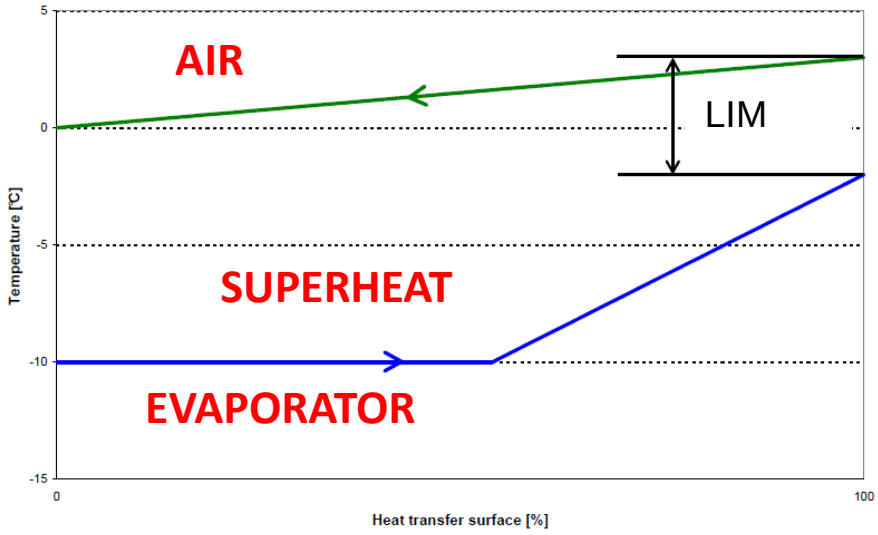
Identified solutions - enJECTOR®

1. EVAPORATORS OVERFEEDING (REDUCTION OF LOSSES FOR SUPERHEAT- HIGHER EVAPORATION TEMPERATURE)

2. RECOMPRESSION OF FLASH VAPOR AND PRECOMPRESSION WITH EJECTOR (REDUCTION OF THROTTLING LOSSES)

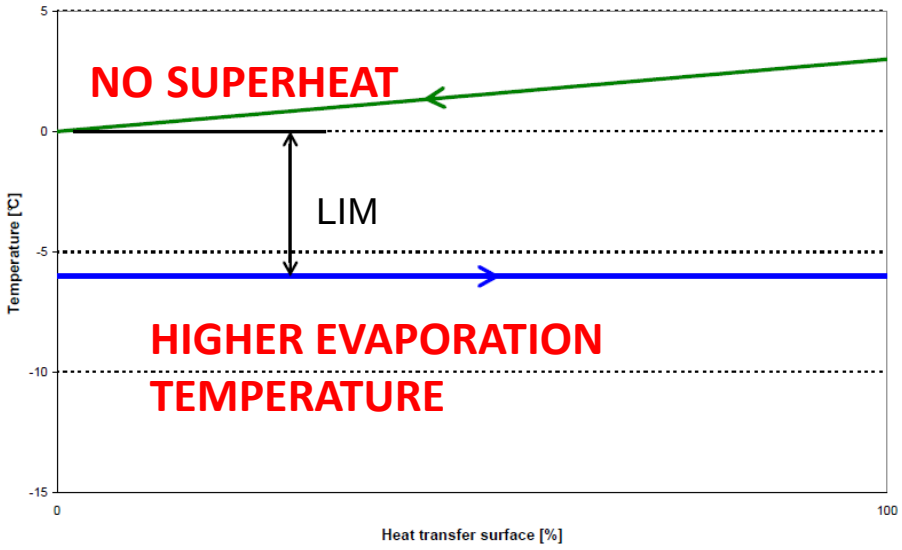
Evaporators temperature profile

SUPERHEAT EVAPORATOR (THERMOSTATIC EXPANSION VALVE)



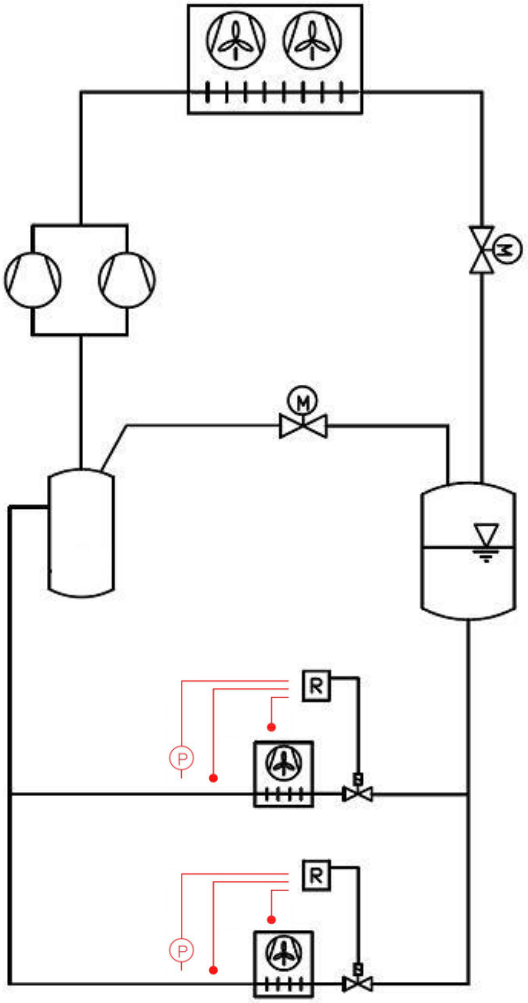
- DRY EXPANSION

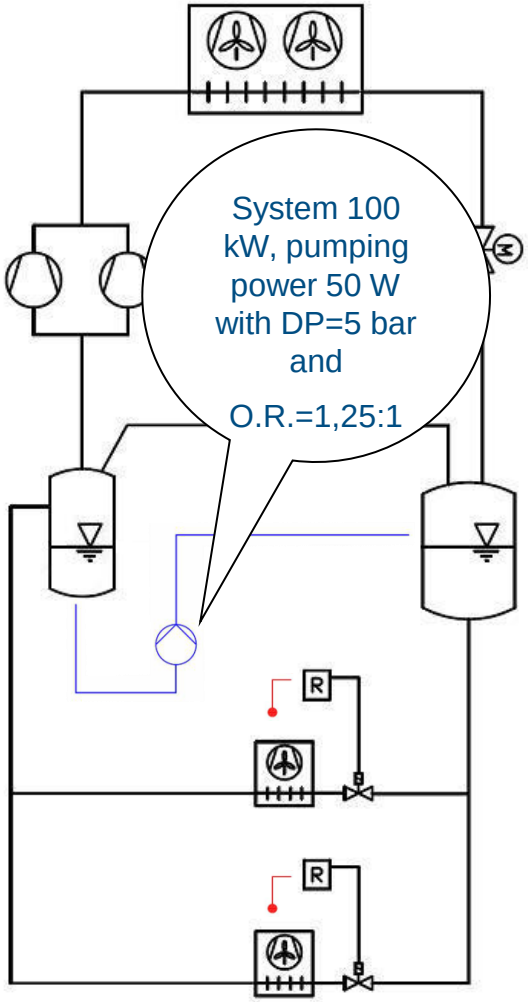
FLOODED EVAPORATOR (OVERFEEDING)

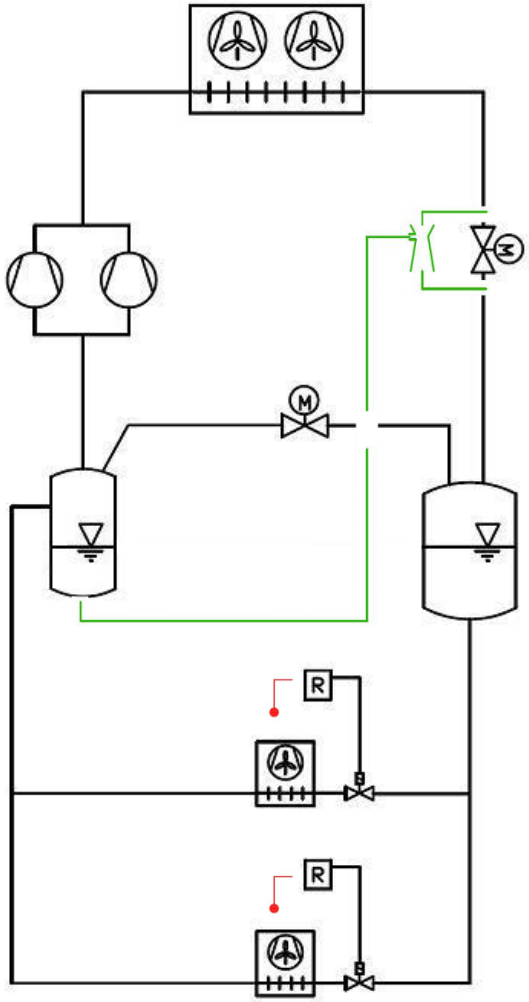


- NO SUPERHEAT CONTROL
- EXCESS LIQUID MANAGEMENT IS REQUIRED

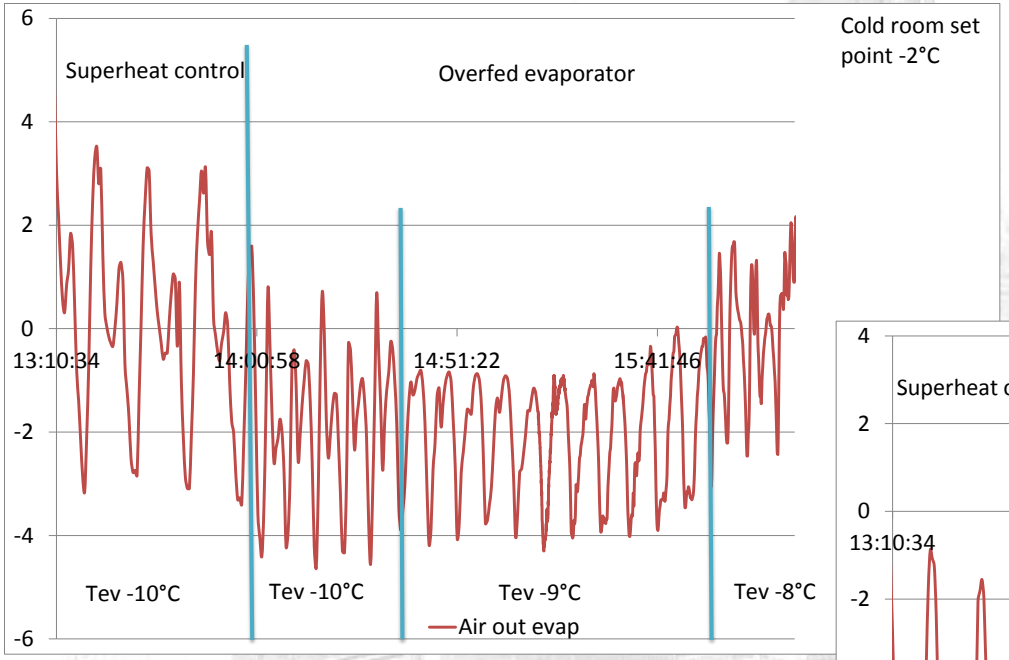
Overfed evaporators: system design

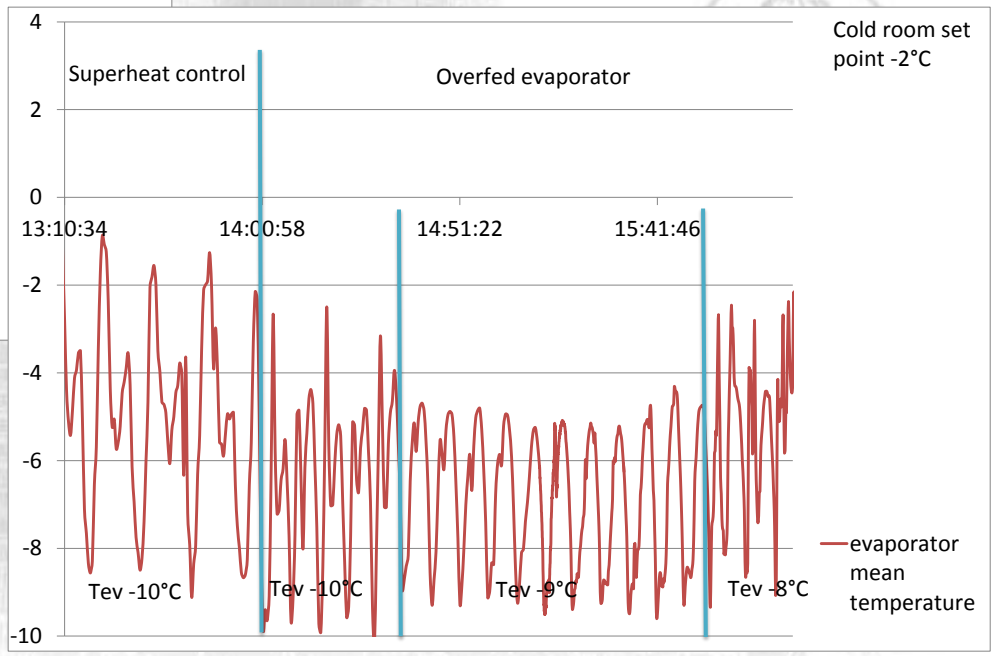






Overfed evaporator with ejector liquid suction: test results





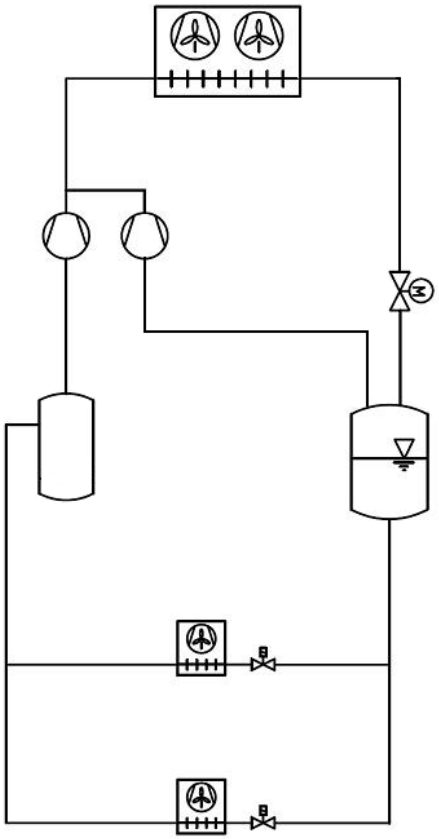
Overfed evaporators advantages

COMPARED WITH "OLD GENERATION CO_2" THE NEW DESIGN IS CHARACTERIZED BY:

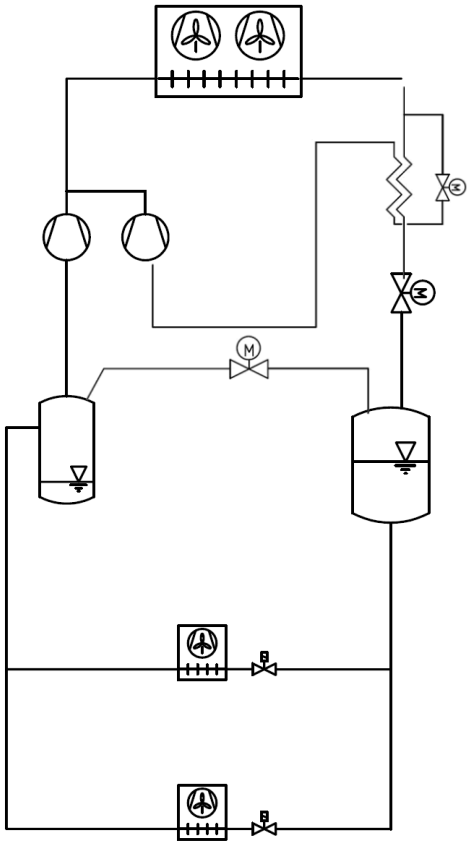
- INCREASE OF EVAPORATING TEMPERATURE IN TYPICAL COMMERCIAL CABINET FROM 3 TO 5K, DEPENDING ON REFRIGERATION LOAD AND EVAPORATOR DESIGN
- ENERGY SAVING 10-12% IN ALL CLIMATIC CONDITIONS DUE TO LOWER COMPRESSION WORK
- SIMPLE EVAPORATOR CONTROL
- INCREASED RELIABILITY: NO RISK OF LIQUID AND OIL SLUGS SUCTION FROM COMPRESSORS/LESS COMPONENTS
- LOWER TOTAL COST (SIMPLER EVAPORATOR CONTROLS, SMALLER COMPRESSOR, REDUCED SIZE OF ELECTRICAL EQUIPMENT)

Reduction of Throttling losses: flash vapour recompression

RECOMPRESSION OF FLASH VAPOR FROM RECEIVER AT INTERMEDIATE PRESSURE (OFT)



SUBCOOLING WITH AUXILIARY COMPRESSOR(S)



Flash vapour recompression

• FIELD TEST ON 2 SYSTEMS (ITALY) –ONE YEAR DATA COLLECTION FROM THE FIELD (JUNE 2011-JULY 2012)

• EXPERIENCE FROM THE FIELD:

- ENERGY SAVING DEPENDS ON EXTERNAL CONDITIONS (AIR COOLED SYSTEMS), IT BECOMES RELEVANT FOR AIR TEMPERATURES HIGHER THAN 25° C
- PAY BACK CAN BE TOO LONG IN MEDIUM CLIMATIC CONDITIONS (THE AUXILIARY SYSTEM IS SELDOM IN OPERATION)
- CAPACITY CONTROL IS A CRITICAL ISSUE FOR OBTAINING EFFICIENCY IMPROVEMENT
- DESIGN WITH SUBCOOLING HEAT EXCHANGER:
  - a) THEORETICALLY MORE FLEXIBLE, BUT HX DESIGN IS CRITICAL
  - b) ADDITIONAL ΔT ON HX REDUCES THE ADVANTAGE OVER THE OFT DESIGN
  - c) MORE COMPLEX IN CONTROL

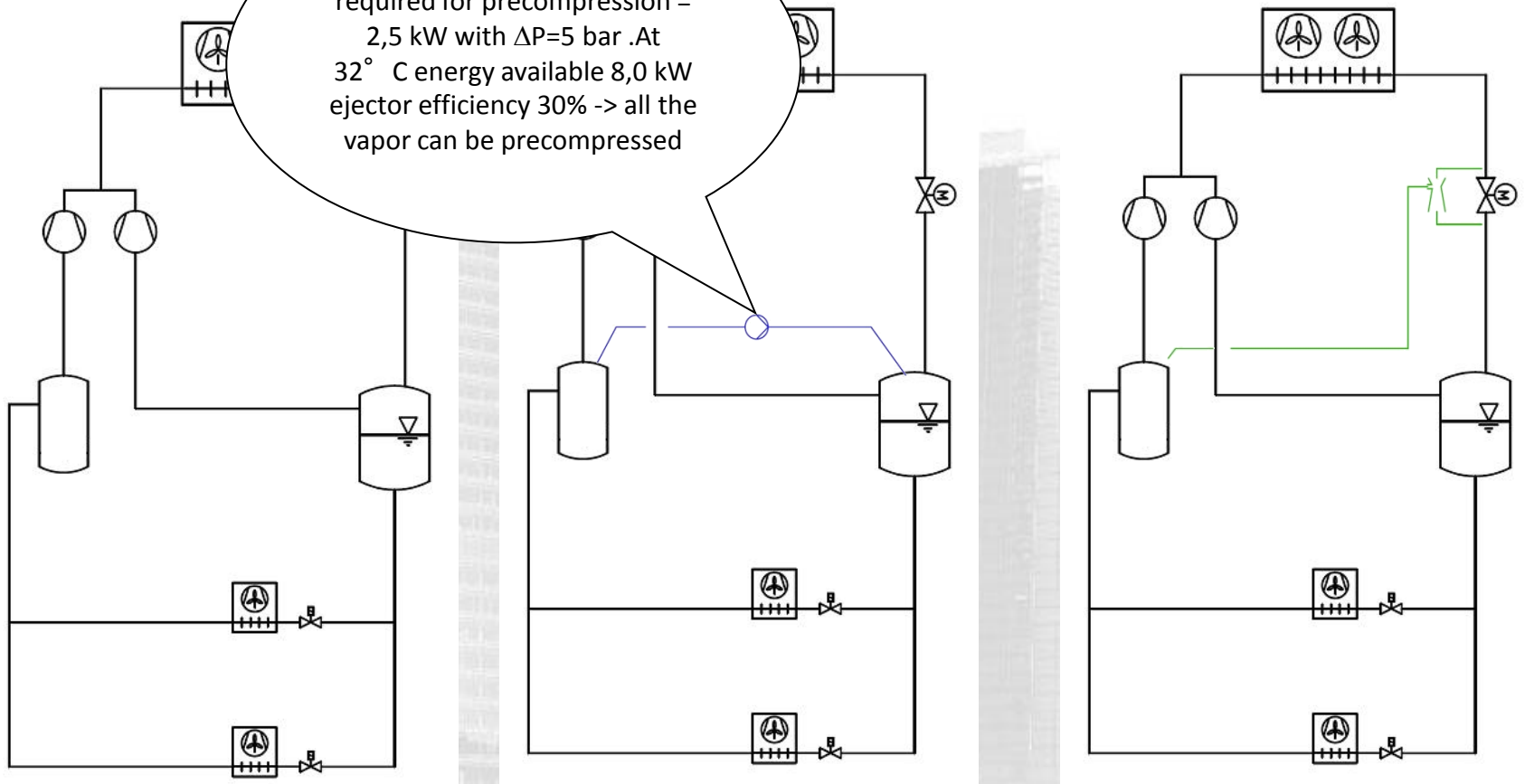
<u>ENEX OPTION IS "FLASH VAPOUR RECOMPRESSION FROM INTERMEDIATE RECEIVER":</u>

- SIMPLER DESIGN AND CONTROL
- COMPATIBILITY WITH EJECTOR PRE-COMPRESSION

Reduction of Throttling losses -3

FLASH VAPOR REC… …OMBINED WITH EJECTOR PRECOMPRESSION

System 100 kW, power required for precompression = 2,5 kW with ΔP=5 bar .At 32° C energy available 8,0 kW ejector efficiency 30% -> all the vapor can be precompressed



a) THE SIMPLE ADD-ON OF ONE OR MORE EJECTORS EXTEND THE PERIOD OF USE OF AUXILIARY COMPRESSOR(S) REDUCING PAY BACK
b) EFFICIENCY INCREASE UP TO 20% AT PEAK CONDITIONS

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How the ejector looks

Overall results

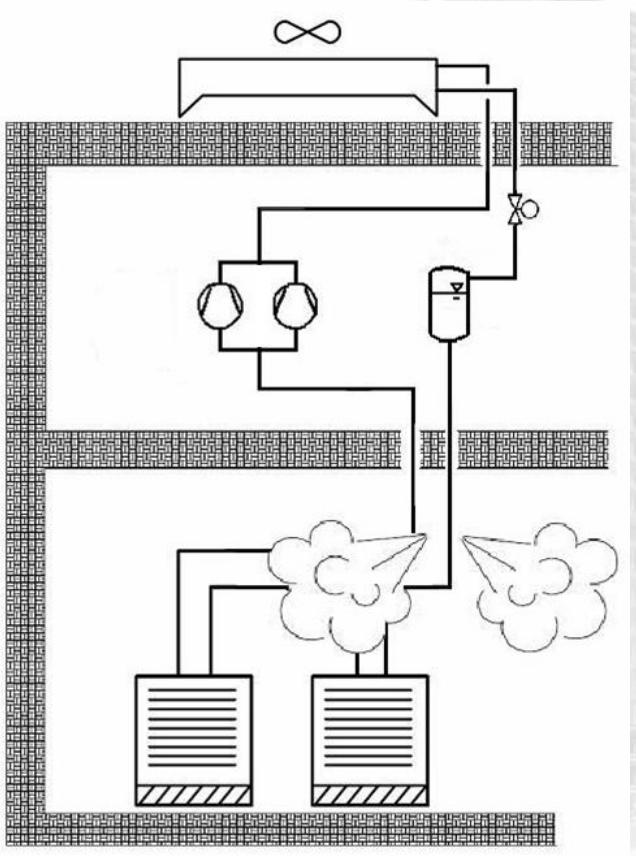
- ENERGY GAIN DEPENDS STRONGLY ON DESIGN AND CONTROL
- CAREFUL BALANCE OF COST/BENEFITS IS NEEDED
- WHAT CAN BE EXPECTED IN TERMS OF ENERGY SAVING?

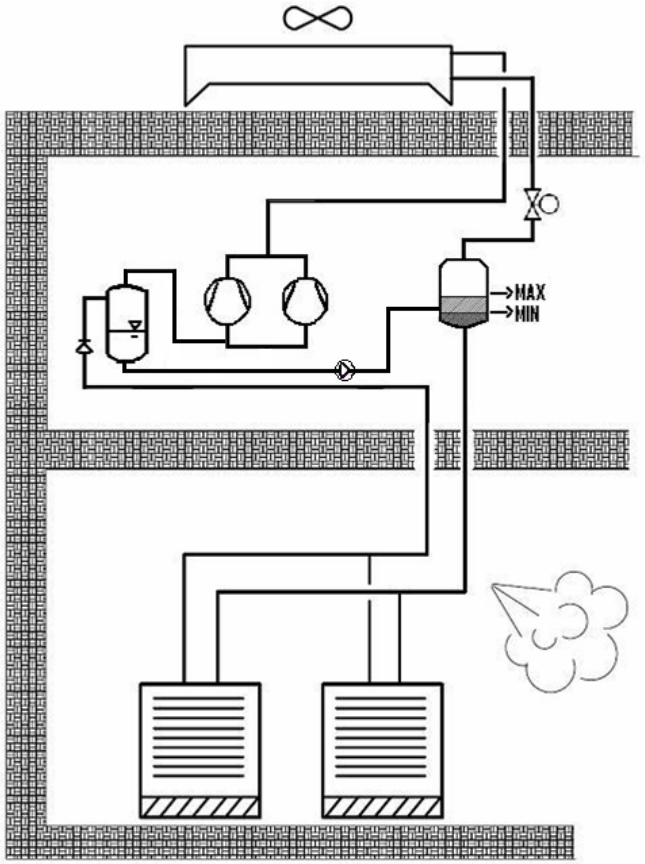
	YEARLY AVERAGE
A: EVAPORATOR OVERFEEDING	10-12%
B: FLASH RECOMPRESSION *	8-10%
C: FLASH RECOMPRESSION + EJECTOR *	15-18%
A+C	20-22%

(*) REFERRED TO ITALIAN CLIMATE

Further development/possibilities

THE POSSIBILITY OF REFRIGERANT CHARGE TRANSFER MAY INCREASE SAFETY LEVEL IN SUPERMARKETS





a) IT IS POSSIBLE TO LIMIT THE LIQUID CHARGE LEVEL IN RECEIVER
b) POSSIBLE REDUCTION OF LIQUID CHARGE DUE TO REDUCTION OF LIQUID PIPING DIAMETER (PRESSURE DROP IS NOT AS CRITICAL AS WITH A CLOSE SUPERHEAT CONTROL)
a)+b) -> SIGNIFICANT REDUCTION OF CO_2 MASS IN SALES AREA OF A SUPERMARKET

Conclusions

a) COMMERCIALLY AVAILABLE OVERFEEDING SYSTEMS AND FLASH RECOMPRESSION

b) "OVERFED" DESIGN VERY COST EFFECTIVE AND SIGNIFICANTLY SIMPLER THAN A CONVENTIONAL DRY-EX

c) EJECTOR PRECOMPRESSION REDUCES PAYBACK AND INCREASES EFFICIENCY OF THE SIMPLE FLASH VAPOR RECOMPRESSION

d) PRESENTED TWO PRACTICAL SOLUTIONS AVAILABLE TODAY FOR CONVENIENT USE OF CO_2 ONLY SYSTEMS IN SOUTHERN EUROPE CLIMATE

e) OPENING TO FURTHER IMPROVEMENT POSSIBILITIES, ESPECIALLY REGARDING SAFETY FOR PUBLIC

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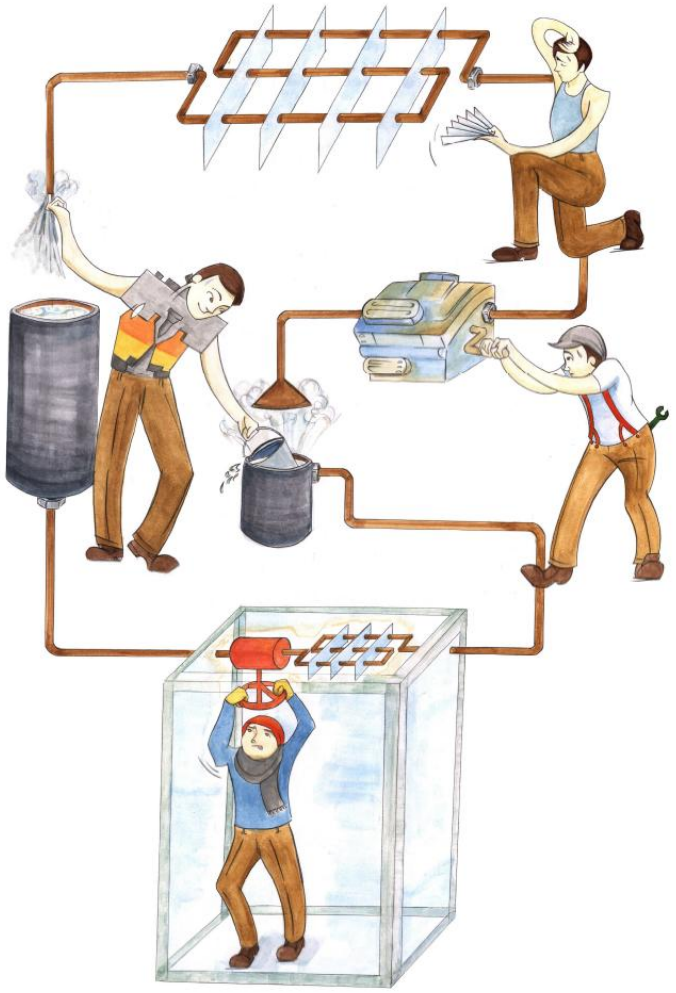

THANK YOU!