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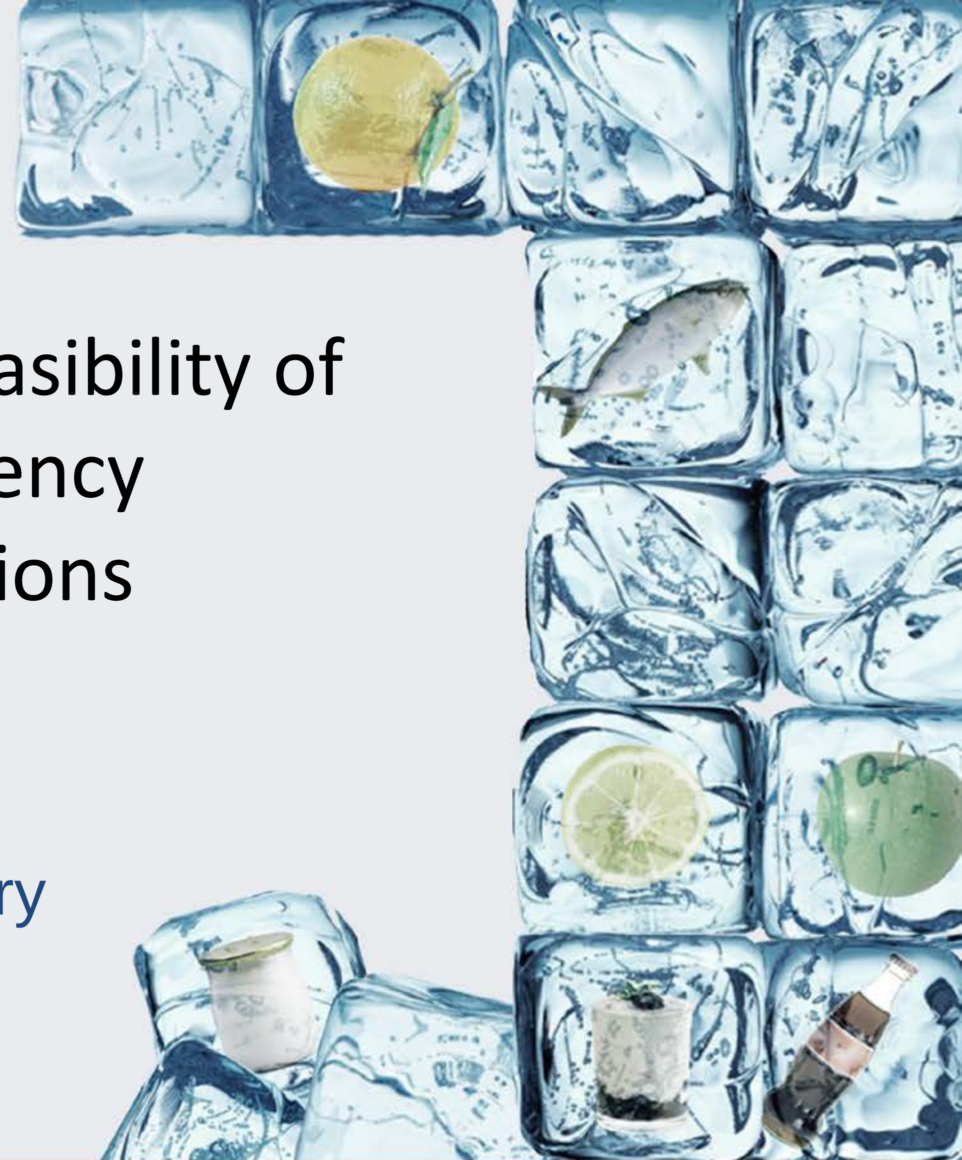
Economic and technical feasibility of generic energy efficiency optimatization solutions



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FIAB Federación Española de Industrias de la Alimentación y Bebidas

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ClimaCheck

Presentation content

1. Objectives of the COOLSAVE project
2. Determination of cooling performance and energy efficiency in general
3. Cost benefit analysis of the suggested energy saving solutions
4. Strategies/solutions to be implemented in the project
5. Generic energy saving solutions
6. Generic energy saving solutions in details
7. Key questions

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OBJECTIVES

Main objective

- To reach up to 15% savings in the industrial cooling facilities by mechanical compression of the companies participating in the project.

Specific objectives

- To identify potential savings and best strategies based on results of savings and investments required to improve energy efficiency of industrial refrigeration plants.
- To optimize the control and operation of mechanical compression facilities in the industrial drink and food sector.
- Implement the energy efficiency saving strategies identified with the best return on investment.
- Prepare a document of good practices based on real data collected in the companies analyzed.

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UNTIL NOW…

- Collecting data from cooling systems of 25 different companies - simulations, cost analyses (Denmark, France, Germany, Hungary, Netherlands, Spain, United Kingdom)
- Development of solutions for improving the energy efficiency
- Calculation of returns of investment and the analysis of the solutions in terms of (industrial differences, climate zone, condition of the equipment, cooling systems, etc.) are in progress
- Re-measurements of the implemented solutions have started

Cooling performance & energy efficiency

1. Characterisation of the refrigeration systems of the food industry, and collecting the generic methods of the measurement of the efficiency of a refrigeration system and those energy saving solutions, which can be applied in general, based on the literature references

2. Identification of energy saving solutions, which were identified as the most relevant general solutions for the food and drink industry, based on the measurements carried out in the selected plants

3. Analysis of the strategies in terms of product line, plant size and climate zone considering the economic and technical feasibility as well

Cooling performance & energy efficiency (2)

1. Description of the general way of analyze the performance of a food cooling system, and collection of typical areas, where the minimization of energy losses is possible
   i. Determination of cooling performance
   ii. Identification of ways for minimizing energy losses in the cycle
   iii. Identification of places of energy losses and ways of their decrease on technological side
   iv. Description of energy efficiency methods in general

Cooling performance & energy efficiency (3)

ii. Ways for minimizing energy losses in the cycle

- Cooling temperature
  - specified by comfort feeling, industry technology demands and food hygiene requirements
- Evaporator
  - size, structure, control and operation
  - economic planning, regulation and cleaning are significantly important
- Suction line
  - size, placement and insulation
  - halogenated refrigerant - size and structure is extremely important because of oil recharge.
- Compressor
  - oversized - deficiency in electric efficiency
  - performance regulation is more effective energetically

Cooling performance & energy efficiency (4)

ii. Ways for minimizing energy losses in the cycle (2)

- Discharge line
  - important for operation safety
- Condenser
  - size and structure controls the temperature grade
  - its cleaning is essentially important
- Liquid transport pipe
  - important for operation safety
- Dosing valve
  - important role in flooding
  - electronic dosing serves more economic and more precise dosing
- Pressure control valves
  - their controlling role causes choke and bigger energy consumption

Cooling performance & energy efficiency (5)

ii. Ways for minimizing energy losses in the cycle (3)

- Liquid-vapour heat exchanger
  - a tool for subcooling prior to the dosing valve
  - causes the increase of performance and makes the process more economic
- Air cooled condenser
  - important control point mostly in case of equipment operating with halogenated refrigerant
  - electric energy consumption of fans should also take into consideration.
- Varying or constant cooling demand
  - can be solved economically by electronic regulation
  - thermostatic valves are not so expensive nowadays
- Equipment with added heat recuperation
  - heat utilization is one way of energy saving
  - significant saving can get by using a pre-cooler prior to the condenser

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Cooling performance & energy efficiency (6)

iv. Energy efficiency methods in general

- ➢ Fundamental ways to minimize the amount of energy required
  - *Avoid removing more heat than is necessary*
  - *Minimize the temperature lift of the refrigeration system*
  - *Optimize the mechanical design of the refrigeration plant*
- ➢ System optimization can benefit from the followings
  - *Using multiple smaller compressors*
  - *Selecting a combination of different compressor sizes, which allows the control system to mix and match for the best refrigeration operation and performance*
  - *Using control systems and strategies to minimize part-load operation.*

(Energy Efficiency Reference Guide, 2010)

Cooling performance & energy efficiency (7)

iv. Energy efficiency methods in general (2)

- Other operational practices and procedures
  - *Avoid overcooling or overfilling*
  - *Control the temperature to the required level*
  - *Ensure door seals are fitting and functional*
  - *Minimize air change rate*
  - *Situate the equipment to minimize external heat gains*
- Refrigeration system components and control points also can be used for overall system optimization
  - *Use condensers with modestly larger capacity readings than suggested by conventional practice*
  - *Allow the condensing temperature to float down with ambient temperature based on season of the year or time of day*
  - *Etc.*

(Energy Efficiency Reference Guide, 2010)

Strategies/solutions to be implemented

After the different measurements carried out in the selected plants the technical partners of the projects suggested some energy saving solutions for the plants. Considering the expected energy saving, the related costs and the payback period of the necessary investment, some strategies were suggested for real implementation.

For the cost benefit analysis a simplified analyses method was applied focusing on the return of investments and the time of return, because of the limited information concerning the internal factors and the individual attributes of the plants.

Cost benefit analysis of the suggested energy saving solutions

Information provided by the technical partners about each plant:

- Yearly energetic consumption of the whole cooling system (kWh/year)
- Equipment to be involved
- Estimated cost of the equipment (EUR)
- Estimated energy saving (kWh/year)

Calculated data:

» Saving (EUR/year)
» Saving (%/Yearly energetic consumption)
» Return of investment (ROI)
» Payback period (PP)

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Strategies/solutions to be implemented (2)

SUGGESTED STRATEGIES	Total strategy cost	Estimated Energy saving (kWh/year)	Saving (%/Yearly energetic consumption)	Saving (EUR/year)	ROI	PR
Installing a variable frequency drive in the ammonia pumps	4 000,00 €	4 487 kWh	0,36%	405,64 €	-0,90	9,86
Installing a variable frequency drive in a compressor of each stage	56 000,00 €	227 078 kWh	5,00%	20 527,81 €	-0,63	2,73
Replacing electrical induction motors for permanent magnet motors with VFD	400 000,00 €	454 155 kWh	10,00%	41 055,62 €	-0,90	9,74
Increasing suction pressure	16 100,00 €	65600,00	2,81%	7 642,40 €	-0,53	2,11
Installing a High Pressure Heat Pump	385 000,00 €	1830000,00	21,03%	219 600,00 €	-0,43	1,75
6. Create an operational compression stage at -37°C: Sizing and commissioning of a new compressor CK(3) with regulation "drawer + variator"	178 500 €	2 240 000	28,00%	134 400 €	-0,25	1,3
7. Improve the regulation of screw compressors according to the load: With drawer and speed variator (external conditions) -> Optimization of operating temperatures -> Optimization of condensing temperature (evaporative condenser)	178 500 €	2 240 000	28,00%	134 400 €	-0,25	1,3

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Strategies/solutions to be implemented (3)

SUGGESTED STRATEGIES	Total strategy cost	Estimated Energy saving (kWh/year)	Saving (%/Yearly energetic consumption)	Saving (EUR/year)	ROI	PR
1. Speed variator + low consumption engine: - Depending on the mechanical properties of the screw compressor: Variable speed (required oil pressure) - Depending on the electrical characteristics of the compressor: Motor EI2 with speed variator	109 200 €	360 000	18,00%	21 600 €	-0,80	5,1
4. Improvement of flow regulation water condensation	8 250 €	60 000	3,00%	3 600 €	-0,56	2,3
2. Evaporative condenser VCX320 Nota: adequacy of heat rejection capacity of the condenser a) Installation HP regulation system (VSD motor ventilator/ pump) on the evaporative condenser b) Installation regulation valve "heat recovery" on HP line discharge (regulation/ automatism)	15 300 €	202752	13,52%	12 165 €	-0,20	1,3
1. Improvement of the "isentropic compression efficiency" by the improvement of the cooling of yokes (flow regulation / pump temperature (pump n°510)).	10 500 €	171360	12%	9 667 €	-0,08	1,1
3. Floating HP system -> Installation of floating HP system on evaporative/ condensers (speed variator ventilation/ auxiliaries)	37 500 €	214200	15,00%	14 994 €	-0,60	2,5

Generic energy saving solutions

After evaluating the proper energy saving solutions for each individual plants, some of them were identified as the most relevant general solutions for the food and drink industry.

1. Installation of variable speed devices (VSD) Compressors Speed variator + low consumption engine
2. Installation of variable speed devices (VSD) Compressors Speed variator + high efficiency engine
3. Optimize compressors capacity control system
4. Control and Optimization of Cooling Cycle Temperatures and Pressures
5. Heat recovery

Generic energy saving solutions (2)

6. Repairing any important weak point in the pipe system thermal insulator from the high stage liquid separator to the low stage one (thermal insulation of pipes of refrigeration systems)
7. Switching the valves at the suction line from the services for others with a lower pressure drop (new high technology valves)
8. Resizing the whole pipe system
9. Installation of electronic valves after studying the existing expansion on TRANE Chiller (electronic valves)
10. Replacing the fans at the automatic freeze and replacing the fans at the condenser
11. Installing CO_2-NH_3 system

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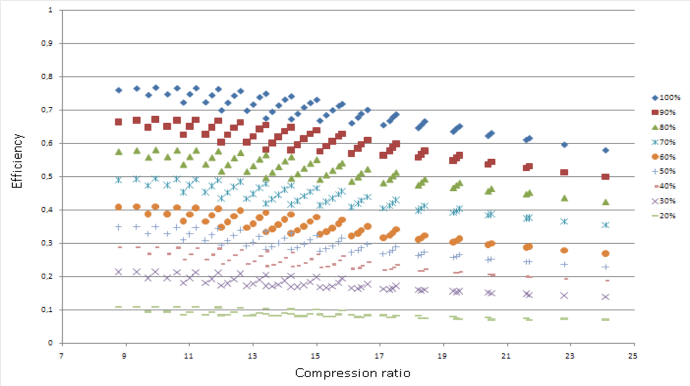
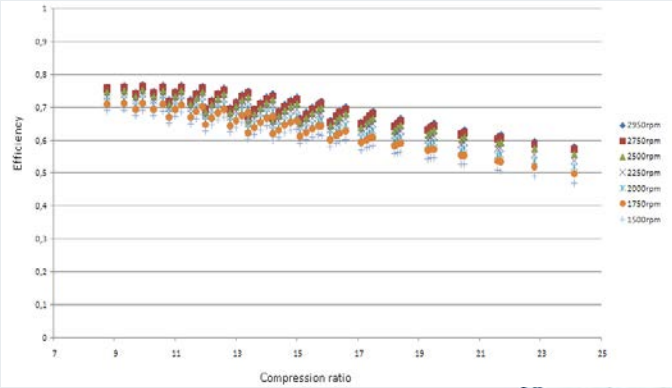
1./2. Installation of variable speed devices (VSD) Compressors Speed variator + low consumption engine / high efficiency engine

- current compressors have certain possibilities of capacity regulation - compressors allow a continuous variation of mechanical capacity (0% - 100%) → good to adjust cooling production to demand ←→ penalizes greatly the equipment performance

Normal control



Control with VSD



Compressor efficiency

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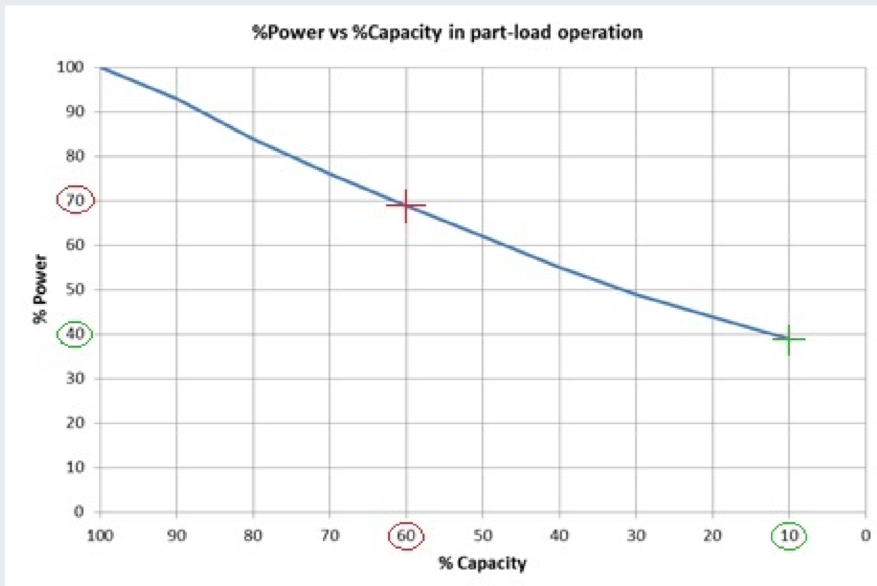
a) VSD on reciprocating compressors
   - combination of modifying the number of active cylinders in the compressor and the change in rotational speed of the motor

b) VSD on screw compressor *(better adjustment)*
   - mechanical capacity control system (0-100%) is combined with the setting of the rotational speed of the electric motor

➢ VSD devices:
   - possible to reduce the electric consumption of the equipment (almost linear to the reduction in capacity)
   - during the modification, the equipment must remain off
      - requires a high economic investment

3. Optimize compressors capacity control system

- in general, it is very important to keep screw compressors running at as highest load capacity as possible
- could be done by means of a VSD, reducing capacity with higher



Capacity and power consumption of a screw compressor

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Benefits for the refrigerant system:

- prevents part load operations, the major cause of inefficiency in a conventional refrigeration plant
- prevents compressors working in short cycles, reduction of compressor starts.
- reduces compressors running hours → lower maintenance costs

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- VSD has a little consumption that must be taken into account when comparing with a slide valve control system
- before implementation, a performance audit of the refrigeration system should be carried out to determine how the compressors are working

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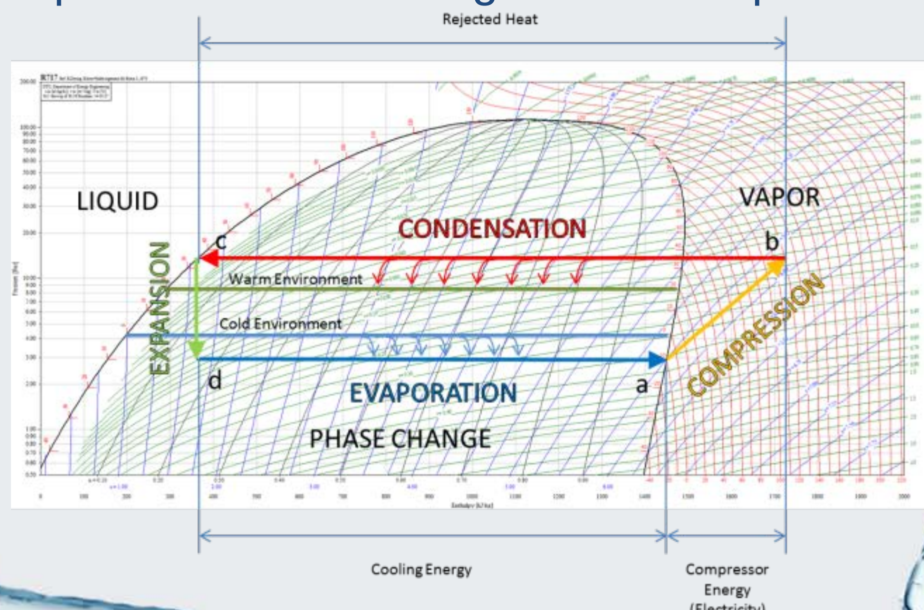
4. Control and Optimization of Cooling Cycle Temperatures and Pressures

- "vapor compression cycle" has relevance and high predominance in the food and drink industry
- COP (Coefficient Of Performance) = ratio between compressor energy and cooling energy ≈ cycle's efficiency
- the higher the compression ratio the higher the compressors' consumption



Typical single stage vapor compression cycle

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- Single stage systems
  - cold side temperature (evaporation)
    - as a general rule, an increase of 1ºC in the evaporating temperature results in about 3% energy savings
  - warm side temperature (condensation)
    - as a general rule, a decrease of 1ºC in the condensing temperature results in about 1% energy savings
- Multi-stage systems - Intermediate temperatures and pressures
  - compressors have a poor efficiency at very high compression ratios, making single-stage cycles working at very low evaporating temperatures inefficient → two-stage systems, using two compressors each facing a more manageable compression ratio

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Implementation

- technically not challenging, but depending on the specific characteristics of each plant
  - ➢ climates with higher daily of seasonal temperature
    - ✓ optimization of the condensing temperatures;
  - ➢ plants with long or complex refrigerant distribution lines
    - ✓ optimization of evaporating temperatures (by upgrading thermal isolation, reducing pressure losses and/or optimizing terminal elements);
  - ➢ plants with multi-stage cycles
    - ✓ checking for correctness of intermediate parameters

5. Heat recovery

- possible to use the cooling cycles' rejected heat to obtain some useful effect, thus avoiding additional energy expenditures
  - Sources of "recoverable" heat in a cooling cycle
    - Condenser heat recovery
    - Desuperheaters *(heat exchangers placed before the condenser)*
    - Compressor cooling heat recovery
    - Oil cooling heat recovery
  - Heat recovery means and processes
    - Heat exchangers
    - Heat pumps
    - Thermally driven cooling cycles
      - Direct use

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6. Repairing any important weak point in the pipe system thermal insulator from the high stage liquid separator to the low stage one *(thermal insulation of pipes of refrigeration systems)*
    - Selected technical options are generally:
        - No insulation of the pipes HP (liquid and discharge lines)
        - Insulation of pipes BP (suction and pipe pumping)
        - Insulation of distribution pipes coolant
    - Inadequate thickness of insulation or deterioration of existing insulation
        - increase aperditions (→ loss of low thermal conductivity and low thermal inertia)
        - increase the risk of water condensation (→ loss of vapor barrier)
        - corrosion (→ electrolysis with water condensation)

Financially

- the simplest method to choice economical insulation is by comparing the cost of energy losses with the cost of insulating the pipe
- superior insulating materials (type/ thickness) at reasonable prices which have made retrofitting or re-insulation are very attractive energy saving option

⇕

- installation of various hardware increases the labor cost in the total cost

Other hardware

- thermal insulating sleeve (glued to the tubes) / thermal insulating shells (glued to the tubes) / in situ injection of insulation (large diameter tube)
- sailing plastic material / steel or aluminum sheet for vapor barrier

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7. Switching the valves at the suction line from the services for others with a lower pressure drop (new high technology valves)

   a) Suction electronic regulator
      - electronic control allows cooling based on need
      - calculated on power absorbed at minimum allowable suction pressure, for partial charges the energy savings can reach 30 %

   b) Evaporator pressure regulator
      - frequently used when the power reduction does not exceed 40-50%
      - prevents evaporation against the risk of frost from the evaporator

      ↕

      - the efficiency of the machine is found degraded

7. Switching the valves at the suction line from the services for others with a lower pressure drop (new high technology valves)

   c) Switch off cylinders compressor

      - adjusting the cooling capacity by switching off one or more cylinders of compressors
      - moderately effective in terms of energy
      - it is possible to start the vacuum compressor to avoid peak starting current
      - the variation of the power is not continuous
      - wear of the machine is virtually identical to laden or idled

8. Resizing the whole pipe system

- good piping design results in a balance between the variations of the refrigeration system application, the pressure drop and initial cost
- energy cost is impacted by the diameter and the layout of the piping
- Good sizing and maintain a high insulation for:
  - suction line
  - discharge line
  - liquid lines
  - pipe installation in a circulation pump
    - piping „feed”

      easy installation and no negative impact on refrigeration
    - piping „return”

9. Installation of electronic valves after studying the existing expansion on TRANE Chiller (electronic valves)

- Electronic valves
  - give better control compared to analogue technology, improving the EER and the compression ratio (resulting in energy savings)
  - make the evaporator more efficient
  - are especially suitable for plants with varying refrigeration loads
  - maximize efficiency and save energy in two main ways:
    - measures pressure and temperature refrigerant more precisely
    - allows the compressor suction temperature to be reduced (decrease compression ratio and therefore energy use)

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Investment and saving

- costs depend on the size of the plant, but a typical valve would be around 2.000 € plus another 1.000 € to install
- on a 100kW cooling capacity chiller operating for 8.000 hours a year, the expected savings would be 2.000 € → paying back the investment in 1.5 years

Common problems

- in case of using electronic expansion valves, make sure that:
  - no refrigerant vapor in liquid line
  - minimum pressure drop in liquid (valve; filter…)
  - no waste in liquid line (filter drier)

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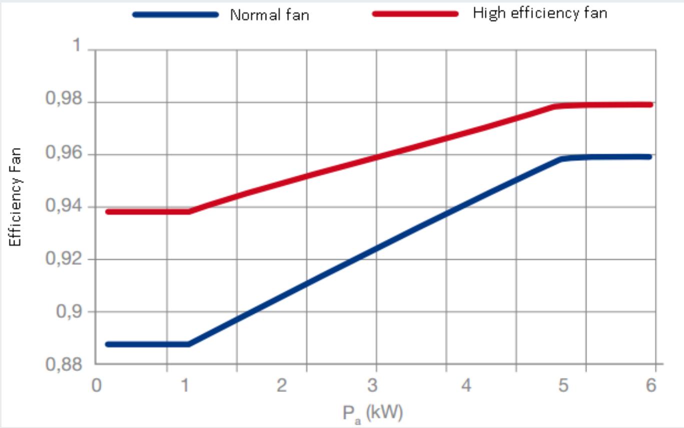
10. Replacing the fans at the automatic freeze and replacing the fans at the condenser

- high-efficiency fans on the evaporator and on the condenser need less energy to operate and generate less heat loads, thereby reducing the cooling load
- potential energy savings estimated between 3% and 15% of the electric consumption of that equipment
- during the modification
  the equipment must remain off



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11. Installing CO_2 - NH_3 system

a) CO_2 - NH_3 cascade system

- high volumetric refrigerant capacity → small CO_2 compressors with a small consumption giving big refrigerant capacities
- overall efficiency is better compared with a traditional NH_3 system, when the refrigerant temperature is below -40ºC down to -54ºC

b) CO_2 - NH_3 brine system

- no oil present in the CO_2 side → coolers have good heat transfer coefficient → smaller pipes and pumps → lower consumption than pumps for traditional brines

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Best solution

- when there is already a CO2 - NH3 cascade system
- where brine low temperatures are necessary, as the high concentration of glycol could penalize efficiency

Disadvantages and aspects to consider

- a small separate refrigeration system is required to maintain saturated pressure under the design pressure during stand still
- CO_2 hot gas defrost demands special attention, because of high defrosting pressures
- CO_2 leakage detection systems are necessary
  - difficult to implement this solution in an existing brine refrigeration system because the high design pressure makes existing equipment not valid any more

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KEY QUESTIONS FOR THE INDUSTRY

1. Are the presented solutions / strategies relevant for your sector?
2. If you know already some of these solutions / strategies and not implement them, what is the reason?
3. If you are already aware of some other solutions / strategies and not implement them, what is the reason?
4. Are there any additional feasible solutions available from / for your sector for long and short term future?
5. Is there anything that might be important related to the topic which has not been discussed?

We would be grateful if you share your opinion with us, with comments and concerns regarding the strategies explained!

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Thank you very much for your kind attention!

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