ENERGY EFFICIENCY IN INDUSTRIAL REFRIGERATION

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EUROVENT SUMMIT ANTALYA
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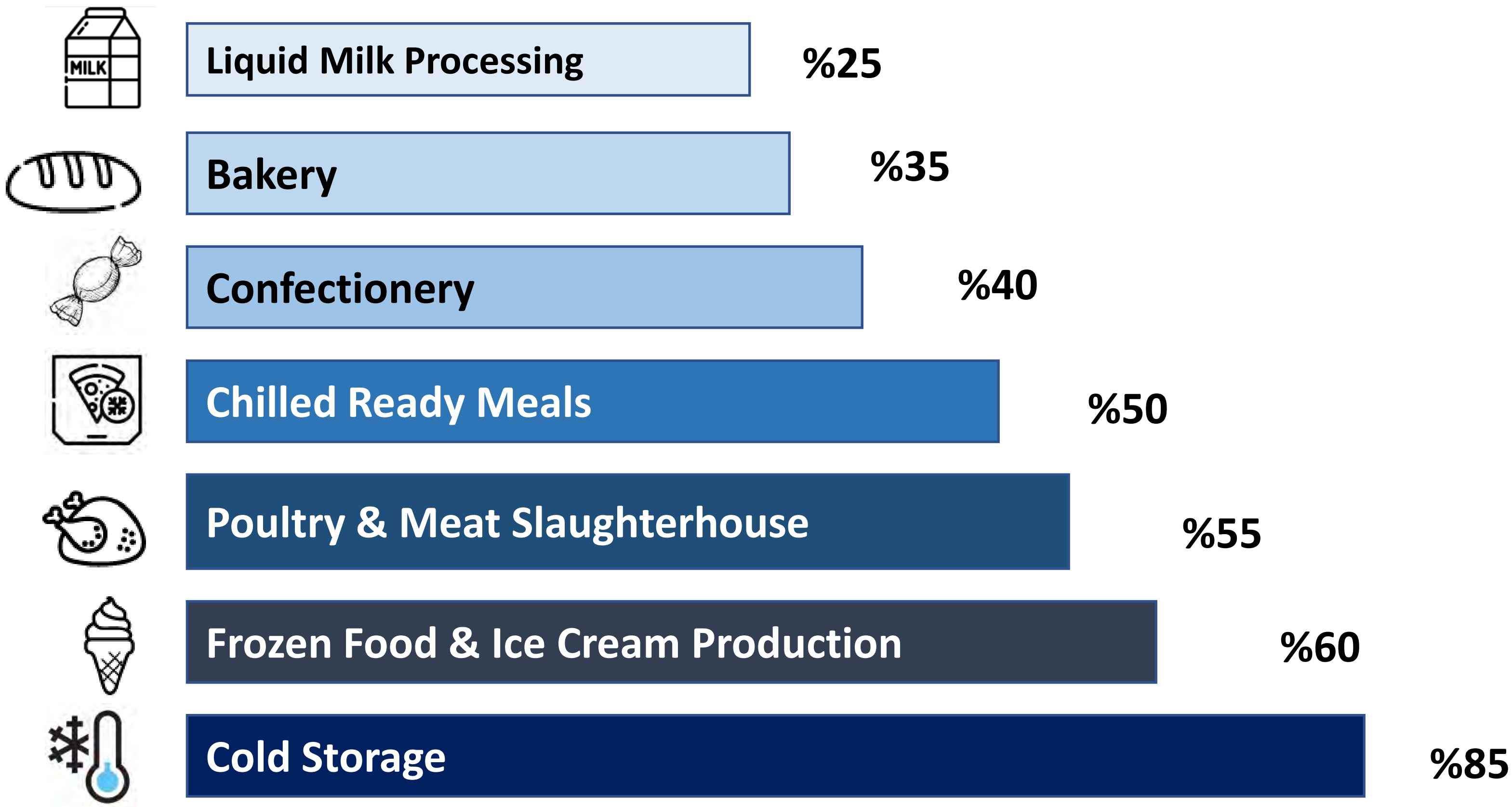
Electricity Used for Refrigeration at different Industry Sectors



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Where do we start?

Effective system design

Effective system design, considering customer needs.

The choice of refrigerant suitable for the system

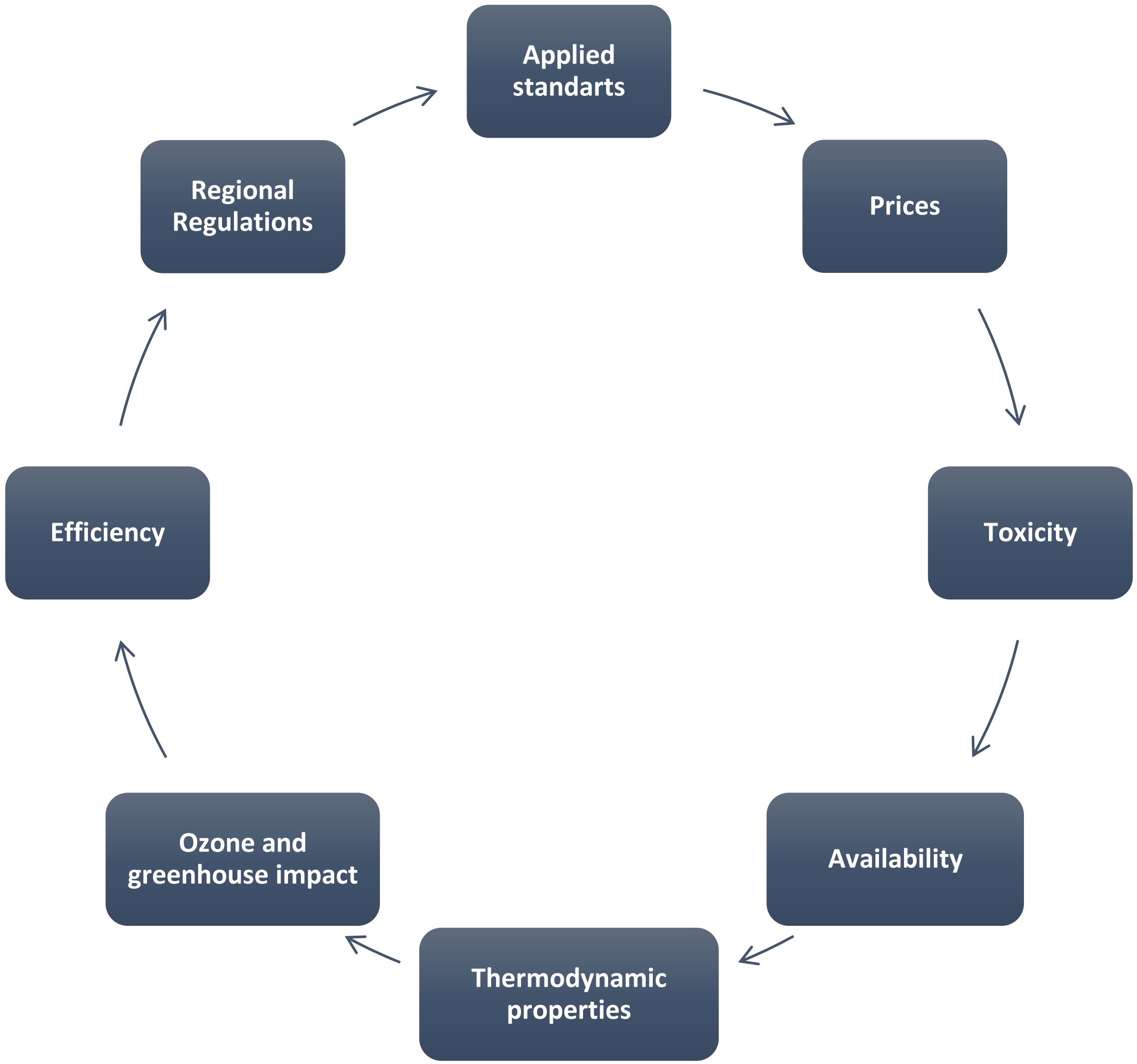
To determine the waste heat points along with the energy consumption points in this system design.

Optimize the system design to **reduce energy consumption.**

Apart from these titles, there are other factors such as;
Operating procedures, Equipment performance, Design effective control systems, Weather etc.

Refrigerants

Choosing an effective refrigerant



Refrigerants

Carbon dioxide and **ammonia** gases have always been at the forefront since the beginning of the discussions on the depletion of the ozone layer or global warming.

Let's look at a comparison of these gases in terms of energy.

Refrigerant	Evap. Press. (psia)	Cond. Press. (psia)	Latent heat (Btu/lb)[2]	Mass flow rate (lb/min)	Spec. vol. suc. vapor (ft^3/lb)	Compr. Displ. (ft^3/min)	Compr. Power (hp)	Compr. Disch. Temp. (°F)	COP
R-134a	23.6	111.2	90.13	0.89	1.95	1.74	0.290	98.3	4.60
R-125	58.5	226.4	61.98	1.51	0.631	0.952	0.327	87.5	3.99
R-717	34.1	168.5	564.93	0.12	8.197	0.981	0.282	209.9	4.76
R-744	326.9	1041.4	115.99	0.51	0.269	0.138	0.257	157.7	2.69
R-290	41.5	155.9	169.79	0.47	2.502	1.17	0.292	96.5	4.50
R-404A	52.9	206.0	77.43	1.16	0.860	0.996	0.318	96.53	4.21
R-410A	69.3	271.5	102.55	0.77	0.873	0.674	0.298	123.5	4.41
R-507A	55.0	211.6	75.13	1.20	0.814	0.977	0.321	94.7	4.18

[1] Calculation basis: 5°F evaporating and 86°F condensing temperatures. Saturated suction vapor and isentropic compression. ASHRAE Fundamentals (2005).

If there is consumption, there are saving points;

- First, find out saving points
- Then clear barriers

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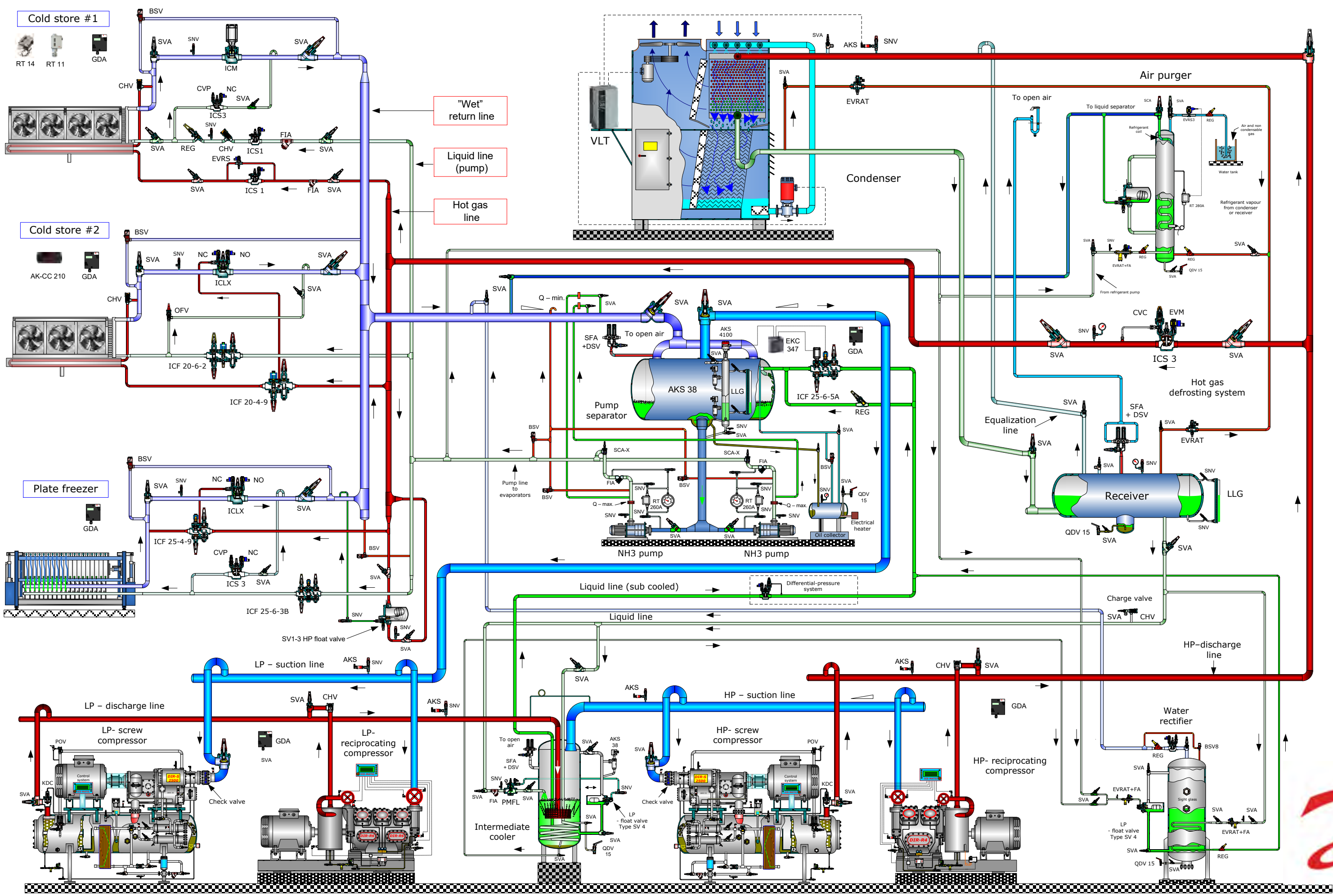
Ammonia Plant



Two-stage ammonia plant with pump separator and hot gas defrosting system - principle

Energy Consumption Points

- Compressors 80% to 85%
- Cooling fans 5% to 10%
- Condenser fans 3% to 5%
- Pumps
- Defrost system
- Automation etc.

Industrial Refrigeration Savings Opportunities In The System

- Thermodynamic design
- Choice of equipment
  (Compressors – Condensers – Evaporators-Defrost system)
- Heat recovery
- Water and air removal

Thermodynamic system design-cycle points

Cycle efficiency depends on;

- **Evaporation pressure -** Higher evaporating pressure higher efficiency. Lower DT on evaporator. Larger heat transfer area
- **Condensing pressure -** Lower condensing pressure. Lower DT on condenser. Larger heat transfer area
- **Optimization –** The capital cost versus operation cost

Compressors

The most energy-intensive part of the refrigeration process

Design considerations for efficient system design;

- Take account of variable operating conditions
- Using VSDs (Variable Speed Drives) to increase part-load efficiency significantly. It is stated in the literature that **up to 31% savings** can be achieved with correct capacity control *
- Compressor staging (multi-compressor systems) and unloading strategies. Proper staging **can reduce** annual system energy usage by **5% to 15%.**
- Reducing temperature lift (difference between the evaporating and condensing temperatures). **1°C extra temperature** lift will **add 2% to 4%** to the energy used by a plant.
- Increasing suction pressure and/or decreasing discharge pressure

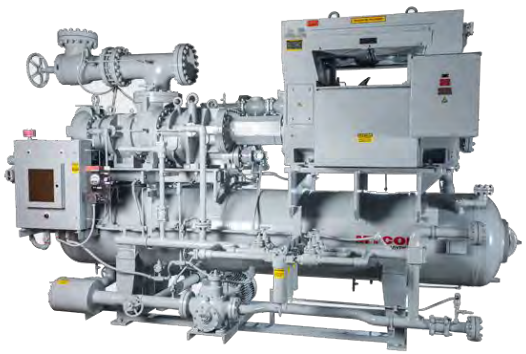
* Javier Cárcel-Carrasco * , Manuel Pascual-Guillamón and Fidel Salas-Vicente, Improve the Energy Efficiency of the Cooling System by Slide Regulating the Capacity of Refrigerator Compressors, Appl. Sci. 2021, 11, 2019. https://doi.org/10.3390/app11052019

Compressors

Choice of the right type of compressor for a specific application

- Screw versus reciprocating. Depends on the application. There is no right choice for every application.
- In general reciprocating has better real-life efficiency for small-medium size plants with dynamic load profiles.

Reciprocating Compressor



Screw Compressor

Compressors

Reciprocating Compressors

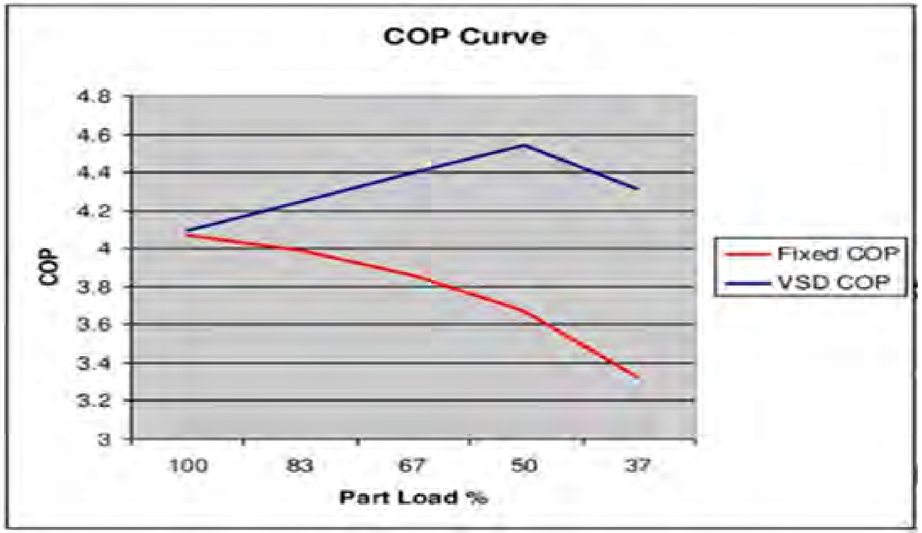
- Reciprocating compressors with cylinder unloading have very good part-load efficiency
- Compressor staging (multi-compressor systems) and unloading strategies help manage suction pressure
- Generally, more unloading stages allow better control and load matching

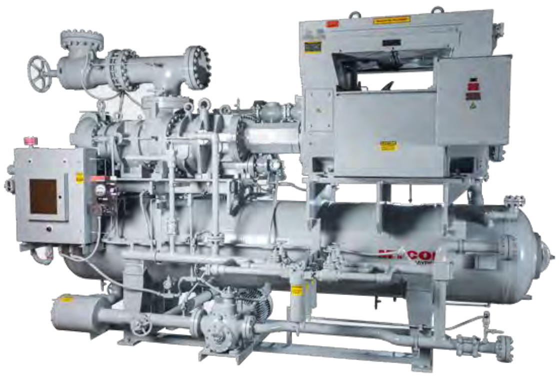
Compressors

Screw Compressors

Screw compressors have poor part load performance

- Screw compressors using slide valves should be base
- Loaded most of the time if possible
- Variable frequency drives increase part-load efficiency significantly





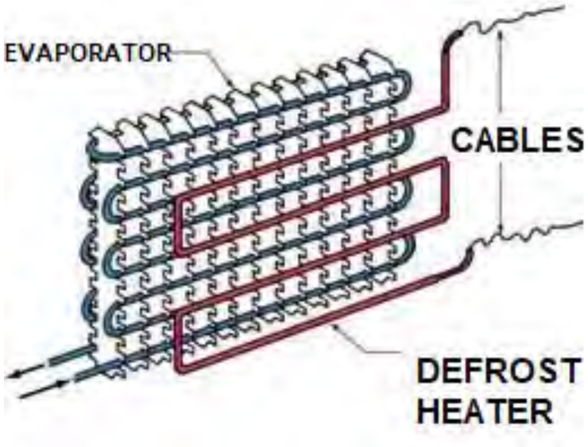
Evaporator

- Use the **most efficient motors** possible for the application
- For smaller fans, replace single-phase shaded pole motors with **electronically commutated motors (ECMs)**
- Use **automatically controlled defrost** (reduce annual system energy usage by about 3%)
- Use **electronic expansion valves** where possible, especially on small systems.
- **Increasing suction temperature** by 1 C will reduce input power by approximately 2%
- **VSD control of fans** in cold stores is another valuable source of power savings– up to 2% annual system energy savings

Evaporator

Defrosting

should be carefully controlled



- Select hot Gas defrost system
- Most defrost methods increase refrigeration loads by adding heat to the refrigerated space
- Minimize defrosting frequency and duration,
- Prevent heat gain in cold room during defrosting. Use defrost Flap

Actively managing to defrost frequency and duration can reduce annual system energy usage by about 3%

Condenser

Choice of the right type:

- Air-cooled, water-cooled with a cooling tower, evaporative
- For hot and dry climates evaporative type has the advantage.
- The efficiency of the evaporative condenser depends only on the wet bulb temperature
- Evaporative types have always better efficiency than air-cooled and water-cooled. For large systems, it is the common choice

Evaporative Condenser

Air-cooled Condenser

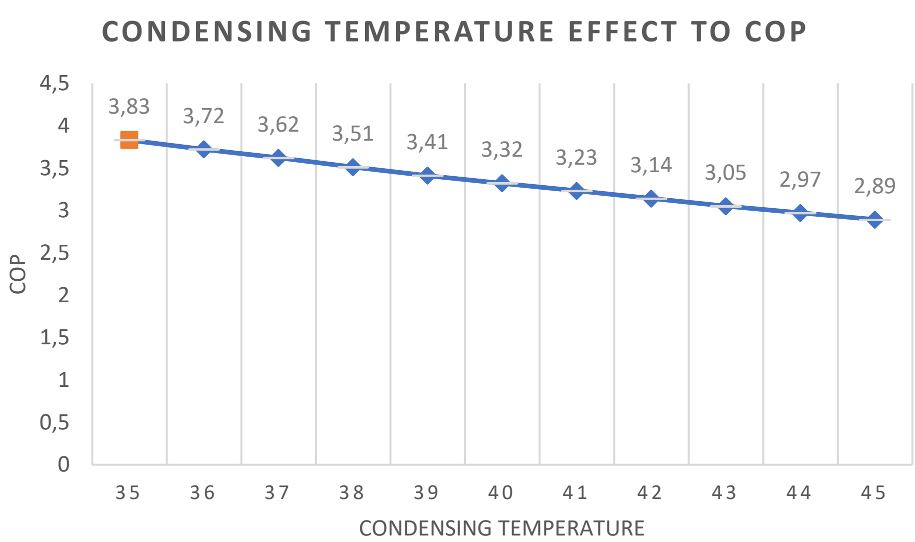
Condenser

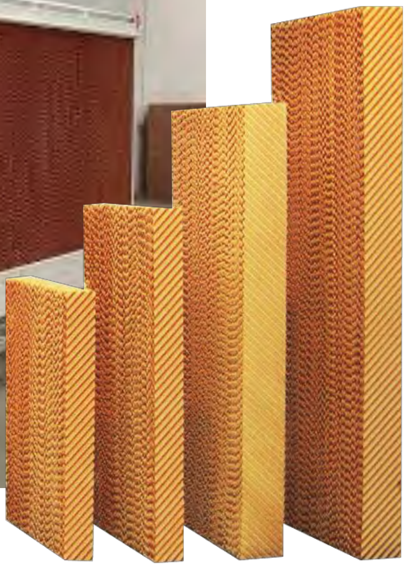
Saving points in the condenser

- Capacity control in low ambient temperatures
- Speed regulation or on-off control of condenser fans
- Floating point condenser pressure control for evaporative type condensers. No fixed condensing pressure setting. The optimum condenser pressure setting depends only on wet bulb temperature. Saves fan power at low humidity ambient conditions.
- Use adiabatic pad for air cooled condenser

Condenser

Use evaporative pad for air cooled condenser to decrease condensing temperature





For every 1°C decrease in condensing temperature, energy use is reduced by %2

Heat Recovery

Apart from equipment consumption, there is waste heat in the system. if indirect use is provided from these waste heats, the efficiency of the system will increase. This will contribute to carbon footprint consumption.

There are four areas in refrigerant systems where heat can be recovered;

1. The condenser
2. Superheat in the discharge gas
3. Oil coolers
4. Compressor jacket

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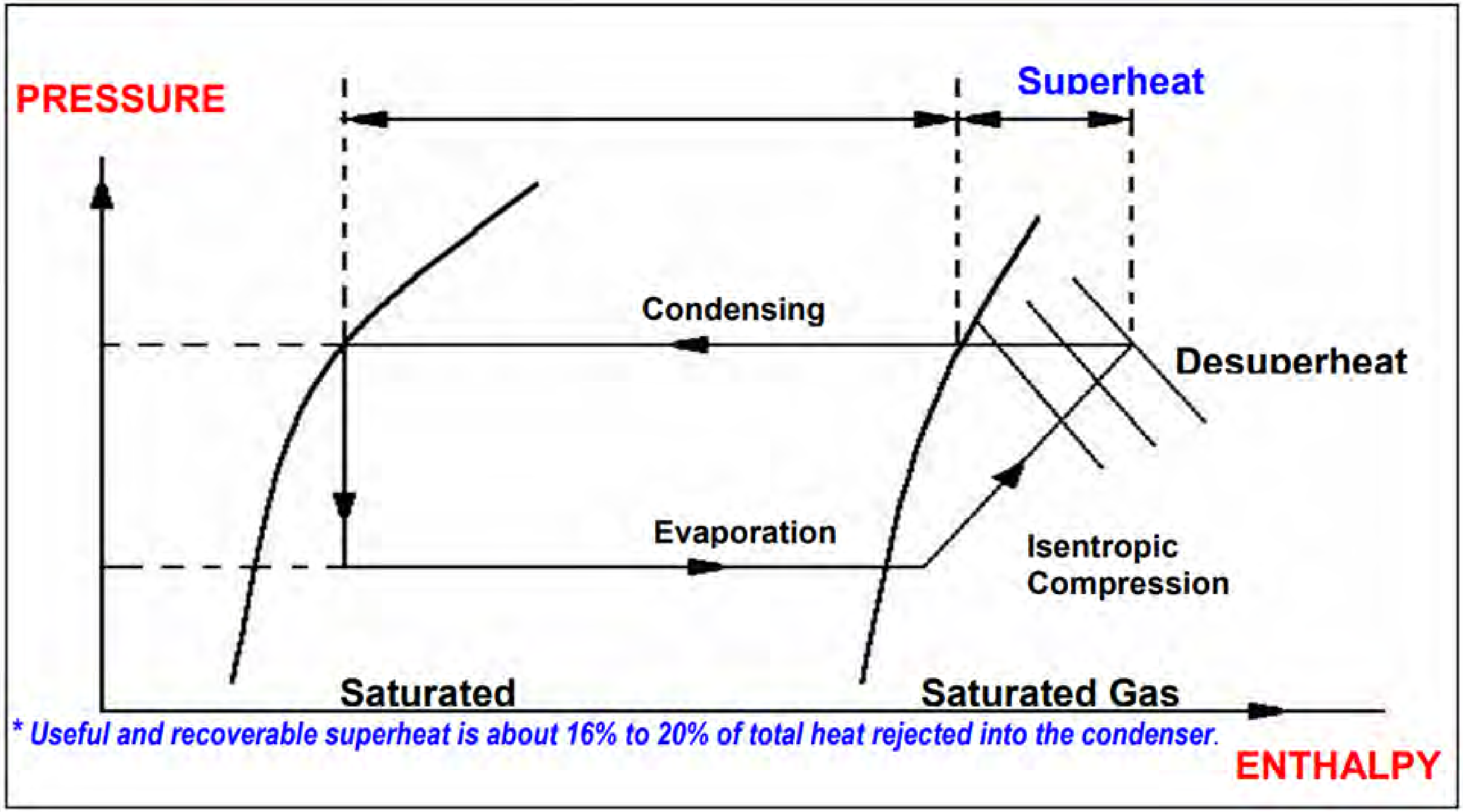
Heat Recovery



* *Useful and recoverable superheat is about 16% to 20% of total heat rejected into the condenser.*

Air Removal

- **Air reduces the heat transmission** in the condenser and evaporator. The result is high pressure in the condenser and evaporator.
- **1°C increase** in condensing temperature means; **%1 lower cooling capacity - %3 higher power consumption - %3 lower COP**
- **1°C decrease** in evaporating temperature means**(look at the table)**

Evaporating temperature

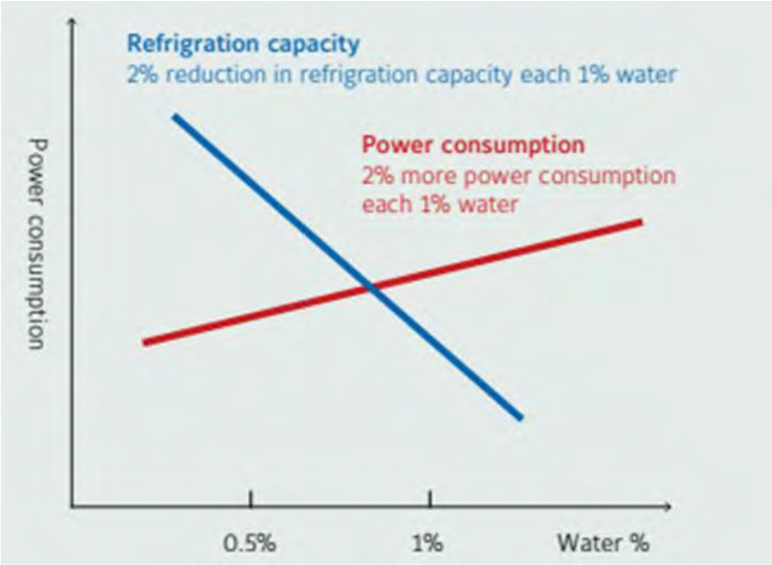
1°C decrease mean approximately

At	Capacity	COP	Power
+10°C	-3.6%	-5.0%	+5.2%
0°C	-4.0%	-4.3%	+4.5%
-10°C	-4.4%	-3.8%	+4.0%
-20°C	-5.1%	-3.5%	+3.6%
-30°C	-5.5%	-3.9%	+4.1%
-40°C	-6.5%	-4.4%	+4.6%
-50°C	-7.3%	-5.0%	+5.2%

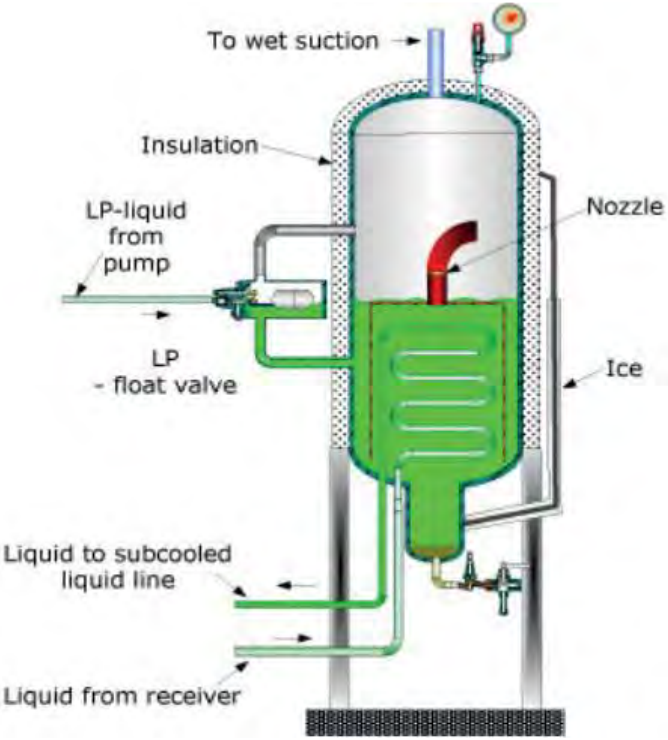
Effects of water in ammonia refrigeration plant

-Reduction of refrigeration capacity

- Increase in power consumption



Use Water Purger

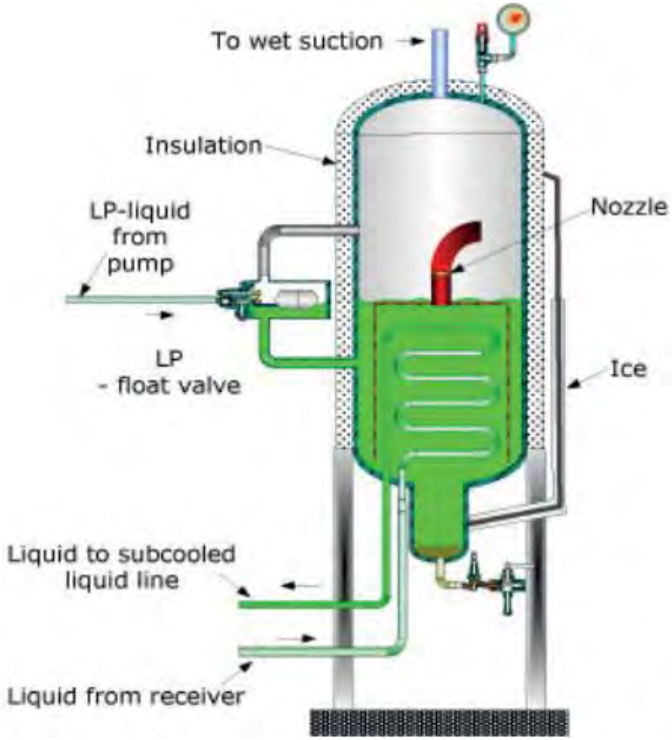


Effects of water in ammonia refrigeration plant

Consequences of water in ammonia systems

- Increased power consumption
- Reduced refrigeration capacity
- Lower evap pressure at the same temperature
- Oil is broken down and creates nitro compounds
- Nitro compounds can dissolve in the NH_3 and colour it
- Leaks due to embrittlement of O-rings and gaskets
- Leaks due to galvanic corrosion
- Wear and tear on valves and controls

Use Water Purger



Cold rooms

«Reduce unnecessary refrigeration loads»

- **Kept closed the doors** as much as possible and do not open them unless necessary.
- There must be a **uniform airflow** in the room
- Cold storage should be **stacked correctly**, and the excess product should not be placed.
- **Prevent cold air** from escaping out of the room
- Panels and doors must be **sealed**.
- Upgrade lighting to **LED with auto control**.
- The **temperature of the product** entering the cold storage should be monitored.
- **Reduce heat gain** with correct isolation

Thank you for your time