The Original Plate & Shell Heat Exchanger

First sustainable technology. Custom-made for your business.
4. Refrigeration process comparison:
Heat Exchangers in refrigeration and heat pumps

Valtteri Haavisto, Customer Service Director
Company

- Manufacturer of Plate and Shell heat exchangers (PSHE)
- Established in 1990
- Privately owned
- Subsidiary companies in UK, Germany, USA and China
- Over 95% products exported from Finland
- Over 50,000 units in operation worldwide
- Yearly ~2000 units installed to Industrial Refrigeration or Liquefied Gas plants
Vahterus Product

- Fully welded plate and shell heat exchangers
- Circular plates inside round shell
- Plates are automatically fully welded to each other
- Heat transfer happens in corrugated plate channels • highly turbulent flow
- Shell around the plates protects the environment from any possible leaks
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Household, Commercial and Industrial Refrigeration

Household Refrigeration:
- Fridge, Freezers, Heat Pumps
- Capacities typically up to 20kW
- Heat is transferred from refrigerant to air, very simple systems and small volumes

Commercial Refrigeration:
- Supermarkets, cold rooms, small air conditioning systems
- Typically air blast coolers or small centralized cold distribution
- Capacities up to 200kW
Household, Commercial and Industrial Refrigeration

Industrial Refrigeration
- Centralized system, cold energy distributed with water, glycol or CO2
- Cold storages, ice rinks, freezing plants, AC system
- Capacities starting from 150kW
- Largest cooling capacity of single evaporator for Vahterus is 9500kW
  (System included 3 similar units, enduser is Chemical producer)

Same process fundamentals are valid for all systems:
Compress, condense, expand, vaporize!
Used Refrigerants

- The selection of the used refrigerant in the system is highly important:
  - GWP (Global Warming Potential) of the selected fluid
  - Flammability and toxicity
  - Thermodynamic properties: Heat transfer performance, viscosity, latent heat, pressure at condensing temperature
  - Chemical stability
  - Oil solubility

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<td>744 (CO2)</td>
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System Description – Single stage
System Description – Two stage

A = liquid sub-cooling high pressure system.
B = discharge gas cooling.
C = ΔT between evaporating temperature of HP-system and condensing temperature of LP-system.
Condenser

Selection criteria for condenser type:
- Used secondary side media: air, water, glycol
- Condensing pressure
- Possible limits in refrigerant charge

Refrigerant Condensing
- Target to close approach temperatures between condensing and secondary side ‡ Saves Energy!
- Condensing happens mainly through the condensate film
- Typically refrigerant gas is superheated when entering the condenser, so gas cooling needs to be calculated in
Condenser: Air Cooled (Dry Cooler)

- Commonly used in AC systems
- Mainly tube type coil heat exchanger based on convective heat transfer
- Air flow passes the tubes
- Cheap and easy solution
- High condensing temperature
- Large refrigerant charge, especially in winter time
- High Fan power
- Heat transfer coefficient U: 20..40 W/m²K
Condenser: Evaporative Condenser

- Improved heat transfer against air cooled
- Base on water evaporation on the air side that enhances heat transfer
- Heat transfer part can be made from metal or plastic
- Air flow passes the tubes, water sprayed from the top
- Water treatment important: bacteria like legionella etc possible
- High condensing temperature
- High Fan power
- Heat transfer coefficient $U$: 200..500 W/m^2K
Condenser: Water or Brine Cooled 1

- Plate type heat exchangers mainly used in industrial solutions with Ammonia and CO2
- Fully welded or semi-welded plate heat exchanger used for ammonia
- Brazed plate heat exchangers used for small HFC systems (R134a etc)
- Shell and Tube used still for large HFC systems
- Heat transfer coefficient for water cooled ammonia condensing
  - Shell and Tube 1500 – 2000 W/m2K
  - Plate and Shell 2500 – 4500 W/m2K
- Cooling water must be available
- If water can’t be used because of freezing risk, brines can be used:
  Ethylene Glycol, Propylene Glycol, CaCl, Alcali etc.
Condenser: Water or Brine Cooled 2

Example of Ammonia Condenser to AC system:
- Capacity 1200kW
- Ammonia temperature in 100C, condensing 36C (13barg)
- Water inlet temperature 26C, outlet 32C
- Plate & shell HE U value 3000W/m2K
  - Alfa for ammonia desuperheating and condensing ~5500W/m2K
  - Alfa for water ~11800W/m2K
  - Stainless steel plate thickness 0.8mm
- Surface area for such unit is ~51m2
- Can be used on top of condensate receiver or high pressure float valve
Condenser: Cascade Condenser

Cascade Condenser is a condenser with refrigerant evaporating on the other side.
- Cascade system is used especially at lower evaporation temperatures like freezing of meat, fish, ice-cream and in snow/ice – build ups.
- Cold evaporation temperature is better for denser gas (like CO2)
- Liquid heat transfer decreases at low temperature due to the viscosity increase, that’s why better to use phase changing media
- Typical system works with NH3 and CO2. NH3 is used as a refrigerant and CO2 as brine.
- No temperature difference in evaporator side: ideal for ice rinks
Condenser – things to notice

What to remember:
- Ensure always good condensate draining from the condenser
- Condenser is located after compressor, pulses exists
- Keep the water quality in control
- Remove all the non-condensable gases
- Parallel heat recovery condensers can be good option for energy saving ‡ make sure that condensers do have similar pressure drop.
Evaporators

Selection criteria for evaporator type:

- Heat is removed to refrigerant
- Used secondary side media: air, water, glycol
- Requirements for outlet gas quality
- Possible limits and need for refrigerant charge
- Refrigerant type: mist or droplets, saturation glide

Refrigerant Evaporation:

- Is either Flooded (Saturated) or Dry (Superheated)
- Pool boiling or forced convection boiling
- Oil is typically partly in evaporator and that decreases heat transfer
System Description – Single stage DX (Dry expansion)

- Dry expansion is an evaporator where refrigerant evaporated completely and is superheated (3 – 8K)
- Always once through type heat exchanger
- DX evaporator is used mainly for industrial made refrigerants (R134a etc)
  - Droplets are difficult to separate due to the small droplet size (= mist)
  - Small latent heat ⇒ easier control
- Worse heat transfer, because gas heat transfer
- No droplet separator needed
System Description – Single stage Flooded

- Can be pool type and forced convection evaporation
- Outlet from the evaporator is wet and partly returned back to the evaporator
- Typically 20 – 50% of the liquid evaporates
- Droplets are separated with a demister (Surge Drum)
- Flooded evaporators are natural (Thermosyphon) or pump driven
- High heat transfer due to fully wetted surfaces
- Mostly used method for natural refrigerants
- Quick response to capacity change 0 – 100%
- Smaller temperature differences
Evaporator: Liquid Cooler 1

- Liquid can be water or freezing resistant brine
- Mostly used heat exchanger for the duty
  - Welded, brazed, gasketed plate heat exchanger and shell and tube units
- Compressor always requires droplet free gas
  - Superheating
  - Droplet separation
- Feed is controlled by expansion valve or high pressure float valve
- Heat transfer coefficient for water coolers with ammonia or R134a flooded evaporators:
  - Shell and Tube 200 – 700 W/m2K
  - Plate and Shell 1500 – 2300 W/m2K
Evaporator: Liquid Cooler 2

Example of Water Cooler with Ammonia in AC system:

- Capacity 1000kW
- Ammonia evaporation temperature 3C (3.8barg)
- Water inlet temperature 12C, outlet 6C (Typical air cooler temperatures)
- Plate & Shell heat exchanger U value 2500W/m²K
  - Alfa for ammonia pool boiling ~4800W/m²K
  - Alfa for water ~6800W/m²K
  - Stainless steel plate thickness 0.7mm
- Surface area for such unit is ~74m²
- Special construction with pool boiling type evaporation, used for small charge ammonia system
- Modern small charge ammonia systems < 100kgNH₃ / 1000kW Cooling
Evaporator: Air Blast Cooler

- Designed to remove the heat from air to refrigerant
- Sustains adequate humidity in the cold room
- Air circulation can be natural or forced convection (Fan)
- Finned tube - type most common, refrigerant on pipe side
- Air freezes to heat transfer surfaces, defrosting required:
  - Natural, electric or hot gas defrosting
  - Manual hot water defrosting also in batch processes
- Heat transfer coefficient for Air blast coolers, Dry Expansion
  - Natural Air Circulation 5…10 W/m2K
  - Forced Air Circulation 15…25 W/m2K
Evaporator: Oil Removal

- Some amount of compressor is collected to evaporator
- Oil accumulates to evaporator if not removed
- Oil can be soluble or non-soluble to refrigerant
  - Non-solubles removed by gravity
  - Solubles removed by separate devices
- Oil pour point needs to be at least 10K lower than evaporation temperature
- Oil layer on heat transfer surfaces works like an insulation
  - 0.1mm layer on top of tube reduces U-value from 1000 to 600W/m²K in S&T heat exchanger

Fig. 10.20 Basic system diagram

1 = oil separator
2 = oil return
3 = refrigerant with oil
4 = expansion valve
5 = oil with refrigerant
6 = oil back to compressor
7 = oil free refrigerant
Evaporator – things to notice

- Energy efficiency: how small temperature difference is best?
- Vapor Quality entering the compressor
- Liquid level in evaporator, too low level decreases the performance
- Oil removal and correct quality
Thanks!

- Questions and Comments?

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