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# The Original Plate & Shell Heat Exchanger

**First sustainable technology. Custom-made for your business.**

# Steam Generation with heat pump

# - Vahterus heat exchanger solution

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# Company Introduction

- Inventor and leading manufacturer of fully welded Plate and Shell heat exchanger (PSHE)
- Established in 1990
- 700 employees in the group
- Main location in Finland
- Over 80 000 units in operation worldwide

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# Plate and Shell Technology

- Fully welded plate heat exchanger
- Round plates inside a round shell
- Plate and Shell heat exchanger (PSHE)
- Plate pack can be placed into the shell according to the need, enabling eccentric design and customized shell nozzle orientations
- Design temperatures -190C to +550C
- Design pressures FV to 150barg

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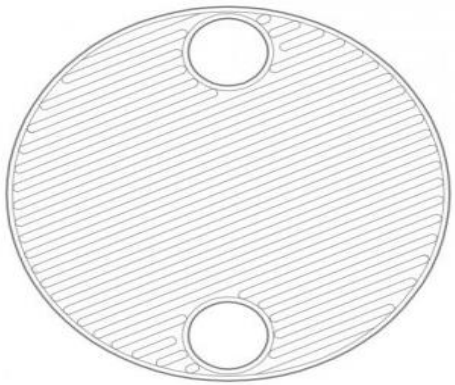
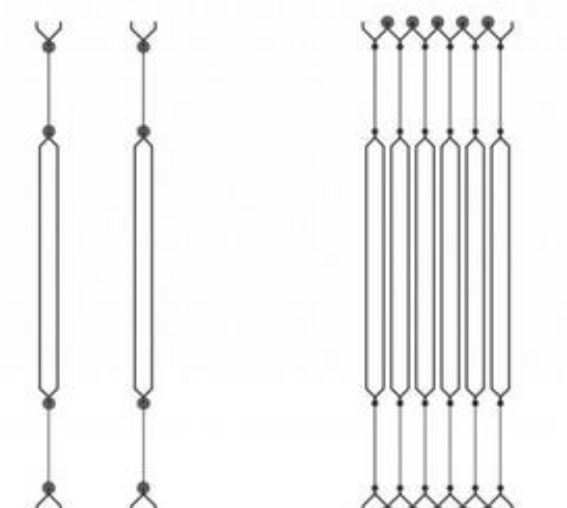
# Plate and Shell Technology

- Round plates are welded from perimeters and port holes
- True countercurrent flow

- Heat exchangers are designed individually to each cases. Vahterus uses inhouse selection software.

- Calculation methods verified with intensive testing:
  - Vahterus testing (single and two-phase)
  - HTRI testing





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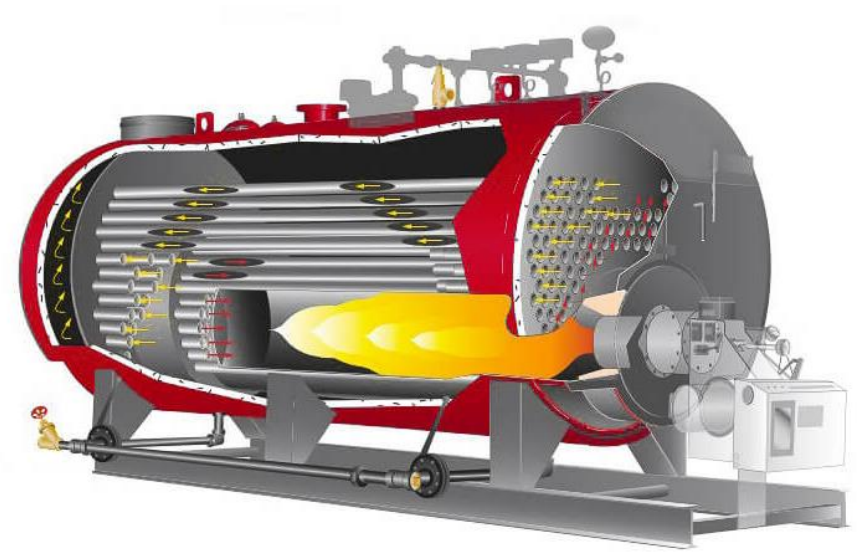
# Generating Steam with heat pump

- Steam is traditionally generated in boiler by burning oil, gas, biomass etc.
- Heat pump can be used to generate steam from lower temperature heat sources
- Heat pump main features are similar than in traditional water heating system, but some differences are present



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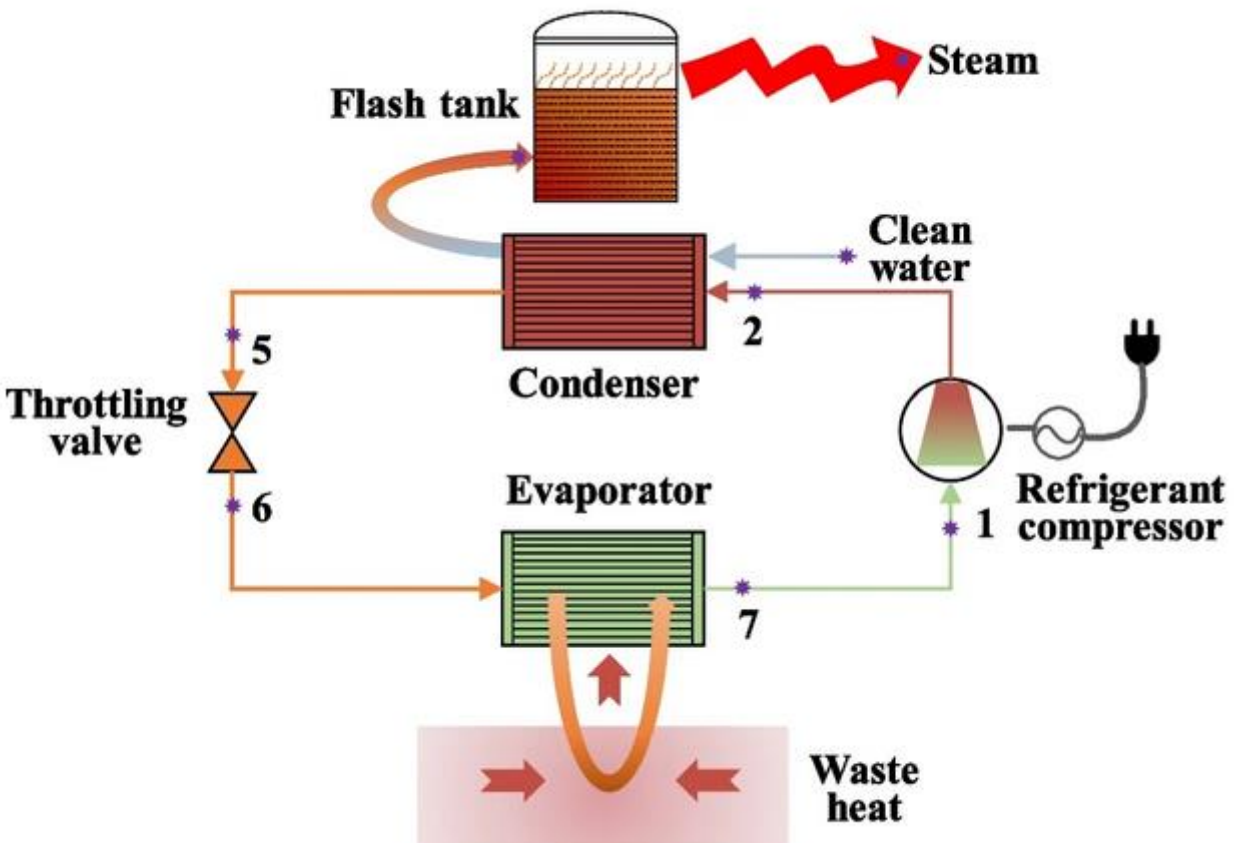
# Key questions when designing the steam generating heat pump

- What is the needed steam pressure?
- What is the heat source?
- What refrigerant should be used?
- Is it direct or in-direct steam generation?

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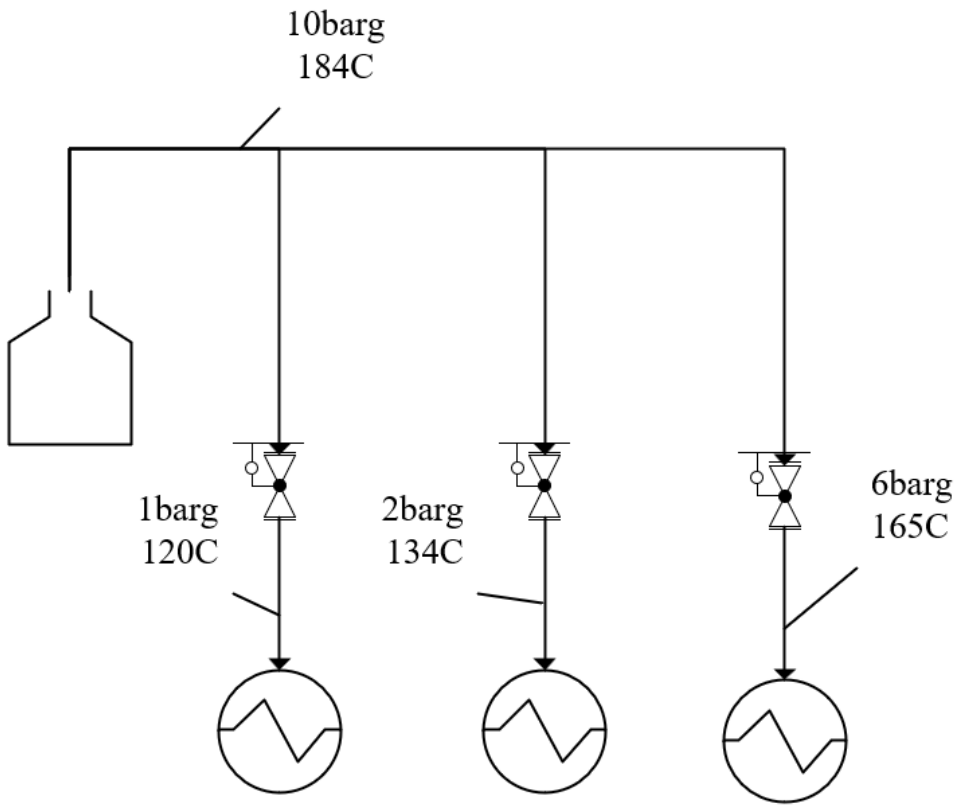
# Steam pressure - heat pump considerations

- Traditionally, steam pressure (temperature) has not affected to the boiler efficiency
- Heat pump efficiency is highly dependent on temperature lift

→ steam pressure is the most critical effect to COP

- Typical steam systems do have steam lines and pressure reduction valves to different steam users
- Consider what pressure is really needed from steam generating heat pump

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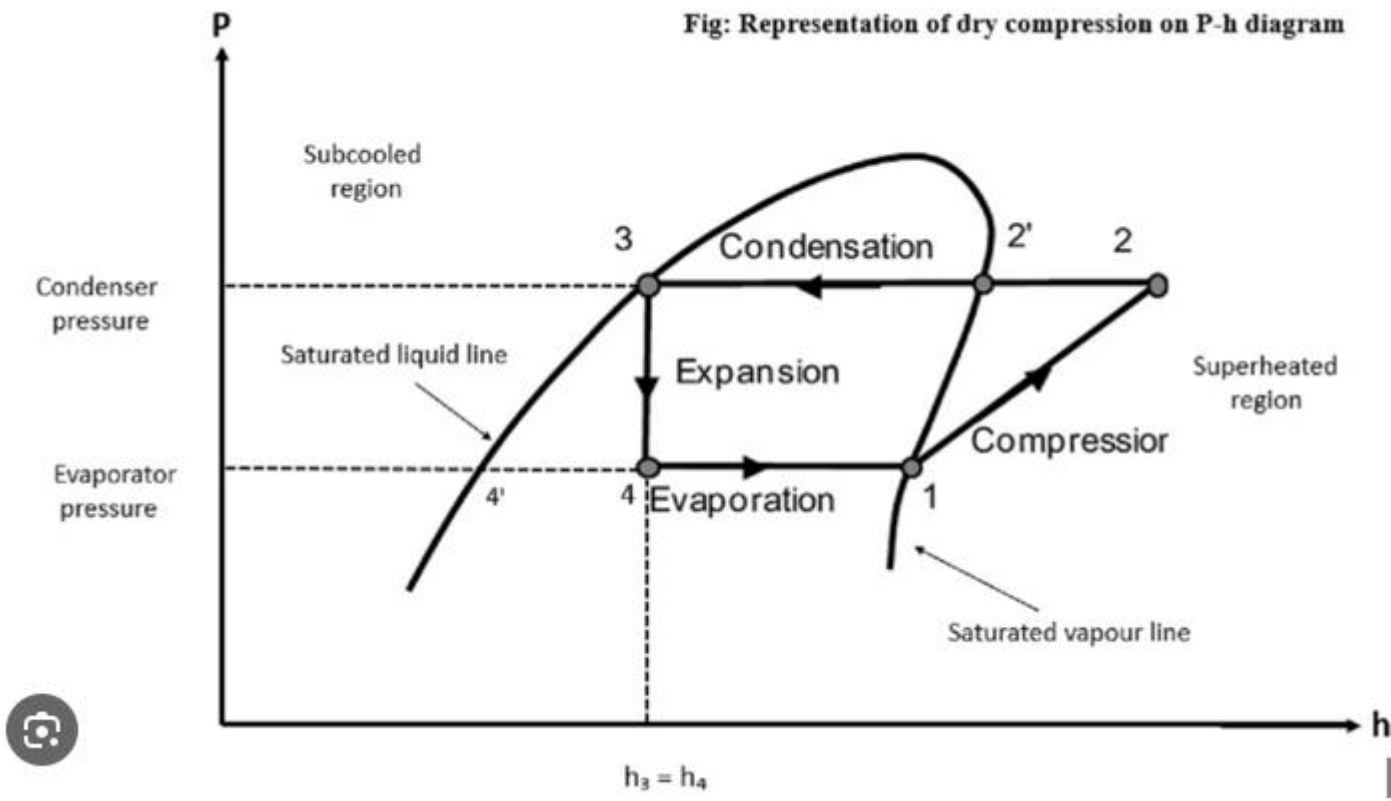
# Source temperature - heat pump considerations

- Source can be gas, liquid or condensing gas
- Quality of the source liquid/gas to be checked in case of fouling medias
- Source temperature will also have direct effect to COP
- Different heat pumps do offer different lift possibilities

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# Source temperature - heat pump considerations

Example of source temperature effect to COP indicated in the table:

- Butane (R600) refrigerant
- Steam at 110C
- 10K temperature different on the source side

- Different refrigerants are having different characteristics, but always high lift causes low COP

| Source inlet T (C) | COP |
|---|---|
| 40 | 1.5 |
| 50 | 1.9 |
| 60 | 2.4 |
| 70 | 3.2 |

For indication only. Real COP of the heat pump depends on the equipment and manufacturer

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# Refrigerant selection

Refrigerant selection to any heat pump should have following selection criteria:

- Environmental compatibility
- Temperature range
- Pressure level
- Volumetric heat capacity
- COP
- Toxicity/Flammability
- Cost / Availability


Development of Refrigerants Used, © Fraunhofer IEG 2024

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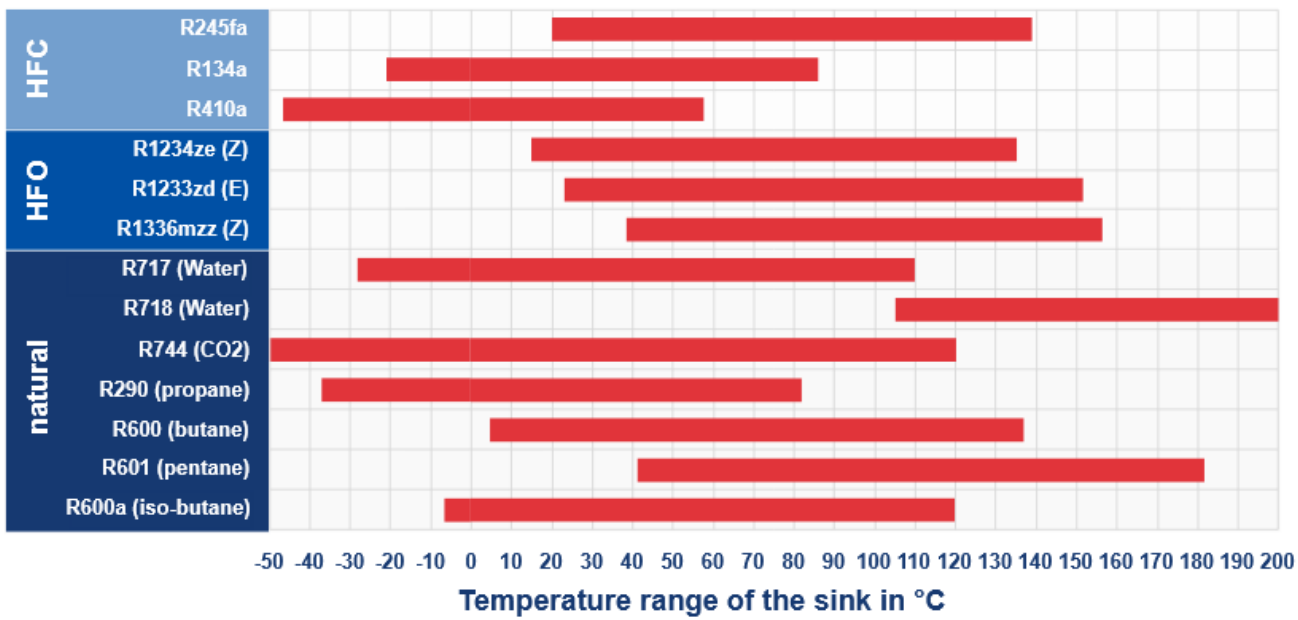
# Refrigerant selection

- Steam generation requires more latent heat from refrigerant
- Lighter hydrocarbons are option for high temperature steam generation (>120C)
- Condensing pressure at high temperatures limits use of some refrigerants
- What is the future of the selected refrigerant?

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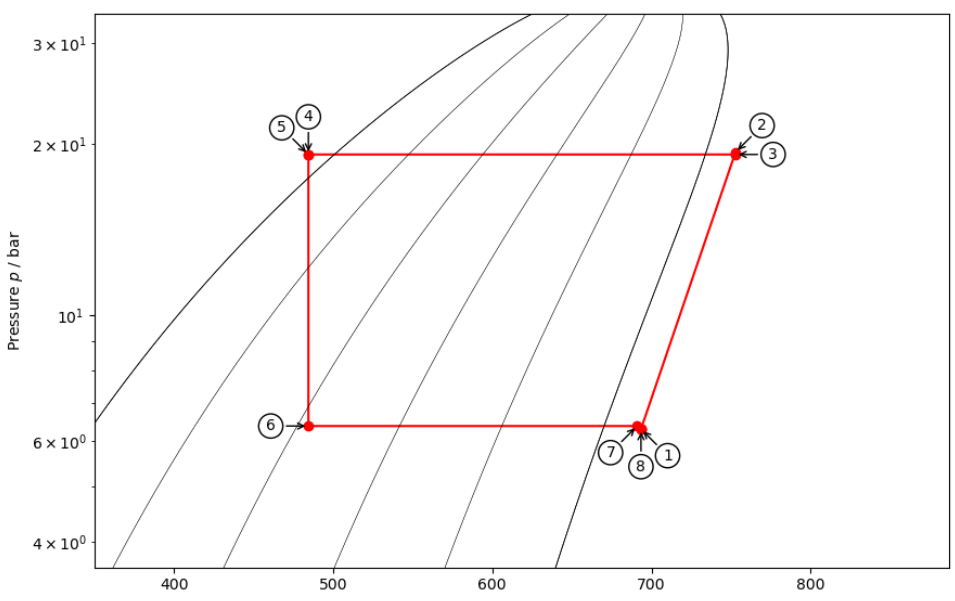
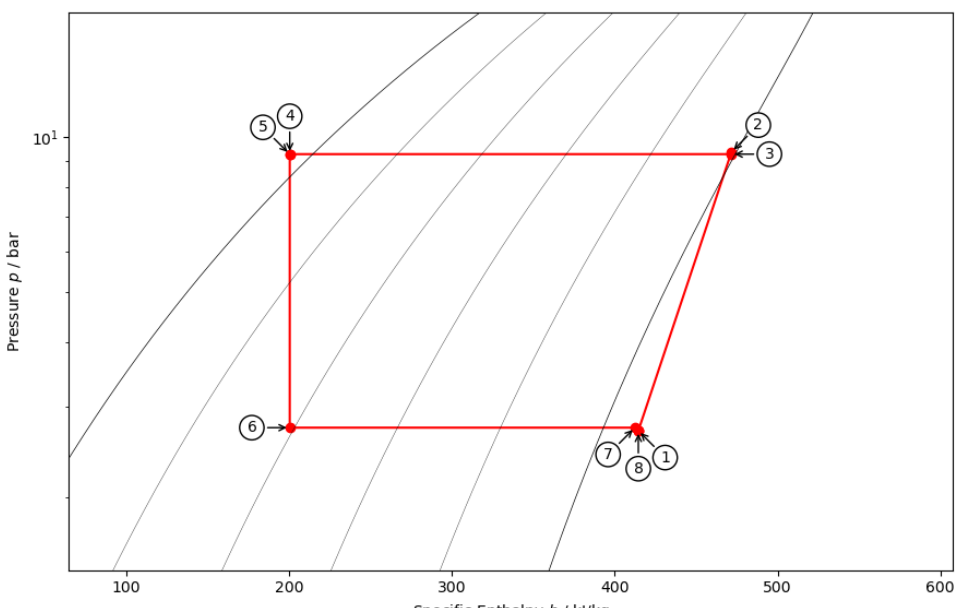
# Refrigerant selection

Same process conditions for different refrigerants

Butane (R600)




Iso-pentane (R601a)

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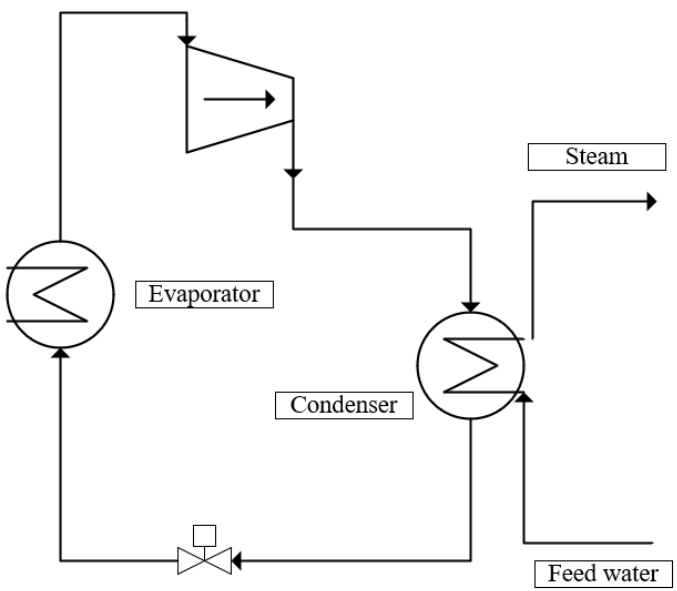
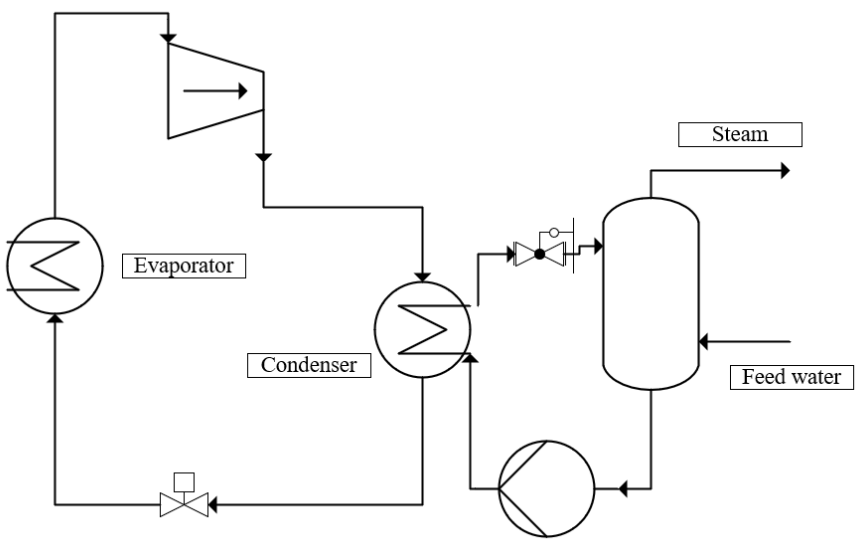
# Direct or in-direct steam generation

Direct steam generation




In-direct steam generation

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# Direct or in-direct steam generation

Direct steam generation

- Does not require external vessel and pump
- Higher COP
- Requires heat exchanger designed for steam generation
- Not possible to utilize “standard” heat pump system

In-direct steam generation

- “Standard” heat pump configuration with liquid heating can be utilized
- High water flows required
- Suffers from lower efficiency due to demand for overheating the water to be able to flash

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# Direct or in-direct steam generation

Comparison:

- R600 (Butane) heat pump
- Steam 1.5bara
- Evaporation at 50C
  - Source temperature ~60C

| | Direct | In-direct |
|---|---|---|
| **Condensing temperature** | 115C | 122C |
| **COP** | 2.56 | 2.14 |

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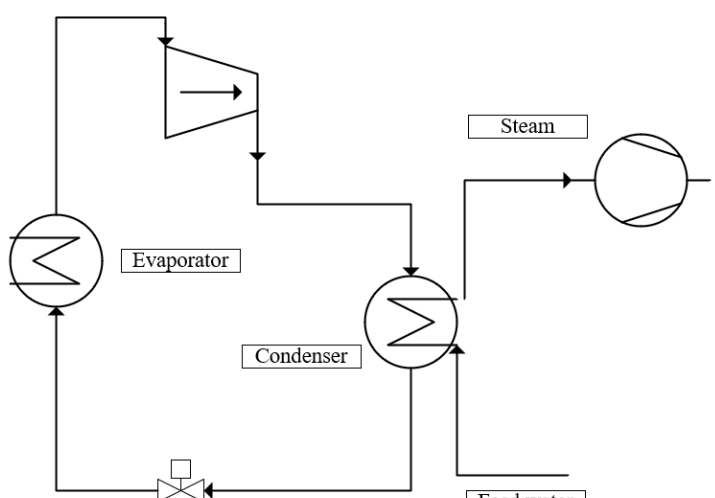
# Direct or in-direct steam generation

Things to consider:

- Similar ammonia heat pump producing steam could deliver ~85C steam
- Significantly better COP
- Rest of the pressure can be increased with Mechanical Vapor Recompressor (MVR)

| | Direct (R600) | In-direct (R600) | Direct (NH3) |
|---|---|---|---|
| **Steam** | 1.5bara | 1.5bara | 0.6bara |
| **Condensing temperature** | 115C | 122C | 90C |
| **COP** | 2.56 | 2.14 | 4.61 |

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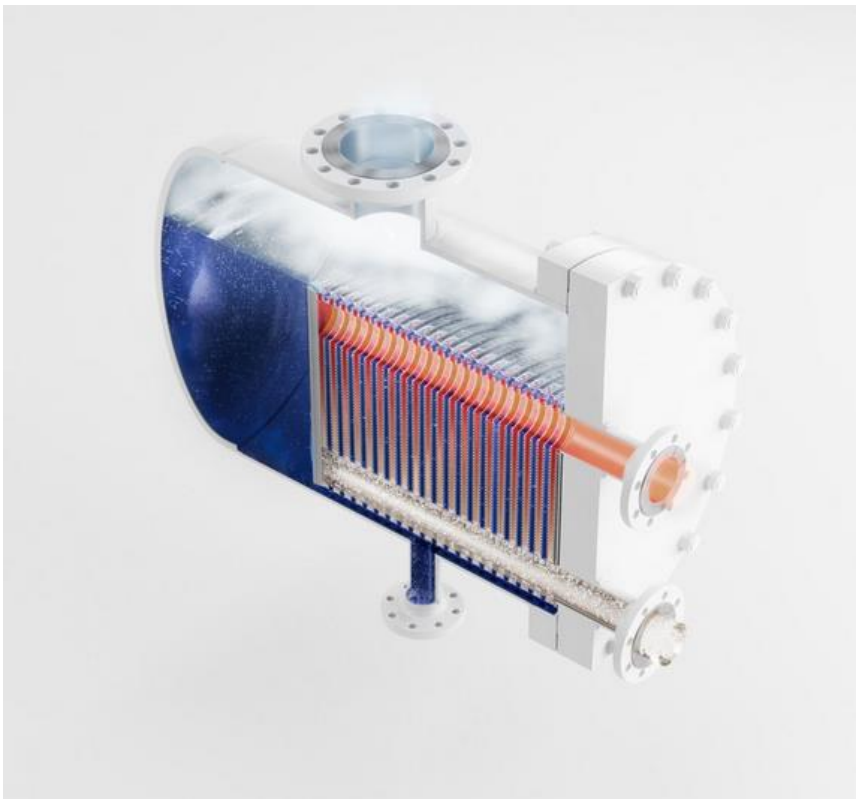
# Heat Exchanger solutions

- Focus today on direct steam generation
- Requires a kettle type heat exchanger where water is vaporized on the shell side
- Offers a compact solution for direct steam generation



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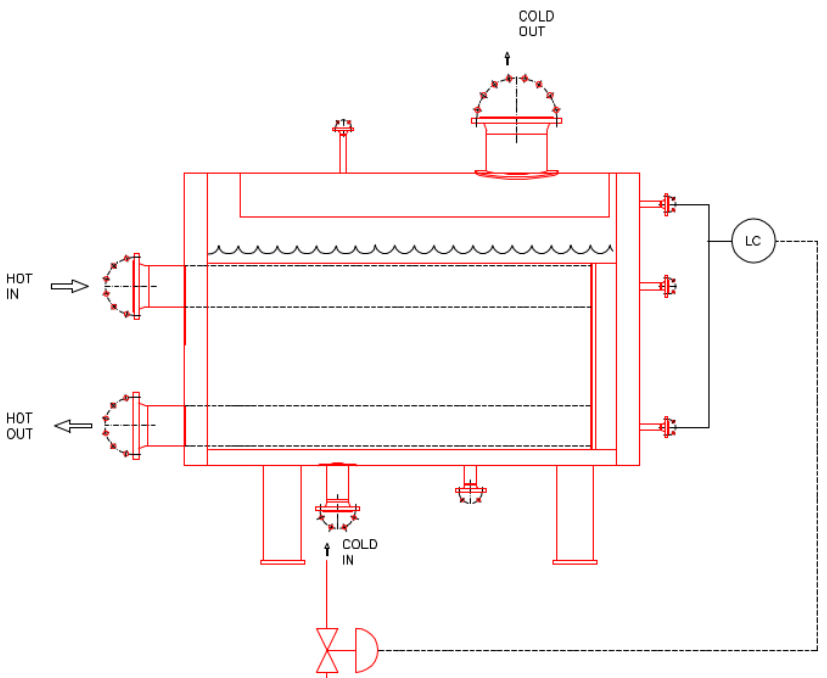
# Vahterus Steam Generator

- Design temperature up to +380C
- Design pressure up 80barg as standard
- Materials:
  - Plate pack normally from stainless steel
  - Shell from CS or SS
- Supplied with Vahterus standard auxiliary connections for level control and others
- Many times larger units are made with openable structure to enable shell side cleaning

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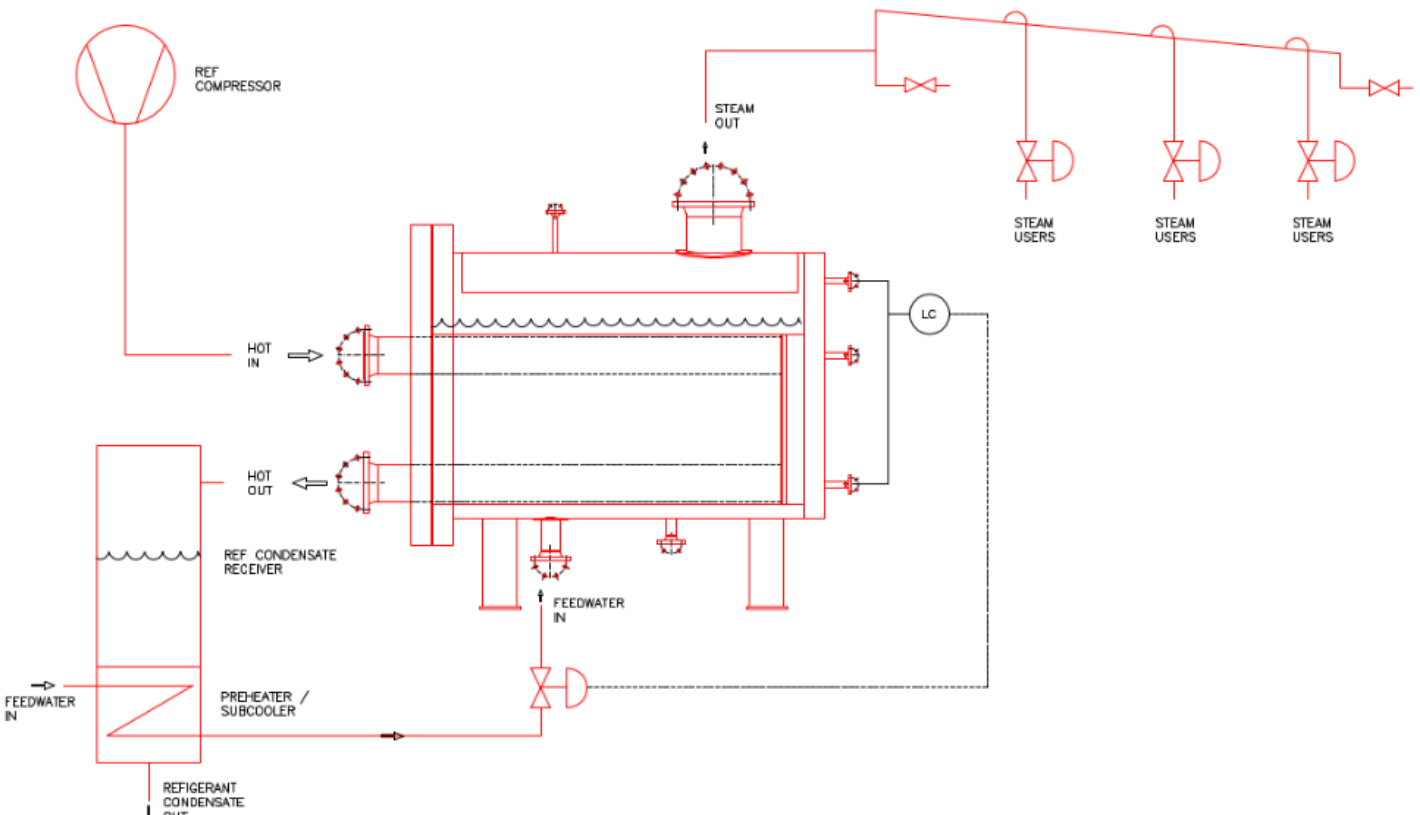
# How to connect to heat pump

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# Vahterus Steam Generator

**Takeaways**

- Substantial cost savings compared to traditional arrangement
- Very compact
- Gasket free
- Can withstand high pressures and temperatures
- Proven solution


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# Steam generating heat pumps - challenges

**Water Quality**

- The single most important item in steam generator design
- Can cause corrosion if not taken care
- Boiling water → Pure steam will get out of the heat exchanger, water pool gets rich of dirt

Example:

- 20ppm of contaminant in the feed water
- 1500kW steam generator

→ 31kg of contaminant collected into steam generator in one month!

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# Steam generating heat pumps - challenges

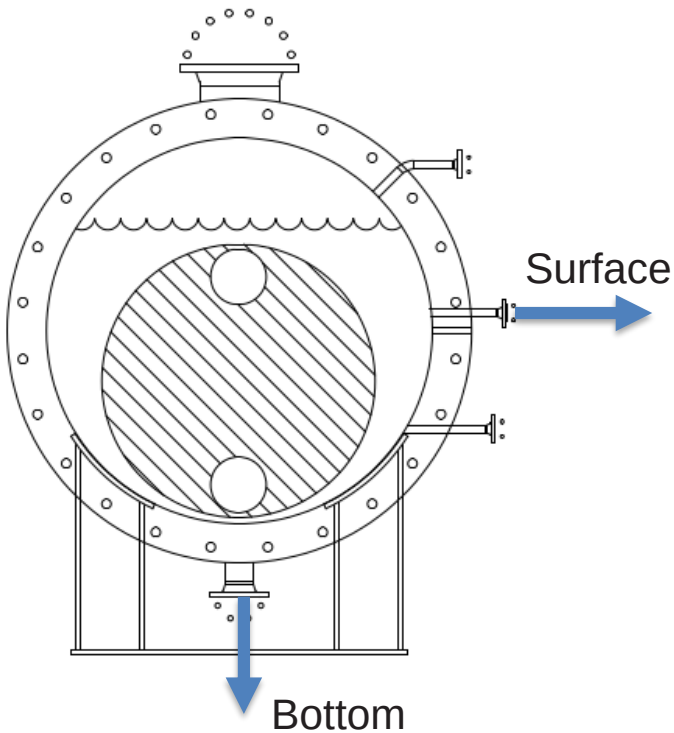
**Water Quality – How to prevent problems**

1) Design the blow downs: Surface and/or bottom

- Use those either constantly or in intervals to remove part of the water to prevent accumulation

2) Measure conductivity from feed and pool

3) Take care of the feed water quality

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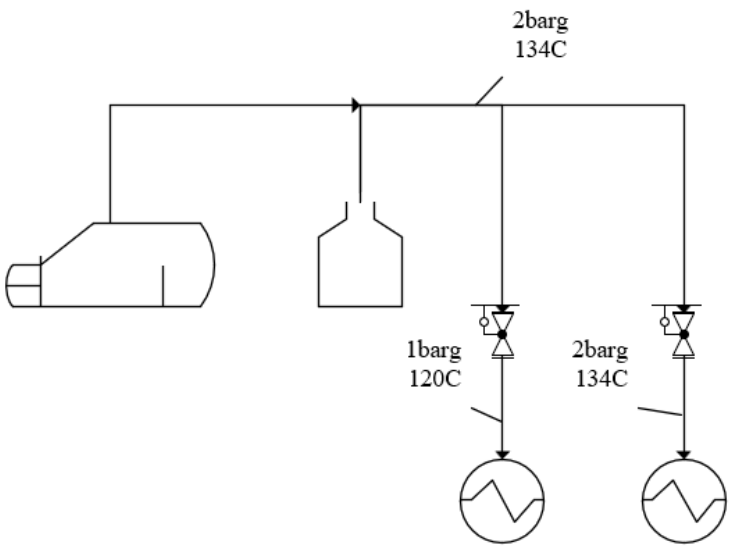
# Steam generating heat pumps - challenges

**Capacity Control:**

- Normally capacity is controlled with water outlet temperature
- In traditional steam systems boiler control the steam pressure
- Heat pump might be required to start very fast to react into the steam use
- What if several steam producers are in the system

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# Conclusion

- Steam pressure and use have significant impact to the technical solutions
- Refrigerant selection have effect to thermodynamics and efficiency, without forgetting the environmental impact
- Vahterus offers Steam generator solutions with long experience
  - Long experience from steam and refrigeration
  - Many delivered units in both industries over the years

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# Thanks

Questions?

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