# Full Scale Thermosyphon Design Parameters and Technical Description

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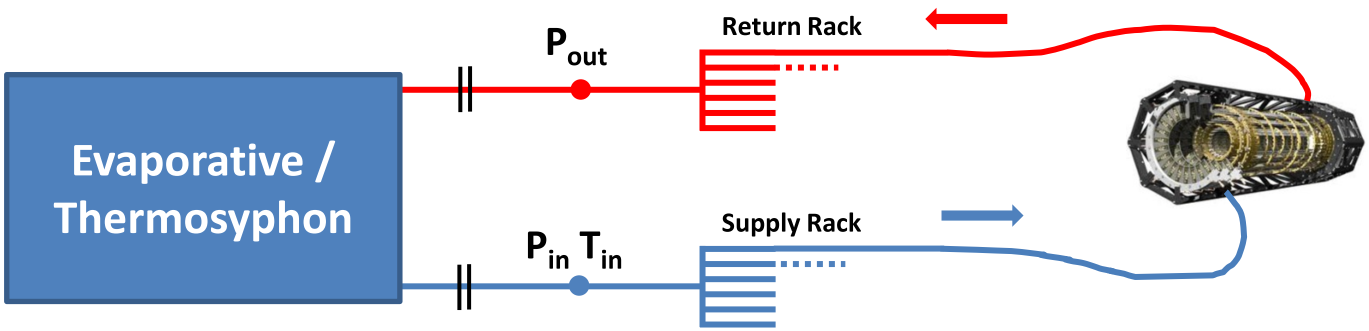
# Outline

- Design specifications
- Thermodynamic cycle
- Power requirement and power consumption
- Pipe sizing and insulation
- Condenser/Tank design

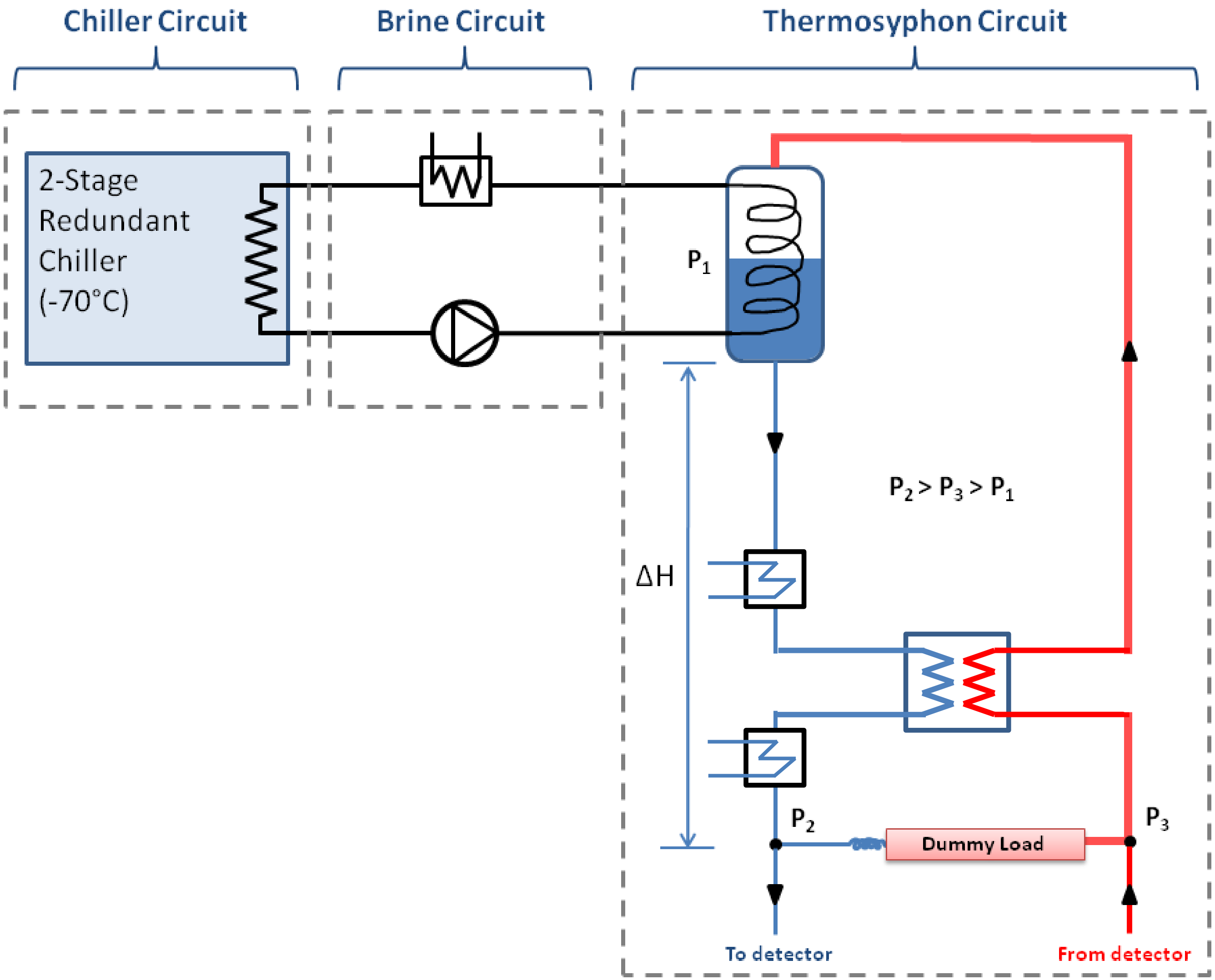
# Thermosyphon Design Specification



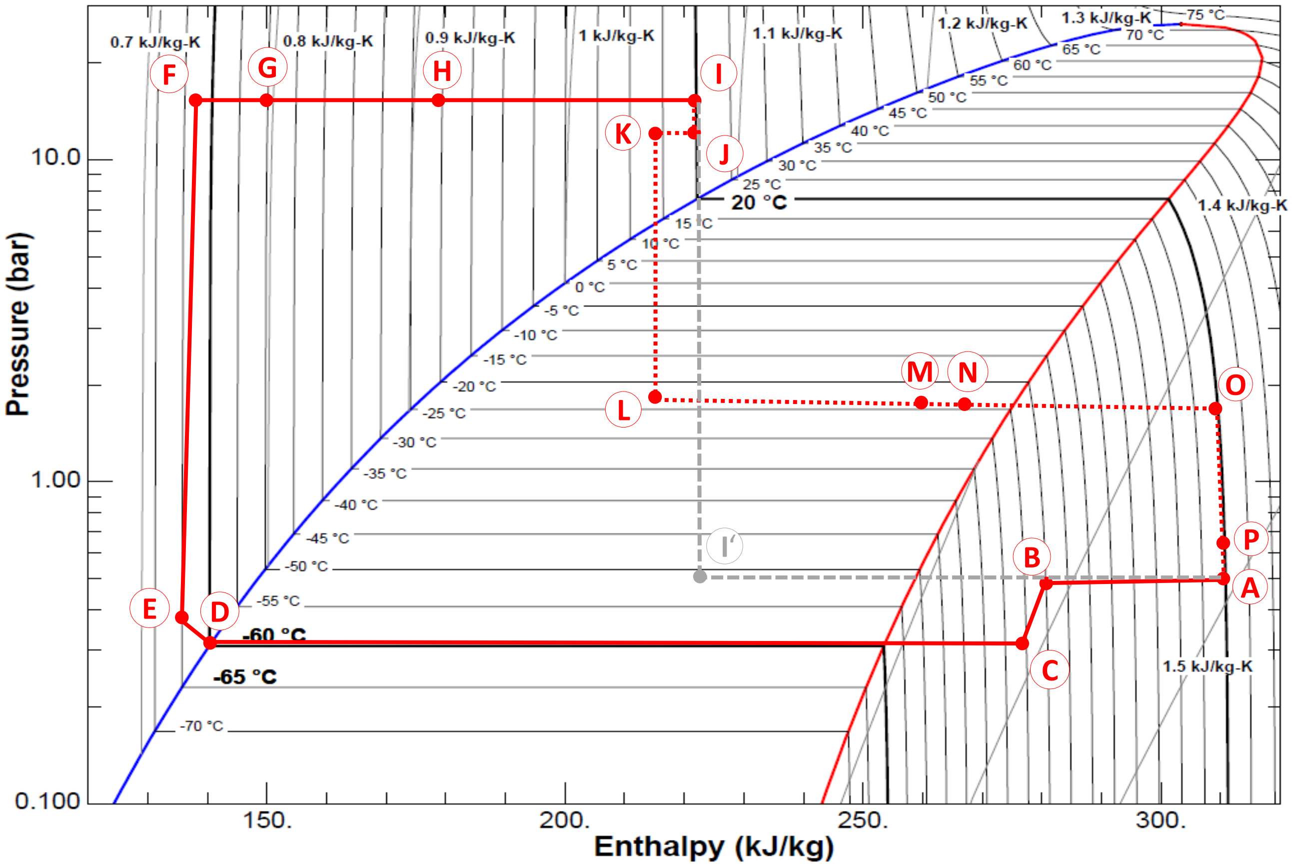

| Parameter | Actual Plant | Thermosyphon Design Specification |
|---|---|---|
| Flow of C3F8 at full power | 1.1 kg/s [(1)] | 1.2 kg/s |
| Liquid pressure at the supply distribution lines (plant side) | 15 bara | 15 bara (Height required = 95 m) |
| Temperature at the supply rack | 20°C | 20°C |
| Nominal pressure of the C3F8 at the return rack (plant side) | 0.8 bara | 0.5 bara ($P_{sat}$=0.31 bara;$T_{sat}$=-60°C) |
| Temperature at the return rack | 20°C | 20°C |
| Maximum operating pressure | PN25 | PN40 |

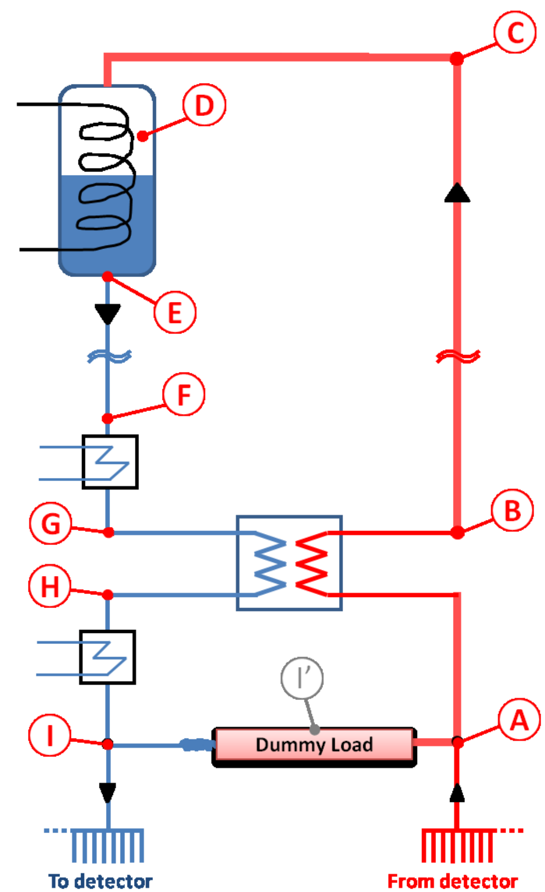
(1) Read from the plant flow meter.

# Thermosyphon Basic Scheme



# Thermodynamic Cycle

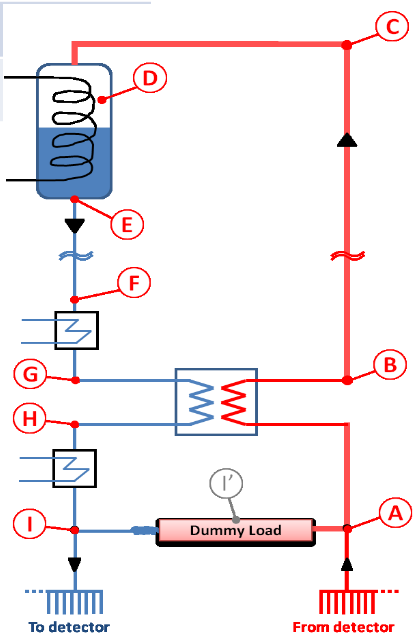


# Cooling and Electrical Power

| Operation Line0 | Description | Component | Power [kW] | Power Type |
|---|---|---|---|---|
| Point A to B | Cooling of the Return vapour | Sub-Cooling HX | 35 | Passive component |
| Point B to C | Return line | Return pipe | (+) 4 | Passive component |
| Point C to D | Condensation | Tank Condensation | 165 | - |
| Point D to E | Sub-Cooling | Tank sub-cooling | 5.5 | - |
| Point C to E | Condensing + Sub-cooling | Condenser/Tank | (-) 170 | Chiller Power |
| Point E to F | Supply line | Supply pipe | (+) 4 | Passive component |
| **Point F to G** | **Heating up to the dew point** | **Electrical Heater** | **(-) 13** | **Electrical** |
| Point G to H | Heating the liquid using the return vapour | Heat Exchanger | 35 | Passive component |
| **Point H to I** | **Heating to room temperature** | **Electrical Heater** | **(-) 51** | **Electrical** |
| **Point I' to A** | **Evaporation and super heating** | **Dummy Load** | **(-) 107(1)/22(2)/0(3)** | **Electrical** |

(1) During the commissioning period only.
(2) Start up.
(3) Running trough the detector.

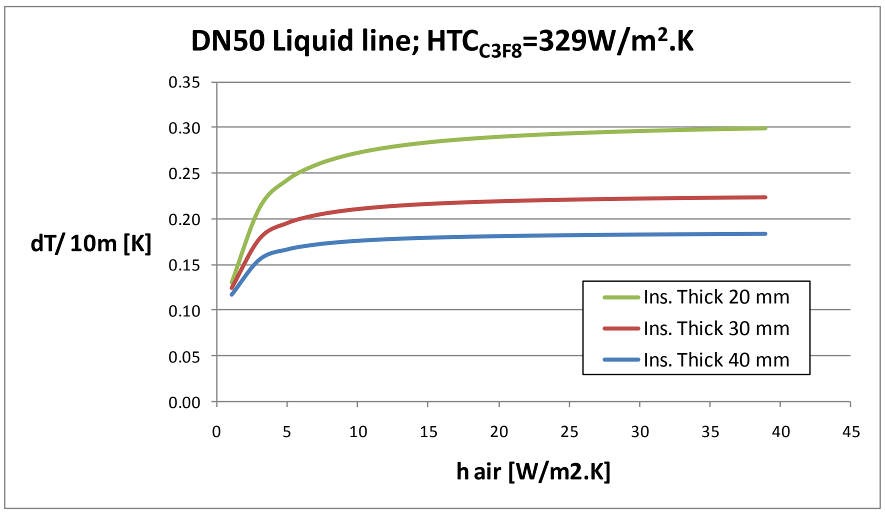


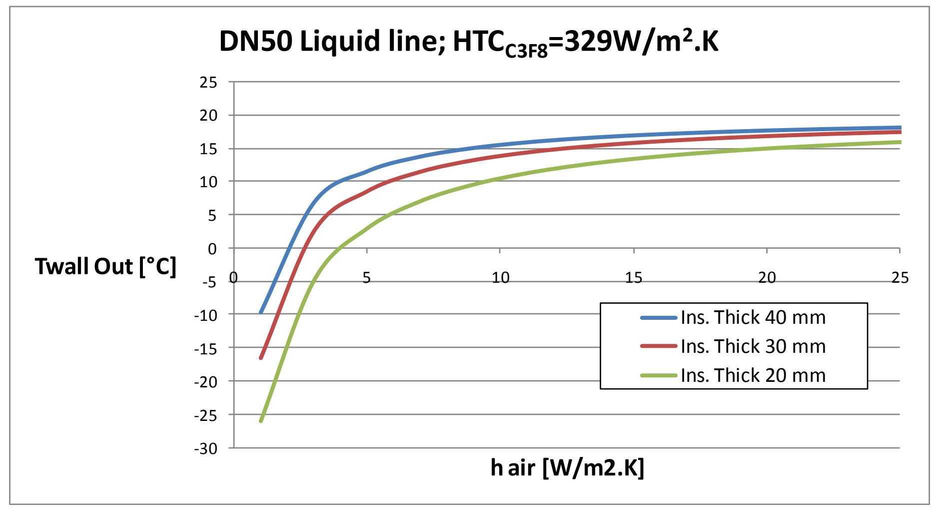
# Pipe Sizing and Insulation

- Supply Pipe:
  - Minimize pressure drop -> Larger diameter.
  - Minimize liquid volume and cost of pipes and installation -> Smaller diameter.
- Return Pipe:
  - Minimize pressure drop
    - A high pressure drop can force us to decrease saturation pressure, increasing the Chiller cost!
  - Minimize cost of pipes and installation
- Insulation:
  - Minimize heat pick up on the return line.
    - taking into account the external wall temperature of the Insulation.
  - Maximize heat pick up on the supply line.
    - Tanking into account the external wall temperature of the insulation.

# Pipe Sizing and Insulation: Supply

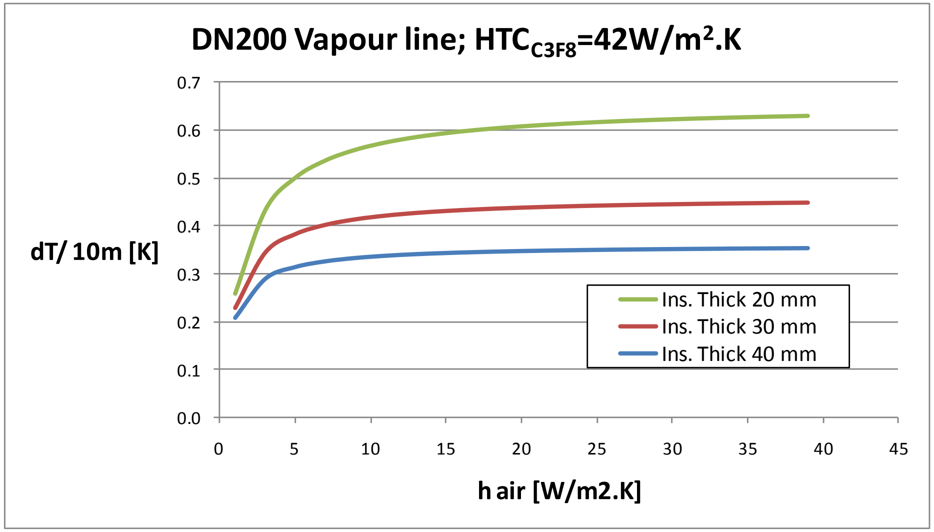
- Pipe Size and Insulation Supply:
  - DN50; $\Delta P_{friction}$=55mbar
  - Insulation Thickness: 40mm; $\Delta T_{max}$/100m=1.8K

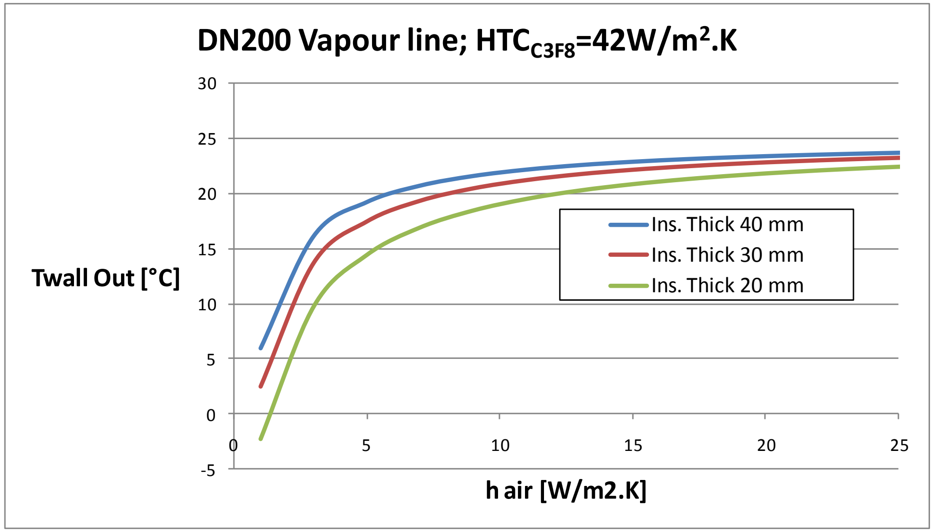


# Pipe Sizing and Insulation: Return

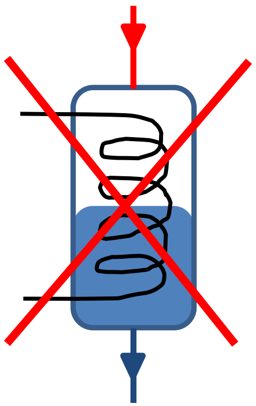
- Pipe Size and Insulation Return:
  - DN200; $\Delta P_{friction}$=25mbar; $\Delta P_{height}$=35mbar (independent from the pipe)
  - Insulation Thickness: 40mm; $\Delta T_{max}$/100m=3.5K

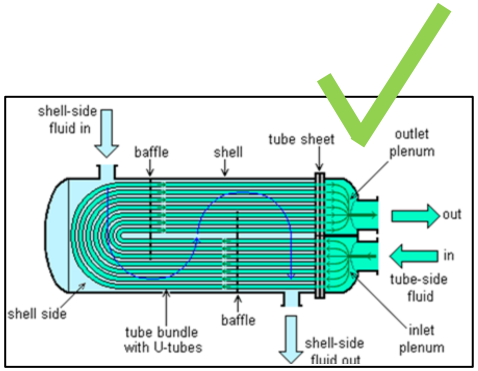


# Condenser/Tank Design

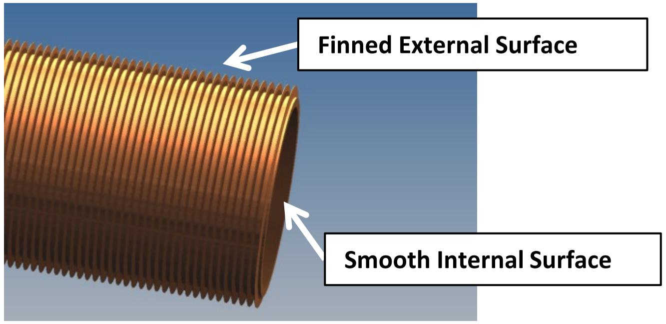
- Total Cooling Power: 170kW (164.5kW of condensation + 5.5kW of sub-cooling).
- Required flow of C6F14: 40kg/s (ΔT=5K)
  - The pressure drop would be too high using only one coolant coil (standard size of ≈16mm ID).
  - The solution is the use of a Shell and Tube Heat Exchanger.

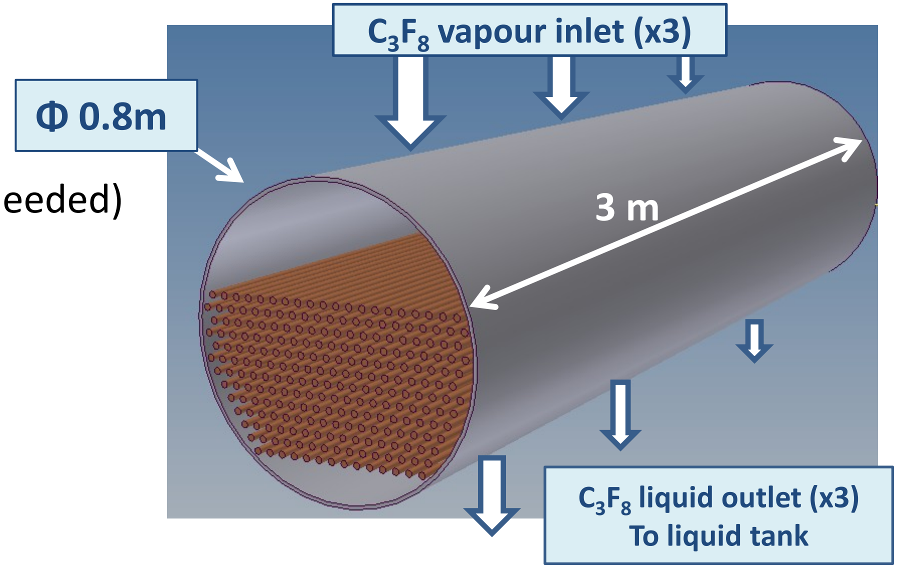




# Condenser Design

- First Approach* on the Condenser Design:
  - HTC on Condensing side: 12 $kW/m^2.K$
  - HTC on Brine side: 1.1 $kW/m^2.K$
  - Overall HTC: 253 $W/m^2.K$
  - Required surface area of heat exchange: 93 $m^2$
  - Required number of tubes: 225 (with 3m length; 0.208 $m^2/m$ of external finned surface area)
  - Number of tubes: 253 (12% over surface)
  - Number of loops: 42
  - Number of tube passes: 4
  - Velocity of C6F14: 2.6m/s (Copper alloy needed)
  - Pressure drop: 1.9 bar




* Calculations will be verified by Claudio Zilio (Padova University) and by the manufacture company.

# Tank Design

- Total required mass of Liquid: 2750kg
  - Liquid side: 1565 kg
  - Vapour side: 644kg
  - Compensation for leaks: 540kg (3kg/day; 180days)
- Maximum volume: 2.15m$^3$ (@32°C)
- Minimum volume: 1.6m$^3$ (@-65°C)
- Approximate recommended total volume of the Tank: 2.5m$^3$
- The possibility of joining the Condenser and the Tank is being studied.

# Thermosyphon P&ID