Tech UPGRADE

# D4.2 Design layouts and simulation packages

Funded by
the European Union

This project has received funding from European Union's Horizon Europe's Research and Innovation Program under grant agreement No. 101103966. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

# Deliverable 4.2 Design layouts and simulation packages

| | |
|---|---|
| Actual Submission Date: | **31/10/2025** |
| Produced by: | **DTU- Rahbari, Hamid Reza** |

# TechUPGRADE

techupgrade.eu

**HORIZON-CL5-2022-D4-01**

**Thermochemical Heat Recovery and Upgrade for Industrial Processes**

*Grant Agreement no.: 101103966*

*Start date of project: 1 May 2023 - Duration: 48 months*

Tech UPGRADE

## DELIVERABLE FACTSHEET

| **Deliverable D4.2** | |
|---|---|
| **Nature of the Deliverable:** | Other |
| **Due date of the Deliverable:** | M30 – 31/10/2025 |
| **Actual Submission Date:** | M30 – 31/10/2025 |
| **Produced by:** | DTU- Hamid Reza Rahbari |
| **Contributors:** | Hamid Reza Rahbari, Ahmad Arabkoohsar |
| **Work Package Leader** | DTU – Ahmad Arabkoohsar |
| **Reviewed by:** | DTU- Hamid Reza Rahbari |

| **Dissemination level** | |
|---|---|
| **X** | PU = Public |
| | PP = Restricted to other programme participants (including the EC) |
| | RE = Restricted to a group of the consortium (including the EC) |
| | CO = Confidential, only members of the consortium (including the EC) |

## Contents



## Figures



## Tables

# 1 Summary

This deliverable provides the finalized design layouts and simulation packages developed to define the optimal configuration of the thermochemical heat transformer (THT) system. The results of modelling, parametric analysis, sensitivity analysis, and optimization activities, which have been done in the previous task, are presented here as a practical system layout for demonstration. The document and attached files include drawing layouts, setpoint tables, and simulation codes (Aspen EDR and MATLAB). These results could be utilized as the technical basis for the construction and validation of the test sites.

# 2 Development procedure

The development of design layouts and simulation packages used an approach that combined thermodynamic modeling, component-level simulations, and system integration. First, the key components of the THT system, such as the reactor, evaporator, condenser, pump, and heat exchangers, were designed and sized. Then, parametric and sensitivity analyses were conducted to investigate the impact of different variables on the system performance. The results could be used to determine the range of different variables for multi-criteria optimization. Based on these outcomes, the final system layouts were generated, including the system schematic and P &ID diagram. The simulation packages (Aspen EDR [1] and MATLAB [2]) were tested for different operations and boundary conditions.

# 3 System layouts and configurations

The final system layout of the system shows the concept of the integrated HHT system developed from the simulation and sizing procedures. The layout includes all the main components, such as evaporator, condenser, reactor, heat exchangers, and pump, which are arranged to ensure efficient thermal connection and operational flexibility. On the other hand, the P&ID diagram is a detailed schematic that shows the functional relationship between piping, instrumentation, and system components in a process plant. The final design of the HHT system, as the concept of the TechUPGRADE project, is shown in Figure 1. As can be seen, the main components of the system-the hydration/dehydration reactor, district heating (DH) heat exchanger, condenser, pump, preheater, evaporator, waste heat (WH) recovery unit, mixer, and steam generator- are shown in this figure. Also, this figure shows the integration between these components. Figure 2 represents the P&ID diagram of the TechUPGRADE project.

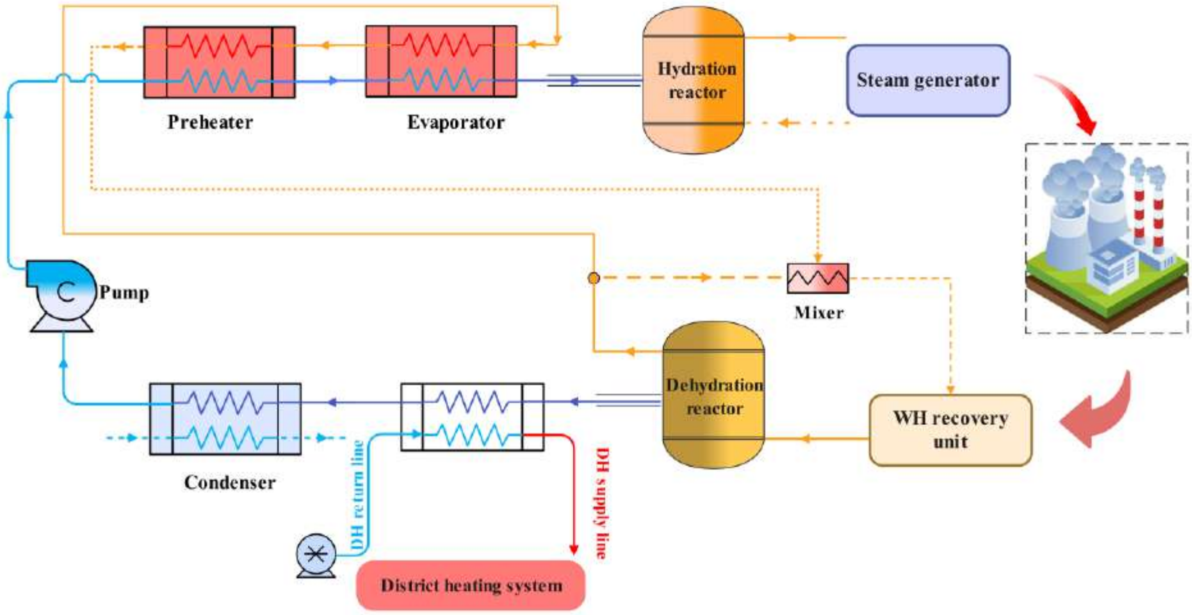



**Figure 1. The final system layout of the TechUPGRADE project**

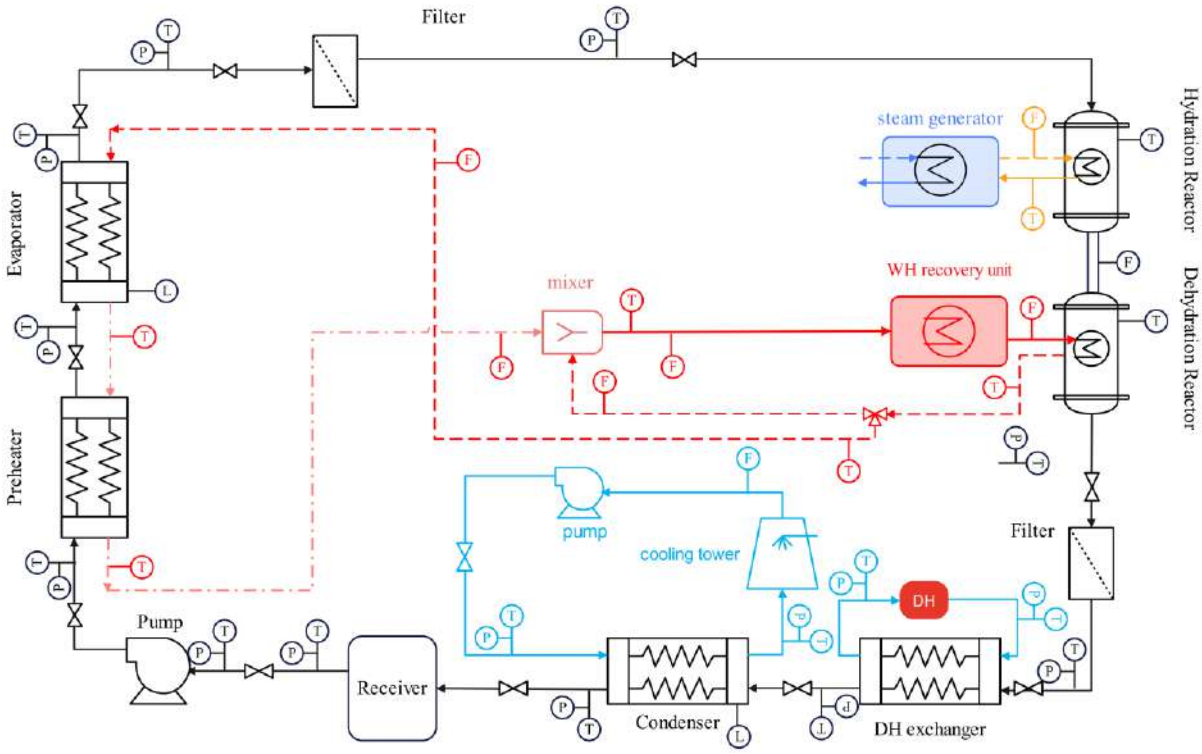



**Figure 2. The P&ID diagram of the TechUPGRADE project**

## 4 Setpoints and operation conditions

To identify the setpoints and operation conditions of the proposed HHT system, it is essential first to introduce the limitations and boundaries of our system. The range of operation temperature for the HHT in the TechUPGRADE project is between 150-250°C. The SrBr2.$H_2O$ (strontium bromine/ Water) is chosen as the main thermochemical material for the TechUPGRADE project. Due to its favorable properties, this salt hydrate-based material is a potential candidate for THT systems in temperatures above 150°C. The reversible reaction for this material takes place at 150-250°C, which is very interesting for industrial process heating applications in different sectors [3].

The next step is to select suitable industrial WH and process heating applications that match this temperature range. Among different industries, Textile, Plastics and Rubber, Food and Beverage Chemicals, Petrochemicals, and Iron and Steel are potential candidates to select as case studies for the proposed HHT system within the temperature range of 150-250°C [4,5]. The petrochemical industry is chosen as the first case for the TechUPGRADE project. The WH can be recovered from various products by different processes in the petrochemical industry. In the case of xylene production, the bottom oil of xylene and the xylene products serve as low-temperature WH sources, with temperatures ranging from 80°C to 215°C. The available WH load is approximately 2.2 MW with a mass flow rate of about 78.5 kg/s [6]. A typical process in the petrochemical industry is the distillation process, which has temperatures between 110 and 300 °C. The most common working fluid for heat transfer in the distillation process is steam, with an average temperature of 250°C [7]. The second case is the iron and steel industry. In the iron and steel industry, there are available WH streams coming from ovens and furnaces. These exhaust gas streams reach temperature values up to 230°C [8], while a typical mass flow rate is equal to 22 kg/s [9]. On the other hand, the hydrothermal carbonization process requires heat at a temperature of about 290°C [10]. Thus, this sector has significant WH and the potential to upgrade medium-grade heat for process heating applications.

Table 1 provides detailed information on WH and process hearing in the petrochemical industry. According to Table 1, thermal oil (Terminal 66 [11]) is chosen as a high-temperature fluid (HTF) to transfer heat from the WH recovery unit into the dehydration reactor and hydration heat to the steam in the steam generator for process heating applications.

**Table 1. Industrial WH and process heating in the Petrochemical case**

| Parameter | Unit | Value | |
|---|---|---|---|
| | | **WH side** | **Process heating side** |
| HTF type | - | Thermal oil | Thermal oil |
| HTF inlet temperature | °C | 200 | 230 |
| HTF outlet temperature | °C | 185 | 250 |
| HTF mass flow rate | kg/s | 78.5 | 58.5 |

Also, Table 2 provides detailed information on WH and process hearing in the iron and steel industry. In this case, the air is the HTF for the WH side (i.e., dehydration reactor), and Thermal oil is the HTF for the process heating side (i.e., hydration reactor).

**Table 2. Industrial WH and process heating in the Iron and Steel case**

| Parameter | Unit | Value | |
|---|---|---|---|
| | | **WH side** | **Process heating side** |
| HTF type | - | Air | Thermal oil |
| HTF inlet temperature | °C | 230 | 265 |
| HTF outlet temperature | °C | 196.6 | 290 |
| HTF mass flow rate | kg/s | 65.9 | 46.3 |

Table 3 summarizes the main design setpoints of the HHT system for the petrochemical industry in the TechUPGRADE project.

**Table 3. Design setpoints of the HHT system for the petrochemical industry**

| Parameter | Unit | Value |
|---|---|---|
| System capacity | MW | 2.2 |
| Condenser temperature | °C | 20.4 |
| Evaporator temperature | °C | 112.8 |
| Hydration temperature | °C | 260 |
| Dehydration temperature | °C | 175 |
| Pinch temperature | K | 10 |
| Heat capacity of thermal oil | kJ/kg. K | 1.98 |
| Time period for each cycle | hour (s) | 1 (3600) |
| Isentropic efficiency of the pump | % | 75 |
| Real temperature lift | °C | 50 |

Also, Table 4 summarizes the main design setpoints of the HHT system for the iron and steel industry in the TechUPGRADE project.

**Table 4. Design setpoints of the HHT system for the iron and steel industry**

| Parameter | Unit | Value |
|---|---|---|
| System capacity | MW | 2.2 |
| Condenser temperature | °C | 35 |
| Evaporator temperature | °C | 144.6 |
| Hydration temperature | °C | 300 |
| Dehydration temperature | °C | 186.6 |
| Pinch temperature | K | 10 |
| Heat capacity of air | kJ/kg. K | 1 |
| Heat capacity of thermal oil | kJ/kg. K | 1.98 |
| Time period for each cycle | hour (s) | 1 (3600) |
| Isentropic efficiency of the pump | % | 75 |
| Real temperature lift | °C | 50 |

To complete the operating setting points provided in Tables 3 and 4, the main results of the simulation analysis are summarized in Tables 5 and 6 for petrochemical and iron and steel, respectively. These results define the important parameters of the system that guide the final design configuration and confirm the system's technical feasibility under selected operation conditions.

**Table 5. The simulation results of the HHT system for the petrochemical industry**

| Parameter | Unit | Value |
|---|---|---|
| Mass of water | kg | $1.98\times10^3$ |
| Mass of SrBr2 | kg | $2.72\times10^4$ |
| Mass of SrBr2.H2O | kg | $2.92\times10^4$ |
| Volume of reactor | $m^3$ | 21.96 |

| | | |
|---|---|---|
| The mass flow rate of water | kg/s | 0.55 |
| The mass flow rate of SrBr2 | kg/s | 7.56 |
| Temperature of mixer | °C | 112 |
| Heat transfer rate of condenser | kW | $1.35\times10^3$ |
| Pump power | kW | 0.0855 |
| Heat transfer rate of preheater | kW | 213.4 |
| Heat transfer rate of evaporator | kW | $1.23\times10^3$ |
| $COP_h$ | - | 0.635 |

**Table 6. The simulation results of the HHT system for the iron and steel industry**

| **Parameter** | **Unit** | **Value** |
|---|---|---|
| Mass of water | kg | 1.98×103 |
| Mass of SrBr2 | kg | 2.72×104 |
| Mass of SrBr2.H2O | kg | 2.92×104 |
| Volume of reactor | $m^3$ | 21.96 |
| The mass flow rate of water | kg/s | 0.55 |
| The mass flow rate of SrBr2 | kg/s | 7.56 |
| Temperature of mixer | °C | 175 |
| Heat transfer rate of condenser | kW | $1.33\times10^3$ |
| Pump power | kW | 0.23 |
| Heat transfer rate of preheater | kW | 254.4 |
| Heat transfer rate of evaporator | kW | $1.17\times10^3$ |
| $COP_h$ | - | 0.635 |

To provide the multi-criteria optimization process, Tables 7 and 8 list the main decision variables and the range of changes related to them that have been reviewed during the design/sizing and simulation phase. These ranges are defined based on practical operating limits, component limitations, and thermodynamic feasibility.

**Table 7. Decision variables for multi-criteria optimization (Petrochemical case)**

| **Parameter** | **Range** |
|---|---|
| Condenser temperature | 20.41 – 35 °C |
| Evaporator temperature | 104 – 120 °C |
| Effectiveness factor of condenser | 0.6 – 0.9 |
| Effectiveness factor of evaporator | 0.6 – 0.9 |
| Pinch temperature of dehydration | 5 – 20 °C |

| | |
|---|---|
| Pinch temperature of hydration | 5 – 20 °C |

**Table 8. Decision variables for multi-criteria optimization (iron and steel case)**

| Parameter | Range |
|---|---|
| Condenser temperature | 35 – 70 °C |
| Evaporator temperature | 128 – 161 °C |
| Effectiveness factor of condenser | 0.5 – 0.95 |
| Effectiveness factor of evaporator | 0.5 – 0.95 |
| Pinch temperature of dehydration | 5 – 20 °C |
| Pinch temperature of hydration | 5 – 20 °C |

# 5 Simulation packages and files

The simulation packages developed for this deliverable contain the full simulation code and data sheets for the results of the TechUPGRADE project. These include the steady-state model created in MATLAB for designing/sizing all components, as well as the data sheets of different heat exchangers modeled in Aspen EDR.

The MATLAB code uses thermodynamic analysis to simulate the system in the steady-state mode. On the other hand, Aspen EDR reported the data sheets for different components, such as evaporator, condenser, and heat exchangers.

# 6 Conclusion

This deliverable collects the final design layouts, setting points tables, and simulation packages that define the configuration of the TechUPGRADE project. The system parameters were determined through precise simulation and a parametric study. The simulation packages include the MATLAB simulation code for designing/sizing the system, as well as the data sheets for the results of the different heat exchanger designs in Aspen EDR.

# 7 Bibliography

[1] Aspen Exchanger Design and Rating (EDR) | AspenTech n.d. https://www.aspentech.com/en/products/engineering/aspen-exchanger-design-and-rating (accessed September 15, 2025).

[2] Language T, Computing T. MATLAB The Language of Technical Computing. Components 2004;3:750. https://doi.org/10.1007/s10766-008-0082-5.

[3] Richter M, Habermann EM, Siebecke E, Linder M. A systematic screening of salt hydrates as materials for a thermochemical heat transformer. Thermochim Acta 2018;659:136–50. https://doi.org/10.1016/J.TCA.2017.06.011.

[4] Song J, Li Y, Gu C wei, Zhang L. Thermodynamic analysis and performance optimization of an ORC (Organic Rankine Cycle) system for multi-strand waste heat sources in petroleum refining industry. Energy 2014;71:673–80. https://doi.org/10.1016/J.ENERGY.2014.05.014.

[5] Brunner C, Slawitsch B, Giannakopoulou K, Schnitzer H. Industrial process indicators and heat integration in industries. NachhaltigwirtschaftenAtC Brunner, B Slawitsch, K Giannakopoulou, H SchnitzerBooklet IEA SHC Task, 2008•nachhaltigwirtschaftenAt 2008.

[6] Su Z, Zhang M, Xu P, Zhao Z, Wang Z, Huang H, et al. Opportunities and strategies for multigrade waste heat utilization in various industries: A recent review.

Energy Convers Manag 2021;229:113769. https://doi.org/10.1016/J.ENCONMAN.2020.113769.
[7] Brückner S, Liu S, Miró L, Radspieler M, Cabeza LF, Lävemann E. Industrial waste heat recovery technologies: An economic analysis of heat transformation technologies. Appl Energy 2015;151:157–67. https://doi.org/10.1016/J.APENERGY.2015.01.147.
[8] Trapp C, Mathijssen T, Larjola J, Turunen-Saaresti T, Uusitalo A. Organic Rankine cycle power systems: from the concept to current technology, applications, and an outlook to the future. AsmedigitalcollectionAsmeOrgP Colonna, E Casati, C Trapp, T Mathijssen, J Larjola, T Turunen-Saaresti, A UusitaloJournal of Engineering for Gas Turbines and Power, 2015•asmedigitalcollectionAsmeOrg 2015. https://doi.org/10.1115/1.4029884.
[9] Campana F, Bianchi M, … LB-EC and, 2013 undefined. ORC waste heat recovery in European energy intensive industries: Energy and GHG savings. ElsevierF Campana, M Bianchi, L Branchini, A De Pascale, A Peretto, M Baresi, A Fermi, N RossettiEnergy Conversion and Management, 2013•Elsevier n.d.
[10] Dang H, Xu R, Zhang J, Wang M, Journal KX-CE, 2023 undefined. Hydrothermal carbonization of waste furniture for clean blast furnace fuel production: Physicochemical, gasification characteristics and conversion mechanism. ElsevierH Dang, R Xu, J Zhang, M Wang, K XuChemical Engineering Journal, 2023•Elsevier n.d.
[11] Therminol 66 Heat Transfer Fluid | Therminol | Eastman n.d. https://www.therminol.com/product/71093438 (accessed February 17, 2025).

Tech UPGRADE

# 8 Annex A: Simulation codes and data sheets

This annex provides the full simulation codes created by MATLAB and the data sheets modeled in Aspen EDR, as part of **Deliverable 4.2 – Design layouts and simulation packages**.

## 8.1 MATLAB code

The thermo-economic simulation for the TechUPGRADE project was created in MATLAB. The following code provides the full simulation code:
**Note:** Requires the MATLAB CoolProp wrapper (CoolProp.PropsSI). Units are SI unless noted.

```
%% Main Code – TechUPGRADE Project-Thermochemical Heat Transformer (SrBr₂.H₂O)

%% Input parameters and reference conditions
Q_nominal = 2200;       % Nominal heating capacity (kW)
delta_t   = 60*60;      % One-hour operation period (s)
DeltaH_r  = 71.98;      % Reaction enthalpy of SrBr2/H2O (kJ/mol)
M_H2O     = 18.02/1000; % Molar mass of water (kg/mol)

T0 = 15;                % Ambient (reference) temperature (°C)
h0 = CoolProp.PropsSI('H','T',T0+273.15,'P',1e5,'Water')/1e3; % Ref. enthalpy
(kJ/kg)
s0 = CoolProp.PropsSI('S','T',T0+273.15,'P',1e5,'Water')/1e3; % Ref. entropy
(kJ/kg·K)

%% Condensation and hydration temperature estimation
T_cond = 20.41;                                                 % Condenser
saturation temperature (°C)
P_l = CoolProp.PropsSI('P','T',T_cond+273.15,'Q',0,'Water')/1e3; % Pressure at
condenser (kPa)
Tdyh = ((6.41e3)/(14.69 - log10(P_l))) - 273.15;                % Derived
dehydration temp (°C)
T_eva = 112;                                                    % Evaporator
temperature (°C)
P_h = CoolProp.PropsSI('P','T',T_eva+273.15,'Q',1,'Water')/1e3;% High-pressure
side (kPa)
Thyd = 3190 / (8.18 - log10(P_h)) - 273.15;                     % Hydration
temperature (°C)

%% Salt and water property definitions
M_Salt_0 = 247.42/1000;   % Molar mass of SrBr2 (kg/mol)
Rho_Salt_0 = 4216;        % Density of anhydrous salt (kg/m³)
CP_Salt_0 = 304.54;       % Heat capacity of SrBr2 (J/kg·K)
M_Salt_1 = 265.44/1000;   % Molar mass of SrBr2·H2O (kg/mol)
Rho_Salt_1 = 3911;        % Density of monohydrate (kg/m³)
CP_Salt_1 = 455.47;       % Heat capacity of SrBr2·H2O (J/kg·K)

%% Bulk porosity and effective density
Epsilon_1 = 0.66; % Porosity of monohydrate bed
Epsilon_0 = 1-(1-Epsilon_1)*(Rho_Salt_1/M_Salt_1)*(M_Salt_0/Rho_Salt_0); %
Effective bed porosity

%% Material mass and volume calculations
n_H2O = Q_nominal*delta_t/DeltaH_r; % Moles of water reacted
m_H2O = n_H2O*M_H2O;                % Mass of water (kg)
          m0 = n_H2O*M_Salt_0;                % Mass of SrBr2 (kg)
          m1 = n_H2O*M_Salt_1;                % Mass of SrBr2·H2O (kg)
          V_reactor = m0 / ((1-Epsilon_0)*Rho_Salt_0); % Reactor volume (m³)
```

```
%% Mass flow rates and reaction heat flow
mdot_H2O    = m_H2O / delta_t;                   % Water mass flow (kg/s)
Qdot_Dhyd   = mdot_H2O * DeltaH_r / M_H2O;       % Dehydration heat rate (kW)
mdot_SrBr2 = m0 / delta_t;                       % SrBr2 mass flow (kg/s)

%% WH1 loop – oil circuit heating for dehydration
T_WH1_in = 200;                % Oil inlet temp (°C)
T_pinch  = 10;                 % Minimum temperature difference (°C)
T_WH1_out = Tdyh + T_pinch;    % Oil outlet temp (°C)
CP_oil = 1.868;                % Oil specific heat (kJ/kg·K)
mdot_WH1 = Qdot_Dhyd/(CP_oil*(T_WH1_in - T_WH1_out)); % Oil flow (kg/s)

%% Condenser performance calculation
deltah_cond = (CoolProp.PropsSI('H','T',T_cond+273.15,'Q',1,'Water') - ...
CoolProp.PropsSI('H','T',T_cond+273.15,'Q',0,'Water'))/1e3; % Latent heat (kJ/kg)
Q_cond = mdot_H2O * deltah_cond;   % Condensation heat rate (kW)

T_cold_in = 15; eps_cond = 0.8;    % Cooling water inlet temp and effectiveness
[A_cond, T_cold_out, m_cold] = Acond(T_cond, mdot_H2O, T_cold_in, eps_cond); % HX
design call

%% Pump section – liquid water compression
P_in_p = CoolProp.PropsSI('P','T',T_cond+273.15,'Q',1,'Water')/1e3;
P_out_p = CoolProp.PropsSI('P','T',T_eva+273.15,'Q',1,'Water')/1e3;
v_p = 1/CoolProp.PropsSI('D','T',T_cond+273.15,'Q',0,'Water');   % Specific volume
(m³/kg)
W_p = mdot_H2O * v_p * (P_out_p - P_in_p);                        % Pump power
(kJ/s)
h_in_p = CoolProp.PropsSI('H','T',T_cond+273.15,'Q',0,'Water')/1e3;
h_out_p = h_in_p + (W_p/mdot_H2O);                                % Outlet enthalpy
(kJ/kg)
T_out_p = CoolProp.PropsSI('T','H',h_out_p*1e3,'P',P_out_p*1e3,'Water')-273.15; %
Outlet temp (°C)

%% Preheater and evaporator heat duties
h_in_eva  = CoolProp.PropsSI('H','T',T_eva+273.15,'Q',0,'Water')/1e3;
h_out_eva = CoolProp.PropsSI('H','T',T_eva+273.15,'Q',1,'Water')/1e3;
Q_preheat = mdot_H2O*(h_in_eva - h_out_p);    % Preheating load (kW)
Q_eva     = mdot_H2O*(h_out_eva - h_in_eva); % Evaporation load (kW)

%% WH2 & WH3 loops – heat recovery oil circuits
eps_eva = 0.8;                                % Effectiveness of evaporator HX
T_WH2_in = T_WH1_out;
[T_WH2_out, m_hot, A_eva] = Aeva(T_eva, mdot_H2O, T_WH2_in, eps_eva); % HX design
for evaporator
mdot_WH2 = m_hot * 1.1;                       % Adjusted oil flow (kg/s)
T_WH3_in = T_WH2_out;
T_WH3_out = T_WH3_in - (Q_preheat / (mdot_WH2*CP_oil)); % Outlet after preheater
(°C)

%% Process heat section – final useful output
T_PH_in  = 230; T_PH_out = Thyd - 10;        % Process heat inlet/outlet (°C)
CP_PH    = CP_oil;
mdot_PH  = Q_nominal / (CP_PH * (T_PH_out - T_PH_in)); % Process fluid mass flow
          (kg/s)

          %% Mixer – calculate mixed outlet temperature
```

```matlab
T_mixer = (((mdot_WH1 - mdot_WH2)*(T_WH2_in+273.15) +
mdot_WH2*(T_WH3_out+273.15))/mdot_WH1) - 273.15;

%% System performance indicators
COP = Q_nominal / (Q_eva + Q_preheat + Qdot_Dhyd);  % Coefficient of performance
% Exergy flows for each subsystem are calculated below for η_ex

%% Exergy analysis of each component
% Calculate the exergy balance and efficiency of each component
% Reference temperature: T0 = 15°C (ambient)

%% 1. Exergy input from hot oil stream
Ex_in = (mdot_WH1 * CP_oil * ((T_WH1_in - T0) - ...
((T0+273.15) * log((T_WH1_in+273.15)/(T0+273.15)))));
% Total exergy supplied by WH1 hot oil to the system

%% 2. Dehydration reactor exergy balance
Ex_dehy_in = (mdot_WH1 * CP_oil * ((T_WH1_in - T0) - ...
((T0+273.15) * log((T_WH1_in+273.15)/(T0+273.15))))) ...
+ ((n_H2O/delta_t)*154.65) ... % Water vapor chemical exergy
+ ((m1/delta_t) * (CP_Salt_1/1000) * ...
((Thyd - T0) - ((T0+273.15)*log((Thyd+273.15)/(T0+273.15)))));
% Inlet exergy for dehydration step (heat + chemical + solid phase)

h_w1 = CoolProp.PropsSI('H','T',Tdyh+273.15,'P',P_l*1e3,'Water')/1e3;
s_w1 = CoolProp.PropsSI('S','T',Tdyh+273.15,'P',P_l*1e3,'Water')/1e3;

Ex_dehy_out = (mdot_WH1 * CP_oil * ((T_WH1_out - T0) - ...
((T0+273.15)*log((T_WH1_out+273.15)/(T0+273.15))))) ...
+ ((n_H2O/delta_t)*(9.33+153.9)) ... % Released vapor exergy
+ ((m0/delta_t)*(CP_Salt_0/1000) * ...
((Thyd - T0) - ((T0+273.15)*log((Thyd+273.15)/(T0+273.15))))) ...
+ (mdot_H2O*((h_w1 - h0) - (T0+273.15)*(s_w1 - s0)));
% Exergy output from dehydration reactor

Ex_dehy = Ex_dehy_in - Ex_dehy_out;      % Exergy destruction (kW)
eta_ex_dehy = Ex_dehy_out / Ex_dehy_in;  % Dehydration exergy efficiency (-)

%% 3. Hydration reactor exergy balance
h_w2 = CoolProp.PropsSI('H','T',Thyd+273.15,'P',P_h*1e3,'Water')/1e3;
s_w2 = CoolProp.PropsSI('S','T',Thyd+273.15,'P',P_h*1e3,'Water')/1e3;

Ex_hyd_in = ((n_H2O/delta_t)*(9.33+153.9)) ... % Input water vapor exergy
+ ((m0/delta_t)*(CP_Salt_0/1000) * ...
((Thyd - T0) - ((T0+273.15)*log((Thyd+273.15)/(T0+273.15))))) ...
+ (mdot_H2O*((h_w2 - h0) - (T0+273.15)*(s_w2 - s0)));
% Exergy entering the hydration reactor

Ex_hyd_out = ((n_H2O/delta_t)*154.65) ... % Product chemical exergy
+ ((m1/delta_t)*(CP_Salt_1/1000) * ...
((Thyd - T0) - ((T0+273.15)*log((Thyd+273.15)/(T0+273.15)))));
% Exergy leaving the hydration reactor

Ex_hyd = Ex_hyd_in - Ex_hyd_out;          % Exergy destruction in hydration
eta_ex_hyd = Ex_hyd_out / Ex_hyd_in;      % Hydration exergy efficiency (-)

          %% 4. Condenser exergy balance
```

```
Ex_cond_in = (mdot_H2O*((h_in_cond - h0) - (T0+273.15)*(s_in_cond - s0))) ...
+ (mdot_cool*((h_in_cool - h0) - (T0+273.15)*(s_in_cool - s0)));

Ex_cond_out = (mdot_H2O*((h_out_cond - h0) - (T0+273.15)*(s_out_cond - s0))) ...
+ (mdot_cool*((h_out_cool - h0) - (T0+273.15)*(s_out_cool - s0)));

Ex_cond = Ex_cond_in - Ex_cond_out;        % Exergy destruction (kW)
eta_ex_cond = Ex_cond_out / Ex_cond_in;    % Condenser exergy efficiency (-)

%% 5. Evaporator exergy balance
Ex_eva_in = (mdot_H2O*((h_in_eva - h0) - (T0+273.15)*(s_in_eva - s0))) ...
+ (mdot_WH2*CP_WH2*((T_WH2_in - T0) - ...
(T0+273.15)*log((T_WH2_in+273.15)/(T0+273.15))));

Ex_eva_out = (mdot_H2O*((h_out_eva - h0) - (T0+273.15)*(s_out_eva - s0))) ...
+ (mdot_WH2*CP_WH2*((T_WH2_out - T0) - ...
(T0+273.15)*log((T_WH2_out+273.15)/(T0+273.15))));

Ex_eva = Ex_eva_in - Ex_eva_out;           % Exergy destruction (kW)
eta_ex_eva = Ex_eva_out / Ex_eva_in;       % Evaporator exergy efficiency (-)

%% 6. Overall system exergy efficiency
eta_ex = (1 - ((Ex_hyd + Ex_dehy + Ex_eva + Ex_cond) / Ex_in)) * 100;
% Global exergy efficiency (%) considering all major components


%% Capital cost estimation
% Correlation constants (from literature for heat exchangers/pumps/reactors)
C1=0.03881; C2=-0.11272; C3=0.08183;
K1=4.3247; K2=-0.303; K3=0.1634;
FM=1.35; B1=1.63; B2=1.66;

Q_target = (Q_eva + Q_preheat + Qdot_Dhyd)*1e3; % Total heat load (W)
A_HX = AHX(Q_target, T_mixer, T_WH1_in);        % HX area from auxiliary function

%% Cost of individual components
salt_c = 20; FP=1; FP_HX=1; FP_pump=1;          % Cost factors and correction
terms
Cp0_eva = 10^(K1 + K2*log10(A_eva) + K3*(log10(A_eva)^2));
Cp0_cond= 10^(K1 + K2*log10(A_cond) + K3*(log10(A_cond)^2));
Cp0_HX   = 10^(K1 + K2*log10(A_HX) + K3*(log10(A_HX)^2));
Cp0_pump= 10^(3.39 + 0.0536*log10(W_p) + 0.154*(log10(W_p)^2));

%% Component cost scaling
C_eva = Cp0_eva*(B1+(B2*FM*FP))*(650/394.3)*0.95;
C_cond= Cp0_cond*(B1+(B2*FM*FP))*(650/394.3)*0.95;
C_HX   = Cp0_HX*(B1+(B2*FM*FP_HX))*(650/394.3)*0.95;
C_pump= Cp0_pump*(1.89+(1.35*1*FP_pump))*(650/394.3)*0.95;
C_reactor = 4.57e4*(V_reactor^0.67)*(650/394.3)*0.95;
C_salt = salt_c*2.92e4;
C_total = C_eva + C_cond + C_reactor + C_salt + C_HX + C_pump; % Total capital
cost (€)

%% LCOH calculation
Capacity = Q_nominal/1000;                    % MW installed
          Capacity_year = Capacity*5*24*52;             % MWh produced per year
          CA = C_total*1.2;                             % Annualized capital
          adjustment
```

```
MC = CA*0.05;                               % Maintenance cost (5%)
WHC = 0*(Capacity_year/COP);                % Waste heat cost (€/MWh)
EC = 0.07*Capacity_year*106;                % Electricity cost
OC = WHC + EC;                              % Total operational cost
Heat_produced = Capacity*5*24*52;           % Useful heat per year (MWh)
r = 5; N = 20;                              % Discount rate and system lifetime

for i=1:N
a(i) = ((MC+OC) / (1 + (r/100))^i);      % Annualized cost
b(i) = (Heat_produced / (1 + (r/100))^i);% Annualized heat output
end

%% Final results
LCOH = (CA + sum(a)) / sum(b);              % Levelized Cost of Heat (€/MWh)
LCOH2 = LCOH / 10;                          % Converted to c€/kWh

%% =========================== Local Functions ==============================
function [A, T_cold_out, m_cold] = Acond(T_cond, m_H2O, T_cold_in, eps)
% Plate condenser area from effectiveness definition (crossflow approx.)
hfg = CoolProp.PropsSI('H','T',T_cond+273.15,'Q',1,'Water') - ...
CoolProp.PropsSI('H','T',T_cond+273.15,'Q',0,'Water'); % J/kg
Q_target = m_H2O * hfg;                   % W
T_hot_in = T_cond; T_hot_out = T_cond;    % condensing isothermal

cp_cold = CoolProp.PropsSI('C','T', T_cold_in+273.15, 'Q', 0, 'Water'); % J/kg-K

% Geometry (from your polynomials/assumptions)
n_plates = -13.1760*T_cond^3 + 1400.4*T_cond^2 - 49532*T_cond + 5.8515e5;
if T_cond < 30
pitch = 0.00411; chevron_angle = 45;
else
pitch = 0.00528; chevron_angle = 60;
end
plate_thk = 0.0006;
b    = pitch - plate_thk;
phi = 1.25;
Dh   = 2*b/phi;
w_channel = 1.07;
A_channel = b*w_channel;

% Effectiveness → capacity rate
deltaT1 = T_hot_in - T_cold_in;
C_min    = Q_target/(eps*max(deltaT1,1e-6));
m_cold   = C_min/cp_cold;
T_cold_out = T_cold_in + Q_target/(m_cold*cp_cold);
deltaT2 = T_hot_out - T_cold_out;

% LMTD
if abs(deltaT1 - deltaT2) < 1e-6
LMTD = (deltaT1 + deltaT2)/2;
else
LMTD = (deltaT1 - deltaT2)/log(max(deltaT1,1e-6)/max(deltaT2,1e-6));
end

% Cold-side properties
          T_ave = (T_cold_in + T_cold_out)/2;
          mu_cold  = CoolProp.PropsSI('V','T', T_ave+273.15, 'Q', 0, 'Water');
```

```
k_cold   = CoolProp.PropsSI('CONDUCTIVITY','T',T_ave+273.15,'Q',0,'Water');
rho_cold = CoolProp.PropsSI('D','T', T_ave+273.15, 'Q', 0, 'Water');
Pr_cold  = CoolProp.PropsSI('PRANDTL','T', T_ave+273.15, 'Q', 0, 'Water');

% Channel flow
n_channels    = max((n_plates - 1)/2, 1);
m_dot_chan    = m_cold/n_channels;
G             = m_dot_chan/max(A_channel,1e-6);

% HTC
Re_cold = G*Dh/max(mu_cold,1e-9);
Nu_cold = compute_Nu_chevron(Re_cold, Pr_cold, chevron_angle);
h_cold  = Nu_cold*k_cold/max(Dh,1e-6);

% Hot-side overall HTC (film condensing correlation encapsulated)
h_hot = 109.16*T_cond^2 - 8483.24*T_cond + 184458.3; % W/m2-K
U = 1/(1/max(h_hot,1) + 1/max(h_cold,1));

% Area
A = Q_target/(U*max(LMTD,1e-3));
end

function [T_hot_out, m_hot, A] = Aeva(Teva, m_cold, T_hot_in, epsilo)
% Evaporator plate-HX: hot oil heats water to evaporation at Teva
hfg = CoolProp.PropsSI('H','T',Teva+273.15,'Q',1,'Water') - ...
CoolProp.PropsSI('H','T',Teva+273.15,'Q',0,'Water');   % J/kg
Q_target = m_cold*hfg;       % W

T_cold_in = Teva;            % evaporation isothermal on cold side
cp_hot = mean([2.15, 1.916])*1e3; % J/kg-K (oil)

% Geometry (assumed)
n_plates = 99;
pitch = 0.00352; chevron_angle = 30; plate_thk = 0.0006;
b    = pitch - plate_thk;
phi = 1.25;
Dh   = 2*b/phi;
w_channel = 0.38;
A_channel = b*w_channel;

% Effectiveness → capacity rate and hot outlet temp
deltaT1 = T_hot_in - T_cold_in;
C_min   = Q_target/(epsilo*max(deltaT1,1e-6));
m_hot   = C_min/cp_hot;
T_hot_out = T_hot_in - Q_target/(m_hot*cp_hot);
deltaT2 = T_hot_out - T_cold_in;

% LMTD
if abs(deltaT1 - deltaT2) < 1e-6
LMTD = (deltaT1 + deltaT2)/2;
else
LMTD = (deltaT1 - deltaT2)/log(max(deltaT1,1e-6)/max(deltaT2,1e-6));
end

% Hot-side properties (oil, averaged)
          T_ave = (T_hot_in + T_hot_out)/2;
          mu_hot = mean([0.9603, 2.3019])/1e3;  % Pa·s
          k_hot  = mean([0.1066, 0.112]);       % W/m-K
```

```
rho_hot= mean([893.39, 939.7]);        % kg/m3
Pr_hot = cp_hot*mu_hot/max(k_hot,1e-6);

% Channel flow
n_channels = max((n_plates - 1)/2, 1);
m_dot_ch    = m_hot/n_channels;
G           = m_dot_ch/max(A_channel,1e-6);

% HTC
Re_hot = G*Dh/max(mu_hot,1e-9);
Nu_hot = compute_Nu_chevron(Re_hot, Pr_hot, chevron_angle);
h_hot  = Nu_hot*k_hot/max(Dh,1e-6);

% Cold-side HTC (from your Aspen estimate)
h_cold = 19085.9;            % W/m2-K
U = 1/(1/max(h_hot,1) + 1/max(h_cold,1));

% Area
A = Q_target/(U*max(LMTD,1e-3));
end

function A_required = AHX(Q_target_W, T_cold_in, T_cold_out)
% Generic plate HX area (hot steam 300→220°C vs oil T_cold_in→T_cold_out)
T_hot_in  = 300;  T_hot_out = 220;  % °C

% Hot side (steam-like)
cp_hot = mean([1.941, 1.977])*1e3;      % J/kg-K
mu_hot = mean([0.02, 0.0168])/1e3;      % Pa·s
k_hot  = mean([0.0423, 0.0351]);        % W/m-K
rho_hot= mean([0.57, 0.59]);            % kg/m3
Pr_hot = cp_hot*mu_hot/max(k_hot,1e-6);

% Cold side (oil)
cp_cold = mean([2.123, 2.18])*1e3;      % J/kg-K
mu_cold = mean([1.0386, 0.8813])/1e3;   % Pa·s
k_cold  = mean([0.1073, 0.1059]);       % W/m-K
rho_cold= mean([898.68, 887.58]);       % kg/m3
Pr_cold = cp_cold*mu_cold/max(k_cold,1e-6);

% Geometry
n_plates = 1012; chevron_angle = 60; pitch = 0.00528; plate_thk = 0.0006;
b   = pitch - plate_thk; phi = 1.25; Dh = 2*b/phi; w_channel = 1.07;
A_channel = b*w_channel;

% Mass flows from Q = m*cp*ΔT
m_cold = Q_target_W/(cp_cold*(T_cold_out - T_cold_in));
m_hot  = Q_target_W/(cp_hot *(T_hot_in  - T_hot_out));
C_cold = m_cold*cp_cold; C_hot = m_hot*cp_hot; %#ok<NASGU>

% LMTD
DT1 = T_hot_in - T_cold_out;
DT2 = T_hot_out - T_cold_in;
if abs(DT1 - DT2) < 1e-6
LMTD = (DT1 + DT2)/2;
else
          LMTD = (DT1 - DT2)/log(max(DT1,1e-6)/max(DT2,1e-6));
          end
```

```
% Channel flows
n_channels   = max((n_plates - 1)/2, 1);
m_dot_hot_ch = m_hot/n_channels;
m_dot_cold_ch= m_cold/n_channels;
G_hot  = m_dot_hot_ch/max(A_channel,1e-6);
G_cold = m_dot_cold_ch/max(A_channel,1e-6);

Re_hot  = G_hot*Dh/max(mu_hot,1e-9);
Re_cold = G_cold*Dh/max(mu_cold,1e-9);

Nu_hot  = compute_Nu_chevron(Re_hot,  Pr_hot,  chevron_angle);
Nu_cold = compute_Nu_chevron(Re_cold, Pr_cold, chevron_angle);
h_hot   = Nu_hot *k_hot /max(Dh,1e-6);
h_cold  = Nu_cold*k_cold/max(Dh,1e-6);

U = 1/(1/max(h_hot,1) + 1/max(h_cold,1));
A_required = Q_target_W/(U*max(LMTD,1e-3));
end

function Nu = compute_Nu_chevron(Re, Pr, chevron_angle)
% Nusselt number correlations by chevron angle and regime
switch chevron_angle
case 30
if Re <= 10, Ch=0.718; n=0.349; else, Ch=0.348; n=0.663; end
case 45
if Re < 10, Ch=0.718; n=0.349;
elseif Re <= 100, Ch=0.400; n=0.598; else, Ch=0.300; n=0.663; end
case 50
if Re < 20, Ch=0.630; n=0.333;
elseif Re <= 300, Ch=0.291; n=0.591; else, Ch=0.130; n=0.732; end
case 60
if Re < 20, Ch=0.562; n=0.326;
elseif Re <= 400, Ch=0.306; n=0.529; else, Ch=0.108; n=0.703; end
case 65
if Re < 20, Ch=0.562; n=0.326;
elseif Re <= 500, Ch=0.331; n=0.503; else, Ch=0.087; n=0.718; end
otherwise
error('Unsupported chevron angle. Use 30, 45, 50, 60, or 65 deg.');
end
Nu = Ch * max(Re,1e-6)^n * max(Pr,1e-6)^(1/3);
end
```

## 8.2 Aspen EDR

The following data sheets present the results of designing and sizing the different heat exchangers in Aspen EDR, a powerful tool for heat exchanger simulation.

**a) Petrochemical case**

**1. Condenser**

## Plate Heat Exchanger Specification Sheet

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | **Company:** | | | | | |
| 2 | **Location:** | | | | | |
| 3 | **Service of Unit:** | | **Our Reference:** | | | |
| 4 | **Item No.:** | | **Your Reference:** | | | |
| 5 | **Date:** | **Rev No.:** | **Job No.:** | | | |
| 6 | **CASE** | | **HOT SIDE** | | **COLD SIDE** | |
| 7 | Fluid | | Water | | Coolant | |
| 8 | Total flow | kg/s | 0,55 | | 65 | |
| 9 | Flow per PHE | kg/s | 0,0367 | | 4,3333 | |
| 10 | Pressure drop allow. / calc. | bar | 0,00024 / 0,00024 | | 0,1 / 0,00012 | |
| 11 | Velocity between plates | m/s | 0,62 | | 0 | |
| 12 | Wall shear stress | N/m² | 0,02 | | 0,01 | |
| 13 | Fouling margin | % | 0 | | 0 | |
| 14 | **OPERATING DATA** | | **INLET** | **OUTLET** | **INLET** | **OUTLET** |
| 15 | Liquid flow | kg/s | 0 | 0,55 | 65 | 65 |
| 16 | Vapor flow | kg/s | 0,55 | 0 | 0 | 0 |
| 17 | Operating temperature | °C | 20,48 | 20,32 | 13 | 17,97 |
| 18 | Operating pressure | bar | 0,0241 | 0,02386 | 1 | 0,99988 |
| 19 | **LIQUID PROPERTIES** | | | | | |
| 20 | Density | kg/m³ | | 998,19 | 999,48 | 998,7 |
| 21 | Specific heat | kJ/(kg-K) | | 4,184 | 4,191 | 4,185 |
| 22 | Viscosity | mPa-s | | 0,9938 | 1,2005 | 1,0537 |
| 23 | Thermal conductivity | W/(m-K) | | 0,5985 | 0,5849 | 0,5943 |
| 24 | Surface tension | N/m | | 0,0727 | 0,0738 | 0,073 |
| 25 | **VAPOR PROPERTIES** | | | | | |
| 26 | Density | kg/m³ | 0,02 | | | |
| 27 | Specific heat | kJ/(kg-K) | 1,906 | | | |
| 28 | Viscosity | mPa-s | 0,0096 | | | |
| 29 | Thermal conductivity | W/(m-K) | 0,0181 | | | |
| 30 | Relative molecular mass | | 18,02 | | | |
| 31 | Dew point / bubble point | °C | 20,48 / 20,32 | | / | |
| 32 | Latent heat | kJ/kg | 2452,4 | | | |
| 33 | Critical pressure | bar | 220,64 | | 220,64 | |
| 34 | Critical temperature | °C | 373,95 | | 373,95 | |
| 35 | Total heat exchanged | kW | 1350,1 | | | |
| 36 | $U^a$ | W/(m²-K) | Clean condition: | 294,8 | Service: | 294,8 |
| 37 | LMTD / Effective MTD | °C | 4,5 / 4,5 | | | |
| 38 | Heat transfer area | m² | 73335,2 | | | |
| 39 | Stream heat transfer coeff. | W/(m²-K) | 45978,7 | | 300,1 | |
| 40 | **CONFIGURATION FOR EXCHANGER AND PLATE DETAILS** | | | | | |
| 41 | Number of PHE in parallel | 15 | Heat transfer area/PHE | | m² | 73335,2 |
| 42 | Number of passes, hot side | 1 | Heat transfer area/plate | | m² | 2,786 |
| 43 | Number of passes, cold side | 1 | Plate chevron angles(s) | | Degrees | 45 |
| 44 | Number of plates per PHE | 1757 | Nominal plate thickness | | mm | 0,6 |
| 45 | | | Nominal plate gap | | mm | 3,51 |
| 46 | Mass empty / full of water | kg | 23335,4 / 346078,9 | | | |
| 47 | Remarks: | | | | | |
| 48 | | | | | | |
| 49 | | | | | | |
| 50 | | | | | | |

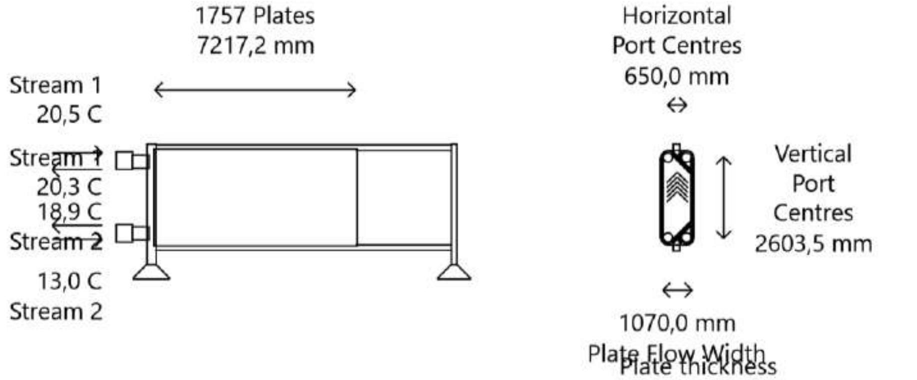
### Overall Performance

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 0,55 | | 65 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0,55 | 0 | 0 | 0 |
| Liquid mass flow rate | kg/s | 0 | 0,55 | 65 | 65 |
| Vapor mass quality | | 1 | 0 | 0 | 0 |
| Temperatures | °C | 20,48 | 20,32 | 13 | 17,97 |
| Dew / Bubble point | °C | 20,48 | 20,32 | | |
| Pressure (abs) | bar | 0,0241 | 0,02386 | 1 | 0,99988 |
| Heat transfer coeff (mean) | W/(m²-K) | 45978,7 | | 300,1 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 16,38 / 0,62 | | 0,03 / 0 | |
| Mean wall shear stress | N/m² | 0,02 | | 0,01 | |
| Pressure drop (allow/calc.) | bar | 0,00024 / 0,00024 | | 0,1 / 0,00012 | |
| Residence volume | m³ | 161,3717 | | 161,3717 | |
| Residence time | Seconds | 10,45 | | 2480,37 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total heat exchanged | kW | 1350,1 | | Exchangers | 15 | Plates | 26355 |
| Overall coef. (dirty/clean) | W/(m²-K) | 294,8 / 294,8 | | Passes – hot / cold | | 1 / 1 | |
| Effective surface area | m² | 73335,2 | | Channels – hot / cold | | 878 / 878 | |
| Overall effective MTD | °C | 4,5 | | Plate – length / width | mm | 3023,52 / 1070 | |
| Actual/Reqd. area (dirty/clean) | | 72,02 / 72,02 | | Plate – pitch / thk | mm | 4,11 / 0,6 | |
| Actual/Reqd. area (incl. fouling margin) | | | | Port diameter | mm | 400 | |
| Risk of maldistribution | | No | | Chevron angle | Degrees | 45 | |

### Resistance Distribution

| **Overall Coefficient/Resistance Summary** | | | **Clean** | **Dirty** |
|---|---|---|---|---|
| Required area | | m² | 1018,3 | 1018,3 |
| Area ratio: actual/required | | | 72,02 | 72,02 |
| Overall coefficient | | W/(m²-K) | 294,8 | 294,8 |
| Overall heat transfer resistance | | m²-K/W | 0,00339 | 0,00339 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| **Resistance Distribution** | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 45978,7 | 2E-05 | 0,64 | 0,64 |
| Hot side fouling | | 0 | | 0 |
| Wall | 25870,4 | 4E-05 | 1,14 | 1,14 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 300,1 | 0,00333 | 98,22 | 98,22 |




| | | | |
|---|---|---|---|
| | | Plate thickness | 0,6 mm |
| Effective surface area | 4889,012 m2 | Compressed plate pitch | 4,1 mm |
| Number of passes Stream 1 / 2 | 1 / 1 | Area of each plate | 2,786 m2 |
| Effective channels Stream 1 / 2 | 878 / 878 | Chevron angle (to horizontal) | 45 |
| Number of exchangers | 15 | Material type | SS-304 |
| | | Port diameter | 400,0 mm |

## 2. Evaporator

## Plate Heat Exchanger Specification Sheet

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | **Company:** | | | | | | |
| 2 | **Location:** | | | | | | |
| 3 | **Service of Unit:** | | **Our Reference:** | | | | |
| 4 | **Item No.:** | | **Your Reference:** | | | | |
| 5 | **Date:** | **Rev No.:** | **Job No.:** | | | | |
| 6 | **CASE** | | **HOT SIDE** | | **COLD SIDE** | | |
| 7 | Fluid | | Oil | | Water | | |
| 8 | Total flow | kg/s | 9,7142 | | 0,55 | | |
| 9 | Flow per PHE | kg/s | 9,7142 | | 0,55 | | |
| 10 | Pressure drop allow. / calc. | bar | 0,15 / 0,13971 | | 0,157 / 0,15692 | | |
| 11 | Velocity between plates | m/s | 0,2 | | 12,74 | | |
| 12 | Wall shear stress | N/m² | 28,8 | | 30,69 | | |
| 13 | Fouling margin | % | 0 | | 0 | | |
| 14 | **OPERATING DATA** | | **INLET** | **OUTLET** | **INLET** | **OUTLET** | |
| 15 | Liquid flow | kg/s | 9,7142 | 9,7142 | 0,55 | 0 | |
| 16 | Vapor flow | kg/s | 0 | 0 | 0 | 0,55 | |
| 17 | Operating temperature | °C | 185 | 122,8 | 112,8 | 112,8 | |
| 18 | Operating pressure | bar | 1,5 | 1,36029 | 1,57 | 1,41308 | |
| 19 | **LIQUID PROPERTIES** | | | | | | |
| 20 | Density | kg/m³ | 895,97 | 939,7 | 948,81 | | |
| 21 | Specific heat | kJ/(kg-K) | 2,137 | 1,916 | 4,203 | | |
| 22 | Viscosity | mPa-s | 0,9975 | 2,3019 | 0,2557 | | |
| 23 | Thermal conductivity | W/(m-K) | 0,1069 | 0,112 | 0,684 | | |
| 24 | Surface tension | N/m | 0,0001 | 0,0001 | 0,0561 | | |
| 25 | **VAPOR PROPERTIES** | | | | | | |
| 26 | Density | kg/m³ | | | | 0,79 | |
| 27 | Specific heat | kJ/(kg-K) | | | | 2,135 | |
| 28 | Viscosity | mPa-s | | | | 0,0127 | |
| 29 | Thermal conductivity | W/(m-K) | | | | 0,0257 | |
| 30 | Relative molecular mass | | | | | 18,01 | |
| 31 | Dew point / bubble point | °C | / | | 111,9 / 115,03 | | |
| 32 | Latent heat | kJ/kg | | | 2209,5 | | |
| 33 | Critical pressure | bar | 24,33887 | | 24,33887 | | |
| 34 | Critical temperature | °C | 568,91 | | 568,91 | | |
| 35 | Total heat exchanged | kW | 1221,6 | | | | |
| 36 | $U^a$ | W/(m²-K) | Clean condition: | 1098,4 | Service: | 1098,4 | |
| 37 | LMTD / Effective MTD | °C | 31,46 / 31,46 | | | | |
| 38 | Heat transfer area | m² | 38,8 | | | | |
| 39 | Stream heat transfer coeff. | W/(m²-K) | 1216,5 | | 19090 | | |
| 40 | **CONFIGURATION FOR EXCHANGER AND PLATE DETAILS** | | | | | | |
| 41 | Number of PHE in parallel | 1 | Heat transfer area/PHE | | m² | 38,8 | |
| 42 | Number of passes, hot side | 1 | Heat transfer area/plate | | m² | 0,4 | |
| 43 | Number of passes, cold side | 1 | Plate chevron angles(s) | | Degrees | 30 | |
| 44 | Number of plates per PHE | 99 | Nominal plate thickness | | mm | 0,6 | |
| 45 | | | Nominal plate gap | | mm | 2,92 | |
| 46 | Mass empty / full of water | kg | 212,5 / 332,5 | | | | |
| 47 | Remarks: | | | | | | |
| 48 | | | | | | | |
| 49 | | | | | | | |
| 50 | | | | | | | |

### Overall Performance

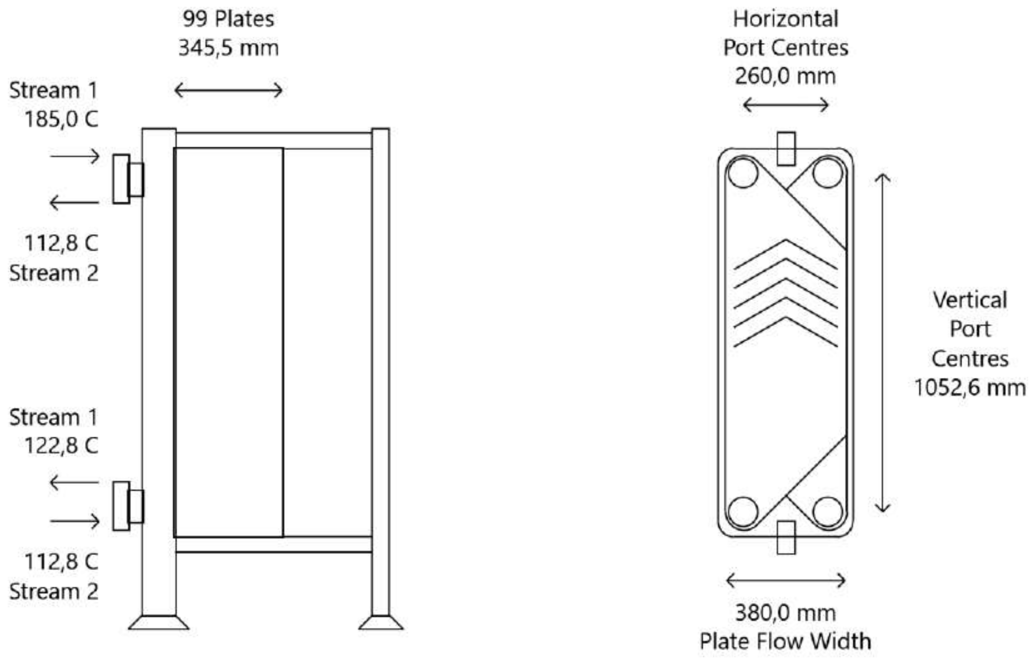
| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 9,7142 | | 0,55 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0 | 0 | 0,55 | 0,55 |
| Liquid mass flow rate | kg/s | 9,7142 | 9,7142 | 0 | 0 |
| Vapor mass quality | | 0 | 0 | 0 | 1 |
| Temperatures | °C | 185 | 122,8 | 112,8 | 112,8 |
| Dew / Bubble point | °C | | | 111,9 | 115,03 |
| Pressure (abs) | bar | 1,5 | 1,36029 | 1,57 | 1,41308 |
| Heat transfer coeff (mean) | $W/(m^2\text{-}K)$ | 1216,5 | | 19090 | |
| Fouling Resistance | $m^2\text{-}K/W$ | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 1,38 / | 0,2 | 88,29 / | 12,74 |
| Mean wall shear stress | $N/m^2$ | 28,8 | | 30,69 | |
| Pressure drop (allow/calc.) | bar | 0,15 / | 0,13971 | 0,157 / | 0,15692 |
| Residence volume | $m^3$ | 0,06 | | 0,06 | |
| Residence time | Seconds | 5,67 | | 0,17 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total heat exchanged | kW | 1221,6 | | | Exchangers | | 1 | Plates 99 |
| Overall coef. (dirty/clean) | $W/(m^2\text{-}K)$ | 1098,4 | / | 1098,4 | Passes – hot / cold | | 1 / | 1 |
| Effective surface area | $m^2$ | 38,8 | | | Channels – hot / cold | | 49 / | 49 |
| Overall effective MTD | °C | 31,46 | | | Plate – length / width | mm | 1172,63 / | 380 |
| Actual/Reqd. area (dirty/clean) | | 1,1 | / | 1,1 | Plate – pitch / thk | mm | 3,52 / | 0,6 |
| Actual/Reqd. area (incl. fouling margin) | | | | | Port diameter | mm | 100 | |
| Risk of maldistribution | | No | | | Chevron angle | Degrees | 30 | |

### Resistance Distribution

| **Overall Coefficient/Resistance Summary** | | | **Clean** | **Dirty** |
|---|---|---|---|---|
| Required area | | $m^2$ | 35,3 | 35,3 |
| Area ratio: actual/required | | | 1,1 | 1,1 |
| Overall coefficient | | $W/(m^2\text{-}K)$ | 1098,4 | 1098,4 |
| Overall heat transfer resistance | | $m^2\text{-}K/W$ | 0,00091 | 0,00091 |
| Hot side fouling | | $m^2\text{-}K/W$ | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| **Resistance Distribution** | $W/(m^2\text{-}K)$ | $m^2\text{-}K/W$ | % | % |
| Hot side coefficient | 1216,5 | 0,00082 | 90,29 | 90,29 |
| Hot side fouling | | 0 | | 0 |
| Wall | 27782,4 | 4E-05 | 3,95 | 3,95 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 19090 | 5E-05 | 5,75 | 5,75 |

2 warnings




| | | | |
|---|---|---|---|
| | | Plate thickness | 0,6 mm |
| Effective surface area | 38,800 m2 | Compressed plate pitch | 3,5 mm |
| Number of passes Stream 1 / 2 | 1 / 1 | Area of each plate | 0,400 m2 |
| Effective channels Stream 1 / 2 | 49 / 49 | Chevron angle (to horizontal) | 30 |
| Number of exchangers | 1 | Material type | SS-304 |
| | | Port diameter | 100,0 mm |

**3. Preheater**

Tech UPGRADE

## Plate Heat Exchanger Specification Sheet

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | **Company:** | | | | | |
| 2 | **Location:** | | | | | |
| 3 | **Service of Unit:** | | **Our Reference:** | | | |
| 4 | **Item No.:** | | **Your Reference:** | | | |
| 5 | **Date:** | **Rev No.:** | **Job No.:** | | | |
| 6 | **CASE** | | **HOT SIDE** | | **COLD SIDE** | |
| 7 | Fluid | | Oil | | Water | |
| 8 | Total flow | kg/s | 9,7 | | 0,55 | |
| 9 | Flow per PHE | kg/s | 9,7 | | 0,55 | |
| 10 | Pressure drop allow. / calc. | bar | 0,15 / | 0,14565 | 0,157 / | 0,00052 |
| 11 | Velocity between plates | m/s | 0,38 | | 0,02 | |
| 12 | Wall shear stress | N/m² | 33,2 | | 0,12 | |
| 13 | Fouling margin | % | 0 | | 0 | |
| 14 | **OPERATING DATA** | | **INLET** | **OUTLET** | **INLET** | **OUTLET** |
| 15 | Liquid flow | kg/s | 9,7 | 9,7 | 0,55 | 0,55 |
| 16 | Vapor flow | kg/s | 0 | 0 | 0 | 0 |
| 17 | Operating temperature | °C | 122,8 | 111,42 | 20,4 | 111,9 |
| 18 | Operating pressure | bar | 1,5 | 1,35435 | 1,57 | 1,56948 |
| 19 | **LIQUID PROPERTIES** | | | | | |
| 20 | Density | kg/m³ | 939,7 | 947,58 | 1024,39 | 949,54 |
| 21 | Specific heat | kJ/(kg-K) | 1,916 | 1,876 | 4,133 | 4,203 |
| 22 | Viscosity | mPa-s | 2,3019 | 2,798 | 0,5255 | 0,2575 |
| 23 | Thermal conductivity | W/(m-K) | 0,112 | 0,1128 | 0,6465 | 0,6836 |
| 24 | Surface tension | N/m | 0,0001 | 0,0001 | 0,0749 | 0,0563 |
| 25 | **VAPOR PROPERTIES** | | | | | |
| 26 | Density | kg/m³ | | | | |
| 27 | Specific heat | kJ/(kg-K) | | | | |
| 28 | Viscosity | mPa-s | | | | |
| 29 | Thermal conductivity | W/(m-K) | | | | |
| 30 | Relative molecular mass | | | | | |
| 31 | Dew point / bubble point | °C | / | | / | |
| 32 | Latent heat | kJ/kg | | | | |
| 33 | Critical pressure | bar | 24,33887 | | 24,33887 | |
| 34 | Critical temperature | °C | 568,91 | | 568,91 | |
| 35 | Total heat exchanged | kW | 211,5 | | | |
| 36 | $U^a$ | W/(m²-K) | Clean condition: | 588,7 | Service: | 588,7 |
| 37 | LMTD / Effective MTD | °C | 37,75 / | | 37,75 | |
| 38 | Heat transfer area | m² | 12,6 | | | |
| 39 | Stream heat transfer coeff. | W/(m²-K) | 1051 | | 1407,7 | |
| 40 | **CONFIGURATION FOR EXCHANGER AND PLATE DETAILS** | | | | | |
| 41 | Number of PHE in parallel | 1 | Heat transfer area/PHE | | m² | 12,6 |
| 42 | Number of passes, hot side | 1 | Heat transfer area/plate | | m² | 0,267 |
| 43 | Number of passes, cold side | 1 | Plate chevron angles(s) | | Degrees | 45 |
| 44 | Number of plates per PHE | 49 | Nominal plate thickness | | mm | 0,6 |
| 45 | | | Nominal plate gap | | mm | 3,51 |
| 46 | Mass empty / full of water | kg | 73,7 / | | 119,7 | |
| 47 | Remarks: | | | | | |
| 48 | | | | | | |
| 49 | | | | | | |
| 50 | | | | | | |

### Overall Performance

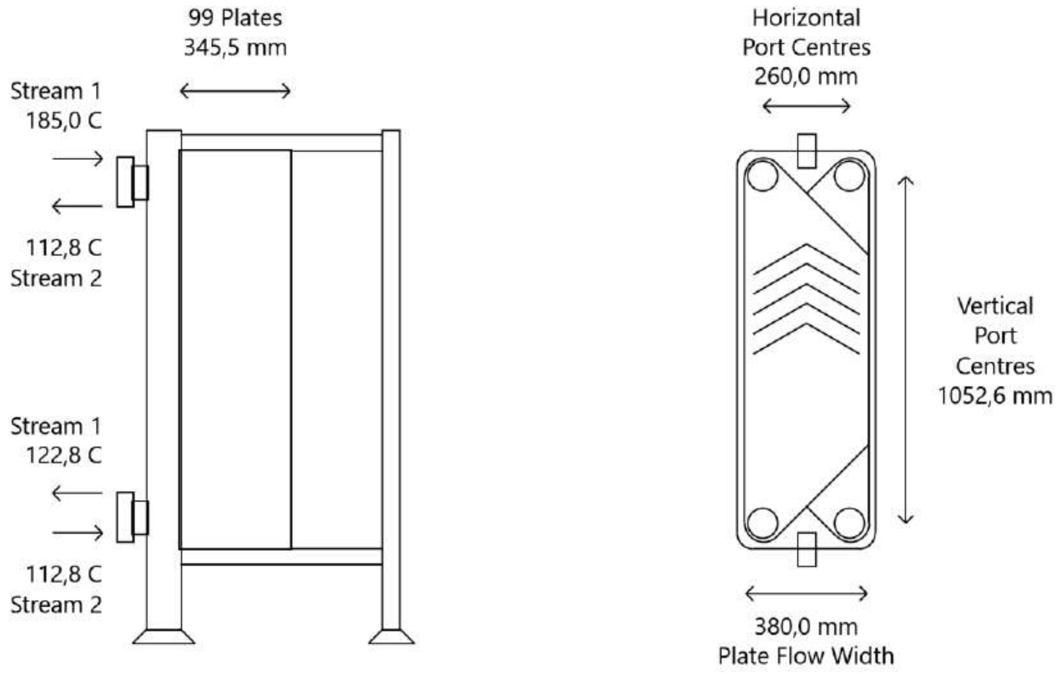
| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 9,7 | | 0,55 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0 | 0 | 0 | 0 |
| Liquid mass flow rate | kg/s | 9,7 | 9,7 | 0,55 | 0,55 |
| Vapor mass quality | | 0 | 0 | 0 | 0 |
| Temperatures | °C | 122,8 | 111,42 | 20,4 | 111,9 |
| Dew / Bubble point | °C | | | | |
| Pressure (abs) | bar | 1,5 | 1,35435 | 1,57 | 1,56948 |
| Heat transfer coeff (mean) | W/(m²-K) | 1051 | | 1407,7 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 2,34 / 0,38 | | 0,13 / 0,02 | |
| Mean wall shear stress | N/m² | 33,2 | | 0,12 | |
| Pressure drop (allow/calc.) | bar | 0,15 / 0,14565 | | 0,157 / 0,00052 | |
| Residence volume | m³ | 0,023 | | 0,023 | |
| Residence time | Seconds | 2,24 | | 41,25 | |

| | | | | | |
|---|---|---|---|---|---|
| Total heat exchanged | kW | 211,5 | Exchangers | 1 | Plates 49 |
| Overall coef. (dirty/clean) | W/(m²-K) | 588,7 / 588,7 | Passes – hot / cold | | 1 / 1 |
| Effective surface area | m² | 12,6 | Channels – hot / cold | | 24 / 24 |
| Overall effective MTD | °C | 37,75 | Plate – length / width | mm | 919,12 / 322,5 |
| Actual/Reqd. area (dirty/clean) | | 1,32 / 1,32 | Plate – pitch / thk | mm | 4,11 / 0,6 |
| Actual/Reqd. area (incl. fouling margin) | | | Port diameter | mm | 75 |
| Risk of maldistribution | | No | Chevron angle | Degrees | 45 |

### Resistance Distribution

| **Overall Coefficient/Resistance Summary** | | | **Clean** | **Dirty** |
|---|---|---|---|---|
| Required area | | m² | 9,5 | 9,5 |
| Area ratio: actual/required | | | 1,32 | 1,32 |
| Overall coefficient | | W/(m²-K) | 588,7 | 588,7 |
| Overall heat transfer resistance | | m²-K/W | 0,0017 | 0,0017 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| **Resistance Distribution** | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 1051 | 0,00095 | 56,02 | 56,02 |
| Hot side fouling | | 0 | | 0 |
| Wall | 27221,5 | 4E-05 | 2,16 | 2,16 |
| Cold side fouling | | 0 | 0 | 0 |
| Cold side coefficient | 1407,7 | 0,00071 | 41,82 | 41,82 |

2 warnings




| | | | |
|---|---|---|---|
| | | Plate thickness | 0,6 mm |
| Effective surface area | 38,800 m2 | Compressed plate pitch | 3,5 mm |
| Number of passes Stream 1 / 2 | 1 / 1 | Area of each plate | 0,400 m2 |
| Effective channels Stream 1 / 2 | 49 / 49 | Chevron angle (to horizontal) | 30 |
| Number of exchangers | 1 | Material type | SS-304 |
| | | Port diameter | 100,0 mm |

**4. WH recovery unit**

Tech UPGRADE

## Plate Heat Exchanger Specification Sheet

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | **Company:** | | | | | |
| 2 | **Location:** | | | | | |
| 3 | **Service of Unit:** | | **Our Reference:** | | | |
| 4 | **Item No.:** | | **Your Reference:** | | | |
| 5 | **Date:** | **Rev No.:** | **Job No.:** | | | |
| 6 | **CASE** | | **HOT SIDE** | | **COLD SIDE** | |
| 7 | Fluid | | Water | | Oil | |
| 8 | Total flow | kg/s | 28,6695 | | 78,5 | |
| 9 | Flow per PHE | kg/s | 5,7339 | | 15,7 | |
| 10 | Pressure drop allow. / calc. | bar | 0,15 / | 0,14966 | 0,15 / | 0,00136 |
| 11 | Velocity between plates | m/s | 16,83 | | 0,03 | |
| 12 | Wall shear stress | N/m² | 11,94 | | 0,11 | |
| 13 | Fouling margin | % | 0 | | 0 | |
| 14 | **OPERATING DATA** | | **INLET** | **OUTLET** | **INLET** | **OUTLET** |
| 15 | Liquid flow | kg/s | 0 | 0 | 78,5 | 78,5 |
| 16 | Vapor flow | kg/s | 28,6695 | 28,6695 | 0 | 0 |
| 17 | Operating temperature | °C | 300 | 220 | 175,3 | 200 |
| 18 | Operating pressure | bar | 1,5 | 1,35034 | 1,5 | 1,49864 |
| 19 | **LIQUID PROPERTIES** | | | | | |
| 20 | Density | kg/m³ | | | 902,89 | 885,24 |
| 21 | Specific heat | kJ/(kg-K) | | | 2,102 | 2,192 |
| 22 | Viscosity | mPa-s | | | 1,1103 | 0,8513 |
| 23 | Thermal conductivity | W/(m-K) | | | 0,1078 | 0,1056 |
| 24 | Surface tension | N/m | | | 0,0001 | 0,0001 |
| 25 | **VAPOR PROPERTIES** | | | | | |
| 26 | Density | kg/m³ | 0,57 | 0,59 | | |
| 27 | Specific heat | kJ/(kg-K) | 1,941 | 1,977 | | |
| 28 | Viscosity | mPa-s | 0,02 | 0,0168 | | |
| 29 | Thermal conductivity | W/(m-K) | 0,0423 | 0,0351 | | |
| 30 | Relative molecular mass | | | | | |
| 31 | Dew point / bubble point | °C | / | | / | |
| 32 | Latent heat | kJ/kg | | | | |
| 33 | Critical pressure | bar | 221,0597 | | 221,0597 | |
| 34 | Critical temperature | °C | 374,13 | | 374,13 | |
| 35 | Total heat exchanged | kW | 4130,4 | | | |
| 36 | *U*[a] | W/(m²-K) | Clean condition: | 101 | Service: | 101 |
| 37 | LMTD / Effective MTD | °C | 68,68 | / | 68,68 | |
| 38 | Heat transfer area | m² | 3329 | | | |
| 39 | Stream heat transfer coeff. | W/(m²-K) | 190,1 | | 217 | |
| 40 | **CONFIGURATION FOR EXCHANGER AND PLATE DETAILS** | | | | | |
| 41 | Number of PHE in parallel | 5 | Heat transfer area/PHE | | m² | 3329 |
| 42 | Number of passes, hot side | 1 | Heat transfer area/plate | | m² | 2,786 |
| 43 | Number of passes, cold side | 1 | Plate chevron angles(s) | | Degrees | 60 |
| 44 | Number of plates per PHE | 241 | Nominal plate thickness | | mm | 0,6 |
| 45 | | | Nominal plate gap | | mm | 4,68 |
| 46 | Mass empty / full of water | kg | 3200,8 | / | 22582,1 | |
| 47 | Remarks: | | | | | |
| 48 | | | | | | |
| 49 | | | | | | |
| 50 | | | | | | |

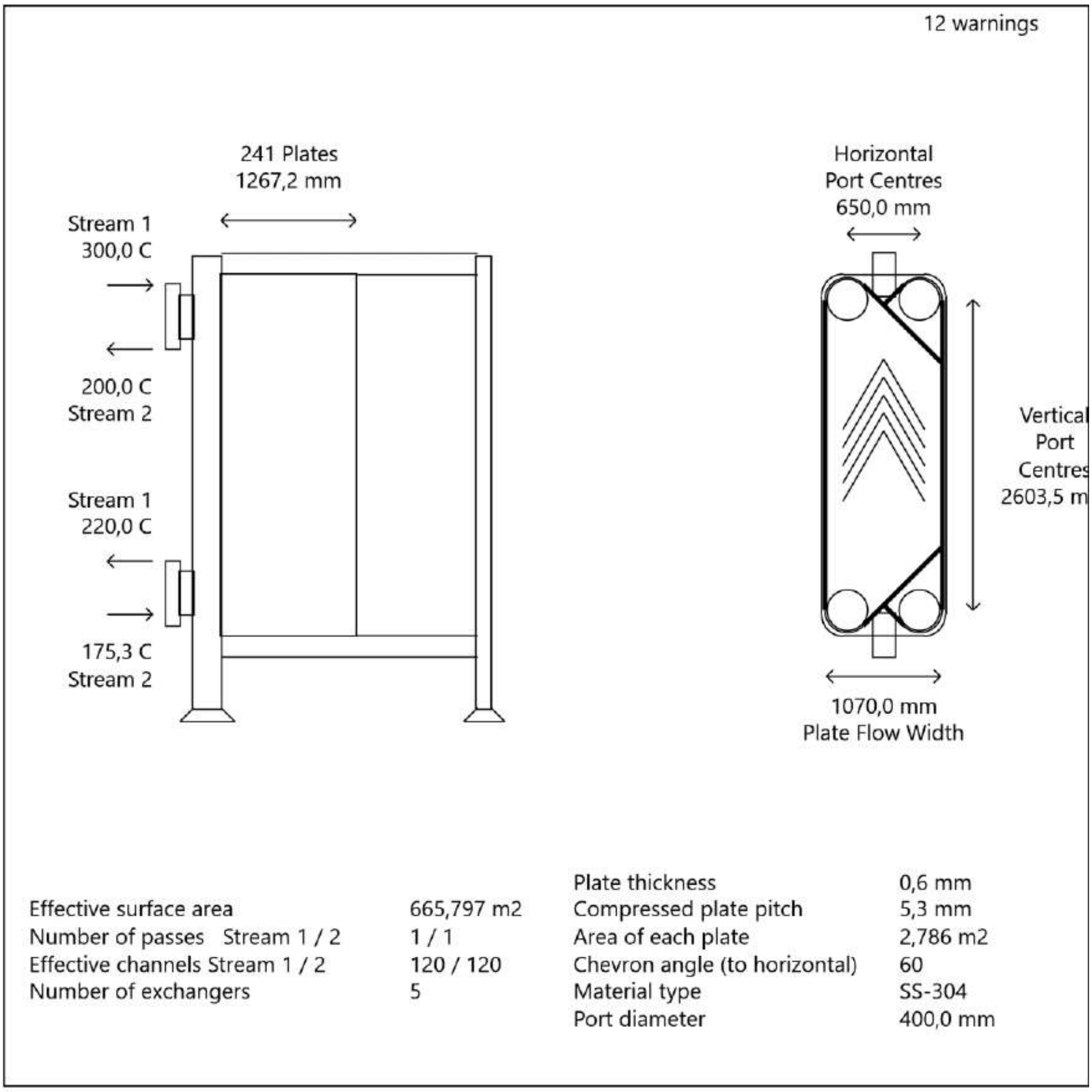
### Overall Performance

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 28,6695 | | 78,5 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 28,6695 | 28,6695 | 0 | 0 |
| Liquid mass flow rate | kg/s | 0 | 0 | 78,5 | 78,5 |
| Vapor mass quality | | 1 | 1 | 0 | 0 |
| Temperatures | °C | 300 | 220 | 175,3 | 200 |
| Dew / Bubble point | °C | | | | |
| Pressure (abs) | bar | 1,5 | 1,35034 | 1,5 | 1,49864 |
| Heat transfer coeff (mean) | W/(m²-K) | 190,1 | | 217 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 80,47 / 16,83 | | 0,14 / 0,03 | |
| Mean wall shear stress | N/m² | 11,94 | | 0,11 | |
| Pressure drop (allow/calc.) | bar | 0,15 / 0,14966 | | 0,15 / 0,00136 | |
| Residence volume | m³ | 9,6907 | | 9,6907 | |
| Residence time | Seconds | 0,2 | | 110,36 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total heat exchanged | kW | 4130,4 | Exchangers | | 5 | Plates 1205 |
| Overall coef. (dirty/clean) | W/(m²-K) | 101 / 101 | Passes – hot / cold | | | 1 / 1 |
| Effective surface area | m² | 665,8 | Channels – hot / cold | | | 120 / 120 |
| Overall effective MTD | °C | 68,68 | Plate – length / width | mm | | 3023,52 / 1070 |
| Actual/Reqd. area (dirty/clean) | | 5,59 / 5,59 | Plate – pitch / thk | mm | | 5,28 / 0,6 |
| Actual/Reqd. area (incl. fouling margin) | | | Port diameter | mm | | 400 |
| Risk of maldistribution | | No | Chevron angle | Degrees | | 60 |

### Resistance Distribution

| **Overall Coefficient/Resistance Summary** | | | **Clean** | **Dirty** |
|---|---|---|---|---|
| Required area | | m² | 595,4 | 595,4 |
| Area ratio: actual/required | | | 5,59 | 5,59 |
| Overall coefficient | | W/(m²-K) | 101 | 101 |
| Overall heat transfer resistance | | m²-K/W | 0,0099 | 0,0099 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| **Resistance Distribution** | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 190,1 | 0,00526 | 53,13 | 53,13 |
| Hot side fouling | | 0 | | 0 |
| Wall | 29893 | 3E-05 | 0,34 | 0,34 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 217 | 0,00461 | 46,54 | 46,54 |




**5. Steam generator**

## Plate Heat Exchanger Specification Sheet

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | **Company:** | | | | | |
| 2 | **Location:** | | | | | |
| 3 | **Service of Unit:** | **Our Reference:** | | | | |
| 4 | **Item No.:** | **Your Reference:** | | | | |
| 5 | **Date:** **Rev No.:** | **Job No.:** | | | | |
| 6 | **CASE** | | **HOT SIDE** | | **COLD SIDE** | |
| 7 | Fluid | | Oil | | Steam | |
| 8 | Total flow | kg/s | 58,5 | | 1,1285 | |
| 9 | Flow per PHE | kg/s | 58,5 | | 1,1285 | |
| 10 | Pressure drop allow. / calc. | bar | 0,15 / 0,139 | | 3,98 / 0,00153 | |
| 11 | Velocity between plates | m/s | 0,22 | | 0,21 | |
| 12 | Wall shear stress | N/m² | 12,47 | | 0,14 | |
| 13 | Fouling margin | % | 0 | | 0 | |
| 14 | **OPERATING DATA** | | **INLET** | **OUTLET** | **INLET** | **OUTLET** |
| 15 | Liquid flow | kg/s | 58,5 | 58,5 | 1,1285 | 0 |
| 16 | Vapor flow | kg/s | 0 | 0 | 0 | 1,1285 |
| 17 | Operating temperature | °C | 250 | 233,98 | 200 | 249 |
| 18 | Operating pressure | bar | 1,5 | 1,361 | 39,8 | 39,79847 |
| 19 | **LIQUID PROPERTIES** | | | | | |
| 20 | Density | kg/m³ | 848,18 | 860,23 | 867,95 | |
| 21 | Specific heat | kJ/(kg-K) | 2,378 | 2,318 | 4,358 | |
| 22 | Viscosity | mPa-s | 0,567 | 0,6399 | 0,1464 | |
| 23 | Thermal conductivity | W/(m-K) | 0,1004 | 0,1022 | 0,6628 | |
| 24 | Surface tension | N/m | 0,0001 | 0,0001 | 0,0374 | |
| 25 | **VAPOR PROPERTIES** | | | | | |
| 26 | Density | kg/m³ | | | | 18,86 |
| 27 | Specific heat | kJ/(kg-K) | | | | 3,829 |
| 28 | Viscosity | mPa-s | | | | 0,0186 |
| 29 | Thermal conductivity | W/(m-K) | | | | 0,0458 |
| 30 | Relative molecular mass | | | | | 18,01 |
| 31 | Dew point / bubble point | °C | / | | 248,75 / 248,75 | |
| 32 | Latent heat | kJ/kg | | | 1731,7 | |
| 33 | Critical pressure | bar | 24,33887 | | 24,33887 | |
| 34 | Critical temperature | °C | 568,91 | | 568,91 | |
| 35 | Total heat exchanged | kW | 2200 | | | |
| 36 | *U*ª | W/(m²-K) | Clean condition: | 453 | Service: | 453 |
| 37 | LMTD / Effective MTD | °C | 9,35 / 9,35 | | | |
| 38 | Heat transfer area | m² | 522,7 | | | |
| 39 | Stream heat transfer coeff. | W/(m²-K) | 1251,4 | | 735,8 | |
| 40 | **CONFIGURATION FOR EXCHANGER AND PLATE DETAILS** | | | | | |
| 41 | Number of PHE in parallel | 1 | Heat transfer area/PHE | | m² | 522,7 |
| 42 | Number of passes, hot side | 1 | Heat transfer area/plate | | m² | 1,784 |
| 43 | Number of passes, cold side | 1 | Plate chevron angles(s) | | Degrees | 45 |
| 44 | Number of plates per PHE | 295 | Nominal plate thickness | | mm | 0,9 |
| 45 | | | Nominal plate gap | | mm | 3,51 |
| 46 | Mass empty / full of water | kg | 3921,9 / 5906,4 | | | |
| 47 | Remarks: | | | | | |
| 48 | | | | | | |
| 49 | | | | | | |
| 50 | | | | | | |

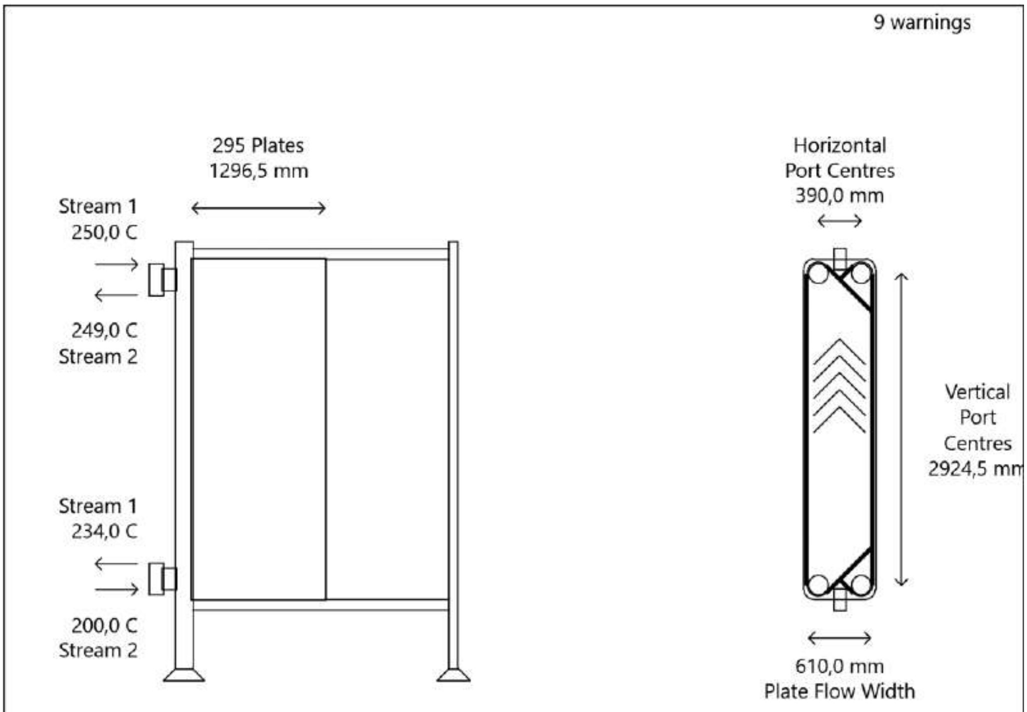
### Overall Performance

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 58,5 | | 1,1285 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0 | 0 | 1,1285 | 1,1285 |
| Liquid mass flow rate | kg/s | 58,5 | 58,5 | 0 | 0 |
| Vapor mass quality | | 0 | 0 | 0 | 1 |
| Temperatures | °C | 250 | 233,98 | 200 | 249 |
| Dew / Bubble point | °C | | | 248,75 | 248,75 |
| Pressure (abs) | bar | 1,5 | 1,361 | 39,8 | 39,79847 |
| Heat transfer coeff (mean) | W/(m²-K) | 1251,4 | | 735,8 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 2,19 / 0,22 | | 1,9 / 0,21 | |
| Mean wall shear stress | N/m² | 12,47 | | 0,14 | |
| Pressure drop (allow/calc.) | bar | 0,15 / 0,139 | | 3,98 / 0,00153 | |
| Residence volume | m³ | 0,9923 | | 0,9923 | |
| Residence time | Seconds | 14,49 | | 32,46 | |

| | | | | | |
|---|---|---|---|---|---|
| Total heat exchanged | kW | 2200 | Exchangers | 1 | Plates 295 |
| Overall coef. (dirty/clean) | W/(m²-K) | 453 / 453 | Passes – hot / cold | | 1 / 1 |
| Effective surface area | m² | 522,7 | Channels – hot / cold | | 147 / 147 |
| Overall effective MTD | °C | 9,35 | Plate – length / width | mm | 3144,55 / 610 |
| Actual/Reqd. area (dirty/clean) | | 1,01 / 1,01 | Plate – pitch / thk | mm | 4,41 / 0,9 |
| Actual/Reqd. area (incl. fouling margin) | | | Port diameter | mm | 200 |
| Risk of maldistribution | | No | Chevron angle | Degrees | 45 |

### Resistance Distribution

| **Overall Coefficient/Resistance Summary** | | | **Clean** | **Dirty** |
|---|---|---|---|---|
| Required area | | m² | 519,2 | 519,2 |
| Area ratio: actual/required | | | 1,01 | 1,01 |
| Overall coefficient | | W/(m²-K) | 453 | 453 |
| Overall heat transfer resistance | | m²-K/W | 0,00221 | 0,00221 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| **Resistance Distribution** | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 1251,4 | 0,0008 | 36,2 | 36,2 |
| Hot side fouling | | 0 | | 0 |
| Wall | 20235,7 | 5E-05 | 2,24 | 2,24 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 735,8 | 0,00136 | 61,56 | 61,56 |




| | | | |
|---|---|---|---|
| | | Plate thickness | 0,9 mm |
| Effective surface area | 522,705 m2 | Compressed plate pitch | 4,4 mm |
| Number of passes Stream 1 / 2 | 1 / 1 | Area of each plate | 1,784 m2 |
| Effective channels Stream 1 / 2 | 147 / 147 | Chevron angle (to horizontal) | 45 |
| Number of exchangers | 1 | Material type | SS-304 |
| | | Port diameter | 200,0 mm |

## b) Iron and Steel case

### 1. Condenser

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 0,55 | | 50 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0,55 | 0 | 0 | 0 |
| Liquid mass flow rate | kg/s | 0 | 0,55 | 50 | 50 |
| Vapor mass quality | | 1 | 0 | 0 | 0 |
| Temperatures | °C | 35 | 34,74 | 25 | 31,37 |
| Dew / Bubble point | °C | 34,91 | 34,74 | | |
| Pressure (abs) | bar | 0,056 | 0,05544 | 1 | 0,99965 |
| Heat transfer coeff (mean) | W/(m²-K) | 22780 | | 517,3 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 27,71 / 2,64 | | 0,1 / 0,01 | |
| Mean wall shear stress | N/m² | 0,04 | | 0,02 | |
| Pressure drop (allow/calc.) | bar | 0,00056 / 0,00056 | | 0,1 / 0,00035 | |
| Residence volume | m³ | 16,9803 | | 16,9803 | |
| Residence time | Seconds | 2,44 | | 338,33 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total heat exchanged | kW | 1331,2 | | Exchangers | | 4 | Plates | 2108 |
| Overall coef. (dirty/clean) | W/(m²-K) | 496,2 / 496,2 | | Passes – hot / cold | | | 1 / 1 | |
| Effective surface area | m² | 5850,1 | | Channels – hot / cold | | | 263 / 263 | |
| Overall effective MTD | °C | 6,19 | | Plate – length / width | mm | | 3023,52 / 1070 | |
| Actual/Reqd. area (dirty/clean) | | 13,49 / 13,49 | | Plate – pitch / thk | mm | | 5,28 / 0,6 | |
| Actual/Reqd. area (incl. fouling margin) | | | | Port diameter | mm | | 400 | |
| Risk of maldistribution | | No | | Chevron angle | Degrees | | 60 | |

| Overall Coefficient/Resistance Summary | | | | Clean | Dirty |
|---|---|---|---|---|---|
| Required area | | | m² | 433,7 | 433,7 |
| Area ratio: actual/required | | | | 13,49 | 13,49 |
| Overall coefficient | | | W/(m²-K) | 496,2 | 496,2 |
| Overall heat transfer resistance | | | m²-K/W | 0,00202 | 0,00202 |
| Hot side fouling | | | m²-K/W | 0 | 0 |
| Cold side fouling | | | | 0 | 0 |
| Resistance Distribution | W/(m²-K) | m²-K/W | | % | % |
| Hot side coefficient | 22780 | 4E-05 | | 2,18 | 2,18 |
| Hot side fouling | | 0 | | | 0 |
| Wall | 26156,5 | 4E-05 | | 1,9 | 1,9 |
| Cold side fouling | | 0 | | | 0 |
| **Cold side coefficient** | 517,3 | 0,00193 | | 95,92 | 95,92 |

### 2. Preheater

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 8,86 | | 0,55 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0 | 0 | 0 | 0 |
| Liquid mass flow rate | kg/s | 8,86 | 8,86 | 0,55 | 0,55 |
| Vapor mass quality | | 0 | 0 | 0 | 0 |
| Temperatures | °C | 122,8 | 112,19 | 35 | 111,9 |
| Dew / Bubble point | °C | | | | |
| Pressure (abs) | bar | 1,5 | 1,35024 | 1,57 | 1,56936 |
| Heat transfer coeff (mean) | W/($m^2$-K) | 1096,8 | | 1558,5 | |
| Fouling Resistance | $m^2$-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 2,13 / | 0,4 | 0,13 / | 0,02 |
| Mean wall shear stress | N/$m^2$ | 35,83 | | 0,16 | |
| Pressure drop (allow/calc.) | bar | 0,15 / | 0,14976 | 0,157 / | 0,00064 |
| Residence volume | $m^3$ | 0,0201 | | 0,0201 | |
| Residence time | Seconds | 2,14 | | 35,89 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Total heat exchanged | kW | | 178,9 | | Exchangers | 1 | Plates | | 43 |
| Overall coef. (dirty/clean) | W/($m^2$-K) | 628,9 | / | 628,9 | Passes – hot / cold | | 1 | / | 1 |
| Effective surface area | $m^2$ | | 11 | | Channels – hot / cold | | 21 | / | 21 |
| Overall effective MTD | °C | | 33,87 | | Plate – length / width | mm | 919,12 | / | 322,5 |
| Actual/Reqd. area (dirty/clean) | | 1,31 | / | 1,31 | Plate – pitch / thk | mm | 4,11 | / | 0,6 |
| Actual/Reqd. area (incl. fouling margin) | | | | | Port diameter | mm | | 75 | |
| Risk of maldistribution | | | No | | Chevron angle | Degrees | | 45 | |

| Overall Coefficient/Resistance Summary | | | Clean | Dirty |
|---|---|---|---|---|
| Required area | | $m^2$ | 8,4 | 8,4 |
| Area ratio: actual/required | | | 1,31 | 1,31 |
| Overall coefficient | | W/($m^2$-K) | 628,9 | 628,9 |
| Overall heat transfer resistance | | $m^2$-K/W | 0,00159 | 0,00159 |
| Hot side fouling | | $m^2$-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| Resistance Distribution | W/($m^2$-K) | $m^2$-K/W | % | % |
| Hot side coefficient | 1096,8 | 0,00091 | 57,34 | 57,34 |
| Hot side fouling | | 0 | | 0 |
| Wall | 27295,7 | 4E-05 | 2,3 | 2,3 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 1558,5 | 0,00064 | 40,35 | 40,35 |

**3. Evaporator**

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 8,1171 | | 0,55 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0 | 0 | 0,55 | 0,55 |
| Liquid mass flow rate | kg/s | 8,1171 | 8,1171 | 0 | 0 |
| Vapor mass quality | | 0 | 0 | 0 | 1 |
| Temperatures | °C | 196,6 | 122,8 | 112,8 | 112,8 |
| Dew / Bubble point | °C | | | 111,9 | 115,03 |
| Pressure (abs) | bar | 1,5 | 1,3997 | 1,57 | 1,41308 |
| Heat transfer coeff (mean) | W/(m²-K) | 1086,3 | | 19075 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 1,16 / 0,17 | | 88,29 / 12,74 | |
| Mean wall shear stress | N/m² | 20,71 | | 30,69 | |
| Pressure drop (allow/calc.) | bar | 0,15 / 0,1003 | | 0,157 / 0,15692 | |
| Residence volume | m³ | 0,06 | | 0,06 | |
| Residence time | Seconds | 6,75 | | 0,17 | |

| | | | | | |
|---|---|---|---|---|---|
| Total heat exchanged | kW | 1221,6 | Exchangers | 1 | Plates 99 |
| Overall coef. (dirty/clean) | W/(m²-K) | 991,1 / 991,1 | Passes – hot / cold | | 1 / 1 |
| Effective surface area | m² | 38,8 | Channels – hot / cold | | 49 / 49 |
| Overall effective MTD | °C | 34,72 | Plate – length / width | mm | 1172,63 / 380 |
| Actual/Reqd. area (dirty/clean) | | 1,09 / 1,09 | Plate – pitch / thk | mm | 3,52 / 0,6 |
| Actual/Reqd. area (incl. fouling margin) | | | Port diameter | mm | 100 |
| Risk of maldistribution | | No | Chevron angle | Degrees | 30 |

| Overall Coefficient/Resistance Summary | | | Clean | Dirty |
|---|---|---|---|---|
| Required area | | m² | 35,5 | 35,5 |
| Area ratio: actual/required | | | 1,09 | 1,09 |
| Overall coefficient | | W/(m²-K) | 991,1 | 991,1 |
| Overall heat transfer resistance | | m²-K/W | 0,00101 | 0,00101 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| Resistance Distribution | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 1086,3 | 0,00092 | 91,24 | 91,24 |
| Hot side fouling | | 0 | | 0 |
| Wall | 27784 | 4E-05 | 3,57 | 3,57 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 19075 | 5E-05 | 5,2 | 5,2 |

## 4. WH recovery unit

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 23,7662 | | 346,4 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 23,7662 | 23,7662 | 0 | 0 |
| Liquid mass flow rate | kg/s | 0 | 0 | 346,4 | 346,4 |
| Vapor mass quality | | 1 | 1 | 0 | 0 |
| Temperatures | °C | 300 | 220 | 194,4 | 200 |
| Dew / Bubble point | °C | | | | |
| Pressure (abs) | bar | 1,5 | 1,35172 | 1,5 | 1,47458 |
| Heat transfer coeff (mean) | W/(m²-K) | 189 | | 600,4 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 83,38 / 16,61 | | 0,78 / 0,15 | |
| Mean wall shear stress | N/m² | 11,66 | | 2,05 | |
| Pressure drop (allow/calc.) | bar | 0,15 / 0,14828 | | 0,15 / 0,02542 | |
| Residence volume | m³ | 8,1392 | | 8,1392 | |
| Residence time | Seconds | 0,2 | | 20,86 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total heat exchanged | kW | 3424 | Exchangers | 4 | Plates | 1012 |
| Overall coef. (dirty/clean) | W/(m²-K) | 143,1 / 143,1 | Passes – hot / cold | | | 1 / 1 |
| Effective surface area | m² | 2796,9 | Channels – hot / cold | | | 126 / 126 |
| Overall effective MTD | °C | 54,93 | Plate – length / width | mm | | 3023,52 / 1070 |
| Actual/Reqd. area (dirty/clean) | | 6,42 / 6,42 | Plate – pitch / thk | mm | | 5,28 / 0,6 |
| Actual/Reqd. area (incl. fouling margin) | | | Port diameter | mm | | 400 |
| Risk of maldistribution | | No | Chevron angle | Degrees | | 60 |

| Overall Coefficient/Resistance Summary | | | Clean | Dirty |
|---|---|---|---|---|
| Required area | | m² | 435,8 | 435,8 |
| Area ratio: actual/required | | | 6,42 | 6,42 |
| Overall coefficient | | W/(m²-K) | 143,1 | 143,1 |
| Overall heat transfer resistance | | m²-K/W | 0,00699 | 0,00699 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| Resistance Distribution | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 189 | 0,00529 | 75,69 | 75,69 |
| Hot side fouling | | 0 | | 0 |
| Wall | 29700,8 | 3E-05 | 0,48 | 0,48 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 600,4 | 0,00167 | 23,83 | 23,83 |

## 5. Steam generator

| Design | | Hot Side | | Cold Side | |
|---|---|---|---|---|---|
| Total mass flow rate | kg/s | 35,4394 | | 1,1285 | |
| | | In | Out | In | Out |
| Vapor mass flow rate | kg/s | 0 | 0 | 1,1285 | 1,1285 |
| Liquid mass flow rate | kg/s | 35,4394 | 35,4394 | 0 | 0 |
| Vapor mass quality | | 0 | 0 | 0 | 1 |
| Temperatures | °C | 290 | 265 | 200 | 249 |
| Dew / Bubble point | °C | | | 248,75 | 248,75 |
| Pressure (abs) | bar | 1,5 | 1,35143 | 39,8 | 39,79603 |
| Heat transfer coeff (mean) | W/(m²-K) | 1864 | | 4613,1 | |
| Fouling Resistance | m²-K/W | 0 | | 0 | |
| Velocity (Port/Plate) | m/s | 2,45 / 0,62 | | 3,38 / 0,96 | |
| Mean wall shear stress | N/m² | 20,61 | | 0,56 | |
| Pressure drop (allow/calc.) | bar | 0,15 / 0,14857 | | 3,98 / 0,00397 | |
| Residence volume | m³ | 0,1087 | | 0,1087 | |
| Residence time | Seconds | 2,54 | | 3,56 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Total heat exchanged | kW | 2200 | | Exchangers | 1 | Plates | | 61 |
| Overall coef. (dirty/clean) | W/(m²-K) | 1246,5 / 1246,5 | | Passes – hot / cold | | 1 | / | 1 |
| Effective surface area | m² | 41,6 | | Channels – hot / cold | | 30 | / | 30 |
| Overall effective MTD | °C | 52,08 | | Plate – length / width | mm | 1595,55 | / | 495 |
| Actual/Reqd. area (dirty/clean) | | 1,23 / 1,23 | | Plate – pitch / thk | mm | 5,58 | / | 0,9 |
| Actual/Reqd. area (incl. fouling margin) | | | | Port diameter | mm | | 150 | |
| Risk of maldistribution | | No | | Chevron angle | Degrees | | 60 | |

| Overall Coefficient/Resistance Summary | | | Clean | Dirty |
|---|---|---|---|---|
| Required area | | m² | 33,9 | 33,9 |
| Area ratio: actual/required | | | 1,23 | 1,23 |
| Overall coefficient | | W/(m²-K) | 1246,5 | 1246,5 |
| Overall heat transfer resistance | | m²-K/W | 0,0008 | 0,0008 |
| Hot side fouling | | m²-K/W | 0 | 0 |
| Cold side fouling | | | 0 | 0 |
| Resistance Distribution | W/(m²-K) | m²-K/W | % | % |
| Hot side coefficient | 1864 | 0,00054 | 66,87 | 66,87 |
| Hot side fouling | | 0 | | 0 |
| Wall | 20402,8 | 5E-05 | 6,11 | 6,11 |
| Cold side fouling | | 0 | | 0 |
| Cold side coefficient | 4613,1 | 0,00022 | 27,02 | 27,02 |

## CONTACT US

techupgrade.eu

## FOLLOW US

Funded by
the European Union

This project has received funding from European Union's Horizon Europe's Research and Innovation Program under grant agreement No. 101103966. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.