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ProSec Application Example

Simulation of a Brazed Plate Fin Heat Exchanger (BPFHE) with CO-ProSec CAPE-OPEN Operation

Simple Example

Example purpose
This example shows a brazed plate-fin heat exchanger with two fluids. There is a side stream on the hot stream and an external recirculation on the cold stream. This heat exchanger is modeled using CO-ProSec, Fives ProSim's CAPE-OPEN compliant unit operation dedicated to the simulation of brazed plate-fin heat exchangers. CO-ProSec can take into account the effect of the stacking and of the pressure drop on the enthalpy curves. In this example, the CO-ProSec unit operation runs inside the ProSimPlus environment, *i.e.*, within the ProSimPlus simulation software where the thermodynamic and physico-chemical data needed are automatically calculated using Simulis Thermodynamics, the thermodynamic calculation server of ProSimPlus.

Access	☑ Free Internet	☐ Restricted to clients	☐ Restricted	☐ Confidential

Corresponding ProSec file	*COPROSEC_EX_EN-Simple-example.pmp3*

Energy

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1. PROCESS MODELING

1.1. Process description

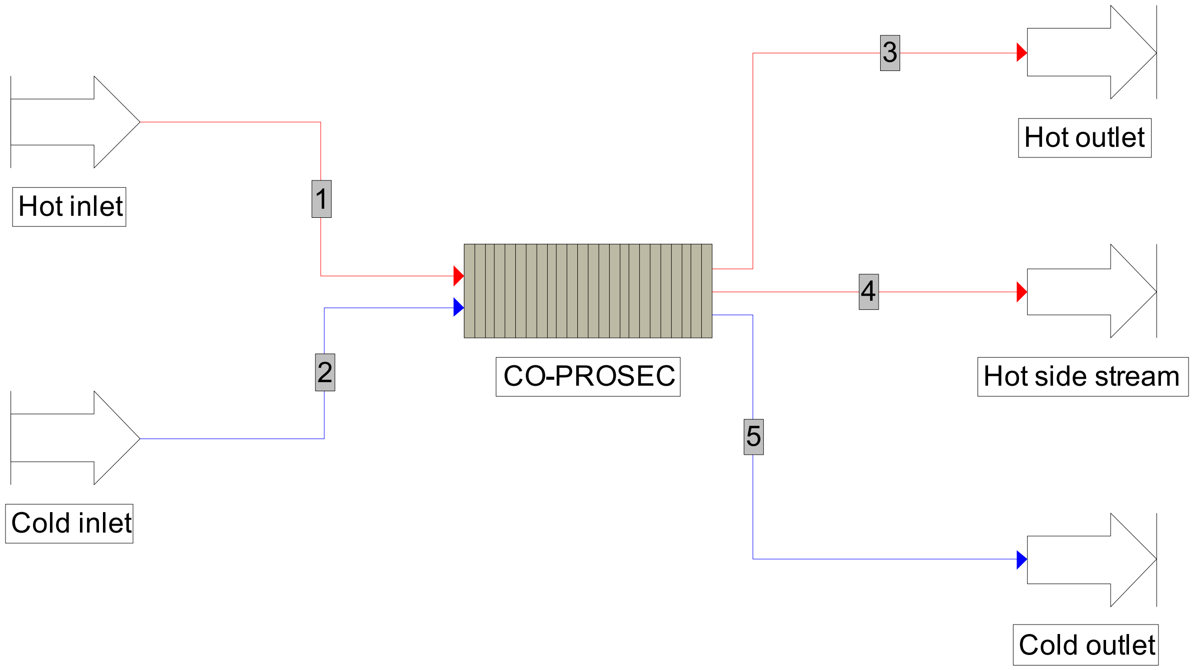
This simple example is the simulation of a brazed plate-fin heat exchanger (BPFHE) with two streams, one hot stream and one cold stream, composed of a mixture of methane and ethane. A side stream is present on the hot stream. The cold stream has an external recirculation.

Typically, one BPFHE can contain as many as ten different streams. Thanks to their low cost of production and its high performance (BPFHE are generally made of aluminum), BPFHE are widely used in cryogenic processes. Here, the BPFHE are simulated with the CO-ProSec CAPE-OPEN unit operation. The detailed model implemented in this unit operation takes into account the complex geometries of this type of heat exchangers, notably the stacking. The assumption of common wall temperature is used only in the initialization step.

The hot stream enters the heat exchanger as stream “1”. Ten percent (10%) of this stream leaves the heat exchanger by a side stream before the end of the heat exchanger (stream “4”). The rest of the hot stream flows out at the end of the heat exchanger in stream “3”. The inlet stream “2” is the cold stream. The entire cold stream leaves the heat exchanger at approximately 1/3rd of the length. It re-enters the heat exchanger at approximately 2/3rd of the length. The hot stream and the cold stream flow is counter current.

In this example, the CO-ProSec CAPE-OPEN unit operation is used within the ProSimPlus simulation environment, i.e., the Simulis Thermodynamics calculation server for thermophysical properties and phase equilibria calculations is used. So, for this example it has been chosen to let the unit operation automatically calculate the thermodynamic and physico-chemical data needed for the simulation.

1.2. Process flowsheet



1.3. Compounds

The compounds in the simulation, their chemical formula and CAS numbers are shown in the following table. Their pure component properties are extracted from the standard database provided with ProSimPlus [ROW23].

Compound	Chemical formula	CAS number[1]
Methane	CH_4	74-82-8
Ethane	C_2H_6	74-84-0

1.4. Thermodynamic model

The thermodynamic model is based on an equation of state approach. The chosen equation of state is the Peng Robinson (PR) [PEN76] model with binary interaction parameters extracted from the ProSimPlus database.

[1] *CAS Registry Numbers® are the intellectual property of the American Chemical Society and are used by Fives ProSim SAS with the express permission of ACS. CAS Registry Numbers® have not been verified by ACS and may be inaccurate.*

1.5. Operating parameters

1.5.1. Process feeds

	Hot inlet	Cold inlet
Temperature (K)	299	267
Pressure (bar)	69.4	69.4
Total flow rate (kg/h)	4 790	4 790
Mass fractions		
Methane	0.5	0.5
Ethane	0.5	0.5

1.5.2. Brazed plate-fin heat exchanger

✓ General parameters

Parameters	Value
Type of exchanger	CO-ProSec
Number of bodies	1
Orientation	Vertical
Fin data base	-> 2002
Material	Aluminium TRANE
Used width (mm)	589
Thickness of the side bars (mm)	14.3
Thickness of the end bars (mm)	27
Thickness of the separation plates (mm)	1.8
Thickness of the closing plates (mm)	1.8

✓ Streams parameters

	Stream	
Parameter	**Hot**	**Cold**
Flow direction	From top to bottom	From bottom to top
Heat exchange correlation	HTFS85	
Other parameters	Dfault values	
Side stream		
Name	Side_Hot	
Splitting ratio flow rate (%)	10	

- ✓ Fins characteristics

Name	Fin #1	Fin #2
Origin	User	
Reference	1001	7844
Calculation mode	Performance data provided	From geometry
Type	Right fin	
Height (mm)	7.13	
Thickness (mm)	0.40	
Fins number per meter	673.2	200
Other parameters	Default values	

The performance data of the fin #1 are listed in the follwing table.

Reynolds number	Fanning number	Colburn number
46	0.98874	0.06258
122	0.39326	0.04122
200	0.26355	0.03266
538	0.14066	0.02048
881	0.11300	0.01643
442	0.09665	0.01337
363	0.08753	0.01106
6 338	0.08180	0.00797
17 003	0.08171	0.00604
45 614	0.07260	0.00462

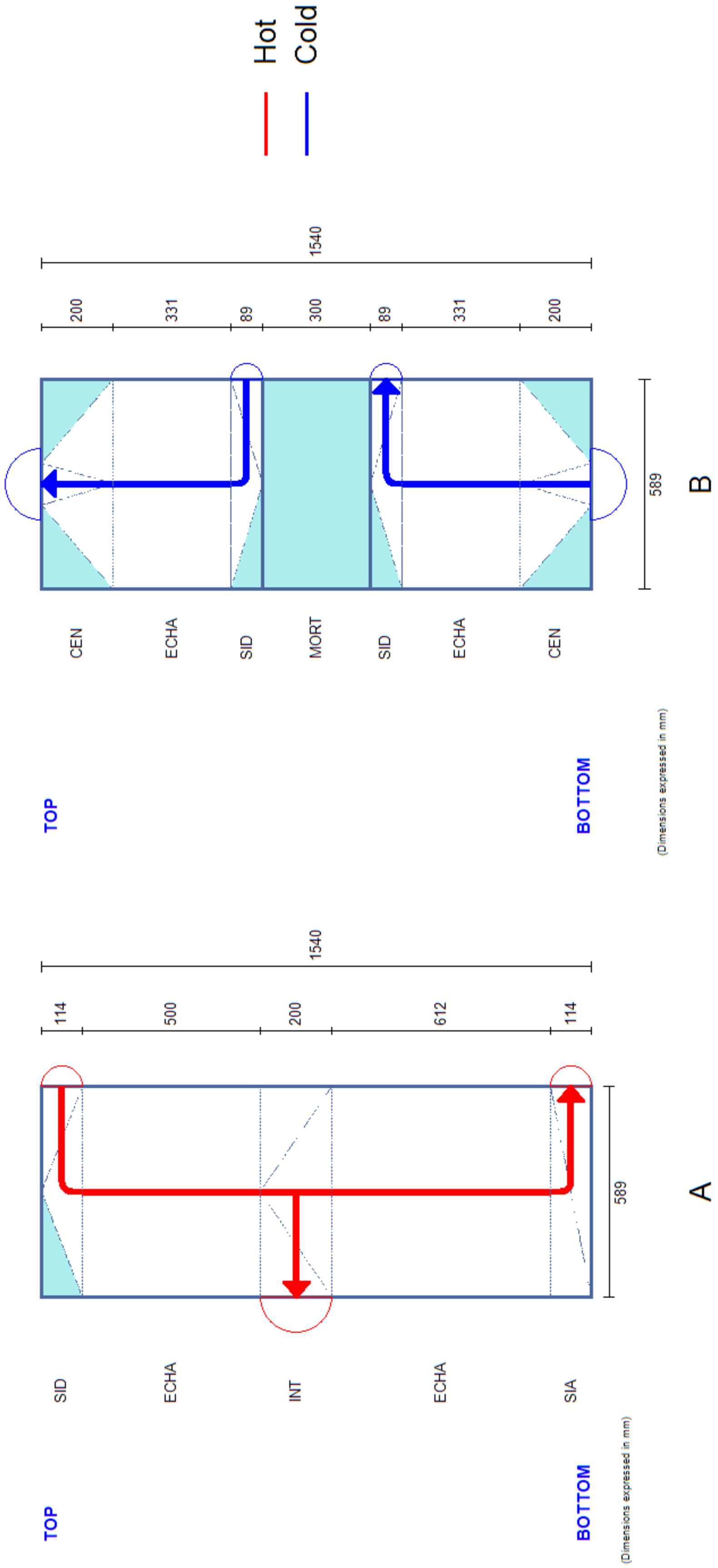
- ✓ Reference passages

The fins used for each type of zone (whatever the stream) are shown in the table below:

Zone	Fin
Heat exchange zone and “MORT” zone	Fin #1
Distributor	Fin #2

A “MORT” type zone is a zone in which no fluid flows. Only conduction phenomena occur.

The following figure shows the two reference passages of the heat exchanger. Dimensions are expressed in millimeters.

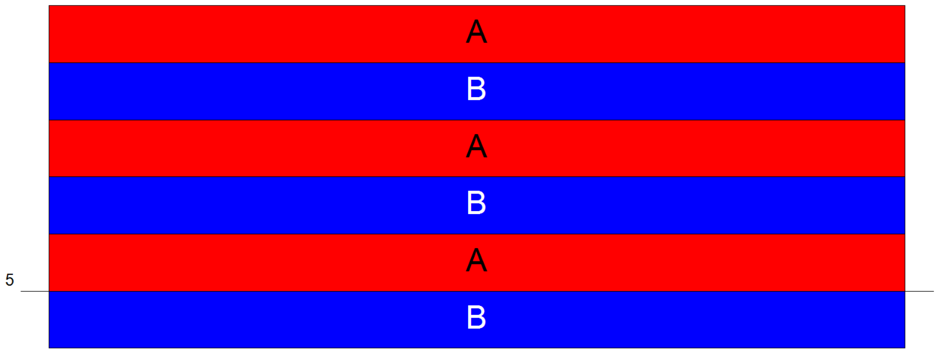


The characteristics of the distributors are displayed in the following table.

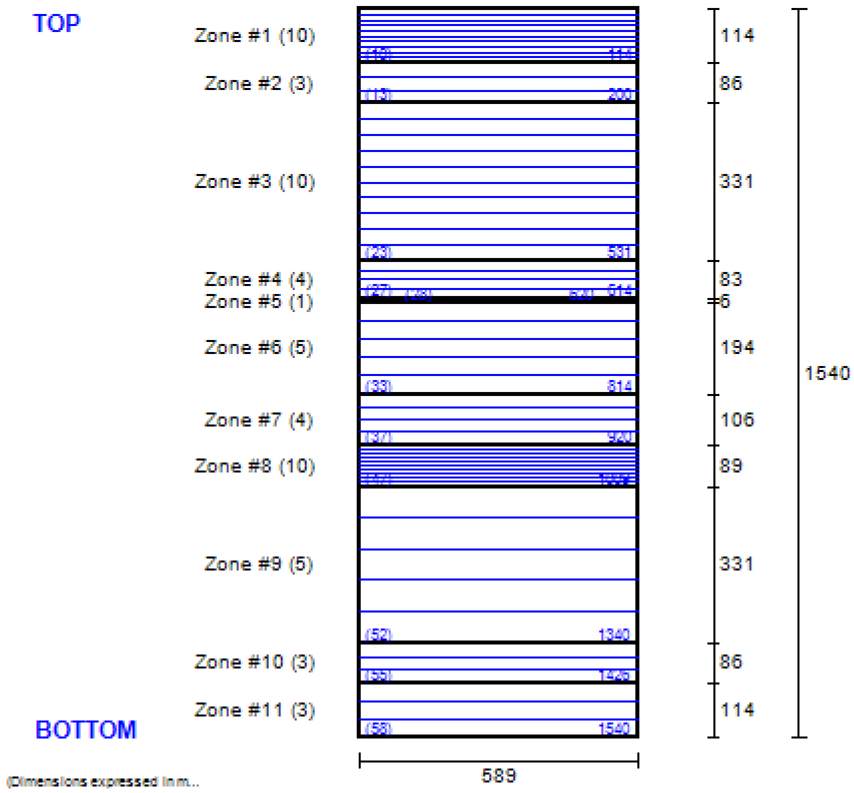
	Distributors characteristics				
Parameter	**Hot stream**			**Cold stream**	
Distributor type	SIA	INT	SID	CEN	SID
Block height (mm)	114	200	114	200	89
Number of heads	1				
Number of prickings	1				
Distributor opening (mm)	114	200	114	200	89
Distributor height (mm)	114	200	114	200	89
Pricking diameter (mm)	0				
Head height (mm)	57	100	57	100	44.5
Other parameters	Default values				

✓ Stacking

Parameters	**Value**
Number of repetitions of the sequence	3
Sequence	A B



✓ Number of meshes for each elementary zone (dimensions are expressed in milimeters)



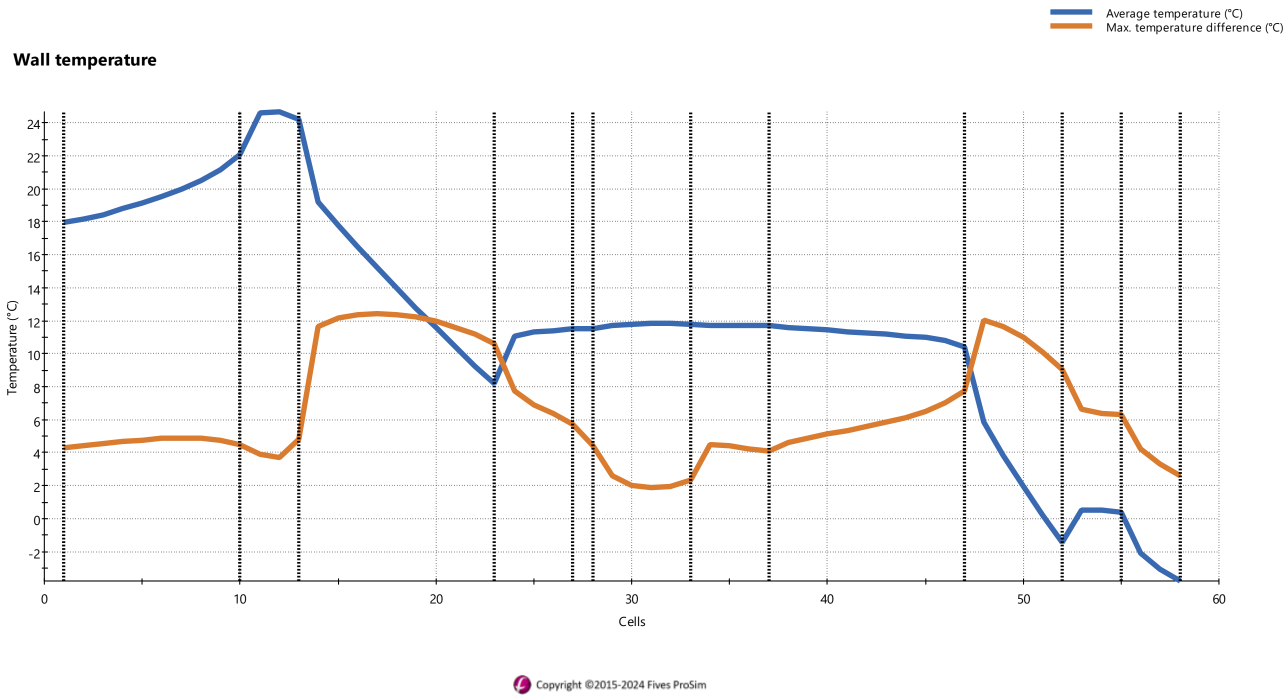
2. Results

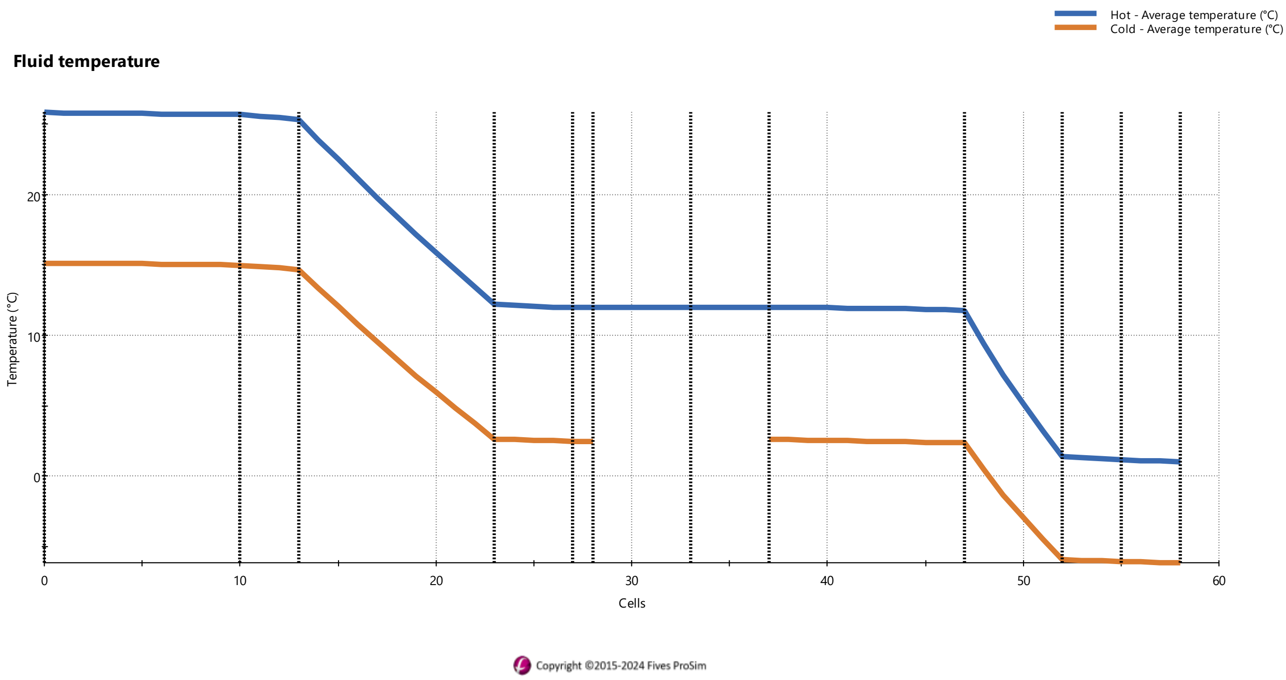
2.1. Mass and energy balances

Streams		1	2	3	4	5
From		Hot inlet	Cold stream	CO-PROSEC	CO-PROSEC	CO-PROSEC
To		CO-PROSEC	CO-PROSEC	Hot outlet	Hot side str...	Cold outlet
Partial flow s		kg/h	kg/h	kg/h	kg/h	kg/h
METHANE		2395	2395	2155.5	239.5	2395
ETHANE		2395	2395	2155.5	239.5	2395
Total flow	kg/h	4790	4790	4311	479	4790
Mass fractions						
METHANE		0.5	0.5	0.5	0.5	0.5
ETHANE		0.5	0.5	0.5	0.5	0.5
Physical state		Vapor	Vapor	Vapor	Vapor	Vapor
Temperature	°C	25.85	-6.15	1.0212	11.956	15.096
Pressure	bar	69.4	69.4	69.005	69.005	69.045
Enthalpic flow	kcal/h	-1.2518E005	-2.5107E005	-1.9611E005	-17428	-1.6272E005
Vapor molar fraction		1	1	1	1	1

2.2. Brazed plate-fin heat exchanger profiles

Several profiles (wall temperature, fluid temperature, pressure, heat transfer coefficient, vaporization ratio, etc.) in the heat exchanger are available after the simulation from the ProSec edition window ("Results" tab). The following figures show the wall temperature profiles (average and maximal deviation) and the fluid mean temperature profiles along the length of the heat exchanger.





3. REFERENCES

[PEN76] PENG Y.D., ROBINSON D.B., "A New Two Constant Equation of State", Ind. Eng. Chem. Fundam., 15, 59-64 (1976)

[ROW23] ROWLEY R.L., WILDING W.V., OSCARSON J.L., GILES N.F., "DIPPR® Data Compilation of Pure Chemical Properties", Design Institute for Physical Properties, AIChE (2023)