

**PROSIMPLUS APPLICATION EXAMPLE**

**SIMULATION OF A CROSS-FLOW PLATE-FIN HEAT EXCHANGER (PFHE) WITH PROSEC CAPE-OPEN UNIT OPERATION**

**INTEREST OF THIS EXAMPLE**

This example shows a cross-flow plate-fin heat exchanger used in a gas-gas application. This heat exchanger is modeled using ProSec, ProSim's CAPE-OPEN compliant unit operation dedicated to the simulation of plate-fin heat exchangers. Regarding the thermodynamic and physico-chemical data needed, they are automatically calculated using the thermodynamic calculation server of the process simulation software.

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| <b>ACCESS</b> | <input checked="" type="checkbox"/> <b>Free-Internet</b> | <input type="checkbox"/> <b>Restricted to ProSim clients</b> | <input type="checkbox"/> <b>Restricted</b> | <input type="checkbox"/> <b>Confidential</b> |
|---------------|--|--|--|--|

|                                      |   |
|--------------------------------------|---|
| <b>CORRESPONDING PROSIMPLUS FILE</b> | <i>COPROSEC_E03_EN - Cross flow heat exchanger.pmp3</i> |
|--------------------------------------|---|

*Reader is reminded that this use case is only an example and should not be used for other purposes. Although this example is based on actual case it may not be considered as typical nor are the data used always the most accurate available. ProSim shall have no responsibility or liability for damages arising out of or related to the use of the results of calculations based on this example.*

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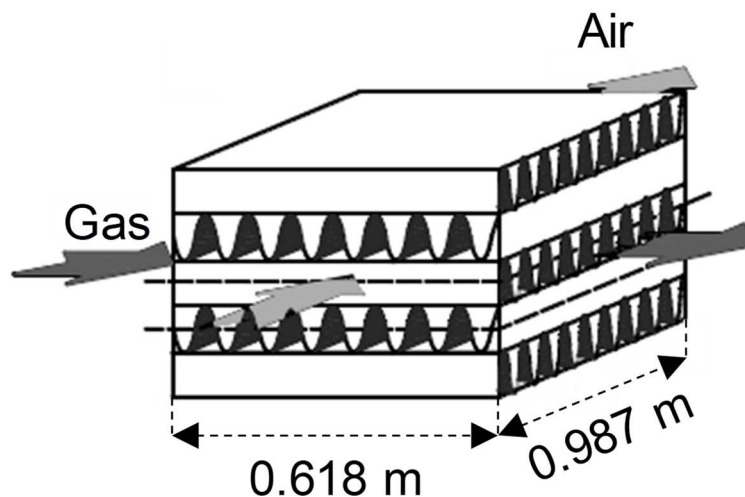
## 1. PROCESS MODELING

### 1.1. Process description

This example deals with a gas-gas cross-flow plate-fin heat exchanger (PFHE). Compact heat exchangers are characterized by a large heat transfer surface area per unit volume. Amongst different varieties of compact heat exchangers, crossflow plate-fin heat exchangers are widely used in aerospace, automobile, cryogenic and chemical process plants for their low weight and volume, high efficiency. It will be simulated with ProSec CAPE-OPEN unit operation. In ProSec, cross-flow heat exchangers are modeled as counter-flow heat exchangers and an efficiency coefficient [ROE10] is computed and applied to take into account the cross-flow behavior. The assumptions of the model are:

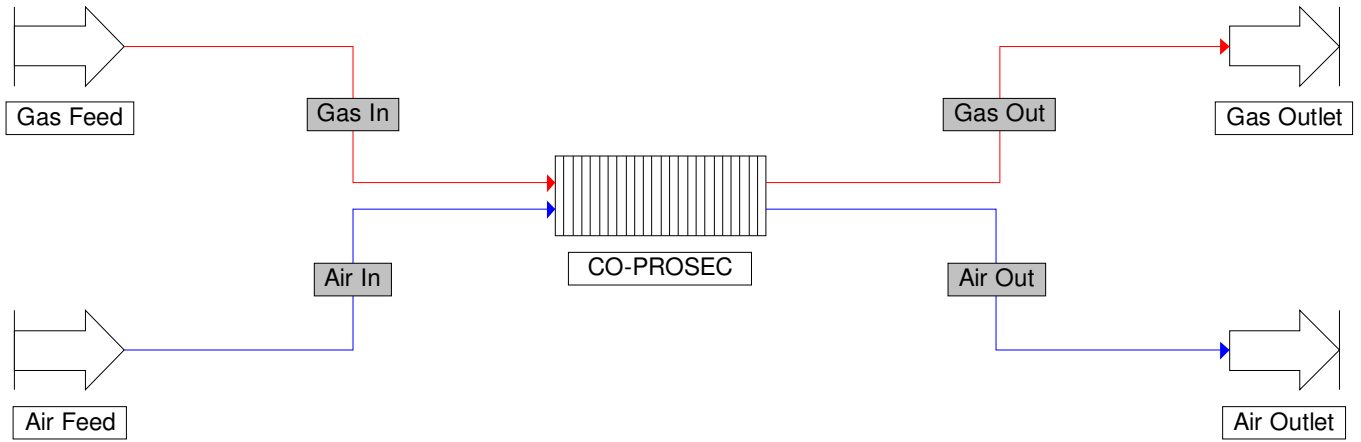
- ✓ Common wall temperature,
- ✓ Longitudinal conduction not taken into account,
- ✓ Two fluids,
- ✓ Continuous thermodynamic option not available.

The example is extracted from [MIS09]. The sketch is shown below. The two fluids are modeled as air. The “Gas” is the main stream and the “Air” is the cross-flow stream.



The thermodynamic and physico-chemical data needed for the simulation are automatically calculated by the unit operation. In this example, as the ProSec CAPE-OPEN unit operation is used in ProSimPlus simulation environment, it uses Simulis Thermodynamics, the calculation server for thermophysical properties and phase equilibria calculations available in ProSimPlus.

## 1.2. Process flowsheet



### 1.3. Compounds

The compounds taken into account in the simulation, their chemical formula and CAS numbers are shown in the following table. Their pure component properties are extracted from the standard data base provided with ProSimPlus [ROW17].

| Compound | Chemical formula | CAS number |
|----------|------------------|------------|
| Oxygen   | O <sub>2</sub>   | 7782-44-7  |
| Nitrogen | N <sub>2</sub>   | 7727-37-9  |

### 1.4. Thermodynamic model

The PSRK profile, which is based on a predictive combined approach model [HOL91], [GME91], [CHE02] is selected.

### 1.5. Operating parameters

#### 1.5.1. Process feed

|                        | Gas    | Air    |
|------------------------|--------|--------|
| Temperature (°C)       | 240    | 4      |
| Pressure (bar)         | 1      | 1      |
| Total flow rate (kg/s) | 0.8962 | 0.8296 |
| <b>Molar fraction</b>  |        |        |
| Oxygen                 | 0.21   |        |
| Nitrogen               | 0.79   |        |

### 1.5.2. Plate-fin heat exchanger

✓ General parameters

| Parameters                              | Value       |
|---|-------------|
| Type of exchanger                       | CO-ProSec   |
| Number of body                          | 1           |
| Orientation                             | Horizontal  |
| Fin data base                           | 2015 -> Now |
| Material                                |             |
| Type                                    | Other       |
| a1                                      | 160         |
| a2 = a3 = a4 = a5 = a6 =a7              | 000         |
| Used width (m)                          | 0.987       |
| Thickness of the side bars (mm)         | 0.001       |
| Thickness of the end bars (mm)          | 0.001       |
| Thickness of the separation plates (mm) | 0.500       |

✓ Streams parameters

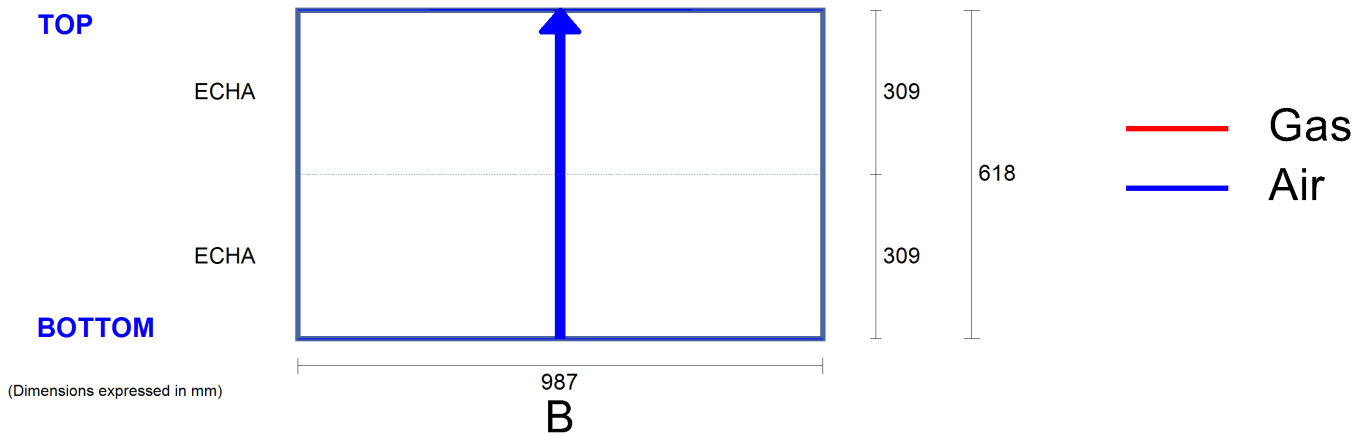
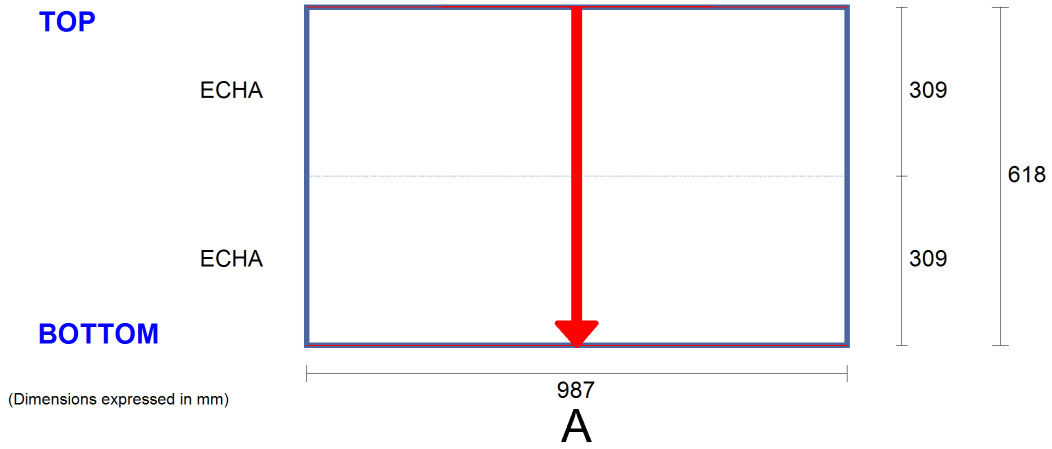
| Parameter                 | Stream             |                    |
|---------------------------|--------------------|--------------------|
|                           | Gas                | Air                |
| Flow direction            | From top to bottom | From bottom to top |
| Cross flow                | No                 | Yes                |
| Heat exchange correlation | HTFS85             |                    |

✓ Fin characteristics

|                              |               |
|------------------------------|---------------|
| <b>Name</b>                  | Fin #1        |
| <b>Origin</b>                | User          |
| <b>Calculation mode</b>      | From geometry |
| <b>Reference</b>             | 1001          |
| <b>Type</b>                  | Serrated      |
| <b>Height (mm)</b>           | 9.799         |
| <b>Thickness (mm)</b>        | 0.101         |
| <b>Fins number per meter</b> | 654.5         |
| <b>Serration length (mm)</b> | 7.551         |

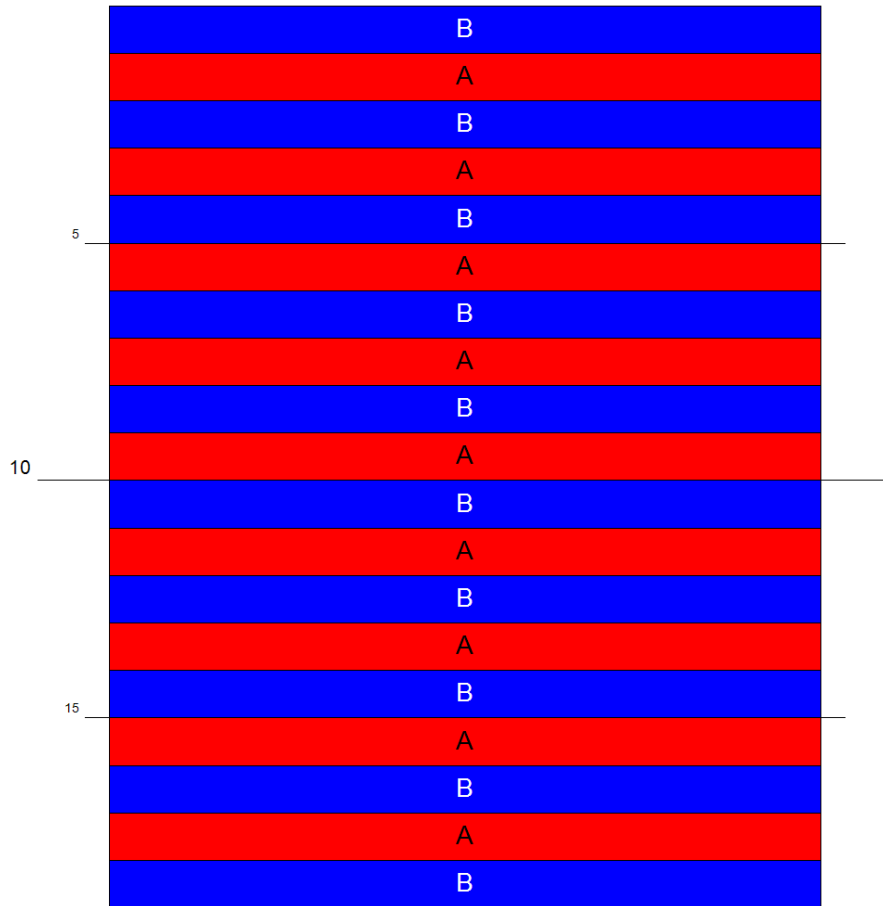
✓ Reference passages

Fin #1 is used for each stream. The following figures show the two reference passages of the heat exchanger. The dimensions are expressed in millimeter.



✓ Stacking

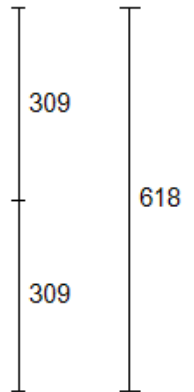
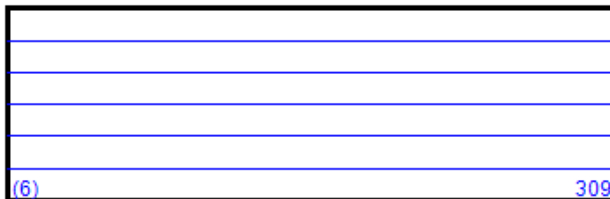
| Parameters                            | Value |
|---------------------------------------|-------|
| Sequence 1                            |       |
| Number of repetitions of the sequence | 9     |
| Sequence                              | B A   |
| Sequence 2                            |       |
| Number of repetitions of the sequence | 1     |
| Sequence                              | B     |



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

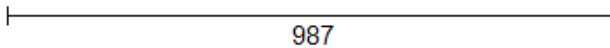
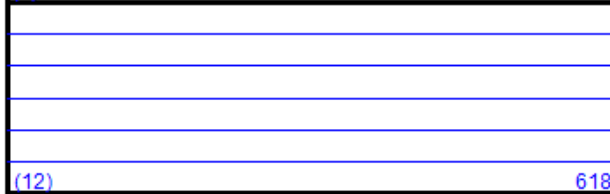
**TOP**

Zone #1 (6)



Zone #2 (6)

**BOTTOM**



(Dimensions expressed in mm)



## 2. RESULTS

### 2.1. Mass and energy balances

| Streams              |      | Air In  | Air Out | Gas In | Gas Out |
|----------------------|------|---------|---------|--------|---------|
| Total flow           | kg/s | 0.8296  | 0.8296  | 0.8962 | 0.8962  |
| Mole fractions       |      |         |         |        |         |
| OXYGEN               |      | 0.21    | 0.21    | 0.21   | 0.21    |
| NITROGEN             |      | 0.79    | 0.79    | 0.79   | 0.79    |
| Physical state       |      | Vapor   | Vapor   | Vapor  | Vapor   |
| Temperature          | °C   | 4       | 201.81  | 240    | 57.828  |
| Pressure             | kPa  | 100     | 95.282  | 100    | 97.997  |
| Enthalpic flow       | kW   | -17.831 | 149.49  | 196.94 | 29.624  |
| Vapor molar fraction |      | 1       | 1       | 1      | 1       |

### 2.2. Global results

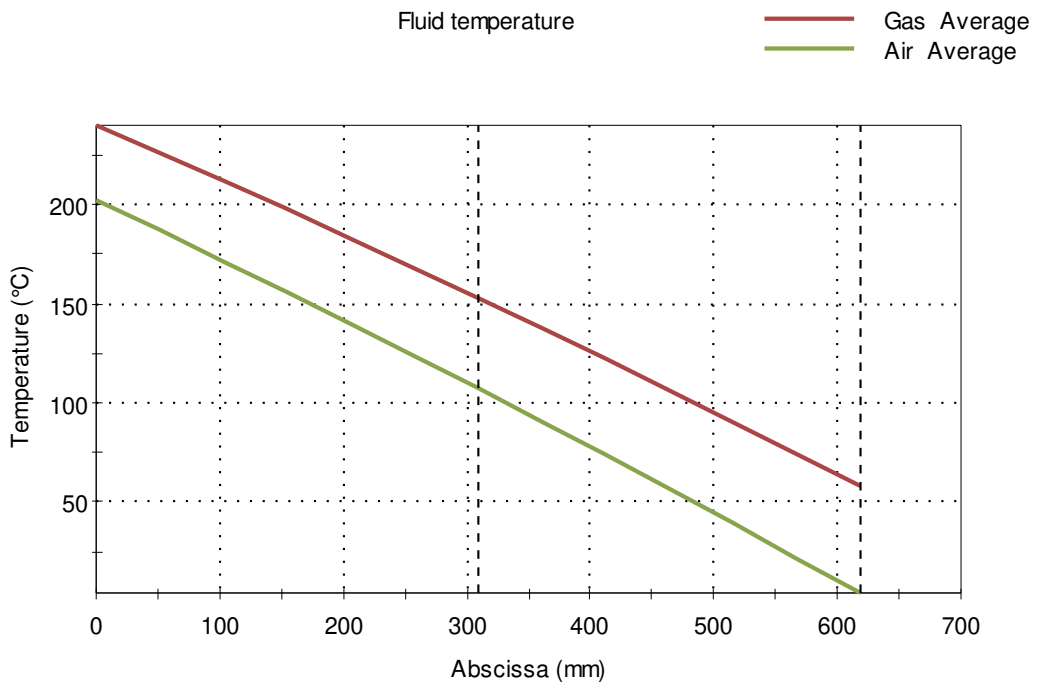
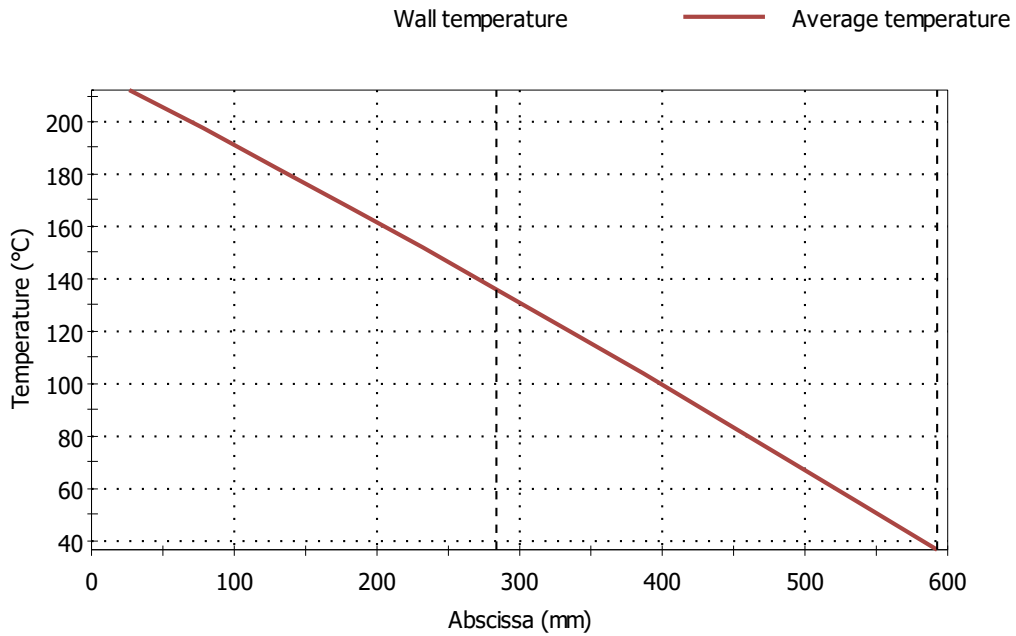
The heat duty computed by ProSec is 167 kW. [MIS09] indicates a value of 160 kW. The deviation is explained by the differences in the assumptions:

- ✓ Constant physico-chemical properties for [MIS09] vs temperature dependent for ProSec,
- ✓ The correlations used to compute the Colburn and Fanning factors are not the same.

The pressure drops computed by ProSec (2 003 Pa for the gas stream and 4 718 Pa for the air stream) are closed to the ones calculated by [MIS09].

### 2.3. Plate-fin heat exchanger profiles

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



### 3. REFERENCES

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- [ROE10] ROETZEL W., SPANG B., "VDI Heat Atlas, Chapter C1: Thermal Design of Heat Exchangers", Springer-Verlag, 2nd Edition (2010)
- [ROW17] 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, New York, NY (2017)