





Solvent Crossflow Heat Exchanger

User Manual

Version 2.0.0

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**Revision Log**

| Version Number | Release Date | Description |
| --- | --- | --- |
| Version 2015.03.00 | 03/31/2015 | Initial release. |
| Version 2.0.0 | 03/31/2018 | Initial Open Source release |

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To obtain support for the products within this package, please send an e-mail to   
[ccsi-support@acceleratecarboncapture.org](mailto:ccsi-support@acceleratecarboncapture.org).

Solvent Crossflow Heat Exchanger

1. Installation Requirements

This product requires Aspen Plus® V8.4 or newer. As such, the supported environments are limited to:

* Windows® XP SP3
* Windows Vista® Business SP2
* Windows Vista Ultimate SP2
* Windows 7 Ultimate (32- and 64-Bit)
* Windows 7 Professional (32- and 64-Bit)
* Windows 8

1. Introduction

The heat exchanger model can be used to optimize the size of the heat exchangers and their log-mean temperature difference (LMTD) to minimize capital and operating expenses. The model consists of the “HeatCalc.bkp” file. This manual was written using Aspen Plus V8.4.

* 1. Features List

This product sizes a non-flashing plate and frame heat exchanger for amine scrubbing. As this product consists of a calculator block and an optimization block, it does not interfere with convergence of the flowsheet. In addition to exchanger size, many other quantities of interest are reported, such as pressure drop, flow length, and velocity.

1. Tutorial

This tutorial assumes basic knowledge of the Aspen Plus software. Consult the Aspen Plus documentation **“Getting Started Building and Running a Process Model”** for additional information.

The provided file is a template. This tutorial will explain how to cut and paste the necessary components into an existing process simulation, herein referred to as “the destination file.”

* 1. Setup: Property Sets

The heat exchanger calculator block depends on property sets. These need to be verified as present with the correct units.

1. Open the “HeatCalc.bkp” file.
2. In the navigation pane, navigate to “Analysis” → “EXPROP” → “Results.” The results should be like Table 25.
3. Confirm that the units match for the property sets by navigating to “Property Sets,” clicking each “Property Set” listed in Table 26, and then checking the value in the “Units” column.
4. In the “HeatCalc.bkp” file, navigate to “Property Sets,” and then select all.
5. Click “Copy.”
6. In the destination file, navigate to “Property Sets” and then click “Paste.”

Table : EXPROP Results

| TEMP  K | MOLEFLOW MEA kmol/sec | MOLEFLOW CO2 kmol/sec | LIQUID KMX Watt/m-K | LIQUID CPMX J/kg-K | LIQUID MUMX Pa-sec | LIQUID RHOMX kg/cum | VAPOR RHOMX kg/cum | LIQUID SIGMAMX N/m |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 313 | 7 | 3.15 | 5.54E-01 | 3.11E+03 | 1.57E-03 | 1.10E+03 | 4.96E-02 | 7.07E-02 |
| 313 | 7 | 3.85 | 6.02E-01 | 3.01E+03 | 1.62E-03 | 1.13E+03 | 2.98E-01 | 7.43E-02 |
| 323 | 7 | 3.15 | 5.61E-01 | 3.12E+03 | 1.29E-03 | 1.10E+03 | 8.30E-02 | 6.90E-02 |
| 323 | 7 | 3.85 | 6.07E-01 | 3.03E+03 | 1.33E-03 | 1.12E+03 | 5.45E-01 | 7.24E-02 |
| 333 | 7 | 3.15 | 5.66E-01 | 3.13E+03 | 1.09E-03 | 1.09E+03 | 1.36E-01 | 6.73E-02 |
| 333 | 7 | 3.85 | 6.09E-01 | 3.04E+03 | 1.12E-03 | 1.12E+03 | 9.70E-01 | 7.06E-02 |
| 343 | 7 | 3.15 | 5.69E-01 | 3.14E+03 | 9.27E-04 | 1.08E+03 | 2.23E-01 | 6.56E-02 |
| 343 | 7 | 3.85 | 6.07E-01 | 3.05E+03 | 9.59E-04 | 1.11E+03 | 1.69E+00 | 6.87E-02 |
| 353 | 7 | 3.15 | 5.71E-01 | 3.16E+03 | 8.02E-04 | 1.07E+03 | 3.64E-01 | 6.39E-02 |
| 353 | 7 | 3.85 | 5.99E-01 | 3.07E+03 | 8.30E-04 | 1.10E+03 | 2.85E+00 | 6.68E-02 |
| 363 | 7 | 3.15 | 5.71E-01 | 3.18E+03 | 7.04E-04 | 1.06E+03 | 6.02E-01 | 6.22E-02 |
| 363 | 7 | 3.85 | 5.84E-01 | 3.09E+03 | 7.27E-04 | 1.09E+03 | 4.67E+00 | 6.50E-02 |
| 373 | 7 | 3.15 | 5.68E-01 | 3.20E+03 | 6.24E-04 | 1.06E+03 | 1.01E+00 | 6.05E-02 |
| 373 | 7 | 3.85 | 5.63E-01 | 3.11E+03 | 6.43E-04 | 1.08E+03 | 7.41E+00 | 6.30E-02 |
| 383 | 7 | 3.15 | 5.62E-01 | 3.22E+03 | 5.60E-04 | 1.05E+03 | 1.72E+00 | 5.87E-02 |
| 383 | 7 | 3.85 | 5.36E-01 | 3.14E+03 | 5.73E-04 | 1.07E+03 | 1.13E+01 | 6.11E-02 |
| 393 | 7 | 3.15 | 5.50E-01 | 3.24E+03 | 5.06E-04 | 1.04E+03 | 2.95E+00 | 5.70E-02 |
| 393 | 7 | 3.85 | 5.04E-01 | 3.17E+03 | 5.14E-04 | 1.05E+03 | 1.67E+01 | 5.91E-02 |
| 403 | 7 | 3.15 | 5.33E-01 | 3.28E+03 | 4.60E-04 | 1.03E+03 | 5.04E+00 | 5.52E-02 |
| 403 | 7 | 3.85 | 4.69E-01 | 3.20E+03 | 4.63E-04 | 1.04E+03 | 2.37E+01 | 5.70E-02 |
| 413 | 7 | 3.15 | 5.08E-01 | 3.31E+03 | 4.20E-04 | 1.02E+03 | 8.41E+00 | 5.33E-02 |
| 413 | 7 | 3.85 | 4.34E-01 | 3.24E+03 | 4.18E-04 | 1.03E+03 | 3.23E+01 | 5.49E-02 |
| 423 | 7 | 3.15 | 4.75E-01 | 3.36E+03 | 3.85E-04 | 1.00E+03 | 1.35E+01 | 5.14E-02 |
| 423 | 7 | 3.85 | 3.99E-01 | 3.29E+03 | 3.79E-04 | 1.01E+03 | 4.27E+01 | 5.28E-02 |

Table : Property Sets

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Physical Properties | Units | Qualifiers |
| CONDUC-L | KMX | Watt/m-K | Phase=Liquid |
| CPMX | CPMX | J/kg-K | Phase=Liquid |
| MDOT-V | MASSFLMX | kg/sec | Phase=Vapor |
| MU-L | MUMX | Pa-sec | Phase=Liquid |
| MU-V | MUMX | Pa-sec | Phase=Vapor |
| RHO-L | RHOMX | kg/cum | Phase=Liquid |
| RHO-V | RHOMX | kg/cum | Phase=Vapor |
| SURFT | SIGMAMX | N/m | Phase=Liquid |

* 1. Setup: Flowsheet

Before moving the calculator blocks, the template streams must be renamed to the destination stream names.

1. Click the “Main Flowsheet” tab at the top to view the flowsheet of Figure 64.

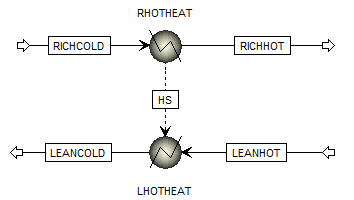


Figure : Linked heater blocks.

1. Rename the heat and material streams by right-clicking and selecting “Rename” to match the corresponding stream names of the destination flowsheet.
2. Navigate to “Flowsheeting Options” → “Calculator” → “C-HX” → “Results,” and then select the “Define Variable” tab. Verify that the results are similar to those of Table 27. If not, check the Property Set Units.

Table : C-HX Results

|  |  |  |  |
| --- | --- | --- | --- |
| Variable | Value Written | Description | Units |
| EXCAP | 4.38E-01 | exchanger CAPEX | $/tonne CO2 |
| RPUMPOP | 6.83E-02 | rich pump CAPEX | $/tonne CO2 |
| RPUMPCAP | 3.58E-02 | rich pump OPEX | $/tonne CO2 |
| TAC | 5.42E-01 | total annualized capital | $/tonne CO2 |
| AREA | 4.25E+03 | exchanger area | m2 |
| LMTD | 1.52E+01 | log mean temperature difference | K |
| U | 5.17E+03 | overall heat transfer coefficient | W/K‒m2 |
| DPRICH | 9.43E+04 | rich-side pressure drop | Pa |
| DPLEAN | 9.17E+04 | lean-side pressure drop | Pa |
| LPLATE | 2.80E+00 | plate length | m |
| VRICH | 4.43E-01 | rich-side fluid velocity | m/sec |
| VLEAN | 4.72E-01 | lean-side fluid velocity | m/sec |

* 1. Setup: Calculator Blocks

Now that the property sets exist and the stream names agree, the calculator blocks can be imported.

1. In the “HeatCalc.bkp” file, navigate to “Flowsheeting Options” → “Calculator,” and then select “C-HX.” Click “Copy.”
2. In the destination file, navigate to “Flowsheeting Options” → “Calculator.”
3. Click “Paste.”
   1. Setup: Optimization Block

This block functions similarly to Solver in Excel®. The provided optimization block minimizes the total annualized capital of the exchanger and the rich pump by varying the total width (NW) of the exchanger.

1. Return to the “HeatCalc.bkp” file, navigate to “Model Analysis Tools” → “Optimization,” and then select “O-TAC.” Click “Copy.”
2. Navigate to “Model Analysis Tools” → “Optimization” in the destination file.
3. Click “Paste.”
   1. Running the Simulation

Aspen Plus will sequence the calculator and optimization blocks after the flowsheet calculations, meaning the heat exchanger model has no impact on flowsheet convergence. Running the simulation is no different from running the simulation before adding in the heat exchanger model.

1. Usage Information
   1. Support

Support can be obtained from [ccsi-support@acceleratecarboncapture.org](mailto:ccsi-support@acceleratecarboncapture.org) or by filling out the “Submit Feedback/Request Support” form available on the product distribution page.

* 1. Restrictions

This model works with any non-flashing solvent in a plate and frame heat exchanger. Note that the heat transfer coefficient assumes turbulence and 45° herringbone plates. Additional restricting assumptions include:

* a plate spacing of 2 mm
* a plate thickness of 6 mm
* plate material of 304 stainless steel
* assumptions on capital and electricity cost
  1. Known Issues
* The exchanger and pump sizing is continuous, while in reality it is discrete.

1. Debugging

* If the provided file does not yield similar results to those described here, then:
* check the Property Set Units
* check that the Streams are properly named
* use the four provided debugging outputs to troubleshoot
  1. How to Debug

Always run the simulation with the control panel visible. The output will notify the user about potential problems and errors. For problems specific to C-HX, the four debugging output parameters (OUT1, OUT2, OUT3, and OUT4) can be used to check intermediate values.

* 1. Reporting Issues

To report an issue, please send an email to [ccsi-support@acceleratecarboncapture.org](mailto:ccsi-support@acceleratecarboncapture.org).

1. Model History
   1. Block Descriptions

C-HX

This block sizes and costs a non-flashing plate and frame heat exchanger.

Variables

The variables defined are listed in Table 28. As variable names are limited to seven characters, the following shorthand is used:

* CR = cold, rich
* HR = hot, rich
* HL = hot, lean
* CL = cold, lean

Table : C-HX Variable Definitions

| Variable | Information Flow | Definition |
| --- | --- | --- |
| EXCAP | Export variable | Parameter Parameter no. = 311 |
| RPUMPOP | Export variable | Parameter Parameter no. = 312 |
| RPUMPCAP | Export variable | Parameter Parameter no. = 313 |
| TAC | Export variable | Parameter Parameter no. = 315 |
| AREA | Export variable | Parameter Parameter no. = 310 |
| LMTD | Export variable | Parameter Parameter no. = 314 |
| U | Export variable | Parameter Parameter no. = 319 |
| DPRICH | Export variable | Parameter Parameter no. = 316 |
| DPLEAN | Export variable | Parameter Parameter no. = 317 |
| LPLATE | Export variable | Parameter Parameter no. = 318 |
| VRICH | Export variable | Parameter Parameter no. = 320 |
| VLEAN | Export variable | Parameter Parameter no. = 321 |
| OUT1 | Export variable | Parameter Parameter no. = 300 |
| OUT2 | Export variable | Parameter Parameter no. = 301 |
| OUT3 | Export variable | Parameter Parameter no. = 303 |
| OUT4 | Export variable | Parameter Parameter no. = 304 |
| TCR | Import variable | Stream-Var Stream = RICHCOLD; Substream = MIXED; Variable = TEMP; Units = K |
| THL | Import variable | Stream-Var Stream = LEANWRM; Substream = MIXED; Variable = TEMP; Units = K |
| THR | Import variable | Stream-Var Stream = RICHWRM1; Substream = MIXED; Variable = TEMP; Units = K |
| TCL | Import variable | Stream-Var Stream = LEANCOLD; Substream = MIXED; Variable = TEMP; Units = K |
| MCR | Import variable | Stream-Var Stream = RICHCOLD; Substream = MIXED;  Variable = MASS-FLOW; Units = kg/sec |
| MHL | Import variable | Stream-Var Stream = LEANWRM; Substream = MIXED;  Variable = MASS-FLOW; Units = kg/sec |
| MHR | Import variable | Stream-Var Stream = RICHWRM1; Substream = MIXED;  Variable = MASS-FLOW; Units = kg/sec |
| MCL | Import variable | Stream-Var Stream = LEANCOLD; Substream = MIXED;  Variable = MASS-FLOW; Units = kg/sec |
| MUCR | Import variable | Stream-Prop Stream = RICHCOLD; Prop-Set = MU-L; Units = Pa-sec |
| MUHL | Import variable | Stream-Prop Stream = LEANWRM; Prop-Set = MU-L; Units = Pa-sec |
| MUHR | Import variable | Stream-Prop Stream = RICHWRM1; Prop-Set = MU-L; Units = Pa-sec |
| MUCL | Import variable | Stream-Prop Stream = LEANCOLD; Prop-Set = MU-L; Units = Pa-sec |
| RHOCR | Import variable | Stream-Prop Stream = RICHCOLD; Prop-Set = RHO-L; Units = kg/cum |
| RHOHL | Import variable | Stream-Prop Stream = LEANWRM; Prop-Set = RHO-L; Units = kg/cum |
| RHOHR | Import variable | Stream-Prop Stream = RICHWRM1; Prop-Set = RHO-L; Units = kg/cum |
| RHOCL | Import variable | Stream-Prop Stream = LEANCOLD; Prop-Set = RHO-L; Units = kg/cum |
| CPCR | Import variable | Stream-Prop Stream = RICHCOLD; Prop-Set = CPMX; Units = J/kg-K |
| CPHL | Import variable | Stream-Prop Stream = LEANWRM; Prop-Set = CPMX; Units = J/kg-K |
| CPHR | Import variable | Stream-Prop Stream = RICHWRM1; Prop-Set = CPMX; Units = J/kg-K |
| CPCL | Import variable | Stream-Prop Stream = LEANCOLD; Prop-Set = CPMX; Units = J/kg-K |
| KCR | Import variable | Stream-Prop Stream = RICHCOLD; Prop-Set = CONDUC-L;  Units = Watt/m-K |
| KHL | Import variable | Stream-Prop Stream = LEANWRM; Prop-Set = CONDUC-L; Units = Watt/m-K |
| KHR | Import variable | Stream-Prop Stream = RICHWRM1; Prop-Set = CONDUC-L;  Units = Watt/m-K |
| KCL | Import variable | Stream-Prop Stream = LEANCOLD; Prop-Set = CONDUC-L;  Units = Watt/m-K |
| DUTY | Import variable | Heat-Duty Stream = WRMHS; Units = Watt |
| CO2RM | Import variable | Mole-Flow Stream = PRODUCT1; Substream = MIXED; Component = CO2; Units = kmol/sec |
| NW | Import variable | Parameter Parameter no. = 366; Initial value = 1962.13 |

All of the variables defined in the “Define” tab of the calculator block input are included in Table 29 in addition to all the variables defined in the “Calculate” tab.

Table : C-HX Variable Description

| Variable | I/O | Description | Units |
| --- | --- | --- | --- |
| EXCAP | O | Annualized exchanger CAPEX | $/tonne CO2 |
| AREA | O | Exchanger area | m2 |
| RPUMPOP | O | Annualized rich pump OPEX | $/tonne CO2 |
| RPUMPCAP | O | Annualized rich pump CAPEX | $/tonne CO2 |
| TAC | O | Total annualized capital cost of exchanger and rich pump | $/tonne CO2 |
| LMTD | O | LMTD of warm exchanger | K |
| U | O | Overall heat transfer coefficient | W/K-m2 |
| DPRICH | O | Pressure drop of rich stream | Pa |
| DPLEAN | O | Pressure drop of lean stream | Pa |
| LPLATE | O | Plate length | m |
| VRICH | O | Velocity of rich stream | m/sec |
| VLEAN | O | Velocity of lean stream | m/sec |
| OUT1 | O | Debugging output | arbitrary |
| OUT2 | O | Debugging output | arbitrary |
| OUT3 | O | Debugging output | arbitrary |
| OUT4 | O | Debugging output | arbitrary |
| TCR | I | Temperature of CR | K |
| THL | I | Temperature of HL | K |
| THR | I | Temperature of HR | K |
| TCL | I | Temperature of CL | K |
| MCR | I | Mass flow of CR | kg/sec |
| MHL | I | Mass flow of HL | kg/sec |
| MHR | I | Mass flow of HR | kg/sec |
| MCL | I | Mass flow of CL | kg/sec |
| MUCR | I | Liquid viscosity of CR | Pa‒sec |
| MUHL | I | Liquid viscosity of HL | Pa‒sec |
| MUHR | I | Liquid viscosity of HR | Pa-sec |
| MUCL | I | Liquid viscosity of CL | Pa-sec |
| RHOCR | I | Liquid density of CR | kg/m3 |
| RHOHL | I | Liquid density of HL | kg/m3 |
| RHOHR | I | Liquid density of HR | kg/m3 |
| RHOCL | I | Liquid density of CL | kg/m3 |
| CPCR | I | Liquid heat capacity of CR | J/kg‒K |
| CPHL | I | Liquid heat capacity of HL | J/kg‒K |
| CPHR | I | Liquid heat capacity of HR | J/kg‒K |
| CPCL | I | Liquid heat capacity of CL | J/kg‒K |
| KCR | I | Liquid thermal conductivity of CR | W/m‒K |
| KHL | I | Liquid thermal conductivity of HL | W/m‒K |
| KHR | I | Liquid thermal conductivity of HR | W/m‒K |
| KCL | I | Liquid thermal conductivity of CL | W/m‒K |
| DUTY | I | Heat duty | W |
| CO2RM | I | Mole flow of CO2 in stripper overhead | kmol/sec |
| VCLW | O | Volumetric flowrate of CL | m3/sec |
| NW | I | Total exchanger width | m |
| PLATESPACE | I | Plate spacing | m |
| GRICH | O | Mass flux of rich stream | kg/m2‒sec |
| GLEAN | O | Mass flux of lean stream | kg/m2‒sec |
| VELCR | O | Velocity of CR | m/sec |
| VELCL | O | Velocity of CL | m/sec |
| VELHR | O | Velocity of HR | m/sec |
| VELHL | O | Velocity of HL | m/sec |
| DIAM | I | Equivalent diameter | m |
| RECR | O | Reynolds number of CR | — |
| RECL | O | Reynolds number of CL | — |
| REHR | O | Reynolds number of HR | — |
| REHL | O | Reynolds number of HL | — |
| PRCR | O | Prandtl number of CR | — |
| PRCL | O | Prandtl number of CL | — |
| PRHR | O | Prandtl number of HR | — |
| PRHL | O | Prandtl number of HL | — |
| HCR | O | Heat transfer coefficient of CR | W/m2‒K |
| HCL | O | Heat transfer coefficient of CL | W/m2‒K |
| HHR | O | Heat transfer coefficient of HR | W/m2‒K |
| HHL | O | Heat transfer coefficient of HL | W/m2‒K |
| KPLATE | I | Plate thermal conductivity | W/m2‒K |
| PLATETHICK | I | Plate thickness | m |
| HPLATE | O | Plate heat transfer coefficient | W/m2‒K |
| UCOLD | O | Cold side overall heat transfer coefficient | W/m2‒K |
| UHOT | O | Hot side overall heat transfer coefficient | W/m2‒K |
| DELTC | O | Cold side temperature approach | K |
| DELTH | O | Cold side temperature approach | K |
| FCR | O | Fanning friction factor of CR | — |
| FCL | O | Fanning friction factor of CL | — |
| FHR | O | Fanning friction factor of HR | — |
| FHL | O | Fanning friction factor of HL | — |
| DPCR | O | Pressure drop per length of CR | Pa/m |
| DPCL | O | Pressure drop per length of CL | Pa/m |
| DPHR | O | Pressure drop per length of HR | Pa/m |
| DPHL | O | Pressure drop per length of HL | Pa/m |
| ACOST | I | CAPEX of exchanger area | $/m2 |
| ECOST | I | Cost of electricity | $/MWh |
| ALPHA | I | Converts PEC to total capital requirement | — |
| BETA | I | Lang factor (annualizes cost) | — |
| CFACTOR | I | Capacity factor | — |
| PETA | I | Pump efficiency | — |
| PCOST | I | Pump CAPEX | $/W |
| CO2RMA | O | CO2 removed per annum | tonne/annum |
| VCR | O | Volumetric flowrate of CR | m3/sec |

Fortran Code

The first part of the code calculates and maps all necessary properties for the model calculations. The next part calculates the exchanger size. The last part calculates the economics and formats miscellaneous outputs.

If a comment line ends with a number in parentheses, e.g., (1), then there is a comment in this documentation. The comment shows the equation in a more readable format, explains all variables, and elucidates the equation origin.

C Brent Sherman

C 2014-11-17

C PURPOSE: Size a non-flashing plate and frame heat exchanger

C and cost it and the rich pump.

C Numbers in parentheses refer to comments in documentation.

C --- Calculations begin ---

C Set plate spacing (m).

PSPACE=0.002

C Calculate mass flux (kg/sec-m2). (1)

GRICH=MCR/(PSPACE\*NW)

GLEAN=MHL/(PSPACE\*NW)

C Calculate stream velocity (m/sec). (2)

VELCR=GRICH/(RHOCR)

VELCL=GLEAN/(RHOCL)

VELHR=GRICH/(RHOHR)

VELHL=GLEAN/(RHOHL)

C Output velocities of rich and lean sides.

VRICH=VELCR

VLEAN=VELHR

C Calculate the Reynolds number. (3)

DIAM=2\*PSPACE

RECR=GRICH\*DIAM/MUCR

RECL=GLEAN\*DIAM/MUCL

REHR=GRICH\*DIAM/MUHR

REHL=GLEAN\*DIAM/MUHL

C Calculate the Prandtl number. (4)

PRCR=(CPCR\*MUCR)/KCR

PRCL=(CPCL\*MUCL)/KCL

PRHR=(CPHR\*MUHR)/KHR

PRHL=(CPHL\*MUHL)/KHL

C Calculate the heat transfer coefficient (W/m2-K). (5)

C h=Nu\*ki/D

HCR=(0.3\*KCR/DIAM)\*(PRCR\*\*0.333)\*(RECR\*\*0.663)

HCL=(0.3\*KCL/DIAM)\*(PRCL\*\*0.333)\*(RECL\*\*0.663)

HHR=(0.3\*KHR/DIAM)\*(PRHR\*\*0.333)\*(REHR\*\*0.663)

HHL=(0.3\*KHL/DIAM)\*(PRHL\*\*0.333)\*(REHL\*\*0.663)

C Set wall thermal conductivity (W/m-K)

KPLATE=16

C Set Plate thickness in m.

PTHK=0.0006

C Calculate the plate heat transfer coefficient (W/m2-K).

HPLATE=KPLATE/PTHK

C Calculate the overall heat transfer coefficients (W/m2-K). (6)

UCOLD=(1/HCR)+(1/HCL)+(1/HPLATE)

UCOLD=1/UCOLD

UHOT=(1/HHR)+(1/HHL)+(1/HPLATE)

UHOT=1/UHOT

C Calculate the temperature approaches (K).

DELTC=TCL-TCR

DELTH=THL-THR

C Calculate the area (m2). (7)

AREA=-DUTY/((UHOT\*DELTC-UCOLD\*DELTH)

. /DLOG((UHOT\*DELTC)/(UCOLD\*DELTH)))

C LMTD (K)

LMTD=(DELTC-DELTH)/DLOG(DELTC/DELTH)

C Overall heat transfer coefficient (W/K-m2) (8)

U=-DUTY/(AREA\*LMTD)

C --- Economic Calculations Begin ---

C Calculate plate length (m).

LPLATE=AREA/NW

C Calculate Fanning friction factor for turbulent flow. (9)

FCR=1.441\*RECR\*\*-0.206

FCL=1.441\*RECL\*\*-0.206

FHR=1.441\*REHR\*\*-0.206

FHL=1.441\*REHL\*\*-0.206

C Calculate the pressure drop per length (Pa/m). (10)

DPCR=(2\*FCR\*GRICH\*\*2)/(RHOCR\*DIAM)

DPCL=(2\*FCL\*GLEAN\*\*2)/(RHOCL\*DIAM)

DPHR=(2\*FHR\*GRICH\*\*2)/(RHOHR\*DIAM)

DPHL=(2\*FHL\*GLEAN\*\*2)/(RHOHL\*DIAM)

C Calculate the rich-, and lean-side pressure drop (Pa). (11)

DPRICH=((DPCR+DPHR)/2)\*LPLATE

DPLEAN=((DPCL+DPHL)/2)\*LPLATE

C Economic parameters.

ACOST=231.61

ECOST=100

ALPHA=5

BETA=0.2

CFACTOR=0.90

PETA=0.65

PCOST=0.4135

C Exchanger CAPEX ($/tonne CO2)

C Convert CO2 removed from kmol/sec to tonne/sec. (12)

CO2RMA=CO2RM\*44/1D3

EXCAP=(AREA\*ACOST\*ALPHA\*BETA)

. /(CO2RMA\*3600\*24\*365\*CFACTOR)

C Calculate pump CAPEX ($/tonne CO2). (13)

VCR=MCR/RHOCR

RPUMPCAP=(DPRICH\*VCR/PETA)

. \*PCOST\*ALPHA\*BETA

. /(CO2RMA\*3600\*24\*365\*CFACTOR)

C Calculate pump OPEX ($/tonne CO2). (14)

RPUMPOP=(DPRICH\*VCR/PETA)

. \*ECOST/(3600\*1D6)/CO2RMA

C Calculate Total annualized capital ($/tonne CO2). (15)

TAC=EXCAP+RPUMPOP+RPUMPCAP

C Debugging outputs (16)

OUT1= FCR

OUT2= DPCR

OUT3= DPHR

OUT4= LPLATE

Code Comments

1. The mass flux is calculated using Equation 1,

|  |  |  |
| --- | --- | --- |
|  |  | (1) |

where *G* is mass flux (kg/m2‒sec), *ṁ* is mass flow rate (kg/sec), *δ* is plate spacing (m), *n* is number of plates, and *W* is plate width (m).

1. The velocity is calculated from the mass flux using Equation 2,

|  |  |  |
| --- | --- | --- |
|  |  | (2) |

where *v* is velocity (m/sec) and *ρ* is liquid density (kg/m3).

1. The Reynolds number *Re* is calculated using Equation 3,

|  |  |  |
| --- | --- | --- |
|  |  | (3) |

where *μ* is the liquid viscosity (Pa‒sec), and *D* is the equivalent diameter (m), which is twice the plate spacing.

1. The Prandtl number *Pr* is calculated in Equation 4,

|  |  |  |
| --- | --- | --- |
|  |  | (4) |

where *Cp* is the liquid heat capacity (J/kg‒K), and *k* is the liquid thermal conductivity (W/m‒K).

1. The heat transfer coefficient *h* (W/m2‒K) is calculated using Equation 5,

|  |  |  |
| --- | --- | --- |
|  |  | (5) |

where *Nu* is the Nusselt number. This assumes herringbone plates with 45° corrugation angle (Ayub, 2003).

1. The overall heat transfer coefficient *Ui* of the hot or cold side (W/m2‒K) is calculated using Equation 6,

|  |  |  |
| --- | --- | --- |
|  |  | (6) |

where *h1* is the heat transfer coefficient of the rich stream (W/m2‒K), *h2* is the heat transfer coefficient of the lean stream (W/m2‒K), and *hplate* is the heat transfer coefficient of the plate (W/m2‒K) equal to the plate thermal conductivity divided by plate thickness.

1. The exchanger area *A* (m2) is calculated using Equation 7,

|  |  |  |
| --- | --- | --- |
|  |  | (7) |

where *Q* is the duty (W), *Uhot* (*Ucold*) is the overall heat transfer coefficient of the hot (cold) side (W/m2‒K), and *ΔThot* (*ΔTcold*) is the hot- (cold-) side temperature approach (K).

1. The overall heat transfer coefficient *U* (W/m2‒K) is calculated using Equation 8.

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  | (8) |

1. The Fanning friction factor *ff* is calculated using Equation 9.

|  |  |  |
| --- | --- | --- |
|  |  | (9) |

1. The pressure drop per length (Pa/m) is calculated using Equation 10,

|  |  |  |
| --- | --- | --- |
|  |  | (10) |

where *L* is the length (m). This is calculated for each stream.

1. The pressure drop of the rich and lean sides (Pa) is calculated using Equation 11.

|  |  |  |
| --- | --- | --- |
|  |  | (11) |

The equivalent equation is used for the lean side pressure drop.

1. The exchanger CAPEX *EXCAP* ($/tonne CO2) is calculated using Equation 12,

|  |  |  |
| --- | --- | --- |
|  |  | (12) |

where *$A* is the cost per unit area ($/m2), *α* is the conversion of PEC to total capital requirement, *β* is the Lang factor, is the mass flowrate of CO2 leaving the stripper overhead (tonne/sec), and *C* is the capacity factor, which accounts for 10% plant downtime. The purchased equipment cost (PEC) came from vendor quotes. It is assumed to vary linearly with area.

1. The rich pump CAPEX *RPUMPCAP* ($/tonne CO2) is calculated using Equation 13,

|  |  |  |
| --- | --- | --- |
|  |  | (13) |

where *QCR* is the volumetric flowrate of the cold, rich stream (m3/sec), η is the pump efficiency, and *$P* is the cost of the pump ($/W).

1. The rich pump operating cost RPUMPOP ($/tonne CO2) is calculated using Equation 14,

|  |  |  |
| --- | --- | --- |
|  |  | (14) |

where *COE* is the cost of electricity ($/MWh).

1. The total annualized capital *TAC* ($/tonne CO2) is calculated using Equation 15.

|  |  |  |
| --- | --- | --- |
|  |  | (15) |

1. The following four outputs were used for debugging: OUT1, OUT2, OUT3, and OUT4. They are available for displaying intermediate values. Change the variable on the right side of the equal sign to the variable or expression to display.
2. References

Ayub, Z.H. Plate Heat Exchanger Literature Survey and New Heat Transfer and Pressure Drop Correlations for Refrigerant Evaporators. *Heat Transf Eng* **2003**, *24*, 3–16.