



Part 5

Heat Exchangers in Aspen Plus





Problem Definition

In basic stage of an Ammonia project the process engineering department has decided that the saturator blow down should be cooled to 65 C before introducing the stream to treatment facility. In order to do so a water-cooled shell and tube heat exchanger is used to serve the purpose. The process conditions of the fluids are provided below.

Please using Aspen Plus calculate the followings:

- 1.The amount of cooling water needed.
- 2.The duty of the Heat exchanger.
- 3.Using HeatX, determine surface area,

Operating Data (One Unit)					
Description	Shell Side		Tube Side		Units
	Inlet	Outlet	Inlet	Outlet	
Fluids	Process condensate		Cooling water		
Quantity: total	47200		166009		kg/h
liquid	47200	47200	166009	166009	kg/h
gas					kg/h
Operating temperature	100	65	38	48	°C
Operating pressure	1,5		4,5		bar g
Liquid: molecular weight	18,02	18,02	18,02	18,02	kg/kmol
density	958	980	993	989	kg/m ³
viscosity	0,283	0,434	0,681	0,567	cP
specific heat capacity	4,213	4,184	4,175	4,177	kJ/kg/°C
thermal conductivity	0,6768	0,6505	0,6199	0,6323	W/m/°C
boiling temperature	106				°C
Gas: molecular weight					kg/kmol
density					kg/m ³
viscosity					cP
specific heat capacity					kJ/kg/°C
thermal conductivity					W/m/°C
dew point					°C
Performance					
Pressure drop, max. allowable/calculated	/ 0,1		/ 0,6		bar
Fouling resistance	0,00017		0,00030		m ² ·°C/W



How to simulate

1. Open a new simulation
2. Select Water as the component

Component ID	Type	Component name	Alias	CAS number
WATER	Conventional	WATER	H2O	7732-18-5

3. Select STEAMNBS as the property package and click Next.

Property methods & options

Method filter: ALL

Base method: STEAMNBS

Henry components:

Petroleum calculation options

Free-water method: STEAM-TA

Water solubility: 3

Electrolyte calculation options

Chemistry ID:

Use true components

Method name: STEAMNBS

Modify

EOS: ESSTEAM

Data set: 1

Liquid gamma:

Data set:

Liquid molar enthalpy: HLMX90

Liquid molar volume: VLMX90

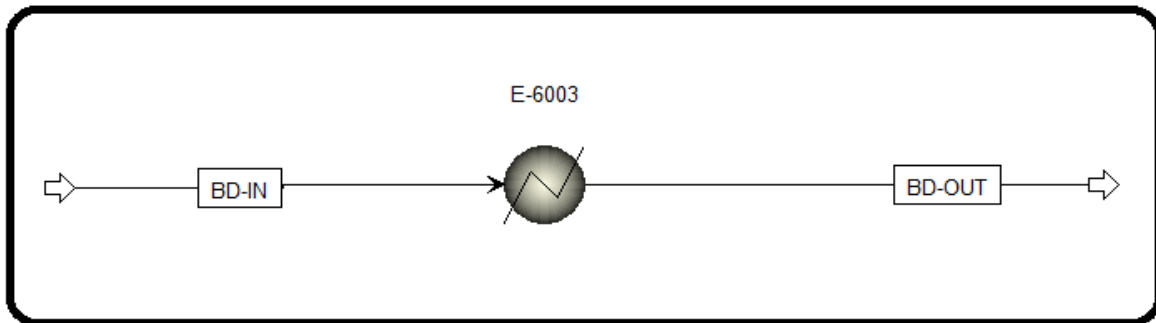
Heat of mixing

Poynting correction

Use liquid reference state enthalpy



4. Create the flowsheet like below and add inputs for the stream and the block like below:



Specifications

Flash Type: **Temperature** Pressure

State variables

Temperature: 100 C

Pressure: 1.5 barg

Vapor fraction: []

Total flow basis: **Mass**

Total flow rate: 47200 kg/hr

Solvent: []

Reference Temperature

Volume flow reference temperature: [] C

Component concentration reference temperature: [] C

Composition: **Mass-Frac**

Component	Value
WATER	100

Total: 100



Specifications | Flash Options | Utility | Comments

Flash specifications

Flash Type: **Temperature**

Pressure: **Pressure**

Temperature: 65 C

Temperature change: C

Degrees of superheating: C

Degrees of subcooling: C

Pressure: 1.5 barg

Duty: cal/sec

Vapor fraction:

Pressure drop correlation parameter:

Always calculate pressure drop correlation parameter

Valid phases: Vapor-Liquid

5.Run Aspen Plus and check the results.

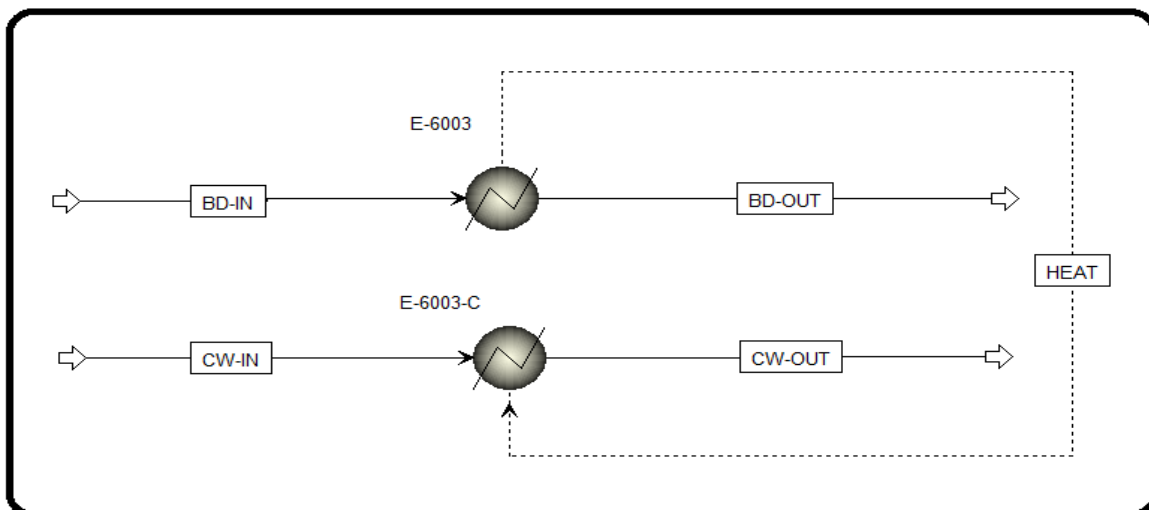
Summary | Balance | Phase Equilibrium | Utility Usage | Status

Outlet temperature	65	C
Outlet pressure	2.51325	bar
Vapor fraction	0	
Heat duty	-1926.18	kW
Net duty	-1926.18	kW
1st liquid / Total liquid	1	
Pressure-drop correlation parameter		
Pressure drop	0	bar



Material	Heat	Load	Vol.% Curves	Wt. % Curves	Petroleum	Polymers	Solids			
								Units		
									BD-IN	BD-OUT
▶	Temperature							C	100	65
▶	Pressure							bar	2.51325	2.51325
▶	Molar Vapor Fraction								0	0
▶	Molar Liquid Fraction								1	1
▶	Molar Solid Fraction								0	0
▶	Mass Vapor Fraction								0	0
▶	Mass Liquid Fraction								1	1
▶	Mass Solid Fraction								0	0
▶	Molar Enthalpy							cal/mol	-66957.6	-67589.7
▶	Mass Enthalpy							cal/gm	-3716.71	-3751.8
▶	Molar Entropy							cal/mol-K	-34.9235	-36.7022
▶	Mass Entropy							cal/gm-K	-1.93855	-2.03728
▶	Molar Density							mol/cc	0.0532027	0.054433
▶	Mass Density							gm/cc	0.958462	0.980625

6. Perform the same procedure for cooling water but this time the heat exchanger needs just one input since the Q is calculated in last step and is connected to this block.





Mixed | CI Solid | NC Solid | Flash Options | EO Options | Costing | Comments

Specifications

Flash Type: **Temperature** | **Pressure**

State variables

Temperature: 38 C

Pressure: 4.5 barg

Vapor fraction: []

Total flow basis: **Mass**

Total flow rate: 100000 kg/hr

Solvent: []

Reference Temperature

Volume flow reference temperature: [] C

Component concentration reference temperature: [] C

Composition

Mass-Flow | kg/hr

Component	Value
WATER	100

Total: 100

Specifications | Flash Options | Utility | Comments

Flash specifications

Flash Type: **Pressure**

Inlet heat stream: []

Temperature: [] C

Temperature change: [] C

Degrees of superheating: [] C

Degrees of subcooling: [] C

Pressure: 4.5 barg

Duty: [] cal/sec

Vapor fraction: []

Pressure drop correlation parameter: []

Always calculate pressure drop correlation parameter

Valid phases: **Vapor-Liquid**



7.Run Aspen Plus and check the results.

Summary	Balance	Phase Equilibrium	Utility Usage	Status
Outlet temperature	54.5864	C		
Outlet pressure	5.51325	bar		
Vapor fraction	0			
Heat duty	1926.18	kW		
Net duty	0	cal/sec		
1st liquid / Total liquid	1			
Pressure-drop correlation parameter				
Pressure drop	0	bar		

	Units	CW-IN	CW-OUT
Phase		Liquid Phase	Liquid Phase
Temperature	C	38	54.5864
Pressure	bar	5.51325	5.51325
Molar Vapor Fraction		0	0
Molar Liquid Fraction		1	1
Molar Solid Fraction		0	0
Mass Vapor Fraction		0	0
Mass Liquid Fraction		1	1
Mass Solid Fraction		0	0
Molar Enthalpy	cal/mol	-68074.4	-67776
Mass Enthalpy	cal/gm	-3778.7	-3762.14
Molar Entropy	cal/mol-K	-38.2001	-37.2658
Mass Entropy	cal/gm-K	-2.12043	-2.06857
Molar Density	mol/cc	0.0551287	0.0547361



8.To calculate the exact cooling water needed, we should create a Design Spec under Flowsheeting Option. Act like below:

The screenshot shows a software interface with a table of design specifications. The table has columns for Name, Hide, Active, Status, Description, and Delete. A row is visible with Name 'DS-1', Hide unchecked, Active checked, Status 'Results Available', and a red 'X' in the Delete column. A dialog box titled 'Create New ID' is open, with 'Enter ID:' and a text field containing 'DS-1'. The dialog has 'OK' and 'Cancel' buttons.

Name	Hide	Active	Status	Description	Delete
DS-1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Results Available		X

The screenshot shows the configuration for a Design Spec variable named 'CWT'. The 'Define' tab is selected. The 'Active' checkbox is checked. Under 'Sampled variables', a table lists the variable 'CWT' with the definition 'Stream-Var Stream=CW-OUT Substream=MIXED Variable=TEMP Units=C'. Below the table are buttons for 'New', 'Delete', 'Copy', 'Paste', 'Move Up', 'Move Down', and 'View Variables'. The 'Edit selected variable' section shows 'CWT' selected in the 'Variable' dropdown. The 'Reference' section has dropdowns for 'Type' (Stream-Var), 'Stream' (CW-OUT), 'Substream' (MIXED), 'Variable' (TEMP), and 'Units' (C). The 'Category' section has radio buttons for 'All', 'Blocks', 'Streams', 'Model Utility', 'Property Parameters', and 'Reactions'.

Active

Sampled variables (drag and drop variables from form to the grid below)

Variable	Definition
CWT	Stream-Var Stream=CW-OUT Substream=MIXED Variable=TEMP Units=C

Variable: CWT

Reference

Type: Stream-Var

Stream: CW-OUT

Substream: MIXED

Variable: TEMP

Units: C

Category

All

Blocks

Streams

Model Utility

Property Parameters

Reactions



Define Spec Vary Fortran Declarations EO Options Comments

Design specification expressions

Spec	CWT
Target	48
Tolerance	0.001

Define Spec Vary Fortran Declarations EO Options Comments

Manipulated variable

Type	Stream-Var
Stream:	CW-IN
Substream:	MIXED
Variable:	MASS-FLOW
Units:	kg/hr

Manipulated variable limits

Lower	100000
Upper	200000
Step size	
Maximum step size	

Report labels

Line 1	Line 2	Line 3	Line 4

EO input

Open variable	
Description	

Copy Paste Clear

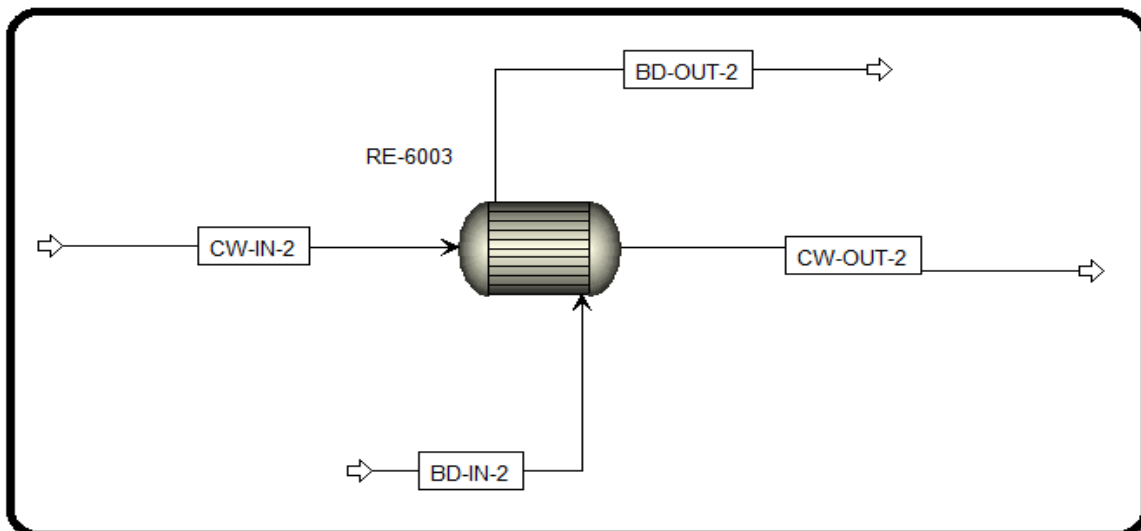
9. Check the results:



Summary Spec History Status				
Design spec DS-1				
	Iteration	Variable value	Error	Error / Tolerance
▶	1	100000	6.58635	6586.35
▶	2	101000	6.42213	6422.13
▶	3	140106	1.8382	1838.2
▶	4	155633	0.657066	657.066
▶	5	167482	-0.0969654	-96.9654
▶	6	165838	0.00118203	1.18203
▶	7	165858	7.52732e-07	0.000752732

Results Status				
	Variable	Initial value	Final value	Units
▶	MANIPULATED	100000	165858	KG/HR
▶	CWT	54.5864	48	C

So now we can see that we need 165858 kg/hr to be able to reduce the saturator blow down to 65C. Now we switch to HEATX type to calculate other characteristics of the heat exchanger.





Mixed CI Solid NC Solid Flash Options EO Options Costing Comments

Specifications

Flash Type: Temperature Pressure

State variables

Temperature: 38 C

Pressure: 4.5 barg

Vapor fraction: []

Total flow basis: Mass

Total flow rate: 165858 kg/hr

Solvent: []

Reference Temperature

Volume flow reference temperature: [] C

Component concentration reference temperature: [] C

Composition: Mass-Frac

Component	Value
WATER	100

Total: 100

Mixed CI Solid NC Solid Flash Options EO Options Costing Comments

Specifications

Flash Type: Temperature Pressure

State variables

Temperature: 100 C

Pressure: 1.5 barg

Vapor fraction: []

Total flow basis: Mass

Total flow rate: 47200 kg/hr

Solvent: []

Reference Temperature

Volume flow reference temperature: [] C

Component concentration reference temperature: [] C

Composition: Mass-Frac

Component	Value
WATER	100

Total: 100



Specifications Streams LMTD Pressure Drop U Methods Film Coefficients Utilities Comments

Model fidelity

- Shortcut
- Detailed
- Shell & Tube
- Kettle Reboiler
- Thermosyphon
- Air Cooled
- Plate

Hot fluid

- Shell
- Tube

Shortcut flow direction

- Countercurrent
- Cocurrent
- Multipass, calculate number of shells
- Multipass, shells in series

Calculation mode **Design**

Exchanger specification

Specification	Exchanger duty		
Value	1926.18	kW	
Exchanger area		sqm	Copy calculated area to input
Constant UA		cal/sec-K	Copy calculated UA to input
Minimum temperature approach	1	C	

Size Exchanger Specify Geometry Results



Note:

For “Exchanger specification” option, there are different options to choose from. Remember that each specification gives a different calculation scenario for Aspen Plus to execute. They are as follows:

1. Hot stream outlet temperature: Specifies the outlet temperature of the hot stream, used for situations where there is no phase change on the hot stream side.
2. Hot stream outlet temperature decrease: Specifies the temperature decrease for the hot stream.
3. Hot outlet–cold inlet temperature difference: Specifies the temperature difference between the hot stream outlet temperature and the cold stream inlet temperature, used with the countercurrent flow.
4. Hot stream outlet degrees subcooling: Specifies the outlet temperature below the dew point for the hot stream, *used for boiling and condensation*.
5. Hot stream outlet vapor fraction: Specifies the outlet vapor fraction for the hot stream (1.0=sat. vapor and 0.0=sat. liquid), used for boiling and condensation.
6. Hot inlet–cold outlet temperature difference: Specifies the temperature difference between the hot stream inlet temperature and the cold stream outlet temperature, used with the countercurrent flow.
7. Cold stream outlet temperature: Specifies the outlet temperature of the cold stream, used for situations where there is no phase change on the cold stream side.
8. Cold stream outlet temperature increase: Specifies the temperature increase for the cold stream.
9. Cold stream outlet degrees superheat: Specifies the outlet temperature above the bubble point for the cold stream, used for boiling and condensation.
10. Cold stream outlet vapor fraction: Specifies the outlet vapor fraction for the cold stream (1.0=sat. vapor and 0.0=sat. liquid), used for boiling and condensation.
11. Exchanger duty: Specifies the amount of energy transferred from one stream to another.
12. Hot/cold outlet temperature approach: Specifies the temperature difference between the hot/cold stream outlet temperature and the cold/hot stream inlet temperature, *used with the countercurrent flow*.



10. Now run Aspen Plus and check the results.

By going to the thermal result, you can check the followings:

Inlet		Outlet	
Hot stream:	BD-IN-2	BD-OUT-2	
Temperature	100 C	65 C	
Pressure	2.51325 bar	2.51325 bar	
Vapor fraction	0	0	
1st liquid / Total liquid	1	1	
Cold stream	CW-IN-2	CW-OUT-2	
Temperature	38 C	48 C	
Pressure	5.51325 bar	5.51325 bar	
Vapor fraction	0	0	
1st liquid / Total liquid	1	1	
Heat duty	1926.18 kW		

11. Click TQ Curves and get the results.

Calculate TQ curves Number of points: 8

Pressure profile

- Constant at inlet pressures
- Constant at outlet pressures
- Inlet and outlet pressures
- Specify pressures

Curve ID	Hot stream	Cold stream
	bar	bar



☑ TQ Curves Setup TQ Profiles

Curve ID INLET

	Heat duty MW	Cold stream temperature C	Hot stream temperature C	Cold stream pressure bar	Hot stream pressure bar	Cold stream vapor fraction	Hot stream vapor fraction	Cold stream status	Hot stream status
▶	0	48	100	5.51325	2.51325	0	0	OK	OK
▶	0.21402	46.8888	96.1264	5.51325	2.51325	0	0	OK	OK
▶	0.42804	45.7776	92.2482	5.51325	2.51325	0	0	OK	OK
▶	0.642059	44.6664	88.3657	5.51325	2.51325	0	0	OK	OK
▶	0.856079	43.5553	84.4791	5.51325	2.51325	0	0	OK	OK
▶	1.0701	42.4442	80.589	5.51325	2.51325	0	0	OK	OK
▶	1.28412	41.3331	76.6955	5.51325	2.51325	0	0	OK	OK
▶	1.49814	40.222	72.7993	5.51325	2.51325	0	0	OK	OK
▶	1.71216	39.111	68.9006	5.51325	2.51325	0	0	OK	OK
▶	1.92618	38	65	5.51325	2.51325	0	0	OK	OK



Appendix

The description of each item is quoted from Aspen Plus built-in help.

1. “Heater”: The basic heat exchanger model that performs simple energy balance calculations; it requires only one process stream. You can use “Heater” to represent heaters, coolers, valves, pumps (whenever work-related results are not needed), and compressors (whenever work-related results are not needed). You can also use “Heater” to set the thermodynamic condition of a stream. When the user specifies the outlet conditions, “Heater” will determine the thermal and phase conditions of a mixture with one or more inlet streams. This block will be initially used in this running tutorial for calculating the heat duty, which will then be used to calculate heat-transfer area requirement.

2. “HeatX”: The fundamental heat exchanger model that is used in a rigorous design; it will calculate energy balance, pressure drop, exchanger area, velocities, and so on and requires two process streams: hot and cold. “HeatX” can model a wide variety of shell and tube heat exchanger types and perform heat transfer related tasks, including

- a) countercurrent and co-current exchangers
- b) TEMA E, F, G, H, I/J, K, X shells (see Figure 10.19), and double pipe and multitube exchangers
- c) bare, low-finned, and longitudinal-finned tubes exchangers
- d) single and double segmental baffles, rod baffles, and unbaffled exchangers
- e) “HeatX” will perform the required calculations (all combinations of a single-phase boiling or condensing heat transfer, with associated pressure drop calculations), returning key calculation results to be viewed within Aspen Plus.
- f) perform mechanical vibration and ρv^2 analysis
- g) estimate maximum fouling
- h) display setting plan and tube-sheet layout drawing.

“HeatX” can perform a full zone analysis with heat transfer coefficient and pressure drop estimation for single- and two-phase streams. For rigorous heat transfer and pressure drop calculations, you must supply the exchanger geometry. If exchanger geometry is unknown or unimportant, “HeatX” can perform simplified shortcut rating calculations. For example, you may want to perform only heat and material balance calculations. “HeatX” has correlations to estimate sensible heat, nucleate boiling, and condensation film coefficients. “HeatX” uses a rigorous heat exchanger program to perform these calculations. Available programs include “Shell&Tube”, “AirCooled”, and “Plate”. Collectively, these programs are referred to as Aspen Exchanger Design and Rating (EDR).

This block will be used in this running tutorial for design calculations.

3. “MHeatX”: As its name tells, a multi-heat-exchanger model can be used to represent heat transfer between multiple hot and cold streams, as in an LNG exchanger, for example. “MHeatX” can perform a detailed and rigorous internal zone analysis to determine the internal pinch points and heating and cooling curves for all streams in the heat exchanger. “MHeatX” can also calculate, UA, the multiplication of the overall heat transfer coefficient by the area, for the exchanger and model heat leak to or from an exchanger. “MHeatX” uses multiple heater blocks and heat streams to enhance flowsheet convergence. Aspen Plus automatically sequences block and stream convergence unless you specify a sequence or tear stream.



4. “HXFlux”: A heat exchanger model that is used to perform heat transfer calculations between a heat sink and a heat source, using convective heat transfer and does not require any input or output material stream; nevertheless, you may add heat streams to substitute the heat exchange duty. The driving force for the convective heat transfer is calculated as a function of log-mean temperature difference (LMTD). The user has to specify all variables, except one, among inlet and outlet stream temperatures, duty, heat transfer coefficient, and heat transfer area. “HXFlux” calculates the unknown variable and determines the LMTD, using either the rigorous or the approximate method.

For the sake of calculating the heat duty that will be used to calculate the area requirement, let us use the first type, that is, “Heater”.



Reference

1. Our team experience
2. Aspen Plus – Chemical Engineering Application by KAMAL I.M. AL-MALAH
3. Aspen build-in help