Tips on Exchanger Process Design

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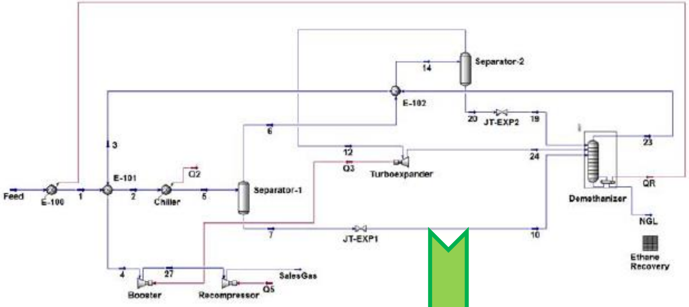
Putting Things in Perspective

Process Simulation



Mechanical Design / Fabrication

Process Datasheet

			Hot fluid		Cold fluid	
Fluid name			Hydrogen		Cooling water	
Fluid quantity, total		kg/h	8900 (1)		220 739	
Vapor	(In/Out)	kg/h	8900	8900		
Liquid		kg/h				
Steam		kg/h				
Water		kg/h			220 739	220 739
Non condensable		kg/h				
Temperature	(In/Out)	°C	124	45	35	45
Vapor	Density (PT)	kg/m3	2.56	3.16		
	Viscosity	cP	0.010	0.008		
	Molecular weight	kg/kmol	2.23	2.23		
	Specific heat	kcal/kg.°C	3.16	3.12		
	Thermal cond.	kcal/h.m.°C	0.182	0.155		
Liquid	Density (PT)	kg/m3			994	990
	Viscosity	cP			0.72	0.6
	Specific heat	kcal/kg.°C			1	1
	Thermal cond.	kcal/h.m.°C			0.52	0.54
Latent heat		kcal/kg				
Inlet pressure		kg/cm² g	20		4.5	
Velocity		m/s				
Pressure drop		[illegible]	Allow. [illegible].4	Calc.	Allow. [illegible]	Calc.
Fouling resistance		[illegible]°C.h/kcal	0.[illegible]		[illegible].0004	
Heat exchanged		Mkcal/h	2.207		LMTD (corrected) :	°C
Transfer rate		kcal./h.m².°C				

CONSTRUCTION

Design pressure		kg/cm² g	42.1		8.0	
Design temperature		°C	154		65	
Material			CS		CS	
Corrosion allowance		mm	3		3	
Connection size	(In/Out)	in	8"	8"	10"	10"
Connections rating	(In/Out)		300 RF	300 RF	150 RF	150 RF
Code requirements :	ASME				TEMA class :	R

NOTES

1. Provide 10% margin on area and flow
2. Turndown shall be 50% of normal flow.

Thermal Design

Size 745.000 x 6095.93 mm Type AES Horz. Connected In 1 Parallel 1 Series

Surf/Unit (Gross/Eff) 141.07 / 138.71 m2 Shell/Unit 1 Surf/Shell (Gross/Eff) 141.07 / 138.71 m2

PERFORMANCE OF ONE UNIT

Fluid Allocation		Shell Side		Tube Side	
Fluid Name		Naphtha		Cooling water	
Fluid Quantity, Total	kg/hr	36141.6		40446.0	
Vapor (In/Out)		8377.62	6685.68		
Liquid		27764.0	29455.9	40446.0	40446.0
Steam					
Water				40446.0	40446.0
Noncondensables					
Temperature (In/Out)	C	60.40	45.00	35.00	45.00
Specific Gravity		0.6684	0.6698	0.9947	0.9909
Viscosity	cP	0.0110 V/L 0.34	0.0110 V/L 0.37	0.7192	0.5960
Molecular Weight, Vapor					
Molecular Weight, Noncondensables					
Specific Heat	kcal/kg-C	0.5120 V/L 0.510	0.5100 V/L 0.500	0.9985	0.9985
Thermal Conductivity	kcal/hr-m-C	0.0360 V/L 0.093	0.0360 V/L 0.096	0.5352	0.5461
Latent Heat	kcal/kg	65.0152	61.1524		
Inl[illegible]ressure	kgf/cm2A	10.400		5.500	
Velocity	m/s	2.99		1.01	
Pressure Drop, Allow/Calc	kgf/cm2	0.400	0.136	0.500	0.458
Fouling Resistance (min)	m2-hr-C/kca	0.000400		0.000600	

Heat Exchanged kcal/hr 405334 MTD (Corrected) 9.8 C

Transfer Rate, Service 298.70 kcal/m2-hr-C Clean 486.45 kcal/m2-hr-C Actual 310.20 kcal/m2-hr-C

CONSTRUCTION OF ONE SHELL — Sketch (Bundle/Nozzle Orientation)

		Shell Side	Tube Side
Design/Test Pressure	kg[illegible]cm2G	[illegible] /	9.2[illegible]
Design Temperature	C	95.00	65.00
No Passes per Shell		1	8
Corrosion Allowance	mm		
Connections Size & Rating — In	mm	1 @ 304.801	1 @ 102.261
Out	mm	1 @ 304.801	1 @ 102.261
Intermediate		@	@

Tube No. 290 OD 25.400 mm Thk(Avg) 2.769 mm Length 6096. mm Pitch 31.750 mm Layout 90

Tube Type Plain Material CARBON STEEL

Shell ID 745.000 mm OD mm Shell Cover

Channel or Bonnet Channel Cover

Tubesheet-Stationary Tubesheet-Floating

Fl[illegible]g Head Cover Impingement Plate Circular plate

Baffles-Cross Type SINGLE-SEG. %Cut (Diam) 26.2 Spacing(c/c) 315.000 Inlet 870.174 mm

Baffles-Long Seal Type

Supports-Tube U-Bend Type

Bypass Seal Arrangement Tube-Tubesheet Joint

Expansion Joint Type

Rho-V2-Inlet Nozzle 379.97 kg/m-s2 Bundle Entrance 243.21 Bundle Exit 352.68 kg/m-s2

Gaskets-Shell Side Tube Side

-Floating Head

Code Requirements TEMA Class

Weight/Shell 6560.01 Filled with Water 9268.60 Bundle 3234.10 kg

Remarks: 1. Tube side design pressure is considered based on 10/13 rule as per design basis document.

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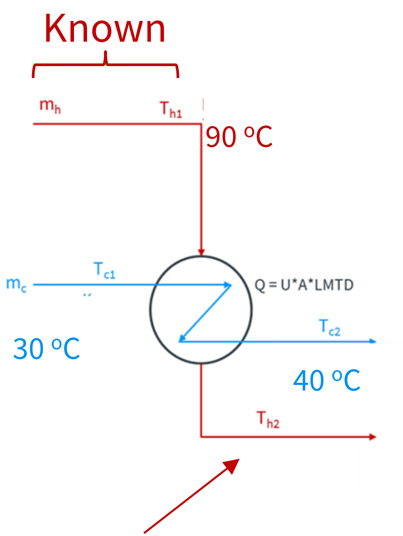
Heat Exchanger in Design – Sensible Cooling Utility

E.g. Stabilized oil Cooler, overhead condenser, compressor aftercooler, tempered water cooler etc

Process fluid (hot fluid) outlet temperature:

- Maximize cooling
  - E.g. Naphtha rundown cooler to API 650 storage tank vapour pressure constraint
  - Compressor power decreases with cooler suction
- Condenser as per process requirement / simulation
- Can be limited by hydrate / freezing point e.g. dehydration package inlet exchanger limited to ~21 deg C
- Can be as high as 90 deg C for very viscous fluid
- Setting temperature approach



- Preferably above 40 °C (5 deg C approach)
- Can not go below 30 °C
- Avoid below 40 °C – temperature pinch / severe cross if between 30 and 40 °C

Cooling water / sea water / tempered water / chilled water:

- Specify inlet / outlet temperatures as per design basis
- Keep flowrate floating
- Simulation / datasheet flowrate has no meaning without confirmation by network analysis
- Liberally size cooling water lines to users at elevation / condensers
- Avoid control valve for cooling water lines

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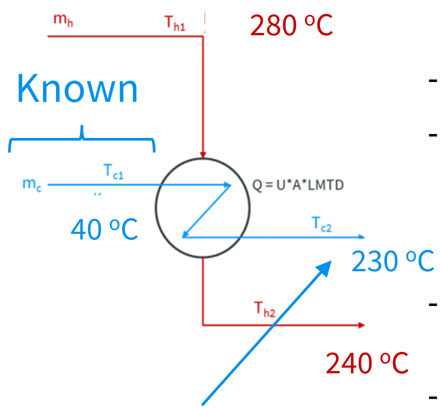
Heat Exchanger in Design – Sensible Heating Utility

E.g. Regeneration gas hot oil heater; Stabilizer reboiler, crude feed hot water heater

Process fluid (hot fluid) outlet temperature:

- For crude heaters, usually set by RVP requirement
- For reboilers, set by column simulation
- For regeneration gas heater, check 3A or 4A molecular sieve
- Do not preferably increase temperature above hot utility return temperature
- For reboilers, carry out runs with same temperature, same vapour fraction and same duty in thermal design software



- Preferably below 230 °C
- Can not go above 280 °C
- Avoid above 240 °C – temperature pinch / severe cross if between 240 and 280 °C

Hot oil / hot wate heater:

- Specify inlet / outlet temperatures as per design basis
- Keep flowrate floating
- Usually control valve present, so may be possible to adjust flowrate, subject to impact on overall heat duty
- Bypass almost always present to avoid thermal shock
- Process conditions first be decided and then hot utility temperatures set
- For vaporization of process fluid, avoid large DT between hot and cold fluids to avoid film boiling

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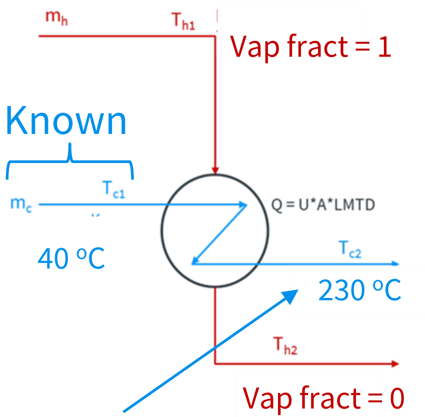
Heat Exchanger in Design – Latent Heating Utility

E.g. Reboiler using steam, regeneration gas heater using steam, feed heater, Condensers using refrigerant

Process fluid (hot fluid) outlet temperature:

- For reboilers, as per column simulation
- For regeneration gas heater, check 3A or 4A molecular sieve
- Do not preferably increase temperature above hot utility return temperature



- Preferably below 5 – 10 °C margin
- Can not go above steam temperature

Steam:

- Specify inlet pressure carefully → if control valve on fluid, pressure can not be same as header
- If significant drop in steam control valve, use desuperheater
- Specify inlet vapour fraction as 1 if desuperheated
- Specify outlet vapour fraction as 0
- Do not specify temperatures
- For vaporization of process fluid, avoid large DT between hot and cold fluids to avoid film boiling
- Pumping trap may be needed for steam if water vapour pressure at cold side inlet temperature below backpressure

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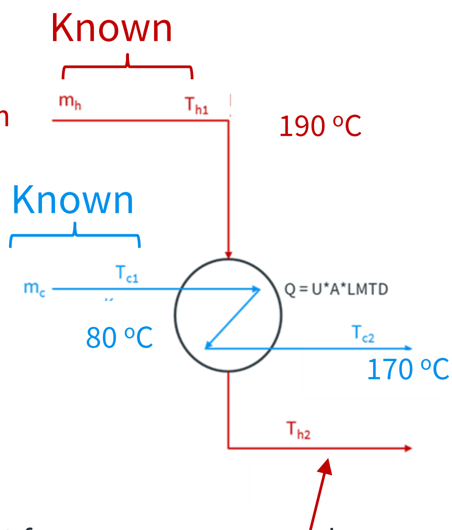
Heat Exchanger in Design – Feed / Effluent

E.g. Lean / Rich TEG, Lean / Rich amine, column feed / bottom, reactor feed / bottom, J-T dew-pointing unit, crude feed / separator effluent exchanger etc

Hot fluid:

- Usually idea is to extract optimum from hot fluid and reject rest to cold utility



- Either fix Tc2 or Th2 for process reason e.g. lean amine / lean TEG
- Other option is to maintain minimum approach ~5 – 10 deg C
- These situations usually have severe cross → either multiple STHEs in series / F-shell or PHE used

Cold fluid:

- Usually lean amine temperature limited to ~99 deg C
- Usually lean glycol temperature limited to ~170 deg C
- For refinery reactor feed temperature heating limited to ensure sufficient duty for heater turndown
- For column feed, usually target is to reach close to saturated temperature
- Dew-pointing unit, min approach ~3 deg C; J-T outlet pressure adjusted to meet export gas dew point
- Crude feed / effluent exchanger; min approach and downstream separator pressure adjust to meet RVP

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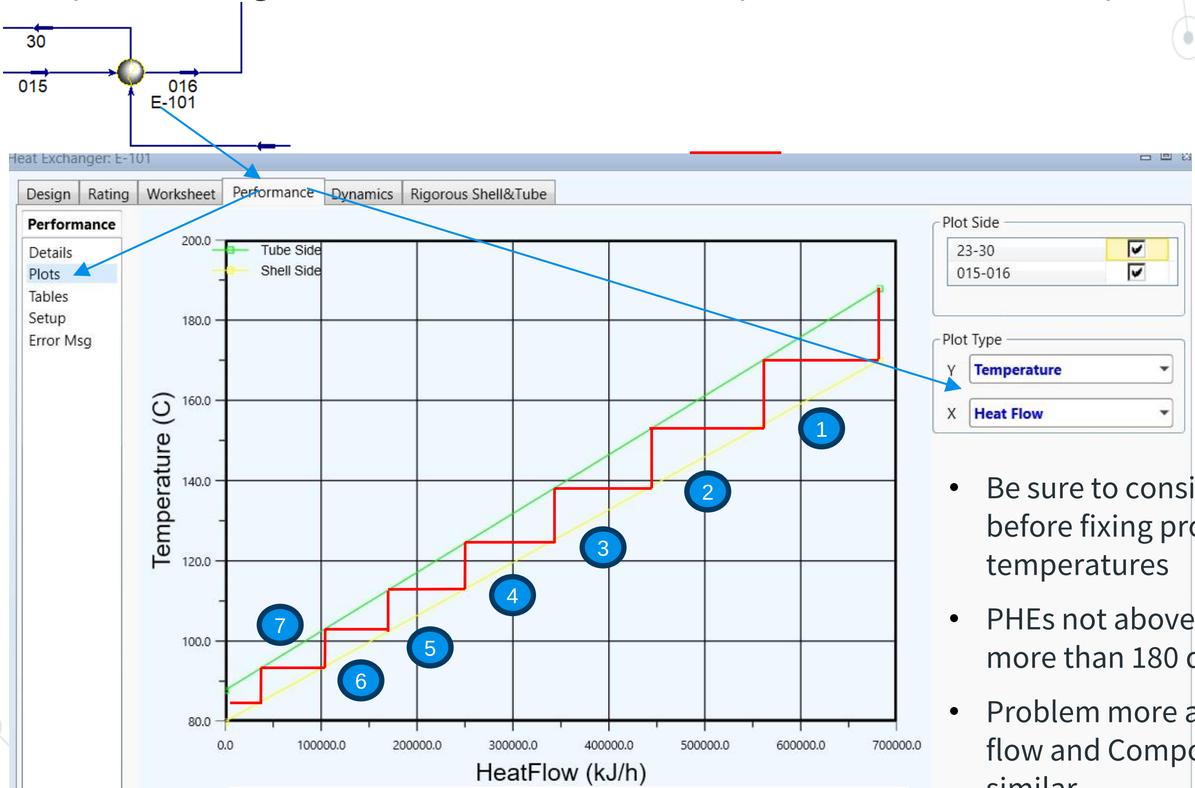
Estimating Shells in Series

Open Exchanger window → Performance → plots → heat flow / temperature



- Be sure to consider this before fixing process temperatures
- PHEs not above 300# or more than 180 deg C
- Problem more acute if mass flow and Composition similar

~8 E-Shells in series would be needed

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Deciding Pressure Drop: Design Stage

- Typical allowed pressure drops
  - Liquid Service = 0.5 – 1 bar (economics of OPEX of pumping and CAPEX of exchanger)
  - Gas service = 0.1 – 0.3 bar (compression is costly)
  - Two-phase = 0.2 – 0.5 bar
  - Kettle reboiler, thermosiphon reboilers and condensers usually have very low calculated pressure drop → hydraulics of loop critical
  - Multiple shells in series / viscous fluids may need larger pressure drop
- One design allocated and consumed 1 bar pressure drop for gas → very high gas velocity in shell and acoustic vibration

Pressure Drop: Fouled or Clean

- Allowed pressure drop is always for Fouled condition
- Softwares give pressure drop in clean condition
- Three ways to account for fouled pressure drop
  - Fouling thickness estimated from fouling resistance

    $\delta_t = 134 * R_{ft}$ (R_{ft}, tube side fouling factor in m2*hr*C/kcal)

    $\delta_s = 268 * R_{fs}$ (R_{fs}, shell side fouling factor in m2*hr*C/kcal)
  - Curve of fouling resistance versus fouling layer thickness for various common fluids → from memory, HTRI software help file had such graph
  - Hydraulic multiplier for clean pressure drop → approach used by Shell, Aramco and other companies