HEAT EXCHANGER WORLD CONFERENCE & EXPO AMERICAS

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ALFA LAVAL

Designing for Less Fouling

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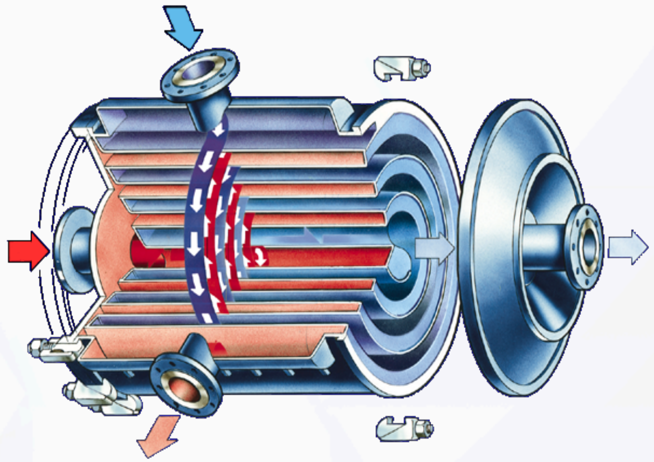


Figure of Alfa Laval Spiral Heat Exchanger

What is fouling?

- Unwanted matter inside the heat exchanger which can significantly impact thermal/ hydraulic performance. It can occur slowly or very quickly based on the designer's selection philosophy.

Fouling Resistance

- In more simplistic terms, fouling may be thought of as an additional wall with thickness and thermal conductivity.

$$\frac{1}{U_{fouled}} = \frac{1}{h_h} + \frac{x_w}{k_w} + \frac{1}{h_c} + R_f \qquad R_f = \frac{x_f}{k_f}$$

- We may further simplify fouling to a margin over the U_{clean} as below. The margin approach is utilized in Plate Heat Exchangers (PHEs) based on operational experience.

$$Margin = \frac{U_{clean} - U_{service}}{U_{service}} \bullet 100 \qquad \frac{1}{Uclean} = \frac{1}{h_h} + \frac{x_w}{k_w} + \frac{1}{h_c}$$

Standardized fouling resistances

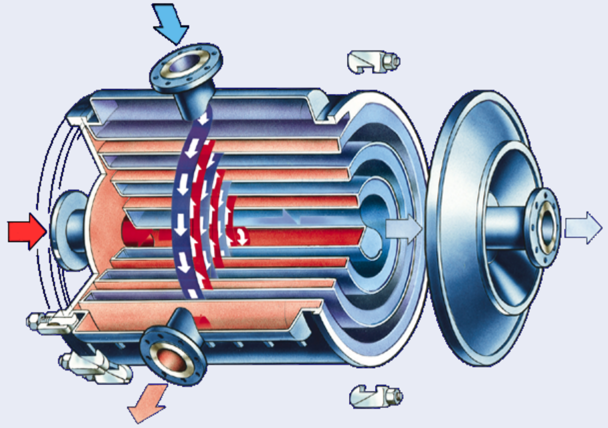
- TEMA values are a typical industry standard in the design of S&T Heat Exchangers.
- Many of the resistances are a function of velocity and temperature.
- LIMITATION: Utilizing these values on non-S&T Heat Exchangers such as Plate Heat Exchangers (PHEs) could result in exorbitant margins due to PHEs having a higher U-Value to pressure drop ratio.

$$Margin = \frac{U_{clean} - U_{service}}{U_{service}} \bullet 100$$

Margin	5%	10%	15%
$\mathbf{U_{service}}$ (W/m2*K)	476.1904762	909.0909	1304.348
$\mathbf{U_{clean}}$ (W/m2*K)	500	1000	1500
$\mathbf{R_f}$ (m2*K/W)	0.0001	0.0001	0.0001

Fouling Mechanisms Vary

- Debris (can come from the process itself, coking, corrosion or other particles)
- Biological growth (for example algae, sea shells in water)
- Scaling (from dissolved salts or similar at lower or elevated temperatures)
- Sedimentation (suspended fine particles)
- Chemical reaction (change in chemical structure due to temperature increase)
- Freezing (common in cryogenic applications)

	Performance Inhibitor	Design Measure	*Alfa Laval Spiral Heat Exchanger (top) , S&T with 1" OD tube diameter layout (bottom – HTRI software generated)*
Debris	Heat Exchanger may become plugged from debris being pulled into pump, process particles, corrosion or remnants from maintenance activities.	-Install a filter after pump and before heat exchanger, -Size flow path cross-sectional area larger than the largest single debris cross-sectional area (*Spiral Heat Exchangers are ideal for slurries & high fouling media*) -Port filters may be utilized in Gasketed Plate Heat Exchangers (GPHEs). -Utilize redundant strainers, -Utilize an appropriate strainer/filter metallurgy.	

Unit	Shell 1
TEMA type	AFU
Shell ID	60.0000 inch
Actual OTL	58.4425 inch
Height under inlet nozzle	2.8125 inch
Height under outlet nozzle	2.0625 inch
Tube type	Plain
Tube OD	1.0000 inch
Tube pitch	1.2500 inch
Tube layout angle	90 deg

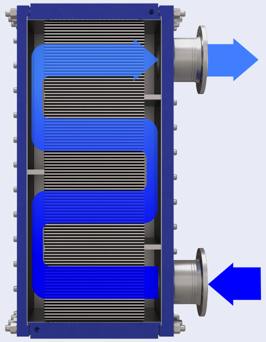
	Performance Inhibitor	Design Measure	
Biological Growth	Organism growth under ideal temperature and flow conditions.	-Preventive chlorination and chemical treatment, -Consider environmental regulations, -Utilize appropriate metallurgy with chemical treatment.	

	Performance Inhibitor	Design Measure	
Scaling	Temperature dependent solubility of salts where solubility decreases with temperature increase or decrease. This results in crystallization occurring in the piping and on the heat transfer surface.	-Keep bulk temperature and wall temperature below set limits for decreasing solubility with temperature rise, -Keep bulk temperature and wall temperature above set limits for increasing solubility with temperature rise. *-**Very difficult to design around. Choose largest flow path as velocity and U-Value permits. Common velocity for S&T CW is 3 ft/s.*	

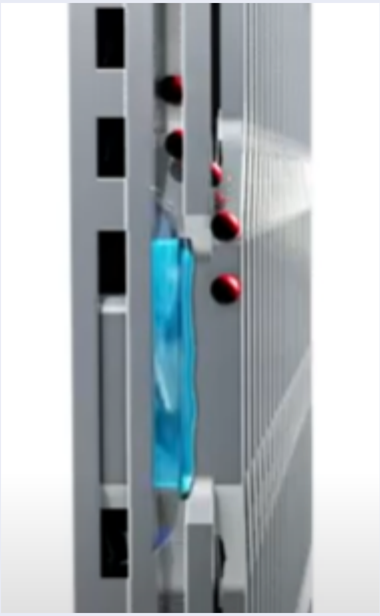
	Performance Inhibitor	Design Measure	*S&T multi-pass (top – HTRI software generated), single channel flow geometry of SHE (bottom right), Compabloc HX multi-pass (bottom left)*
Sedimentation	Fine particles suspended in media. Particle size is harder to separate and deposits on heat transfer surface.	-Design with minimum recommended shear stress and velocity. This can be achieved by: **Utilizing multi-pass arrangements or using smaller diameter tubes in S&T HXs for tube-side. **Utilizing inserts in S&T HXs for tube-side. **Adding baffles to induce velocity on shell-side OR eliminating segmental baffles to eliminate dead zones. **Utilizing Spiral HXs (*ideal for sedimentation due to single channel*). **Utilizing multi-pass arrangements in Compabloc HXs and GPHEs.	See TUBEPASS DETAILS and diagrams below

TUBEPASS DETAILS

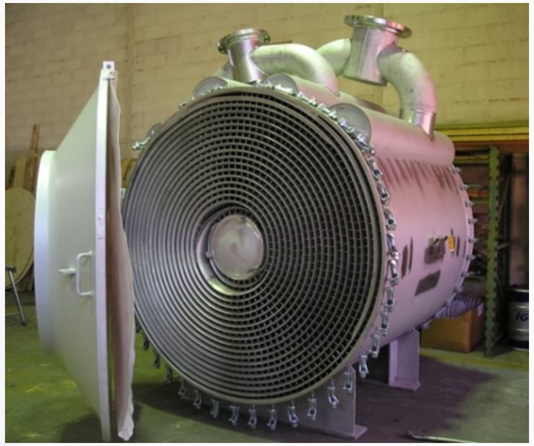
Pass	Rows	Tubes+ Tie Rods	Pass	Rows	Tubes+ Tie Rods
1	13	195	5	9	195
2	13	195	6	9	195
3	9	195	7	12	189
4	9	195	8	12	189



	Performance Inhibitor	Design Measure	
Chemical Reaction	Breakdown or polymerization of compounds due to high temperature.	-Have a set limit on maximum wall temperature. Changing from counter-current to co-current flow can help to reduce the wall temperature. -Reduce steam pressure in Steam Heaters. Operators sometimes increase the steam pressure for lost performance due to fouling however, this can exacerbate the fouling. -Consider a lower temperature heating medium.	

	Performance Inhibitor	Design Measure	*Alfa Laval PCHE 3DPlate™ diverting fluid around frozen fluid (left) , Model of Alfa Laval Printed Circuit Heat Exchanger – PCHE (right)*
Freezing	Common in cryogenic applications where water may be present resulting in ice formation.	-If possible, remove/knockout unwanted water from stream. -Utilize a **Diffusion Bonded Heat Exchanger** for high pressure applications where the fluids are clean, but the fouling mechanism is freezing.	 

Maintenance Considerations



- Cleanability (Are there accessible lanes/channels – square and rotated square layouts in S&Ts? Are there removeable covers? Is the bundle removeable in the case of S&T?)
- Accessibility to inspect fouled surfaces before and after cleaning.
- Downtime for cleaning operation (What is the production cost associated with extended downtime for cleaning? Is fouling *linear* or *asymptotic*?)
- Lifting capacity for cleaning operation (S&T bundles can be larger and heavier. PHEs may be considered in lieu of S&Ts if weight and footprint are limitations)
- Removeable S&T bundles require a footprint that is double the shell length to remove the bundle.

Cost Considerations

- Does the Heat Exchanger design selection fit within the overall budget? For example; Spiral Heat Exchangers are superior at handling most high fouling applications but are not always the lowest cost option.
- At times there may be alternative technologies suitable to the different severities of fouling.
- The designer must consider all aspects when making decisions. A lower capital cost Heat Exchanger may result in higher maintenance costs due to fouling.

Summary

- Fouling can be complex but with the right considerations, we can extend runtimes.
- Fouling margins based on experience can be more useful to optimize a design when there is no standard literature.
- It is important to understand the fouling mechanism/s upfront.
- Increasing shear stress does NOT always solve our fouling issue.

Thank you!

Questions/Comments?

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