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Implications Fouling for Differing Exchanger Technology

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Observations on Reaction Fouling

- Increases with increased temperature
- Decreases with increased wall shear stress
- Deposition on a deposit is easier than on a metal surface



Exchanger Technology

- Baffle designs: segmental, helical
- Use of tube inserts
- Compabloc
- Twisted tube bundles



Using Shell-Side for Crude



Placing Crude on shell-side

- Immediate wall temperature benefit: heat being transferred through surface area that is up to 30% greater than that on tube-side
- Benefit can be lost if the heat transfer coefficient is significantly lower than that for tube-side



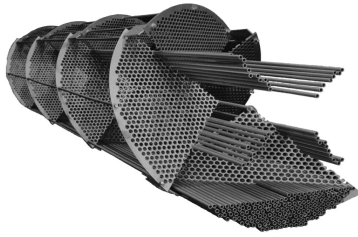
Baffle Geometry



- Baffle Cut should be as low as possible (certainly not above 30 %)
- Spacing should be such that cross-flow and window flow areas are approximately equal



Helical Baffles



Velocity is solely a function of baffle angle and shell diameter. Shear stresses and heat transfer coefficients with helical baffles are lower than with segmental baffles



Shell Diameter Effects

- Large diameter shells lead to lower shell-side velocities, lower coefficients and lower shear.
- Particularly the case when helical baffles are used..
- **NEED** to check effects using EXPRESS



Cleaning

- It is much harder to efficiently clean the shell-side of an exchanger
- Fouling induction periods for shells will be lower than with tubes



Using Tube Inserts

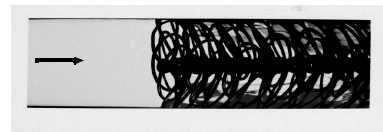


Types

- Wire Matrix Inserts
- Turbotal Inserts
- Spirelf Inserts
- Helical Coils



Wire Matrix (HiTRAN)



- Ideally operate at low Reynolds Numbers (typically 500 – 5000)
- Operation in turbulent region has high pressure drop penalty
- Wire loops generate high shear at the wall of the tube – it is this action that gibes the high enhancement



Refinery Application

Wire matrix inserts have been used to achieve inexpensive performance improvement of exchangers handling vacuum residues.

Residues switched to tube-side and inserts positioned in tubes.

Solids (which were giving rise to sedimentation fouling within shell) kept in suspension by high shear at wall. Higher shell-side h.t.c. obtained with crude than with residues.



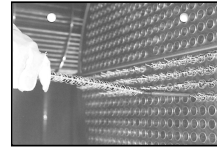
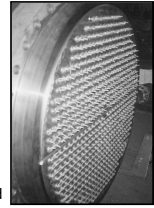
Crude pre-heater - Wintershall Refinery (BP) - Germany

Process had a long history of fouling
Many un-planned shutdowns

Vacuum residue tube side, Crude (preheat) shell-side

Helical Baffle/hiTRAN installed – one shell only needed
(without enhancement 2 larger shells would be required)

Installation 1996 – 9 year operation
Re-tubed in 2005, hiTRAN Elements removed and re-installed



Application with Crude

Problem

Mitigation is through improved heat transfer and increased wall shear.

Enhancement is due to the interaction between wall and loop.

If loop becomes "buried" in deposit, then heat transfer enhancement is suppressed, and wall shear effects are eliminated. The wires in the core present a significant form drag that does not supplement heat transfer improvement or act at the wall.

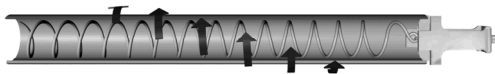


Conclusions: HiTRAN

- Evaluation of using HiTRAN in VR/Crude heat exchangers should be undertaken during design
- Caution should be applied when considering use of HiTRAN on crude side (only use in cases in which low fouling rates will be achieved)



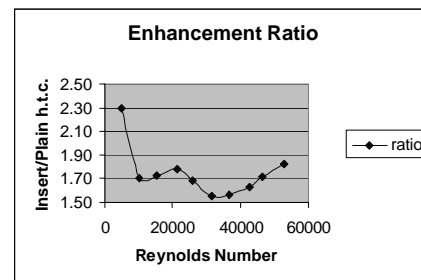
Turbotal Inserts



- Rotating Wire Coil
- Need to be orientated in the proper flow direction.
- Operate over limited velocity range. Require minimum velocity (0.7 m/s) in order to rotate, if velocity is too high they can break. Maximum velocity 1.6 m/s (safety margin applied).
- Replaced every two years.

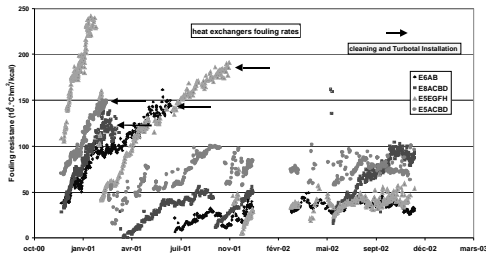


Enhanced Heat Transfer

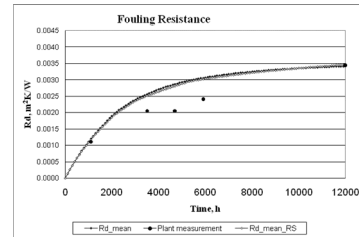




Significant Benefit



Asymptote

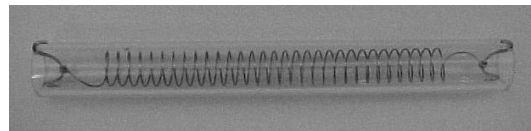


Conclusions: Turbotal

- Of significant benefit when used in exchangers that would otherwise exhibit high fouling rates and high fouling resistances
- Proper installation essential
- Limited life span has to be recognised and accepted



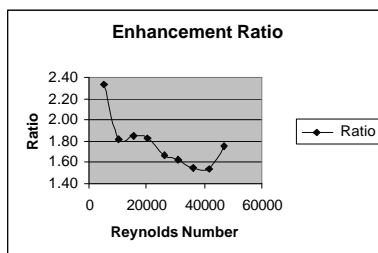
Spirelf



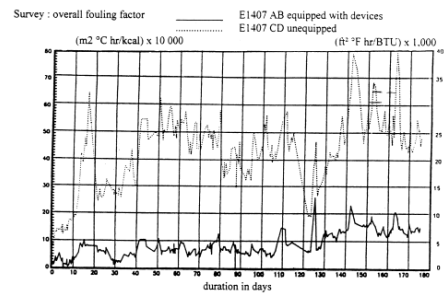
- Coil has circular and longitudinal motions
- Can be used at higher velocity than Turbotal
- Life-span 6 years



Spirelf



Spirelf



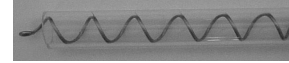


Conclusions: Spiirelf

- Of significant benefit when used in exchangers that would otherwise exhibit high fouling rates and high fouling resistances
- Models for prediction of fouling rates with these inserts have to be proven (data evaluation about to start)
- Do not know if these inserts also exhibit asymptotic behaviour.



Helical Coils



Petroval report a case in which these inserts have been used in a VDU unit that fouled heavily.

Results indicate significant improvement over plain tube performance.

No other applications known.

Efficiency will decline as fouling progresses.

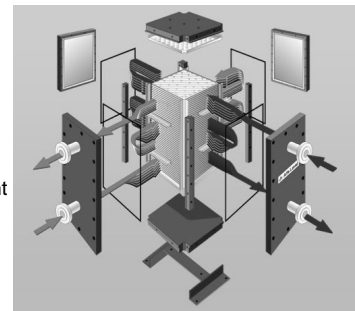


Compabloc



Compabloc Product description

- Plate heat exchanger
- Gasket-free
- Stainless or high-alloy plates
- Globally counter-current flow
- Complete accessibility



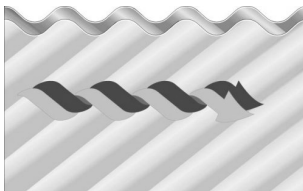
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Slide 28



Compabloc Plate turbulence

Corrugated plate design promotes:
High turbulence



- Efficient heat transfer – 3-5 times higher in liquid/liquid applications
- High Shear Stress

	CP	S&T
Flow velocity (m/s)	0.45	1.8
Shear stress (Pa)	ca 60	ca 15



Comparison with S&T Units

Factor	Shell-and-tube	Compabloc
Area/Volume	7 - 9	60 - 70
Operational Shear Stress	Max. 20 Pa	> 100 Pa
Typical H.T.C. W/sq.m.K	Tubeside 2000 Shellside 800	Both sides 4000
Mechanical needs	none	Tightness of bolts to be checked on start-up.
Process Needs	none	In line filters during commissioning of new plant – cannot handle large solids
Maintenance	Large units require specialised handling equipment, relatively long extraction & restoration times, longer cleaning times	Low weight units having maximum length of 1.5 m. Quicker extraction & restoration. Faster cleaning.

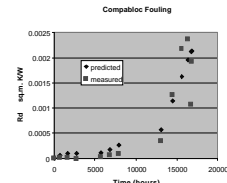


Important Considerations

- Heat transfer enhanced on hot side as well as tube-side
- Can lead to increased wall temperatures
- Use more passes on cold side than hot side to reduce wall temperature



Changed Operating Scenarios



- Place units in series rather than parallel in order to maximise shear stresses.



Cleaning

- Partial cleaning by mechanical means is possible
- Chemical cleaning usually employed
- Data on performance before/after cleaning will be available soon

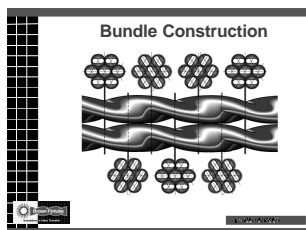


Conclusions: Compabloc

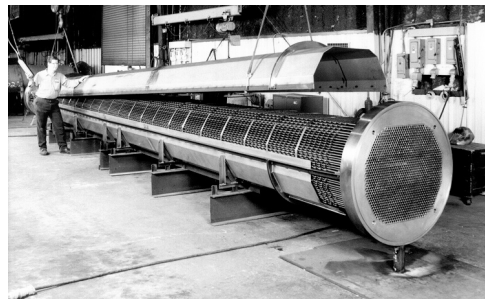
- Can be effectively applied throughout the pre-heat train (user experience generally good).
- Operational safe-guards have to be introduced.
- Modelling results are very encouraging.
- Pass arrangements should be manipulated in order lower wall temperature (not currently standard practice).
- Major maintenance advantages (in some cases uninstalled spares justifiable).
- Plant arrangements that maintain high shear rates should be used.



Twisted Tube Bundles



Longitudinal Flow on Shell-Side





Design & Performance

- Very rigid bundle structure allow closer tube pitches and therefore allow larger number of tubes to be fitted into a given shell diameter
- Longitudinal baffles can be installed on shell-side (necessary to achieve reasonable heat transfer coefficients in some applications)
- Shell-side heat transfer often lower than achieved in standard shell-and-tube exchangers
- Reasonably good access for cleaning of outside of tubes



Crude Oil Applications

- Possible retrofit technology in which crude is placed on shell-side
- Tube-side heat transfer high under clean conditions, but fouling at edges can change the flow field
- Cannot be cleaned mechanically on tube-side



Conclusions: Twisted Tube Bundles

- Do not recommend placing crude on tube-side in units positioned at the hot end of the train or prior to the de-salter
- Can be effectively used with crude on shell-side provided good h.t.c. obtained
- Can be effective revamp technology