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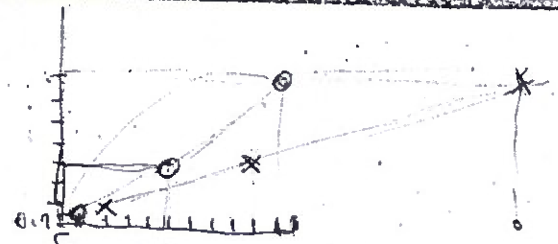

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Increase flow to cut fouling

*Ralph A. Crozier, Jr.**

☐ Increased fluid velocities will reduce or eliminate fouling if the shear stress caused by flow exceeds the bond strength of the fouling deposit. Unfortunately, there are no predictive models available, so one must determine the relationship between flow and fouling by experimentation. In the case described here, raising the velocity in a heat exchanger from 5 to 15 ft/s increased the time between cleanings from 2 to 24 mo. The effective shear stress observed in this heat exchanger was then used to set velocities in similar units.

What causes fouling?

Fouling is the deposition of thermally insulating material onto a heat-transfer surface. In water systems, crystalline scale is caused by precipitation of materials that exhibit inverse solubility; that is, whose solubility decreases with increasing temperature. Silt and corrosion products on a heat-transfer surface act as seeding sites for crystal growth, thus the actual scale is a nonhomogeneous agglomerate of these various materials. In systems that carry organic fluid, coking, polymerization and degradation are the principal causes of deposits.

The rate at which scale thickness increases depends on many factors because scale growth involves simultaneous deposition and removal. The deposition rate depends on the fouling mechanism, surface temperature and fluid velocity, while the removal rate depends on the physical characteristics of the deposited material. Research has shown that these rates are different for each type of fouling.

After the initial deposit is formed, scale thickness increases steadily until it reaches a maximum, or asymptotic, value. As scale grows, the flow area shrinks and therefore fluid velocity increases. At the asymptotic thickness, the shear stress exerted by the flowing fluid just equals the bond strength of the fouling layer.

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The effect of increased shear stress depends on the type of fouling material. In general, one of three things occurs: the bond between the tubewall and the deposit is broken; the crystal-lattice bond in the deposit is broken, causing a layer to break off; or the deposit increases in thickness until the tube is blocked if the shear stress is too low.

How does fouling affect performance? A heat exchanger in which tubewall-deposit bonds periodically break will exhibit cyclic performance; that is, the exchanger will cycle between clean and scaled tube conditions. If the bond that breaks is in the crystal lattice, then the scale will reach and maintain an asymptotic thickness, and performance will decline progressively to a minimum.

Two years between cleanings after tripling velocity

Velocity	Tube ΔP	Motor power	Shear stress†	Cleaning frequency
5.8 ft/s	4.7 psi	111 bhp	0.12 lb/ft^2	2 mo. 46
9.7	13.0	246	0.39	9 23
15.0	32.2	416	0.79	24 14

†Shear stress at the wall (T_W) is: $T_W = \frac{\rho v^2 f}{8 g_c}$

where ρ is density (lb/ft^3), v is velocity (ft/s), f is the Darcy friction factor and g_c is the gravitational constant (32.17 ft/s^2).

Example: A fouled reboiler

In a closed-loop, pumped system, fluid velocities can be manipulated to test the relationship between velocity and fouling. We made such an analysis on a forced-circulation reboiler (no vapor generation inside) that was experiencing severe fouling—this organic liquid was degrading and polymerizing. At the design tubeside velocity of 5.8 ft/s, 1,274 tubes had to be cleaned every two months. When the velocity was increased to 9.7 ft/s and then 15 ft/s, cleaning frequency was cut to 9 and then 24 mo. The table shows these results.

Note that the table lists shear stress as well as velocity. This is because wall shear stress, and not velocity or Reynolds number, is the most relevant parameter in describing fouling behavior. (For more on this distinction, and on fouling in general, see the reference.[1])

For the reboiler, raising the velocity increased the shear stress from 0.12 to 0.39 and finally to 0.79 lb/ft^2. Based on this plant data, one can infer that for this particular process material the bond strength of the deposit was between 0.39 and 0.79 lb/ft^2. We used the 0.79 lb/ft^2 value to calculate the required velocity for similar reboilers, and experienced minimized fouling.

What did it cost? From the table, one can see that increasing the velocity required a fourfold horsepower increase. In any situation, an economic analysis will tell whether the increased operating cost and corrosion or erosion damage (caused by higher fluid velocity) is justified by reduced maintenance cost and product loss.

• *Mark Lipowicz, Editor*

[1]Suitor, J. W., Marner, W. J., and Ritter, R. B., The History and Status of Research in Fouling of Heat Exchangers in Cooling Water Service, *Can. J. Chem. Eng.*, Vol. 55, Aug. 1977, pp. 374–380.