The Effects of Scale on Heat Transfer and Energy

Optimum efficiency and longevity of air conditioning chillers require an effective water treatment program. Deposit build-up, scale formation, corrosion and microbial growths must be controlled to obtain the equipment's performance as rated by the manufacturer. Manufacturers base their performance data on the Air Conditioning and Refrigeration Institute (ARI) standards, which use a water side fouling factor of 0.0005 for both the condenser and chiller. The following (ARI) tables are used to illustrate the effect of CaCO3 and CaSO4 scales on overall heat transfer, and its related effect on power increase required.

Table 1 - Heat transfer surface required to offset fouling

Fouling thermal resistance, (lg)(sq ft)(deg F) per BTU	Overall heat transfer coefficient(1), BTU per sq ft per deg F	Thickness of scale(2) (approximately), Inches	Increase of required heat transfer area(3), approximate percent
Clean Tubes	850	0.000	0
0.005	595	0.006	45
0.001	460	0.012	85
0.002	315	0.024	170
0.003	240	0.036	250

1. The overall heat transfer coefficient, U, selected for this illustration is typical of a water cooled refrigerant condenser. However, because it is possible to have different overall heat transfer coefficients depending of the systems, the effect on the overall heat transfer by the scale will vary.
2. Assume a mean value for the thermal conductivity of the scale of 1.0 BTU per sq ft per deg F.
3. Sq ft of inside surface of tube in heat exchanger.

Table 2 - Effect of $CaCO_3$ scale (of varying thickness) on overall heat transfer coefficient

Scale Thickness, Inches	Overall heat transfer coefficient, BTU per sq ft per deg F	Percent loss in BTU per sq ft per deg F
0.000	92.77	0
0.012	73.68	20.58
0.024	61012	34.12
0.036	52.20	43.73
0.048	45.60	55.85
0.060	40.46	56.39
0.0625 (1/16 in.)	39.52	57.40

Table 3 - Effect of $CaSO_4$ scale (of verying thickness) on overall heat transfer coefficient

Overall heat transfer scale thickness, inches	Coefficient, BTU per sq ft per deg F	Percent loss in BTU per sq ft per deg F
0.000	92.77	0
0.012	63.10	31.98
0.024	47.81	48.46
0.036	38.49	58.51
0.048	32.20	62.00
0.060	27.69	70.00
0.0625 (1/16 in.)	26.89	71.00

Table 4 - Relative increase in power for condenser and chiller units calculated according to fouling factors

Fouling Factor	Condenser Factor	Chiller Factor
0.0005	1.00	1.00
0.001	1.05	1.04
0.002	1.14	1.09
0.003	1.22	1.17
0.004	1.30	1.24