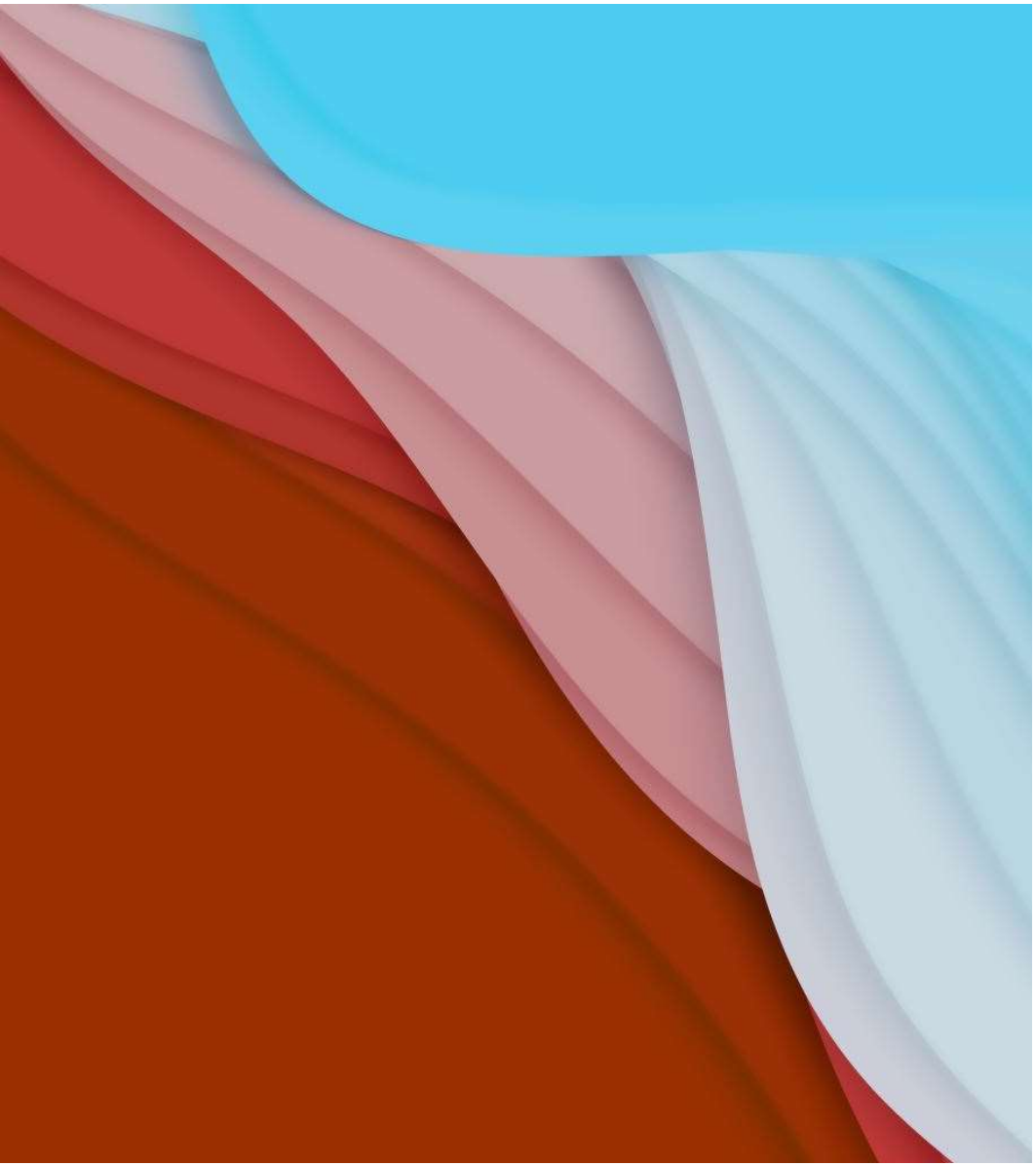

CEN4415
PROCESS DESIGN I

Heat Exchange Area:

Fundamental Heat Exchanger Design Equation:

$$Q=UA\Delta T \Longrightarrow dQ = U\Delta T dA \Rightarrow dA = \frac{dQ}{U\Delta T}$$

- **dA**: surface area where the heat dQ will be transferred through
- **U**: Overall heat transfer coefficient
- **ΔT**: difference between the bulk temperatures of two fluids.

$$\frac{1}{U_0} = \frac{1}{h_0} + \frac{1}{h_{0d}} + \frac{d_0 \ln\left(d_0 / d_i\right)}{2k_w} + \frac{d_0}{d_i}\frac{1}{h_{id}} + \frac{d_0}{d_i}\frac{1}{h_i}$$

U_o : the overall heat transfer coefficient relative to the pipe outer surface area, W/m^2 °C

h_o, h_i : film coefficient of the fluid outside and inside the pipe, W/ m^2 °C

h_{od}, h_{id} : dirt (fouling) factors on the outer and inner surface of the pipe, W/ m^2 °C

k_w : thermal conductivity of the pipe, W/ m^2 °C

d_o, d_i : outer and inner diameters of the pipe, m

Heat transfer area

$$A_0 = \int_0^Q \frac{dQ}{U_0 \Delta T}$$

$$A_0 = \frac{Q_T}{U_0 \Delta T_m}$$

ΔT_m : mean temperature difference

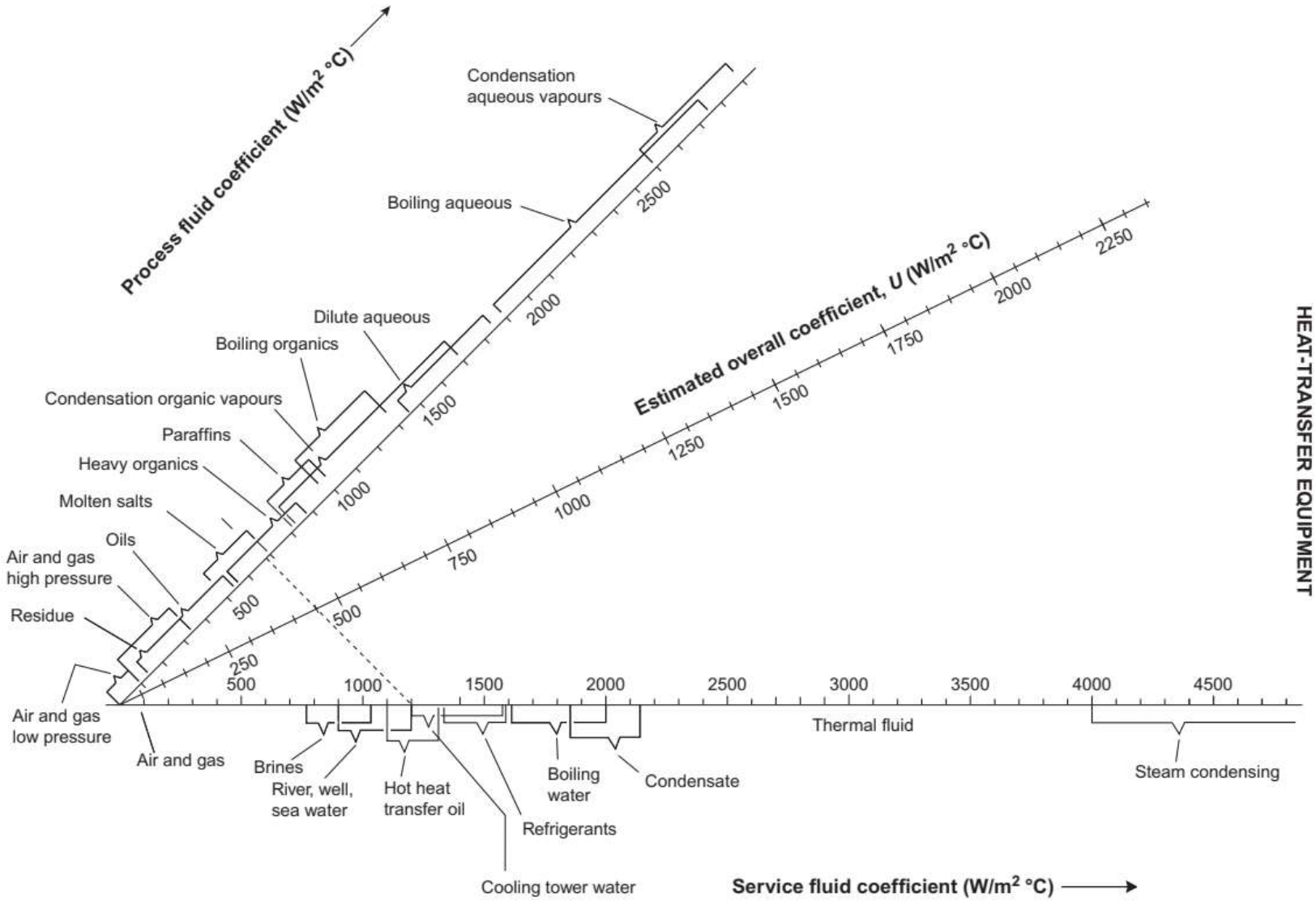

Figure 1. Nomograph, Overall coefficients (join process side duty to service side and read *U* from centre scale)

The effect of fouling is included in the design calculations by substituting it into the overall heat transfer coefficient in the U_0 equation.

$$\frac{1}{U_0} = \frac{1}{h_0} + \frac{1}{h_{0d}} + \frac{d_0 \ln\left(d_0 / d_i\right)}{2k_w} + \frac{d_0}{d_i}\frac{1}{h_{id}} + \frac{d_0}{d_i}\frac{1}{h_i}$$

Typical fouling coefficient values

Fluid	Coefficient (W/m^2 °C)
River water	3000–12,000
Sea water	1000–3000
Cooling water (towers)	3000–6000
Towns water (soft)	3000–5000
Towns water (hard)	1000–2000
Steam condensate	1500–5000
Steam (oil free)	4000–10,000
Steam (oil traces)	2000–5000
Refrigerated brine	3000–5000
Air and industrial gases	5000–10,000
Flue gases	2000–5000
Organic vapours	5000
Organic liquids	5000
Light hydrocarbons	5000
Heavy hydrocarbons	2000
Boiling organics	2500
Condensing organics	5000
Heat transfer fluids	5000
Aqueous salt solutions	3000–5000

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2. Turton R., Bailie R.C., Whitin W.C., Shaeiwitz J.A. 1998, Analysis, Synthesis and Design of Chemical Processes, Prentice Hall, New Jersey.