Overall Heat Transfer Coefficient (U)

A heat exchanger typically involves two flowing fluids separated by a solid wall. Heat is first transferred from the hot fluid to the wall by ***convection***, through the wall by ***conduction*,** and from the wall to the cold fluid again by ***convection*.** Any ***radiation effects*** are usually ***included in the convection heat transfer coefficients***.

The ***effect of conduction, convection and radiation heat transfer within the heat exchangers can be collected in one overall heat transfer coefficient*** (**U**).

In the analysis of heat exchangers, it is convenient to combine all the ***thermal resistances*** in the path of heat flow from the hot fluid to the cold one into a ***single resistance*** R, and to express the rate of heat transfer between the two fluids as,

$$\dot{Q} = \frac{\Delta T}{R} = UA\Delta T = U_i A_i \Delta T = U_o A_o \Delta T \, , \qquad R = \frac{1}{UA} \quad \text{or:} \quad UA = \frac{1}{R}$$

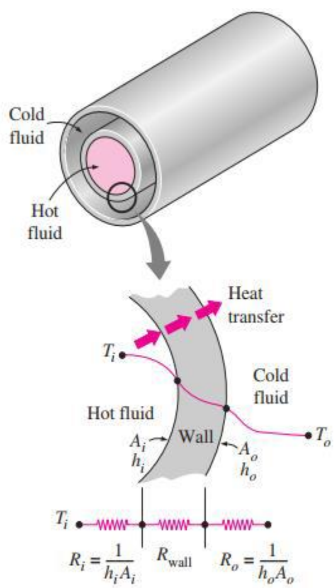
Where U is the **overall heat transfer coefficient,** whose unit is W/m$_2$.°C, which is identical to the unit of the ordinary convection coefficient ***h***. Canceling · T, get,

$$\frac{1}{UA_s} = \frac{1}{U_i A_i} = \frac{1}{U_o A_o} = R = \frac{1}{h_i A_i} + R_{\text{wall}} + \frac{1}{h_o A_o}$$

When the ***wall thickness of the tube is small and the thermal conductivity of the tube material is high***, as is usually the case, the thermal resistance of the tube is negligible ($R_{\text{wall}} = 0$) and the inner and outer surfaces of the tube are almost identical (i o s $A_o \approx A_i \approx A_s$).

Then the overall heat transfer coefficient simplifies to, $\frac{1}{U} \approx \frac{1}{h_i} + \frac{1}{h_o}$

Where $U \approx U_i \approx U_o$. The individual convection heat transfer coefficients inside and outside the tube, h_i and h_o, are determined using the convection relations.



Representative values of the overall heat transfer coefficients in heat exchangers:

Type of heat exchanger	U, W/m$^2 \cdot$ °C*
Water-to-water	850–1700
Water-to-oil	100–350
Water-to-gasoline or kerosene	300–1000
Feedwater heaters	1000–8500
Steam-to-light fuel oil	200–400
Steam-to-heavy fuel oil	50–200
Steam condenser	1000–6000
Freon condenser (water cooled)	300–1000
Ammonia condenser (water cooled)	800–1400
Alcohol condensers (water cooled)	250–700
Gas-to-gas	10–40
Water-to-air in finned tubes (water in tubes)	30–60†
	400–850†
Steam-to-air in finned tubes (steam in tubes)	30–300†
	400–4000‡

Example 9.1

Determine the overall heat transfer coefficient U_o based on the outer surface of a D_i=2.5cm, D_o=3.2cm, steel pipe [k=50W/m.°C] for the following conditions: The inside and outside heat transfer coefficient are, respectively, h_i=1000W/m².°C. and h_o=2000W/m².°C.

Solution; The overall heat transfer based on the outer surface U_o is to be determined, inside heat transfer coefficient h_i=1000W/m².°C, and the outside heat transfer coefficient h_o=2000W/m².°C. and D_i=2.5cm, D_o=3.2cm and k=50W/m.°C.

Property: thermal conductivity and heat transfer coefficients are constant

Analysis: To determine the overall heat transfer coefficient based on the outer surface we can use the following equation.

$$U_o = \frac{1}{\frac{r_o}{h_i r_i} + \frac{r_o}{k}\ln\frac{r_o}{r_i} + \frac{1}{h_o}} = \frac{1}{\frac{3.2}{1000 \times 2.5} + \frac{0.032}{50}\ln\frac{3.2}{2.5} + \frac{1}{2000}} = 516 W/m^2.^oC$$

Sameer.Saad.Raheem@uomus.edu.iq