Q.1 Hot oil enters into a counter flow heat exchanger at 150^0C and leaves at 40 ^0C. The mass flow rate of oil is 4500 kg/hr and its specific heat is 2 kJ/kg k . The oil is cooled by water which enters the heat exchanger at 20^0C. The overall heat transfer coefficient is 1400 W/m^2K. The exit temperature is not to exceed 80^0C Using effectiveness-NTU method find (1) mass flow rate of water (2) effectiveness of heat exchanger (3) surface area required (May-2014)

given Data

hot fluid

$T_{h_1} = 150°C$

$T_{h_2} = 40°C$

$m_h = \frac{4500}{3600} \frac{kg}{sec}$

$C_h = 2$ KJ/kgK

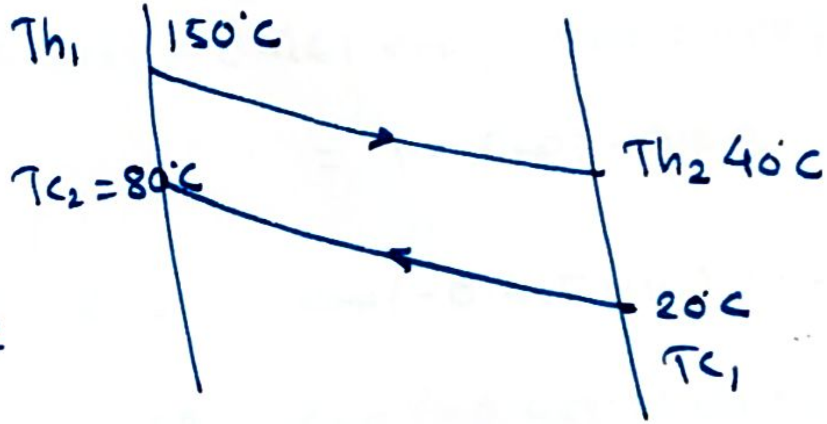
$U = 1400$ W/m^2K

cold fluid

$T_{c_1} = 20°C$

$T_{c_2} = 80°C$

$C_c = 4.186$ KJ/kgK



$$\phi = m_h C_h (T_{h_1} - T_{h_2})$$
$$= m_c C_c (T_{c_2} - T_{c_1})$$

$$\frac{4500}{3600} \times 2 \times (150 - 40) = m_c \times 4.186 \times (80 - 20)$$

$m_c = 1.0949$ kg/sec $= 3941.7$ kg/hr.

$$\varepsilon = \frac{C_h (T_{h1} - T_{h2})}{C_{min} (T_{h1} - T_{c1})}$$

$$C_h = \frac{4500}{3600} \times 2 = 2.5 \text{ kW/K}$$

$$C_c = 4.58 \text{ kW/K}$$

$$C_h < C_c$$

$$C_h = C_{min} \qquad C_{max} = C_c$$

$$R = \frac{C_{min}}{C_{max}} = \frac{2.5}{4.58} = 0.545$$

$$\varepsilon = \frac{C_h (T_{h1} - T_{h2})}{C_h (T_{h1} - T_{c1})}$$

$$= \frac{150 - 40}{150 - 20}$$

$$= 0.8461$$

$$\varepsilon = 84.61\%$$

$$\varepsilon_{counterflow} = \frac{1 - \exp(-NTU(1-R))}{1 - R\exp(-NTU(1-R))}$$

$$0.8461 = \frac{1 - \exp(-NTU(1-0.545)}{1 - 0.545\exp(-NTU(1-0.545}$$

$$0.8461 - 0.461\exp(-NTU \times 0.455)$$

$$= 1 - \exp(-0.455\,NTU)$$

$$1 - 0.8461 = \exp(-0.455\,NTU)(1 - 0.461)$$

$$0.1538 = \exp(-0.455\,NTU) \times 0.539$$

$$\exp(-0.455\,NTU) = 0.285$$

$$NTU = 2.7568$$

$$NTU = \frac{UA}{C_{min}}$$

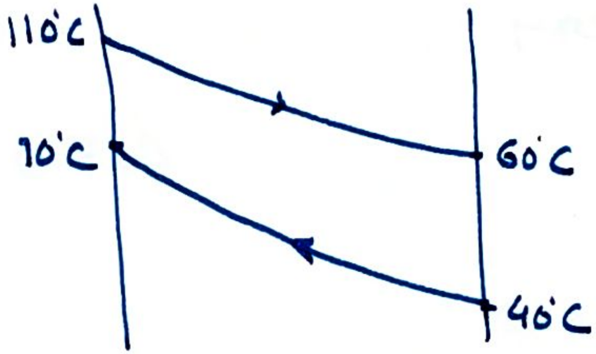
$$2.7568 = \frac{1400 \times A}{4.58} \qquad \boxed{A = 4.923\ m^2}$$

Q.2 Water (Cp=4.187 kJ/kg K) is heated at the rate of 1.4 kg/s from 40 °C to 70 °C by an oil (Cp=1.9 kJ/kg K) entering at 110 °C and leaving at 60°C in a counter flow heat exchanger. If Uo=350 W/m2K, calculate the surface area required. Using the same entering fluid temperature and the same oil flow rate, Calculate the exit temperature of oil and water and the rate of heat transfer, when the water flow rate is halved.

given Data

hot fluid	cold fluid
$T_{h1} = 110°C$	$T_{c1} = 40°C$
$T_{h2} = 60°C$	$T_{c2} = 70°C$
$C_{ph} = 1.9$	$C_{pc} = 4.187$
$m_h = ?$	$m_c = 1.4\ kg/s$

$U = 350\ W/m^2K$



$\phi = m_c C_{pc} (T_{c2} - T_{c1})$

$\phi = 1.4 \times 4.187 \times (70 - 40)$

$= 176.4\ kW$

$\phi = m_h C_{ph} (T_{h1} - T_{h2})$

$176.4 = m_h \times 1.9 \times (110 - 60)$

$m_h = 1.764\ kg/sec$

$\theta_1 = T_{h1} - T_{c2}$

$= 110 - 70$

$= 40$

$\theta_2 = T_{h2} - T_{c1}$

$= 60 - 40$

$= 20$

$\theta_m = \frac{\theta_1 - \theta_2}{\ln \theta_1/\theta_2} = \frac{40 - 20}{\ln 40/20} = 28.85$

$\phi = U A \theta_m$

~~$A = \frac{176.4}{3}$~~

$A = \frac{\phi}{U \theta_m} = \frac{176.4}{350 \times 28.85}$

$\boxed{A = 17.46\ m^2}$

Case – II

$$m_c = \frac{m_c}{2} = \frac{1.4}{2} = 0.7$$

$$m_h = 1.764$$

$$C_h = 0.7 \times 4.187 = 2.93$$

$$C_c = 1.76 \times 1.9 = 3.52$$

$$C_c = C_{max} \qquad C_h = C_{min}$$

$$R = \frac{C_{min}}{C_{max}} = \frac{2.93}{3.52} = 0.833$$

$$\varepsilon = \frac{C_h (T_{h1} - T_{h2})}{C_{min} (T_{h1} - T_{c1})}$$

$$= \frac{110 - 60}{110 - 40}$$

$$= 0.714$$

$$\varepsilon = 71\%$$

$$\varepsilon_{counterflow} = \frac{1 - \exp(-NTU(1-R))}{1 - R\exp(-NTU(1-R))}$$

$$0.714 = \frac{1 - \exp(-NTU(1 - 0.714))}{1 - 0.714 \exp(-NTU(1 - 0.714))}$$

$$NTU = 2.08$$

$$NTU = \frac{UA}{C_{min}} = \frac{350 \times 17.46}{2.93 \times 10^3}$$

$$= 2.08$$

$$\varepsilon = \frac{C_c (T_{c2} - T_{c1})}{C_{min} (T_{h1} - T_{c1})}$$

$$0.71 = \frac{3.52 (T_{c2} - 40)}{2.93 (110 - 40)}$$

$$\boxed{T_{c2} = 89.91^\circ C}$$