EFFECTIVENESS – NTU METHOD

Known: inlet fluid temperatures, fluid mass flowrates, type and size of the heat exchanger

Predict outlet temperature of hot and cold stream in a specified HE

Task is to determine

- Heat transfer performance of a specified heat exchanger
- If a heat exchanger available in storage will do the job

To solve this type of problem by LMTD approach would be tedious because of numerous iterations required.

Kays and London – Effectiveness NTU approach to avoid iterations (1955)

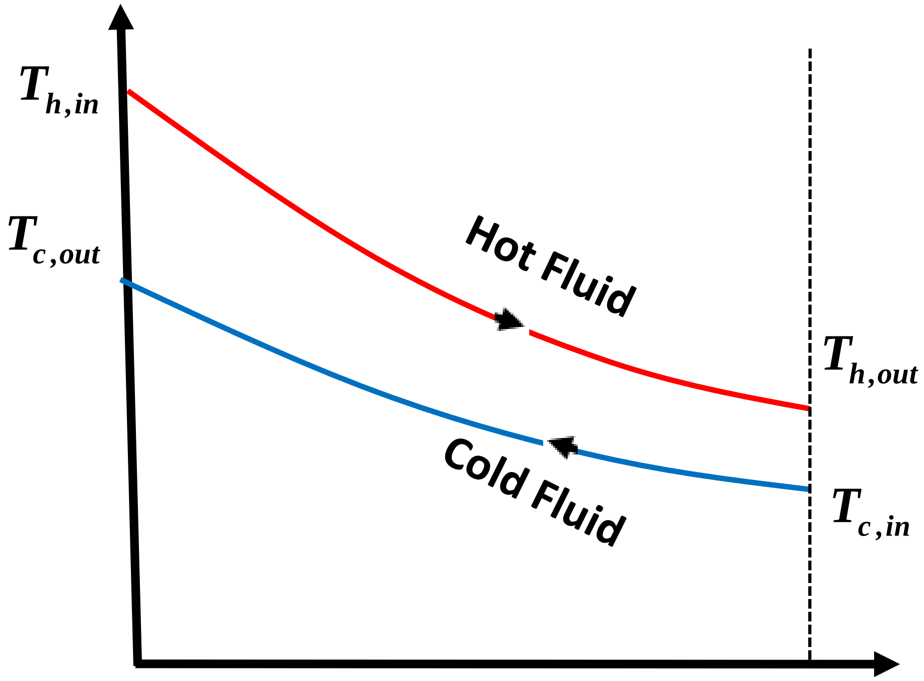
EFFECTIVENESS

$$\epsilon = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{\text{Actual heat transfer rate}}{\text{Maximum possible heat transfer rate}}$$

EFFECTIVENESS – NTU METHOD

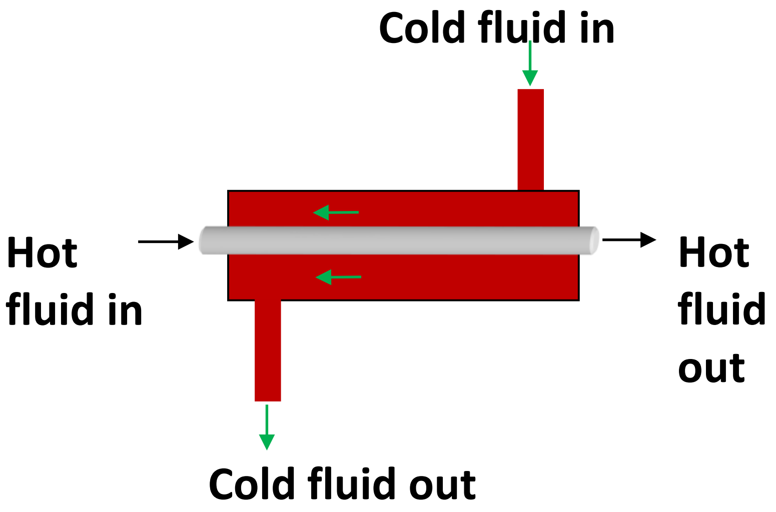
$$\epsilon = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{\text{Actual heat transfer rate}}{\text{Maximum possible heat transfer rate}}$$

$$\dot{Q} = C_c(T_{c,o} - T_{c,i}) = C_h(T_{h,i} - T_{h,o})$$



Maximum possible heat transfer

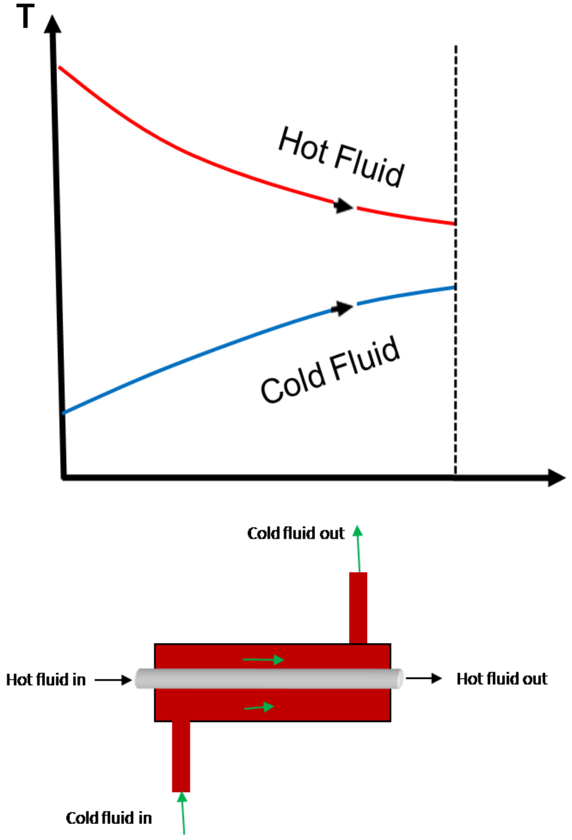
$$\Delta T_{max} = T_{h,i} - T_{c,i}$$

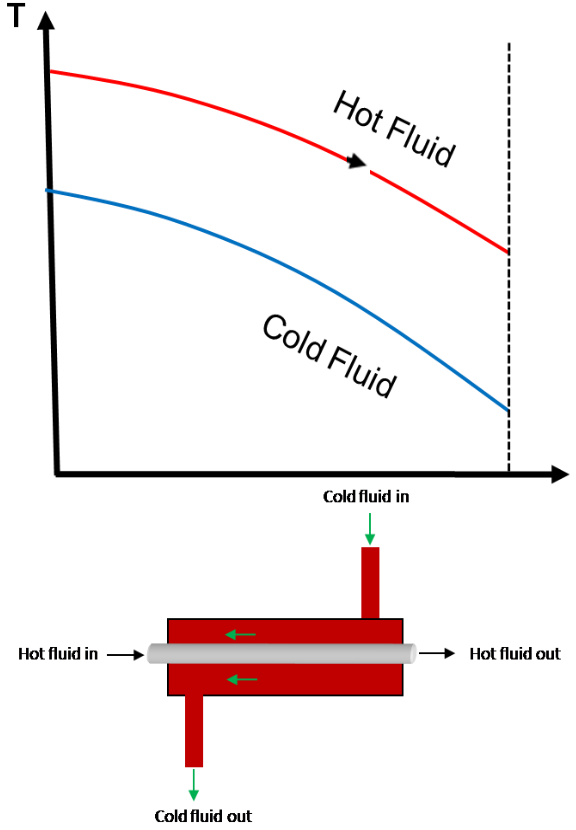


Heat transfer will reach its max value when

- Cold fluid is heated to inlet temperature of hot fluid
- Hot fluid is cooled to inlet temperature of cold fluid

Actual heat transfer rate





$$\dot{Q} = C_h\left(T_{c,o} - T_{c,i}\right) = C_c\left(T_{h,i} - T_{h,o}\right)$$

$$\dot{m}_h C_{ph} = C_h$$
$$\dot{m}_c C_{pc} = C_c$$

$$\Delta T_{max} = T_{h,i} - T_{c,i}$$

$$\therefore \dot{Q}_{max} = C_{min}\left(T_{h,i} - T_{c,i}\right)$$

Maximum heat transfer takes place when

- **the cold fluid is heated to the inlet temperature of the hot fluid**
- **the hot fluid is cooled to the inlet temperature of the cold fluid**

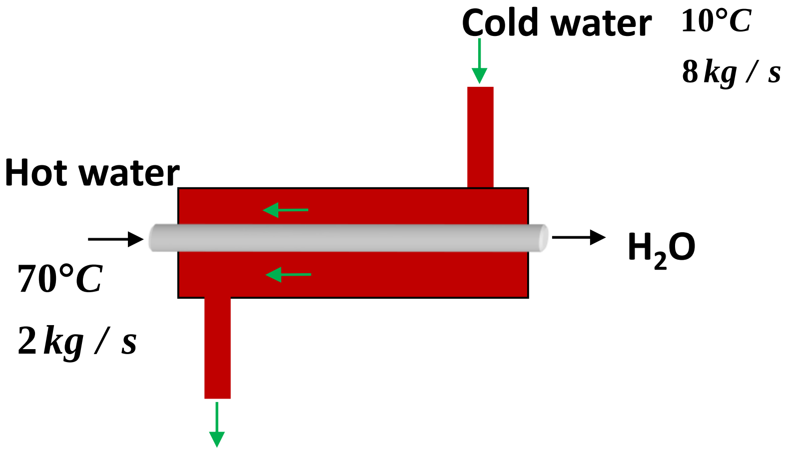
These two limiting conditions will not be reached simultaneously unless C_c=C_h

When $C_c \neq C_h$, the fluid with the smaller heat capacity would experience maximum temperature and the heat transfer would come to a halt

Hence, it will be first to experience the maximum temperature, at which point the heat transfer will come to a halt.

- These two limiting conditions will not be reached simultaneously unless $C_c = C_h$.
- When $C_c \neq C_h$; FLUID WITH SMALLER heat capacity will experience large temperature range.
- Hence, it will be first to experience the maximum temperature, at which point the heat transfer will come to a halt.

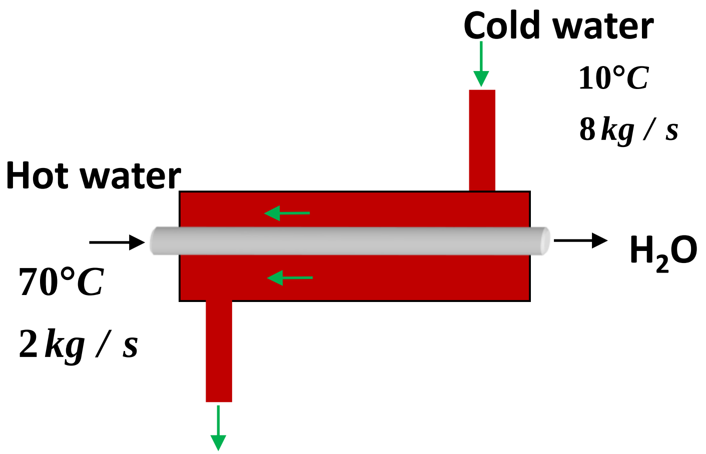
$$\therefore \dot{Q}_{max} = C_{min}(T_{h,i} - T_{c,i})$$

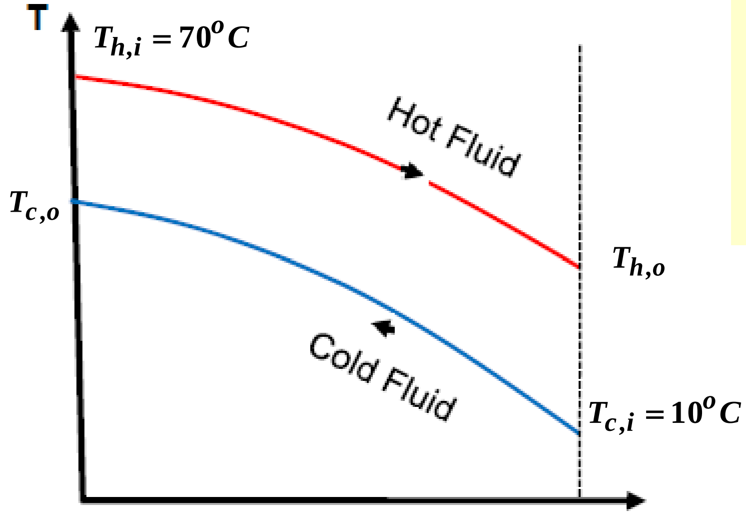


$$C_p = 4.18 \; \frac{kJ}{Kg\;°C}$$

$$C_h = C_p \dot{m}_h = 4.18 \times 2 = 8.36$$

$$C_c = C_p \dot{m}_c = 4.18 \times 8 = 33.44$$





$$C_h = C_p \dot{m}_h = 4.18 \times 2 = 8.36 \frac{kW}{degC}$$

$$C_p = 4.18 \frac{kJ}{kg\ °C}$$

$$C_c = C_p \dot{m}_c = 4.18 \times 8 = 33.44 \frac{kW}{degC}$$

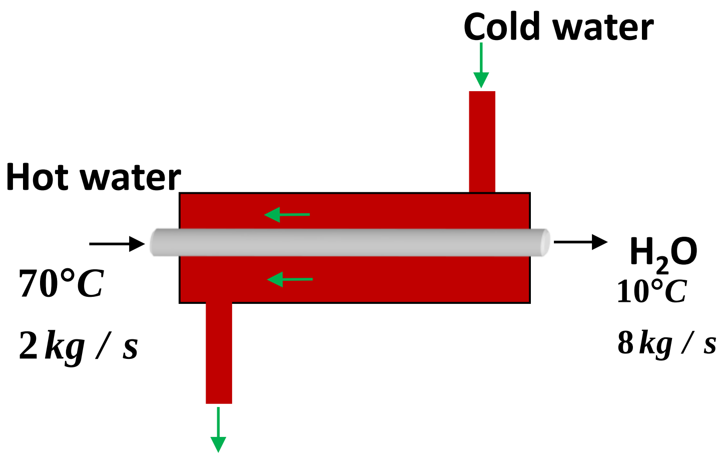
$$\dot{Q}_{max,1} = C_{ph} \dot{m}_h (\mathrm{T}_{h,i} - \mathrm{T}_{h,o}) = 4.18 \times 2\ (70 - 10) = 501.6\ \mathrm{kW}$$

$$\dot{Q}_{max,2} = C_{pc} \dot{m}_c (\mathrm{T}_{c,o} - \mathrm{T}_{c,i}) = 4.18 \times 8\ (70 - 10) = 2000.4\ \mathrm{kW}$$

Considering $\dot{Q}_{max,1} = 501.6$ kW – compute $\mathrm{T}_{c,o}$

$$501.6 = C_{pc} \dot{m}_c (\mathrm{T}_{c,o} - \mathrm{T}_{c,i}) = 4.18 \times 8\ (\mathrm{T}_{c,o} - 10)$$

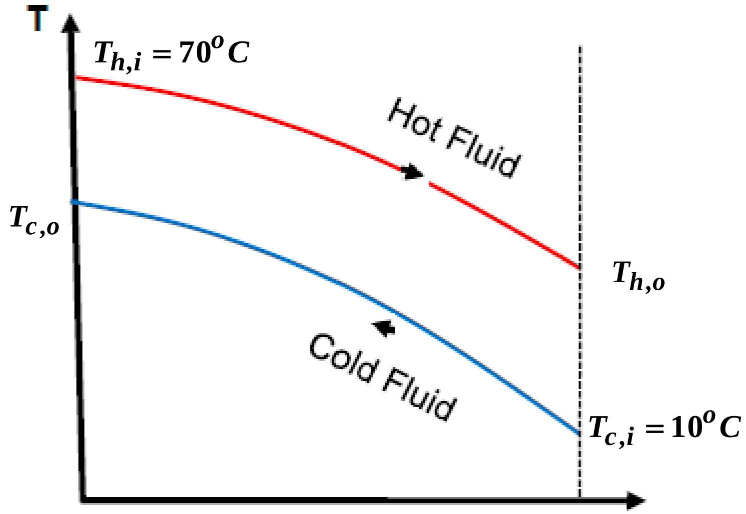
$$\mathrm{T}_{c,o} = 25\ \mathrm{deg\ C}$$



$$C_h = C_p m_h = 4.18 \times 2 = 8.36\ \frac{kW}{degC}$$

$$C_p = 4.18\ \frac{kJ}{kg\ °C}$$

$$C_c = C_p \dot{m}_c = 4.18 \times 8 = 33.44\ \frac{kW}{degC}$$



$\dot{Q}_{max,1} = 501.6\ \text{kW}$ $\dot{Q}_{max,2} = 2000.4\ \text{kW}$

Considering $\dot{Q}_{max,1} = 501.6\ \text{kW}$ – $T_{c,o} = 25\ \text{deg C}$

Considering $\dot{Q}_{max,2} = 2000.4\ \text{kW}$ – compute $T_{h,o}$

$$2000.4 = C_{ph}\dot{m}_h(T_{h,i} - T_{h,o}) = 4.18 \times 2\ (70 - T_{h,o})$$

$$T_{h,o} = -170\ \text{deg C}$$

Hence, the cold water will go on transferring heat to hot water until cold water temperature reaches 25°C, by this time the hot water would have reached already 10°C, then there is no heat transfer between hot water and cold water

$$501.6 = C_{ph}\dot{m}_h(T_{h,i} - T_{h,o}) = 4.18 \times 2\ (70 - T_{h,o})\quad T_{h,o} = 10\ \text{deg C}$$

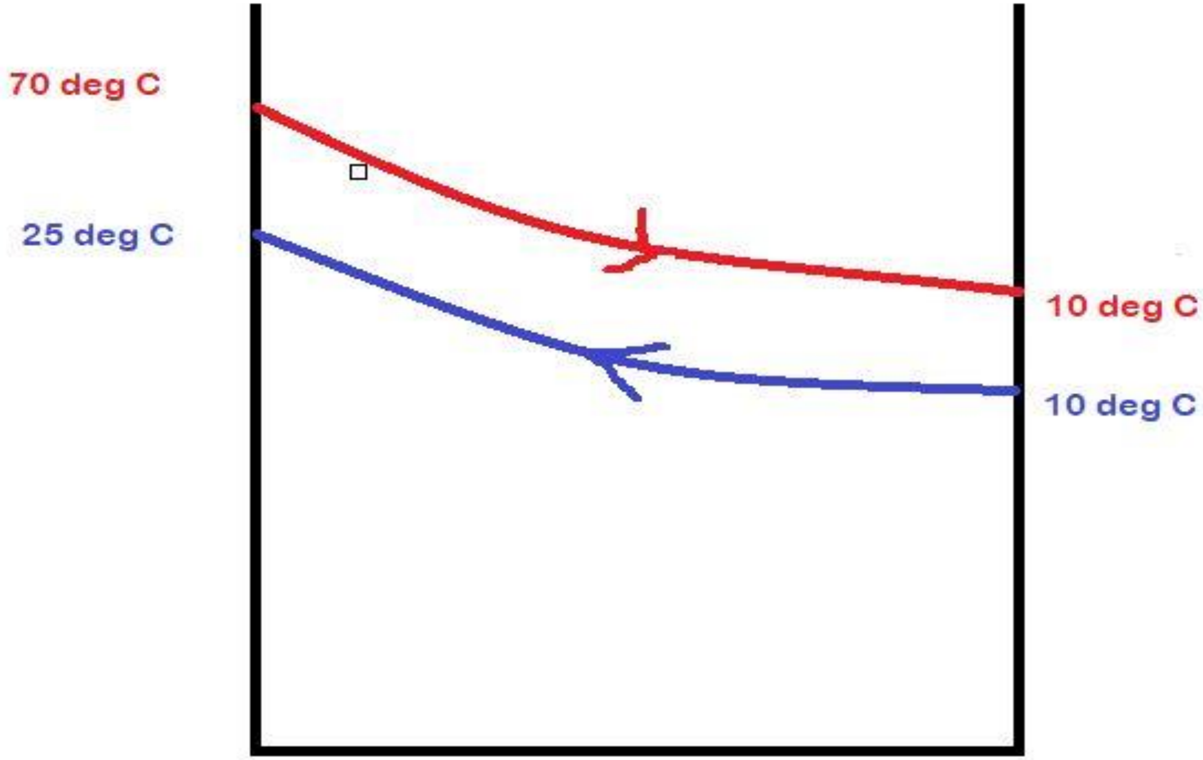
$$\dot{Q}_{max} = \mathrm{C_{min}}(\mathrm{T_{h,i}} - \mathrm{T_{c,i}}) = \mathbf{8.36\ (70 - 10) = 501.6\ kW}$$

$$\dot{Q} = C_c(T_{c,o} - T_{c,i})$$

$$501.6 \times 10^3 = 33.44\ (T_{c,o} - 10) \qquad \therefore T_{c,o} = 25℃$$

$$\dot{Q} = C_h(T_{h,i} - T_{h,o})$$

$$501.6 \times 10^3 = 8.36\ (70 - T_{h,o}) \qquad \therefore T_{h,o} = 25℃$$



$$70℃ \downarrow \textit{to}\ 10℃\ \ldots\ldots\ldots\ldots.. \rightarrow 8.36$$
$$10℃ \uparrow \textit{only}\ 25℃ \ldots\ldots\ldots\ldots \rightarrow 33.34$$

PARALLEL FLOW HEAT EXCHANGER ($\epsilon - NTU\ Method$)

$$\dot{Q} = \epsilon \dot{Q}_{max} = \epsilon C_{min}\,(T_{h,i} - T_{c,i})$$

$$\dot{m}_h\, C_{ph} = C_h$$
$$\dot{m}_c C_{pc} = C_c$$

$$\ln\frac{T_{h,o} - T_{c,o}}{T_{h,i} - T_{c,i}} = -UA_S\left[\frac{1}{\dot{m}_h\, C_{ph}} + \frac{1}{\dot{m}_c C_{pc}}\right]$$

$$\dot{Q} = C_C\left(T_{c,o} - T_{c,i}\right) = C_h(T_{h,i} - T_{h,o})$$

$$\ln\frac{T_{h,o} - T_{c,o}}{T_{h,i} - T_{c,i}} = -UA_S\left[\frac{1}{C_h} + \frac{1}{C_c}\right]$$

$$T_{h,o} = T_{h,i} - \frac{C_C}{C_h}(T_{c,o} - T_{c,i})$$

$$\ln\frac{T_{h,o} - T_{c,o}}{T_{h,i} - T_{c,i}} = -\frac{UA_S}{C_c}\left[\frac{C_C}{C_h} + 1\right]$$

$$\ln\left[\frac{T_{h,i} - \frac{C_C}{C_h}(T_{c,o} - T_{c,i}) - T_{c,o}}{T_{h,i} - T_{c,i}}\right] = -\frac{UA_S}{C_c}\left[1 + \frac{C_C}{C_h}\right]$$

$$\ln\left[\frac{T_{h,i} - T_{c,i} + T_{c,i} - \frac{C_C}{C_h}(T_{c,o} - T_{c,i}) - T_{c,o}}{T_{h,i} - T_{c,i}}\right] = -\frac{UA_S}{C_c}\left[1 + \frac{C_C}{C_h}\right]$$

$$ln\left[\frac{T_{h,i} - T_{c,i} + T_{c,i} - \frac{C_C}{C_h}(T_{c,o} - T_{c,i}) - T_{c,o}}{T_{h,i} - T_{c,i}}\right] = -\frac{UA_S}{C_c}\left[1 + \frac{C_C}{C_h}\right]$$

$$ln\left[1 - \frac{T_{c,o} - T_{c,i} + \frac{C_C}{C_h}(T_{c,o} - T_{c,i})}{T_{h,i} - T_{c,i}}\right] = -\frac{UA_S}{C_c}\left[1 + \frac{C_C}{C_h}\right]$$

$$ln\left[1 - \left(1 + \frac{C_C}{C_h}\right)\frac{T_{c,o} - T_{c,i}}{T_{h,i} - T_{c,i}}\right] = -\frac{UA_S}{C_c}\left[1 + \frac{C_C}{C_h}\right]$$

$$\epsilon = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{C_c(T_{c,o} - T_{c,i})}{C_{min}(T_{h,i} - T_{c,i})} \Rightarrow \frac{T_{c,o} - T_{c,i}}{T_{h,i} - T_{c,i}} = \epsilon\frac{C_{min}}{C_c}$$

$$ln\left[1 - \left(1 + \frac{C_C}{C_h}\right)\epsilon\frac{C_{min}}{C_c}\right] = -\frac{UA_S}{C_c}\left[1 + \frac{C_C}{C_h}\right]$$

$$1 - \left(1 + \frac{C_C}{C_h}\right)\epsilon\frac{C_{min}}{C_c} = exp\left[-\frac{UA_S}{C_c}\left(1 + \frac{C_C}{C_h}\right)\right]$$

$$1-\left(1+\frac{C_C}{C_h}\right)\epsilon\frac{C_{min}}{C_c}=exp\left[-\frac{UA_S}{C_c}\left(1+\frac{C_C}{C_h}\right)\right]$$

$$\left(1+\frac{C_C}{C_h}\right)\epsilon\frac{C_{min}}{C_c}=1-exp\left[-\frac{UA_S}{C_c}\left(1+\frac{C_C}{C_h}\right)\right]$$

$$\epsilon=\frac{1-exp\left[-\frac{UA_S}{C_c}\left(1+\frac{C_C}{C_h}\right)\right]}{\frac{C_{min}}{C_c}\left(1+\frac{C_C}{C_h}\right)}$$

$$\epsilon_{\substack{Parallel\\ flow}}=\frac{1-exp\left[-\frac{UA_S}{C_{min}}\left(1+\frac{C_{min}}{C_{max}}\right)\right]}{\left(1+\frac{C_{min}}{C_{max}}\right)}$$

$$\epsilon = \frac{1 - exp\left[-\frac{UA_S}{C_c}\left(1 + \frac{C_C}{C_h}\right)\right]}{\frac{C_{min}}{C_c}\left(1 + \frac{C_C}{C_h}\right)}$$

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

$$\epsilon = \frac{1 - exp\left[-\frac{UA_S}{C_{min}}\left(1 + \frac{C_{min}}{C_h}\right)\right]}{\frac{C_{min}}{C_{min}}\left(1 + \frac{C_{min}}{C_h}\right)}$$

$$\epsilon_{\substack{Parallel \\ flow}} = \frac{1 - exp\left[-\frac{UA_S}{C_{min}}\left(1 + \frac{C_{min}}{C_{max}}\right)\right]}{\left(1 + \frac{C_{min}}{C_{max}}\right)}$$

$$\epsilon = \frac{1 - exp\left[-\frac{UA_S}{C_c}\left(1 + \frac{C_C}{C_h}\right)\right]}{\frac{C_{min}}{C_c}\left(1 + \frac{C_C}{C_h}\right)}$$

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

$$\epsilon = \frac{1 - exp\left[-\frac{UA_S}{C_{max}}\left(1 + \frac{C_{max}}{C_{min}}\right)\right]}{\frac{C_{min}}{C_{max}}\left(1 + \frac{C_{max}}{C_{min}}\right)} = \frac{1 - exp\left[-\frac{UA_S}{C_{max}}\left(\frac{C_{min} + C_{max}}{C_{min}}\right)\right]}{\frac{C_{min}}{C_{max}}\left(\frac{C_{min} + C_{max}}{C_{min}}\right)}$$

$$\epsilon = \frac{1 - exp\left[-\frac{UA_S}{C_{max}}\left(\frac{C_{min} + C_{max}}{C_{min}}\right)\right]}{\frac{C_{min}}{C_{max}}\left(\frac{C_{min} + C_{max}}{C_{min}}\right)} = \frac{1 - exp\left[-\frac{UA_S}{C_{min}}\left(\frac{C_{min} + C_{max}}{C_{max}}\right)\right]}{\left(\frac{C_{min} + C_{max}}{C_{max}}\right)}$$

$$\epsilon_{\substack{Parallel\\flow}} = \frac{1 - exp\left[-\frac{UA_S}{C_{min}}\left(1 + \frac{C_{min}}{C_{max}}\right)\right]}{\left(1 + \frac{C_{min}}{C_{max}}\right)}$$

NUMBER OF TRANSFER UNITS (NTU)

$$NTU = \frac{UA_S}{C_{min}} = \frac{UA_S}{(\dot{m}_c C_{pc})_{\mathrm{min}}}$$

- Non-dimensional thermal size of the Heat transfer
- Heat transfer per unit heat capacity of fluid
- For specified values of C_{min} and U,

  NTU – measure of heat transfer surface area A_S

  Larger NTU – Larger the heat exchanger

CAPACITY RATIO

$$C = \frac{C_{min}}{C_{max}}$$

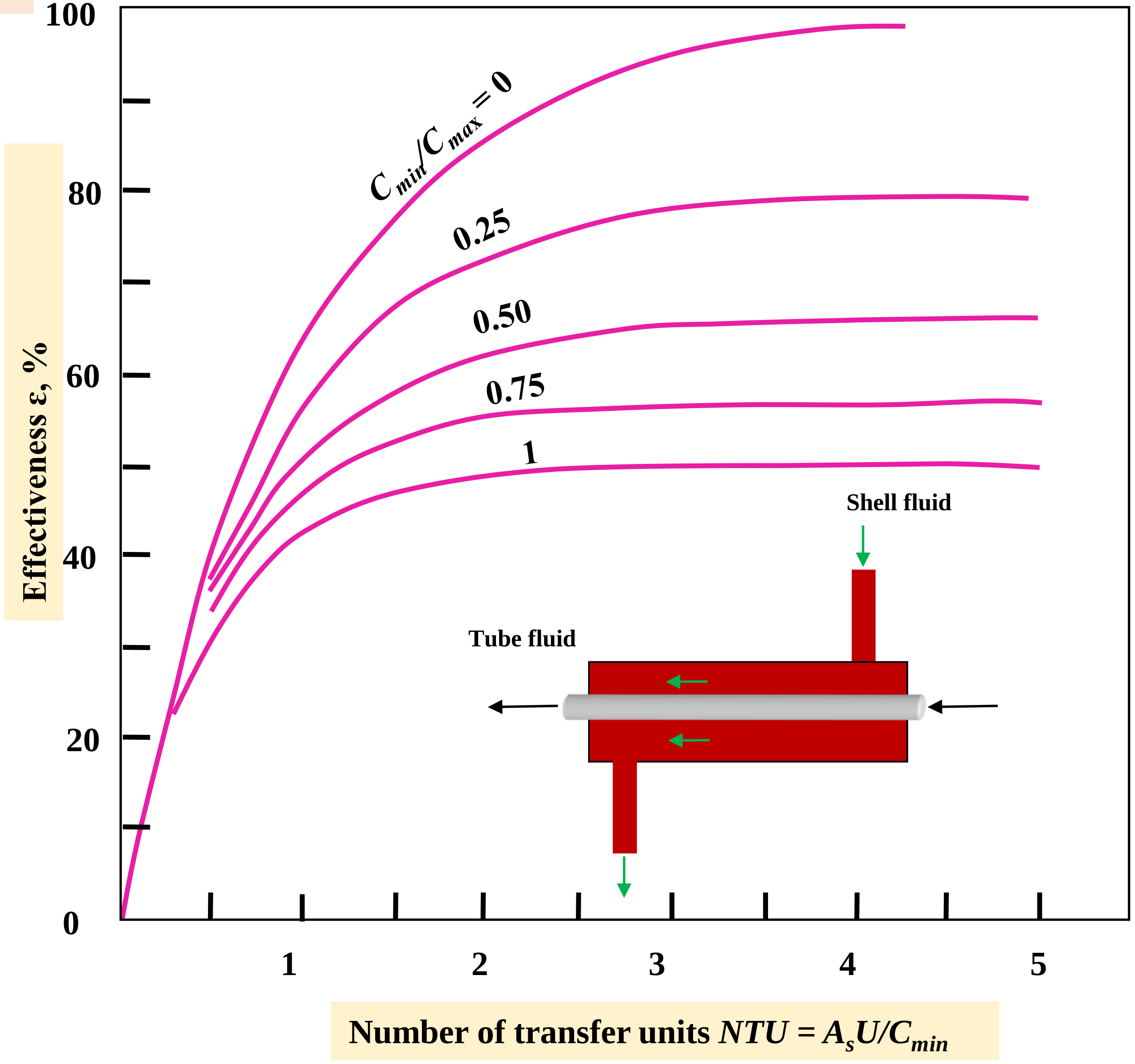
$$\epsilon = \mathrm{f}(NTU, C)$$

Effectiveness relation for heat exchanger: $NTU = \frac{UA_S}{C_{min}}$ and $C = \frac{C_{min}}{C_{max}}$ Kays and London

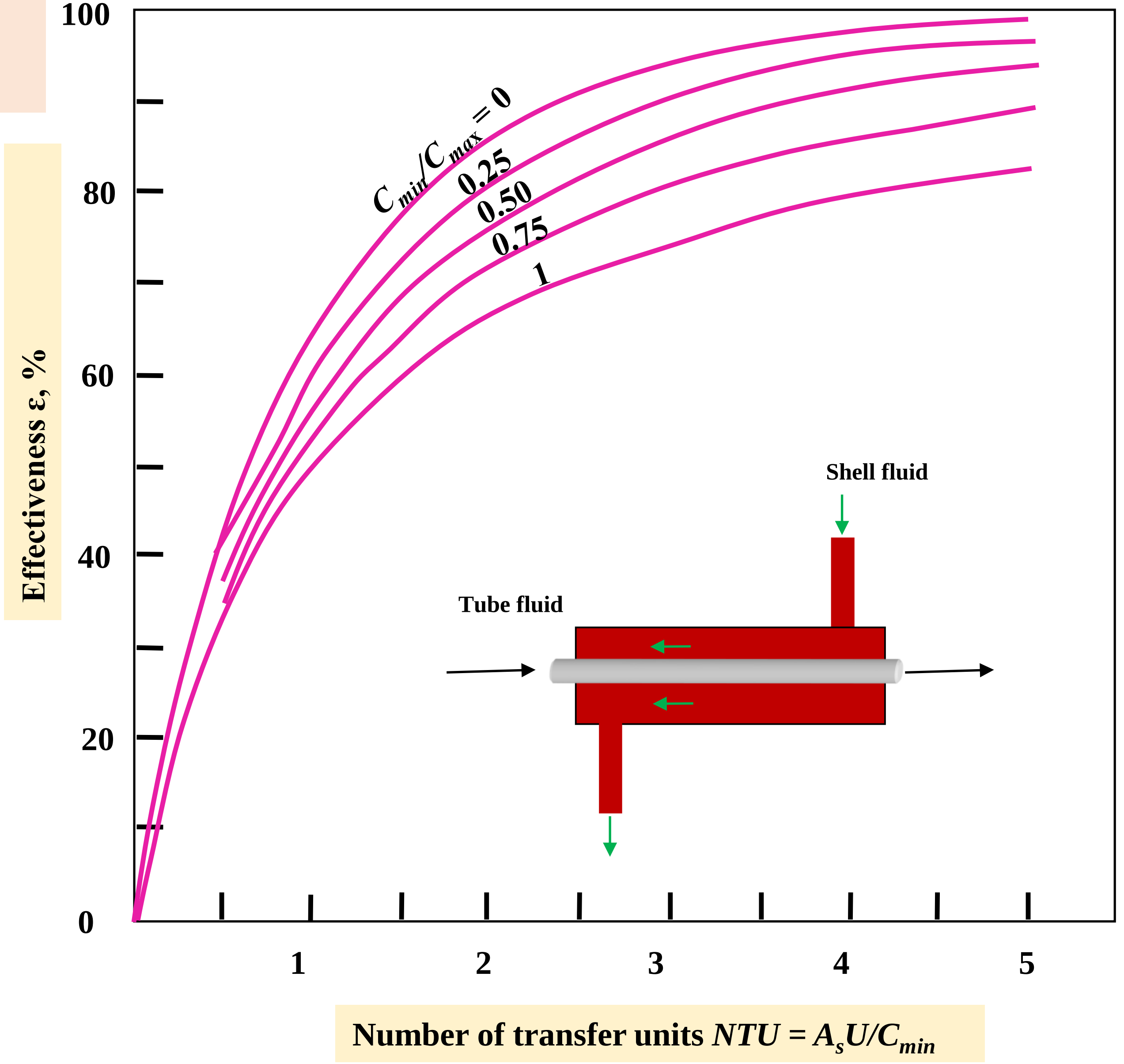
$$C = C_{min}/C_{max} = \left(\dot{m}C_P\right)_{min} \Big/ \left(\dot{m}C_P\right)_{max}$$

Heat exchanger type	Effectiveness relation
1 **Double pipe:** Parallel –flow	$\varepsilon = \frac{1-exp\left[-NTU\left(1+C\right)\right]}{\left(1+C\right)}$
Counter flow	$\varepsilon = \frac{1-exp\left[-NTU\left(1-C\right)\right]}{1-C\,exp\left[-NTU\left(1-C\right)\right]}$
2 **Shell and tube :** One shell pass 2, 4,…tube passes	$\varepsilon = 2\left\{1+C+\sqrt{\left(1+C^2\right)}+\frac{1+exp\left[-NTU\sqrt{\left(1+C^2\right)}\right]}{1-exp\left[-NTU\sqrt{\left(1+C^2\right)}\right]}\right\}$
3 **Cross flow (single pass)** Both fluid unmixed	$\varepsilon = 1-exp\left\{\frac{NTU^{0.22}}{C}\left[exp\left(-C\,NTU^{0.78}\right)-1\right]\right\}$
C_{max} mixed, C_{min} unmixed	$\varepsilon = \frac{1}{C}\left(1-exp\left\{1-C\left[1-exp\left(-NTU\right)\right]\right\}\right)$
C_{min} mixed, C_{max} unmixed	$\varepsilon = \left(1-exp\left\{-\frac{1}{C}\left[1-exp\left(-C\,NTU\right)\right]\right\}\right)$
4 **All heat exchangers with C=0**	$\varepsilon = 1-exp(-NTU)$

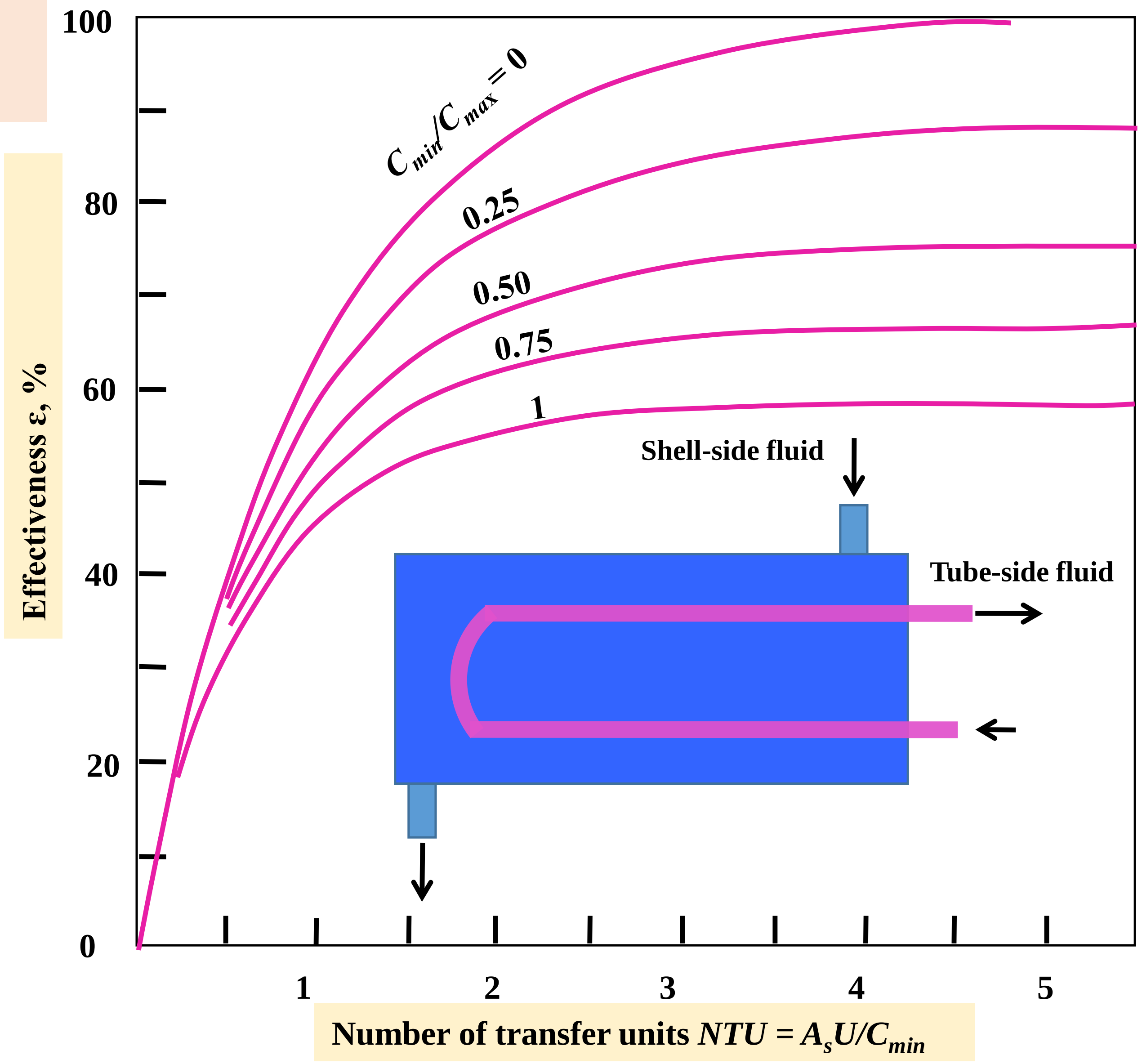
Parallel Flow



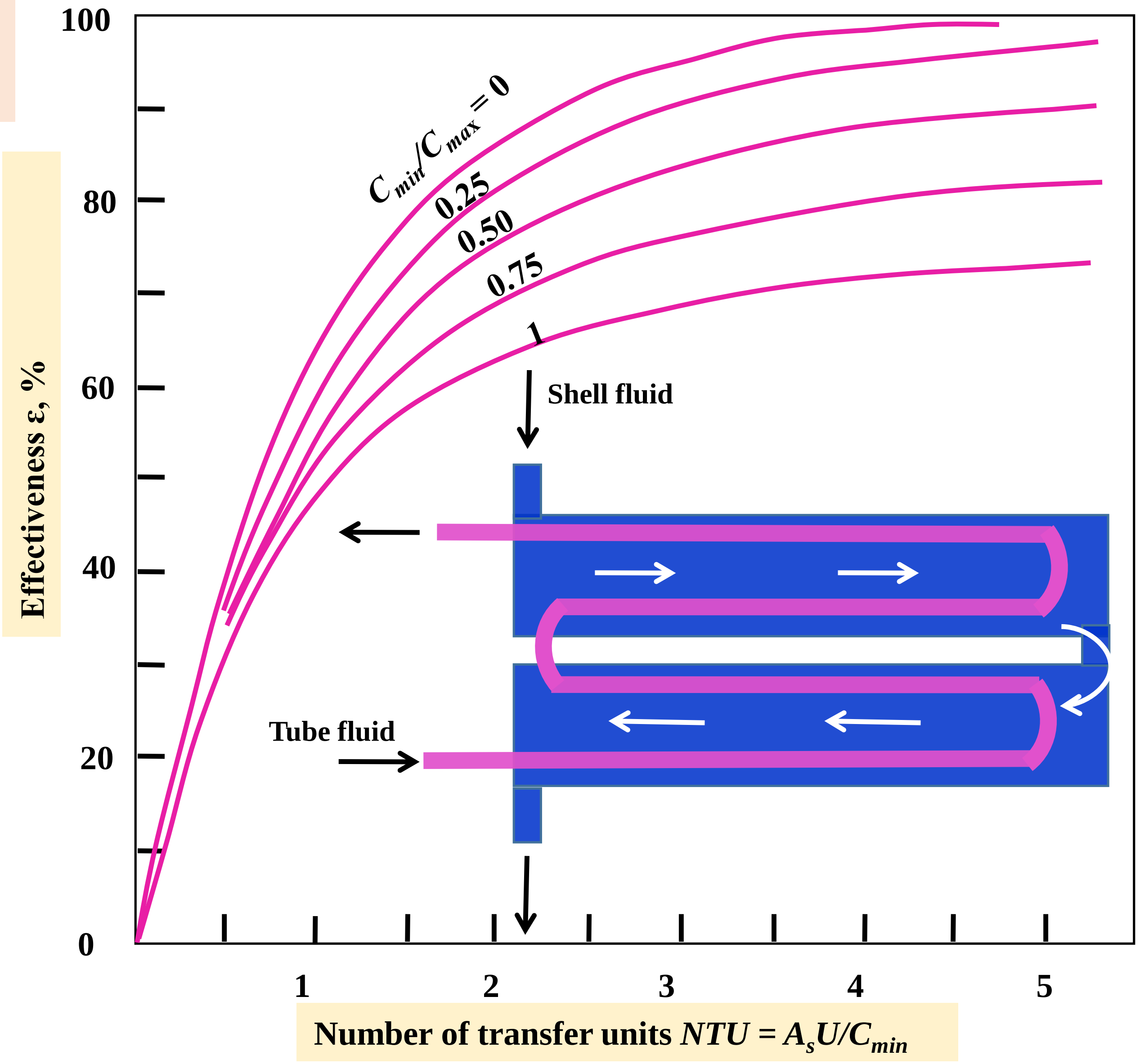
Counter Flow Heat Exchanger



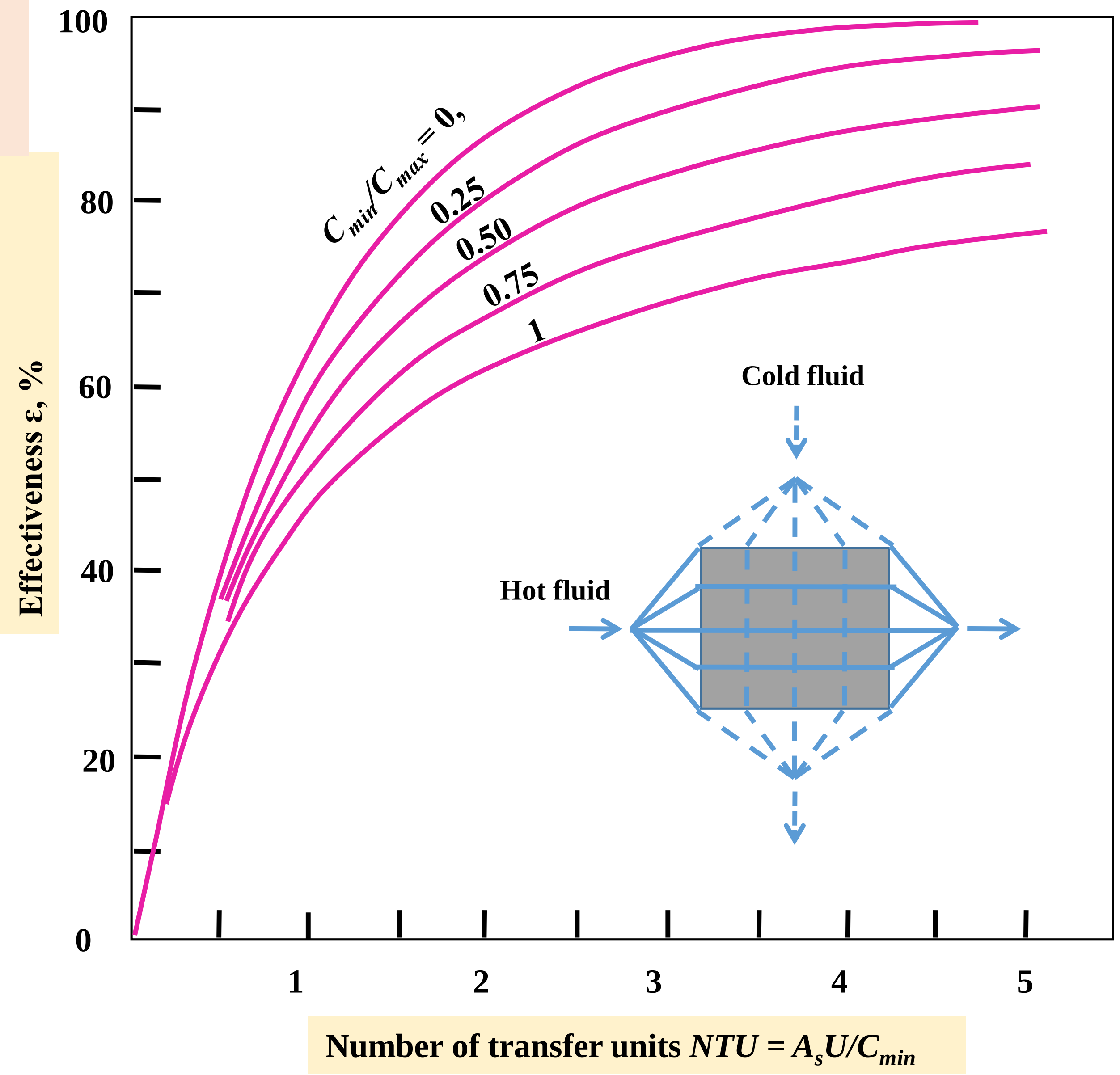
One-shell pass and 2,4,6….tube passes



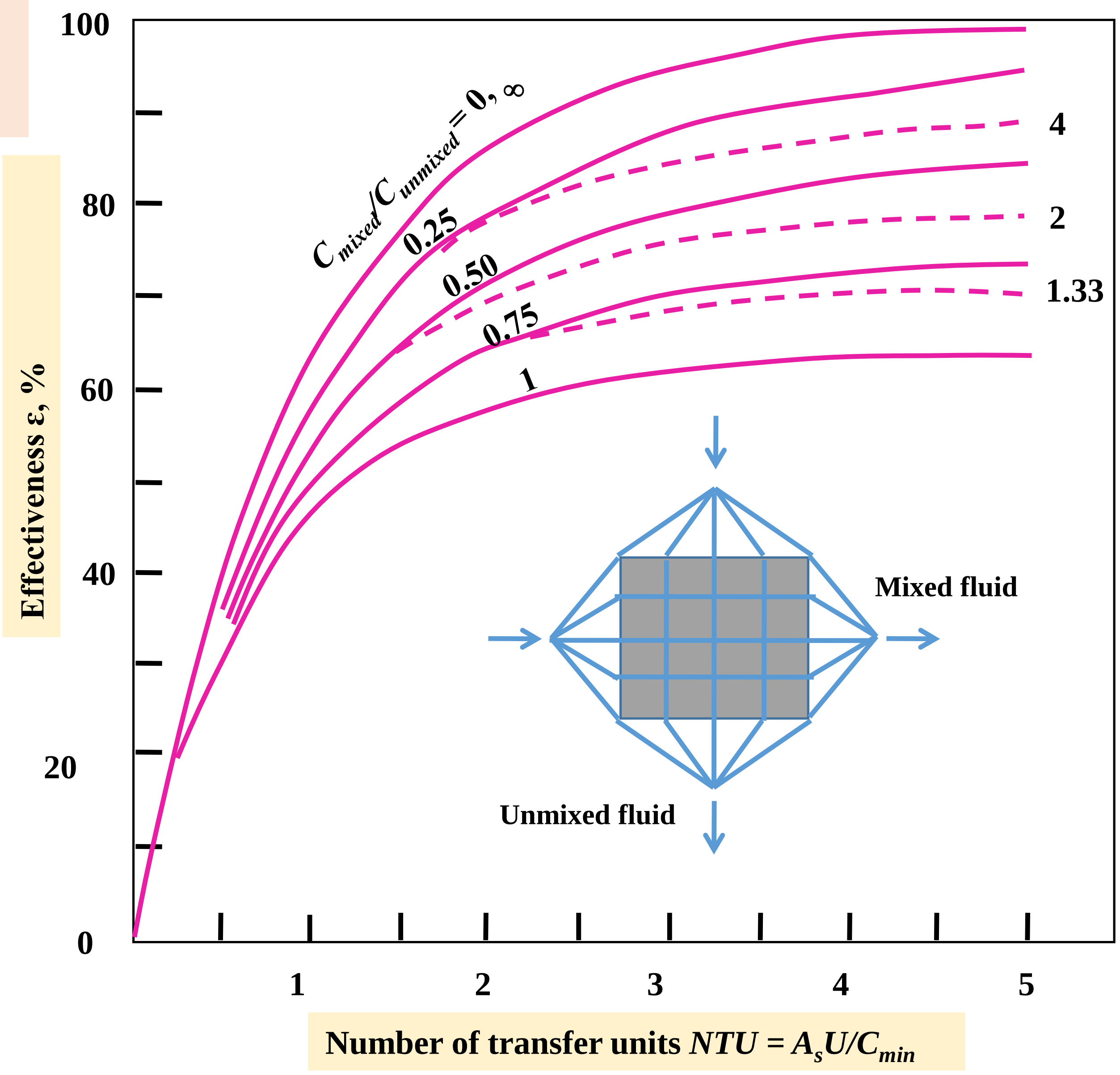
Two-shell passes and 4,8,12….tube passes

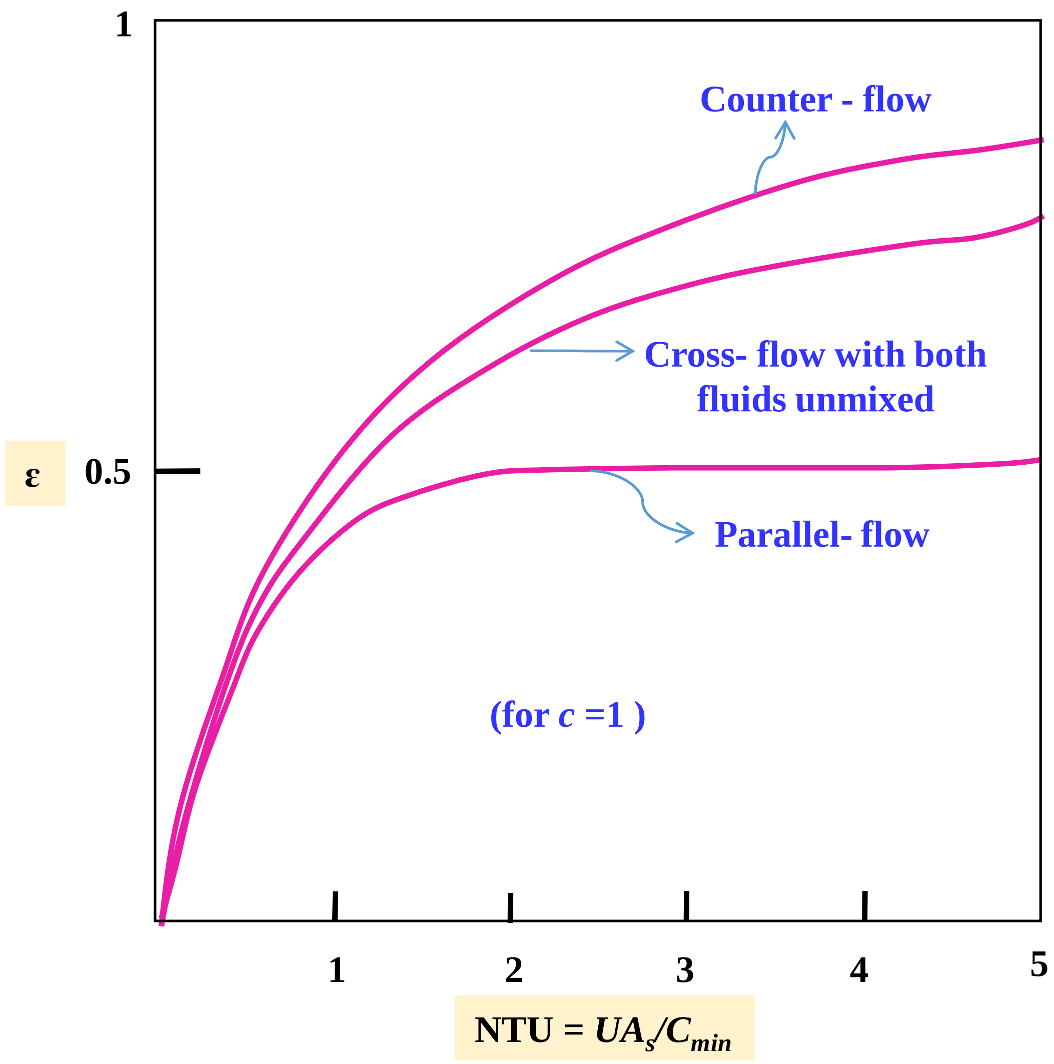


Cross- flow with both fluids unmixed



Cross- flow with one fluid mixed and other unmixed



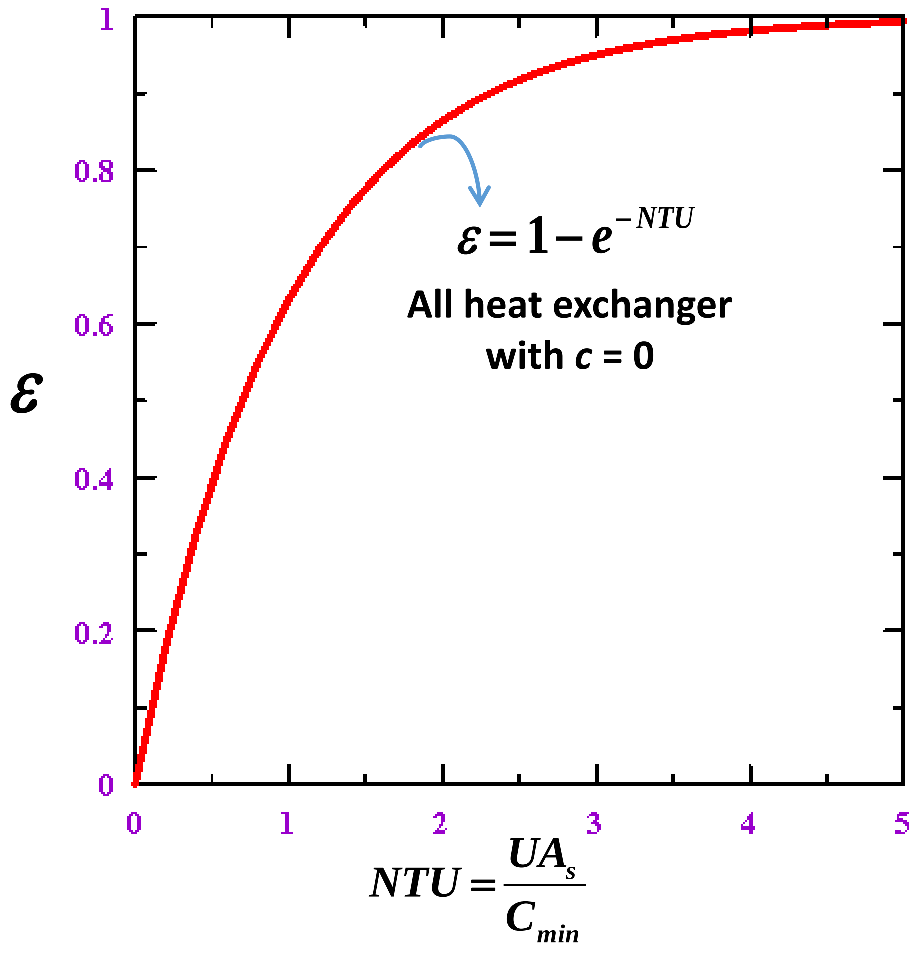


For a given value of NTU and c = C_{min}/C_{max}, the counterflow HE has the highest effectiveness, followed closely by the cross flow HE with both fluids unmixed. Lowest effectiveness is encountered in parallel flow HE

• capacity ratio varies between 0 to 1.

$c = 0 \Rightarrow c = C_{min}/C_{max} \Rightarrow 0\ C_{max} \Rightarrow \infty$, - CONDENSER AND BOILER

$c = 1 \Rightarrow c = C_{min}/C_{max} \Rightarrow 1$; ε is lowest



- ε ranges from 0 to 1. It increases rapidly with NTU for small value (up to NTU = 1.5) but rather slowly for larger values.
- High ε is desirable from heat transfer point of view but undesirable from economic point of view. Hence, NTU larger than 3 is not justified.
- For a given value of NTU and $C = \frac{C_{min}}{C_{max}}$, the counterflow HE has the highest effectiveness, followed closely by the cross flow HE with both fluids unmixed. Lowest effectiveness is encountered in parallel flow HE.
- ε is independent of capacity ratio ‘c’ for NTU Values of less than 0.3
- Capacity ratio varies between 0 to 1.

C=0 $=> C = \frac{C_{min}}{C_{max}} = C_{max} => \infty, -\boldsymbol{CONDENSER\ AND\ BOILER}$

$c = 1 \;=> \frac{C_{min}}{C_{max}} => 1;$ ϵ is lowest

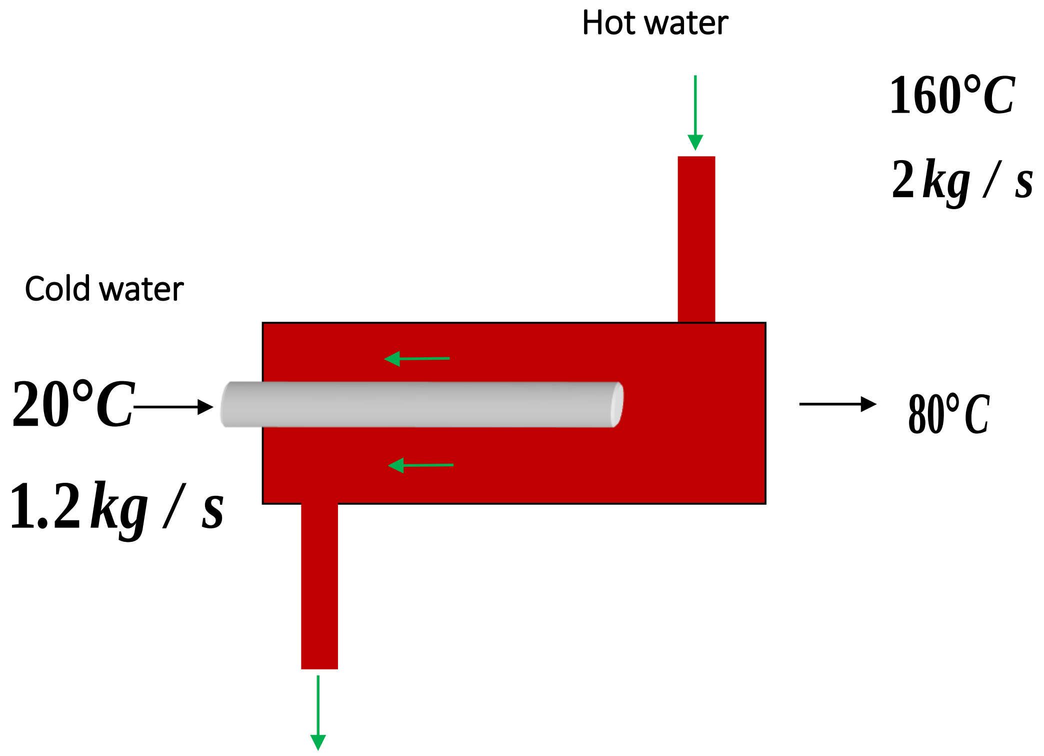
Effectiveness relation for heat exchanger: $NTU = \frac{UA_S}{C_{min}}$ and $C = \frac{C_{min}}{C_{max}}$ Kays and London

$$C = C_{min}/C_{max} = \left(\dot{m}C_P\right)_{min} \Big/ \left(\dot{m}C_P\right)_{max}$$

Heat exchanger type	Effectiveness relation
1 Double pipe: Parallel –flow	$NTU = -\frac{\ln\left[1-\varepsilon(1+C)\right]}{1+C}$
Counter flow	$NTU = \frac{1}{C-1}\ln\left(\frac{\varepsilon-1}{\varepsilon C-1}\right)$
2 Shell and tube : One shell pass 2, 4,…tube passes	$NTU = -\frac{1}{\sqrt{1+C^2}}\ln\left(\frac{2/\varepsilon-1-C-\sqrt{1+C^2}}{2/\varepsilon-1-C+\sqrt{1+C^2}}\right)$
3 Cross flow (single pass) Both fluid unmixed	$NTU = -\ln\left[1+\frac{\ln(1-C\varepsilon)}{C}\right]$
C_{max} mixed, C_{min} unmixed C_{min} mixed, C_{max} unmixed	$NTU = -\frac{\ln\left[C\ln(1-\varepsilon C)+1\right]}{C}$
4 All heat exchangers with C=0	$NTU = -\ln(1-\varepsilon)$

Heating water in a Counter Flow Heat Exchanger

A counter flow double pipe heat exchanger is to heat from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available at 160°C at a mass flow rate 2 kg/s. The inner tube is thin walled and has a diameter of 1.5 cm. If the overall heat transfer coefficient of the heat exchanger is 640 W/m².°C, determine the length of the heat exchanger required to achieve the desired heating.



Solution: Assumptions:

Analysis : In the effectiveness-NTU method, we first determine the heat capacity rates of the hot and cold fluids and identify the smaller one:

$$C_h = \dot{m}_h C_{ph} = (2\,kg/s)(4.31\,kJ / kg.°C) = 8.62\,KW / °C$$

$$C_h = \dot{m}_h C_{ph} = (1.2\,kg/s)(4.31\,kJ / kg.°C) = 5.02\,KW / °C$$

$$c = C_{min}/C_{max} = 5.02/8.62 = 0.583$$

The maximum heat transfer rate

$$\begin{aligned}\dot{Q} &= C_{min}(T_{h,in} - T_{c,in}) \\ &= (5.02\,KW/°C)(160 - 20)°C \\ &= 702.8\,kW\end{aligned}$$

That is, the maximum possible heat transfer rate in this heat exchanger is 702.8 kW. The actual rate of heat transfer in the heat exchanger is

$$\dot{Q} = \left[\dot{m} C_p \left(T_{out} - T_{in}\right)\right]_{water} = \left(1.2\, ks/s\right)\left(4.18\, kJ/kg.°C\right)\left(80 - 20\right)°C = 301.0\, kW$$

Thus, the effectiveness of the heat exchanger is

$$\varepsilon = \frac{\dot{Q}}{\dot{Q}_{max}} = \frac{301.0kW}{702.8kW} = 0.428$$

Knowing the effectiveness, the NTU of this counter flow heat exchanger can be determined from the appropriate relation

$$NTU = \frac{1}{C-1} ln\left(\frac{\varepsilon - 1}{\varepsilon C - 1}\right) = \frac{1}{0.583 - 1} ln\left(\frac{0.428 - 1}{0.428 \times 0.583 - 1}\right) = 0.651$$

Then the heat transfer surface area becomes

$$NTU = \frac{UA_s}{C_{min}} \rightarrow A_s = \frac{NTUC_{min}}{U} = \frac{\left(0.651\right)\left(5020\, W/°C\right)}{640\, W/m^2.°C} = 5.11\, m^2$$

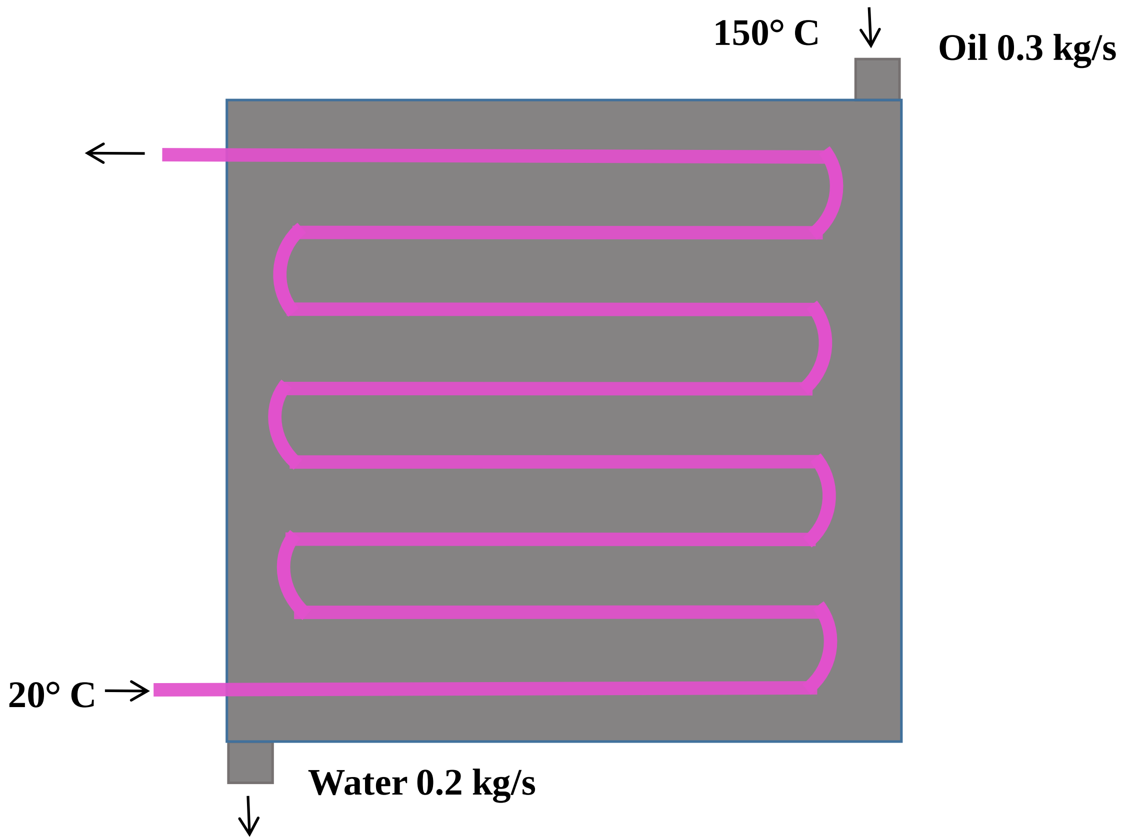
To provide this much heat transfer surface area, the length of the tube

$$A_s = \pi DL \rightarrow L = \frac{A_s}{\pi D} = \frac{5.11m^2}{\pi\left(0.015\, m\right)} = 108\, m$$

Note: This problem can also be solved by ε – NTU method

Cooling Hot Oil by Water in Multipass Heat Exchanger

Hot oil is to b cooled by water in a 1-shell-pass and 8 tube passes heat exchanger. The tubes are thin-walled and are made of copper with an internal diameter of 1.4 cm. The length of each tube pass in the heat exchanger is 5 m, and the overall heat transfer coefficient is 310 W/m^2.°C. Water flows through the tube at a rate of 0.2 kg/s, and the oil through the shell at a rate of 0.3 kg/s. The water an d the oil enter at temperatures of 20°C and 150°C, respectively. Determine the rate of heat transfer in the heat exchanger and the outlet temperature of the water and the oil.



Solution: Hot oil is to be cooled by water in a heat exchanger. The mass flow rates and the inlet temperatures are given. The rate of heat transfer and the outlet temperature are to be determined.

Assumptions:

1) steady operating conditions exist.
2) The heat exchanger is will insulated so that heat loss to the surrounding is negligible and thus heat transfer from the hot fluid is equal to the heat transfer to the cold fluid.
3) The thickness of the tube is negligible since it is thin walled.
4) Changes in the kinetic and potential energies of the fluid streams are negligible.
5) The overall heat transfer coefficient is constant and uniform.

Analysis: The outlet temperature are not specified, and they cannot be determined from an energy balance. The use of the LMTD method in this case will involve tedious iterations, and thus the ε-NTU method is indicated. The first step in the ε-NTU method is to determine the heat capacity rates of the hot and cold fluids and identify the smaller one:

$$C_h = \dot{m}_h C_{ph} = (0.3\,kg/s)(2.13\,kJ\ /\ kg.°C) = 0.639\,KW\ /\ °C$$

$$C_h = \dot{m}_h C_{ph} = (0.2\,kg/s)(4.18\,kJ\ /\ kg.°C) = 0.836\,KW\ /\ °C$$

$$C_{min} = C_h = 0.639\,kW/°C$$

$$c = C_{min}/C_{max} = 0.639/0.836 = 0.764$$

$$\dot{Q}_{max} = (\dot{m}C_p)_{min}(T_{h,i} - T_{c,i}) = 0.639(150 - 20) = 83.1\ kW$$

$$A_s = n\pi DL = 8 \times \pi \times 0.014 \times 5 = 1.76\ m^2$$

$$NTU = \frac{UA_s}{C_{min}} = \frac{310 \times 1.76}{639} = 0.853$$

$$c = 0.764;\ NTU == 0.853$$

$$\varepsilon = 2\left\{1 + C + \sqrt{(1 + C^2)} + \frac{1 + exp\left[-NTU\sqrt{(1 + C^2)}\right]}{1 - exp\left[-NTU\sqrt{(1 + C^2)}\right]}\right\}$$

$$\varepsilon = 0.47$$

$$\dot{Q} = \varepsilon \dot{Q}_{max} = 0.47 \times 83.1 = 39.1 kW$$

$$\dot{Q} = \dot{m}_c C_{pc} \left(T_{c,out} - T_{c,in} \right) \Rightarrow T_{c,out} = T_{c,in} + \frac{\dot{Q}}{\dot{m}_c C_{pc}}$$

$$T_{c,out} = 20 + \frac{39.1}{0.836} = 66.8^o C$$

$$\dot{Q} = \dot{m}_h C_{ph} \left(T_{h,in} - T_{h,out} \right) \Rightarrow T_{h,out} = T_{h,in} - \frac{\dot{Q}}{\dot{m}_h C_{ph}}$$

$$T_{h,out} = 150 - \frac{39.1}{0.639} = 88.8^o C$$

Therefore, the temperature of the cooling water will rise from 20°C to 66.8°C as it cools the hot oil from 150°C to 88.8°C in this heat exchanger.

DESIGN AND CHOICE OF HEAT EXCHANGER

- HEAT TRANSFER RATE
- PUMPING POWER - PRESSURE DROP
- COST
- SIZE AND WEIGHT
- TYPE
- MATERIALS