Methods for design and analysis of heat exchangers

LMTD method

ε-NTU method

Godtyckliga vvx, Arbitrary Hex

$$\dot{Q} = UA \cdot F \cdot LMTD$$

F korrektionsfaktor som beror av två parametrar P och R;

F correction factor depending on two parameters P and R

$$P = \frac{t_{c_{ut}} - t_{c_{in}}}{t_{h_{in}} - t_{c_{in}}}$$

$$R = \frac{(\dot{m}c_p)_c}{(\dot{m}c_p)_h}$$

R kan också skrivas; R can also be written

$$R = \frac{t_{h_{in}} - t_{h_{ut}}}{t_{c_{ut}} - t_{c_{in}}}$$

LMTD – always as for counter-current flow

$$\Delta t_{\mathrm{m}} = LMTD = \frac{(t_{\mathrm{h_{ut}}} - t_{\mathrm{c_{in}}}) - (t_{\mathrm{h_{in}}} - t_{\mathrm{c_{ut}}})}{\ln \dfrac{(t_{\mathrm{h_{ut}}} - t_{\mathrm{c_{in}}})}{(t_{\mathrm{h_{in}}} - t_{\mathrm{c_{ut}}})}}$$

ε - NTU metoden; ε - NTU method

$$\varepsilon = \frac{\text{verkligt värmeflöde, real heat flow}}{\text{maximalt överförbart värmeflöde,}} = \frac{\dot{Q}}{\dot{Q}_{\max}}$$

maximum transferable heat flow

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

ε - NTU method, continued

$$\varepsilon = \frac{C_{\text{h}}(t_{\text{h}_{\text{in}}} - t_{\text{h}_{\text{ut}}})}{C_{\min}(t_{\text{h}_{\text{in}}} - t_{\text{c}_{\text{in}}})} = \frac{C_{\text{c}}(t_{\text{c}_{\text{ut}}} - t_{\text{c}_{\text{in}}})}{C_{\min}(t_{\text{h}_{\text{in}}} - t_{\text{c}_{\text{in}}})}$$

$$\dot{Q}_{\max} = C_{\min}(t_{\text{h}_{\text{in}}} - t_{\text{c}_{\text{in}}})$$

$$\dot{Q} = \varepsilon C_{\min}(t_{\text{h}_{\text{in}}} - t_{\text{c}_{\text{in}}})$$

ε - NTU method, continued

$$NTU = \frac{\dot{Q}/LMTD}{C_{\mathrm{min}}} \qquad (15\text{-}18)$$

Temperaturdifferenserna i *LMTD* (15-9) kan omskrivas enligt. The temperature difference in *LMTD* can be re-written as

$$(t_{\mathrm{h_{ut}}} - t_{\mathrm{c_{in}}}) - (t_{\mathrm{h_{in}}} - t_{\mathrm{c_{ut}}}) = (t_{\mathrm{h_{ut}}} - t_{\mathrm{h_{in}}}) - (t_{\mathrm{c_{in}}} - t_{\mathrm{c_{ut}}}) =$$

$$= -\frac{\dot{Q}}{C_{\mathrm{h}}} + \frac{\dot{Q}}{C_{\mathrm{c}}} = \dot{Q}\left(\frac{1}{C_{\mathrm{c}}} - \frac{1}{C_{\mathrm{h}}}\right)$$

$$\frac{(t_{\mathrm{h_{ut}}} - t_{\mathrm{c_{in}}})}{(t_{\mathrm{h_{in}}} - t_{\mathrm{c_{ut}}})} = \frac{-(t_{\mathrm{h_{in}}} - t_{\mathrm{h_{ut}}}) + (t_{\mathrm{h_{in}}} - t_{\mathrm{c_{in}}})}{(t_{\mathrm{h_{in}}} - t_{\mathrm{c_{in}}}) + (t_{\mathrm{c_{in}}} - t_{\mathrm{c_{ut}}})} = \qquad (15\text{-}20)$$

$$= \frac{-\dot{Q}/C_{\mathrm{h}} + \dot{Q}/(\varepsilon C_{\mathrm{min}})}{\dot{Q}/(\varepsilon C_{\mathrm{min}}) - \dot{Q}/C_{\mathrm{c}}} = \frac{C_{\mathrm{c}}(C_{\mathrm{h}} - \varepsilon C_{\mathrm{min}})}{C_{\mathrm{h}}(C_{\mathrm{c}} - \varepsilon C_{\mathrm{min}})}$$

Med (With) (15-9), (15-18), (15-19) och/and (15-20) fås nu/one obtains

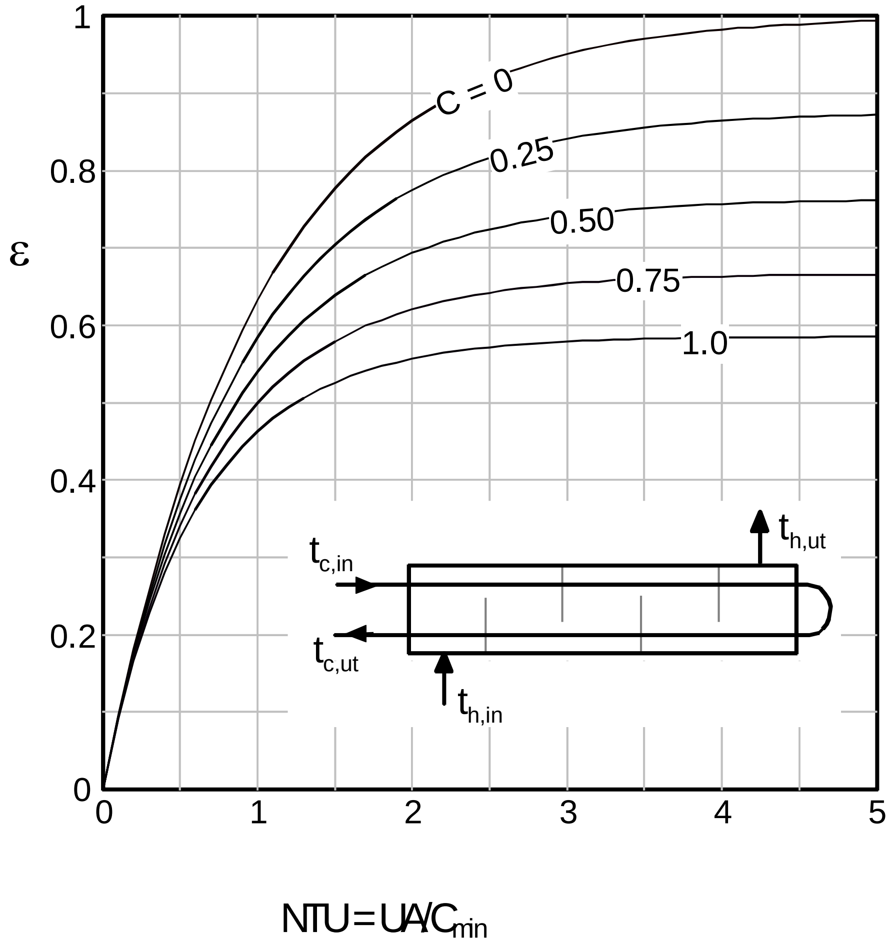
$$NTU = \frac{1}{C_{\mathrm{min}}} \frac{\ln\left(\frac{C_{\mathrm{c}}}{C_{\mathrm{h}}} \cdot \frac{C_{\mathrm{h}} - \varepsilon C_{\mathrm{min}}}{C_{\mathrm{c}} - \varepsilon C_{\mathrm{min}}}\right)}{\frac{1}{C_{\mathrm{c}}} - \frac{1}{C_{\mathrm{h}}}} \qquad (15\text{-}21)$$

ε - NTU method

$C_{min} = C_c$ vilket medför att, which means that $C_{max} = C_h$. Efter några räkningar finner man, after a few calculations one finds

$$\varepsilon = \frac{1-\exp\left[-(1-C_{min}/C_{max})NTU\right]}{1-C_{min}/C_{max}\exp\left[-(1-C_{min}/C_{max})NTU\right]} \tag{15-22}$$

ε - NTU för tubvärmeväxlare med ett mantelpass och två tubpass; shell-and-tube heat exchanger with one shell pass, two tube passes



Tabell, Table 15-II. ε - NTU samband för några vanliga värmeväxlartyper (VVX).

ε - NTU relations for some hexs

VVX-typ, HEX type	**Verkningsgrad , Effectiveness ε**	
Medström, **Parallel flow**	$\varepsilon = \dfrac{1-\exp\left[-NTU(1+C)\right]}{1+C}$	Fig. 15-20b
Motström **Counter current**	$\varepsilon = \dfrac{1-\exp\left[-NTU(1-C)\right]}{1-C\exp\left[-NTU(1-C)\right]} \qquad C<1$ $\varepsilon = \dfrac{NTU}{1+NTU} \qquad C=1$	Fig. 15-20a
Tubvärmeväxlare (”Shell and tube”)		
1 shell pass 2,4,6,..tube passs	$\varepsilon_1 = 2\left\{1+C+(1+C^2)^{1/2}\times\dfrac{1+\exp\left[-NTU(1+C^2)^{1/2}\right]}{1-\exp\left[-NTU(1+C^2)^{1/2}\right]}\right\}^{-1}$	Fig. 15-21a
n Shell passes 2*n*, 4*n*, ..tube passes	$\varepsilon_n = \left[\left(\dfrac{1-\varepsilon_1 C}{1-\varepsilon_1}\right)^n - 1\right]\left[\left(\dfrac{1-\varepsilon_1 C}{1-\varepsilon_1}\right)^n - C\right]^{-1}$	Fig. 15-21b
Korsström, Cross flow (single pass)		
Båda fluiderna oblandade Both fluids unmixed	$\varepsilon \approx 1-\exp\left[C^{-1}(NTU)^{0.22}\left\{\exp\left[-C(NTU)^{0.78}\right]-1\right\}\right]$	Fig. 15-21c
Båda fluiderna blandade Both fluids mixed	$\varepsilon = NTU\left[\dfrac{NTU}{1-\exp(-NTU)}+\dfrac{C(NTU)}{1-\exp\left[-C(NTU)\right]}-1\right]^{-1}$	Fig. 15-21d
C_{min} oblandad, unmixed C_{max} blandad, mixed	$\varepsilon = C^{-1}\left(1-\exp\left[-C\left\{1-\exp(-NTU)\right\}\right]\right)$	Fig. 15-21f
C_{min} blandad, mixed C_{max} oblandad, unmixed	$\varepsilon = 1-\exp\left(-C^{-1}\left\{1-\exp\left[-C(NTU)\right]\right\}\right)$	Fig. 15-21e
Alla växlare $C=0$ All hex	$\varepsilon = 1-\exp(-NTU)$	

$C = C_{min}/C_{max}$