Heat Exchanger Effectiveness and Outlet Temperatures (ε–NTU)

Duty and outlet temperatures of an existing heat exchanger from UA and the inlet conditions, by the effectiveness–NTU method for six flow arrangements.

Method: ε–NTU relations (Incropera, Fundamentals of Heat and Mass Transfer, Table 11.3)

Input parameters

Unit system: SI

Parameter	Value	Unit
Flow arrangement	Counterflow	
Hot fluid flow	7,200.0	kg/h
Hot fluid specific heat	4.1900	kJ/(kg·K)
Hot fluid inlet temperature	90.000	°C
Cold fluid flow	10,800	kg/h
Cold fluid specific heat	4.1800	kJ/(kg·K)
Cold fluid inlet temperature	30.000	°C
Overall heat transfer coefficient	1,200.0	W/(m²·K)
Heat transfer area	10.000	m²

Calculated results

Parameter	Value	Unit
Number of transfer units	1.4320	
Heat capacity rate ratio C_min/C_max	0.66826	
Effectiveness	64.702	%
Heat duty	325.32	kW
Hot fluid outlet temperature	51.179	°C
Cold fluid outlet temperature	55.943	°C

Formula and method

$$NTU = \frac{UA}{C_{min}}, \quad C_r = \frac{C_{min}}{C_{max}}$$

$$\varepsilon = \frac{1 - e^{-NTU(1-C_r)}}{1 - C_r e^{-NTU(1-C_r)}} \ \text{(counterflow; others from Table 11.3)}$$

$$\text{parallel}: \ \varepsilon = \frac{1 - e^{-NTU(1+C_r)}}{1 + C_r} \qquad \text{one shell pass}: \ \varepsilon = 2\left[1 + C_r + \sqrt{1+C_r^2}\,\frac{1 + e^{-NTU\sqrt{1+C_r^2}}}{1 - e^{-NTU\sqrt{1+C_r^2}}}\right]^{-1}$$

$$\text{cross, both unmixed}: \ \varepsilon = 1 - \exp\left[\frac{NTU^{0.22}}{C_r}\left(e^{-C_r NTU^{0.78}} - 1\right)\right]$$

$$\text{cross, } C_{max} \text{ mixed}: \ \varepsilon = \frac{1}{C_r}\left[1 - e^{-C_r(1-e^{-NTU})}\right] \qquad \text{cross, } C_{min} \text{ mixed}: \ \varepsilon = 1 - \exp\left[-\frac{1 - e^{-C_r NTU}}{C_r}\right]$$

$$C_r = 0:\ \varepsilon = 1 - e^{-NTU}\ \text{(all)}, \qquad C_r = 1\ \text{counterflow}:\ \varepsilon = \frac{NTU}{1 + NTU}$$

$$Q = \varepsilon\, C_{min}(T_{h,i} - T_{c,i})$$

Variables

arr	flow arrangement	-
$\dot{m}_h$	hot fluid flow	kg/s
$c_{p,h}$	hot fluid specific heat	J/(kg·K)
$T_{h,i}$	hot inlet temperature	K
$\dot{m}_c$	cold fluid flow	kg/s
$c_{p,c}$	cold fluid specific heat	J/(kg·K)
$T_{c,i}$	cold inlet temperature	K
U	overall coefficient	W/(m²·K)
A	area	m²
C_{min}	smaller heat capacity rate	W/K
C_{max}	larger heat capacity rate	W/K
NTU	number of transfer units	-
C_r	capacity rate ratio	-
$\mathcal{E}$	effectiveness	-
Q	duty	W
$T_{h,o}$	hot outlet temperature	K
$T_{c,o}$	cold outlet temperature	K

Method and standards

Effectiveness is the actual duty over the most the smaller-capacity stream could transfer. For each arrangement it depends only on NTU and C_r, by the relations in Incropera's Table 11.3. The outlet temperatures then follow from energy balances.

Assumptions and limits

- Constant U and specific heats; no phase change except the C_r = 0 case.

References

• ε–NTU relations (Incropera, Fundamentals of Heat and Mass Transfer, Table 11.3)

Report details

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