



Design and performance evaluation of heat exchangers: The effectiveness – N_{TU} method

Part 4: Case studies

Endorsed by
The Institution of Chemical Engineers
The Institution of Mechanical Engineers

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This Data Item is one of a group that supersedes Data Items developed for ESDU under contract by

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(Continued on inside back cover)

DESIGN AND PERFORMANCE EVALUATION OF HEAT EXCHANGERS: THE EFFECTIVENESS - N_{TU} METHOD

PART 4: CASE STUDIES

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DESIGN AND PERFORMANCE EVALUATION OF HEAT EXCHANGERS: THE EFFECTIVENESS - N_{TU} METHOD

PART 4: CASE STUDIES

1. NOTATION AND UNITS

Two sets of self-consistent units are given.

		Units	
		SI	British
A	effective surface area of heat exchanger, see Section 4.1 of Part 1	m^2	ft^2
C^*	thermal capacity ratio, defined in Section 4.2.3 of Part 1	—	—
c_p	specific heat capacity	J/kg K	Btu/lb °F
E	thermal effectiveness, defined in Section 4.2.1 of Part 1	—	—
$\dot{M}$	mass flow rate	kg/s	lb/h
N_{TU}	number of heat transfer units, defined in Section 4.2.2 of Part 1	—	—
$\dot{Q}$	rate of heat transfer between streams (heat load)	W	Btu/h
S	number of identical heat exchangers (shells) in train	—	—
T	stream temperature	K	°F
U	overall heat transfer coefficient	W/m ² K	Btu/h ft ² °F
Δh	latent heat of vaporisation	J/kg	Btu/lb
ΔT	temperature difference between streams	K	°F
x	factor in approximate equation for air stream temperature (see Section 3.4.3)	—	—
Δx	vapour quality	—	—
η	parameter in Equation (3.1)	—	—
<i>Subscripts</i>			
<i>asympt</i>	asymptotic value		
<i>co</i>	co-current flow		
<i>cu</i>	counter-current flow		

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<i>in</i>	value of parameter at inlet to heat exchanger
<i>larger</i>	larger value of parameter in streams
<i>lm</i>	log mean value
<i>m</i>	mean
<i>out</i>	value of parameter at outlet from heat exchanger
<i>smaller</i>	smaller value of parameter in streams
<i>s</i>	refers to value for single shell
<i>total</i>	refers to total value
1	refers to stream number 1 or location 1
2	refers to stream number 2 or location 2

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2. PURPOSE AND SCOPE

This is the fourth of a group of Data Items concerning the effectiveness (E) - number of transfer units (N_{TU}) method for the thermal analysis of two-stream heat exchangers. Its purpose is to illustrate the features and use of the $E - N_{TU}$ method by means of a series of case studies.

Both heat exchanger design and rating are covered by the case studies, which are based around practical applications.

Aspects of the method presented in the Data Items in this group are as follows.

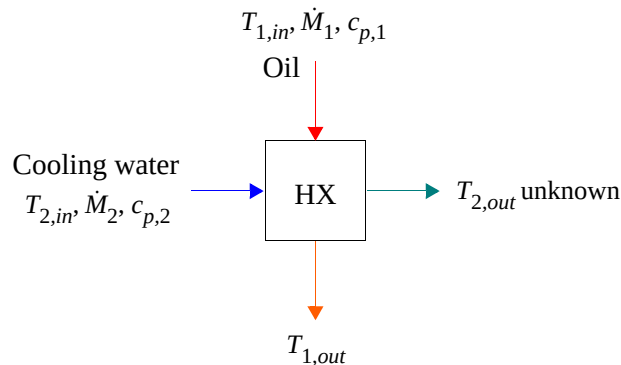
Data Item Number	Title	Description
98003	Part 1. Introduction	Description and overview of the $E-N_{TU}$ method.
98004	Part 2. Performance comparisons and selection of configurations presented in Part 3	Comparative performance and performance limitations of particular heat exchanger configurations.
98005	Part 3. Graphical and analytical data	Data required to use the method. The range of heat exchangers covered includes pure counter-current, pure co-current, crossflow, shell-and-tube and plate heat exchanger configurations.
98006	Part 4. Case studies	Case studies, incorporating all elements of the method presented.
98007	Part 5. Analytical techniques	Numerical and algebraic techniques for relating heat transfer effectiveness, E , to the number of heat transfer units, N_{TU} .

3. CASE STUDIES

3.1 Design Case: Shell-and-tube Exchanger to Cool Oil

3.1.1 Description

A heat exchanger is required to cool a hot oil stream using cooling water. All the inlet flow data are known and the tubeside process stream (hot oil) outlet temperature is known. From this information the $E - N_{TU}$ method is used to select a suitable heat exchanger.



The calculation procedure of Table 7.1 in Part 1 is adapted for this example.

3.1.2 Thermal specification and thermal capacity rates, $\dot{M}c_p$

	Fluid	T_{in} (°C)	T_{out} (°C)	$\dot{M}$ (kg/s)	c_p (kJ/kg K)	$\dot{M}c_p$
Hot stream 1	Oil	125	45	300	2.14	642 kW/K
Cold stream 2	Cooling water	25		809	4.18	3382 kW/K

3.1.3 Unknown terminal temperature, $T_{2,out}$

This temperature can be estimated using Equation (4.1) of Part 1:

$$T_{2,out} = \frac{(\dot{M}c_p)_1}{(\dot{M}c_p)_2} (T_{1,in} - T_{1,out}) + T_{2,in} = 40^\circ\text{C}.$$

3.1.4 Effectiveness, E , and thermal capacity ratio, C^*

These parameters are calculated using Equations (4.11) and (4.16) of Part 1. As the oil stream has the smaller thermal capacity rate, $\dot{M}c_p$, an energy balance shows that it has the larger temperature difference, ΔT , and hence

$$\begin{aligned} \varepsilon &= \frac{|(T_{in} - T_{out})_{\text{larger}}|}{(T_{1,in} - T_{2,in})} = \frac{(T_{1,in} - T_{1,out})}{(T_{1,in} - T_{2,in})} = 0.80, \\ C^* &= \frac{(\dot{M}c_p)_{\text{smaller}}}{(\dot{M}c_p)_{\text{larger}}} = 0.19. \end{aligned}$$