Double-Pipe (Hairpin) Exchanger: Coefficients, Area, Hairpins and Δp

Inner-tube and annulus film coefficients, fouled and clean overall coefficients, area, number of hairpins and pressure drops of a double-pipe heat exchanger.

Input parameters

Unit system: SI

Parameter	Value	Unit
Heat duty	60.000	kW
Mean temperature difference	40.000	K
Inner tube inside diameter	35.100	mm
Inner tube outside diameter	42.200	mm
Outer pipe inside diameter	52.500	mm
Hairpin leg length	6.0000	m
Inner tube wall conductivity	45.000	W/(m·K)
Fouling resistance, inside	1.7600e-04	m²·K/W
Fouling resistance, annulus side	3.5200e-04	m²·K/W
Inner tube flow	5,400.0	kg/h
Inner fluid density	995.00	kg/m³
Inner fluid viscosity	0.80000	mPa·s
Inner fluid conductivity	0.62000	W/(m·K)
Inner fluid Prandtl number	5.4000	
Annulus flow	7,200.0	kg/h
Annulus fluid density	860.00	kg/m³
Annulus fluid viscosity	3.0000	mPa·s
Annulus fluid conductivity	0.13000	W/(m·K)
Annulus fluid Prandtl number	45.000	

Calculated results

Parameter	Value	Unit
Inner tube velocity	1.5580	m/s
Inner Reynolds number	68,015	
Inner film coefficient	5,482.7	W/(m²·K)
Annulus velocity	3.0357	m/s
Annulus Reynolds number (on D_h)	8,963.3	
Annulus film coefficient (on D_e)	362.67	W/(m²·K)
Fouled overall coefficient (outside area)	275.74	W/(m²·K)
Clean overall coefficient	326.48	W/(m²·K)
Required outside area	5.4399	m²
Hairpins required (exact)	3.4194	
Hairpins installed (rounded up)	4.0000	

Parameter	Value	Unit
Inner tube pressure drop (straight lengths)	32.297	kPa
Annulus pressure drop (straight lengths)	599.57	kPa

Notes for this case

- Turbulent Prandtl-type correlation Nu = (f/2)RePr/[1 + 8.7(f/2)^½(Pr − 1)] with f = (1.58 ln Re − 3.28)$^{-2}$, used by for both streams; the annulus uses D_h = D_i − d_o for Re and friction and D_e = (D_i² − d_o²)/d_o for heat transfer. Return bends, inlet and outlet losses are extra.
- One stream has Re below 10,000; the turbulent correlation becomes uncertain.

Formula and method

$$Nu = \frac{(f/2)RePr}{1 + 8.7(f/2)^{1/2}(Pr - 1)}, \quad f = (1.58 \ln Re - 3.28)^{-2}$$

$$\frac{1}{U_f} = \frac{d_o}{d_i h_i} + \frac{d_o R_{fi}}{d_i} + \frac{d_o \ln(d_o/d_i)}{2k_w} + R_{fo} + \frac{1}{h_o}, \quad \Delta p = 4f\frac{2LN_{hp}}{D}\frac{\rho u^2}{2}$$

Variables

Q	Heat duty	W
ΔT_m	Mean temperature difference	K
d_i	Inner tube inside diameter	m
d_o	Inner tube outside diameter	m
D_i	Outer pipe inside diameter	m
L	Hairpin leg length	m
k_w	Inner tube wall conductivity	W/(m·K)
R_{fi}	Fouling resistance, inside	m²·K/W
R_{fo}	Fouling resistance, annulus side	m²·K/W
$\dot{m}_i$	Inner tube flow	kg/s
ρ_i	Inner fluid density	kg/m³
μ_i	Inner fluid viscosity	Pa·s
k_i	Inner fluid conductivity	W/(m·K)
Pr_i	Inner fluid Prandtl number	-
$\dot{m}_a$	Annulus flow	kg/s
ρ_a	Annulus fluid density	kg/m³
μ_a	Annulus fluid viscosity	Pa·s
k_a	Annulus fluid conductivity	W/(m·K)
Pr_a	Annulus fluid Prandtl number	-
u_i	Inner tube velocity	m/s
Re_i	Inner Reynolds number	-
h_i	Inner film coefficient	W/(m²·K)
u_a	Annulus velocity	m/s
Re_a	Annulus Reynolds number (on D_h)	-
h_o	Annulus film coefficient (on D_e)	W/(m²·K)
U_f	Fouled overall coefficient (outside area)	W/(m²·K)
U_c	Clean overall coefficient	W/(m²·K)

A_o	Required outside area	m²
A_o/A_{hp}	Hairpins required (exact)	-
N_{hp}	Hairpins installed (rounded up)	-
Δp_i	Inner tube pressure drop (straight lengths)	Pa
Δp_a	Annulus pressure drop (straight lengths)	Pa

Method and standards

Double-pipe exchanger thermal design.

Assumptions and limits

- Turbulent flow, counterflow, constant properties.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/chemical/process-heat-exchangers/double-pipe-hairpin-exchanger

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.