Shell-and-Tube Exchanger: Shells in Series for a Temperature Cross

Number of 1-2 shells in series needed to keep the LMTD correction factor above a minimum when outlet temperatures cross (Bowman's F).

Method: Bowman; Mueller and Nagle; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Hot fluid in	200.00	°C
Hot fluid out	90.000	°C
Cold fluid in	30.000	°C
Cold fluid out	130.00	°C
Minimum acceptable F	0.80000	

Calculated results

Parameter	Value	Unit
Overall thermal effectiveness (cold side)	0.58824	
Capacity ratio	1.1000	
Shells in series needed	2.0000	
F with N shells	0.87948	
Corrected mean temperature difference	57.053	K

Notes for this case

- One 1-2 shell cannot achieve these temperatures, so F_1 is not shown.

Formula and method

$$P=\frac{t_{c,o}-t_{c,i}}{T_{h,i}-t_{c,i}},\quad R=\frac{T_{h,i}-T_{h,o}}{t_{c,o}-t_{c,i}},\quad P_1=\frac{1-X}{R-X},\quad X=\left(\frac{1-PR}{1-P}\right)^{1/N}$$

$$F=\frac{\sqrt{R^2+1}}{R-1}\frac{\ln\frac{1-P_1}{1-P_1R}}{\ln\frac{2-P_1(R+1-\sqrt{R^2+1})}{2-P_1(R+1+\sqrt{R^2+1})}}$$

Variables

$T_{h,in}$	Hot fluid in	K
$T_{h,out}$	Hot fluid out	K
$T_{c,in}$	Cold fluid in	K
$T_{c,out}$	Cold fluid out	K
F_{min}	Minimum acceptable F	-
P	Overall thermal effectiveness (cold side)	-
R	Capacity ratio	-
F_1	F with one shell	-
N	Shells in series needed	-
F_N	F with N shells	-

$F_N \Delta T_{lm}$	Corrected mean temperature difference	K

Method and standards

Bowman's F for 1-2 shells, applied per shell for N shells in series.

Assumptions and limits

- Each shell one shell pass and an even number of tube passes.
- When one shell cannot reach the temperatures at all, F_1 is not shown and a note says so.

References

• Bowman
• Mueller and Nagle
• Trans. ASME 62: 283 (1940): F for 1-2 shells and N shells in series (Perry's Chemical Engineers' Handbook, 9th ed. (McGraw-Hill, 2019), sec. 11, Fig. 11-4)

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/exchanger-shells-temperature-cross

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Reopens the calculator with the inputs of this report.