Flat-Plate Collector F, F' and FR: Useful Gain and Outlet Temperature

Fin efficiency, collector efficiency factor, flow factor and heat removal factor of a tube-and-sheet collector, with useful gain, outlet temperature and efficiency.

Input parameters

Unit system: SI

Parameter	Value	Unit
Overall loss coefficient	4.5000	W/(m²·K)
Tube spacing	100.00	mm
Tube outside diameter	12.000	mm
Tube inside diameter	10.000	mm
Plate (fin) thickness	0.40000	mm
Plate conductivity (copper 385, aluminium 211)	211.00	W/(m·K)
Bond conductance per unit length (0 = perfect bond)	30.000	W/m
Heat transfer coefficient inside the tubes	1,000.0	W/(m²·K)
Collector area	2.5000	m²
Fluid flow through the collector	0.020000	kg/s
Fluid specific heat	4.1800	kJ/(kg·K)
Absorbed solar radiation per unit area	700.00	W/m²
Incident radiation on the collector (for efficiency)	900.00	W/m²
Fluid inlet temperature	50.000	°C
Ambient temperature	25.000	°C

Calculated results

Parameter	Value	Unit
Fin parameter	7.3019	1/m
Fin efficiency	96.696	%
Collector efficiency factor	94.404	%
Collector flow factor	93.909	%
Heat removal factor	88.654	%
Useful gain	1,302.1	W
Useful gain per unit area	520.84	W/m²
Outlet temperature	65.575	°C
Collector efficiency	57.871	%

Notes for this case

• Hottel–Whillier–Bliss analysis for a sheet-and-tube absorber with uniform flow; F' depends on geometry and h_fi, F'' only on the capacitance ratio ṁc_p/(A_c U_L F').

Formula and method

$$F=\frac{\tanh[m(W-D)/2]}{m(W-D)/2},\quad m=\sqrt{\frac{U_L}{k\delta}},\quad F'=\frac{1/U_L}{W\left[\frac{1}{U_L[D+(W-D)F]}+\frac{1}{C_b}+\frac{1}{\pi D_i h_{fi}}\right]}$$

$$F_R=F'F''=\frac{\dot{m}c_p}{A_cU_L}\left[1-\exp\left(-\frac{A_cU_LF'}{\dot{m}c_p}\right)\right],\quad Q_u=A_cF_R[S-U_L(T_i-T_a)]$$

Variables

U_L	Overall loss coefficient	W/(m²·K)
W	Tube spacing	m
D	Tube outside diameter	m
D_i	Tube inside diameter	m
δ	Plate (fin) thickness	m
k	Plate conductivity (copper 385, aluminium 211)	W/(m·K)
C_b	Bond conductance per unit length (0 = perfect bond)	W/m
h_{fi}	Heat transfer coefficient inside the tubes	W/(m²·K)
A_c	Collector area	m²
$\dot{m}$	Fluid flow through the collector	kg/s
c_p	Fluid specific heat	J/(kg·K)
S	Absorbed solar radiation per unit area	W/m²
G_T	Incident radiation on the collector (for efficiency)	W/m²
T_i	Fluid inlet temperature	K
T_a	Ambient temperature	K
m	Fin parameter	1/m
F	Fin efficiency	-
F'	Collector efficiency factor	-
F''	Collector flow factor	-
F_R	Heat removal factor	-
Q_u	Useful gain	W
q_u	Useful gain per unit area	W/m²
T_o	Outlet temperature	K
η	Collector efficiency	-

Method and standards

Hottel–Whillier–Bliss flat-plate collector theory.

Assumptions and limits

- Steady state, uniform flow in parallel tubes, constant U_L.

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/environmental/solar-thermal/flat-plate-collector-heat-removal-factor

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.