Solar Air Heater (Air Under the Absorber): F′, F_R, Outlet Temperature

Useful gain, outlet air temperature and efficiency of a covered solar air heater with the air flowing in a duct behind the absorber, in common practice.

Input parameters

Unit system: SI

Parameter	Value	Unit
Collector width	2.0000	m
Collector length (flow direction)	6.0000	m
Air channel depth	50.000	mm
Radiation on the collector	800.00	W/m²
Effective transmittance–absorptance product	80.000	%
Top loss coefficient	5.5000	W/(m²·K)
Back and edge loss coefficient	0.80000	W/(m²·K)
Emittance of the absorber underside	90.000	%
Emittance of the duct back plate	90.000	%
Inlet air temperature	30.000	°C
Ambient temperature	30.000	°C
Air mass flow	540.00	kg/h
Air specific heat	1.0070	kJ/(kg·K)
Air thermal conductivity	0.026500	W/(m·K)
Air viscosity	0.018600	mPa·s

Calculated results

Parameter	Value	Unit
Overall loss coefficient U_t + U_b	6.3000	W/(m²·K)
Duct Reynolds number	8,064.5	
Air-side coefficient (each duct wall)	5.5868	W/(m²·K)
Radiation coefficient across the duct	5.8790	W/(m²·K)
Collector efficiency factor	57.292	%
Collector flow factor	86.940	%
Heat removal factor	49.810	%
Useful gain	3,825.4	W
Outlet air temperature	55.325	°C
Collector efficiency	39.848	%
Mean air temperature	43.267	°C
Mean absorber temperature	80.987	°C

Notes for this case

- Type (b) air heater: air flows between the absorber and an insulated back plate, with radiation between them; U_t should be taken at the mean absorber temperature (repeat with a new U_t if T_pm differs much from the value assumed).
- Turbulent duct flow: Nu = 0.0158 Re^0.8 (fully developed, one side heated).

Formula and method

$$F' = \left[1 + \frac{U_L}{h + (1/h + 1/h_r)^{-1}}\right]^{-1}, \quad h_r = \frac{4\sigma \bar{T}^3}{1/\varepsilon_1 + 1/\varepsilon_2 - 1}$$

$$F_R = F'F'', \quad F'' = \frac{\dot{m}c_p}{A_c U_L F'}\left[1 - e^{-A_c U_L F'/(\dot{m}c_p)}\right], \quad Q_u = A_c F_R \left[G_T(\tau\alpha) - U_L(T_i - T_a)\right]$$

Variables

W	Collector width	m
L	Collector length (flow direction)	m
d	Air channel depth	m
G_T	Radiation on the collector	W/m²
$(\tau\alpha)$	Effective transmittance–absorptance product	-
U_t	Top loss coefficient	W/(m²·K)
U_b	Back and edge loss coefficient	W/(m²·K)
ε_1	Emittance of the absorber underside	-
ε_2	Emittance of the duct back plate	-
T_i	Inlet air temperature	K
T_a	Ambient temperature	K
$\dot{m}$	Air mass flow	kg/s
c_p	Air specific heat	J/(kg·K)
k	Air thermal conductivity	W/(m·K)
μ	Air viscosity	Pa·s
U_L	Overall loss coefficient U_t + U_b	W/(m²·K)
Re	Duct Reynolds number	-
h	Air-side coefficient (each duct wall)	W/(m²·K)
h_r	Radiation coefficient across the duct	W/(m²·K)
F'	Collector efficiency factor	-
F''	Collector flow factor	-
F_R	Heat removal factor	-
Q_u	Useful gain	W
T_o	Outlet air temperature	K
η	Collector efficiency	-
T_{fm}	Mean air temperature	K
T_{pm}	Mean absorber temperature	K

Method and standards

Hottel–Whillier analysis of an air heater with the duct behind the absorber.

Assumptions and limits

- Steady state; uniform flow; U_t entered for the absorber temperature.

Report details

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This calculator online

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Reopens the calculator with the inputs of this report.