Unglazed Transpired Solar Air Collector: Temperature and Gain

Absorber temperature, useful gain, outlet air temperature and efficiency of a perforated (transpired) solar air heating wall from hole geometry and suction rate.

Method: Kutscher's hole heat transfer correlation with a radiation-only loss and ε-NTU suction heat transfer

Input parameters

Unit system: SI

Parameter	Value	Unit
Collector area	60.000	m^2
Solar radiation on the collector	650.00	W/m^2
Solar absorptance	94.000	%
Infrared emittance	90.000	%
Suction mass flux	108.00	$kg/(m^2 \cdot h)$
Hole diameter	1.6000	mm
Hole pitch (equilateral triangles)	20.000	mm
Ambient temperature	5.0000	°C
Sky temperature	-5.0000	°C
View factor to the ground (0.5 for a vertical wall)	50.000	%
Air density	1.2700	kg/m^3
Air conductivity	0.024500	W/(m·K)
Air specific heat	1.0060	kJ/(kg·K)
Air viscosity	0.017500	mPa·s

Calculated results

Parameter	Value	Unit
Porosity (hole area share)	0.58042	%
Velocity in the holes	4.0698	m/s
Hole Reynolds number	472.57	
Heat transfer coefficient	28.715	$W/(m^2 \cdot K)$
Number of transfer units	0.94593	
Absorber temperature	30.130	°C
Useful gain	27.835	kW
Outlet air temperature	20.372	°C
Collector efficiency	71.372	%

Notes for this case

- Kutscher's correlation Nu_D = 2.75 (P/D)^−1.2 Re_D^0.43 for the plate-to-air coefficient; the absorber loses heat by radiation only (no wind convection, valid at suction fluxes high enough to keep the boundary layer attached).

Formula and method

$$Nu_D = \frac{hD}{k} = 2.75\left(\frac{P}{D}\right)^{-1.2} Re_D^{0.43}, \quad NTU = \frac{h(A_c - A_h)}{\dot{m}c_p}$$

$$\alpha G_T - \varepsilon\sigma\left[F_{c-g}(T_c^4 - T_a^4) + (1 - F_{c-g})(T_c^4 - T_{sky}^4)\right] = \frac{\dot{m}}{A_c} c_p (T_c - T_a)(1 - e^{-NTU})$$

Variables

A_c	Collector area	m²
G_T	Solar radiation on the collector	W/m²
α	Solar absorptance	-
ε	Infrared emittance	-
$\dot{m}/A_c$	Suction mass flux	kg/(m²·s)
D	Hole diameter	m
P	Hole pitch (equilateral triangles)	m
T_a	Ambient temperature	K
T_{sky}	Sky temperature	K
F_{c-g}	View factor to the ground (0.5 for a vertical wall)	-
ρ	Air density	kg/m³
k	Air conductivity	W/(m·K)
c_p	Air specific heat	J/(kg·K)
μ	Air viscosity	Pa·s
σ	Porosity (hole area share)	-
V_h	Velocity in the holes	m/s
Re_D	Hole Reynolds number	-
h	Heat transfer coefficient	W/(m²·K)
NTU	Number of transfer units	-
T_c	Absorber temperature	K
Q_u	Useful gain	W
T_o	Outlet air temperature	K
η	Collector efficiency	-

Method and standards

Energy balance of a perforated absorber with suction and radiative loss.

Assumptions and limits

- Uniform suction; wind effects neglected; steady state.

References

Kutscher's hole heat transfer correlation with a radiation-only loss and ε-NTU suction heat transfer

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/transpired-solar-collector

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Reopens the calculator with the inputs of this report.