Partly Shaded Solar Collector: Gain with Series Flow Through Two Zones

Useful gain of a collector with a shaded and an unshaded zone in series, for flow from the low- to high-irradiance zone or the reverse direction.

Method: Hottel–Whillier gain of two collector zones in series

Input parameters

Unit system: SI

Parameter	Value	Unit
Share of area in zone 1 (entered first by the flow)	30.000	%
Radiation on zone 1	180.00	W/m²
Radiation on zone 2	950.00	W/m²
Transmittance–absorptance product, zone 1	75.000	%
Transmittance–absorptance product, zone 2	85.000	%
Heat removal factor	95.000	%
Heat removal factor times loss coefficient	5.0000	W/(m²·K)
Flow per unit collector area	36.000	kg/(m²·h)
Fluid specific heat	4.1900	kJ/(kg·K)
Inlet temperature	45.000	°C
Ambient temperature	15.000	°C

Calculated results

Parameter	Value	Unit
Zone coupling factor A_2F_RU_L/(ṁc_p)	0.083532	
Useful gain per unit area, flow as entered	426.01	W/m²
Useful gain per unit area with the flow reversed	410.00	W/m²
Gain using the area-average radiation	425.46	W/m²
Temperature leaving zone 1	44.844	°C
Collector outlet temperature	55.167	°C

Notes for this case

- The two zones share F_R and U_L; the second zone sees the warmer outlet of the first. The difference between flow directions is usually small, and an area-average radiation gives nearly the same answer.

Formula and method

$$Q_u = A_1 F_R (\tau\alpha)_1 (1-K) G_{T,1} + A_2 F_R (\tau\alpha)_2 G_{T,2} - F_R U_L [A_1(1-K) + A_2](T_i - T_a)$$

$$K = \frac{A_2 F_R U_L}{\dot{m} c_p}$$

Variables

A_1/A	Share of area in zone 1 (entered first by the flow)	-
$G_{T,1}$	Radiation on zone 1	W/m²
$G_{T,2}$	Radiation on zone 2	W/m²

$(\tau\alpha)_1$	Transmittance–absorptance product, zone 1	-
$(\tau\alpha)_2$	Transmittance–absorptance product, zone 2	-
F_R	Heat removal factor	-
$F_R U_L$	Heat removal factor times loss coefficient	W/(m²·K)
$\dot{m}/A$	Flow per unit collector area	kg/(m²·s)
c_p	Fluid specific heat	J/(kg·K)
T_i	Inlet temperature	K
T_a	Ambient temperature	K
K	Zone coupling factor A_2F_RU_L/(ṁc_p)	-
Q_u/A	Useful gain per unit area, flow as entered	W/m²
$Q_u/A\ (reversed)$	Useful gain per unit area with the flow reversed	W/m²
$Q_u/A\ (average)$	Gain using the area-average radiation	W/m²
$T_{o,1}$	Temperature leaving zone 1	K
T_o	Collector outlet temperature	K

Method and standards

Series zones of one collector at different irradiance.

Assumptions and limits

- Same F_R and U_L for both zones; steady state.

References

Hottel–Whillier gain of two collector zones in series

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

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/partially-shaded-collector

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Reopens the calculator with the inputs of this report.