Uninsulated Stack or Duct: Wall Temperature and Heat Loss

Wall temperature, heat loss and exit gas temperature of an uninsulated steel stack or round duct, from gas flow, wind and emissivity.

Method: Ganapathy; Steam Plant Calculations Manual; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Gas flow	49,895	kg/h
Gas inlet temperature	210.00	°C
Inside diameter	1,219.2	mm
Wall thickness	25.400	mm
Length (height)	15.240	m
Ambient temperature	21.110	°C
Wind speed	0.50800	m/s
Outer surface emissivity	90.000	%
Gas viscosity	0.024000	cP
Gas thermal conductivity	0.035000	W/(m·K)
Gas specific heat	1.0800	kJ/(kg·K)

Calculated results

Parameter	Value	Unit
Gas-side coefficient	24.652	W/(m²·K)
Wall temperature (average)	125.19	°C
Heat loss per outer area	1,915.1	W/m²
Total heat loss	116.45	kW
Gas outlet temperature	202.22	°C

Notes for this case

- Wall below about 140 °C: check against the acid dew point of the flue gas; consider insulation.
- Steel wall resistance neglected; one segment. Split a tall stack into segments for accuracy.

Formula and method

$$q = \sigma\varepsilon(T_w^4 - T_a^4) + 1.947(T_w - T_a)^{1.25}\sqrt{\frac{196.85V + 69}{69}}, \quad (T_g - T_w)h_c\frac{d_i}{d_o} = q$$

$$h_c = 0.023Re^{0.8}Pr^{0.4}\frac{k}{d_i}, \quad T_{g2} = T_{g1} - \frac{q\pi d_o H}{Wc_p}$$

Variables

W	Gas flow	kg/s
T_{g1}	Gas inlet temperature	K
d_i	Inside diameter	m
t	Wall thickness	m
H	Length (height)	m

T_a	Ambient temperature	K
V	Wind speed	m/s
ε	Outer surface emissivity	-
μ	Gas viscosity	Pa·s
k	Gas thermal conductivity	W/(m·K)
c_p	Gas specific heat	J/(kg·K)
h_c	Gas-side coefficient	W/(m²·K)
T_w	Wall temperature (average)	K
q	Heat loss per outer area	W/m²
Q	Total heat loss	W
T_{g2}	Gas outlet temperature	K

Method and standards

Ganapathy's casing-loss equation (radiation plus natural and wind convection, Eq. 106) converted to SI through FireCAD's unit factors, with a Dittus–Boelter gas film (exponent 0.4, as Ganapathy uses). The wall and gas outlet temperatures are solved together over one segment.

Assumptions and limits

- Thin steel wall; single segment; turbulent gas flow (a warning below Re 10 000).
- The Dittus–Boelter exponent 0.4 is the heating form; for gas being cooled the classical exponent is 0.3, about 10 % lower h_c at Pr 0.7, which would give a slightly colder wall. Gas radiation to the wall is neglected.
- The gas must stay above ambient over the length, and the wall and gas temperatures must converge; otherwise the calculation stops and asks for a shorter segment.

References

• Ganapathy
• Steam Plant Calculations Manual
• 2nd ed. (Marcel Dekker, 1993)
• Q4.57 (stack and duct wall temperature with and without insulation) and Eq. (106) for casing heat loss; gas-side coefficient by Dittus–Boelter

Report details

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Release checks	2 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/boilers-power-plant/emissions-stacks/stack-wall-temperature-uninsulated

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.