Fire-Tube or Waste-Heat Boiler: Gas Outlet Temperature

Gas outlet temperature, duty and tube length for a target outlet of a fire-tube or waste-heat boiler pass (Dittus–Boelter convection plus non-luminous gas radiation, constant water temperature).

Method: Dittus–Boelter Nu = 0.023 Re^0.8 Pr^0.3 (cooling); constant wall temperature T_out = T_s + (T_in − T_s) e^{−NTU} (Incropera); non-luminous gas radiation; Ganapathy; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Gas flow (all tubes)	20.000	t/h
Tubes in the pass	120.00	
Tube inside diameter	50.800	mm
Tube length	5.0000	m
Gas inlet temperature	800.00	°C
Water (saturation) temperature	184.00	°C
Target gas outlet temperature	250.00	°C
Gas specific heat	1.1500	kJ/(kg·K)
Gas viscosity (mean)	3.2000e-05	Pa·s
Gas thermal conductivity (mean)	0.050000	W/(m·K)
Water vapour in the gas, volume fraction (= partial pressure, atm) From the flue gas analysis on the wet basis; about 0.18 for natural gas, 0.10 to 0.12 for oil, 0.06 to 0.10 for coal. Enter 0 for both gases to leave radiation out.	12.000	%
CO_2 + SO_2 in the gas, volume fraction (= partial pressure, atm) Wet basis; about 0.09 for natural gas, 0.12 to 0.14 for oil and coal.	10.000	%

Calculated results

Parameter	Value	Unit
Reynolds number	36,261	
Convective coefficient (Dittus–Boelter, cooling)	91.717	W/(m²·K)
Non-luminous radiation coefficient at the gas inlet	6.3986	W/(m²·K)
Non-luminous radiation coefficient at the gas outlet	2.4144	W/(m²·K)
Gas outlet temperature	331.22	°C
Duty	2,995.0	kW
Tube length for the target outlet	7.8516	m

Notes for this case

- Gas radiation is Ganapathy's non-luminous estimate (CO_2 and H_2O, beam length equal to the tube bore, gas near atmospheric pressure); soot or ash would add luminous radiation. Fouling lowers both coefficients in service.

Formula and method

$$Nu = \frac{h_c d_i}{k} = 0.023 Re^{0.8} Pr^{0.3}, \quad h_N = \sigma \varepsilon_g \frac{T^4 - T_s^4}{T - T_s}$$

$$\varepsilon_g = 0.9\left(1 - e^{-K d_i}\right), \quad K = \frac{(0.8 + 1.6 p_w)(1 - 0.38\,T/1000)(p_c + p_w)}{\sqrt{(p_c + p_w) d_i}}$$

$$\dot{m}_1 c_p \frac{dT}{dx} = -(h_c + h_N)\,\pi d_i (T - T_s), \quad L_t = \frac{\dot{m}_1 c_p}{\pi d_i} \int_{T_t}^{T_{in}} \frac{dT}{(h_c + h_N)(T - T_s)}$$

Variables

$\dot{m}_g$	Gas flow (all tubes)	kg/s
$\dot{m}_1$	Gas flow per tube, $\dot{m}_g/n$	kg/s
n	Tubes in the pass	-
d_i	Tube inside diameter, also the radiation beam length	m
L	Tube length	m
x	Distance along the tube	m
T	Local gas temperature	K
T_{in}	Gas inlet temperature	K
T_s	Water (saturation) temperature, taken as the wall temperature	K
T_{target}	Target gas outlet temperature (T_t in the formula)	K
c_p	Gas specific heat	J/(kg·K)
μ	Gas viscosity (mean)	Pa·s
k	Gas thermal conductivity (mean)	W/(m·K)
p_w	Water vapour in the gas, volume fraction (partial pressure in atm)	-
p_c	CO_2 + SO_2 in the gas, volume fraction (partial pressure in atm)	-
K	Attenuation factor of the gas	1/m
ε_g	Gas emissivity	-
σ	Stefan–Boltzmann constant	W/(m²·K⁴)
Re	Reynolds number	-
Pr	Prandtl number	-
Nu	Nusselt number	-
h_c	Convective coefficient (Dittus–Boelter, cooling)	W/(m²·K)
h_N	Non-luminous radiation coefficient	W/(m²·K)
$h_{N,in}$	h_N at the gas inlet	W/(m²·K)
$h_{N,out}$	h_N at the gas outlet	W/(m²·K)
T_{out}	Gas outlet temperature	K
$\dot{Q}$	Duty	W
L_t	Tube length for the target outlet	m

Method and standards

Dittus–Boelter convection inside the tubes plus non-luminous radiation from the CO_2 and H_2O in the gas, by Ganapathy's equations (Industrial Boilers and Heat Recovery Steam Generators, 2003, Q8.07b, Eqs. 26, 28a and 28b), with the beam length equal to the tube bore as Ganapathy gives for fire-tube boilers. The radiation coefficient changes with the gas temperature, so the energy balance is integrated along the tube with the wall at the water saturation temperature.

Assumptions and limits

- Turbulent flow; constant convective properties.
- Non-luminous radiation only. The gas is taken near atmospheric pressure, so the volume fractions equal the partial pressures in atm. Soot or ash would add luminous radiation, which is not included. Enter 0 for both gas fractions to see convection alone.
- Wall at the water saturation temperature; tube-wall, scale and soot resistances are neglected.

References

• Dittus–Boelter Nu = 0.023 Re^0.8 Pr^0.3 (cooling); constant wall temperature T_out = T_s + (T_in − T_s) e^{−NTU} (Incropera); non-luminous gas radiation
• Ganapathy
• Industrial Boilers and HRSGs (2003)

- Q8.07b
- Eqs. 26
- 28a
- 28b

Report details

Report reference	FCC-CDZS-E8R0 (the same inputs always give the same reference)
Generated	17 November 2026, 19:50 UTC
Calculator	Fire-Tube or Waste-Heat Boiler: Gas Outlet Temperature
Method last reviewed	13 November 2026
Software release	FireCAD Calc, release of 17 November 2026
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/boilers-power-plant/furnace-heating-surfaces/fire-tube-gas-outlet-temperature

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.