Boiler Efficiency, Gaseous Fuels (ASME PTC 4)

Indirect-method efficiency of a gas-fired boiler from the fuel gas analysis, excess air, stack and air temperatures: PTC 4 losses and credits on GCV and NCV.

Method: ASME PTC 4-2013 Fired Steam Generators §5.14 and §5.15; NIST Chemistry WebBook (heats of combustion)

Input parameters

Unit system: SI

Parameter	Value	Unit
Methane (CH4)	95.000	%
Ethane (C2H6)	2.5000	%
Propane (C3H8)	0.20000	%
Butane (C4H10)	0	%
Pentane (C5H12)	0	%
Ethylene (C2H4)	0	%
Propylene (C3H6)	0	%
Benzene (C6H6)	0	%
Hydrogen (H2)	0	%
Carbon monoxide (CO)	0	%
Hydrogen sulphide (H2S)	0	%
Water vapour (H2O)	0	%
Carbon dioxide (CO2)	0.60000	%
Nitrogen (N2)	1.7000	%
Oxygen (O2)	0	%
Sulphur dioxide (SO2)	0	%
Excess air	10.000	%
Air humidity (kg water per kg dry air)	0.013000	kg/kg
Combustion air temperature entering the boiler	30.000	°C
Flue gas temperature leaving the boiler (after air heater)	120.00	°C
CO in dry flue gas	20.000	ppm
Surface radiation and convection loss Fraction of fuel input; ABMA curve or measured.	1.0000	%
Unaccounted loss / manufacturer's margin	0.50000	%

Calculated results

Parameter	Value	Unit
Gross calorific value per Nm^3	39,686	kJ/Nm^3
Gross calorific value used	52,882	kJ/kg
Net calorific value	47,696	kJ/kg
Dry gas loss	3.0666	%
Water from hydrogen in fuel	10.526	%
Moisture in fuel	0	%

Parameter	Value	Unit
Moisture in air	0.079287	%
Unburned CO	0.014168	%
Surface radiation and convection	1.00000	%
Unaccounted	0.50000	%
Total losses	15.186	%
Credit: entering dry air above 25 °C	0.17160	%
Credit: moisture in entering air	0.004140	%
Total credits	0.17574	%
Fuel efficiency, gross (HHV) basis	84.989	%
Efficiency, net (LHV) basis	94.230	%

Formula and method

$$L_{dg} = m_{g,dry}\left[h_g(T_g) - h_g(T_{ref})\right] \qquad L_H = m_{H_2O,H}\left[h_v(T_g) - h_f(T_{ref})\right] \qquad L_M = m_{H_2O,f}\left[h_v(T_g) - h_f(T_{ref})\right]$$

$$L_\omega = \omega\, m_a\left[h_v(T_g) - h_v(T_{ref})\right] \qquad L_{CO} = y_{CO}\,\frac{m_{g,dry}}{M_{g,dry}}\,M_{CO}\,\Delta h_{CO}$$

$$B_a = m_a\left[h_{air}(T_a) - h_{air}(T_{ref})\right] \qquad B_\omega = \omega\, m_a\left[h_v(T_a) - h_v(T_{ref})\right] \qquad \eta_{GCV} = 1 - \frac{\sum L}{GCV} + \frac{\sum B}{GCV} \qquad \eta_{NCV} = \eta_{GCV}\frac{GCV}{NCV}$$

Variables

y_{CO}	fuel gas analysis by volume; y_{CO} also names the CO reading in dry flue gas under operating data	–
EA	excess air fraction	–
ω	air humidity, kg water per kg dry air	kg/kg
$T_a\$, \$T_g$	entering air and leaving flue gas temperatures	K
T_{ref}	reference temperature, 298.15 K	K
$m_a\$, \$m_{g,dry}$	actual dry air and dry flue gas per kg fuel	kg/kg
$m_{H_2O,H}\$, \$m_{H_2O,f}$	water formed from hydrogen and water vapour carried in the fuel gas, per kg fuel	kg/kg
$M_{g,dry}\$, \$M_{CO}$	molar mass of dry flue gas and of CO	kg/kmol
$h_g\$, \$h_{air}\$, \$h_v\$, \$h_f$	enthalpies of dry flue gas, air, water vapour and liquid water at 25 °C; h_v is IF97 at 1 psia for water from the fuel and ideal-gas (Shomate) H_2O for the moisture in air	J/kg
Δh_{CO}	heat of burning CO to CO_2, 23.63 MJ/kg	J/kg
GCV_v	gross calorific value per normal cubic metre	J/Nm³
$GCV\$, \$NCV$	gross and net calorific value per kg	J/kg
$L_{dg}\$, \$L_H\$, \$L_M\$, \$L_\omega\$, \$L_{CO}\$, \$L_{rc}\$, \$L_u$	losses: dry gas, water from hydrogen, fuel moisture, air moisture, CO, radiation and convection, unaccounted	–
$\sum L\$, \$\sum B\$, \$B_a\$, \$B_\omega$	total losses, total credits, dry air credit, air moisture credit	–
$\eta_{GCV}\$, \$\eta_{NCV}$	efficiency on the gross and the net basis	–

Method and standards

ASME PTC 4-2013 energy balance method (owner decision 2026-11-09) applied to the mass-basis combustion balance of the gaseous combustion calculator. The heating value is built from the standard molar heats of combustion of the species (NIST) so that fuel, air and losses are consistent; gas enthalpies are integrated from Shomate heat capacities of the actual flue gas; water vapour from the fuel from IF97 at 1 psia, the moisture in air (which stays vapour) from the ideal-gas Shomate H_2O enthalpy. Water vapour already in the fuel gas is charged like fuel moisture, from liquid at 25 °C.

Assumptions and limits

- No residue, no unburned carbon; incomplete combustion appears as CO, which replaces CO_2 in the dry gas (leaving half its oxygen) before the dry gas loss is found.
- Excess air is an input; to find it from a measured O_2 reading use the excess air from O_2 calculator.
- Flue gas temperature above about 39 °C and above the entering air temperature.
- Fuel sensible heat is not credited.

References

• ASME PTC 4-2013 Fired Steam Generators §5.14 and §5.15
• NIST Chemistry WebBook (heats of combustion)

Report details

Report reference	FCC-ZEH6-DCAM (the same inputs always give the same reference)
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Method last reviewed	10 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/boilers/boiler-efficiency-gas

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Reopens the calculator with the inputs of this report.