Boiler Efficiency, Solid and Liquid Fuels (ASME PTC 4)

Indirect-method efficiency of a coal, biomass or oil fired boiler: every PTC 4 loss and credit from the fuel analysis, excess air, stack and air temperatures.

Method: ASME PTC 4-2013 Fired Steam Generators §5.14 (losses) and §5.15 (credits); Channiwala & Parikh (2002) for GCV when not entered

Input parameters

Unit system: SI

Parameter	Value	Unit
Carbon	45.000	%
Hydrogen	3.5000	%
Oxygen	5.0000	%
Nitrogen	1.0000	%
Sulphur	0.50000	%
Ash	35.000	%
Moisture	10.000	%
Gross calorific value, as fired (0 = estimate) Leave 0 to estimate by Channiwala–Parikh.	0	kJ/kg
Excess air	20.000	%
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)	140.00	°C
CO in dry flue gas	150.00	ppm
Unburned carbon in residue, per kg fuel Ash flow × carbon in ash. 0.5 % of fuel is typical for a well-run grate or bed.	0.50000	%
Temperature at which ash leaves 25 °C means the sensible heat in ash is not counted.	25.000	°C
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 used	18,613	kJ/kg
Net calorific value	17,605	kJ/kg
Dry gas loss	4.7298	%
Water from hydrogen in fuel	4.4684	%
Moisture in fuel	1.4287	%
Moisture in air	0.11232	%
Unburned CO	0.13311	%
Unburned carbon in residue	0.90600	%
Sensible heat in residue	0	%
Surface radiation and convection	1.0000	%

Parameter	Value	Unit
Unaccounted	0.50000	%
Total losses	13.278	%
Credit: entering dry air above 25 °C	0.20037	%
Credit: moisture in entering air	0.004835	%
Total credits	0.20521	%
Fuel efficiency, gross (HHV) basis	86.927	%
Efficiency, net (LHV) basis	91.903	%

Formula and method

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

$$L_\omega = \omega\, m_a\left[h_v(T_g) - h_v(T_{ref})\right] \qquad L_{CO} = y_{CO}\frac{m_{g,dry}}{M_{g,dry}} M_{CO}\,\Delta h_{CO} \qquad L_{ub} = C_{ub}\,\Delta h_C \qquad L_r = (A + C_{ub})\,c_{p,r}\,(T_r - T_{ref})$$

$$B_a = m_a\left[h_{air}(T_a) - h_{air}(T_{ref})\right] \qquad B_\omega = \omega\, m_a\left[h_v(T_a) - h_v(T_{ref})\right]$$

$$\eta_{GCV} = 1 - \frac{\sum L}{GCV} + \frac{\sum B}{GCV} \qquad \eta_{NCV} = \eta_{GCV}\frac{GCV}{NCV}$$

Variables

$C\$, \$H\$, \$O\$, \$N\$, \$S\$, \$A\$, \$M$	ultimate analysis as fired, mass fractions	–
GCV_{in}	gross calorific value entered (0 = estimate by Channiwala–Parikh)	J/kg
EA	excess air fraction	–
ω	air humidity, kg water per kg dry air	kg/kg
T_a	combustion air temperature entering the boiler boundary	K
T_g	flue gas temperature leaving the boundary (after the air heater)	K
T_{ref}	reference temperature, 298.15 K (25 °C)	K
y_{CO}	CO in dry flue gas, volume fraction	–
C_{ub}	unburned carbon in residue per kg fuel	kg/kg
T_r	temperature at which residue (ash) leaves	K
$m_a\$, \$m_{g,dry}$	actual dry air and dry flue gas per kg fuel (from the combustion balance)	kg/kg
$m_{H_2O,H}$	water formed from hydrogen per kg fuel	kg/kg
$M_{g,dry}\$, \$M_{CO}$	molar mass of dry flue gas and of CO	kg/kmol
$h_g\$, \$h_{air}$	enthalpy of dry flue gas and of air (Shomate integration)	J/kg
h_v	enthalpy of water vapour: IF97 at 1 psia for the water from fuel hydrogen and moisture; ideal-gas (Shomate) H_2O for the moisture in air	J/kg
h_f	enthalpy of liquid water at 25 °C (IF97)	J/kg
Δh_{CO}	heat of burning CO to CO_2, 10 160 Btu/lb = 23.63 MJ/kg	J/kg
Δh_C	heat of burning carbon to CO_2, 14 500 Btu/lb = 33.73 MJ/kg	J/kg
$c_{p,r}$	mean specific heat of residue, 0.2 Btu/(lb·°F) = 837 J/(kg·K)	J/(kg·K)
$GCV\$, \$NCV$	gross and net calorific value used	J/kg
$L_{dg}\$, \$L_H\$, \$L_M\$, \$L_\omega\$, \$L_{CO}\$, \$L_{ub}\$, \$L_r$	losses: dry gas, water from hydrogen, fuel moisture, air moisture, CO, unburned carbon, residue	–
$L_{rc}\$, \$L_{un}$	radiation and convection, unaccounted (entered as fractions of input)	–
$\sum L\$, \$\sum B$	total losses and total credits, fractions of GCV	–
$B_a\$, \$B_\omega$	credits for entering dry air and its moisture	–

η_{GCV}\$, \$$\eta_{NCV}$	efficiency on the gross and on the net basis	–

Method and standards

The energy balance (indirect) method of ASME PTC 4-2013 (owner decision 2026-11-09): losses and credits referred to 25 °C on the gross calorific value. The combustion balance is the same as in the combustion calculator (exact molar ratios, PTC 4 air). Gas enthalpies are integrated from NIST Shomate heat capacities of the actual flue gas composition rather than taken from a fixed 1.005 kJ/(kg·K); water vapour enthalpy for the water from the fuel comes from IF97 at 1 psia as PTC 4 §5.19.5 specifies; the moisture entering with the air stays vapour throughout, so its loss and credit use the ideal-gas (Shomate) H_2O enthalpy. Radiation and unaccounted losses are entered, as the standard measures or agrees them.

Assumptions and limits

- Steady state, single fuel, no flue gas recirculation or sorbent; fuel sensible heat credit is not included.
- Excess air is an input. To find it from a measured O_2 reading, use the excess air from O_2 calculator first.
- The air is the excess air entered on the full fuel analysis. As in PTC 4, the dry gas is built from the carbon burned: unburned carbon forms no CO_2 and leaves its oxygen in the gas, and the measured CO replaces CO_2 and leaves half its oxygen.
- The flue gas temperature must be above about 39 °C (saturation at 1 psia) and above the entering air temperature.
- Residue sensible heat uses a mean specific heat of 0.2 Btu/(lb·°F) for coal and biomass ash instead of the PTC 4 temperature curve.

References

• ASME PTC 4-2013 Fired Steam Generators §5.14 (losses) and §5.15 (credits)
• Channiwala & Parikh (2002) for GCV when not entered

Report details

Report reference	FCC-6YNF-DTS5 (the same inputs always give the same reference)
Generated	17 November 2026, 19:34 UTC
Calculator	Boiler Efficiency, Solid and Liquid Fuels (ASME PTC 4)
Method last reviewed	11 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

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.