Combustion Air and Flue Gas Flow

Combustion air and flue gas flows for a firing rate: kg/h, Nm³/h and actual m³/h at the fan and duct temperatures, from the fuel analysis and excess air.

Method: ASME PTC 4-2013 (air composition); IUPAC atomic weights

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	%
Fuel firing rate	12,000	kg/h
Excess air	20.000	%
Air humidity (kg water per kg dry air)	0.013000	kg/kg
Air temperature (at the FD fan)	30.000	°C
Flue gas temperature (at the ID fan or duct)	140.00	°C
Pressure in the duct (absolute) Absolute. For a site above sea level use the site barometric pressure.	1.0132	bar

Calculated results

Parameter	Value	Unit
Dry combustion air	89,076	kg/h
Wet combustion air (with its moisture)	90,234	kg/h
Wet air, normal volume (0 °C, 1 atm)	70,368	Nm³/h
Wet air, actual volume at the air temperature	78,096	m³/h
Wet flue gas	98,034	kg/h
Wet flue gas, normal volume	74,712	Nm³/h
Dry flue gas, normal volume	67,108	Nm³/h
Wet flue gas, actual volume at the gas temperature	113,005	m³/h
Dry air per kg of fuel	7.4230	kg/kg
O_2 in dry flue gas (analyser reading)	3.5863	%

Formula and method

$$m_a = \frac{\frac{M_{O_2}}{M_C}C + \frac{M_{O_2}}{2M_{H_2}}H + \frac{M_{O_2}}{M_S}S - O}{w_{O_2}}(1+EA), \quad M_{O_2}=31.998,\ M_C=12.011,\ M_{H_2}=2.016,\ M_S=32.06$$

$$\dot{m}_a = \dot{m}_f m_a \qquad \dot{m}_g = \dot{m}_f(m_{CO_2} + m_{H_2O} + m_{SO_2} + m_{N_2} + m_{O_2})$$

$$\dot{V}_N = \dot{n}\, V_{m,N} \qquad \dot{V} = \dot{n}\,\frac{RT}{p}$$

Variables

$C\$, \$H\$, \$O\$, \$N\$, \$S$	carbon, hydrogen, oxygen, nitrogen, sulphur in the fuel as fired	–
A	ash	–
M	moisture	–
$\dot{m}_f$	fuel firing rate	kg/s
EA	excess air	–
ω	air humidity, kg water per kg dry air	kg/kg
T_a	air temperature at the FD fan	K
T_g	flue gas temperature at the ID fan or duct	K
p	absolute pressure in the duct	Pa
$\dot{m}_a$	dry combustion air	kg/s
$\dot{m}_{a,wet}$	wet combustion air	kg/s
$\dot{V}_{a,N}$	wet air at 0 °C, 101.325 kPa	Nm³/s
$\dot{V}_a$	wet air at the air temperature	m³/s
$\dot{m}_g$	wet flue gas	kg/s
$\dot{V}_{g,N}$	wet flue gas, normal volume	Nm³/s
$\dot{V}_{g,dry,N}$	dry flue gas, normal volume	Nm³/s
$\dot{V}_g$	wet flue gas at the gas temperature	m³/s
m_a	dry air per kg of fuel	kg/kg
$y_{O_2,dry}$	O_2 in dry flue gas, $\frac{m_{O_2}/M_{O_2}}{\dot{n}_{g,dry}/\dot{m}_f}$ (excess oxygen moles over dry gas moles)	–
$m_{CO_2}\$, \$m_{H_2O}\$, \$m_{SO_2}\$, \$m_{N_2}\$, \$m_{O_2}$	flue gas species per kg of fuel: CO_2, water vapour (from hydrogen, fuel moisture and air humidity), SO_2, nitrogen with argon and air CO_2, excess O_2	kg/kg
M_i	molar masses (IUPAC)	kg/kmol
w_{O_2}	mass fraction of O_2 in dry air (23.15 %)	–
$\dot{n}$	molar flow of air or gas	kmol/s
$V_{m,N}$	molar volume at 0 °C, 101.325 kPa (22.414 m³/kmol)	m³/kmol
R	universal gas constant	J/(mol·K)

Method and standards

The mass balance is the same as the combustion calculator: exact molar ratios from IUPAC atomic weights and the ASME PTC 4-2013 air composition, with argon and CO_2 of air carried as "atmospheric nitrogen". Volumes follow from the molar flows: normal volumes with the ideal-gas molar volume at 0 °C and 101.325 kPa (CODATA 2018), actual volumes with the ideal-gas law at the temperature and pressure entered.

Assumptions and limits

- Complete combustion; no CO or unburned carbon.
- Ideal gas; adequate for air and flue gas at duct pressures.
- Air in-leakage between the boiler and the ID fan is not included; raise the excess air to the value at the point considered.
- Fly ash is not part of the gas flow.
- One pressure is used for both the air and the gas volumes; the FD fan discharge is above and the ID fan inlet below atmospheric, so run the calculator once with each pressure for the two fans.
- All the water is treated as vapour; below the water dew point of the gas (a warning appears) the actual gas volume is overstated.
- Normal volumes are at 0 °C and 101.325 kPa; scfm is converted to the US standard cubic foot (60 °F, 14.696 psia).

References

• ASME PTC 4-2013 (air composition)

- IUPAC atomic weights

Report details

Report reference	FCC-BXW5-4XPQ (the same inputs always give the same reference)
Generated	17 November 2026, 19:36 UTC
Calculator	Combustion Air and Flue Gas Flow
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/combustion/combustion-air-flow

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Reopens the calculator with the inputs of this report.