Excess Air from Flue Gas O_2

Excess air and air ratio from the O_2 reading of a flue gas analyser: the quick formula, the exact value for the fuel, and the N_2-balance value with CO_2 and CO.

Method: ASME PTC 4-2013 (air composition, N_2 balance); IUPAC atomic weights

Input parameters

Unit system: SI

Parameter	Value	Unit
O_2 in dry flue gas	4.0000	%
CO in dry flue gas	150.00	ppm
CO_2 in dry flue gas (0 = not measured)	0	%
Carbon	45.000	%
Hydrogen	3.5000	%
Oxygen	5.0000	%
Nitrogen	1.0000	%
Sulphur	0.50000	%
Ash	35.000	%
Moisture	10.000	%

Calculated results

Parameter	Value	Unit
Excess air for this fuel	22.852	%
Air ratio (1 + EA)	1.2285	
Excess air by the quick formula $O_2/(20.95 - O_2)$	23.599	%
CO_2 in dry flue gas at stoichiometric combustion	18.159	%
CO_2 in dry flue gas expected at this O_2	14.699	%

Formula and method

$$EA_s = \frac{O_{2,dry}}{0.2095 - O_{2,dry}}$$

$$O_{2,dry} = \frac{0.2095\,EA\,a}{D_0 + EA\,a} \Rightarrow EA = \frac{O_{2,dry}\,D_0}{a\,(0.2095 - O_{2,dry})} \qquad \lambda = 1 + EA$$

$$a = \frac{1}{0.2095}\left(\frac{C}{12.011} + \frac{H}{4.032} + \frac{S}{32.06} - \frac{O}{31.998}\right) \qquad D_0 = \frac{C}{12.011} + \frac{S}{32.06} + \frac{N}{28.014} + 0.7905\,a$$

$$CO_{2,max} = \frac{C/12.011 + 0.0004\,a}{D_0} \qquad CO_{2,calc} = \frac{C/12.011 + 0.0004\,a\,(1 + EA)}{D_0 + EA\,a}$$

$$EA_{N_2} = \frac{O_{2,dry} - CO_{dry}/2}{\frac{0.2095}{0.7905}\,N_2 - (O_{2,dry} - CO_{dry}/2)} \qquad N_2 = 1 - O_{2,dry} - CO_{2,dry} - CO_{dry}$$

Variables

$O_{2,dry}$	O_2 in dry flue gas, by volume	–

CO_{dry}	CO in dry flue gas	–
$CO_{2,dry}$	CO_2 in dry flue gas (0 = not measured)	–
$C\$, \$H\$, \$O\$, \$N\$, \$S$	carbon, hydrogen, oxygen, nitrogen, sulphur in the fuel as fired	–
A	ash	–
M	moisture	–
EA	excess air for this fuel	–
λ	air ratio	–
EA_s	excess air by the quick formula	–
EA_{N_2}	excess air by the N_2 balance with CO_2 and CO	–
$CO_{2,max}$	CO_2 in dry flue gas at stoichiometric combustion	–
$CO_{2,calc}$	CO_2 in dry flue gas this fuel gives at the O_2 reading	–
a	stoichiometric dry air per kg of fuel	kmol/kg
D_0	dry flue gas per kg of fuel at stoichiometric combustion	kmol/kg
N_2	nitrogen (and argon) in dry flue gas by difference	–

Method and standards

Mole balance on the dry flue gas with exact molar ratios (IUPAC atomic weights) and the ASME PTC 4-2013 air composition (20.95 % O_2, 79.05 % "atmospheric nitrogen" including argon and CO_2). The N_2-balance value is the form of ASME PTC 4-2013 for excess air from a full Orsat-type analysis. For natural gas enter the analysis by mass: methane is 74.9 % carbon and 25.1 % hydrogen.

Assumptions and limits

- Analyser readings on a dry basis (extractive analyser with a cooler). Convert wet readings first with the flue gas analyser converter.
- The fuel-specific value assumes complete combustion; with CO above about 1 000 ppm use the N_2-balance value.
- Air in-leakage upstream of the probe counts as excess air.
- Ash and moisture enter only the check that the analysis sums to 100 %; they do not change the excess air. An invalid analysis blocks all outputs, including the quick formula.
- The fuel-specific value ignores CO; the N_2 balance counts fuel nitrogen and any SO_2 left in the dry gas as air nitrogen, a small error for most fuels.

References

• ASME PTC 4-2013 (air composition, N_2 balance)
• IUPAC atomic weights

Report details

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Release checks	4 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/excess-air-from-o2

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Reopens the calculator with the inputs of this report.