Water‑Vapour Concentration in Lean Combustion Products

# 1 Introduction

This note summarises the equations implemented in the accompanying Python script for estimating the water‑vapour content in the products of complete, lean combustion (φ < 1) of hydrocarbon and oxygenated fuels.

# 2 Stoichiometric oxygen requirement

For a generic fuel CxHyOz, the moles of O2 required for complete combustion per mole of fuel are

a\_st = x + y/4 – z/2

# 3 Equivalence ratio and excess‑air factor

The equivalence ratio is defined as

φ = (F/A)/(F/A)\_st

and its reciprocal is the excess‑air factor λ = 1/φ. Lean combustion corresponds to λ > 1.

# 4 Ideal combustion reaction (lean, complete)

CxHyOz + λ·a\_st (O2 + 3.76 N2) → x CO2 + y/2 H2O + (λ–1)·a\_st O2 + 3.76 λ·a\_st N2

# 5 Water‑vapour mole fraction

n\_H2O = y/2

Total moles N\_tot = n\_H2O + n\_CO2 + n\_O2(excess) + n\_N2

Mole fraction : X\_H2O = n\_H2O / N\_tot

# 6 Water‑vapour mass fraction

Mass\_H2O = n\_H2O · M\_H2O

Total mass = Σ n\_i M\_i (H2O, CO2, O2, N2)

Mass fraction : w\_H2O = Mass\_H2O / Total\_mass

# 7 Example (Jet‑A, φ = 0.24)

Fuel model : C12H23

a\_st = 12 + 23/4 = 17.75 mol O2/mol

λ = 1/0.24 ≈ 4.17

n\_H2O = 11.5, n\_CO2 = 12, n\_O2(excess) = 56.2, n\_N2 = 278.1

N\_tot = 357.8 → X\_H2O ≈ 0.032 (3.2 %)

w\_H2O ≈ 0.020 (2.0 %)

# 8 Assumptions & limitations

* Perfectly complete combustion; no CO, unburned fuel, NOx, SOx.
* Dissociation is neglected (reasonable for φ ≲ 0.5).
* Air composition fixed at 79 % N2 / 21 % O2 by volume.
* Lumped‑formula fuels approximate real blends (Jet‑A, HEFA‑SPK, etc.).