Air Density (Temperature, Humidity, Altitude)

Density of humid air from temperature, relative humidity and site altitude or barometric pressure, with vapour pressure and humidity ratio.

Method: ISO 2533:1975 (standard atmosphere); IAPWS R7-97(2012) IF97 (saturation pressure); …

Input parameters

Unit system: SI

Parameter	Value	Unit
Air temperature (dry bulb)	20.000	°C
Relative humidity	50.000	%
Pressure from	Altitude (ISO 2533 standard atmosphere)	
Site altitude above sea level	0	m
Barometric pressure (absolute)	1.0132	bar

Calculated results

Parameter	Value	Unit
Density of the humid air	1.1989	kg/m³
Density of dry air at the same pressure and temperature	1.2042	kg/m³
Humidity ratio	7.2629	g/kg
Partial pressure of water vapour	1.1696	kPa
Saturation pressure of water	2.3392	kPa
Barometric pressure used	101.33	kPa

Formula and method

$$p_v = \varphi\, p_{sat}(T) \qquad \rho = \frac{(p - p_v)\, M_{da} + p_v\, M_w}{R T} \qquad \rho_{da} = \frac{p\, M_{da}}{R T} \qquad W = \frac{M_w}{M_{da}} \cdot \frac{p_v}{p - p_v}$$

$$p = p_0 \left(1 - \frac{L\, z}{T_0}\right)^{\frac{g\, M_{ISA}}{R^*\, L}}$$

Variables

T	air temperature (dry bulb)	K
φ	relative humidity	–
site	pressure from altitude or entered	–
z	site altitude above sea level	m
p_s	barometric pressure entered	Pa
ρ	density of the humid air	kg/m³
ρ_{da}	density of dry air at the same pressure and temperature	kg/m³
W	humidity ratio, water vapour per kg of dry air	kg/kg
p_v	partial pressure of water vapour	Pa
p_{sat}	saturation pressure of water at T	Pa
p	barometric pressure used	Pa
$M_{da}\$, \$M_w$	molar mass of dry air (about 28.966, computed from the PTC 4 composition) and water (18.015)	kg/kmol
R	universal gas constant, 8.314 462 618	J/(mol·K)

p_0, T_0, L, M_{ISA}, R^*, g	ISO 2533 constants: 101 325 Pa, 288.15 K, 0.0065 K/m, 28.964 42 kg/kmol, 8.314 32 J/(mol·K), 9.806 65 m/s²

Method and standards

Humid air as an ideal mixture of dry air and water vapour (Dalton). Saturation pressure of water from FireCAD's IAPWS-IF97 region 4 equation; dry-air molar mass from the ASME PTC 4-2013 composition with IUPAC atomic weights; site pressure from ISO 2533:1975.

Assumptions and limits

- 0 °C to 100 °C (the IF97 saturation line starts at 0 °C; over ice is not covered).
- Ideal gas, no enhancement factor: the density error is below 0.1 % at atmospheric pressure.
- Standard-atmosphere pressure is a long-term mean; weather moves the actual pressure by ±2 %.

References

• ISO 2533:1975 (standard atmosphere)
• IAPWS R7-97(2012) IF97 (saturation pressure)
• ASME PTC 4-2013 (dry air composition)

Report details

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Release checks	5 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/hvac/psychrometry/air-density

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Reopens the calculator with the inputs of this report.