Air Vision,

Density

The fans curves are generally illustrated with a density equal to 1.2 kg/m³, this value is set for the air at 20°C and at the see level.

Therefore it is needed to adapt those curves when working with different gas or mix, or, if the fan is in an environment with different barometric and temperature conditions.

The main formula to use is :

$$r = r_0 \times \frac{273}{(273+T)} \times \frac{(101300 + P)}{101300}$$

with
r = *Density in the real operating conditions (kg/m³).*
r_0 = *Density of the mix at 0°C and* atmospheric pressure *at the sea level (kg/m³) .*
T = Temperature in the real operating conditions (°C)
P = Pressure in the real operating conditions (Pa)

r_0 *:*
For the air, r_0 = 1.293 kg/m³. For a gas mix, the density will be the right value according the proportion of the several mix contents. Below, for example, a non-exhaustive list of the main gases carried by fans with a density at 0°C and at sea level.

DRY GAS DENSITY AT 0°C AND AT ATMOSPHERIC PRESSURE AT SEA LEVEL

Name of the gazes	***Chemical Formula***	***Density … (kg/m³)***
Air	-	1.2930
Ammonia	NH_3	0.7710
Nitrogen	N_2	1.2507
Chlorine	Cl_2	3.2170
Carbon dioxide	CO_2	1.9760
Hydrogen	H_2	0.0899
Methane	CH_4	0.7170
Carbon monoxide	CO	1.2500
Oxygen	O_2	1.4290
Water vapour	H_2O	0.8040

T :
We will be using indeed the value of the gas temperature at the inlet of the fan. If we should select a fan operating with ambient air at higher altitude than sea level, then we should care about decreasing middle value temperature while we increase the altitude according the table below.

Altitude (m)	***Middle temperature in °C***
1000	12.8
2000	6.6
3000	1
4000	-3.8
5000	-8.3

P :

To define a fan we should take into account:
- The altitude where the fan will be placed. We must replace the value 101300 at the numerator by the following calculated value:

$$101300 \times (1-2.25577.10^{-5}.A)^{5.25588} \qquad \text{with A=Altitude in m,}$$

ex : at 1000 m, and with 12.8°C, the density of the air will be : 1.293 * 273/ (273+12.8) * 89852/101300 = 1.095 kg/m³

- The pressure at the inlet
  For the fans placed at the end of the system (for example an exhaust fan installed at the bottom of a chimney), the influence of the depression at the inlet of the fan might be important. We should then introduce a negative value P corresponding to the depression in the formula.

Ex : At 200°C and at the sea level, a fan which has a 5000 Pa drop pressure at the inlet, will be carrying the air with a density of :: 1.293 x 273 / (273 + 200) x (101300 -5000)/ 101300 = 0.709 kg/m³

- The hygrometry of the air.
  The air is able to absorb the water according the ambient temperature and pressure. We should then follow the table conversion in order to know the correct density of the mix (please see for example: http://www.thermexcel.com/french/tables/massair.htm)

To use a right value of the density is very important and might be explained to you according the following: the pressure (mmwg) which a fan is able to provide is calculated as the next formula:

$$\mathbf{H = \mu . r \quad . w^2 . r^2 / 9.81,} \text{ in which :}$$

--> µ is a coefficient without unit, calculated by the manufacturer during the prototype test, and which includes all the fan geometry (amount, shape and angle of the blades, shape of the spiral, width of the impeller and the casing..)
--> w is the angular rotation speed
--> r is the radius of the impeller
--> 9.81 is the velocity of the gravity

We see that H is directly proportional to r, which shows us that we need to calculate this value with a good accuracy.

By the way, the fan is a machine which « sees » only the m³/h, or in another words, it operates only with effective m³/h. If the flow is expressed in kg/h or Nm³/h, we understand that it is necessary to transform this flow with an effective value and density calculated with enough accuracy.