PROPERTIES OF DRY AIR AT ONE ATMOSPHERE

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by

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Several correlations have been developed to compute the thermodynamic and transport properties of dry air at atmospheric pressure, for the range 200-400 K. A non-linear least squares algorithm is used based on a procedure developed by Marquardt (1963), which combines the Gauss method (Taylor series) and the method of steepest descent. All correlations deviate by less than 0.15% from tabulated values.

Density can be shown to follow a simple inverse relationship (ideal gas) with a small correction term:

$$\rho = \frac{351.99}{T} + \frac{344.84}{T^2} \qquad \left[\frac{kg}{m^3}\right]$$

Sutherland's equation [Reid (1966)] is used to correlate viscosity and thermal conductivity with temperature:

$$\mu = \frac{1.4592\, T^{3/2}}{109.10 + T} \qquad \left[10^{-6}\ \frac{(N \cdot s)}{m^2}\right]$$

$$\kappa = \frac{2.3340 \times 10^{-3}\, T^{3/2}}{164.54 + T} \qquad \left[\frac{W}{(m \cdot K)}\right]$$

Specific heat follows a quadratic relationship:

$$C_p = 1030.5 - 0.19975\, T + 3.9734 \times 10^{-4}\, T^2 \qquad \left[\frac{J}{kg \cdot K}\right]$$

Two groups which appear in the Reynolds and Rayleigh numbers have also been examined:

$$\mathrm{Re}_L = \left(\frac{\rho}{\mu}\right) UL$$

$$\mathrm{Ra}_L = \left(\frac{g\beta}{\nu\alpha}\right) \Delta T L^3$$

where U is the bulk velocity, L is the characteristic length, g is the gravitational acceleration, β is the expansion coefficient, α is the thermal diffusivity and ΔT is the temperature difference. Using the correlations for the individual properties, a general form for these groups was developed, with higher order terms neglected if they did not contribute to the accuracy of the correlation. The final expressions are:

$$\left(\frac{\rho}{\mu}\right) = \frac{2.4090 \times 10^{8}}{T^{3/2}} + \frac{2.6737 \times 10^{10}}{T^{5/2}} \qquad \left[\frac{s}{m^2}\right]$$

$$\frac{g\beta}{\nu\alpha} = \frac{1}{[6.8568 \times 10^{-3} - 1.5079 \times 10^{-4}\, T + 1.5715 \times 10^{-6}\, T^2]^2} \quad \left[\frac{10^6}{(m^3 \cdot K)}\right]$$

The relation for thermal diffusivity is:

$$\alpha = -4.3274 + 4.1190 \times 10^{-2}\, T + 1.5556 \times 10^{-4}\, T^2 \qquad \left[10^{-6}\frac{m^2}{s}\right]$$

Table 1: Properties of Dry Air at One Atmosphere

Density and specific heat are from Hilsenrath (1955); thermal conductivity and viscosity are from Touloukian (1970); other values are calculated.

T $[K]$	ρ $\left[\frac{kg}{m^3}\right]$	μ $\left[10^{-6}\frac{N\cdot s}{m^2}\right]$	κ $\left[10^{-3}\frac{W}{m\cdot K}\right]$	C_p $\left[\frac{J}{kg\cdot K}\right]$	ρ/μ $\left[10^{3}\frac{s}{m^2}\right]$	$g\beta/(\nu\alpha)$ $\left[10^{6}\frac{1}{m^3\cdot K}\right]$	α $\left[10^{-6}\frac{m^2}{s}\right]$
200	1.7690	13.36	18.10	1006.4	132.4	638.6	10.17
210	1.6842	13.92	18.95	1006.1	121.0	505.2	11.18
220	1.6071	14.47	19.80	1005.7	111.1	404.2	12.25
230	1.5368	15.01	20.63	1005.6	102.4	327.0	13.35
240	1.4728	15.54	21.45	1005.5	94.8	267.3	14.49
250	1.4133	16.06	22.26	1005.4	88.0	220.4	15.67
260	1.3587	16.57	23.05	1005.5	82.0	183.3	16.87
270	1.3082	17.07	23.84	1005.5	76.6	153.6	18.12
280	1.2614	17.57	24.61	1005.7	71.8	129.6	19.40
290	1.2177	18.05	25.38	1006.0	67.5	110.1	20.72
300	1.1769	18.53	26.14	1006.3	63.5	94.1	22.07
310	1.1389	19.00	26.87	1006.8	59.9	80.9	23.43
320	1.1032	19.46	27.59	1007.3	56.7	70.0	24.83
330	1.0697	19.92	28.30	1007.9	53.7	60.8	26.25
340	1.0382	20.37	29.00	1008.5	51.0	53.1	27.70
350	1.0086	20.81	29.70	1009.2	48.5	46.5	29.18
360	0.9805	21.25	30.39	1010.0	46.1	41.0	30.69
370	0.9539	21.68	31.07	1010.9	44.0	36.2	32.22
380	0.9288	22.11	31.73	1012.0	42.0	32.1	33.76
390	0.9050	22.52	32.39	1013.0	40.2	28.6	35.33
400	0.8822	22.94	33.05	1014.2	38.5	25.5	36.94

References

1. Hilsenrath et al., 1955, *Tables of Thermal Properties of Gases*, NBS Circular 564.

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4. Touloukian et al., 1970, *Thermophysical Properties of Matter*.