

ATMOSPHERIC DATA FOR PERFORMANCE CALCULATIONS

1. NOTATION AND UNITS

		British	SI
a	speed of sound	ft/s, kn	m/s, kn
H	geopotential height	ft	m
H_p	pressure height	ft	m
l	characteristic length	ft	m
M	Mach Number		
p	pressure	lbf/ft ²	N/m ²
q^*	kinetic pressure for $M = 1$, ($= \rho a^2/2$)	lbf/ft ²	N/m ²
Re^*	Reynolds number at $M = 1$, ($= \frac{\rho a l}{\mu}$)		
T	temperature	K	K
V_e^*	equivalent airspeed for $M = 1$, ($= a\sqrt{\sigma}$)	ft/s, kn	m/s, kn
Z	geometric height	ft	m
δ	relative pressure, p/p_0		
θ	relative temperature, T/T_0		
μ	dynamic viscosity	lbf s/ft ²	N s/m ²
ρ	density	slug/ft ³	kg/m ³
σ	relative density, ρ/ρ_0		
Subscript			
0	Standard (sea level) value		

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2. INTRODUCTION

Properties of the International Standard Atmosphere (Derivation 1) are presented in Tables 8.1, 8.2 and 8.3 of this Data Item and in the Table which is issued as Addendum[†] Item No. 72018. Properties of off-standard atmospheres, which differ in a prescribed way from the Standard, are presented in Table 8.4. The Item is primarily intended for use in aircraft performance calculations and so the parameters tabulated are the ones that are required most frequently in such work. The contents of the tables are described in detail in Sections 4 and 5.

Amendment C makes this Data Item consistent with the International Standard Atmosphere of Derivation 1. To this end the maximum height considered is now 50 km (about 164 000 ft) and, in consequence, for the heights covered there are no significant differences between the data presented here and in References 2, 3, 8 and 10. The opportunity has been taken to include a description of the historical development of the Standard Atmosphere (see Section 4.1). In addition, all equations and numerical constants used in defining the Standard and off-standard atmospheres have been incorporated in Data Item No. 77022 in a form suitable for use in direct calculation of properties of the atmosphere.

Further information on properties of the atmosphere is given in Item No. 77021, in the *Aerodynamics Sub-series*, which gives atmospheric data for heights up to 1 000 km (*i.e.* much greater than herein) and includes values of thermal conductivity and viscosity.

Wind Engineering Sub-series

A number of Items provide information on winds and turbulence at heights up to 1 000 ft:

Volume 1a

82026	Strong winds in the atmospheric boundary layer. Part 1: mean-hourly wind speeds.
83045	Strong winds in the atmospheric boundary layer. Part 2: discrete gust speeds.
74030	Characteristics of atmospheric turbulence near the ground. Part 1: definitions and general information.
85020	Characteristics of atmospheric turbulence near the ground. Part II: single point data for strong winds (neutral atmosphere).
86010	Characteristics of atmospheric turbulence near the ground. Part III: variations in space and time for strong winds (neutral atmosphere).
87034	World-wide extreme wind speeds. Part 1: origins and methods of analysis.
88037	World-wide extreme wind speeds. Part 2: examples using various methods of analysis.

Volume 1b

84011	Wind speed profiles over terrain with roughness changes for flat or hilly sites.
84030	Longitudinal turbulence intensities over terrain with roughness changes for flat or hilly sites.
85003	Computer program for wind speeds and longitudinal turbulence intensity. Flat or hilly sites in terrain with roughness changes.
86035	Integral length scales of turbulence over flat terrain with roughness changes.
87006	Computer program for wind speeds, turbulence intensities and length scales of all wind speed components: flat or hilly sites in terrain with roughness changes.

Noise Sub-Series

78002	Evaluation of the attenuation of sound by a uniform atmosphere.
78003	Evaluation of the attenuation of broad-band sound by a non-uniform still atmosphere.

[†] This addendum constitutes Item No. 72018 and presents the same basic information as Table 8.1 of the present Item. However, while heights are quoted in feet, all other quantities are given in SI units. The reason for issuing such data is that while much engineering work is now conducted in SI units, the international use of the foot for height measurement (and the knot for airspeed) is likely to be maintained for the foreseeable future.

3. HEIGHT UNITS AND SCALES

3.1 Height Units

The Standard Atmosphere of Derivation 1 is defined entirely in terms of SI units but in aircraft performance work there is widespread use of the foot as the unit of measurement for height. This practice is reflected in the Tables given here and in Item No. 72018 in that only Table 8.3 contains data for heights expressed in metres.

3.2 Height Scales

In this Section, brief definitions are given of the height scales commonly in use.

Geometric Height, Z

Geometric (or tape line) height is the vertical distance between a point and some datum level. In aircraft performance work it is normally confined to the context of ground clearance and is used to define the height of, for example, buildings and mountains. The use of geopotential height (see below) has advantages in the calculation of aircraft performance, and so information has not been presented directly in terms of geometric height in this Item.

Geopotential Height, H

This is the (geometric) height, in a uniform gravitational field, which would give the same potential energy as the point under consideration in the actual (variable) gravity field. Thus, if the standard value of gravity, g_0 , is used in conjunction with geopotential height in calculating energy height (see Item No. 90012), the variation of gravity with height is automatically taken into account. This results in a considerable simplification of the performance equations.

The following table presents the relationship between geopotential height, H , and geometric height, Z , for the height ranges considered in this Item.

H m	Z m	H ft	Z ft	H ft	Z ft
0	0	0	0	110 000	110 583
5 000	5 004	5 000	5 001	120 000	120 695
10 000	10 016	10 000	10 005	130 000	130 816
15 000	15 035	20 000	20 019	140 000	140 946
20 000	20 063	30 000	30 043	150 000	151 087
25 000	25 099	40 000	40 077	160 000	161 237
30 000	30 142	50 000	50 120	170 000	171 397
35 000	35 194	60 000	60 173		
40 000	40 253	70 000	70 236		
45 000	45 321	80 000	80 308		
50 000	50 396	90 000	90 390		
55 000	55 480	100 000	100 482		

Pressure Height, H_p

The Standard Atmosphere defines a unique relationship between pressure and geopotential height. The geopotential height in the Standard Atmosphere can therefore be considered as a scale of pressure and this is used in the concept of pressure height. The pressure height at a point in any atmosphere (Standard or off-standard – see Section 5) is the height in the Standard Atmosphere giving the same pressure.

4. THE INTERNATIONAL STANDARD ATMOSPHERE

4.1 Development of the International Standard Atmosphere

The International Standard Atmosphere defined in Derivation 1 is the culmination of many years work and represents the latest stage in a continuing process of definition. Standard Atmospheres were originally developed in the 1920's in the United States by the National Advisory Committee on Aeronautics (NACA) and in Europe by the International Committee on Aerial Navigation (ICAN). There were slight differences between these two independently-derived atmospheres. These were reconciled and international uniformity was achieved through the publication by the International Civil Aviation Organization (ICAO) in 1954 of a new International Standard Atmosphere for heights up to 20 km. Work on extending this atmosphere was undertaken by the US Committee on Extension to the Standard Atmosphere (COESA) and one of the results of this work was the US Standard Atmosphere, 1962 (Reference 2) which included data up to 700 km. In 1964 the data of Reference 2 for heights up to 32 km were adopted by ICAO (Reference 3) to supersede the 1954 ICAO Atmosphere. Reference 10 is the result of further work by COESA and contains atmospheric data up to 1000 km. For heights below 51 km the equations and constants used to define the data in References 2 and 10 are identical although differences exist at greater heights. In 1975 the International Organization for Standardization (ISO) adopted a Standard Atmosphere (Derivation 1) which covers heights up to 80 km. For heights below 50 km (*i.e.* the height range covered by this Data Item) the atmosphere defined in Derivation 1 is termed "International Standard Atmosphere" and is in close agreement[†] with the atmospheres defined in References 2, 3 and 10. For heights between 50 and 80 km the atmosphere defined in Derivation 1 is termed "Interim Standard Atmosphere" and is in close agreement with that given in Reference 10 for these heights. It is thought unlikely that there will be an early revision of the "Interim" atmosphere.

4.2 Tables of Properties of the International Standard Atmosphere

The International Standard Atmosphere is a mean with respect to latitude, annual variation and solar activity. In this Item values of T , θ , $\sqrt{\theta}$, p , δ , $\sqrt{\delta}$, ρ , σ , $\sqrt{\sigma}$, a , V_e^* , q^* and Re^*/l in the Standard Atmosphere are tabulated for the following combinations of heights and units.

Table	Range of geopotential height	Height interval	Units for atmospheric data
8.1	– 2 000 to 104 987 ft	200 ft	British
8.2	104 987 to 164 000 ft	1 000 ft	British
8.3	– 500 to 50 000 m	500 m	SI
See Addendum Item No. 72018	– 2 000 to 104 987 ft	200 ft	SI

[†] See Item No. 77022 for a discussion of the sources of minor discrepancies (*i.e.* in sixth and occasionally fifth significant figures of calculated values).

The data presented in Tables 8.1, 8.2, 8.3 and in Addendum Item No. 72018 are based on the model of the earth's atmosphere defined in Derivation 1 (see also Item No. 77022). In this model the atmosphere is assumed to consist of air which is static with respect to the earth and the air is assumed to be a perfect gas consisting of neutral particles in chemical equilibrium and to be free from moisture, water vapour and dust. Atmospheric properties are defined by a temperature-height profile which consists of a series of connected segments in each of which temperature varies linearly with height. The user should consult Item No. 77022 for the equations, temperature gradients and defining constants used in computing the properties of the International Standard Atmosphere.

5. OFF-STANDARD ATMOSPHERES

The off-standard atmospheric data presented in Table 8.4 have been obtained by adjusting, *in a prescribed way*, the model used in computing properties of the International Standard Atmosphere. The temperature in these off-standard atmospheres is defined in terms of pressure height since this results in a convenient form for general use. The temperature profile is constructed by adding a constant increment to the temperature at each height in the Standard Atmosphere. Thus, on a day when the sea-level temperature is 10 K above standard, the temperature at each pressure height is taken as 10 K above the value given in Table 8.1.

Table 8.4 gives values of H_p , T , θ , $\sqrt{\theta}$, p , δ , $\sqrt{\delta}$, ρ , σ , $\sqrt{\sigma}$, a , V_e^* , q^* and Re^*/l , in British Units. The off-standard conditions included are: (ISA ± 5), (ISA ± 10) and (ISA + 15) K from – 2 000 to 36 000 ft and (ISA – 15), (ISA + 20), (ISA + 30) K from – 2 000 to 20 000 ft.

6. ALTERNATIVE OFF-STANDARD ATMOSPHERES

There are many situations and applications where the above approach to an off-standard atmosphere is not appropriate. This Section gives guidance on other methods of representing the wide variety of temperature conditions occurring in nature.

6.1 Mean Monthly Atmospheres

An atmosphere may be defined for a specific latitude and/or period of the year. Good examples are contained in References 6 in which mean monthly atmospheres (generally January and July) are given for latitudes: 15, 30, 45, 60, and 75 degrees North.

6.2 Probabilistic Atmospheres

Instead of using average temperatures to define an atmosphere, point temperatures that occur at a specified frequency may be used. In Reference 7, point temperatures are given for four frequencies of occurrence (10 days per year, 5 days per year, 1 day per year and 1 day per 10 years) for latitudes 0, 20, 30, 50, 70, 80 and 90 degrees North.

References 4 and 5 give comprehensive surveys of temperatures experienced on air routes and at major airports. Temperatures are given for a number of frequencies of occurrence during monthly, quarterly and annual periods.

6.3 Design Atmospheres

Design atmospheres are closely related to probabilistic atmospheres. An assessment is made of frequency with which temperatures outside the design range may be permitted to occur. On the basis of these considerations, temperature profiles are constructed to represent the extreme conditions for which a product must be designed. A typical set of design atmospheres is given in References 8.

7. DERIVATION AND REFERENCES

Derivation

1. – *Standard Atmosphere (Identical with the ICAO and WMO Standard Atmospheres from –2 to 32 km)*. International Organization for Standardization, ISO 2533, 1975.

References

2. – *US Standard Atmosphere, 1962*. US Committee on Extension to the Standard Atmosphere. US Government Printing Office, 1962.
3. – *Manual of the ICAO Standard Atmosphere*. International Civil Aviation Organization Document 7488/2, 1964.
4. BARR, N.M.
HANSEN, E.M. World en-route temperatures; en-route temperatures for subsonic and supersonic cruise altitudes over world air routes. The Boeing Company, Rep. D6-15650-2, Vol. 1, 1967.
5. BARR, N.M.
HANSEN, E.M. World en-route temperatures; en-route temperatures for subsonic and supersonic cruise altitudes over North American air routes. The Boeing Company, Rep. D6-15650-2, Vol. 2, 1967.
6. – *US Standard Atmosphere Supplements, 1966*. US Committee on Extension to the Standard Atmosphere. US Government Printing Office, 1967.
7. – TSS Standard No. 1-10, general and definitions, including atmospheric conditions. British Aircraft Corporation/Sud-Aviation. Issue 2, May 1972.
8. – *British Civil Airworthiness Requirements*. Chapter D1-2, CAA Airworthiness Division, August 1974.
9. – Conversion factors and tables. British Standards Institution, B.S.350: Part 1: 1974.
10. – *US Standard Atmosphere, 1976*. US Committee on Extension to the Standard Atmosphere. US Government Printing Office, 1976.

8. TABLES

Tables 8.1 to 8.3 present data for the International Standard Atmosphere and Table 8.4 provides data for off-standard atmospheres.



TABLE 8.1 – INTERNATIONAL STANDARD ATMOSPHERE (–2 000 to 104 987 ft)

H ft	T K	θ	$\sqrt{\theta}$	p lbf/ft ²	δ	$\sqrt{\delta}$	ρ slugs/ft ³	σ	$\sqrt{\sigma}$	a ft/s	a kn	V^* ft/s	V^* kn	q* lbf/ft ²	(Re*/l) × 10 ⁻⁶ 1/ft
– 2 000	292.11	1.013 75	1.006 85	2 273.7	1.074 42	1.036 54	0.002 519 1	1.059 85	1.029 49	1 124.1	666.01	1 157.2	685.65	1 591.6	7.497
– 1 800	291.72	1.012 38	1.006 17	2 257.5	1.066 78	1.032 85	0.002 504 6	1.053 74	1.026 52	1 123.3	665.56	1 153.1	683.21	1 580.3	7.457
– 1 600	291.32	1.011 00	1.005 49	2 241.5	1.059 19	1.029 17	0.002 490 2	1.047 66	1.023 55	1 122.6	665.11	1 149.0	680.77	1 569.0	7.417
– 1 400	290.92	1.009 63	1.004 80	2 225.5	1.051 64	1.025 49	0.002 475 8	1.041 61	1.020 59	1 121.8	664.65	1 144.9	678.34	1 557.8	7.377
– 1 200	290.53	1.008 25	1.004 12	2 209.6	1.044 13	1.021 83	0.002 461 5	1.035 59	1.017 64	1 121.0	664.20	1 140.8	675.92	1 546.7	7.337
– 1 000	290.13	1.006 88	1.003 43	2 193.8	1.036 67	1.018 17	0.002 447 2	1.029 59	1.014 69	1 120.3	663.75	1 136.7	673.50	1 535.7	7.297
– 800	289.73	1.005 50	1.002 75	2 178.1	1.029 25	1.014 52	0.002 433 0	1.023 62	1.011 74	1 119.5	663.30	1 132.7	671.08	1 524.7	7.257
– 600	289.34	1.004 13	1.002 06	2 162.5	1.021 87	1.010 88	0.002 418 9	1.017 68	1.008 80	1 118.8	662.84	1 128.6	668.67	1 513.7	7.218
– 400	288.94	1.002 75	1.001 37	2 147.0	1.014 54	1.007 24	0.002 404 8	1.011 76	1.005 86	1 118.0	662.39	1 124.5	666.27	1 502.9	7.179
– 200	288.55	1.001 38	1.000 69	2 131.6	1.007 25	1.003 62	0.002 390 8	1.005 87	1.002 93	1 117.2	661.93	1 120.5	663.87	1 492.1	7.140
0	288.15	1.000 00	1.000 00	2 116.2	1.000 00	1.000 00	0.002 376 9	1.000 00	1.000 00	1 116.5	661.48	1 116.5	661.48	1 481.3	7.101
200	287.75	0.998 62	0.999 31	2 101.0	0.992 79	0.996 39	0.002 363 0	0.994 16	0.997 08	1 115.7	661.02	1 112.4	659.09	1 470.7	7.062
400	287.36	0.997 25	0.998 62	2 085.8	0.985 63	0.992 79	0.002 349 2	0.988 35	0.994 16	1 114.9	660.57	1 108.4	656.71	1 460.1	7.023
600	286.96	0.995 87	0.997 94	2 070.7	0.978 51	0.989 20	0.002 335 4	0.982 56	0.991 24	1 114.1	660.11	1 104.4	654.33	1 449.5	6.985
800	286.57	0.994 50	0.997 25	2 055.8	0.971 43	0.985 61	0.002 321 7	0.976 80	0.988 33	1 113.4	659.66	1 100.4	651.96	1 439.0	6.947
1 000	286.17	0.993 12	0.996 56	2 040.9	0.964 39	0.982 03	0.002 308 1	0.971 06	0.985 43	1 112.6	659.20	1 096.4	649.59	1 428.6	6.909
1 200	285.77	0.991 75	0.995 87	2 026.0	0.957 39	0.978 46	0.002 294 5	0.965 35	0.982 52	1 111.8	658.74	1 092.4	647.23	1 418.2	6.871
1 400	285.38	0.990 37	0.995 18	2 011.3	0.950 43	0.974 90	0.002 281 0	0.959 67	0.979 63	1 111.1	658.29	1 088.4	644.88	1 407.9	6.833
1 600	284.98	0.989 00	0.994 48	1 996.7	0.943 52	0.971 35	0.002 267 6	0.954 01	0.976 74	1 110.3	657.83	1 084.5	642.53	1 397.7	6.795
1 800	284.58	0.987 62	0.993 79	1 982.1	0.936 64	0.967 80	0.002 254 2	0.948 38	0.973 85	1 109.5	657.37	1 080.5	640.18	1 387.5	6.758
2 000	284.19	0.986 25	0.993 10	1 967.7	0.929 81	0.964 27	0.002 240 9	0.942 77	0.970 97	1 108.7	656.91	1 076.6	637.84	1 377.4	6.720
2 200	283.79	0.984 87	0.992 41	1 953.3	0.923 02	0.960 74	0.002 227 6	0.937 19	0.968 09	1 108.0	656.46	1 072.6	635.51	1 367.3	6.683
2 400	283.40	0.983 50	0.991 71	1 939.0	0.916 26	0.957 22	0.002 214 4	0.931 64	0.965 21	1 107.2	656.00	1 068.7	633.18	1 357.3	6.646
2 600	283.00	0.982 12	0.991 02	1 924.8	0.909 55	0.953 70	0.002 201 2	0.926 10	0.962 34	1 106.4	655.54	1 064.8	630.85	1 347.4	6.609
2 800	282.60	0.980 75	0.990 33	1 910.7	0.902 88	0.950 20	0.002 188 2	0.920 60	0.959 48	1 105.7	655.08	1 060.8	628.54	1 337.5	6.572
3 000	282.21	0.979 37	0.989 63	1 896.6	0.896 24	0.946 70	0.002 175 1	0.915 12	0.956 62	1 104.9	654.62	1 056.9	626.22	1 327.6	6.536
3 200	281.81	0.978 00	0.988 94	1 882.7	0.889 65	0.943 21	0.002 162 2	0.909 66	0.953 76	1 104.1	654.16	1 053.0	623.91	1 317.9	6.500
3 400	281.41	0.976 62	0.988 24	1 868.8	0.883 09	0.939 73	0.002 149 3	0.904 23	0.950 91	1 103.3	653.70	1 049.2	621.61	1 308.2	6.463
3 600	281.02	0.975 25	0.987 55	1 855.0	0.876 58	0.936 26	0.002 136 4	0.898 82	0.948 06	1 102.5	653.24	1 045.3	619.31	1 298.5	6.427
3 800	280.62	0.973 87	0.986 85	1 841.3	0.870 10	0.932 79	0.002 123 6	0.893 44	0.945 22	1 101.8	652.78	1 041.4	617.02	1 288.9	6.391
4 000	280.23	0.972 50	0.986 15	1 827.7	0.863 66	0.929 33	0.002 110 9	0.888 09	0.942 38	1 101.0	652.32	1 037.6	614.73	1 279.4	6.355
4 200	279.83	0.971 12	0.985 46	1 814.2	0.857 26	0.925 88	0.002 098 2	0.882 75	0.939 55	1 100.2	651.86	1 033.7	612.45	1 269.9	6.320
4 400	279.43	0.969 75	0.984 76	1 800.7	0.850 90	0.922 44	0.002 085 6	0.877 45	0.936 72	1 099.4	651.40	1 029.9	610.18	1 260.5	6.284
4 600	279.04	0.968 37	0.984 06	1 787.3	0.844 58	0.919 01	0.002 073 0	0.872 16	0.933 90	1 098.7	650.93	1 026.0	607.91	1 251.1	6.249
4 800	278.64	0.967 00	0.983 36	1 774.0	0.838 29	0.915 58	0.002 060 5	0.866 90	0.931 08	1 097.9	650.47	1 022.2	605.64	1 241.8	6.214
5 000	278.24	0.965 62	0.982 66	1 760.8	0.832 05	0.912 17	0.002 048 1	0.861 67	0.928 26	1 097.1	650.01	1 018.4	603.38	1 232.6	6.179
5 200	277.85	0.964 25	0.981 96	1 747.7	0.825 84	0.908 76	0.002 035 7	0.856 46	0.925 45	1 096.3	649.55	1 014.6	601.12	1 223.4	6.144
5 400	277.45	0.962 87	0.981 26	1 734.6	0.819 67	0.905 36	0.002 023 4	0.851 27	0.922 65	1 095.5	649.08	1 010.8	598.87	1 214.2	6.109
5 600	277.06	0.961 50	0.980 56	1 721.6	0.813 53	0.901 96	0.002 011 1	0.846 11	0.919 84	1 094.7	648.62	1 007.0	596.63	1 205.1	6.075
5 800	276.66	0.960 12	0.979 86	1 708.7	0.807 44	0.898 58	0.001 998 9	0.840 97	0.917 05	1 094.0	648.15	1 003.2	594.39	1 196.1	6.040
6 000	276.26	0.958 75	0.979 16	1 695.9	0.801 38	0.895 20	0.001 986 7	0.835 86	0.914 25	1 093.2	647.69	999.44	592.15	1 187.1	6.006
6 200	275.87	0.957 37	0.978 45	1 683.1	0.795 35	0.891 83	0.001 974 6	0.830 77	0.911 47	1 092.4	647.23	995.68	589.92	1 178.2	5.972
6 400	275.47	0.956 00	0.977 75	1 670.5	0.789 37	0.888 46	0.001 962 6	0.825 70	0.908 68	1 091.6	646.76	991.93	587.70	1 169.3	5.938
6 600	275.07	0.954 62	0.977 05	1 657.9	0.783 42	0.885 11	0.001 950 6	0.820 66	0.905 90	1 090.8	646.30	988.18	585.48	1 160.5	5.904
6 800	274.68	0.953 25	0.976 34	1 645.4	0.777 51	0.881 76	0.001 938 7	0.815 64	0.903 13	1 090.0	645.83	984.44	583.27	1 151.8	5.870
7 000	274.28	0.951 87	0.975 64	1 632.9	0.771 63	0.878 42	0.001 926 8	0.810 64	0.900 36	1 089.3	645.36	980.72	581.06	1 143.1	5.837
7 200	273.89	0.950 50	0.974 93	1 620.6	0.765 79	0.875 09	0.001 915 0	0.805 67	0.897 59	1 088.5	644.90	977.00	578.86	1 134.4	5.803
7 400	273.49	0.949 12	0.974 23	1 608.3	0.759 98	0.871 77	0.001 903 2	0.800 72	0.894 83	1 087.7	644.43	973.29	576.66	1 125.8	5.770
7 600	273.09	0.947 75	0.973 52	1 596.1	0.754 21	0.868 45	0.001 891 5	0.795 80	0.892 08	1 086.9	643.96	969.59	574.46	1 117.3	5.737
7 800	272.70	0.946 37	0.972 82	1 583.9	0.748 48	0.865 15	0.001 879 9	0.790 90	0.889 32	1 086.1	643.50	965.89	572.28	1 108.8	5.704



TABLE 8.1 (continued) – INTERNATIONAL STANDARD ATMOSPHERE

H ft	T °K	θ	√θ	p lbf/ft ²	δ	√δ	ρ slugs/ft ³	σ	√σ	a ft/s	a kn	V _e [*] ft/s	V _e [*] kn	q [*] lbf/ft ²	(Re [*] /l) × 10 ⁻⁶ 1/ft
8 000	272.30	0.945 00	0.972 11	1 571.9	0.742 78	0.861 85	0.001 868 3	0.786 02	0.886 58	1 085.3	643.03	962.21	570.09	1 100.3	5.671
8 200	271.90	0.943 62	0.971 40	1 559.9	0.737 12	0.858 56	0.001 856 7	0.781 16	0.883 83	1 084.5	642.56	958.53	567.92	1 091.9	5.639
8 400	271.51	0.942 25	0.970 69	1 548.0	0.731 49	0.855 27	0.001 845 2	0.776 33	0.881 09	1 083.7	642.09	954.87	565.74	1 083.6	5.606
8 600	271.11	0.940 87	0.969 98	1 536.2	0.725 90	0.852 00	0.001 833 8	0.771 52	0.878 36	1 082.9	641.62	951.21	563.58	1 075.3	5.574
8 800	270.72	0.939 49	0.969 28	1 524.4	0.720 34	0.848 73	0.001 822 4	0.766 73	0.875 63	1 082.1	641.15	947.56	561.41	1 067.1	5.541
9 000	270.32	0.938 12	0.968 57	1 512.7	0.714 81	0.845 47	0.001 811 1	0.761 96	0.872 91	1 081.4	640.69	943.92	559.26	1 058.9	5.509
9 200	269.92	0.936 74	0.967 86	1 501.1	0.709 32	0.842 21	0.001 799 8	0.757 22	0.870 18	1 080.6	640.22	940.29	557.11	1 050.8	5.477
9 400	269.53	0.935 37	0.967 15	1 489.5	0.703 87	0.838 97	0.001 788 6	0.752 50	0.867 47	1 079.8	639.75	936.67	554.96	1 042.7	5.446
9 600	269.13	0.933 99	0.966 43	1 478.1	0.698 45	0.835 73	0.001 777 4	0.747 81	0.864 76	1 079.0	639.28	933.05	552.82	1 034.6	5.414
9 800	268.73	0.932 62	0.965 72	1 466.7	0.693 06	0.832 50	0.001 766 3	0.743 13	0.862 05	1 078.2	638.80	929.45	550.68	1 026.7	5.382
10 000	268.34	0.931 24	0.965 01	1 455.3	0.687 70	0.829 28	0.001 755 3	0.738 48	0.859 35	1 077.4	638.33	925.85	548.55	1 018.7	5.351
10 200	267.94	0.929 87	0.964 30	1 444.1	0.682 38	0.826 07	0.001 744 3	0.733 85	0.856 65	1 076.6	637.86	922.26	546.42	1 010.8	5.320
10 400	267.55	0.928 49	0.963 58	1 432.9	0.677 10	0.822 86	0.001 733 3	0.729 24	0.853 96	1 075.8	637.39	918.68	544.30	1 003.0	5.289
10 600	267.15	0.927 12	0.962 87	1 421.8	0.671 84	0.819 66	0.001 722 4	0.724 66	0.851 27	1 075.0	636.92	915.11	542.19	995.23	5.258
10 800	266.75	0.925 74	0.962 16	1 410.7	0.666 62	0.816 47	0.001 711 6	0.720 09	0.848 58	1 074.2	636.45	911.55	540.08	987.50	5.227
11 000	266.36	0.924 37	0.961 44	1 399.7	0.661 43	0.813 29	0.001 700 8	0.715 55	0.845 90	1 073.4	635.97	907.99	537.97	979.81	5.196
11 200	265.96	0.922 99	0.960 73	1 388.8	0.656 28	0.810 11	0.001 690 0	0.711 03	0.843 23	1 072.6	635.50	904.45	535.87	972.18	5.166
11 400	265.56	0.921 62	0.960 01	1 378.0	0.651 16	0.806 94	0.001 679 4	0.706 53	0.840 56	1 071.8	635.03	900.91	533.77	964.59	5.135
11 600	265.17	0.920 24	0.959 29	1 367.2	0.646 07	0.803 78	0.001 668 7	0.702 06	0.837 89	1 071.0	634.55	897.38	531.68	957.05	5.105
11 800	264.77	0.918 87	0.958 58	1 356.5	0.641 01	0.800 63	0.001 658 1	0.697 61	0.835 23	1 070.2	634.08	893.86	529.60	949.55	5.075
12 000	264.38	0.917 49	0.957 86	1 345.9	0.635 98	0.797 48	0.001 647 6	0.693 17	0.832 57	1 069.4	633.60	890.35	527.52	942.11	5.045
12 200	263.98	0.916 12	0.957 14	1 335.3	0.630 99	0.794 35	0.001 637 1	0.688 76	0.829 92	1 068.6	633.13	886.85	525.44	934.71	5.015
12 400	263.58	0.914 74	0.956 42	1 324.8	0.626 03	0.791 22	0.001 626 7	0.684 37	0.827 27	1 067.8	632.65	883.35	523.37	927.36	4.985
12 600	263.19	0.913 37	0.955 70	1 314.4	0.621 09	0.788 10	0.001 616 3	0.680 01	0.824 62	1 067.0	632.18	879.87	521.31	920.06	4.955
12 800	262.79	0.911 99	0.954 98	1 304.0	0.616 20	0.784 98	0.001 606 0	0.675 66	0.821 98	1 066.2	631.70	876.39	519.25	912.80	4.926
13 000	262.39	0.910 62	0.954 26	1 293.7	0.611 33	0.781 87	0.001 595 7	0.671 33	0.819 35	1 065.4	631.22	872.92	517.19	905.59	4.897
13 200	262.00	0.909 24	0.953 54	1 283.5	0.606 49	0.778 78	0.001 585 5	0.667 03	0.816 72	1 064.6	630.75	869.46	515.14	898.42	4.867
13 400	261.60	0.907 87	0.952 82	1 273.3	0.601 69	0.775 68	0.001 575 3	0.662 75	0.814 09	1 063.8	630.27	866.01	513.10	891.31	4.838
13 600	261.21	0.906 49	0.952 10	1 263.2	0.596 91	0.772 60	0.001 565 1	0.658 49	0.811 47	1 063.0	629.79	862.57	511.06	884.23	4.809
13 800	260.81	0.905 12	0.951 38	1 253.2	0.592 17	0.769 52	0.001 555 1	0.654 24	0.808 85	1 062.2	629.31	859.14	509.02	877.21	4.781
14 000	260.41	0.903 74	0.950 65	1 243.2	0.587 45	0.766 46	0.001 545 0	0.650 02	0.806 24	1 061.4	628.84	855.71	506.99	870.22	4.752
14 200	260.02	0.902 37	0.949 93	1 233.3	0.582 77	0.763 39	0.001 535 1	0.645 83	0.803 63	1 060.5	628.36	852.29	504.97	863.29	4.723
14 400	259.62	0.900 99	0.949 21	1 223.4	0.578 12	0.760 34	0.001 525 1	0.641 65	0.801 03	1 059.7	627.88	848.88	502.95	856.39	4.695
14 600	259.22	0.899 62	0.948 48	1 213.6	0.573 50	0.757 30	0.001 515 2	0.637 49	0.798 43	1 058.9	627.40	845.48	500.93	849.55	4.667
14 800	258.83	0.898 24	0.947 76	1 203.9	0.568 90	0.754 26	0.001 505 4	0.633 35	0.795 84	1 058.1	626.92	842.09	498.93	842.74	4.638
15 000	258.43	0.896 87	0.947 03	1 194.3	0.564 34	0.751 23	0.001 495 6	0.629 24	0.793 24	1 057.3	626.44	838.71	496.92	835.99	4.610
15 200	258.04	0.895 49	0.946 30	1 184.7	0.559 81	0.748 20	0.001 485 9	0.625 14	0.790 66	1 056.5	625.96	835.33	494.92	829.27	4.582
15 400	257.64	0.894 12	0.945 58	1 175.1	0.555 31	0.745 19	0.001 476 2	0.621 07	0.788 08	1 055.7	625.48	831.97	492.93	822.60	4.555
15 600	257.24	0.892 74	0.944 85	1 165.7	0.550 83	0.742 18	0.001 466 6	0.617 01	0.785 50	1 054.9	625.00	828.61	490.94	815.97	4.527
15 800	256.85	0.891 37	0.944 12	1 156.3	0.546 39	0.739 18	0.001 457 0	0.612 98	0.782 93	1 054.1	624.52	825.26	488.95	809.39	4.500
16 000	256.45	0.889 99	0.943 39	1 146.9	0.541 97	0.736 19	0.001 447 4	0.608 96	0.780 36	1 053.3	624.03	821.92	486.97	802.85	4.472
16 200	256.05	0.888 62	0.942 66	1 137.6	0.537 58	0.733 20	0.001 437 9	0.604 97	0.777 80	1 052.4	623.55	818.58	485.00	796.35	4.445
16 400	255.66	0.887 24	0.941 93	1 128.4	0.533 23	0.730 22	0.001 428 5	0.600 99	0.775 24	1 051.6	623.07	815.26	483.03	789.89	4.418
16 600	255.26	0.885 87	0.941 20	1 119.3	0.528 90	0.727 25	0.001 419 1	0.597 04	0.772 68	1 050.8	622.59	811.94	481.06	783.48	4.391
16 800	254.87	0.884 49	0.940 47	1 110.2	0.524 60	0.724 29	0.001 409 7	0.593 11	0.770 13	1 050.0	622.10	808.63	479.10	777.11	4.364
17 000	254.47	0.883 12	0.939 74	1 101.1	0.520 32	0.721 33	0.001 400 4	0.589 19	0.767 59	1 049.2	621.62	805.33	477.15	770.78	4.337
17 200	254.07	0.881 74	0.939 01	1 092.1	0.516 08	0.718 39	0.001 391 2	0.585 30	0.765 05	1 048.4	621.13	802.04	475.20	764.49	4.310
17 400	253.68	0.880 36	0.938 28	1 083.2	0.511 86	0.715 45	0.001 382 0	0.581 42	0.762 51	1 047.5	620.65	798.76	473.25	758.25	4.284
17 600	253.28	0.878 99	0.937 54	1 074.4	0.507 67	0.712 51	0.001 372 8	0.577 57	0.759 98	1 046.7	620.17	795.48	471.31	752.04	4.258
17 800	252.88	0.877 61	0.936 81	1 065.5	0.503 51	0.709 59	0.001 363 7	0.573 73	0.757 45	1 045.9	619.68	792.22	469.38	745.88	4.231



TABLE 8.1 (continued) – INTERNATIONAL STANDARD ATMOSPHERE

H ft	T °K	θ	$\sqrt{\theta}$	p lbf/ft ²	δ	$\sqrt{\delta}$	ρ slugs/ft ³	σ	$\sqrt{\sigma}$	a ft/s	a kn	v^* ft/s	v^* kn	q^* lbf/ft ²	$(Re^*/l) \times 10^{-6}$ 1/ft
18 000	252.49	0.876 24	0.936 08	1 056.8	0.499 38	0.706 67	0.001 354 6	0.569 91	0.754 93	1 045.1	619.19	788.96	467.45	739.76	4.205
18 200	252.09	0.874 86	0.935 34	1 048.1	0.495 28	0.703 76	0.001 345 6	0.566 12	0.752 41	1 044.3	618.71	785.71	465.52	733.68	4.179
18 400	251.70	0.873 49	0.934 61	1 039.5	0.491 20	0.700 86	0.001 336 6	0.562 34	0.749 89	1 043.4	618.22	782.47	463.60	727.63	4.153
18 600	251.30	0.872 11	0.933 87	1 030.9	0.487 15	0.697 96	0.001 327 7	0.558 58	0.747 38	1 042.6	617.74	779.24	461.69	721.63	4.127
18 800	250.90	0.870 74	0.933 13	1 022.4	0.483 12	0.695 07	0.001 318 8	0.554 84	0.744 88	1 041.8	617.25	776.01	459.77	715.67	4.102
19 000	250.51	0.869 36	0.932 40	1 013.9	0.479 13	0.692 19	0.001 310 0	0.551 12	0.742 38	1 041.0	616.76	772.80	457.87	709.75	4.076
19 200	250.11	0.867 99	0.931 66	1 005.5	0.475 16	0.689 32	0.001 301 2	0.547 42	0.739 88	1 040.2	616.27	769.59	455.97	703.87	4.051
19 400	249.71	0.866 61	0.930 92	997.19	0.471 21	0.686 45	0.001 292 4	0.543 74	0.737 39	1 039.3	615.78	766.39	454.07	698.03	4.026
19 600	249.32	0.865 24	0.930 18	988.90	0.467 30	0.683 59	0.001 283 7	0.540 08	0.734 90	1 038.5	615.30	763.20	452.18	692.23	4.000
19 800	248.92	0.863 86	0.929 44	980.67	0.463 41	0.680 74	0.001 275 0	0.536 44	0.732 42	1 037.7	614.81	760.01	450.29	686.47	3.975
20 000	248.53	0.862 49	0.928 70	972.49	0.459 54	0.677 90	0.001 266 4	0.532 81	0.729 94	1 036.8	614.32	756.84	448.41	680.74	3.950
20 200	248.13	0.861 11	0.927 96	964.37	0.455 71	0.675 06	0.001 257 9	0.529 20	0.727 46	1 036.0	613.83	753.67	446.54	675.06	3.926
20 400	247.73	0.859 74	0.927 22	956.31	0.451 89	0.672 23	0.001 249 3	0.525 62	0.724 99	1 035.2	613.34	750.51	444.67	669.41	3.901
20 600	247.34	0.858 36	0.926 48	948.29	0.448 11	0.669 41	0.001 240 9	0.522 05	0.722 53	1 034.4	612.85	747.36	442.80	663.80	3.876
20 800	246.94	0.856 99	0.925 74	940.34	0.444 35	0.666 59	0.001 232 4	0.518 50	0.720 07	1 033.5	612.35	744.22	440.94	658.23	3.852
21 000	246.54	0.855 61	0.924 99	932.43	0.440 61	0.663 79	0.001 224 0	0.514 97	0.717 61	1 032.7	611.86	741.08	439.08	652.70	3.828
21 200	246.15	0.854 24	0.924 25	924.58	0.436 90	0.660 99	0.001 215 7	0.511 45	0.715 16	1 031.9	611.37	737.96	437.23	647.21	3.803
21 400	245.75	0.852 86	0.923 51	916.79	0.433 22	0.658 19	0.001 207 4	0.507 96	0.712 71	1 031.0	610.88	734.84	435.38	641.75	3.779
21 600	245.36	0.851 49	0.922 76	909.05	0.429 56	0.655 41	0.001 199 1	0.504 48	0.710 27	1 030.2	610.39	731.73	433.54	636.33	3.755
21 800	244.96	0.850 11	0.922 02	901.36	0.425 93	0.652 63	0.001 190 9	0.501 02	0.707 83	1 029.4	609.89	728.63	431.70	630.95	3.731
22 000	244.56	0.848 74	0.921 27	893.72	0.422 32	0.649 86	0.001 182 7	0.497 58	0.705 40	1 028.6	609.40	725.54	429.87	625.60	3.708
22 200	244.17	0.847 36	0.920 52	886.13	0.418 73	0.647 10	0.001 174 6	0.494 16	0.702 97	1 027.7	608.91	722.45	428.04	620.29	3.684
22 400	243.77	0.845 99	0.919 78	878.60	0.415 18	0.644 34	0.001 166 5	0.490 76	0.700 54	1 026.9	608.41	719.37	426.22	615.02	3.660
22 600	243.37	0.844 61	0.919 03	871.12	0.411 64	0.641 59	0.001 158 4	0.487 37	0.698 12	1 026.0	607.92	716.31	424.40	609.78	3.637
22 800	242.98	0.843 24	0.918 28	863.69	0.408 13	0.638 85	0.001 150 4	0.484 00	0.695 70	1 025.2	607.42	713.25	422.59	604.58	3.614
23 000	242.58	0.841 86	0.917 53	856.32	0.404 64	0.636 12	0.001 142 5	0.480 65	0.693 29	1 024.4	606.93	710.19	420.78	599.42	3.591
23 200	242.19	0.840 49	0.916 78	848.99	0.401 18	0.633 39	0.001 134 5	0.477 32	0.690 88	1 023.5	606.43	707.15	418.97	594.29	3.568
23 400	241.79	0.839 11	0.916 03	841.72	0.397 74	0.630 67	0.001 126 7	0.474 01	0.688 48	1 022.7	605.93	704.11	417.17	589.20	3.545
23 600	241.39	0.837 74	0.915 28	834.49	0.394 33	0.627 96	0.001 118 8	0.470 71	0.686 08	1 021.9	605.44	701.08	415.38	584.14	3.522
23 800	241.00	0.836 36	0.914 53	827.32	0.390 94	0.625 25	0.001 111 0	0.467 43	0.683 69	1 021.0	604.94	698.06	413.59	579.12	3.499
24 000	240.60	0.834 99	0.913 78	820.19	0.387 57	0.622 55	0.001 103 3	0.464 17	0.681 30	1 020.2	604.44	695.05	411.81	574.13	3.476
24 200	240.20	0.833 61	0.913 02	813.12	0.384 23	0.619 86	0.001 095 6	0.460 92	0.678 91	1 019.3	603.95	692.05	410.03	569.18	3.454
24 400	239.81	0.832 24	0.912 27	806.09	0.380 91	0.617 18	0.001 087 9	0.457 70	0.676 53	1 018.5	603.45	689.05	408.25	564.26	3.431
24 600	239.41	0.830 86	0.911 52	799.12	0.377 62	0.614 50	0.001 080 3	0.454 49	0.674 16	1 017.7	602.95	686.06	406.48	559.38	3.409
24 800	239.02	0.829 49	0.910 76	792.19	0.374 34	0.611 83	0.001 072 7	0.451 29	0.671 78	1 016.8	602.45	683.08	404.72	554.53	3.387
25 000	238.62	0.828 11	0.910 01	785.31	0.371 09	0.609 17	0.001 065 1	0.448 12	0.669 42	1 016.0	601.95	680.11	402.95	549.72	3.365
25 200	238.22	0.826 74	0.909 25	778.48	0.367 86	0.606 52	0.001 057 6	0.444 96	0.667 05	1 015.1	601.45	677.15	401.20	544.93	3.343
25 400	237.83	0.825 36	0.908 49	771.70	0.364 66	0.603 87	0.001 050 2	0.441 82	0.664 69	1 014.3	600.95	674.19	399.45	540.19	3.321
25 600	237.43	0.823 99	0.907 74	764.97	0.361 48	0.601 23	0.001 042 7	0.438 69	0.662 34	1 013.4	600.45	671.24	397.70	535.47	3.299
25 800	237.04	0.822 61	0.906 98	758.28	0.358 32	0.598 60	0.001 035 3	0.435 59	0.659 99	1 012.6	599.95	668.30	395.96	530.79	3.278
26 000	236.64	0.821 23	0.906 22	751.64	0.355 18	0.595 97	0.001 028 0	0.432 50	0.657 64	1 011.7	599.45	665.37	394.22	526.15	3.256
26 200	236.24	0.819 86	0.905 46	745.05	0.352 07	0.593 35	0.001 020 7	0.429 42	0.655 30	1 010.9	598.94	662.45	392.49	521.53	3.235
26 400	235.85	0.818 48	0.904 70	738.51	0.348 97	0.590 74	0.001 013 4	0.426 37	0.652 97	1 010.1	598.44	659.53	390.76	516.95	3.214
26 600	235.45	0.817 11	0.903 94	732.01	0.345 90	0.588 14	0.001 006 2	0.423 33	0.650 63	1 009.2	597.94	656.62	389.04	512.40	3.192
26 800	235.05	0.815 73	0.903 18	725.56	0.342 85	0.585 54	0.000 999 01	0.420 30	0.648 31	1 008.4	597.43	653.72	387.32	507.89	3.171
27 000	234.66	0.814 36	0.902 42	719.15	0.339 83	0.582 95	0.000 991 86	0.417 30	0.645 98	1 007.5	596.93	650.83	385.61	503.40	3.150
27 200	234.26	0.812 98	0.901 66	712.79	0.336 82	0.580 36	0.000 984 75	0.414 30	0.643 66	1 006.7	596.43	647.95	383.90	498.95	3.129
27 400	233.87	0.811 61	0.900 89	706.48	0.333 84	0.577 79	0.000 977 68	0.411 33	0.641 35	1 005.8	595.92	645.07	382.19	494.53	3.109
27 600	233.47	0.810 23	0.900 13	700.21	0.330 88	0.575 22	0.000 970 65	0.408 37	0.639 04	1 005.0	595.42	642.20	380.50	490.14	3.088
27 800	233.07	0.808 86	0.899 37	693.99	0.327 94	0.572 66	0.000 963 66	0.405 43	0.636 73	1 004.1	594.91	639.34	378.80	485.79	3.067