Appendix A **NUMERIC DATA**

A.1 Data on Air

Table A.1

Flow Parameters *versus* Mach Number for Subsonic Flow.

Values from National Advisory Commitee for Aeronautics TN 1428.

After L. Prandtl: *Essentials of Fluid Dynamics*, Blackie & Son, London, 1952.

M	$\frac{p}{p_0}$	$\frac{\rho}{\rho_0}$	$\frac{T}{T_0}$	$\frac{a}{a_0}$	$\frac{A^*}{A}$
0.00	1.0000	1.0000	1.0000	1.0000	0.00000
0.01	0.9999	1.0000	1.0000	1.0000	0.01728
0.02	0.9997	0.9998	0.9999	1.0000	0.03455
0.03	0.9994	0.9996	0.9998	0.9999	0.05181
0.04	0.9989	0.9992	0.9997	0.9998	0.06905
0.05	0.9983	0.9988	0.9995	0.9998	0.08627
0.06	0.9975	0.9982	0.9993	0.9996	0.10350
0.07	0.9966	0.9976	0.9990	0.9995	0.12060
0.08	0.9955	0.9968	0.9987	0.9994	0.13770
0.09	0.9944	0.9960	0.9984	0.9992	0.15480
0.10	0.9930	0.9950	0.9980	0.9990	0.1718
0.11	0.9916	0.9940	0.9976	0.9988	0.1887
0.12	0.9900	0.9928	0.9971	0.9986	0.2056
0.13	0.9883	0.9916	0.9966	0.9983	0.2224
0.14	0.9864	0.9903	0.9961	0.9980	0.2391
0.15	0.9844	0.9888	0.9955	0.9978	0.2557
0.16	0.9823	0.9873	0.9949	0.9974	0.2723
0.17	0.9800	0.9857	0.9943	0.9971	0.2887
0.18	0.9776	0.9840	0.9936	0.9968	0.3051
0.19	0.9751	0.9822	0.9928	0.9964	0.3213
0.20	0.9725	0.9803	0.9021	0.9960	0.3374
0.21	0.9697	0.9783	0.9913	0.9956	0.3534
0.22	0.9668	0.9762	0.9904	0.9952	0.3693
0.23	0.9638	0.9740	0.9895	0.9948	0.3851
0.24	0.9607	0.9718	0.9886	0.9943	0.4007
0.25	0.9875	0.9694	0.9877	0.9938	0.4162
0.26	0.9541	0.9670	0.9867	0.9933	0.4315
0.27	0.9506	0.9645	0.9856	0.9928	0.4467
0.28	0.9470	0.9619	0.9846	0.9923	0.4618
0.29	0.9433	0.9592	0.9835	0.9917	0.4767

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Table A.1
Continuation
Flow Parameters *versus* Mach Number for Subsonic Flow.

M	$\frac{p}{p_0}$	$\frac{\rho}{\rho_0}$	$\frac{T}{T_0}$	$\frac{a}{a_0}$	$\frac{A^*}{A}$
0.30	0.9395	0.9564	0.9823	0.9911	0.4914
0.31	0.9355	0.9535	0.9811	0.9905	0.5059
0.32	0.9315	0.9506	0.9799	0.9899	0.5203
0.33	0.9274	0.9476	0.9787	0.9893	0.5345
0.34	0.9231	0.9445	0.9774	0.9886	0.5486
0.35	0.9188	0.9413	0.9761	0.9880	0.5624
0.36	0.9143	0.9380	0.9747	0.9873	0.5761
0.37	0.9098	0.9347	0.9733	0.9866	0.5896
0.38	0.9052	0.9313	0.9719	0.9859	0.6029
0.39	0.9004	0.9278	0.9705	0.9851	0.6160
0.40	0.8956	0.9243	0.9690	0.9844	0.6289
0.41	0.8907	0.9207	0.9675	0.9836	0.6416
0.42	0.8857	0.9170	0.9659	0.9828	0.6541
0.43	0.8807	0.9132	0.9643	0.9820	0.6663
0.44	0.8755	0.9094	0.9627	0.9812	0.6784
0.45	0.8703	0.9055	0.9611	0.9803	0.6903
0.46	0.8650	0.9016	0.9594	0.9795	0.7019
0.47	0.8596	0.8976	0.9577	0.9786	0.7134
0.48	0.8541	0.8935	0.9560	0.9777	0.7246
0.49	0.8486	0.8894	0.9542	0.9768	0.7356
0.50	0.8430	0.8852	0.9524	0.9759	0.7464
0.51	0.8374	0.8809	0.9506	0.9750	0.7569
0.52	0.8317	0.8766	0.9487	0.9740	0.7672
0.53	0.8259	0.8723	0.9468	0.9730	0.7773
0.54	0.8201	0.8679	0.9449	0.9721	0.7872
0.55	0.8142	0.8634	0.9430	0.9711	0.7968
0.56	0.8082	0.8580	0.9410	0.9701	0.8063
0.57	0.8022	0.8544	0.9390	0.9690	0.8155
0.58	0.7962	0.8498	0.9370	0.9680	0.8244
0.59	0.7901	0.8451	0.9349	0.9669	0.8331
0.60	0.7840	0.8405	0.9328	0.9658	0.8416
0.61	0.7778	0.8357	0.9307	0.9647	0.8499
0.62	0.7716	0.8310	0.9286	0.9636	0.8579
0.63	0.7654	0.8262	0.9265	0.9625	0.8657
0.64	0.7591	0.8213	0.9243	0.9614	0.8732
0.65	0.7528	0.8164	0.9221	0.9603	0.8806
0.66	0.7464	0.8115	0.9199	0.9591	0.8877
0.67	0.7401	0.8066	0.9176	0.9579	0.8945
0.68	0.7338	0.8016	0.9153	0.9567	0.9012
0.69	0.7274	0.7966	0.9131	0.9555	0.9076
0.70	0.7200	0.7916	0.9107	0.9543	0.9138
0.71	0.7145	0.7865	0.9084	0.9531	0.9197
0.72	0.7080	0.7814	0.9061	0.9519	0.9254
0.73	0.7016	0.7763	0.9037	0.9506	0.9309
0.74	0.6951	0.7712	0.9013	0.9494	0.9362

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Table A.1
Continuation
Flow Parameters *versus* Mach Number for Subsonic Flow.

M	$\frac{p}{p_0}$	$\frac{\rho}{\rho_0}$	$\frac{T}{T_0}$	$\frac{a}{a_0}$	$\frac{A^*}{A}$
0.75	0.6886	0.7660	0.8989	0.9481	0.9412
0.76	0.6821	0.7609	0.8964	0.9468	0.9461
0.77	0.6756	0.7557	0.8940	0.9455	0.9507
0.78	0.6690	0.7505	0.8915	0.9442	0.9551
0.79	0.6625	0.7452	0.8890	0.9429	0.9592
0.80	0.6560	0.7400	0.8865	0.9416	0.9632
0.81	0.6495	0.7347	0.8840	0.9502	0.9669
0.82	0.6430	0.7295	0.8815	0.9389	0.9704
0.83	0.6365	0.7242	0.8789	0.9375	0.9737
0.84	0.6300	0.7189	0.8763	0.9361	0.9769
0.85	0.6235	0.7136	0.8737	0.9347	0.9797
0.86	0.6170	0.7083	0.8711	0.9333	0.9824
0.87	0.6106	0.7030	0.8685	0.9319	0.9849
0.88	0.6041	0.6977	0.8659	0.9305	0.9872
0.89	0.5977	0.6924	0.8632	0.9291	0.9893
0.90	0.5913	0.3870	0.8606	0.9277	0.9912
0.91	0.5849	0.6817	0.8579	0.9262	0.9929
0.92	0.5785	0.6764	0.8552	0.9248	0.9944
0.93	0.5721	0.6711	0.8525	0.9233	0.9958
0.94	0.5658	0.6658	0.8498	0.9218	0.9969
0.95	0.5595	0.6604	0.8471	0.9204	0.9979
0.96	0.5532	0.6551	0.8444	0.9189	0.9986
0.97	0.5469	0.6498	0.8416	0.9174	0.9992
0.98	0.5407	0.6445	0.8389	0.9159	0.9997
0.99	0.5345	0.6392	0.8361	0.9144	0.9999
1.00	0.5283	0.6339	0.8333	0.9129	1.0000

Dynamic viscosity of air may be calculated from Sutherland's equation with the Suntherland's constant of 114:

$$\eta_a = 1.709 \cdot 10^{-5} \frac{387.15}{T + 114} \left(\frac{T}{273.15}\right)^{1.5} = 1.4656 \cdot 10^{-6} \frac{T^{1.5}}{T + 114} \tag{A.1}$$

where T is in $^\circ K$ and viscosity in $Pa \cdot s$.

Density of air may be calculated as

$$\rho_a = \frac{378.99725}{T} \tag{A.2}$$

where T is in $^\circ K$ and density in Kg/m^3.

Heat conductivity of air may be calculated from Sutherland's equation with the Sutherland's constant of 114:

$$\lambda_a = 0.0243067\frac{387.15}{T+114}\left(\frac{T}{273.15}\right)^{1.5} = 2.0845 \cdot 10 * -3\frac{T^{1.5}}{T+114} \qquad (A.3)$$

where T is in $°K$ and heat conductivity in $J/(m \cdot °C \cdot s)$.

Heat capacity of air:

$0°C - 1297.91 J/m^3$ $100°C - 1302.09 J/m^3$ $200°C - 1318.84 J/m^3$

$$c_p = 935.44 + 3.1956(T - 273.15)(J/Kg) \qquad (A.4)$$

A.2 Data on Mass Transfer

Table A.2
Coefficients of Diffusion of Air - Solvent. *After* Y. Ohzawa, Y. Nagano, J. Appl. Polymer Sci., **14 (1970)**, 1879.

Solvent	D^0_{as} at $0°C$ cm^2/s	m in eq. 5
Methanol	0.1325	2.0
Ethanol	0.1016	2.0
Water	0.220	1.75
Toluene	0.0709	2.0

$$D_{as} = D^0_{as}\left(\frac{T}{T_{(0)}}\right)^m \qquad (A.5)$$

A.3 Data on Heat of Evaporation

Table A.3
Spacific Heat, Heat of Evaporation and Data for Eqn. 6. *After* Y. Ohzawa, Y. Nagano, J. Appl. Polymer Sci., **14 (1970)**, 1879.

Solvent	C_{ps} at $0°C$ $cal/(mole°C)$	H_s $cal/mole$	T_b $°C$	T_c $°C$	α/k $cal/(mole°C)$
Methanol	15	8450	64.7	240.0	8,1
Ethanol	21	9410	78.5	243.0	9.6
Water	8.6	9717	100	374.2	6.5
Toluene	45	8000	110.6	320.8	11.1
Acetone	20	6950	56.5	235	
DMF	26	8480	153	373	

$$H_s(T) = H_s(0)\left(\frac{T_c - T}{T_c - T_b}\right)^{0,38} \qquad (A.6)$$

where T_b = boiling point; T_c = critical temperature.

A.4 Data on Polymers

Density

Nylon 6

(J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-25.)

Amorphous $\rho_a = 1110 \quad kg/m^3$

Crystalline $\rho_c = 1230$ to $1250 \quad kg/m^3$

Nylon 66

(J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-28.)

Amorphous $\rho_a = 1090 \quad kg/m^3$

Crystalline $\rho_c = 1240 \quad kg/m^3$

Poly(ethylene terephthalate)

(H. W. Starkweather, Jr., P. Zoller, and G. A. Jones, *J. Polymer Sci., Polymer Phys. Ed.*, **21 (1983)**, 295.)

Amorphous $\rho_a = 1185.96\ kg/m^3$ at $261.8°C$

Crystalline $\rho_c = 1385.6\ kg/m^3$ at $261.8°C$

$\rho_c = 1474.9\ kg/m^3$ at room temp.

Polypropylene

Amorphous $\rho_a = 1028.5 - 0.639\,T$ in kg/m^3

T in $°K$

Crystalline $\rho_c = 946\ kg/m^3$ at $22°C$

Equilibrium Melting Point

Nylon 6

(J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-25.)

$T_m^0 = 223$ to $250 \quad °C$

Nylon 66

(J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-28.)

$T_m^0 = 265$ to $270 \quad °C$

Poly(ethylene terephthalate)

(H. W. Starkweather, Jr., P. Zoller, and G. A. Jones, *J. Polymer Sci., Polymer Phys. Ed.*, **21 (1983)**, 295.)

$T_m^0 = 261.8 \pm 0.5 \quad °C$

Polypropylene

Equilibrium melting point is strongly dependent on the stereoregularity and other chain imperfections, therefore it must be determined for any given polymer. Usually T_m^0 ranges from 195 *to* 212 $°C$.

Heat of Fusion

Heat of fusion depends on temperature at which the polymer specimen crystallized, it is on the size of the long period. Values at any given temperature of crystallization may be determined from

$$\Delta H_m = \Delta H_m^0 \left(1 - \frac{T_m^0 - T_m}{T_m^0}\right) \ kJ/kg \tag{A.7}$$

where temperatures in $^\circ K$.

Nylon 6

(J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-25.)$\Delta H_f^0 = 212.98 \quad kJ/kg$

Nylon 66

(J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-28.) $\Delta H_f^0 = 205.45 \quad kJ/kg$

Poly(ethylene terephthalate)

(H. W. Starkweather, Jr., P. Zoller, and G. A. Jones, *J. Polymer Sci., Polymer Phys. Ed.*, **21 (1983)**, 295.)

$\Delta H_f = 129.79 \quad kJ/kg \qquad \Delta S_f = 0.2512 \quad kJl/(kg^\circ C)$

Other values for heat of fusion are quoted between 128.53 and 143.2 kJ/kg.

Polypropylene

Heat of fusion of polypropylene depends on the chain perfection and may be estimated from the equilibrium melting point. The equation has been derived on the basis of this author's work and using the published (J. Brandrup, E. H. Immergut, and W. McDowell, *Polymer Handbook*, John Wiley & Sons, New York, 2nd edition, 1975, pp, III-217, V-25.) .

$\Delta H_f^0 = 0.1320 \cdot T_m^0 + 164.245 \quad kJ/kg$

T in $^\circ C$

Specific Heat

Poly(ethylene terephthalate)

(C. W. Smith and M. Oda, *J. Polymer Sci.*, **20 (1956)**, 37.)

Amorphous $C_p = 1.143 \quad kJ/kg$

Crystalline $C_p = 1.1011 \quad kJ/kg$

Polypropylene

Amorphous $C_p = 0.005694 \cdot T + 1.725 \quad kJ/kg$

Semicrystalline $C_p = 0.00512 \cdot T + 1.5948 \quad kJ/kg$

T in $^\circ C$

Thermal Expansion

Poly(ethylene terephthalate)

P. Zoller and P. Bolli, *J. Macromol. Sci., Phys.*, **B18 (1980)**, 555.

Melt $\beta = 6.55 \cdot 10^{-4} \quad 1/^\circ C$

Thermal Conductivity

Polypropylene

D. Hands, K. Lane, and R. P. Sheldon, *J. Polymer Sci., Symp.*, **No 42 (1973)**, 717; C. L. Choy, *Polymer*, **18 (1977)**, 984.

On introduction into Weber's formula one obtains the temperature dependence of thermal conductivity:

$$\lambda = 1.2925 \cdot 10^{-5} \cdot C_p \cdot M_w^{1/3} \cdot \rho^{4/3} \quad \frac{kJ}{ms^\circ C} \tag{A.8}$$

SUBJECT INDEX