

COMPRESSIBLE AERODYNAMICS

FORMULAS, GRAPHS, TABLES

Do not write on these sheets
Do not forget to return them at the end of the exam

Thermodynamic relations:

Equation of state:

$$p = \rho R T \quad [7.1]$$

For a calorically perfect gas,

$$e = c_v T \quad \text{and} \quad h = c_p T \quad [7.6a \text{ and } b]$$

$$c_p = \frac{\gamma R}{\gamma - 1} \quad [7.9]$$

$$c_v = \frac{R}{\gamma - 1} \quad [7.10]$$

Forms of the first law:

$$\delta q + \delta w = de \quad [7.11]$$

$$T ds = de + p dv \quad [7.18]$$

$$T ds = dh - v dp \quad [7.20]$$

Definition of entropy:

$$ds = \frac{\delta q_{\text{rev}}}{T} \quad [7.13]$$

Also,

$$ds = \frac{\delta q}{T} + ds_{\text{irrev}} \quad [7.14]$$

The second law:

$$ds \geq \frac{\delta q}{T} \quad [7.16]$$

or, for an adiabatic process,

$$ds \geq 0 \quad [7.17]$$

Entropy changes can be calculated from (for a calorically perfect gas)

$$s_2 - s_1 = c_p \ln \frac{T_2}{T_1} - R \ln \frac{p_2}{p_1} \quad [7.25]$$

and

$$s_2 - s_1 = c_v \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1} \quad [7.26]$$

For an isentropic flow,

$$\frac{p_2}{p_1} = \left(\frac{\rho_2}{\rho_1} \right)^\gamma = \left(\frac{T_2}{T_1} \right)^{\gamma/(\gamma-1)} \quad [7.32]$$

General definition of compressibility:

$$\tau = -\frac{1}{v} \frac{dv}{dp} \quad [7.33]$$

For an isothermal process,

$$\tau_T = -\frac{1}{v} \left(\frac{\partial v}{\partial p} \right)_T \quad [7.34]$$

For an isentropic process,

$$\tau_s = -\frac{1}{v} \left(\frac{\partial v}{\partial p} \right)_s \quad [7.35]$$

The governing equations for inviscid, compressible flow are

Continuity:

$$\frac{\partial}{\partial t} \iiint_V \rho dV + \iint_S \rho \mathbf{V} \cdot d\mathbf{S} = 0 \quad [7.39]$$

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \mathbf{V} = 0 \quad [7.40]$$

Momentum:

$$\frac{\partial}{\partial t} \iiint_V \rho \mathbf{V} dV + \iint_S (\rho \mathbf{V} \cdot d\mathbf{S}) \mathbf{V} = - \iint_S p d\mathbf{S} + \iiint_V \rho \mathbf{f} dV \quad [7.41]$$

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x} + \rho f_x \quad [7.42a]$$

$$\rho \frac{Dv}{Dt} = -\frac{\partial p}{\partial y} + \rho f_y \quad [7.42b]$$

$$\rho \frac{Dw}{Dt} = -\frac{\partial p}{\partial z} + \rho f_z \quad [7.42c]$$

Energy:

$$\begin{aligned} \frac{\partial}{\partial t} \iiint_V \rho \left(e + \frac{V^2}{2} \right) dV + \iint_S \rho \left(e + \frac{V^2}{2} \right) \mathbf{V} \cdot d\mathbf{S} \\ = \iiint_V \dot{q} \rho dV - \iint_S p \mathbf{V} \cdot d\mathbf{S} + \iiint_V \rho (\mathbf{f} \cdot \mathbf{V}) dV \end{aligned} \quad [7.43]$$

$$\rho \frac{D(e + V^2/2)}{Dt} = \rho \dot{q} - \nabla \cdot p \mathbf{V} + \rho (\mathbf{f} \cdot \mathbf{V}) \quad [7.44]$$

If the flow is steady and adiabatic, Equations (7.43) and (7.44) can be replaced by

$$h_0 = h + \frac{V^2}{2} = \text{const}$$

Equation of state (perfect gas):

$$p = \rho RT \quad [7.1]$$

Internal energy (calorically perfect gas):

$$e = c_v T \quad [7.6a]$$

The speed of sound in a gas is given by

$$a = \sqrt{\left(\frac{\partial p}{\partial \rho}\right)_s} \quad [8.18]$$

For a calorically perfect gas,

$$a = \sqrt{\frac{\gamma p}{\rho}} \quad [8.23]$$

or

$$a = \sqrt{\gamma R T} \quad [8.25]$$

The speed of sound depends only on the gas temperature.

For a steady, adiabatic, inviscid flow, the energy equation can be expressed as

$$h_1 + \frac{u_1^2}{2} = h_2 + \frac{u_2^2}{2} \quad [8.29]$$

$$c_p T_1 + \frac{u_1^2}{2} = c_p T_2 + \frac{u_2^2}{2} \quad [8.30]$$

$$\frac{a_1^2}{\gamma - 1} + \frac{u_1^2}{2} = \frac{a_2^2}{\gamma - 1} + \frac{u_2^2}{2} \quad [8.32]$$

$$\frac{a^2}{\gamma - 1} + \frac{u^2}{2} = \frac{a_0^2}{\gamma - 1} \quad [8.33]$$

$$\frac{a^2}{\gamma - 1} + \frac{u^2}{2} = \frac{\gamma + 1}{2(\gamma - 1)} a^{*2} \quad [8.35]$$

Total conditions in a flow are related to static conditions via

$$c_p T + \frac{u^2}{2} = c_p T_0 \quad [8.38]$$

$$\frac{T_0}{T} = 1 + \frac{\gamma - 1}{2} M^2 \quad [8.40]$$

$$\frac{p_0}{p} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\gamma/(\gamma - 1)} \quad [8.42]$$

$$\frac{\rho_0}{\rho} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{1/(\gamma - 1)} \quad [8.43]$$

Note that the ratios of total to static properties are a function of local Mach number only. These functions are tabulated in Appendix A.

The basic normal shock equations are

$$\text{Continuity:} \quad \rho_1 u_1 = \rho_2 u_2 \quad [8.2]$$

$$\text{Momentum:} \quad p_1 + \rho_1 u_1^2 = p_2 + \rho_2 u_2^2 \quad [8.6]$$

$$\text{Energy:} \quad h_1 + \frac{u_1^2}{2} = h_2 + \frac{u_2^2}{2} \quad [8.10]$$

These equations lead to relations for changes across a normal shock as a function of upstream Mach number M_1 only:

$$M_2^2 = \frac{1 + [(\gamma - 1)/2]M_1^2}{\gamma M_1^2 - (\gamma - 1)/2} \quad [8.59]$$

$$\frac{\rho_2}{\rho_1} = \frac{u_1}{u_2} = \frac{(\gamma + 1)M_1^2}{2 + (\gamma - 1)M_1^2} \quad [8.61]$$

$$\frac{p_2}{p_1} = 1 + \frac{2\gamma}{\gamma + 1}(M_1^2 - 1) \quad [8.65]$$

$$\frac{T_2}{T_1} = \frac{h_2}{h_1} = \left[1 + \frac{2\gamma}{\gamma + 1}(M_1^2 - 1) \right] \frac{2 + (\gamma - 1)M_1^2}{(\gamma + 1)M_1^2} \quad [8.67]$$

$$s_2 - s_1 = c_p \ln \left\{ \left[1 + \frac{2\gamma}{\gamma + 1}(M_1^2 - 1) \right] \frac{2 + (\gamma - 1)M_1^2}{(\gamma + 1)M_1^2} \right\} \\ - R \ln \left[1 + \frac{2\gamma}{\gamma + 1}(M_1^2 - 1) \right] \quad [8.68]$$

$$\frac{p_{0,2}}{p_{0,1}} = e^{-(s_2 - s_1)/R} \quad [8.73]$$

The normal shock properties are tabulated versus M_1 in Appendix B.

$$M_1^2 = \frac{2}{\gamma - 1} \left[\left(\frac{p_{0,1}}{p_1} \right)^{(\gamma - 1)/\gamma} - 1 \right] \quad [8.74]$$

$$\frac{p_{0,2}}{p_1} = \left[\frac{(\gamma + 1)^2 M_1^2}{4\gamma M_1^2 - 2(\gamma - 1)} \right]^{\gamma/(\gamma - 1)} \frac{1 - \gamma + 2\gamma M_1^2}{\gamma + 1} \quad [8.80]$$

An infinitesimal disturbance in a multidimensional supersonic flow creates a Mach wave which makes an angle μ with respect to the upstream velocity. This angle is defined as the Mach angle and is given by

$$\mu = \sin^{-1} \frac{1}{M} \quad [9.1]$$

Changes across an oblique shock wave are determined by the normal component of velocity ahead of the wave. For a calorically perfect gas, the normal component of the upstream Mach number is the determining factor. Changes across an oblique shock can be determined from the normal shock relations derived in Chapter 8 by using $M_{n,1}$ in these relations, where

$$M_{n,1} = M_1 \sin \beta \quad [9.13]$$

The governing factor in the analysis of a centered expansion wave is the Prandtl-Meyer function $\nu(M)$. The key equation which relates the downstream Mach number M_2 , the upstream Mach number M_1 , and the deflection angle θ is

$$\theta = \nu(M_2) - \nu(M_1) \quad [9.43]$$

The isentropic flow of a calorically perfect gas through a nozzle is governed by the relation

$$\left(\frac{A}{A^*}\right)^2 = \frac{1}{M^2} \left[\frac{2}{\gamma + 1} \left(1 + \frac{\gamma - 1}{2} M^2 \right) \right]^{(\gamma + 1)/(\gamma - 1)} \quad [10.32]$$

This tells us that the Mach number in a duct is governed by the ratio of local duct area to the sonic throat area; moreover, for a given area ratio, there are two values of Mach number that satisfy Equation (10.32)—a subsonic value and a supersonic value.

In a supersonic wind tunnel, the ratio of second throat area to first throat area should be approximately

$$\frac{A_{t,2}}{A_{t,1}} = \frac{p_{0,1}}{p_{0,2}} \quad [10.38]$$

If $A_{t,2}$ is reduced much below this value, the diffuser will choke and the tunnel will unstart.

The pressure coefficient, based on linearized theory, on a surface inclined at a small angle θ to the freestream is

$$C_p = \frac{2\theta}{\sqrt{M_\infty^2 - 1}} \quad [12.15]$$

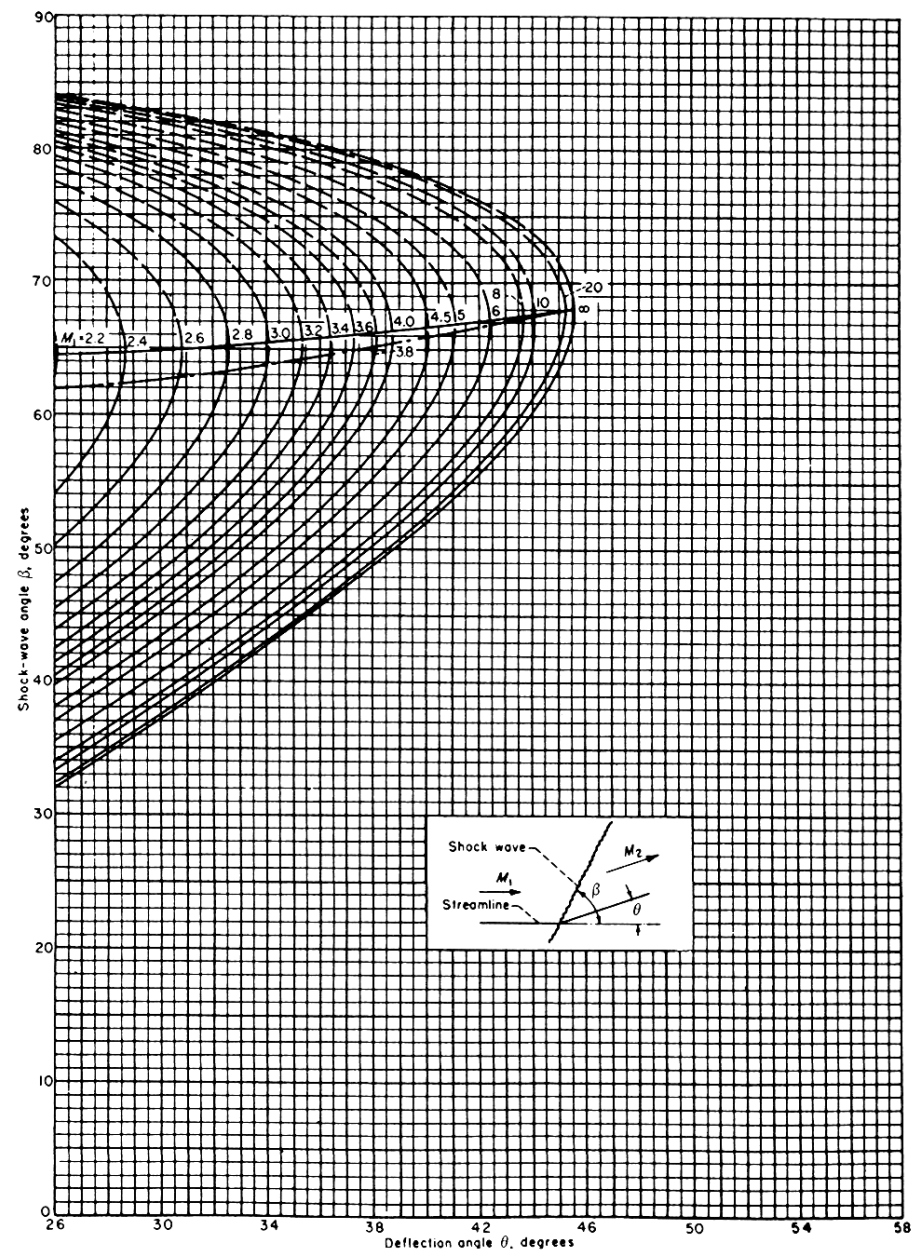
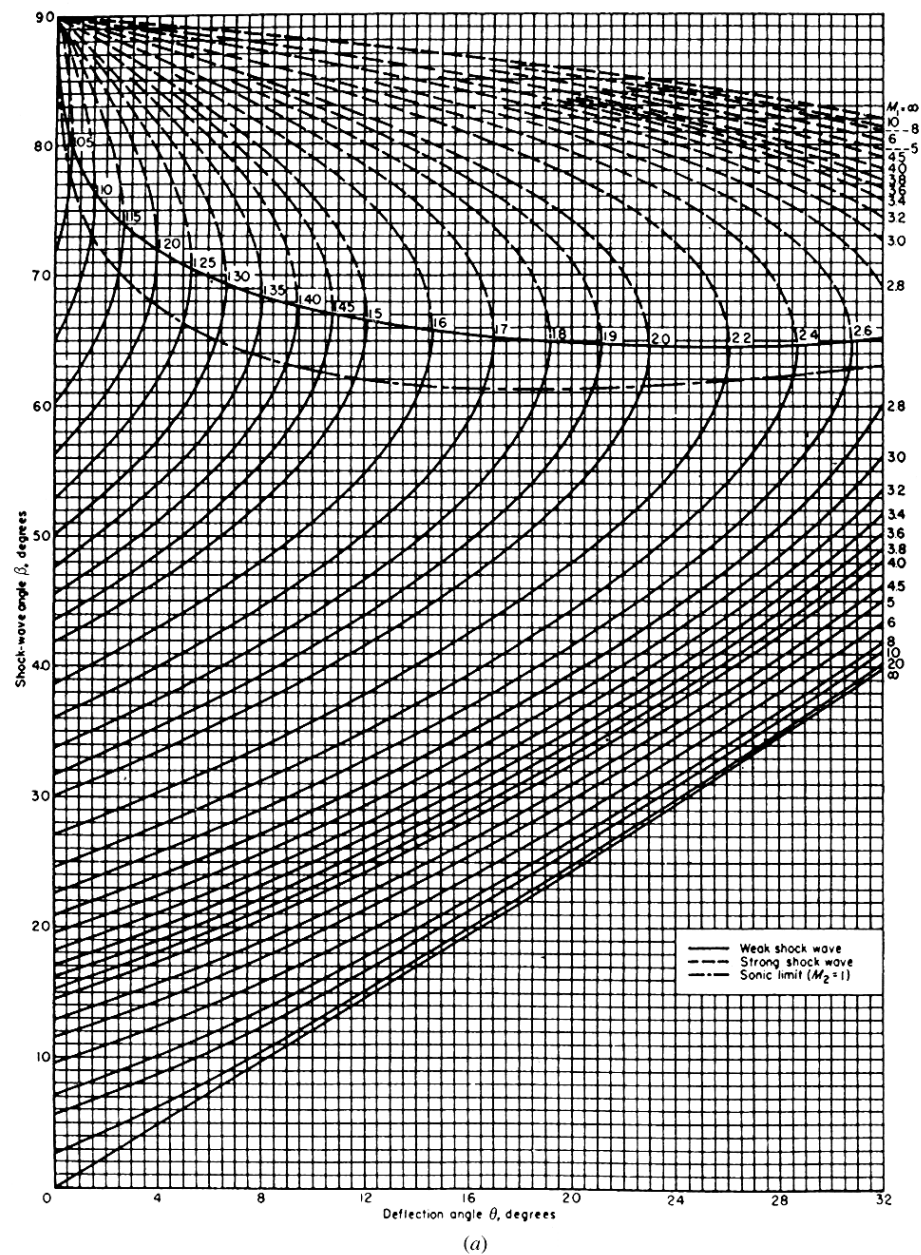
If the surface is inclined into the freestream, C_p is positive; if the surface is inclined away from the freestream, C_p is negative.

Based on linearized supersonic theory, the lift and wave-drag coefficients for a flat plate at an angle of attack are

$$c_l = \frac{4\alpha}{\sqrt{M_\infty^2 - 1}} \quad [12.23]$$

and

$$c_d = \frac{4\alpha^2}{\sqrt{M_\infty^2 - 1}} \quad [12.24]$$



appendix**A****ISENTROPIC FLOW PROPERTIES**

| M | $\frac{p_0}{p}$ | $\frac{\rho_0}{\rho}$ | $\frac{T_0}{T}$ | $\frac{A}{A^*}$ |
|-------------|-----------------|-----------------------|-----------------|-----------------|
| <hr/> | | | | |
| 0.2000 - 01 | 0.1000 + 01 | 0.1000 + 01 | 0.1000 + 01 | 0.2894 + 02 |
| 0.4000 - 01 | 0.1001 + 01 | 0.1001 + 01 | 0.1000 + 01 | 0.1448 + 02 |
| 0.6000 - 01 | 0.1003 + 01 | 0.1002 + 01 | 0.1001 + 01 | 0.9666 + 01 |
| 0.8000 - 01 | 0.1004 + 01 | 0.1003 + 01 | 0.1001 + 01 | 0.7262 + 01 |
| 0.1000 + 00 | 0.1007 + 01 | 0.1005 + 01 | 0.1002 + 01 | 0.5822 + 01 |
| 0.1200 + 00 | 0.1010 + 01 | 0.1007 + 01 | 0.1003 + 01 | 0.4864 + 01 |
| 0.1400 + 00 | 0.1014 + 01 | 0.1010 + 01 | 0.1004 + 01 | 0.4182 + 01 |
| 0.1600 + 00 | 0.1018 + 01 | 0.1013 + 01 | 0.1005 + 01 | 0.3673 + 01 |
| 0.1800 + 00 | 0.1023 + 01 | 0.1016 + 01 | 0.1006 + 01 | 0.3278 + 01 |
| 0.2000 + 00 | 0.1028 + 01 | 0.1020 + 01 | 0.1008 + 01 | 0.2964 + 01 |
| 0.2200 + 00 | 0.1034 + 01 | 0.1024 + 01 | 0.1010 + 01 | 0.2708 + 01 |
| 0.2400 + 00 | 0.1041 + 01 | 0.1029 + 01 | 0.1012 + 01 | 0.2496 + 01 |
| 0.2600 + 00 | 0.1048 + 01 | 0.1034 + 01 | 0.1014 + 01 | 0.2317 + 01 |
| 0.2800 + 00 | 0.1056 + 01 | 0.1040 + 01 | 0.1016 + 01 | 0.2166 + 01 |
| 0.3000 + 00 | 0.1064 + 01 | 0.1046 + 01 | 0.1018 + 01 | 0.2035 + 01 |
| 0.3200 + 00 | 0.1074 + 01 | 0.1052 + 01 | 0.1020 + 01 | 0.1922 + 01 |
| 0.3400 + 00 | 0.1083 + 01 | 0.1059 + 01 | 0.1023 + 01 | 0.1823 + 01 |
| 0.3600 + 00 | 0.1094 + 01 | 0.1066 + 01 | 0.1026 + 01 | 0.1736 + 01 |
| 0.3800 + 00 | 0.1105 + 01 | 0.1074 + 01 | 0.1029 + 01 | 0.1659 + 01 |
| 0.4000 + 00 | 0.1117 + 01 | 0.1082 + 01 | 0.1032 + 01 | 0.1590 + 01 |
| 0.4200 + 00 | 0.1129 + 01 | 0.1091 + 01 | 0.1035 + 01 | 0.1529 + 01 |
| 0.4400 + 00 | 0.1142 + 01 | 0.1100 + 01 | 0.1039 + 01 | 0.1474 + 01 |
| 0.4600 + 00 | 0.1156 + 01 | 0.1109 + 01 | 0.1042 + 01 | 0.1425 + 01 |
| 0.4800 + 00 | 0.1171 + 01 | 0.1119 + 01 | 0.1046 + 01 | 0.1380 + 01 |
| 0.5000 + 00 | 0.1186 + 01 | 0.1130 + 01 | 0.1050 + 01 | 0.1340 + 01 |
| 0.5200 + 00 | 0.1202 + 01 | 0.1141 + 01 | 0.1054 + 01 | 0.1303 + 01 |
| 0.5400 + 00 | 0.1219 + 01 | 0.1152 + 01 | 0.1058 + 01 | 0.1270 + 01 |
| 0.5600 + 00 | 0.1237 + 01 | 0.1164 + 01 | 0.1063 + 01 | 0.1240 + 01 |
| 0.5800 + 00 | 0.1256 + 01 | 0.1177 + 01 | 0.1067 + 01 | 0.1213 + 01 |
| 0.6000 + 00 | 0.1276 + 01 | 0.1190 + 01 | 0.1072 + 01 | 0.1188 + 01 |
| 0.6200 + 01 | 0.1296 + 01 | 0.1203 + 01 | 0.1077 + 01 | 0.1166 + 01 |
| 0.6400 + 00 | 0.1317 + 01 | 0.1218 + 01 | 0.1082 + 01 | 0.1145 + 01 |
| 0.6600 + 00 | 0.1340 + 01 | 0.1232 + 01 | 0.1087 + 01 | 0.1127 + 01 |
| 0.6800 + 00 | 0.1363 + 01 | 0.1247 + 01 | 0.1092 + 01 | 0.1110 + 01 |
| 0.7000 + 00 | 0.1387 + 01 | 0.1263 + 01 | 0.1098 + 01 | 0.1094 + 01 |
| 0.7200 + 00 | 0.1412 + 01 | 0.1280 + 01 | 0.1104 + 01 | 0.1081 + 01 |
| 0.7400 + 00 | 0.1439 + 01 | 0.1297 + 01 | 0.1110 + 01 | 0.1068 + 01 |

| M | $\frac{p_0}{p}$ | $\frac{\rho_0}{\rho}$ | $\frac{T_0}{T}$ | $\frac{A}{A^*}$ |
|-------------|-----------------|-----------------------|-----------------|-----------------|
| 0.7600 + 00 | 0.1466 + 01 | 0.1314 + 01 | 0.1116 + 01 | 0.1057 + 01 |
| 0.7800 + 00 | 0.1495 + 01 | 0.1333 + 01 | 0.1122 + 01 | 0.1047 + 01 |
| 0.8000 + 00 | 0.1524 + 01 | 0.1351 + 01 | 0.1128 + 01 | 0.1038 + 01 |
| 0.8200 + 00 | 0.1555 + 01 | 0.1371 + 01 | 0.1134 + 01 | 0.1030 + 01 |
| 0.8400 + 00 | 0.1587 + 01 | 0.1391 + 01 | 0.1141 + 01 | 0.1024 + 01 |
| 0.8600 + 00 | 0.1621 + 01 | 0.1412 + 01 | 0.1148 + 01 | 0.1018 + 01 |
| 0.8800 + 00 | 0.1655 + 01 | 0.1433 + 01 | 0.1155 + 01 | 0.1013 + 01 |
| 0.9000 + 00 | 0.1691 + 01 | 0.1456 + 01 | 0.1162 + 01 | 0.1009 + 01 |
| 0.9200 + 00 | 0.1729 + 01 | 0.1478 + 01 | 0.1169 + 01 | 0.1006 + 01 |
| 0.9400 + 00 | 0.1767 + 01 | 0.1502 + 01 | 0.1177 + 01 | 0.1003 + 01 |
| 0.9600 + 00 | 0.1808 + 01 | 0.1526 + 01 | 0.1184 + 01 | 0.1001 + 01 |
| 0.9800 + 00 | 0.1850 + 01 | 0.1552 + 01 | 0.1192 + 01 | 0.1000 + 01 |
| 0.1000 + 01 | 0.1893 + 01 | 0.1577 + 01 | 0.1200 + 01 | 0.1000 + 01 |
| 0.1020 + 01 | 0.1938 + 01 | 0.1604 + 01 | 0.1208 + 01 | 0.1000 + 01 |
| 0.1040 + 01 | 0.1985 + 01 | 0.1632 + 01 | 0.1216 + 01 | 0.1001 + 01 |
| 0.1060 + 01 | 0.2033 + 01 | 0.1660 + 01 | 0.1225 + 01 | 0.1003 + 01 |
| 0.1080 + 01 | 0.2083 + 01 | 0.1689 + 01 | 0.1233 + 01 | 0.1005 + 01 |
| 0.1100 + 01 | 0.2135 + 01 | 0.1719 + 01 | 0.1242 + 01 | 0.1008 + 01 |
| 0.1120 + 01 | 0.2189 + 01 | 0.1750 + 01 | 0.1251 + 01 | 0.1011 + 01 |
| 0.1140 + 01 | 0.2245 + 01 | 0.1782 + 01 | 0.1260 + 01 | 0.1015 + 01 |
| 0.1160 + 01 | 0.2303 + 01 | 0.1814 + 01 | 0.1269 + 01 | 0.1020 + 01 |
| 0.1180 + 01 | 0.2363 + 01 | 0.1848 + 01 | 0.1278 + 01 | 0.1025 + 01 |
| 0.1200 + 01 | 0.2425 + 01 | 0.1883 + 01 | 0.1288 + 01 | 0.1030 + 01 |
| 0.1220 + 01 | 0.2489 + 01 | 0.1918 + 01 | 0.1298 + 01 | 0.1037 + 01 |
| 0.1240 + 01 | 0.2556 + 01 | 0.1955 + 01 | 0.1308 + 01 | 0.1043 + 01 |
| 0.1260 + 01 | 0.2625 + 01 | 0.1992 + 01 | 0.1318 + 01 | 0.1050 + 01 |
| 0.1280 + 01 | 0.2697 + 01 | 0.2031 + 01 | 0.1328 + 01 | 0.1058 + 01 |
| 0.1300 + 01 | 0.2771 + 01 | 0.2071 + 01 | 0.1338 + 01 | 0.1066 + 01 |
| 0.1320 + 01 | 0.2847 + 01 | 0.2112 + 01 | 0.1348 + 01 | 0.1075 + 01 |
| 0.1340 + 01 | 0.2927 + 01 | 0.2153 + 01 | 0.1359 + 01 | 0.1084 + 01 |
| 0.1360 + 01 | 0.3009 + 01 | 0.2197 + 01 | 0.1370 + 01 | 0.1094 + 01 |
| 0.1380 + 01 | 0.3094 + 01 | 0.2241 + 01 | 0.1381 + 01 | 0.1104 + 01 |
| 0.1400 + 01 | 0.3182 + 01 | 0.2286 + 01 | 0.1392 + 01 | 0.1115 + 01 |
| 0.1420 + 01 | 0.3273 + 01 | 0.2333 + 01 | 0.1403 + 01 | 0.1126 + 01 |
| 0.1440 + 01 | 0.3368 + 01 | 0.2381 + 01 | 0.1415 + 01 | 0.1138 + 01 |
| 0.1460 + 01 | 0.3465 + 01 | 0.2430 + 01 | 0.1426 + 01 | 0.1150 + 01 |
| 0.1480 + 01 | 0.3566 + 01 | 0.2480 + 01 | 0.1438 + 01 | 0.1163 + 01 |
| 0.1500 + 01 | 0.3671 + 01 | 0.2532 + 01 | 0.1450 + 01 | 0.1176 + 01 |
| 0.1520 + 01 | 0.3779 + 01 | 0.2585 + 01 | 0.1462 + 01 | 0.1190 + 01 |
| 0.1540 + 01 | 0.3891 + 01 | 0.2639 + 01 | 0.1474 + 01 | 0.1204 + 01 |
| 0.1560 + 01 | 0.4007 + 01 | 0.2695 + 01 | 0.1487 + 01 | 0.1219 + 01 |
| 0.1580 + 01 | 0.4127 + 01 | 0.2752 + 01 | 0.1499 + 01 | 0.1234 + 01 |
| 0.1600 + 01 | 0.4250 + 01 | 0.2811 + 01 | 0.1512 + 01 | 0.1250 + 01 |
| 0.1620 + 01 | 0.4378 + 01 | 0.2871 + 01 | 0.1525 + 01 | 0.1267 + 01 |
| 0.1640 + 01 | 0.4511 + 01 | 0.2933 + 01 | 0.1538 + 01 | 0.1284 + 01 |
| 0.1660 + 01 | 0.4648 + 01 | 0.2996 + 01 | 0.1551 + 01 | 0.1301 + 01 |
| 0.1680 + 01 | 0.4790 + 01 | 0.3061 + 01 | 0.1564 + 01 | 0.1319 + 01 |
| 0.1700 + 01 | 0.4936 + 01 | 0.3128 + 01 | 0.1578 + 01 | 0.1338 + 01 |
| 0.1720 + 01 | 0.5087 + 01 | 0.3196 + 01 | 0.1592 + 01 | 0.1357 + 01 |
| 0.1740 + 01 | 0.5244 + 01 | 0.3266 + 01 | 0.1606 + 01 | 0.1376 + 01 |

| M | $\frac{p_0}{p}$ | $\frac{\rho_0}{\rho}$ | $\frac{T_0}{T}$ | $\frac{A}{A^*}$ |
|-------------|-----------------|-----------------------|-----------------|-----------------|
| 0.1760 + 01 | 0.5406 + 01 | 0.3338 + 01 | 0.1620 + 01 | 0.1397 + 01 |
| 0.1780 + 01 | 0.5573 + 01 | 0.3411 + 01 | 0.1634 + 01 | 0.1418 + 01 |
| 0.1800 + 01 | 0.5746 + 01 | 0.3487 + 01 | 0.1648 + 01 | 0.1439 + 01 |
| 0.1820 + 01 | 0.5924 + 01 | 0.3564 + 01 | 0.1662 + 01 | 0.1461 + 01 |
| 0.1840 + 01 | 0.6109 + 01 | 0.3643 + 01 | 0.1677 + 01 | 0.1484 + 01 |
| 0.1860 + 01 | 0.6300 + 01 | 0.3723 + 01 | 0.1692 + 01 | 0.1507 + 01 |
| 0.1880 + 01 | 0.6497 + 01 | 0.3806 + 01 | 0.1707 + 01 | 0.1531 + 01 |
| 0.1900 + 01 | 0.6701 + 01 | 0.3891 + 01 | 0.1722 + 01 | 0.1555 + 01 |
| 0.1920 + 01 | 0.6911 + 01 | 0.3978 + 01 | 0.1737 + 01 | 0.1580 + 01 |
| 0.1940 + 01 | 0.7128 + 01 | 0.4067 + 01 | 0.1753 + 01 | 0.1606 + 01 |
| 0.1960 + 01 | 0.7353 + 01 | 0.4158 + 01 | 0.1768 + 01 | 0.1633 + 01 |
| 0.1980 + 01 | 0.7585 + 01 | 0.4251 + 01 | 0.1784 + 01 | 0.1660 + 01 |
| 0.2000 + 01 | 0.7824 + 01 | 0.4347 + 01 | 0.1800 + 01 | 0.1687 + 01 |
| 0.2050 + 01 | 0.8458 + 01 | 0.4596 + 01 | 0.1840 + 01 | 0.1760 + 01 |
| 0.2100 + 01 | 0.9145 + 01 | 0.4859 + 01 | 0.1882 + 01 | 0.1837 + 01 |
| 0.2150 + 01 | 0.9888 + 01 | 0.5138 + 01 | 0.1924 + 01 | 0.1919 + 01 |
| 0.2200 + 01 | 0.1069 + 02 | 0.5433 + 01 | 0.1968 + 01 | 0.2005 + 01 |
| 0.2250 + 01 | 0.1156 + 02 | 0.5746 + 01 | 0.2012 + 01 | 0.2096 + 01 |
| 0.2300 + 01 | 0.1250 + 02 | 0.6076 + 01 | 0.2058 + 01 | 0.2193 + 01 |
| 0.2350 + 01 | 0.1352 + 02 | 0.6425 + 01 | 0.2104 + 01 | 0.2295 + 01 |
| 0.2400 + 01 | 0.1462 + 02 | 0.6794 + 01 | 0.2152 + 01 | 0.2403 + 01 |
| 0.2450 + 01 | 0.1581 + 02 | 0.7183 + 01 | 0.2200 + 01 | 0.2517 + 01 |
| 0.2500 + 01 | 0.1709 + 02 | 0.7594 + 01 | 0.2250 + 01 | 0.2637 + 01 |
| 0.2550 + 01 | 0.1847 + 02 | 0.8027 + 01 | 0.2300 + 01 | 0.2763 + 01 |
| 0.2600 + 01 | 0.1995 + 02 | 0.8484 + 01 | 0.2352 + 01 | 0.2896 + 01 |
| 0.2650 + 01 | 0.2156 + 02 | 0.8965 + 01 | 0.2404 + 01 | 0.3036 + 01 |
| 0.2700 + 01 | 0.2328 + 02 | 0.9472 + 01 | 0.2458 + 01 | 0.3183 + 01 |
| 0.2750 + 01 | 0.2514 + 02 | 0.1001 + 02 | 0.2512 + 01 | 0.3338 + 01 |
| 0.2800 + 01 | 0.2714 + 02 | 0.1057 + 02 | 0.2568 + 01 | 0.3500 + 01 |
| 0.2850 + 01 | 0.2929 + 02 | 0.1116 + 02 | 0.2624 + 01 | 0.3671 + 01 |
| 0.2900 + 01 | 0.3159 + 02 | 0.1178 + 02 | 0.2682 + 01 | 0.3850 + 01 |
| 0.2950 + 01 | 0.3407 + 02 | 0.1243 + 02 | 0.2740 + 01 | 0.4038 + 01 |
| 0.3000 + 01 | 0.3673 + 02 | 0.1312 + 02 | 0.2800 + 01 | 0.4235 + 01 |
| 0.3050 + 01 | 0.3959 + 02 | 0.1384 + 02 | 0.2860 + 01 | 0.4441 + 01 |
| 0.3100 + 01 | 0.4265 + 02 | 0.1459 + 02 | 0.2922 + 01 | 0.4657 + 01 |
| 0.3150 + 01 | 0.4593 + 02 | 0.1539 + 02 | 0.2984 + 01 | 0.4884 + 01 |
| 0.3200 + 01 | 0.4944 + 02 | 0.1622 + 02 | 0.3048 + 01 | 0.5121 + 01 |
| 0.3250 + 01 | 0.5320 + 02 | 0.1709 + 02 | 0.3112 + 01 | 0.5369 + 01 |
| 0.3300 + 01 | 0.5722 + 02 | 0.1800 + 02 | 0.3178 + 01 | 0.5629 + 01 |
| 0.3350 + 01 | 0.6152 + 02 | 0.1896 + 02 | 0.3244 + 01 | 0.5900 + 01 |
| 0.3400 + 01 | 0.6612 + 02 | 0.1996 + 02 | 0.3312 + 01 | 0.6184 + 01 |
| 0.3450 + 01 | 0.7103 + 02 | 0.2101 + 02 | 0.3380 + 01 | 0.6480 + 01 |
| 0.3500 + 01 | 0.7627 + 02 | 0.2211 + 02 | 0.3450 + 01 | 0.6790 + 01 |
| 0.3550 + 01 | 0.8187 + 02 | 0.2325 + 02 | 0.3520 + 01 | 0.7113 + 01 |
| 0.3600 + 01 | 0.8784 + 02 | 0.2445 + 02 | 0.3592 + 01 | 0.7450 + 01 |
| 0.3650 + 01 | 0.9420 + 02 | 0.2571 + 02 | 0.3664 + 01 | 0.7802 + 01 |
| 0.3700 + 01 | 0.1010 + 03 | 0.2701 + 02 | 0.3738 + 01 | 0.8169 + 01 |
| 0.3750 + 01 | 0.1082 + 03 | 0.2838 + 02 | 0.3812 + 01 | 0.8552 + 01 |
| 0.3800 + 01 | 0.1159 + 03 | 0.2981 + 02 | 0.3888 + 01 | 0.8951 + 01 |
| 0.3850 + 01 | 0.1241 + 03 | 0.3129 + 02 | 0.3964 + 01 | 0.9366 + 01 |

| M | $\frac{p_0}{p}$ | $\frac{\rho_0}{\rho}$ | $\frac{T_0}{T}$ | $\frac{A}{A^*}$ |
|-------------|-----------------|-----------------------|-----------------|-----------------|
| 0.3900 + 01 | 0.1328 + 03 | 0.3285 + 02 | 0.4042 + 01 | 0.9799 + 01 |
| 0.3950 + 01 | 0.1420 + 03 | 0.3446 + 02 | 0.4120 + 01 | 0.1025 + 02 |
| 0.4000 + 01 | 0.1518 + 03 | 0.3615 + 02 | 0.4200 + 01 | 0.1072 + 02 |
| 0.4050 + 01 | 0.1623 + 03 | 0.3791 + 02 | 0.4280 + 01 | 0.1121 + 02 |
| 0.4100 + 01 | 0.1733 + 03 | 0.3974 + 02 | 0.4362 + 01 | 0.1171 + 02 |
| 0.4150 + 01 | 0.1851 + 03 | 0.4164 + 02 | 0.4444 + 01 | 0.1224 + 02 |
| 0.4200 + 01 | 0.1975 + 03 | 0.4363 + 02 | 0.4528 + 01 | 0.1279 + 02 |
| 0.4250 + 01 | 0.2108 + 03 | 0.4569 + 02 | 0.4612 + 01 | 0.1336 + 02 |
| 0.4300 + 01 | 0.2247 + 03 | 0.4784 + 02 | 0.4698 + 01 | 0.1395 + 02 |
| 0.4350 + 01 | 0.2396 + 03 | 0.5007 + 02 | 0.4784 + 01 | 0.1457 + 02 |
| 0.4400 + 01 | 0.2553 + 03 | 0.5239 + 02 | 0.4872 + 01 | 0.1521 + 02 |
| 0.4450 + 01 | 0.2719 + 03 | 0.5480 + 02 | 0.4960 + 01 | 0.1587 + 02 |
| 0.4500 + 01 | 0.2894 + 03 | 0.5731 + 02 | 0.5050 + 01 | 0.1656 + 02 |
| 0.4550 + 01 | 0.3080 + 03 | 0.5991 + 02 | 0.5140 + 01 | 0.1728 + 02 |
| 0.4600 + 01 | 0.3276 + 03 | 0.6261 + 02 | 0.5232 + 01 | 0.1802 + 02 |
| 0.4650 + 01 | 0.3483 + 03 | 0.6542 + 02 | 0.5324 + 01 | 0.1879 + 02 |
| 0.4700 + 01 | 0.3702 + 03 | 0.6833 + 02 | 0.5418 + 01 | 0.1958 + 02 |
| 0.4750 + 01 | 0.3933 + 03 | 0.7135 + 02 | 0.5512 + 01 | 0.2041 + 02 |
| 0.4800 + 01 | 0.4177 + 03 | 0.7448 + 02 | 0.5608 + 01 | 0.2126 + 02 |
| 0.4850 + 01 | 0.4434 + 03 | 0.7772 + 02 | 0.5704 + 01 | 0.2215 + 02 |
| 0.4900 + 01 | 0.4705 + 03 | 0.8109 + 02 | 0.5802 + 01 | 0.2307 + 02 |
| 0.4950 + 01 | 0.4990 + 03 | 0.8457 + 02 | 0.5900 + 01 | 0.2402 + 02 |
| 0.5000 + 01 | 0.5291 + 03 | 0.8818 + 02 | 0.6000 + 01 | 0.2500 + 02 |
| 0.5100 + 01 | 0.5941 + 03 | 0.9579 + 02 | 0.6202 + 01 | 0.2707 + 02 |
| 0.5200 + 01 | 0.6661 + 03 | 0.1039 + 03 | 0.6408 + 01 | 0.2928 + 02 |
| 0.5300 + 01 | 0.7457 + 03 | 0.1127 + 03 | 0.6618 + 01 | 0.3165 + 02 |
| 0.5400 + 01 | 0.8335 + 03 | 0.1220 + 03 | 0.6832 + 01 | 0.3417 + 02 |
| 0.5500 + 01 | 0.9304 + 03 | 0.1320 + 03 | 0.7050 + 01 | 0.3687 + 02 |
| 0.5600 + 01 | 0.1037 + 04 | 0.1426 + 03 | 0.7272 + 01 | 0.3974 + 02 |
| 0.5700 + 01 | 0.1154 + 04 | 0.1539 + 03 | 0.7498 + 01 | 0.4280 + 02 |
| 0.5800 + 01 | 0.1283 + 04 | 0.1660 + 03 | 0.7728 + 01 | 0.4605 + 02 |
| 0.5900 + 01 | 0.1424 + 04 | 0.1789 + 03 | 0.7962 + 01 | 0.4951 + 02 |
| 0.6000 + 01 | 0.1579 + 04 | 0.1925 + 03 | 0.8200 + 01 | 0.5318 + 02 |
| 0.6100 + 01 | 0.1748 + 04 | 0.2071 + 03 | 0.8442 + 01 | 0.5708 + 02 |
| 0.6200 + 01 | 0.1933 + 04 | 0.2225 + 03 | 0.8688 + 01 | 0.6121 + 02 |
| 0.6300 + 01 | 0.2135 + 04 | 0.2388 + 03 | 0.8938 + 01 | 0.6559 + 02 |
| 0.6400 + 01 | 0.2355 + 04 | 0.2562 + 03 | 0.9192 + 01 | 0.7023 + 02 |
| 0.6500 + 01 | 0.2594 + 04 | 0.2745 + 03 | 0.9450 + 01 | 0.7513 + 02 |
| 0.6600 + 01 | 0.2855 + 04 | 0.2939 + 03 | 0.9712 + 01 | 0.8032 + 02 |
| 0.6700 + 01 | 0.3138 + 04 | 0.3145 + 03 | 0.9978 + 01 | 0.8580 + 02 |
| 0.6800 + 01 | 0.3445 + 04 | 0.3362 + 03 | 0.1025 + 02 | 0.9159 + 02 |
| 0.6900 + 01 | 0.3779 + 04 | 0.3591 + 03 | 0.1052 + 02 | 0.9770 + 02 |
| 0.7000 + 01 | 0.4140 + 04 | 0.3833 + 03 | 0.1080 + 02 | 0.1041 + 03 |
| 0.7100 + 01 | 0.4531 + 04 | 0.4088 + 03 | 0.1108 + 02 | 0.1109 + 03 |
| 0.7200 + 01 | 0.4953 + 04 | 0.4357 + 03 | 0.1137 + 02 | 0.1181 + 03 |
| 0.7300 + 01 | 0.5410 + 04 | 0.4640 + 03 | 0.1166 + 02 | 0.1256 + 03 |
| 0.7400 + 01 | 0.5903 + 04 | 0.4939 + 03 | 0.1195 + 02 | 0.1335 + 03 |
| 0.7500 + 01 | 0.6434 + 04 | 0.5252 + 03 | 0.1225 + 02 | 0.1418 + 03 |
| 0.7600 + 01 | 0.7006 + 04 | 0.5582 + 03 | 0.1255 + 02 | 0.1506 + 03 |
| 0.7700 + 01 | 0.7623 + 04 | 0.5928 + 03 | 0.1286 + 02 | 0.1598 + 03 |

| M | $\frac{p_0}{p}$ | $\frac{\rho_0}{\rho}$ | $\frac{T_0}{T}$ | $\frac{A}{A^*}$ |
|-------------|-----------------|-----------------------|-----------------|-----------------|
| 0.7800 + 01 | 0.8285 + 04 | 0.6292 + 03 | 0.1317 + 02 | 0.1694 + 03 |
| 0.7900 + 01 | 0.8998 + 04 | 0.6674 + 03 | 0.1348 + 02 | 0.1795 + 03 |
| 0.8000 + 01 | 0.9763 + 04 | 0.7075 + 03 | 0.1380 + 02 | 0.1901 + 03 |
| 0.9000 + 01 | 0.2110 + 05 | 0.1227 + 04 | 0.1720 + 02 | 0.3272 + 03 |
| 0.1000 + 02 | 0.4244 + 05 | 0.2021 + 04 | 0.2100 + 02 | 0.5359 + 03 |
| 0.1100 + 02 | 0.8033 + 05 | 0.3188 + 04 | 0.2520 + 02 | 0.8419 + 03 |
| 0.1200 + 02 | 0.1445 + 06 | 0.4848 + 04 | 0.2980 + 02 | 0.1276 + 04 |
| 0.1300 + 02 | 0.2486 + 06 | 0.7144 + 04 | 0.3480 + 02 | 0.1876 + 04 |
| 0.1400 + 02 | 0.4119 + 06 | 0.1025 + 05 | 0.4020 + 02 | 0.2685 + 04 |
| 0.1500 + 02 | 0.6602 + 06 | 0.1435 + 05 | 0.4600 + 02 | 0.3755 + 04 |
| 0.1600 + 02 | 0.1028 + 07 | 0.1969 + 05 | 0.5229 + 02 | 0.5145 + 04 |
| 0.1700 + 02 | 0.1559 + 07 | 0.2651 + 05 | 0.5880 + 02 | 0.6921 + 04 |
| 0.1800 + 02 | 0.2311 + 07 | 0.3512 + 05 | 0.6580 + 02 | 0.9159 + 04 |
| 0.1900 + 02 | 0.3356 + 07 | 0.4584 + 05 | 0.7320 + 02 | 0.1195 + 05 |
| 0.2000 + 02 | 0.4783 + 07 | 0.5905 + 05 | 0.8100 + 02 | 0.1538 + 05 |
| 0.2200 + 02 | 0.9251 + 07 | 0.9459 + 05 | 0.9780 + 02 | 0.2461 + 05 |
| 0.2400 + 02 | 0.1691 + 08 | 0.1456 + 06 | 0.1162 + 03 | 0.3783 + 05 |
| 0.2600 + 02 | 0.2949 + 08 | 0.2165 + 06 | 0.1362 + 03 | 0.5624 + 05 |
| 0.2800 + 02 | 0.4936 + 08 | 0.3128 + 06 | 0.1578 + 03 | 0.8121 + 05 |
| 0.3000 + 02 | 0.7978 + 08 | 0.4408 + 06 | 0.1810 + 03 | 0.1144 + 06 |
| 0.3200 + 02 | 0.1250 + 09 | 0.6076 + 06 | 0.2058 + 03 | 0.1576 + 06 |
| 0.3400 + 02 | 0.1908 + 09 | 0.8216 + 06 | 0.2322 + 03 | 0.2131 + 06 |
| 0.3600 + 02 | 0.2842 + 09 | 0.1092 + 07 | 0.2602 + 03 | 0.2832 + 06 |
| 0.3800 + 02 | 0.4143 + 09 | 0.1430 + 07 | 0.2898 + 03 | 0.3707 + 06 |
| 0.4000 + 02 | 0.5926 + 09 | 0.1846 + 07 | 0.3210 + 03 | 0.4785 + 06 |
| 0.4200 + 02 | 0.8330 + 09 | 0.2354 + 07 | 0.3538 + 03 | 0.6102 + 06 |
| 0.4400 + 02 | 0.1153 + 10 | 0.2969 + 07 | 0.3882 + 03 | 0.7694 + 06 |
| 0.4600 + 02 | 0.1572 + 10 | 0.3706 + 07 | 0.4242 + 03 | 0.9603 + 06 |
| 0.4800 + 02 | 0.2116 + 10 | 0.4583 + 07 | 0.4618 + 03 | 0.1187 + 07 |
| 0.5000 + 02 | 0.2815 + 10 | 0.5618 + 07 | 0.5010 + 03 | 0.1455 + 07 |

appendix

B

NORMAL SHOCK PROPERTIES

| M | $\frac{p_2}{p_1}$ | $\frac{\rho_2}{\rho_1}$ | $\frac{T_2}{T_1}$ | $\frac{p_{0_2}}{p_{0_1}}$ | $\frac{p_{0_2}}{p_1}$ | M_2 |
|-------------|-------------------|-------------------------|-------------------|---------------------------|-----------------------|-------------|
| 0.1000 + 01 | 0.1000 + 01 | 0.1000 + 01 | 0.1000 + 01 | 0.1000 + 01 | 0.1893 + 01 | 0.1000 + 01 |
| 0.1020 + 01 | 0.1047 + 01 | 0.1033 + 01 | 0.1013 + 01 | 0.1000 + 01 | 0.1938 + 01 | 0.9805 + 00 |
| 0.1040 + 01 | 0.1095 + 01 | 0.1067 + 01 | 0.1026 + 01 | 0.9999 + 00 | 0.1984 + 01 | 0.9620 + 00 |
| 0.1060 + 01 | 0.1144 + 01 | 0.1101 + 01 | 0.1039 + 01 | 0.9998 + 00 | 0.2032 + 01 | 0.9444 + 00 |
| 0.1080 + 01 | 0.1194 + 01 | 0.1135 + 01 | 0.1052 + 01 | 0.9994 + 01 | 0.2082 + 01 | 0.9277 + 00 |
| 0.1100 + 01 | 0.1245 + 01 | 0.1169 + 01 | 0.1065 + 01 | 0.9989 + 00 | 0.2133 + 01 | 0.9118 + 00 |
| 0.1120 + 01 | 0.1297 + 01 | 0.1203 + 01 | 0.1078 + 01 | 0.9982 + 00 | 0.2185 + 01 | 0.8966 + 00 |
| 0.1140 + 01 | 0.1350 + 01 | 0.1238 + 01 | 0.1090 + 01 | 0.9973 + 00 | 0.2239 + 01 | 0.8820 + 00 |
| 0.1160 + 01 | 0.1403 + 01 | 0.1272 + 01 | 0.1103 + 01 | 0.9961 + 00 | 0.2294 + 01 | 0.8682 + 00 |
| 0.1180 + 01 | 0.1458 + 01 | 0.1307 + 01 | 0.1115 + 01 | 0.9946 + 00 | 0.2350 + 01 | 0.8549 + 00 |
| 0.1200 + 01 | 0.1513 + 01 | 0.1342 + 01 | 0.1128 + 01 | 0.9928 + 00 | 0.2408 + 01 | 0.8422 + 00 |
| 0.1220 + 01 | 0.1570 + 01 | 0.1376 + 01 | 0.1141 + 01 | 0.9907 + 00 | 0.2466 + 01 | 0.8300 + 00 |
| 0.1240 + 01 | 0.1627 + 01 | 0.1411 + 01 | 0.1153 + 01 | 0.9884 + 00 | 0.2526 + 01 | 0.8183 + 00 |
| 0.1260 + 01 | 0.1686 + 01 | 0.1446 + 01 | 0.1166 + 01 | 0.9857 + 00 | 0.2588 + 01 | 0.8071 + 00 |
| 0.1280 + 01 | 0.1745 + 01 | 0.1481 + 01 | 0.1178 + 01 | 0.9827 + 00 | 0.2650 + 01 | 0.7963 + 00 |
| 0.1300 + 01 | 0.1805 + 01 | 0.1516 + 01 | 0.1191 + 01 | 0.9794 + 00 | 0.2714 + 01 | 0.7860 + 00 |
| 0.1320 + 01 | 0.1866 + 01 | 0.1551 + 01 | 0.1204 + 01 | 0.9758 + 00 | 0.2778 + 01 | 0.7760 + 00 |
| 0.1340 + 01 | 0.1928 + 01 | 0.1585 + 01 | 0.1216 + 01 | 0.9718 + 00 | 0.2844 + 01 | 0.7664 + 00 |
| 0.1360 + 01 | 0.1991 + 01 | 0.1620 + 01 | 0.1229 + 01 | 0.9676 + 00 | 0.2912 + 01 | 0.7572 + 00 |
| 0.1380 + 01 | 0.2055 + 01 | 0.1655 + 01 | 0.1242 + 01 | 0.9630 + 00 | 0.2980 + 01 | 0.7483 + 00 |
| 0.1400 + 01 | 0.2120 + 01 | 0.1690 + 01 | 0.1255 + 01 | 0.9582 + 00 | 0.3049 + 01 | 0.7397 + 00 |
| 0.1420 + 01 | 0.2186 + 01 | 0.1724 + 01 | 0.1268 + 01 | 0.9531 + 00 | 0.3120 + 01 | 0.7314 + 00 |
| 0.1440 + 01 | 0.2253 + 01 | 0.1759 + 01 | 0.1281 + 01 | 0.9476 + 00 | 0.3191 + 01 | 0.7235 + 00 |
| 0.1460 + 01 | 0.2320 + 01 | 0.1793 + 01 | 0.1294 + 01 | 0.9420 + 00 | 0.3264 + 01 | 0.7157 + 00 |
| 0.1480 + 01 | 0.2389 + 01 | 0.1828 + 01 | 0.1307 + 01 | 0.9360 + 00 | 0.3338 + 01 | 0.7083 + 00 |
| 0.1500 + 01 | 0.2458 + 01 | 0.1862 + 01 | 0.1320 + 01 | 0.9298 + 00 | 0.3413 + 01 | 0.7011 + 00 |
| 0.1520 + 01 | 0.2529 + 01 | 0.1896 + 01 | 0.1334 + 01 | 0.9233 + 00 | 0.3489 + 01 | 0.6941 + 00 |
| 0.1540 + 01 | 0.2600 + 01 | 0.1930 + 01 | 0.1347 + 01 | 0.9166 + 00 | 0.3567 + 01 | 0.6874 + 00 |
| 0.1560 + 01 | 0.2673 + 01 | 0.1964 + 01 | 0.1361 + 01 | 0.9097 + 00 | 0.3645 + 01 | 0.6809 + 00 |
| 0.1580 + 01 | 0.2746 + 01 | 0.1998 + 01 | 0.1374 + 01 | 0.9026 + 00 | 0.3724 + 01 | 0.6746 + 00 |
| 0.1600 + 01 | 0.2820 + 01 | 0.2032 + 01 | 0.1388 + 01 | 0.8952 + 00 | 0.3805 + 01 | 0.6684 + 00 |
| 0.1620 + 01 | 0.2895 + 01 | 0.2065 + 01 | 0.1402 + 01 | 0.8877 + 00 | 0.3887 + 01 | 0.6625 + 00 |
| 0.1640 + 01 | 0.2971 + 01 | 0.2099 + 01 | 0.1416 + 01 | 0.8799 + 00 | 0.3969 + 01 | 0.6568 + 00 |
| 0.1660 + 01 | 0.3048 + 01 | 0.2132 + 01 | 0.1430 + 01 | 0.8720 + 00 | 0.4053 + 01 | 0.6512 + 00 |
| 0.1680 + 01 | 0.3126 + 01 | 0.2165 + 01 | 0.1444 + 01 | 0.8639 + 00 | 0.4138 + 01 | 0.6458 + 00 |
| 0.1700 + 01 | 0.3205 + 01 | 0.2198 + 01 | 0.1458 + 01 | 0.8557 + 00 | 0.4224 + 01 | 0.6405 + 00 |

| M | $\frac{p_2}{p_1}$ | $\frac{\rho_2}{\rho_1}$ | $\frac{T_2}{T_1}$ | $\frac{p_{02}}{p_{01}}$ | $\frac{p_{02}}{p_1}$ | M_2 |
|-------------|-------------------|-------------------------|-------------------|-------------------------|----------------------|-------------|
| 0.1720 + 01 | 0.3285 + 01 | 0.2230 + 01 | 0.1473 + 01 | 0.8474 + 00 | 0.4311 + 01 | 0.6355 + 00 |
| 0.1740 + 01 | 0.3366 + 01 | 0.2263 + 01 | 0.1487 + 01 | 0.8389 + 00 | 0.4399 + 01 | 0.6305 + 00 |
| 0.1760 + 01 | 0.3447 + 01 | 0.2295 + 01 | 0.1502 + 01 | 0.8302 + 00 | 0.4488 + 01 | 0.6257 + 00 |
| 0.1780 + 01 | 0.3530 + 01 | 0.2327 + 01 | 0.1517 + 01 | 0.8215 + 00 | 0.4578 + 01 | 0.6210 + 00 |
| 0.1800 + 01 | 0.3613 + 01 | 0.2359 + 01 | 0.1532 + 01 | 0.8127 + 00 | 0.4670 + 01 | 0.6165 + 00 |
| 0.1820 + 01 | 0.3698 + 01 | 0.2391 + 01 | 0.1547 + 01 | 0.8038 + 00 | 0.4762 + 01 | 0.6121 + 00 |
| 0.1840 + 01 | 0.3783 + 01 | 0.2422 + 01 | 0.1562 + 01 | 0.7948 + 00 | 0.4855 + 01 | 0.6078 + 00 |
| 0.1860 + 01 | 0.3870 + 01 | 0.2454 + 01 | 0.1577 + 01 | 0.7857 + 00 | 0.4950 + 01 | 0.6036 + 00 |
| 0.1880 + 01 | 0.3957 + 01 | 0.2485 + 01 | 0.1592 + 01 | 0.7765 + 00 | 0.5045 + 01 | 0.5996 + 00 |
| 0.1900 + 01 | 0.4045 + 01 | 0.2516 + 01 | 0.1608 + 01 | 0.7674 + 00 | 0.5142 + 01 | 0.5956 + 00 |
| 0.1920 + 01 | 0.4134 + 01 | 0.2546 + 01 | 0.1624 + 01 | 0.7581 + 00 | 0.5239 + 01 | 0.5918 + 00 |
| 0.1940 + 01 | 0.4224 + 01 | 0.2577 + 01 | 0.1639 + 01 | 0.7488 + 00 | 0.5338 + 01 | 0.5880 + 00 |
| 0.1960 + 01 | 0.4315 + 01 | 0.2607 + 01 | 0.1655 + 01 | 0.7395 + 00 | 0.5438 + 01 | 0.5844 + 00 |
| 0.1980 + 01 | 0.4407 + 01 | 0.2637 + 01 | 0.1671 + 01 | 0.7302 + 00 | 0.5539 + 01 | 0.5808 + 00 |
| 0.2000 + 01 | 0.4500 + 01 | 0.2667 + 01 | 0.1687 + 01 | 0.7209 + 00 | 0.5640 + 01 | 0.5774 + 00 |
| 0.2050 + 01 | 0.4736 + 01 | 0.2740 + 01 | 0.1729 + 01 | 0.6975 + 00 | 0.5900 + 01 | 0.5691 + 00 |
| 0.2100 + 01 | 0.4978 + 01 | 0.2812 + 01 | 0.1770 + 01 | 0.6742 + 00 | 0.6165 + 01 | 0.5613 + 00 |
| 0.2150 + 01 | 0.5226 + 01 | 0.2882 + 01 | 0.1813 + 01 | 0.6511 + 00 | 0.6438 + 01 | 0.5540 + 00 |
| 0.2200 + 01 | 0.5480 + 01 | 0.2951 + 01 | 0.1857 + 01 | 0.6281 + 00 | 0.6716 + 01 | 0.5471 + 00 |
| 0.2250 + 01 | 0.5740 + 01 | 0.3019 + 01 | 0.1901 + 01 | 0.6055 + 00 | 0.7002 + 01 | 0.5406 + 00 |
| 0.2300 + 01 | 0.6005 + 01 | 0.3085 + 01 | 0.1947 + 01 | 0.5833 + 00 | 0.7294 + 01 | 0.5344 + 00 |
| 0.2350 + 01 | 0.6276 + 01 | 0.3149 + 01 | 0.1993 + 01 | 0.5615 + 00 | 0.7592 + 01 | 0.5286 + 00 |
| 0.2400 + 01 | 0.6553 + 01 | 0.3212 + 01 | 0.2040 + 01 | 0.5401 + 00 | 0.7897 + 01 | 0.5231 + 00 |
| 0.2450 + 01 | 0.6836 + 01 | 0.3273 + 01 | 0.2088 + 01 | 0.5193 + 00 | 0.8208 + 01 | 0.5179 + 00 |
| 0.2500 + 01 | 0.7125 + 01 | 0.3333 + 01 | 0.2137 + 01 | 0.4990 + 00 | 0.8526 + 01 | 0.5130 + 00 |
| 0.2550 + 01 | 0.7420 + 01 | 0.3392 + 01 | 0.2187 + 01 | 0.4793 + 00 | 0.8850 + 01 | 0.5083 + 00 |
| 0.2600 + 01 | 0.7720 + 01 | 0.3449 + 01 | 0.2238 + 01 | 0.4601 + 00 | 0.9181 + 01 | 0.5039 + 00 |
| 0.2650 + 01 | 0.8026 + 01 | 0.3505 + 01 | 0.2290 + 01 | 0.4416 + 00 | 0.9519 + 01 | 0.4996 + 00 |
| 0.2700 + 01 | 0.8338 + 01 | 0.3559 + 01 | 0.2343 + 01 | 0.4236 + 00 | 0.9862 + 01 | 0.4956 + 00 |
| 0.2750 + 01 | 0.8656 + 01 | 0.3612 + 01 | 0.2397 + 01 | 0.4062 + 00 | 0.1021 + 02 | 0.4918 + 00 |
| 0.2800 + 01 | 0.8980 + 01 | 0.3664 + 01 | 0.2451 + 01 | 0.3895 + 00 | 0.1057 + 02 | 0.4882 + 00 |
| 0.2850 + 01 | 0.9310 + 01 | 0.3714 + 01 | 0.2507 + 01 | 0.3733 + 00 | 0.1093 + 02 | 0.4847 + 00 |
| 0.2900 + 01 | 0.9645 + 01 | 0.3763 + 01 | 0.2563 + 01 | 0.3577 + 00 | 0.1130 + 02 | 0.4814 + 00 |
| 0.2950 + 01 | 0.9986 + 01 | 0.3811 + 01 | 0.2621 + 01 | 0.3428 + 00 | 0.1168 + 02 | 0.4782 + 00 |
| 0.3000 + 01 | 0.1033 + 02 | 0.3857 + 01 | 0.2679 + 01 | 0.3283 + 00 | 0.1206 + 02 | 0.4752 + 00 |
| 0.3050 + 01 | 0.1069 + 02 | 0.3902 + 01 | 0.2738 + 01 | 0.3145 + 00 | 0.1245 + 02 | 0.4723 + 00 |
| 0.3100 + 01 | 0.1104 + 02 | 0.3947 + 01 | 0.2799 + 01 | 0.3012 + 00 | 0.1285 + 02 | 0.4695 + 00 |
| 0.3150 + 01 | 0.1141 + 02 | 0.3990 + 01 | 0.2860 + 01 | 0.2885 + 00 | 0.1325 + 02 | 0.4669 + 00 |
| 0.3200 + 01 | 0.1178 + 02 | 0.4031 + 01 | 0.2922 + 01 | 0.2762 + 00 | 0.1366 + 02 | 0.4643 + 00 |
| 0.3250 + 01 | 0.1216 + 02 | 0.4072 + 01 | 0.2985 + 01 | 0.2645 + 00 | 0.1407 + 02 | 0.4619 + 00 |
| 0.3300 + 01 | 0.1254 + 02 | 0.4112 + 01 | 0.3049 + 01 | 0.2533 + 00 | 0.1449 + 02 | 0.4596 + 00 |
| 0.3350 + 01 | 0.1293 + 02 | 0.4151 + 01 | 0.3114 + 01 | 0.2425 + 00 | 0.1492 + 02 | 0.4573 + 00 |
| 0.3400 + 01 | 0.1332 + 02 | 0.4188 + 01 | 0.3180 + 01 | 0.2322 + 00 | 0.1535 + 02 | 0.4552 + 00 |
| 0.3450 + 01 | 0.1372 + 02 | 0.4225 + 01 | 0.3247 + 01 | 0.2224 + 00 | 0.1579 + 02 | 0.4531 + 00 |
| 0.3500 + 01 | 0.1412 + 02 | 0.4261 + 01 | 0.3315 + 01 | 0.2129 + 00 | 0.1624 + 02 | 0.4512 + 00 |
| 0.3550 + 01 | 0.1454 + 02 | 0.4296 + 01 | 0.3384 + 01 | 0.2039 + 00 | 0.1670 + 02 | 0.4492 + 00 |
| 0.3600 + 01 | 0.1495 + 02 | 0.4330 + 01 | 0.3454 + 01 | 0.1953 + 00 | 0.1716 + 02 | 0.4474 + 00 |
| 0.3650 + 01 | 0.1538 + 02 | 0.4363 + 01 | 0.3525 + 01 | 0.1871 + 00 | 0.1762 + 02 | 0.4456 + 00 |
| 0.3700 + 01 | 0.1580 + 02 | 0.4395 + 01 | 0.3596 + 01 | 0.1792 + 00 | 0.1810 + 02 | 0.4439 + 00 |
| 0.3750 + 01 | 0.1624 + 02 | 0.4426 + 01 | 0.3669 + 01 | 0.1717 + 00 | 0.1857 + 02 | 0.4423 + 00 |

| M | $\frac{p_2}{p_1}$ | $\frac{\rho_2}{\rho_1}$ | $\frac{T_2}{T_1}$ | $\frac{p_{0_2}}{p_{0_1}}$ | $\frac{p_{0_2}}{p_1}$ | M_2 |
|-------------|-------------------|-------------------------|-------------------|---------------------------|-----------------------|-------------|
| 0.3800 + 01 | 0.1668 + 02 | 0.4457 + 01 | 0.3743 + 01 | 0.1645 + 00 | 0.1906 + 02 | 0.4407 + 00 |
| 0.3850 + 01 | 0.1713 + 02 | 0.4487 + 01 | 0.3817 + 01 | 0.1576 + 00 | 0.1955 + 02 | 0.4392 + 00 |
| 0.3900 + 01 | 0.1758 + 02 | 0.4516 + 01 | 0.3893 + 01 | 0.1510 + 00 | 0.2005 + 02 | 0.4377 + 00 |
| 0.3950 + 01 | 0.1804 + 02 | 0.4544 + 01 | 0.3969 + 01 | 0.1448 + 00 | 0.2056 + 02 | 0.4363 + 00 |
| 0.4000 + 01 | 0.1850 + 02 | 0.4571 + 01 | 0.4047 + 01 | 0.1388 + 00 | 0.2107 + 02 | 0.4350 + 00 |
| 0.4050 + 01 | 0.1897 + 02 | 0.4598 + 01 | 0.4125 + 01 | 0.1330 + 00 | 0.2159 + 02 | 0.4336 + 00 |
| 0.4100 + 01 | 0.1944 + 02 | 0.4624 + 01 | 0.4205 + 01 | 0.1276 + 00 | 0.2211 + 02 | 0.4324 + 00 |
| 0.4150 + 01 | 0.1993 + 02 | 0.4650 + 01 | 0.4285 + 01 | 0.1223 + 00 | 0.2264 + 02 | 0.4311 + 00 |
| 0.4200 + 01 | 0.2041 + 02 | 0.4675 + 01 | 0.4367 + 01 | 0.1173 + 00 | 0.2318 + 02 | 0.4299 + 00 |
| 0.4250 + 01 | 0.2091 + 02 | 0.4699 + 01 | 0.4449 + 01 | 0.1126 + 00 | 0.2372 + 02 | 0.4288 + 00 |
| 0.4300 + 01 | 0.2140 + 02 | 0.4723 + 01 | 0.4532 + 01 | 0.1080 + 00 | 0.2427 + 02 | 0.4277 + 00 |
| 0.4350 + 01 | 0.2191 + 02 | 0.4746 + 01 | 0.4616 + 01 | 0.1036 + 00 | 0.2483 + 02 | 0.4266 + 00 |
| 0.4400 + 01 | 0.2242 + 02 | 0.4768 + 01 | 0.4702 + 01 | 0.9948 - 01 | 0.2539 + 02 | 0.4255 + 00 |
| 0.4450 + 01 | 0.2294 + 02 | 0.4790 + 01 | 0.4788 + 01 | 0.9550 - 01 | 0.2596 + 02 | 0.4245 + 00 |
| 0.4500 + 01 | 0.2346 + 02 | 0.4812 + 01 | 0.4875 + 01 | 0.9170 - 01 | 0.2654 + 02 | 0.4236 + 00 |
| 0.4550 + 01 | 0.2399 + 02 | 0.4833 + 01 | 0.4963 + 01 | 0.8806 - 01 | 0.2712 + 02 | 0.4226 + 00 |
| 0.4600 + 01 | 0.2452 + 02 | 0.4853 + 01 | 0.5052 + 01 | 0.8459 - 01 | 0.2771 + 02 | 0.4217 + 00 |
| 0.4650 + 01 | 0.2506 + 02 | 0.4873 + 01 | 0.5142 + 01 | 0.8126 - 01 | 0.2831 + 02 | 0.4208 + 00 |
| 0.4700 + 01 | 0.2560 + 02 | 0.4893 + 01 | 0.5233 + 01 | 0.7809 - 01 | 0.2891 + 02 | 0.4199 + 00 |
| 0.4750 + 01 | 0.2616 + 02 | 0.4912 + 01 | 0.5325 + 01 | 0.7505 - 01 | 0.2952 + 02 | 0.4191 + 00 |
| 0.4800 + 01 | 0.2671 + 02 | 0.4930 + 01 | 0.5418 + 01 | 0.7214 - 01 | 0.3013 + 02 | 0.4183 + 00 |
| 0.4850 + 01 | 0.2728 + 02 | 0.4948 + 01 | 0.5512 + 01 | 0.6936 - 01 | 0.3075 + 02 | 0.4175 + 00 |
| 0.4900 + 01 | 0.2784 + 02 | 0.4966 + 01 | 0.5607 + 01 | 0.6670 - 01 | 0.3138 + 02 | 0.4167 + 00 |
| 0.4950 + 01 | 0.2842 + 02 | 0.4983 + 01 | 0.5703 + 01 | 0.6415 - 01 | 0.3201 + 02 | 0.4160 + 00 |
| 0.5000 + 01 | 0.2900 + 02 | 0.5000 + 01 | 0.5800 + 01 | 0.6172 - 01 | 0.3265 + 02 | 0.4152 + 00 |
| 0.5100 + 01 | 0.3018 + 02 | 0.5033 + 01 | 0.5997 + 01 | 0.5715 - 01 | 0.3395 + 02 | 0.4138 + 00 |
| 0.5200 + 01 | 0.3138 + 02 | 0.5064 + 01 | 0.6197 + 01 | 0.5297 - 01 | 0.3528 + 02 | 0.4125 + 00 |
| 0.5300 + 01 | 0.3260 + 02 | 0.5093 + 01 | 0.6401 + 01 | 0.4913 - 01 | 0.3663 + 02 | 0.4113 + 00 |
| 0.5400 + 01 | 0.3385 + 02 | 0.5122 + 01 | 0.6610 + 01 | 0.4560 - 01 | 0.3801 + 02 | 0.4101 + 00 |
| 0.5500 + 01 | 0.3512 + 02 | 0.5149 + 01 | 0.6822 + 01 | 0.4236 - 01 | 0.3941 + 02 | 0.4090 + 00 |
| 0.5600 + 01 | 0.3642 + 02 | 0.5175 + 01 | 0.7038 + 01 | 0.3938 - 01 | 0.4084 + 02 | 0.4079 + 00 |
| 0.5700 + 01 | 0.3774 + 02 | 0.5200 + 01 | 0.7258 + 01 | 0.3664 - 01 | 0.4230 + 02 | 0.4069 + 00 |
| 0.5800 + 01 | 0.3908 + 02 | 0.5224 + 01 | 0.7481 + 01 | 0.3412 - 01 | 0.4378 + 02 | 0.4059 + 00 |
| 0.5900 + 01 | 0.4044 + 02 | 0.5246 + 01 | 0.7709 + 01 | 0.3180 - 01 | 0.4528 + 02 | 0.4050 + 00 |
| 0.6000 + 01 | 0.4183 + 02 | 0.5268 + 01 | 0.7941 + 01 | 0.2965 - 01 | 0.4682 + 02 | 0.4042 + 00 |
| 0.6100 + 01 | 0.4324 + 02 | 0.5289 + 01 | 0.8176 + 01 | 0.2767 - 01 | 0.4837 + 02 | 0.4033 + 00 |
| 0.6200 + 01 | 0.4468 + 02 | 0.5309 + 01 | 0.8415 + 01 | 0.2584 - 01 | 0.4996 + 02 | 0.4025 + 00 |
| 0.6300 + 01 | 0.4614 + 02 | 0.5329 + 01 | 0.8658 + 01 | 0.2416 - 01 | 0.5157 + 02 | 0.4018 + 00 |
| 0.6400 + 01 | 0.4762 + 02 | 0.5347 + 01 | 0.8905 + 01 | 0.2259 - 01 | 0.5320 + 02 | 0.4011 + 00 |
| 0.6500 + 01 | 0.4912 + 02 | 0.5365 + 01 | 0.9156 + 01 | 0.2115 - 01 | 0.5486 + 02 | 0.4004 + 00 |
| 0.6600 + 01 | 0.5065 + 02 | 0.5382 + 01 | 0.9411 + 01 | 0.1981 - 01 | 0.5655 + 02 | 0.3997 + 00 |
| 0.6700 + 01 | 0.5220 + 02 | 0.5399 + 01 | 0.9670 + 01 | 0.1857 - 01 | 0.5826 + 02 | 0.3991 + 00 |
| 0.6800 + 01 | 0.5378 + 02 | 0.5415 + 01 | 0.9933 + 01 | 0.1741 - 01 | 0.6000 + 02 | 0.3985 + 00 |
| 0.6900 + 01 | 0.5538 + 02 | 0.5430 + 01 | 0.1020 + 02 | 0.1635 - 01 | 0.6176 + 02 | 0.3979 + 00 |
| 0.7000 + 01 | 0.5700 + 02 | 0.5444 + 01 | 0.1047 + 02 | 0.1535 - 01 | 0.6355 + 02 | 0.3974 + 00 |
| 0.7100 + 01 | 0.5864 + 02 | 0.5459 + 01 | 0.1074 + 02 | 0.1443 - 01 | 0.6537 + 02 | 0.3968 + 00 |
| 0.7200 + 01 | 0.6031 + 02 | 0.5472 + 01 | 0.1102 + 02 | 0.1357 - 01 | 0.6721 + 02 | 0.3963 + 00 |
| 0.7300 + 01 | 0.6200 + 02 | 0.5485 + 01 | 0.1130 + 02 | 0.1277 - 01 | 0.6908 + 02 | 0.3958 + 00 |
| 0.7400 + 01 | 0.6372 + 02 | 0.5498 + 01 | 0.1159 + 02 | 0.1202 - 01 | 0.7097 + 02 | 0.3954 + 00 |
| 0.7500 + 01 | 0.6546 + 02 | 0.5510 + 01 | 0.1188 + 02 | 0.1133 - 01 | 0.7289 + 02 | 0.3949 + 00 |

| M | $\frac{p_2}{p_1}$ | $\frac{\rho_2}{\rho_1}$ | $\frac{T_2}{T_1}$ | $\frac{p_{0_2}}{p_{0_1}}$ | $\frac{p_{0_2}}{p_1}$ | M_2 |
|-------------|-------------------|-------------------------|-------------------|---------------------------|-----------------------|-------------|
| 0.7600 + 01 | 0.6722 + 02 | 0.5522 + 01 | 0.1217 + 02 | 0.1068 - 01 | 0.7483 + 02 | 0.3945 + 00 |
| 0.7700 + 01 | 0.6900 + 02 | 0.5533 + 01 | 0.1247 + 02 | 0.1008 - 01 | 0.7680 + 02 | 0.3941 + 00 |
| 0.7800 + 01 | 0.7081 + 02 | 0.5544 + 01 | 0.1277 + 02 | 0.9510 - 02 | 0.7880 + 02 | 0.3937 + 00 |
| 0.7900 + 01 | 0.7264 + 02 | 0.5555 + 01 | 0.1308 + 02 | 0.8982 - 02 | 0.8082 + 02 | 0.3933 + 00 |
| 0.8000 + 01 | 0.7450 + 02 | 0.5565 + 01 | 0.1339 + 02 | 0.8488 - 02 | 0.8287 + 02 | 0.3929 + 00 |
| 0.9000 + 01 | 0.9433 + 02 | 0.5651 + 01 | 0.1669 + 02 | 0.4964 - 02 | 0.1048 + 03 | 0.3898 + 00 |
| 0.1000 + 02 | 0.1165 + 03 | 0.5714 + 01 | 0.2039 + 02 | 0.3045 - 02 | 0.1292 + 03 | 0.3876 + 00 |
| 0.1100 + 02 | 0.1410 + 03 | 0.5762 + 01 | 0.2447 + 02 | 0.1945 - 02 | 0.1563 + 03 | 0.3859 + 00 |
| 0.1200 + 02 | 0.1678 + 03 | 0.5799 + 01 | 0.2894 + 02 | 0.1287 - 02 | 0.1859 + 03 | 0.3847 + 00 |
| 0.1300 + 02 | 0.1970 + 03 | 0.5828 + 01 | 0.3380 + 02 | 0.8771 - 03 | 0.2181 + 03 | 0.3837 + 00 |
| 0.1400 + 02 | 0.2285 + 03 | 0.5851 + 01 | 0.3905 + 02 | 0.6138 - 03 | 0.2528 + 03 | 0.3829 + 00 |
| 0.1500 + 02 | 0.2623 + 03 | 0.5870 + 01 | 0.4469 + 02 | 0.4395 - 03 | 0.2902 + 03 | 0.3823 + 00 |
| 0.1600 + 02 | 0.2985 + 03 | 0.5885 + 01 | 0.5072 + 02 | 0.3212 - 03 | 0.3301 + 03 | 0.3817 + 00 |
| 0.1700 + 02 | 0.3370 + 03 | 0.5898 + 01 | 0.5714 + 02 | 0.2390 - 03 | 0.3726 + 03 | 0.3813 + 00 |
| 0.1800 + 02 | 0.3778 + 03 | 0.5909 + 01 | 0.6394 + 02 | 0.1807 - 03 | 0.4176 + 03 | 0.3810 + 00 |
| 0.1900 + 02 | 0.4210 + 03 | 0.5918 + 01 | 0.7114 + 02 | 0.1386 - 03 | 0.4653 + 03 | 0.3806 + 00 |
| 0.2000 + 02 | 0.4665 + 03 | 0.5926 + 01 | 0.7872 + 02 | 0.1078 - 03 | 0.5155 + 03 | 0.3804 + 00 |
| 0.2200 + 02 | 0.5645 + 03 | 0.5939 + 01 | 0.9506 + 02 | 0.6741 - 04 | 0.6236 + 03 | 0.3800 + 00 |
| 0.2400 + 02 | 0.6718 + 03 | 0.5948 + 01 | 0.1129 + 03 | 0.4388 - 04 | 0.7421 + 03 | 0.3796 + 00 |
| 0.2600 + 02 | 0.7885 + 03 | 0.5956 + 01 | 0.1324 + 03 | 0.2953 - 04 | 0.8709 + 03 | 0.3794 + 00 |
| 0.2800 + 02 | 0.9145 + 03 | 0.5962 + 01 | 0.1534 + 03 | 0.2046 - 04 | 0.1010 + 04 | 0.3792 + 00 |
| 0.3000 + 02 | 0.1050 + 04 | 0.5967 + 01 | 0.1759 + 03 | 0.1453 - 04 | 0.1159 + 04 | 0.3790 + 00 |
| 0.3200 + 02 | 0.1194 + 04 | 0.5971 + 01 | 0.2001 + 03 | 0.1055 - 04 | 0.1319 + 04 | 0.3789 + 00 |
| 0.3400 + 02 | 0.1348 + 04 | 0.5974 + 01 | 0.2257 + 03 | 0.7804 - 05 | 0.1489 + 04 | 0.3788 + 00 |
| 0.3600 + 02 | 0.1512 + 04 | 0.5977 + 01 | 0.2529 + 03 | 0.5874 - 05 | 0.1669 + 04 | 0.3787 + 00 |
| 0.3800 + 02 | 0.1684 + 04 | 0.5979 + 01 | 0.2817 + 03 | 0.4488 - 05 | 0.1860 + 04 | 0.3786 + 00 |
| 0.4000 + 02 | 0.1866 + 04 | 0.5981 + 01 | 0.3121 + 03 | 0.3477 - 05 | 0.2061 + 04 | 0.3786 + 00 |
| 0.4200 + 02 | 0.2058 + 04 | 0.5983 + 01 | 0.3439 + 03 | 0.2727 - 05 | 0.2272 + 04 | 0.3785 + 00 |
| 0.4400 + 02 | 0.2258 + 04 | 0.5985 + 01 | 0.3774 + 03 | 0.2163 - 05 | 0.2493 + 04 | 0.3785 + 00 |
| 0.4600 + 02 | 0.2468 + 04 | 0.5986 + 01 | 0.4124 + 03 | 0.1733 - 05 | 0.2725 + 04 | 0.3784 + 00 |
| 0.4800 + 02 | 0.2688 + 04 | 0.5987 + 01 | 0.4489 + 03 | 0.1402 - 05 | 0.2967 + 04 | 0.3784 + 00 |
| 0.5000 + 02 | 0.2916 + 04 | 0.5988 + 01 | 0.4871 + 03 | 0.1144 - 05 | 0.3219 + 04 | 0.3784 + 00 |

appendix

C

PRANDTL-MEYER FUNCTION AND] ANGLE

| <i>M</i> | <i>v</i> | <i>μ</i> | <i>M</i> | <i>v</i> | <i>μ</i> |
|-------------|-------------|-------------|-------------|-------------|-------------|
| 0.1000 + 01 | 0.0000 | 0.9000 + 02 | 0.1640 + 01 | 0.1604 + 02 | 0.3757 + 02 |
| 0.1020 + 01 | 0.1257 + 00 | 0.7864 + 02 | 0.1660 + 01 | 0.1663 + 02 | 0.3704 + 02 |
| 0.1040 + 01 | 0.3510 + 00 | 0.7406 + 02 | 0.1680 + 01 | 0.1722 + 02 | 0.3653 + 02 |
| 0.1060 + 01 | 0.6367 + 00 | 0.7063 + 02 | 0.1700 + 01 | 0.1781 + 02 | 0.3603 + 02 |
| 0.1080 + 01 | 0.9680 + 00 | 0.6781 + 02 | 0.1720 + 01 | 0.1840 + 02 | 0.3555 + 02 |
| 0.1100 + 01 | 0.1336 + 01 | 0.6538 + 02 | 0.1740 + 01 | 0.1898 + 02 | 0.3508 + 02 |
| 0.1120 + 01 | 0.1735 + 01 | 0.6323 + 02 | 0.1760 + 01 | 0.1956 + 02 | 0.3462 + 02 |
| 0.1140 + 01 | 0.2160 + 01 | 0.6131 + 02 | 0.1780 + 01 | 0.2015 + 02 | 0.3418 + 02 |
| 0.1160 + 01 | 0.2607 + 01 | 0.5955 + 02 | 0.1800 + 01 | 0.2073 + 02 | 0.3375 + 02 |
| 0.1180 + 01 | 0.3074 + 01 | 0.5794 + 02 | 0.1820 + 01 | 0.2130 + 02 | 0.3333 + 02 |
| 0.1200 + 01 | 0.3558 + 01 | 0.5644 + 02 | 0.1840 + 01 | 0.2188 + 02 | 0.3292 + 02 |
| 0.1220 + 01 | 0.4057 + 01 | 0.5505 + 02 | 0.1860 + 01 | 0.2245 + 02 | 0.3252 + 02 |
| 0.1240 + 01 | 0.4569 + 01 | 0.5375 + 02 | 0.1880 + 01 | 0.2302 + 02 | 0.3213 + 02 |
| 0.1260 + 01 | 0.5093 + 01 | 0.5253 + 02 | 0.1900 + 01 | 0.2359 + 02 | 0.3176 + 02 |
| 0.1280 + 01 | 0.5627 + 01 | 0.5138 + 02 | 0.1920 + 01 | 0.2415 + 02 | 0.3139 + 02 |
| 0.1300 + 01 | 0.6170 + 01 | 0.5028 + 02 | 0.1940 + 01 | 0.2471 + 02 | 0.3103 + 02 |
| 0.1320 + 01 | 0.6721 + 01 | 0.4925 + 02 | 0.1960 + 01 | 0.2527 + 02 | 0.3068 + 02 |
| 0.1340 + 01 | 0.7279 + 01 | 0.4827 + 02 | 0.1980 + 01 | 0.2583 + 02 | 0.3033 + 02 |
| 0.1360 + 01 | 0.7844 + 01 | 0.4733 + 02 | 0.2000 + 01 | 0.2638 + 02 | 0.3000 + 02 |
| 0.1380 + 01 | 0.8413 + 01 | 0.4644 + 02 | 0.2050 + 01 | 0.2775 + 02 | 0.2920 + 02 |
| 0.1400 + 01 | 0.8987 + 01 | 0.4558 + 02 | 0.2100 + 01 | 0.2910 + 02 | 0.2844 + 02 |
| 0.1420 + 01 | 0.9565 + 01 | 0.4477 + 02 | 0.2150 + 01 | 0.3043 + 02 | 0.2772 + 02 |
| 0.1440 + 01 | 0.1015 + 02 | 0.4398 + 02 | 0.2200 + 01 | 0.3173 + 02 | 0.2704 + 02 |
| 0.1460 + 01 | 0.1073 + 02 | 0.4323 + 02 | 0.2250 + 01 | 0.3302 + 02 | 0.2639 + 02 |
| 0.1480 + 01 | 0.1132 + 02 | 0.4251 + 02 | 0.2300 + 01 | 0.3428 + 02 | 0.2577 + 02 |
| 0.1500 + 01 | 0.1191 + 02 | 0.4181 + 02 | 0.2350 + 01 | 0.3553 + 02 | 0.2518 + 02 |
| 0.1520 + 01 | 0.1249 + 02 | 0.4114 + 02 | 0.2400 + 01 | 0.3675 + 02 | 0.2462 + 02 |
| 0.1540 + 01 | 0.1309 + 02 | 0.4049 + 02 | 0.2450 + 01 | 0.3795 + 02 | 0.2409 + 02 |
| 0.1560 + 01 | 0.1368 + 02 | 0.3987 + 02 | 0.2500 + 01 | 0.3912 + 02 | 0.2358 + 02 |
| 0.1580 + 01 | 0.1427 + 02 | 0.3927 + 02 | 0.2550 + 01 | 0.4028 + 02 | 0.2309 + 02 |
| 0.1600 + 01 | 0.1486 + 02 | 0.3868 + 02 | 0.2600 + 01 | 0.4141 + 02 | 0.2262 + 02 |
| 0.1620 + 01 | 0.1545 + 02 | 0.3812 + 02 | 0.2650 + 01 | 0.4253 + 02 | 0.2217 + 02 |

| M | ν | μ | M | ν | μ |
|-------------|-------------|-------------|-------------|-------------|-------------|
| 0.2700 + 01 | 0.4362 + 02 | 0.2174 + 02 | 0.5600 + 01 | 0.8203 + 02 | 0.1029 + 02 |
| 0.2750 + 01 | 0.4469 + 02 | 0.2132 + 02 | 0.5700 + 01 | 0.8280 + 02 | 0.1010 + 02 |
| 0.2800 + 01 | 0.4575 + 02 | 0.2092 + 02 | 0.5800 + 01 | 0.8354 + 02 | 0.9928 + 01 |
| 0.2850 + 01 | 0.4678 + 02 | 0.2054 + 02 | 0.5900 + 01 | 0.8426 + 02 | 0.9758 + 01 |
| 0.2900 + 01 | 0.4779 + 02 | 0.2017 + 02 | 0.6000 + 01 | 0.8496 + 02 | 0.9594 + 01 |
| 0.2950 + 01 | 0.4878 + 02 | 0.1981 + 02 | 0.6100 + 01 | 0.8563 + 02 | 0.9435 + 01 |
| 0.3000 + 01 | 0.4976 + 02 | 0.1947 + 02 | 0.6200 + 01 | 0.8629 + 02 | 0.9282 + 01 |
| 0.3050 + 01 | 0.5071 + 02 | 0.1914 + 02 | 0.6300 + 01 | 0.8694 + 02 | 0.9133 + 01 |
| 0.3100 + 01 | 0.5165 + 02 | 0.1882 + 02 | 0.6400 + 01 | 0.8756 + 02 | 0.8989 + 01 |
| 0.3150 + 01 | 0.5257 + 02 | 0.1851 + 02 | 0.6500 + 01 | 0.8817 + 02 | 0.8850 + 01 |
| 0.3200 + 01 | 0.5347 + 02 | 0.1821 + 02 | 0.6600 + 01 | 0.8876 + 02 | 0.8715 + 01 |
| 0.3250 + 01 | 0.5435 + 02 | 0.1792 + 02 | 0.6700 + 01 | 0.8933 + 02 | 0.8584 + 01 |
| 0.3300 + 01 | 0.5522 + 02 | 0.1764 + 02 | 0.6800 + 01 | 0.8989 + 02 | 0.8457 + 01 |
| 0.3350 + 01 | 0.5607 + 02 | 0.1737 + 02 | 0.6900 + 01 | 0.9044 + 02 | 0.8333 + 01 |
| 0.3400 + 01 | 0.5691 + 02 | 0.1710 + 02 | 0.7000 + 01 | 0.9097 + 02 | 0.8213 + 01 |
| 0.3450 + 01 | 0.5773 + 02 | 0.1685 + 02 | 0.7100 + 01 | 0.9149 + 02 | 0.8097 + 01 |
| 0.3500 + 01 | 0.5853 + 02 | 0.1660 + 02 | 0.7200 + 01 | 0.9200 + 02 | 0.7984 + 01 |
| 0.3550 + 01 | 0.5932 + 02 | 0.1636 + 02 | 0.7300 + 01 | 0.9249 + 02 | 0.7873 + 01 |
| 0.3600 + 01 | 0.6009 + 02 | 0.1613 + 02 | 0.7400 + 01 | 0.9297 + 02 | 0.7766 + 01 |
| 0.3650 + 01 | 0.6085 + 02 | 0.1590 + 02 | 0.7500 + 01 | 0.9344 + 02 | 0.7662 + 01 |
| 0.3700 + 01 | 0.6160 + 02 | 0.1568 + 02 | 0.7600 + 01 | 0.9390 + 02 | 0.7561 + 01 |
| 0.3750 + 01 | 0.6233 + 02 | 0.1547 + 02 | 0.7700 + 01 | 0.9434 + 02 | 0.7462 + 01 |
| 0.3800 + 01 | 0.6304 + 02 | 0.1526 + 02 | 0.7800 + 01 | 0.9478 + 02 | 0.7366 + 01 |
| 0.3850 + 01 | 0.6375 + 02 | 0.1505 + 02 | 0.7900 + 01 | 0.9521 + 02 | 0.7272 + 01 |
| 0.3900 + 01 | 0.6444 + 02 | 0.1486 + 02 | 0.8000 + 01 | 0.9562 + 02 | 0.7181 + 01 |
| 0.3950 + 01 | 0.6512 + 02 | 0.1466 + 02 | 0.9000 + 01 | 0.9932 + 02 | 0.6379 + 01 |
| 0.4000 + 01 | 0.6578 + 02 | 0.1448 + 02 | 0.1000 + 02 | 0.1023 + 03 | 0.5739 + 01 |
| 0.4050 + 01 | 0.6644 + 02 | 0.1429 + 02 | 0.1100 + 02 | 0.1048 + 03 | 0.5216 + 01 |
| 0.4100 + 01 | 0.6708 + 02 | 0.1412 + 02 | 0.1200 + 02 | 0.1069 + 03 | 0.4780 + 01 |
| 0.4150 + 01 | 0.6771 + 02 | 0.1394 + 02 | 0.1300 + 02 | 0.1087 + 03 | 0.4412 + 01 |
| 0.4200 + 01 | 0.6833 + 02 | 0.1377 + 02 | 0.1400 + 02 | 0.1102 + 03 | 0.4096 + 01 |
| 0.4250 + 01 | 0.6894 + 02 | 0.1361 + 02 | 0.1500 + 02 | 0.1115 + 03 | 0.3823 + 01 |
| 0.4300 + 01 | 0.6954 + 02 | 0.1345 + 02 | 0.1600 + 02 | 0.1127 + 03 | 0.3583 + 01 |
| 0.4350 + 01 | 0.7013 + 02 | 0.1329 + 02 | 0.1700 + 02 | 0.1137 + 03 | 0.3372 + 01 |
| 0.4400 + 01 | 0.7071 + 02 | 0.1314 + 02 | 0.1800 + 02 | 0.1146 + 03 | 0.3185 + 01 |
| 0.4450 + 01 | 0.7127 + 02 | 0.1299 + 02 | 0.1900 + 02 | 0.1155 + 03 | 0.3017 + 01 |
| 0.4500 + 01 | 0.7183 + 02 | 0.1284 + 02 | 0.2000 + 02 | 0.1162 + 03 | 0.2866 + 01 |
| 0.4550 + 01 | 0.7238 + 02 | 0.1270 + 02 | 0.2200 + 02 | 0.1175 + 03 | 0.2605 + 01 |
| 0.4600 + 01 | 0.7292 + 02 | 0.1256 + 02 | 0.2400 + 02 | 0.1186 + 03 | 0.2388 + 01 |
| 0.4650 + 01 | 0.7345 + 02 | 0.1242 + 02 | 0.2600 + 02 | 0.1195 + 03 | 0.2204 + 01 |
| 0.4700 + 01 | 0.7397 + 02 | 0.1228 + 02 | 0.2800 + 02 | 0.1202 + 03 | 0.2047 + 01 |
| 0.4750 + 01 | 0.7448 + 02 | 0.1215 + 02 | 0.3000 + 02 | 0.1209 + 03 | 0.1910 + 01 |
| 0.4800 + 01 | 0.7499 + 02 | 0.1202 + 02 | 0.3200 + 02 | 0.1215 + 03 | 0.1791 + 01 |
| 0.4850 + 01 | 0.7548 + 02 | 0.1190 + 02 | 0.3400 + 02 | 0.1220 + 03 | 0.1685 + 01 |
| 0.4900 + 01 | 0.7597 + 02 | 0.1178 + 02 | 0.3600 + 02 | 0.1225 + 03 | 0.1592 + 01 |
| 0.4950 + 01 | 0.7645 + 02 | 0.1166 + 02 | 0.3800 + 02 | 0.1229 + 03 | 0.1508 + 01 |
| 0.5000 + 01 | 0.7692 + 02 | 0.1154 + 02 | 0.4000 + 02 | 0.1233 + 03 | 0.1433 + 01 |
| 0.5100 + 01 | 0.7784 + 02 | 0.1131 + 02 | 0.4200 + 02 | 0.1236 + 03 | 0.1364 + 01 |
| 0.5200 + 01 | 0.7873 + 02 | 0.1109 + 02 | 0.4400 + 02 | 0.1239 + 03 | 0.1302 + 01 |
| 0.5300 + 01 | 0.7960 + 02 | 0.1088 + 02 | 0.4600 + 02 | 0.1242 + 03 | 0.1246 + 01 |
| 0.5400 + 01 | 0.8043 + 02 | 0.1067 + 02 | 0.4800 + 02 | 0.1245 + 03 | 0.1194 + 01 |
| 0.5500 + 01 | 0.8124 + 02 | 0.1048 + 02 | 0.5000 + 02 | 0.1247 + 03 | 0.1146 + 01 |