NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

TECHNICAL NOTE

No. 1120

STANDARD NOMENCLATURE FOR AIRSPEEDS WITH TABLES
AND CHARTS FOR USE IN CALCULATION OF AIRSPEED

By William S. Aiken, Jr.

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

Washington
September 1946
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE No. 1120

STANDARD NOMENCLATURE FOR AIRSPEEDS WITH TABLES
AND CHARTS FOR USE IN CALCULATION OF AIRSPEED

By William S. Aiken, Jr.

SUMMARY

Symbols and definitions of various airspeed terms that have been adopted as standard by the NACA Subcommittee on Aircraft Structural Design are presented. The equations, charts, and tables required in the evaluation of true airspeed, calibrated airspeed, equivalent airspeed, impact and dynamic pressures, and Mach and Reynolds numbers have been compiled. Tables of the standard atmosphere to an altitude of 65,000 feet and a tentative extension to an altitude of 100,000 feet are given along with the basic equations and constants on which both the standard atmosphere and the tentative extension are based.

INTRODUCTION

In analyses of aerodynamic data very often wind-tunnel or flight measurements must be converted into airspeed and related quantities that are used in engineering calculations. Attempts to accomplish such conversion by use of available methods have been complicated by the diversity of symbols and definitions and by the necessity of referring to equations, charts, and tables from a number of different sources. A standard set of symbols and definitions of various airspeed terms that were adopted by the NACA Subcommittee on Aircraft Structural Design and a compilation of the necessary equations, charts, and tables for converting measured pressures and temperatures into airspeeds, determining Mach numbers and Reynolds numbers, and determining other quantities such as dynamic and impact pressures that are of interest are therefore presented herein.

In the preparation of the present paper results that have been included in previous papers have been extended to include higher altitudes and quantities not
given in the previous papers, since recent requests have indicated the need for such an extension of standard-atmosphere tables.

The tables and figures have been arranged for ease in determination of the airspeed, which is usually based on the interpretation of measurements of differential pressures obtained with some pitot-static arrangement. The interrelation of the various airspeed quantities is independent of the method used in the measurement. Instrument and installation errors have been assumed to have been taken into account.

STANDARD SYMBOLS AND DEFINITIONS

At the November 1944 meeting of the NACA Subcommittee on Aircraft Structural Design, representatives from the Army, Navy, CAA, NACA, and several aircraft manufacturers adopted as standard the following symbols and definitions for airspeeds:

\[ \begin{align*}
V & \quad \text{true airspeed} \\
V_i & \quad \text{indicated airspeed (the reading of a differential-pressure airspeed indicator, calibrated in accordance with the accepted standard adiabatic formula to indicate true airspeed for standard sea-level conditions only, uncorrected for instrument and installation errors)} \\
V_c & \quad \text{calibrated airspeed (the airspeed related to differential pressure by the accepted standard adiabatic formula used in the calibration of differential-pressure airspeed indicators and equal to true airspeed for standard sea-level conditions)} \\
V_e & \quad \text{equivalent airspeed} \left(\sqrt{V} \right)
\end{align*} \]

Use of equivalent airspeed in combination with various subscripts is customary, particularly in structural design, to designate various design conditions. It is suggested that the foregoing symbols be retained intact when further subscripts are necessary.
Most of the following symbols, which are used herein, have already been accepted as standard and are used throughout aeronautical literature. The units given apply to the development of the equations in the present report.

$V$, true airspeed, feet per second

$V_c$, calibrated airspeed, feet per second

$V_e$, equivalent airspeed, feet per second

$a$, speed of sound in ambient air, feet per second

$M$, Mach number ($V/a$)

$\rho$, mass density of ambient air, slugs per cubic foot

$\rho_0$, standard mass density of dry ambient air at sea level, 0.002378 slug per cubic foot

$\sigma$, density ratio ($\rho/\rho_0$)

$q$, dynamic pressure, pounds per square foot ($\frac{1}{2} \rho V^2$)

$q_c$, impact pressure, pounds per square foot (total pressure minus static pressure $p$)

$p$, static pressure of free stream, pounds per square foot

$p_0$, static pressure of free stream under standard sea-level conditions, pounds per square foot

$t$, temperature, °F or °C

$\Delta t$, difference between free-air temperature and temperature of standard atmosphere, °F

$T$, absolute temperature, °F absolute or °C absolute

$T_{std}$, standard-atmosphere free-air temperature, °F absolute

$T_0$, standard sea-level absolute temperature, 518.4 °F absolute
\[ T_m \] harmonic mean absolute temperature, °F absolute (defined in equation (65))

\[ f \] compressibility factor defined in equation (11)

\[ f_0 \] compressibility factor defined in equation (16)

\[ \nu \] ratio of specific heat at constant pressure to specific heat at constant volume (assumed equal to 1.4 for air)

\[ h \] absolute altitude, feet

\[ h_p \] pressure altitude, feet

\[ g \] acceleration of gravity, 32.1740 feet per second per second

\[ m \] modulus for common logarithms, \( \log_{10} 10^2 \) (0.434294)

\[ \mu \] coefficient of viscosity, slugs per foot-second

\[ \nu \] kinematic viscosity, square feet per second (\( \mu/\rho \))

\[ R \] Reynolds number \( \left( \frac{\nu L}{\mu} \right) \)

\[ R_{\text{std}} \] Reynolds number for standard atmospheric conditions

\[ l \] characteristic length, feet

**CALCULATION OF AIRSPEED AND RELATED QUANTITIES**

Because pitot-static arrangements are used as the basis for the determination of airspeed, aeronautical engineering practice has developed to include the use of a number of airspeed terms and quantities, each of which has a particular field of usefulness. True airspeed is principally of use to aerodynamicists, and indicated and calibrated airspeeds are principally of use to pilots. Equivalent airspeed is used by structural engineers, since all load specifications have long been based on this quantity.

Definite relationships exist between true airspeed, Mach number, Reynolds number, calibrated airspeed, and equivalent airspeed, and all these quantities may be
related either to the dynamic pressure \( q \) or to the impact pressure \( q_c \). Some of the relations presented herein apply to the calculation of true airspeed and Mach number from airspeed measurements obtained with an airspeed indicator of standard calibration. Other relations apply to the calculation of true airspeed when the impact pressure is measured directly.

If it is assumed that the total-head tube and the static-head tube measure their respective pressures correctly and that these tubes are connected to an appropriate instrument, the impact pressure measured is given by the adiabatic equation when \( V < a \):

\[
q_c = p \left(1 + \frac{\gamma - 1}{2\gamma} \frac{\rho}{p} v^2 \right)^{\frac{\gamma}{\gamma - 1}} - 1
\]

(1)

Standard airspeed indicators used in Army and Navy airplanes since 1925 have been calibrated according to equation (1) for standard sea-level conditions; that is, according to the equation when \( V < a \),

\[
q_c = p_0 \left(1 + \frac{\gamma - 1}{2\gamma} \frac{\rho_0}{p_0} v_c^2 \right)^{\frac{\gamma}{\gamma - 1}} - 1
\]

(2)

where the subscript 0 denotes standard sea-level conditions and \( v_c \) is the calibrated airspeed. The calibrated airspeed is, therefore, equal to true airspeed only for standard sea-level conditions.

Determination of True Airspeed from Calibrated Airspeed

The formula that relates the true airspeed to the calibrated airspeed may be found by equating the right-hand terms of equations (1) and (2) as follows:

\[
p \left(1 + \frac{\gamma - 1}{2\gamma} \frac{\rho}{p} v^2 \right)^{\frac{\gamma}{\gamma - 1}} - 1 = p_0 \left(1 + \frac{\gamma - 1}{2\gamma} \frac{\rho_0}{p_0} v_c^2 \right)^{\frac{\gamma}{\gamma - 1}} - 1
\]

(3)
Because the exact numerical solution of equation (3) for true airspeed is involved and requires a great deal of time, a number of charts for the determination of the true airspeed from the calibrated airspeed for various atmospheric conditions have been derived. (See references 1 to 3.) A typical chart (taken from reference 1) that shows the relationship between Mach number, calibrated airspeed, pressure altitude, temperature, and true airspeed is given in figure 1. This chart is widely used because of its convenience. Airspeed may be obtained from this chart with an accuracy within 2 miles per hour when standard conditions hold and when values of airspeed and pressure altitude explicitly given by the chart are chosen; the possible errors increase to within 5 miles per hour, however, when the temperature conditions are not standard and when interpolation is required for both altitude and airspeed.

For some purposes, charts such as figure 1 are not sufficiently accurate. A series of logarithmic tables that may be used to determine the true airspeed in knots from observed values of calibrated airspeed, pressure altitude, and free-air temperature is given in reference 4. Logarithmic tables of the type given in reference 4 are of limited usefulness since they cannot be used conveniently to evaluate the intermediate quantities (impact pressure and Mach number) that are involved in the computation of true airspeed.

A series of tables (tables I to V) is given in the present report to permit determination of impact pressure \( q_c \) in pounds per square foot, Mach number \( M \), and true airspeed \( V \) in miles per hour or knots for observed values of \( V_C \) in miles per hour or knots, pressure altitude \( h_p \) in feet, and temperature in degrees Fahrenheit or Centigrade. The accuracy of the tables is far greater than that with which experimental data can normally be obtained. With ordinary care in interpolation, errors should be less than 0.25 mile per hour throughout the greater part of the airspeed and altitude ranges.

Table I, which gives values of impact pressure \( q_c \) in pounds per square foot for values of \( V_C \) in miles per hour, was computed directly from equation (2); standard values were used for all the constants occurring in this equation. Table II gives values of impact pressure \( q_c \) in pounds per square foot for values of \( V_C \) in knots.
In computing the values of \( q_c \) in table II, the conversion from feet to nautical miles used was as follows:

\[
1 \text{ nautical mile} = 6080.2 \text{ feet}
\]

Tables I and II give the impact pressures for \( V_c \) in increments of 1 mile per hour and 1 knot for speeds corresponding to Mach numbers at sea level from 0 to 1.000.

Table III gives values of static pressure \( p \) in pounds per square foot for various values of pressure altitude \( h_p \) from -1000 to 60,000 feet in increments of 100 feet and from 60,000 to 100,000 in increments of 1000 feet for standard atmospheric conditions. (The use of the term standard atmosphere throughout this report includes values for the standard atmosphere up to an altitude of 65,000 feet and for the tentative extension of the standard atmosphere from 65,000 to 100,000 feet.) The values given in table III were computed from the equation

\[
h_p = \frac{p_0}{p_{0gm}} \frac{T_m}{T_0} \log_{10} \left( \frac{p_0}{p} \right)
\]

which is given as equation (4) of reference 5 with slightly different symbols.

From tables I or II and III the ratio of impact pressure to static pressure \( q_c/p \) may be established and the Mach number, which is a function of this ratio, may then be found. The relation between Mach number and \( q_c/p \) is given in reference 6 as

\[
M = \left[ 5 \left( \frac{q_c}{p} + 1 \right)^{2/7} - 1 \right]^{1/2}
\]

Table IV, which is taken directly from reference 6, gives values of Mach number for various values of the ratio \( q_c/p \).

The Mach number \( M \) is defined as the ratio of the true airspeed to the speed of sound in ambient air and
thus, with the Mach number determined, the true airspeed may be found by the use of

\[ V = Ma \]  

(6)

The speed of sound in ambient air is found from the equation

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

(7)

which may be rewritten in the following forms when the value of \( \gamma \) is assumed equal to 1.4 and the air is assumed to follow the gas law

\[ p = p_0 \frac{T}{T_0} \]

If \( a \) is in miles per hour and \( T \) is in degrees Fahrenheit absolute

\[ a = 33.42 \sqrt{T} \]  

(3a)

If \( a \) is in knots and \( T \) is in degrees Fahrenheit absolute

\[ a = 29.02 \sqrt{T} \]  

(3b)

If \( a \) is in miles per hour and \( T \) is in degrees Centigrade absolute

\[ a = 44.84 \sqrt{T} \]  

(3c)

If \( a \) is in knots and \( T \) is in degrees Centigrade absolute

\[ a = 38.94 \sqrt{T} \]  

(3d)

Table V gives the speed of sound for values of free-air temperature in degrees Fahrenheit, and table VI gives the speed of sound for temperatures in degrees Centigrade. Tables V and VI give the speed of sound both in miles per hour and in knots.

In order to illustrate the use of tables I to VI to determine the true airspeed from calibrated airspeed, the following example is presented:
Given:
- Calibrated air speed \( V_c = 396 \text{ miles per hour} \)
- Pressure altitude \( h_p = 22,000 \text{ feet} \)
- Temperature \( t = -12^\circ \text{ F} \)

To find:
- True airspeed \( V \) in miles per hour

Step (1)
From table I, for \( V_c = 396 \text{ miles per hour} \),
\[
q_c = \frac{433.7}{393.3} \text{ pounds per square foot}
\]

Step (2)
From table III, for \( h_p = 22,000 \text{ feet} \),
\( p = 593.3 \text{ pounds per square foot} \)

Step (3)
From these values,
\[
\frac{q_c}{p} = \frac{433.7}{593.3} = 0.7255
\]

Step (4)
From table IV, for \( \frac{q_c}{p} = 0.4855 \),
\( M = 0.7736 \)

Step (5)
From table V, for \( t = -12^\circ \text{ F} \),
\( a = 706.9 \text{ miles per hour} \)

Step (6)
By use of equation (6),
\[
V = Ma = 0.7736 \times 706.9 \text{ miles per hour} = 546.8 \text{ miles per hour}
\]

Determination of True Airspeed from Impact Pressure

In order to convert measurements of impact pressure to true airspeed, the static pressure and the speed of sound must be known. It is convenient first to determine the Mach number from measurements of the impact pressure and the static pressure. Table IV may be used to find the Mach number from the ratio of \( q_c \) to \( p \) and
tables V and VI may be used to find the speed of sound for various values of the free-air temperature. The true airspeed may then be determined from equation (6).

Determination of Dynamic Pressure and Equivalent Airspeed

In order to reduce flight-test data to coefficient form or to demonstrate compliance with certain structural requirements, either the dynamic pressure \( q \) or the equivalent airspeed \( V \) must be determined. The relations of dynamic pressure and equivalent airspeed to impact pressure, static pressure, calibrated airspeed, and Mach number are therefore presented.

Since the dynamic pressure \( q \) is by definition

\[
q = \frac{1}{2} \rho V^2
\]  

(9)

it may be expressed as a function of the impact pressure by solving equation (1) for true airspeed and substituting the resultant expression into equation (9), which reduces to

\[
q = f^2 q_c
\]  

(10)

where

\[
f = \sqrt{\frac{\gamma - 1}{\gamma - 1}} \frac{p}{q_c} \left[ \left( \frac{q_c}{p} \right) + 1 \right] \left[ \frac{\gamma - 1}{\gamma} \right] - 1
\]  

(11)

Values of the compressibility factor \( f \) are given in figure 2 as a function of \( q_c/p \). The dynamic pressure may also be expressed as a function of Mach number and static pressure from equations (6), (7), and (9) as

\[
q = \frac{\gamma}{2} p M^2
\]  

(12)

Since the equivalent airspeed \( V_e \) is by definition

\[
V_e = v_c^{1/2} = \frac{v}{\rho_0}
\]  

(13)
the relation between the equivalent airspeed in miles per hour, Mach number, and pressure ratio can be derived from equations (6), (8), (13), and the gas-law equation as

\[ V_e = 760.9 M \sqrt{\frac{p}{p_0}} \]  \hspace{1cm} (14)

The variation, determined from equation (14), of equivalent airspeed with Mach number for pressure altitudes from 0 to 100,000 feet is given in figure 3. For convenience, the true airspeed that applies to the standard atmosphere computed from equations (13) and (14) is also included in figure 3.

Finally, expressions that will relate the true airspeed, the calibrated airspeed, and the equivalent airspeed are determined. If equation (2) is solved for \( V_c \):

\[ V_c = \sqrt{\frac{\frac{\gamma}{\gamma - 1}}{q_c} \left[ \left( \frac{q_c}{p_0} + 1 \right)^{\gamma - 1} \right]} \sqrt{\frac{2q_c}{p_0}} \]  \hspace{1cm} (15)

If

\[ \sqrt{\frac{\gamma}{\gamma - 1}} \frac{p_0}{q_c} \left[ \left( \frac{q_c}{p_0} + 1 \right)^{\gamma - 1} \right] = f_0 \]  \hspace{1cm} (16)

equation (15) becomes:

\[ V_c = f_0 \sqrt{\frac{2q_c}{p_0}} \]  \hspace{1cm} (17)

The compressibility factor \( f_0 \) is given in figure 2 as a function of \( q_c/p_0 \). Similarly, the true airspeed may be written

\[ V = f \sqrt{\frac{2q_c}{p}} \]  \hspace{1cm} (18)
From equations (17) and (18)

\[ V = V_c \frac{c}{f_o} \sqrt{\frac{\rho_0}{\rho}} \]  

(19)

When equations (13) and (19) are summarized

\[ V = V_c \frac{c}{f_o} \sqrt{\frac{\rho_0}{\rho}} = V_c \sqrt{\frac{\rho_0}{\rho}} \]  

(20)

For convenience, equations relating the various airspeed quantities are listed in appendix A.

Determination of Reynolds Number

In comparisons of flight and wind-tunnel results charts relating the Reynolds number to the Mach number have been found convenient.

Reynolds number is defined by the formula

\[ \text{Re} = \frac{Vl_0}{\mu} = \frac{vl}{\mu} \]  

(21)

where \( l \) is a characteristic length such as the chord. Equation (21) may be written so that the Reynolds number is expressed as a function of Mach number and absolute temperature in degrees Fahrenheit for unit values of the characteristic length \( l \) as

\[ \frac{R}{l} = 1.902M\sqrt{T} \]  

(22)

In order to facilitate the determination of Reynolds number, figure 4 has been prepared to show the variation of the factor \( R_{std}/l \) with Mach number and pressure altitude, where \( R_{std} \) is the Reynolds number computed on the basis of the standard atmosphere. Figure 4(a) holds for pressure altitudes from sea level to 60,000 feet, and figure 4(b) holds for pressure altitudes from 60,000 to 100,000 feet.
In order to account for free-air conditions other than standard, figure 5 is given to be used in conjunction with figure 4. When \( \mu = \frac{2.318}{10^6} \frac{T^{3/2}}{T + 216} \) \( \left( \text{justification for the use of this equation given in the section entitled "Properties of Standard Atmosphere"} \right) \) is substituted into equation (21), the Reynolds number factor may be written

\[
\frac{R}{l} = 1.232pM\frac{T + 216}{T^2} \times 10^6 \tag{23}
\]

The Reynolds number factor in the standard atmosphere becomes

\[
\frac{R_{\text{std}}}{l} = 1.232pM\frac{T_{\text{std}} + 216}{T_{\text{std}}^2} \times 10^6 \tag{24}
\]

When equation (23) is divided by equation (24)

\[
\frac{R}{R_{\text{std}}} = \left( \frac{T_{\text{std}}}{T} \right)^2 \left( \frac{T + 216}{T_{\text{std}} + 216} \right) \tag{25}
\]

Figure 5 gives \( R/R_{\text{std}} \) as a function of pressure altitude and the deviation \( \Delta t \) of the free-air temperature from standard temperature for a given pressure altitude. In equation form,

\[
\Delta t = T - T_{\text{std}} \tag{26}
\]

The curves of figure 5 become straight lines for pressure altitudes above 35,332 feet, since \( T_{\text{std}} \) is constant above this altitude range.

In order to illustrate the procedure to be used in determining Reynolds number, the following example is presented:
Given:

Mach number \( M = 0.75 \)
Pressure altitude \( h_p = 35,000 \) feet
Characteristic length \( l = 10 \) feet
Deviation of free-air temperature from standard temperature \( \Delta t = -10^0 \) F

To find:
Reynolds number \( R \)

Step (1)

From figure 4(a), for \( M = 0.75 \) and \( h_p = 35,000 \) feet,

\[
\frac{R_{std}}{l} = 1,800,000 \text{ per foot}
\]

Step (2)

For \( l = 10 \) feet,

\( R_{std} = 18,000,000 \)

Step (3)

From figure 5, for \( h_p = 35,000 \) feet and \( \Delta t = -10^0 \) F,

\[
\frac{R}{R_{std}} = 1.036
\]

Step (4)

From these values,

\( R = 18,600,000 \)
PROPERTIES OF STANDARD ATMOSPHERE

For many purposes, such as performance and load calculations, the concept of a standard atmosphere has proved to be very useful. The United States standard atmosphere was officially adopted in 1925 (reference 7). In reference 7 tables are given that are of most use in the calibration of instruments. The properties of this atmosphere were originally tabulated by Diehl (reference 5).

Table VII gives the standard atmospheric values up to altitudes of 65,000 feet and includes quantities that have been found to be of use in the interpretation of airspeed and related factors. These quantities are the pressure in pounds per square foot, the pressure in inches of water, the speed of sound, the coefficient of viscosity $\mu$, and the kinematic viscosity $\nu$. All the quantities given in table VII are in the English system of units for every 500 feet of altitude up to 65,000 feet.

The values given in table VII for the coefficient of viscosity $\mu$ and the kinematic viscosity $\nu$ are not standard values since a standardization of air viscosity has not been agreed upon as yet. The values listed for $\mu$ and $\nu$ are believed to be sufficiently accurate, however, to be useful in calculations requiring viscosity of air.

For altitudes from sea level to 35,000 feet, the pressure $p$ in pounds per square foot and in inches of water was determined from the ratio $p/p_0$ given in reference 5 and values of the pressure at sea level of 2116.2 pounds per square foot and 407.1 inches of water. The sea-level pressure in pounds per square foot is based on the pressure in inches of mercury at 32°F of 29.921. The sea-level pressure in inches of water is based on the pressure in inches of mercury at 32°F and water at 59°F. The pressure $p$ in inches of mercury for altitudes up to 35,000 feet is taken directly from reference 5.
The quantities mass density $\rho$ and density ratio $\sigma$ are also taken directly from reference 5 for the altitudes from 0 to 35,000 feet. For altitudes over 35,000 feet the pressures, the mass density, and the density ratio were recalculated, since a minor error was discovered in the calculations of reference 5 for the pressure ratio for altitudes above 35,332 feet.

The quantity $1/\sqrt{\sigma}$ is given to facilitate the computation of the true airspeed $V$ from the equivalent airspeed $V_e$.

The absolute temperature in degrees Fahrenheit was obtained from reference 5 except for altitudes above 32,000 feet, where interpolation was necessary at the 500-foot stations.

For ready reference, the standard values and the variation with altitude of temperature and density originally used in the computations for the standard atmosphere are included in appendix B of the present paper.

The speed of sound in miles per hour computed from equation (6) is given in table VII. A value of $\gamma = 1.4$ was assumed to hold for the temperature range that is included in table VII.

The coefficient of viscosity $\mu$ was computed from the formula

$$\mu = \frac{2.318}{10^3} \frac{\sigma^{5/2}}{T + 216}$$  \hspace{1cm} (27)

Equation (27) was obtained from reference 8 by converting the equation given therein to the English system of units and by starting with a value of $\mu = 5.725 \times 10^{-7}$ consistent with the standard sea-level conditions.

The kinematic viscosity of air $\nu$ was obtained from the definition

$$\nu = \frac{\mu}{\rho}$$  \hspace{1cm} (28)
TENTATIVE EXTENSION OF STANDARD ATMOSPHERE

The NACA Special Subcommittee on the Upper Atmosphere at a meeting on June 24, 1946 resolved that the tentative extension of the standard atmosphere from 65,000 to 100,000 feet be based upon a constant composition of the atmosphere and an isothermal temperature which are the same as standard conditions at 65,000 feet. This tentative extended isothermal region ends at 32 kilometers (approximately 105,000 ft). It is possible that as results of higher altitude temperature soundings become available and the standard atmosphere is extended to very high altitudes the present recommendation may be modified.

The Subcommittee also recommended that the values of temperature given in the following table be considered as maximum and minimum values occurring for the given altitudes with the variations between the specified points to be linear:

<table>
<thead>
<tr>
<th>Altitude (km)</th>
<th>Temperature (°C absolute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
</tr>
<tr>
<td>20</td>
<td>180</td>
</tr>
<tr>
<td>25</td>
<td>200</td>
</tr>
<tr>
<td>45</td>
<td>300</td>
</tr>
</tbody>
</table>

A tentative extension of the standard atmosphere computed from the equations given in appendix B using the recommended isothermal temperature is given in table VIII for altitudes from 65,000 to 100,000 feet. All quantities given in table VII are included in table VIII.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., July 17, 1946
APPENDIX A

SUMMARY OF EQUATIONS RELATING AIRSPEED QUANTITIES

The equations relating the various airspeed quantities, which are given in the present paper, are as follows:

\[
q_c = \rho \left( 1 + \frac{\gamma - 1}{2} \frac{\rho_0}{\rho} v^2 \right)^{\frac{\gamma}{\gamma-1}} - 1 \quad \text{for } v < a \quad (A1)
\]

\[
q_c = \rho_0 \left[ \left( 1 + \frac{\gamma - 1}{2} \frac{\rho_0}{\rho_0} v_c^2 \right)^{\frac{\gamma}{\gamma-1}} - 1 \right] \quad \text{for } v < a \quad (A2)
\]

\[
q = \frac{1}{2} \rho v^2 \quad (A3)
\]

\[
q = f^2 q_c \quad (A4)
\]

\[
q = \frac{\gamma}{2} p M^2 \quad (A5)
\]

\[
\rho = \rho_0 \frac{T}{T_0} \quad (A6)
\]

\[
f = \sqrt{\frac{\gamma}{\gamma - 1} \frac{2}{q_c} \left( \frac{q_c}{\rho} + 1 \right)^{\frac{\gamma - 1}{\gamma}}} - 1 \quad (A7)
\]

\[
f_0 = \sqrt{\frac{\gamma}{\gamma - 1} \frac{\rho_0}{q_c} \left( \frac{q_c}{\rho_0} + 1 \right)^{\frac{\gamma - 1}{\gamma}}} - 1 \quad (A8)
\]
\[ M = \left\{ 5 \left[ \left( \frac{a_c}{p} + 1 \right)^{2/7} - 1 \right] \right\}^{1/2} \]  \hspace{1cm} (A9)

\[ a = \sqrt{\frac{p_0}{\rho}} \]  \hspace{1cm} (A10)

If \( a \) is in miles per hour and \( T \) is in degrees Fahrenheit absolute

\[ a = 33.42 \sqrt{T} \]  \hspace{1cm} (A11)

If \( a \) is in knots and \( T \) is in degrees Fahrenheit absolute

\[ a = 29.02 \sqrt{T} \]  \hspace{1cm} (A12)

If \( a \) is in miles per hour and \( T \) is in degrees Centigrade absolute

\[ a = 44.81 \sqrt{T} \]  \hspace{1cm} (A13)

If \( a \) is in knots and \( T \) is in degrees Centigrade absolute

\[ a = 58.34 \sqrt{T} \]  \hspace{1cm} (A14)

\[ V = Ma \]  \hspace{1cm} (A15)

\[ V = f \sqrt{\frac{2a_c}{\rho}} \]  \hspace{1cm} (A16)

\[ V_c = f_0 \sqrt{\frac{2a_c}{\rho_0}} \]  \hspace{1cm} (A17)

\[ V_c = V \sigma^{1/2} = V \sqrt{\frac{\rho}{\rho_0}} \]  \hspace{1cm} (A18)

\[ V_c (mph) = 760.9M \sqrt{\frac{\rho}{\rho_0}} \]  \hspace{1cm} (A19)
APPENDIX B

CONSTANTS AND EQUATIONS FOR USE IN COMPUTATIONS OF STANDARD ATMOSPHERE

The values of the standard atmosphere given herein are based on the following values:

Sea-level pressure \( p_0 = 29.921 \text{ in. Hg} \)
\[ = 407.1 \text{ in. H}_2\text{O} \]
\[ = 2116.2 \text{ lb/ft}^2 \]

Sea-level temperature \( t_0 = 59^\circ \text{ F} \)

Sea-level absolute temperature \( T_0 = 518.14^\circ \text{ F} \)

Sea-level density \( \rho_0 = 0.002373 \text{ slug/ft}^3 \)

Gravity \( g = 32.1740 \text{ ft/sec}^2 \)

Temperature gradient \( \frac{dT}{ch} = 0.00356617^\circ \text{ F/ft} \)

The altitude of the lower limit of the isothermal atmosphere 35,332 ft

Specific weight of mercury at 32\(^\circ\) F \( = 61.37149 \text{ lb/ft}^3 \)

Specific weight of water at 59\(^\circ\) F \( = 62.3724 \text{ lb/ft}^3 \)

Up to the lower limit of the isothermal atmosphere (-57\(^\circ\) F corresponding to 35,332 ft) the temperature is assumed to decrease linearly according to the equation

\[
T = T_0 - \frac{dT}{ch}h
\]  
(El)

Further, the atmosphere is assumed to be a dry perfect gas that obeys the laws of Charles and Boyle, so that the mass density corresponding to the pressure and temperature is

\[
\rho = \rho_0 \frac{p}{p_0} \frac{T_0}{T}
\]  
(E2)
In reference 5 the pressure and altitude are related by

\[ h = \frac{p_0}{\rho_0 \text{sm} T_0} \log_{10} \frac{P_0}{p} \]  

(83)

where \( m \) is the modulus for common logarithms, that is,

\[ m = \log_{10} e = 0.43429 \] 

(84)

The harmonic mean temperature \( T_{m} \) is given by

\[ T_{m} = \frac{\Sigma \Delta h}{\Sigma \Delta h / T_{av}} = \frac{\Delta h_1 + \Delta h_2 + \cdots}{\frac{\Delta h_1}{T_{av_1}} + \frac{\Delta h_2}{T_{av_2}} + \cdots} \]  

(85)

where \( T_{av_1}, T_{av_2}, \cdots \) are the average temperatures for the altitude increments \( \Delta h_1, \Delta h_2, \cdots \).
REFERENCES


### TABLE III

**STATIC PRESSURE \( p \) IN POUNDS PER SQUARE FOOT FOR VALUES OF PRESSURE ALTITUDE \( h_p \) FROM -1000 TO 100,000 FEET**

<table>
<thead>
<tr>
<th>Pressure altitude, ( h_p )</th>
<th>0</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>600</th>
<th>700</th>
<th>800</th>
<th>900</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1000</td>
<td>2135</td>
<td>2156</td>
<td>2170</td>
<td>2182</td>
<td>2194</td>
<td>2206</td>
<td>2218</td>
<td>2230</td>
<td>2241</td>
<td>2253</td>
</tr>
<tr>
<td>-900</td>
<td>2135</td>
<td>2159</td>
<td>2184</td>
<td>2205</td>
<td>2226</td>
<td>2246</td>
<td>2266</td>
<td>2285</td>
<td>2305</td>
<td>2325</td>
</tr>
<tr>
<td>-800</td>
<td>2115</td>
<td>2145</td>
<td>2174</td>
<td>2199</td>
<td>2221</td>
<td>2243</td>
<td>2265</td>
<td>2286</td>
<td>2307</td>
<td>2328</td>
</tr>
<tr>
<td>-700</td>
<td>2092</td>
<td>2123</td>
<td>2153</td>
<td>2180</td>
<td>2205</td>
<td>2229</td>
<td>2253</td>
<td>2277</td>
<td>2298</td>
<td>2320</td>
</tr>
<tr>
<td>-600</td>
<td>2061</td>
<td>2092</td>
<td>2123</td>
<td>2151</td>
<td>2177</td>
<td>2204</td>
<td>2230</td>
<td>2255</td>
<td>2280</td>
<td>2305</td>
</tr>
<tr>
<td>-500</td>
<td>2028</td>
<td>2059</td>
<td>2090</td>
<td>2118</td>
<td>2145</td>
<td>2170</td>
<td>2196</td>
<td>2221</td>
<td>2246</td>
<td>2272</td>
</tr>
<tr>
<td>-400</td>
<td>1991</td>
<td>2022</td>
<td>2053</td>
<td>2080</td>
<td>2107</td>
<td>2132</td>
<td>2157</td>
<td>2183</td>
<td>2208</td>
<td>2234</td>
</tr>
<tr>
<td>-300</td>
<td>1950</td>
<td>1981</td>
<td>2010</td>
<td>2037</td>
<td>2064</td>
<td>2090</td>
<td>2115</td>
<td>2141</td>
<td>2166</td>
<td>2192</td>
</tr>
<tr>
<td>-200</td>
<td>1906</td>
<td>1937</td>
<td>1964</td>
<td>1991</td>
<td>2018</td>
<td>2044</td>
<td>2069</td>
<td>2094</td>
<td>2119</td>
<td>2145</td>
</tr>
<tr>
<td>-100</td>
<td>1857</td>
<td>1886</td>
<td>1913</td>
<td>1939</td>
<td>1965</td>
<td>1991</td>
<td>2016</td>
<td>2041</td>
<td>2066</td>
<td>2092</td>
</tr>
<tr>
<td>0</td>
<td>1810</td>
<td>1839</td>
<td>1865</td>
<td>1891</td>
<td>1916</td>
<td>1941</td>
<td>1966</td>
<td>1991</td>
<td>2016</td>
<td>2041</td>
</tr>
<tr>
<td>100</td>
<td>1755</td>
<td>1780</td>
<td>1804</td>
<td>1829</td>
<td>1854</td>
<td>1879</td>
<td>1904</td>
<td>1929</td>
<td>1954</td>
<td>1979</td>
</tr>
<tr>
<td>200</td>
<td>1690</td>
<td>1713</td>
<td>1736</td>
<td>1759</td>
<td>1783</td>
<td>1807</td>
<td>1831</td>
<td>1855</td>
<td>1879</td>
<td>1903</td>
</tr>
<tr>
<td>300</td>
<td>1618</td>
<td>1638</td>
<td>1657</td>
<td>1676</td>
<td>1694</td>
<td>1713</td>
<td>1732</td>
<td>1751</td>
<td>1769</td>
<td>1788</td>
</tr>
<tr>
<td>400</td>
<td>1536</td>
<td>1553</td>
<td>1570</td>
<td>1587</td>
<td>1604</td>
<td>1621</td>
<td>1638</td>
<td>1655</td>
<td>1672</td>
<td>1689</td>
</tr>
<tr>
<td>500</td>
<td>1448</td>
<td>1460</td>
<td>1471</td>
<td>1481</td>
<td>1491</td>
<td>1501</td>
<td>1511</td>
<td>1521</td>
<td>1531</td>
<td>1541</td>
</tr>
<tr>
<td>600</td>
<td>1350</td>
<td>1359</td>
<td>1365</td>
<td>1370</td>
<td>1375</td>
<td>1380</td>
<td>1385</td>
<td>1390</td>
<td>1395</td>
<td>1400</td>
</tr>
<tr>
<td>700</td>
<td>1244</td>
<td>1249</td>
<td>1252</td>
<td>1255</td>
<td>1258</td>
<td>1261</td>
<td>1264</td>
<td>1267</td>
<td>1270</td>
<td>1273</td>
</tr>
<tr>
<td>800</td>
<td>1131</td>
<td>1134</td>
<td>1136</td>
<td>1137</td>
<td>1139</td>
<td>1140</td>
<td>1141</td>
<td>1142</td>
<td>1143</td>
<td>1144</td>
</tr>
<tr>
<td>900</td>
<td>1011</td>
<td>1012</td>
<td>1013</td>
<td>1013</td>
<td>1014</td>
<td>1014</td>
<td>1014</td>
<td>1014</td>
<td>1014</td>
<td>1014</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>0</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
<th>6000</th>
<th>7000</th>
<th>8000</th>
<th>9000</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000</td>
<td>150.8</td>
<td>133.8</td>
<td>123.7</td>
<td>120.6</td>
<td>118.7</td>
<td>113.2</td>
<td>107.9</td>
<td>102.9</td>
<td>98.10</td>
</tr>
<tr>
<td>7000</td>
<td>142.5</td>
<td>129.7</td>
<td>119.0</td>
<td>116.0</td>
<td>113.0</td>
<td>109.0</td>
<td>104.0</td>
<td>99.0</td>
<td>94.10</td>
</tr>
<tr>
<td>8000</td>
<td>134.1</td>
<td>122.0</td>
<td>111.8</td>
<td>109.0</td>
<td>106.0</td>
<td>102.0</td>
<td>98.0</td>
<td>93.0</td>
<td>88.10</td>
</tr>
<tr>
<td>9000</td>
<td>125.7</td>
<td>114.5</td>
<td>104.4</td>
<td>101.8</td>
<td>98.8</td>
<td>95.8</td>
<td>91.8</td>
<td>87.8</td>
<td>82.10</td>
</tr>
</tbody>
</table>

**NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS**
<table>
<thead>
<tr>
<th>t (°F)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of sound, mph</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-70</td>
<td>659.5</td>
<td>661.1</td>
<td>666.2</td>
<td>665.1</td>
<td>664.5</td>
<td>665.3</td>
<td>663.7</td>
<td>662.9</td>
<td>662.0</td>
<td>661.2</td>
</tr>
<tr>
<td>-60</td>
<td>667.9</td>
<td>669.4</td>
<td>672.8</td>
<td>672.7</td>
<td>671.2</td>
<td>670.9</td>
<td>670.2</td>
<td>669.7</td>
<td>668.9</td>
<td>668.7</td>
</tr>
<tr>
<td>-50</td>
<td>675.2</td>
<td>676.6</td>
<td>680.8</td>
<td>682.0</td>
<td>681.1</td>
<td>680.3</td>
<td>679.5</td>
<td>678.7</td>
<td>677.9</td>
<td>677.0</td>
</tr>
<tr>
<td>-40</td>
<td>682.4</td>
<td>683.6</td>
<td>687.8</td>
<td>688.5</td>
<td>688.5</td>
<td>687.7</td>
<td>686.9</td>
<td>686.0</td>
<td>685.2</td>
<td></td>
</tr>
<tr>
<td>-30</td>
<td>692.5</td>
<td>691.7</td>
<td>690.9</td>
<td>690.1</td>
<td>689.3</td>
<td>688.5</td>
<td>687.7</td>
<td>686.9</td>
<td>686.0</td>
<td></td>
</tr>
<tr>
<td>-20</td>
<td>699.2</td>
<td>698.3</td>
<td>696.5</td>
<td>695.7</td>
<td>694.9</td>
<td>694.1</td>
<td>693.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td>703.0</td>
<td>702.7</td>
<td>701.8</td>
<td>701.0</td>
<td>700.3</td>
<td>700.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>714.8</td>
<td>714.0</td>
<td>712.6</td>
<td>712.8</td>
<td>711.6</td>
<td>711.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>721.6</td>
<td>721.1</td>
<td>720.6</td>
<td>720.2</td>
<td>719.4</td>
<td>719.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>731.7</td>
<td>732.5</td>
<td>732.5</td>
<td>732.4</td>
<td>731.8</td>
<td>731.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>755.3</td>
<td>750.4</td>
<td>749.4</td>
<td>748.5</td>
<td>745.1</td>
<td>748.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>776.8</td>
<td>776.7</td>
<td>776.0</td>
<td>775.0</td>
<td>774.2</td>
<td>773.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>795.0</td>
<td>795.0</td>
<td>794.9</td>
<td>794.0</td>
<td>793.0</td>
<td>792.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>812.6</td>
<td>812.4</td>
<td>811.8</td>
<td>811.1</td>
<td>810.5</td>
<td>810.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>820.0</td>
<td>819.5</td>
<td>818.8</td>
<td>818.3</td>
<td>817.0</td>
<td>815.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>828.0</td>
<td>827.4</td>
<td>826.9</td>
<td>826.1</td>
<td>825.6</td>
<td>825.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>836.4</td>
<td>835.7</td>
<td>835.0</td>
<td>834.4</td>
<td>833.9</td>
<td>833.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>844.4</td>
<td>843.7</td>
<td>843.1</td>
<td>842.4</td>
<td>841.9</td>
<td>841.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>852.6</td>
<td>851.9</td>
<td>851.3</td>
<td>850.6</td>
<td>849.9</td>
<td>849.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>860.9</td>
<td>859.2</td>
<td>858.6</td>
<td>857.9</td>
<td>857.2</td>
<td>856.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed of sound, knots</th>
</tr>
</thead>
<tbody>
<tr>
<td>-70</td>
</tr>
<tr>
<td>-60</td>
</tr>
<tr>
<td>-50</td>
</tr>
<tr>
<td>-40</td>
</tr>
<tr>
<td>-30</td>
</tr>
<tr>
<td>-20</td>
</tr>
<tr>
<td>-10</td>
</tr>
<tr>
<td>0</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>70</td>
</tr>
<tr>
<td>80</td>
</tr>
</tbody>
</table>

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
# TABLE VI

**SPEED OF SOUND FOR VARIOUS VALUES OF FREE-AIR TEMPERATURE IN DEGREES CENTIGRADE**

<table>
<thead>
<tr>
<th>t (°C)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speed of sound, mph</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-60</td>
<td>654.1</td>
<td>668.1</td>
<td>666.6</td>
<td>665.1</td>
<td>663.6</td>
<td>662.0</td>
<td>660.5</td>
<td>659.0</td>
<td>657.5</td>
<td>656.0</td>
</tr>
<tr>
<td>-50</td>
<td>668.6</td>
<td>683.0</td>
<td>681.5</td>
<td>680.0</td>
<td>678.6</td>
<td>677.1</td>
<td>675.6</td>
<td>674.1</td>
<td>672.6</td>
<td>671.1</td>
</tr>
<tr>
<td>-40</td>
<td>684.4</td>
<td>697.5</td>
<td>696.1</td>
<td>694.6</td>
<td>693.2</td>
<td>691.8</td>
<td>690.3</td>
<td>688.8</td>
<td>687.4</td>
<td>685.9</td>
</tr>
<tr>
<td>-30</td>
<td>699.0</td>
<td>711.8</td>
<td>710.4</td>
<td>709.0</td>
<td>707.6</td>
<td>706.1</td>
<td>704.7</td>
<td>703.3</td>
<td>701.8</td>
<td>700.4</td>
</tr>
<tr>
<td>-20</td>
<td>713.2</td>
<td>725.8</td>
<td>724.4</td>
<td>723.0</td>
<td>721.6</td>
<td>720.2</td>
<td>718.8</td>
<td>717.4</td>
<td>716.0</td>
<td>714.6</td>
</tr>
<tr>
<td>-10</td>
<td>727.2</td>
<td>738.2</td>
<td>736.8</td>
<td>735.4</td>
<td>734.1</td>
<td>732.7</td>
<td>731.3</td>
<td>729.9</td>
<td>728.5</td>
<td>726.6</td>
</tr>
<tr>
<td>-0</td>
<td>740.0</td>
<td>759.8</td>
<td>758.4</td>
<td>757.0</td>
<td>755.6</td>
<td>754.2</td>
<td>752.8</td>
<td>751.4</td>
<td>750.0</td>
<td>748.6</td>
</tr>
<tr>
<td>0</td>
<td>754.3</td>
<td>778.8</td>
<td>777.4</td>
<td>776.0</td>
<td>774.6</td>
<td>773.2</td>
<td>771.8</td>
<td>770.4</td>
<td>769.0</td>
<td>767.6</td>
</tr>
<tr>
<td>10</td>
<td>767.5</td>
<td>794.6</td>
<td>793.2</td>
<td>791.8</td>
<td>790.4</td>
<td>789.0</td>
<td>787.6</td>
<td>786.2</td>
<td>784.8</td>
<td>783.4</td>
</tr>
<tr>
<td>20</td>
<td>780.5</td>
<td>805.9</td>
<td>804.5</td>
<td>803.1</td>
<td>801.7</td>
<td>800.3</td>
<td>798.9</td>
<td>797.5</td>
<td>796.1</td>
<td>794.7</td>
</tr>
<tr>
<td>30</td>
<td>793.3</td>
<td>819.8</td>
<td>818.4</td>
<td>817.0</td>
<td>815.6</td>
<td>814.2</td>
<td>812.8</td>
<td>811.4</td>
<td>810.0</td>
<td>808.6</td>
</tr>
<tr>
<td>40</td>
<td>805.9</td>
<td>832.2</td>
<td>830.8</td>
<td>829.4</td>
<td>828.0</td>
<td>826.6</td>
<td>825.2</td>
<td>823.8</td>
<td>822.4</td>
<td>821.0</td>
</tr>
<tr>
<td>50</td>
<td>818.5</td>
<td>845.8</td>
<td>844.4</td>
<td>843.0</td>
<td>841.6</td>
<td>840.2</td>
<td>838.8</td>
<td>837.4</td>
<td>836.0</td>
<td>834.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Speed of sound, knots</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-60</td>
<td>568.3</td>
<td>580.2</td>
<td>578.9</td>
<td>577.6</td>
<td>576.2</td>
<td>574.9</td>
<td>573.6</td>
<td>572.3</td>
<td>571.0</td>
<td>569.6</td>
</tr>
<tr>
<td>-50</td>
<td>581.5</td>
<td>593.1</td>
<td>591.8</td>
<td>590.6</td>
<td>589.3</td>
<td>588.0</td>
<td>586.7</td>
<td>585.4</td>
<td>584.1</td>
<td>582.8</td>
</tr>
<tr>
<td>-40</td>
<td>594.4</td>
<td>605.8</td>
<td>604.5</td>
<td>603.2</td>
<td>601.9</td>
<td>600.6</td>
<td>599.3</td>
<td>598.0</td>
<td>596.7</td>
<td>595.4</td>
</tr>
<tr>
<td>-30</td>
<td>607.0</td>
<td>618.2</td>
<td>616.9</td>
<td>615.7</td>
<td>614.4</td>
<td>613.1</td>
<td>611.8</td>
<td>610.5</td>
<td>609.2</td>
<td>607.9</td>
</tr>
<tr>
<td>-20</td>
<td>619.4</td>
<td>630.3</td>
<td>629.0</td>
<td>627.7</td>
<td>626.4</td>
<td>625.1</td>
<td>623.8</td>
<td>622.5</td>
<td>621.2</td>
<td>619.9</td>
</tr>
<tr>
<td>-10</td>
<td>631.5</td>
<td>642.2</td>
<td>641.0</td>
<td>639.8</td>
<td>638.5</td>
<td>637.2</td>
<td>635.9</td>
<td>634.6</td>
<td>633.3</td>
<td>632.0</td>
</tr>
<tr>
<td>-0</td>
<td>643.4</td>
<td>654.6</td>
<td>653.3</td>
<td>652.0</td>
<td>650.7</td>
<td>649.4</td>
<td>648.1</td>
<td>646.8</td>
<td>645.5</td>
<td>644.2</td>
</tr>
<tr>
<td>0</td>
<td>655.1</td>
<td>666.2</td>
<td>664.9</td>
<td>663.6</td>
<td>662.3</td>
<td>661.0</td>
<td>659.7</td>
<td>658.4</td>
<td>657.1</td>
<td>655.8</td>
</tr>
<tr>
<td>10</td>
<td>666.5</td>
<td>677.5</td>
<td>676.2</td>
<td>674.9</td>
<td>673.6</td>
<td>672.3</td>
<td>671.0</td>
<td>669.7</td>
<td>668.4</td>
<td>667.1</td>
</tr>
<tr>
<td>20</td>
<td>677.8</td>
<td>688.9</td>
<td>687.6</td>
<td>686.3</td>
<td>685.0</td>
<td>683.7</td>
<td>682.4</td>
<td>681.1</td>
<td>679.8</td>
<td>678.5</td>
</tr>
<tr>
<td>30</td>
<td>688.9</td>
<td>699.0</td>
<td>697.8</td>
<td>696.5</td>
<td>695.2</td>
<td>693.9</td>
<td>692.6</td>
<td>691.3</td>
<td>689.9</td>
<td>688.6</td>
</tr>
<tr>
<td>40</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
<td>699.8</td>
</tr>
</tbody>
</table>

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
<table>
<thead>
<tr>
<th>Altitude, ( h ) (ft)</th>
<th>Pressure, ( p ) (lb/ft²)</th>
<th>Density, ( \rho ) (slugs/ft³)</th>
<th>Density ratio, ( \sigma = \frac{\rho}{\rho_0} )</th>
<th>Temperature, ( T ) (ºF abs.)</th>
<th>Speed of sound, ( a ) (mph)</th>
<th>Coefficient of viscosity, ( \mu ) (slugs*ft/sec)</th>
<th>Kinematic viscosity, ( \nu ) (ft²/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2116</td>
<td>107.1</td>
<td>1.0000</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>500</td>
<td>2078</td>
<td>102.6</td>
<td>0.9959</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>1000</td>
<td>2042</td>
<td>98.6</td>
<td>0.9910</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>1500</td>
<td>2006</td>
<td>94.5</td>
<td>0.9862</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>2000</td>
<td>1970</td>
<td>90.5</td>
<td>0.9815</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>2500</td>
<td>1935</td>
<td>86.4</td>
<td>0.9769</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>3000</td>
<td>1899</td>
<td>82.3</td>
<td>0.9724</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>3500</td>
<td>1863</td>
<td>78.2</td>
<td>0.9680</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>4000</td>
<td>1827</td>
<td>74.1</td>
<td>0.9637</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>4500</td>
<td>1791</td>
<td>70.0</td>
<td>0.9595</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>5000</td>
<td>1755</td>
<td>66.0</td>
<td>0.9555</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>5500</td>
<td>1719</td>
<td>62.0</td>
<td>0.9516</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>6000</td>
<td>1683</td>
<td>58.0</td>
<td>0.9478</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>6500</td>
<td>1647</td>
<td>54.0</td>
<td>0.9441</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>7000</td>
<td>1611</td>
<td>50.0</td>
<td>0.9405</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>7500</td>
<td>1575</td>
<td>46.0</td>
<td>0.9371</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>8000</td>
<td>1539</td>
<td>42.0</td>
<td>0.9338</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>8500</td>
<td>1503</td>
<td>38.0</td>
<td>0.9306</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>9000</td>
<td>1467</td>
<td>34.0</td>
<td>0.9275</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>9500</td>
<td>1431</td>
<td>30.0</td>
<td>0.9246</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>10,000</td>
<td>1395</td>
<td>26.0</td>
<td>0.9217</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>10,500</td>
<td>1359</td>
<td>22.0</td>
<td>0.9189</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>11,000</td>
<td>1323</td>
<td>18.0</td>
<td>0.9162</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>11,500</td>
<td>1287</td>
<td>14.0</td>
<td>0.9136</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>12,000</td>
<td>1251</td>
<td>10.0</td>
<td>0.9110</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>12,500</td>
<td>1215</td>
<td>6.0</td>
<td>0.9085</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
<tr>
<td>13,000</td>
<td>1179</td>
<td>2.0</td>
<td>0.9061</td>
<td>516.4</td>
<td>760.9</td>
<td>3.725 \times 10^{-7}</td>
<td>1.566 \times 10^{-4}</td>
</tr>
</tbody>
</table>

\[ \text{NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS} \]
### TABLE VII

**PROPERTIES OF THE STANDARD ATMOSPHERE - Concluded**

<table>
<thead>
<tr>
<th>Altitude, h (ft)</th>
<th>Pressure, p (lb/in²)</th>
<th>Density, ( \rho ) (lbf/sec²/ft²)</th>
<th>Density ratio, ( \sigma )</th>
<th>Temperature, ( T ) (°F)</th>
<th>Speed of sound, ( a ) (fps)</th>
<th>Coefficient of viscosity, ( \eta ) (slugs-ft/sec)</th>
<th>Kinematic viscosity, ( \nu ) (ft²/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35,000</td>
<td>132.6</td>
<td>99.2</td>
<td>0.009756</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>40,000</td>
<td>169.3</td>
<td>99.36</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>50,000</td>
<td>223.7</td>
<td>99.25</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>75,000</td>
<td>275.1</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>100,000</td>
<td>324.7</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>125,000</td>
<td>372.3</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>150,000</td>
<td>418.8</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>200,000</td>
<td>524.7</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>250,000</td>
<td>630.6</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>300,000</td>
<td>736.5</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>350,000</td>
<td>842.4</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>400,000</td>
<td>948.3</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>500,000</td>
<td>1182.0</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
<tr>
<td>600,000</td>
<td>1378.0</td>
<td>99.2</td>
<td>0.00985</td>
<td>0.00298</td>
<td>1929.4</td>
<td>665.0</td>
<td>2.962 × 10⁻⁷</td>
</tr>
</tbody>
</table>

*National Advisory Committee for Aeronautics*
### Table VIII

Properties of the Standard-Atmosphere Extension

<table>
<thead>
<tr>
<th>Altitude, ft</th>
<th>Pressure, psia</th>
<th>Density, $\rho_r$ (slugs/ft$^3$)</th>
<th>Density ratio, $\sigma = \rho / \rho_r$</th>
<th>Temperature, $\theta$ (°F abs.)</th>
<th>Speed of sound, $a$ (mph)</th>
<th>Coefficient of viscosity, $\nu$ (slugs/ft·sec)</th>
<th>Kinematic viscosity, $\nu_k$ (ft$^2$/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60,000</td>
<td>116.7</td>
<td>0.000175</td>
<td>0.07214</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>65,000</td>
<td>100.0</td>
<td>0.000175</td>
<td>0.06970</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>70,000</td>
<td>83.4</td>
<td>0.000175</td>
<td>0.06735</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>75,000</td>
<td>66.8</td>
<td>0.000175</td>
<td>0.06502</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>80,000</td>
<td>50.2</td>
<td>0.000175</td>
<td>0.06274</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>85,000</td>
<td>33.6</td>
<td>0.000175</td>
<td>0.06050</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>90,000</td>
<td>17.0</td>
<td>0.000175</td>
<td>0.05830</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>95,000</td>
<td>10.5</td>
<td>0.000175</td>
<td>0.05612</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
<tr>
<td>100,000</td>
<td>4.25</td>
<td>0.000175</td>
<td>0.05400</td>
<td>307.4</td>
<td>562.0</td>
<td>9.65 x 10$^{-7}$</td>
<td>16.0 x 10$^{-1}$</td>
</tr>
</tbody>
</table>

National Advisory Committee for Aeronautics
Figure 1.—Airspeed—Mach number chart.
(From reference 1.)
Figure 3: Variation of equivalent airspeed with Mach number and pressure altitude.
Figure 4: Variation of Reynolds number factor in the standard atmosphere.
(b) Pressure altitudes from 60,000 to 100,000 feet.

Figure 4.- Concluded.
Figure 5-Variation of Reynolds number temperature correction factor with pressure altitude and the deviation $\Delta T$ of the free-air temperature from the temperature of the standard atmosphere.