1.2 The Standard Atmosphere

A discussion of aerodynamics would not be complete without introducing the concept of a standard atmosphere. Air pressure, temperature, and density (also viscosity) are functions of altitude. The standard atmosphere, typically presented in a tabular form, assigns values to these properties as they change with altitude. It provides a common reference for Department of Defense (DoD), academia, and industry.

For example, suppose the Air Force wants to purchase an interceptor. To compare climb performance (critical to an interceptor mission) between competing aircraft, manufacturers present data based on their aircraft operating on a standard day, which is an imaginary day when the pressure, temperature, and density behave exactly as defined in the standard atmosphere. Otherwise, it would be nearly impossible to accurately assess how one aircraft performs against another.

The standard atmosphere was generated by starting from an assumed (easiest property to measure) temperature distribution. Figure 1.12 shows an ideal variation of temperature with altitude based on many experimental samplings. The temperature is assumed to remain constant between approximately 36,000 and 82,000 ft; this is called the isothermal region.

With a known temperature profile, two laws of physics (hydrostatic equation and the equation of state) were used to mathematically "build" the standard atmosphere. A current version of the standard atmosphere is presented in Appendix B, and a more detailed discussion of the standard atmosphere development is presented in Ref. 5. The standard atmosphere properties of temperature, density, and pressure may be presented in the form of ratios, as defined in Eq. (1.7). Note: \( \theta, \sigma, \) and \( \delta \) all have the value of 1.0 at sea level conditions:

\[
\begin{align*}
\theta &= \frac{T}{T_{SL}} \\
\sigma &= \frac{\rho}{\rho_{SL}} \\
\delta &= \frac{P}{P_{SL}}
\end{align*}
\]

(1.7)

Empirical equations have been developed to predict the temperature and pressure ratios as a function of altitude. These predictions are aligned with the

![Fig. 1.12 Standard atmosphere temperature variation.](image-url)
1962 U.S. Standard Atmosphere. They are divided into the altitude regions below and above approximately 36,000 ft (the troposphere region where temperature decreases at a linear rate, and the isothermal stratosphere region). For altitudes \( h \) less than or equal to 36,089 ft, we have

\[
\begin{align*}
\theta &= 1 - 6.875 \times 10^{-6} h \\
\delta &= (1 - 6.875 \times 10^{-6} h)^{5.2561} \\
\sigma &= \frac{\delta}{\theta} \\
&h \leq 36,089 \text{ ft} 
\end{align*}
\]

(1.8)

For altitudes from 36,000 ft to approximately 65,600 ft, we have

\[
\begin{align*}
\theta &= 0.75189 \\
\delta &= 0.2234e^{(4.306 \times 10^{-5}(36,089 - h))} \\
\sigma &= \frac{\delta}{\theta} \\
&36,089 \text{ ft} < h < 65,600 \text{ ft} 
\end{align*}
\]

(1.9)

The altitude \( h \) must be input in feet in the previous equations. The relationship shown for density ratio can be derived using the equation of state for a perfect gas.

Frequently, in the language of flight and aeronautical engineering, the terms pressure, temperature, and density altitudes are used. Consider an aircraft flying at 10,000 ft above sea level, as shown in Fig. 1.13.

For the ambient pressure and temperatures shown, we use the standard atmosphere table to find these values. The standard atmosphere altitude corresponding to a pressure of 1484 psf is 9500 ft, and the aircraft is said to be flying at a pressure altitude \( h_p \) of 9500 ft. Pressure altitude says nothing about how high the aircraft is above the ground. Rather, the aircraft is "seeing" an air pressure as though it were flying at 9500 ft on a standard day.

Similarly, a temperature altitude \( h_T \) can be defined. For example, with an ambient temperature of 479.5°F, the aircraft is said to be at an 11,000-ft temperature altitude because 479.5°F is the standard atmosphere temperature for 11,000 ft.

Density altitude \( h_d \) follows the same approach. Pressure, temperature, and density altitude relate pressure, temperature, and density, respectively, to the standard atmosphere model. Simply stated, density altitude is the standard

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Fig. 1.13  Aircraft at specified flight conditions.