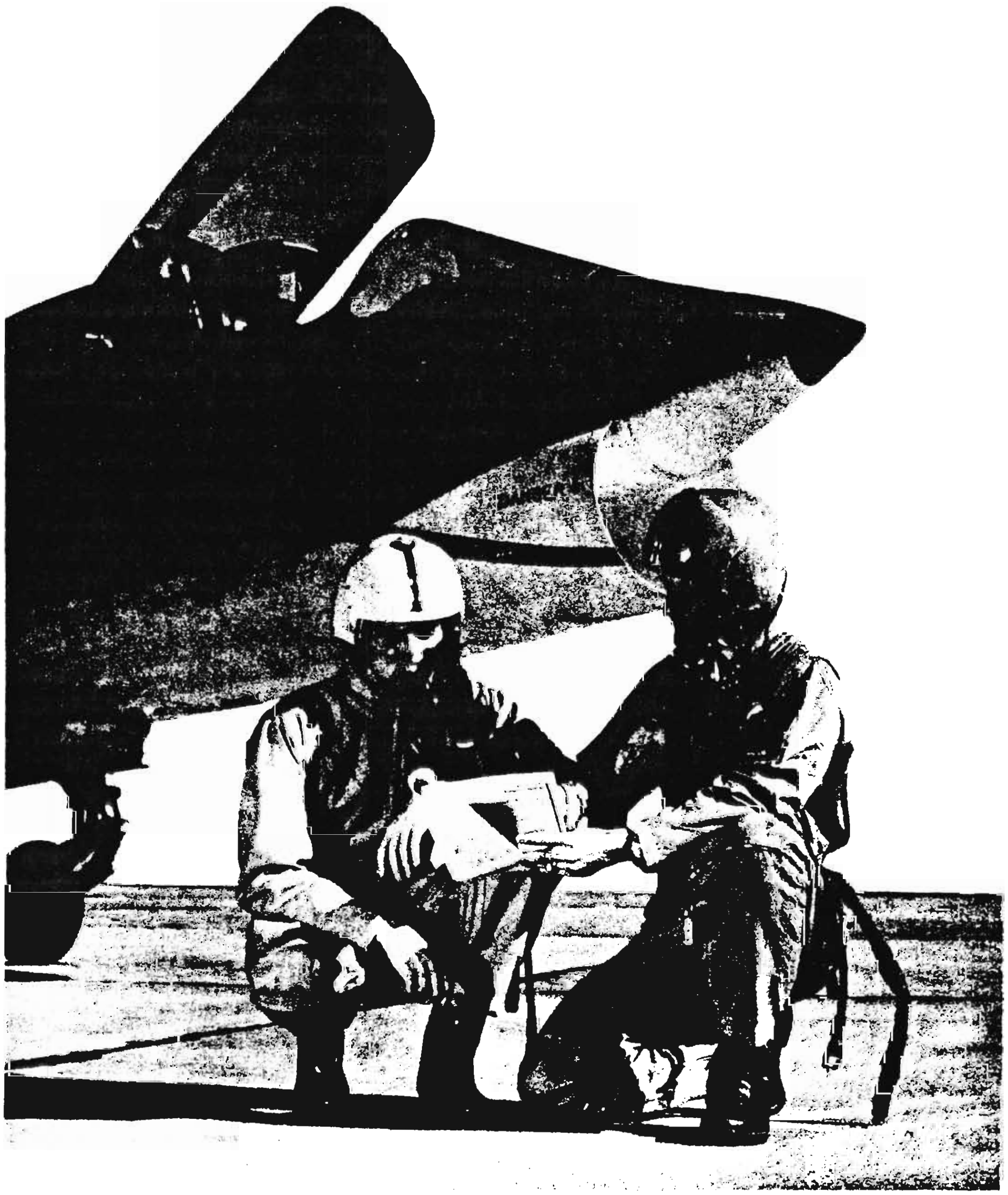
AERODYNAMICS FOR NAVAL AVIATORS

BY

H. H. Hurt, Jr.

University of Southern California



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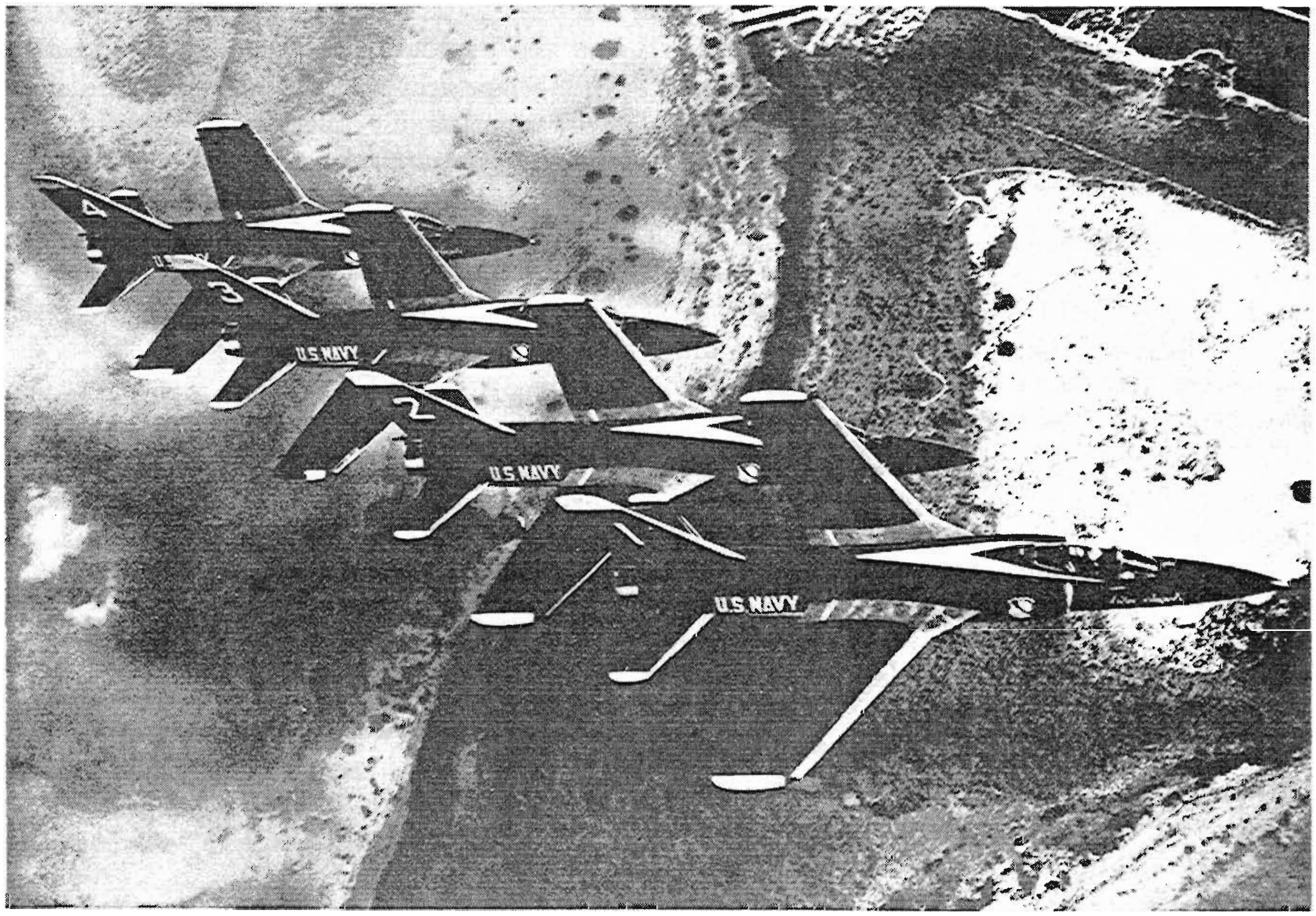


Chapter 1

BASIC AERODYNAMICS

In order to understand the characteristics of his aircraft and develop precision flying techniques, the Naval Aviator must be familiar with the fundamentals of aerodynamics. There are certain physical laws which describe the behavior of airflow and define the various aerodynamic forces and moments acting on a surface. These principles of aerodynamics provide the foundations for good, precise flying techniques.

WING AND AIRFOIL FORCES

PROPERTIES OF THE ATMOSPHERE

The aerodynamic forces and moments acting on a surface are due in great part to the properties of the air mass in which the surface is operating. The composition of the earth's atmosphere by volume is approximately 78 percent nitrogen, 21 percent oxygen, and 1 percent water vapor, argon, carbon dioxide, etc. For the majority of all aerodynamic considerations air is considered as a uniform mixture of these gases. The usual quantities used to define the properties of an air mass are as follows:

STATIC PRESSURE. The absolute static pressure of the air is a property of primary importance. The static pressure of the air at any altitude results from the mass of air supported above that level. At standard sea level conditions the static pressure of the air is 2,116 psf (or 14.7 psi, 29.92 in. Hg, etc.) and at 40,000 feet altitude this static pressure decreases to approximately 19 percent of the sea level value. The shorthand notation for the ambient static pressure is "p" and the standard sea level static pressure is given the subscript "o" for zero altitude, p_0. A more usual reference in aerodynamics and performance is the proportion of the ambient static pressure and the standard sea level static pressure. This static pressure ratio is assigned the shorthand notation of δ (delta).

$$\text{Altitude pressure ratio} = \frac{\text{Ambient static pressure}}{\text{Standard sea level static pressure}}$$

$$\delta = p/p_0$$

Many items of gas turbine engine performance are directly related to some parameter involving the altitude pressure ratio.

TEMPERATURE. The absolute temperature of the air is another important property. The ordinary temperature measurement by the Centigrade scale has a datum at the freezing point of water but absolute zero temperature is obtained at a temperature of $-273°$ Centigrade. Thus, the standard sea level temperature of 15° C. is an absolute temperature of 288°. This scale of absolute temperature using the Centigrade increments is the Kelvin scale, e.g., ° K. The shorthand notation for the ambient air temperature is "T" and the standard sea level air temperature of 288° K. is signified by T_0. The more usual reference is the proportion of the ambient air temperature and the standard sea level air temperature. This temperature ratio is assigned the shorthand notation of θ (theta).

$$\text{Temperature ratio} = \frac{\text{Ambient air temperature}}{\text{Standard sea level air temperature}}$$

$$\theta = T/T_0$$

$$\theta = \frac{C^0 + 273}{288}$$

Many items of compressibility effects and jet engine performance involve consideration of the temperature ratio.

DENSITY. The density of the air is a property of greatest importance in the study of aerodynamics. The density of air is simply the mass of air per cubic foot of volume and is a direct measure of the quantity of matter in each cubic foot of air. Air at standard sea level conditions weighs 0.0765 pounds per cubic foot and has a density of 0.002378 slugs per cubic foot. At an altitude of 40,000 feet the air density is approximately 25 percent of the sea level value.

The shorthand notation used for air density is ρ (rho) and the standard sea level air density is then ρ_0. In many parts of aerodynamics it is very convenient to consider the proportion of the ambient air density and standard sea level air density. This density ratio is assigned the shorthand notation of σ (sigma).

$$\text{density ratio} = \frac{\text{ambient air density}}{\text{standard sea level air density}}$$

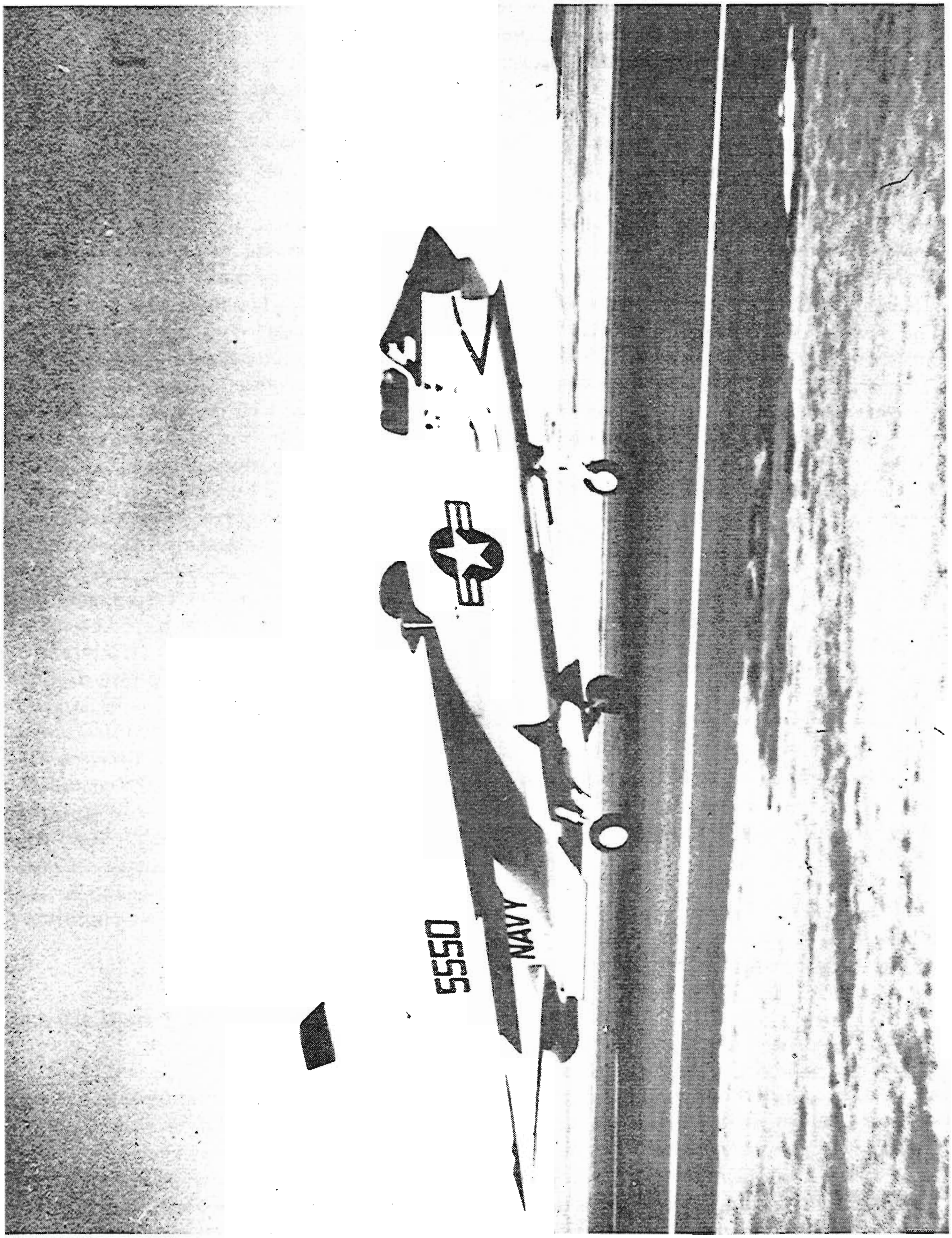
$$\sigma = \rho/\rho_0$$

A general gas law defines the relationship of pressure temperature, and density when there is no change of state or heat transfer. Simply stated this would be "density varies directly with pressure, inversely with temperature." Using the properties previously defined,

$$\text{density ratio} = \frac{\text{pressure ratio}}{\text{temperature ratio}}$$

$$\frac{\rho}{\rho_0} = \left(\frac{P}{P_0}\right)\left(\frac{T_0}{T}\right)$$

$$\sigma = \delta/\theta$$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