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Is the Drag Force on a Supersonic Projectile Proportional to Air Density?

The effect of air density on drag force on supersonic projectiles was measured by testing at air densities of 1.15 kg/m3 (sea level) and at 0.92 kg/m3 (2708 m above sea level). The drag force (force of air on the projectile against the direction of motion) on a given projectile at a given velocity depends in part on the density of the air. The most commonly used relationship between drag force and air density suggests that the drag force is directly proportional to the air density, but experimental data are not widely available.

Test projectiles with masses 2.59, 3.56 and 4.02 g were launched at initial velocities of 1020, 1000 and 950 m/sec (about Mach 2.7). Ten of each projectile were launched at each air density (total of 60 trials). Velocities were measured at an interval of 91.44 m with two chronographs. Data from experiments performed at higher air density were used to predict velocity loss and drag force at lower air density assuming strict proportionality. Drag force was calculated as the change in kinetic energy divided by the distance between the chronographs.

The velocity loss measured at lower air density was 12.6% - 17.2% less than predicted by strict proportionality. It was found that the drag force measured at lower air density was 9.3% - 15.4% lower than predicted by strict proportionality. Results suggest that strict proportionality of drag force with air density may not be supported for all supersonic projectiles.