Chapter 2

Units and Dimensions

§ 2.0 *Units used in this book*

For most international publications on internal ballistics, the metric system is used where lengths are in metres, weights in kilograms, pressures are in mega-Pascals and temperatures are in degrees Kelvin. This is a rather unwieldy set of units, particularly for small-arms where total barrel lengths are usually less than a metre and projectile/charge weights are in grams. The tendency is to end up working with numbers that either have lots of zeros before the number of interest, or lots of zeros after it, which is inconvenient.

The United States still uses the 'English' units of pounds, feet and inches, however, and these units are a much more natural fit to the problems of internal ballistics – particularly for small-arms. Pressures in pounds per square inch come naturally out of computations which use units of pounds and inches, though with a slight complication that pressures in units of weight (pounds) per square area need the appropriate insertion of *g*, the acceleration due to gravity, into the equations in order that the dimensions will balance. Despite this minor difficulty, it was decided to consistently use 'English' units throughout this book, though temperatures in degrees Kelvin will be used. Conversion factors are given below which will enable the reader to work in metric units using the equations herein.

Every chapter in this book has a Nomenclature list of the variables used in the chapter and the units of those variables.

§ 2.1 *Dimensions*

When converting from one set of units to another, or simply to check that an equation really is calculating results in the assumed units, it is convenient to perform a dimensional check and so this process is briefly described.

Any unit of measurement can be described as a combination of three dimensions, which are length [L], mass [M] and time [T].

So, velocity has dimensions of length per unit of time $\left[\frac{\mathrm{L}}{\mathrm{T}}\right]$

Acceleration had dimensions of length per unit time, per unit time $\left[\frac{L}{T^2}\right]$

Energy can be expressed as mass times velocity squared, divided by two $\left[\frac{ML^2}{T^2}\right]$

(The factor 2 does not have any dimensions, so a '2' does not appear in the dimensional expression.)

Power is the amount of Energy used per unit of time $\left[\frac{ML^2}{T^3}\right]$

Force can be expressed as mass times acceleration $\left[\frac{ML}{T^2}\right]$

From which it can be readily seen from dimensional arguments that Power is also Force times Velocity.

Pressure is defined as Force per unit area $\left[\frac{M}{LT^2}\right]$

But when pressures are quoted in pounds per square inch, that has dimensions $\left[\frac{M}{L^2}\right]$

This differs from the definition of pressure above by the term $\left[\frac{L}{T^2}\right]$ which is just the acceleration due to gravity.

$$\left[\frac{M}{L^2}\right]\bullet\left[\frac{L}{T^2}\right]=\left[\frac{M}{LT^2}\right]$$

When pressures in pounds per square inch are required from an expression which calculates force over a given area, then an acceleration due to gravity term *g* needs to be inserted to make the transformation.

In English units, energies are often quoted in foot-pounds having dimensions $\left[ML\right]$. It is readily seen that the usual definition of energy can be recovered by multiplying by the acceleration due to gravity.

$$\left[ML\right]\bullet\left[\frac{L}{T^2}\right]=\left[\frac{ML^2}{T^2}\right]$$

In English units, a 'poundal' is the amount of force required to accelerate a mass of one pound by one foot per second per second. So, energies quoted in 'foot-poundals' (sometimes called foot-pounds-force) will have the correct dimensions for Energy. Energy in foot-poundals can be converted to foot-pounds by dividing by g the acceleration due to gravity.

§ 2.2 *Useful conversions*

1 inch	=	2.540 centimetres
1 metre	=	39.37 inches
1 square inch	=	6.452 square centimetres
1 square metre	=	1550 square inches
1 cubic inch	=	16.39 cubic centimetres
1 litre	=	61.0234 cubic inches
1 cubic metre	=	61023.4 cubic inches
1 pound	=	0.45359 kilograms = 7000 grains
1 kilogram	=	2.205 pounds
1 gram per cubic centimetre	=	62.43 pounds per cubic foot
1 standard atmosphere	=	14.5038 pounds per square inch
	=	1 bar
	=	10^5 Pascals (0.1 MPa)
Acceleration due to gravity	=	9.806 metres per second per second
	=	32.2 feet per second per second
	=	386.4 inches per second per second
1 Joule	=	0.737562 foot-pounds = 23.60 foot-poundals
1 cubic foot of water	=	62.43 pounds
1 cubic centimetre of water	=	0.0361 pounds = 16.39 grams = 252.7 grains

§ 2.3 *Standard pressure*

The reader will be aware that the standard atmospheric pressure is often quoted as 14.7 pounds per square inch. However, there are a number of slightly different definitions of a standard atmosphere. in 1982, the International Union of Pure and Applied Chemistry recommended that for the purposes of specifying the physical properties of substances, *standard pressure* should be precisely 10^5 Pascals or 1 bar. The units of pressure often used internal ballistics is the bar and the mega-pascal, so a standard atmospheric pressure of 14.5038 pounds per square inch is used in this book.