SAAMI®

SPORTING ARMS AND AMMUNITION MANUFACTURERS' INSTITUTE, INC.

SINCE 1926

GUN RECOIL - TECHNICAL

FREE RECOIL ENERGY

Recoil can be described mathematically by the physical law of the Conservation of Momentum. The law states: "If a force and its reaction act between two bodies, and no other forces are present, equal and opposite changes in the momentum will be given to the two bodies." Simply stated, this says that for every action there is an equal and opposite (in direction) action. It must be noted this approach does not consider any impact on ***free*** recoil due to the redirection of propellant gases by attached devices such as muzzle brakes or suppressors. ***Felt*** recoil (also referred to as "***Perceived***" recoil) can also vary by modifying the rate of application of force by devices such as recoil pads or damping devices and the influence of action type.

The momentum, therefore, of a free recoiling firearm is equal and opposite in direction to the momentum of the bullet (or shot charge/slug and wad column) and the propellant gases. Because the propellant gases are extremely difficult to weigh, for purposes of this application, the propellant gas weight will be equated to the powder charge weight.

Free Recoil Energy is simply kinetic energy and so can be expressed mathematically as -

$$FRE = \tfrac{1}{2}MV^2$$

Where:

M = Mass (or the weight of the firearm, including all attachments such as scopes and suppressors, divided by 32.17) and

V = Velocity of the recoiling firearm,

To determine the velocity of the recoiling firearm we can use the formula:

$$V = \frac{W_E V_E + W_{PG} V_{PG}}{7000 W_F}$$

Where:

W_E = Weight (in grains) of the ejecta (bullet or shot and wad column)

V_E = Velocity of ejecta in feet per second

W_{PG} = Weight of propellant gases in grains

V_{PG} = Velocity (fps) of propellant gases in feet per second

7000 = Conversion factor for grains to pounds

W_F = Weight of firearm in pounds

If, therefore:

$$M = \frac{W_F}{32.17}$$

Then,

$$½M = \frac{W_F}{64.34}$$

And

$$V = \frac{W_E V_E + W_{PG} V_{PG}}{7000 W_F}$$

Taking the weight of propellant gases (W_{PG}) as being equal to the propellant charge weight (W_{PC}). The *Free Recoil Energy* of a firearm can be described as:

$$FRE = \left(\frac{W_F}{64.34}\right)\left(\frac{W_E V_E + W_{PC} V_{PG}}{7000 W_F}\right)^2$$

The weights of the gun, of the ejecta and of the propellant gases or powder charge are easily determined. The effective velocity of the propellant gas, a much more difficult measurement, varies, in general, with the muzzle pressure and projectile velocity.

The following V_{PG} should be used: $V_{PG} = V_E f$ where for

High powered rifles	$V_{PG} = 1.75 V_E$
Shotguns (average length)	$V_{PG} = 1.50 V_E$
Shotguns (long barrel)	$V_{PG} = 1.25 V_E$
Pistol & revolvers	$V_{PG} = 1.50 V_E$

[The above velocity relationships were derived from extensive experiments by the British, published in "British Text Book of Small Arms" published in 1929 and confirmed by later work in this country.]

NOTE: Firearm weight must be in pounds; ejecta and powder charge in grains; velocity in feet per second. Free recoil energy will then be expressed in foot pounds.

EXAMPLE: How much *Free Recoil Energy* would be developed by an average length shotgun weighing 7 pounds firing a 12 ga 2¾ - 3½ load of No. 4 shot with wads weighing 43 grains and loaded with 33.4 grains of powder.

Therefore:

W_F = 7 pounds

W_E = Shot is 1 ¼ oz. x 437.5 grains/ounce = 546.9 grains + wads weigh 43 grains = 589.9 grains TOTAL

W_{PC} = Propellant Charge Weight = 33.4 grains

V_E = 1,275 fps (Average velocity from tables)

f = 1.50 (For average length shotguns)

So -

$$FRE = \left(\frac{W_F}{2 \times 32.17}\right)\left(\frac{W_E V_E + W_{PC} V_E f}{7000 \times W_F}\right)^2$$

$$FRE = \left(\frac{7}{64.34}\right)\left(\frac{589.9 \times 1275 + 33.4 \times 1275 \times 1.50}{7000 \times 7}\right)^2$$

$$FRE = (0.109)\left(\frac{752{,}122 + 63{,}877.5}{49{,}000}\right)^2$$

$$FRE = (0.109)\left(\frac{816{,}001}{49{,}000}\right)^2$$

$$FRE = (0.109)(16.65)^2$$

$$FRE = (0.109)(277.3)$$

$$FRE = 30.22 \text{ ft-lb}$$

Or about 30 ft-lb due to the uncertainty of the exact shot charge weight and velocity. Exact *FRE* for a given shot would depend upon knowledge of the exact weight of shot charge and exact velocity of that shot.

Calculations may be made in the metric system if firearm weight is given in kilograms; ejecta and powder charge weight in grams and the velocity in meters per second. Mass to weight conversion factor is then 9.8. The equation would then take the form:

$$FRE = \left(\frac{W_F}{2 \times 9.8}\right)\left(\frac{W_E V_E + W_{PG} V_E f}{W_F}\right)^2$$

The F.R.E. would be given in kilogram-meters