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## 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 it's 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.

The momentum, therefore, of a free recoiling firearm is equal and opposite in direction to the momentum of the bullet (or shot charge 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 really kinetic energy and so can be expressed mathematically as –

$$\text{F.R.E.} = \frac{1}{2} MV^2$$

Where –

M = is the mass (or the weight of the firearm divided by 32.17) and

V = is the velocity of the recoiling firearm,

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

$$V = \frac{W_e \times V_e + W_{pg} \times V_{pg}}{7000 \times W_f}$$

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

$V_{pg}$  = Velocity (fps) of propellant gases

7000 = Conversion factor for grains to pounds

$W_f$  = Weight of firearm in pounds

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If therefore –

$$M = \frac{W_f}{32.17} \text{ then } \frac{1}{2}M = \frac{W_f}{64.34} \quad \text{and}$$

$$V = \frac{W_e x V_e + Chg.Wt. x V_{pg}}{7000 x W_f}$$

The Free Recoil Energy of a Firearm can be described as:

$$F.R.E. = \left( \frac{W_f}{64.34} \right) \left( \frac{W_e x V_e + Chg.Wt. x V_{pg}}{7000 x W_f} \right)^2$$

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:  $V_{pg} = V_e x f$  where for

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

[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.]

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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 2 ¾ - 3 ½ load of No. 4 shot with wads weighing 43 grains and loaded with 33.4 grains of powder.

Therefore:

$$W_f = 7 \text{ pounds}$$

$$W_e = \text{Shot is } 1 \frac{1}{4} \text{ oz. x the conversion factor } 437.5 \text{ or } 546.9 \text{ grains;} \\ \text{wads weigh } 43 \text{ grs. TOTAL: } 589.9 \text{ grains}$$

$$\text{Chg. Wt.} = 33.4 \text{ grains}$$

$$V_e = 1275 \text{ fps (Average velocity from tables)}$$

$$r = 1.5 \text{ (For average length of shotgun)}$$

So -

$$\text{F. R. E.} = \left( \frac{W_f}{2 \times 32.17} \right) \left( \frac{W_e \times V_e + \text{Chg. Wt.} \times V_e \times r}{7000 \times W_f} \right)^2$$

$$\text{F.R.E} = \left( \frac{7}{64.34} \right) \left( \frac{589.9 \times 1275 + 33.4 \times 1275 \times 1.5}{7000 \times 7} \right)^2$$

$$\text{F.R.E} = (0.109) \left( \frac{752122 + 63877.5}{49000} \right)^2$$

$$\text{F.R.E.} = (0.109) \left( \frac{816000.5}{49000} \right)^2$$

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$$\begin{aligned} \text{F.R.E.} &= (0.109)(16.65)^2 \\ &= (0.109)(277.3) \\ &= 30.22 \text{ FT LBS.} \end{aligned}$$

ANS: About 30 ft. lbs.

Exact F.R.E. for a given shot would depend upon 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:

$$\text{F.R.E.} = \left( \frac{W_f}{2 \times 9.8} \right) \left( \frac{W_e \times V_e + \text{Chg. Wt.} \times V_e \times x_f}{W_f} \right)^2$$

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