# New Extended Range Shoulder-Fired 40 mm Grenade System

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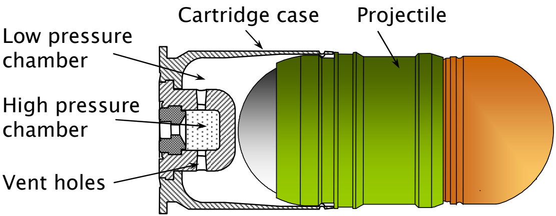
# I
# Introduction

**This section consists of:**

- Overview of 40 mm type ammunition.
- Overview of 40 mm weapon systems.
- Design objectives of new extended range 40 mm ammunition.

# 40mm×46mm Standard Ammunition (Low Velocity)




High/low pressure propulsion system

- Muzzle velocity 76 m/s
- Effective range 375 m
- Maximum range 430 m
- Maximum pressure 13 MPa

# 40 mm Weapon Systems

http://en.wikipedia.org/wiki/M79_Grenade_launcher

M79

M203

# 40 mm Weapon Systems ...

http://www.heckler-koch.de

## HK69 A1

http://www.heckler-koch.de

## AG36, XM320

# 40 mm Weapon Systems ...

http://www.hk-usa.com/le_agc_general.html

## M4/XM320 and M16A2/XM320

## L85A2/L17A2

# 40 mm Weapon Systems ...

http://www.rippeleffect.com/

XRGL40

# Design Objectives

The new Extended Range Low Pressure (ERLP™) 40 mm round was developed with the following objectives:

- Extending the range as much as possible for tactical reasons.
- Keeping the recoil energy below 60 J in accordance with TOP3-2-504, when fired from the XRGL40™ or from under-barrel configurations such as the L85A2/L17A2 so that a maximum of 100 rounds/day/man can be fired.
- Minimizing the propulsion pressure for weapon safety and use in existing weapons.
- Modifying the M118 based cartridge case to prevent accidental loading in weapons where it may be unsafe.

# II
# Recoil Energy Analysis

**This section consists of:**

- Maximum recoil energy limitations.
- Different weapon system mass parameters.
- Recoil energy formulas.
- Calculation of maximum allowable muzzle velocity.
- Simple external ballistics model.
- Calculation of maximum allowable range.

**Maximum recoil energy is the main design constraint**

# Free recoil energy limitations for shoulder fired weapons

| Free recoil energy | Limitations on number of rounds |
|---|---|
| 0 J to 20 J | Unlimited firing |
| 20 J to 40 J | 200 rounds/man/day |
| 40 J to 60 J | 100 rounds/man/day |
| 60 J to 80 J | 25 rounds/man/day |
| Greater than 80 J | No shoulder firing |

Test Operations Procedure (TOP) 3-2-504, *"U.S. Army Safety Evaluation of Hand and Shoulder Weapons"*.

K. Blankenship, et al. *"Shoulder-Fired Weapons with High Recoil Energy:Quantifying Injury and Shooting Performance"*. USARIEM Technical Report T04-05, 2004.

M79 as reference has recoil energy of about 40 J

# Weapon Systems Properties

| Weapon system | Total Empty mass [kg] | Barrel length [mm] |
|---|---|---|
| HK69 A1 | 2.2 | 356 |
| XM320 (Stand Alone) | 2.3 | 215 |
| M79 | 2.7 | 356 |
| M4/XM320 | 4.4 | 215 |
| XRGL40 | 5.0 | 356+ |
| L85A2/L17A2 | 5.3 | 215 |
| M16A2/M203 | 5.4 | 250 |
| M16A2/XM320 | 5.7 | 215 |

# Recoil Energy calculations

Free recoil energy $E$

$$E = \frac{1}{2} m_W \left[ \left( \frac{m_P + \alpha m_g}{m_W} \right) v_e \right]^2 \quad (1)$$

with:

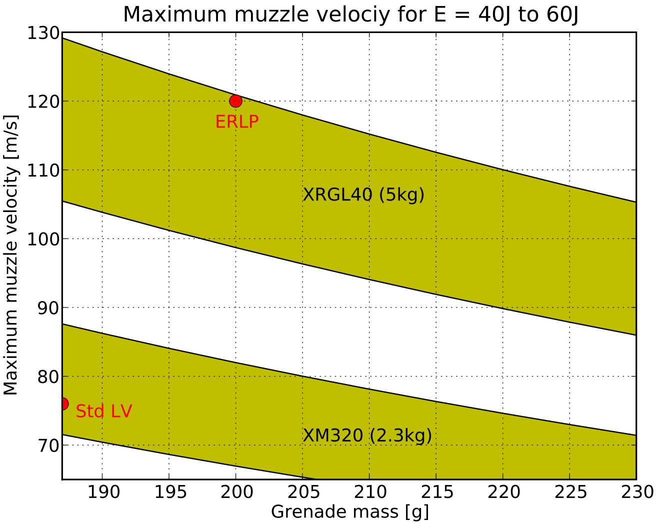
| | | | |
|---|---|---|---|
| $m_W$ | = | weapon mass | [kg] |
| $m_P$ | = | projectile mass | [kg] |
| $m_g$ | = | propellant gas mass | [kg] |
| $v_e$ | = | projectile muzzle velocity | [m/s] |
| $v_g$ | = | propellant gas velocity | [m/s] |
| $\alpha$ | = | $v_g / v_e \approx 1.75$ (contribution of exit gasses) | |

The muzzle velocity $v_e$ for a given recoil energy $E$

$$v_e = \frac{\sqrt{2 m_W E}}{m_P + \alpha m_g} \quad (2)$$

Rippel effect

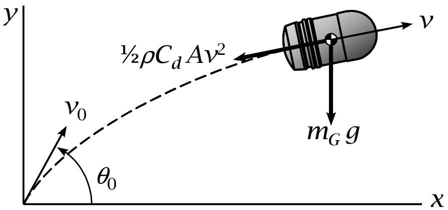
Extended Range 40 mm




**ERLP**

200 g projectile with 120 m/s muzzle velocity

# External Ballistics Calculations



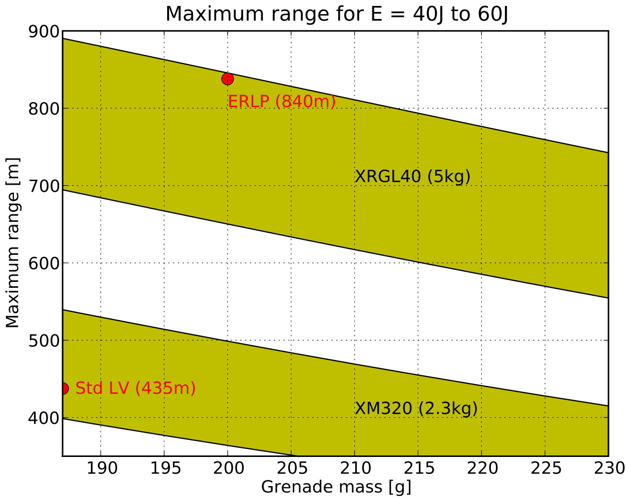

**Simplified 2D external ballistics model**

$$\begin{bmatrix} \ddot{x} \\ \ddot{y} \end{bmatrix} = -\frac{\rho C_d A v}{2 m_G} \begin{bmatrix} \dot{x} \\ \dot{y} \end{bmatrix} - \begin{bmatrix} 0 \\ g \end{bmatrix} \tag{3}$$

with:
- $\rho$ = air density = 1.2 kg/m$^3$
- $C_d$ = drag coefficient = 0.20 to 0.23
- $A$ = sectional area = $0.02^2 \pi$ m$^2$
- $g$ = gravitation = 9.81 m/s$^2$

$$v = \sqrt{\dot{x}^2 + \dot{y}^2} \tag{4}$$

Initial values: $x_0 = 0$ m, $\dot{x}_0 = v_0 \cos\theta_0$ m/s
$y_0 = 0$ m, $\dot{y}_0 = v_0 \sin\theta_0$ m/s




## ERLP

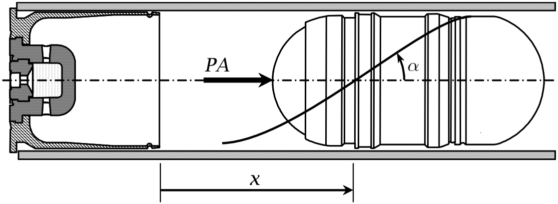
- Maximum range of 840 m and effective range of 800 m.
- Live firings with radar measurements has given a maximum of 890 m.

# III
# Propulsion System Analysis

**This section consists of:**

- Investigate the internal ballistics properties of system
- Establish changes to reduce maximum pressure

# Internal ballistics



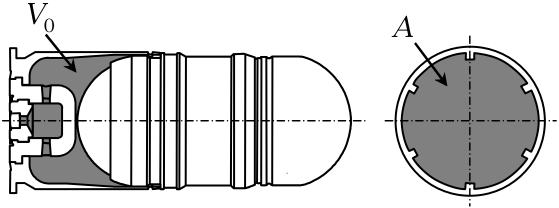

**Simplified internal ballistics model**

$$\ddot{x} = \frac{PA}{m'} \qquad m' = m\left(1 + \frac{r^2}{R^2}\tan(\alpha)\tan(\alpha + \beta)\right) \qquad (5)$$

with:

| | | |
|---|---|---|
| $P$ | = pressure | [ Pa ] |
| $A$ | = barrel projected area | [ $m^2$ ] |
| $R$ | = barrel radius | [ m ] |
| $r$ | = projectile radius of gyration | [ m ] |
| $\alpha$ | = barrel helix angle | [ rad ] |
| $\beta$ | = friction angle ($\tan\beta = \mu$) | [ rad ] |
| $m$ | = projectile mass | [ kg ] |

# Pressure approximation




From ideal gas laws assume no heat transfer, no leakages and that propellent is fully burnt. Approximate pressure as a simple blowdown system

$$P(x) = P_0 \left( \frac{V_0}{V_0 + Ax} \right)^{\gamma} \tag{6}$$

with:
$P_0$ = initial pressure [Pa]
$P$ = pressure [Pa]
$V_0$ = initial volume [m$^3$]
$A$ = barrel projected area [m$^2$]
$\gamma$ = heat capacity ratio (change to compensate for losses)

Equation of motion of projectile from (5) and (6)

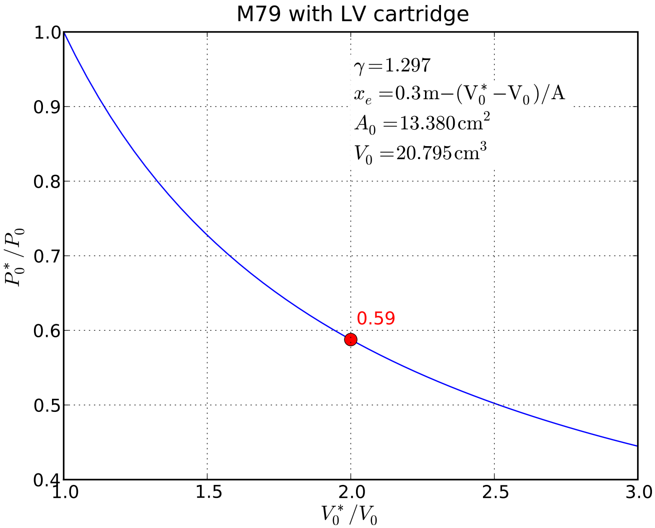
$$\frac{d^2x}{dt^2} = v\frac{dv}{dx} = \frac{P_0 A}{m'}\left(\frac{V_0}{V_0 + Ax}\right)^{\gamma} \tag{7}$$

Integrate with respect to velocity $v$, then

$$v_e^2 = \frac{2P_0V_0}{m'(\gamma-1)}\left[1 - \left(1 + \frac{Ax_e}{V_0}\right)^{1-\gamma}\right] \tag{8}$$

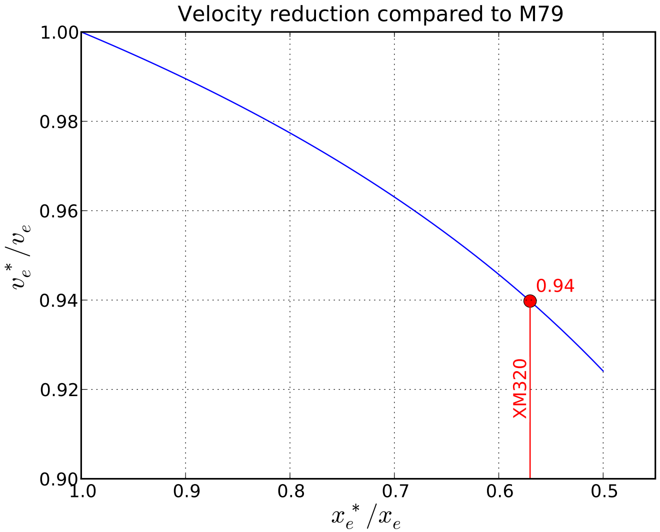
with: $v_e$ = muzzle velocity
$x_e$ = barrel travel distance

Equation (8) can be used to calculate the influence of low pressure chamber volume and the effect of a shortened barrel.




**ERLP**

Doubling of low pressure chamber volume reduces peak pressure by about 40%.



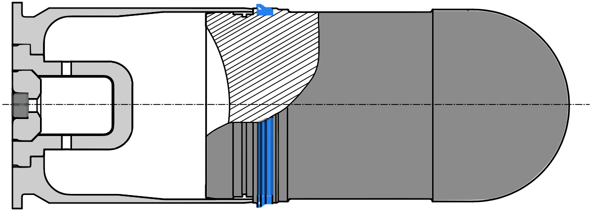

Muzzle velocity of short barreled underslung weapons is 95% compared to that of the M79 reference.

# Final ERLP propulsion system

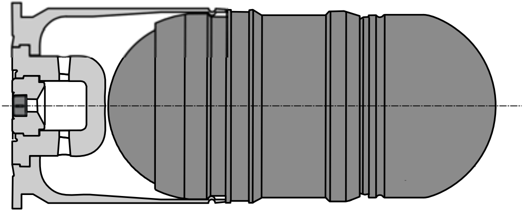
- Based on the M118 cartridge.
- The low-pressure chamber volume was doubled compared to the M406 round with M118 cartridge.
- Different propellents were tested and the final configuration has a maximum pressure of 12 MPa to 14 MPa.
- Optimization of the high pressure chamber and vent holes is still in progress.

# IV
# ERLP Design Specifications

| | | |
|---|---|---|
| Projectile mass | 200 g | |
| Muzzle velocity | 120 m/s | (short barrel: 115 m/s) |
| Maximum range | 840 m | (short barrel: 800 m ) |
| Effective range | 800 m | |
| Maximum pressure | 12–14 MPa | |
| Cartridge length | 51 mm | (Safety & performance) |
| Obturator | | (Efficiency) |



40mm x 51mm Extended Range (ERLP)



40mm x 46mm Standerd Velocity HE

# V
# Conclusions

We have designed and verified an extended range 40 mm system that has met all our objectives.

- The ERLP round has an effective range of 800 m.
- The recoil energy is below 60 J for weapons with a mass of 5 kg or more.
- The recoil energy can be dangerously high from lighter weapons. This necessitates that the ERLP round be prevented from being loaded into such weapons.
- Existing weapons require modification to fire the round.
- The propulsion system resulted in a pressure of 12-14 MPa, which is in the same range as the standard low-velocity 40 mm systems, thereby not reducing the fatigue life of the chamber or barrel of existing weapons.

More than 400 shots have been fired successfully