

## LONG ROD PENETRATOR PERFORMANCE

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**Abstract.** Simple models for the internal, external and terminal ballistics of a tank gun firing a long rod penetrator are described and used to determine the penetration that can be achieved for a typical system. The models also show the effect on penetration of modifications to the penetrator geometry, charge parameters and barrel length. The results show that there are many interdependencies, and that an apparently simple modification to improve penetration may be accompanied by unacceptable consequences elsewhere, particularly high breech pressure and sabot stresses, and an inappropriate all-burnt position. It is also shown that these effects can only be mitigated by further modifications which tend to negate the apparent improvement. The most promising improvement in penetration is based on more energetic propellant and is about 12%.

### INTRODUCTION

The primary target for a tank gun is heavy armour, and the performance of such guns is generally quantified by a combination of hit probability and armour penetration. This performance has shown steady improvement over a number of years for two main reasons. First, the development of sophisticated fire and gun control systems has increased the hit probability. Second, penetration has increased by the introduction of the long rod penetrator, with a target strike velocity sufficient to initiate hydrodynamic, or liquid-like, behaviour of both the penetrator and the target material. This paper is concerned with the second of these two reasons; that is, with penetration, given that a hit has already occurred.

Hydrodynamic penetration is a complex mechanism which begins to appear when the strike velocity exceeds a critical value, typically about 1,150m/s for current penetrators against rolled homogenous armour (RHA) targets. Full hydrodynamic behaviour does not occur until the strike velocity reaches several kilometres per second, such as occurs with shaped charge munitions [1]. At strike velocities less than about 1,150m/s penetration of metal armour occurs mainly through the mechanism of plastic deformation.

A typical penetrator achieves a strike velocity around 1,500m/s to 1,700m/s, depending on range, and therefore target effects generally exhibit both hydrodynamic behaviour and plastic deformation.

A number of models of varying degrees of complexity have been developed [2,3] to predict long rod penetrator performance. A common feature that emerges from these models is the importance of a high strike velocity to exploit more fully the hydrodynamic penetration mechanism, which, in turn, is further improved by the use of longer penetrators having higher densities relative to the target material density. This is amply supported by experimental work [4,5]. Empirical constants are generally included in the models to allow for the less-than-complete hydrodynamic behaviour.

First thoughts suggest that continual improvements in penetration by means of higher strike velocities with ever longer and more dense penetrators might be relatively easy to achieve. However, more careful thought shows that these features interact with each other, and with other important factors such as the internal and external ballistics, the forces on both the ammunition and the gun, and the ammunition stowage and handling. Consider, for example, just some of the consequences of an increase in penetrator length with all other gun and most ammunition parameters remaining unchanged:

- Penetrator surface area will increase giving an increase in drag and a reduction in strike velocity.
- Penetrator mass will increase so that for the same amount of useful energy extracted from the propellant the muzzle velocity and hence strike velocity will decrease.
- A longer penetrator will probably need a longer sabot for in-bore support, further increasing the round mass, and the drag due to the increased length of the threaded portion of the penetrator.
- The lower muzzle velocity implies a longer shot-in-bore time, which will lead to a faster propellant burn and a higher peak pressure.
- A higher peak pressure will lead to higher stresses in the barrel, the sabot and the penetrator.
- A longer penetrator will require more stowage space and more space behind the breech for handling.

Quantifying the effects of such modifications on penetration is therefore not quite so straightforward as some of the predictive penetration models might suggest. There would also need to be careful examination of the effects of such modifications on other parts of the complete gun system.

The following sections describe briefly simple models for the terminal, internal and external ballistics, and use hypothetical but credible data for a tank gun system to show how some of the various interactions can be studied and quantified.

### TERMINAL BALLISTICS MODEL

The simplest theory for the hydrodynamic penetration of a long rod, Figure 1, is almost identical to that for a shaped charge [6].

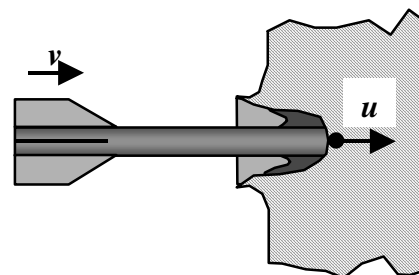


Figure 1. Hydrodynamic penetration model for a long rod.