BALLISTIC PROPERTIES OF DEPLETED URANIUM AND BIOLOGICAL CONSEQUENCES

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Abstract. Over the past quarter century, depleted uranium (DU) has replaced tungsten alloys as the material of choice for penetrators in armour piercing rounds in some armies, as well as a being used as a supplement to steel in tank armour. The tendency for adiabatic shear failure to overcome work hardening, and increased ductility are attributed for the improved ballistic performance. The aerosolisation of a portion of the penetrator on impact creates a potential health hazard, particularly through ingesting resuspended aerosol particles. Bioassays of military and civilian personnel, who were potentially exposed to DU contamination, have failed to establish a link between DU and symptoms of "Gulf War illness". In fact, increased DU body burdens have usually not been detected. Further, Canadian testing has not been able to identify elevated levels of DU or even natural uranium in urine, hair or bone samples of veterans.

INTRODUCTION

Over the past 25 years, depleted uranium (DU) has become the material of choice for armour penetrators for a number of armies around the world. This paper examines the place of DU in the inventories of modern armies, and the biological threat it may pose to combatants and subsequently to peacekeepers and civilians. It will also report on studies currently being conducted on troops, including Canadians, who have potentially been exposed to DU.

BALLISTIC PERFORMANCE

In order to understand the usage of DU as a penetrator material, a brief look at penetration mechanics is warranted. In the hyper velocity regime, for penetrator/target impacts in excess of 3 km/s, penetration is achieved by the mutual erosion of both the target and penetrator. Assuming that both the penetrator and target behave as incompressible fluids, that penetration occurs at constant velocity and invoking conservation of momentum, it can be shown that:

$$P = L\sqrt{\frac{\rho_p}{\rho_t}} \qquad (1)$$

where:

- P is depth of penetration in target
- L is penetrator length
- ρ_t is target density
- ρ_p is penetrator density

It can be seen that the amount of penetration is dependent only on the length of the penetrator and the target and penetrator densities, and is independent of striking velocity. As pressures at the penetrator/target interface are well in excess of the yield strengths of either material, material characteristics (other than densities) are not significant. This type of analysis is valid for shaped charge jets (7-9 km/s) and explosively formed projectiles (2-3 km/s) [1], but not for conventional armour penetrators. The normalized penetration vs velocity plot shown in Figure 1 is typical for both tungsten alloy and DU penetrators on rolled homogeneous armour (RHA) in the ordnance velocity range (1–2 km/s).

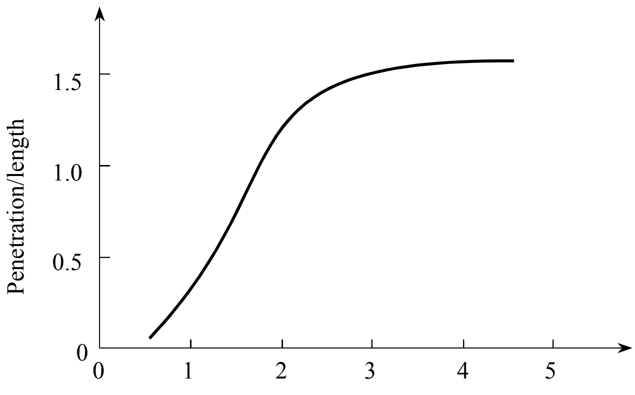

Figure 1. The ballistic "S" curve, showing the increase in penetration with increasing velocity in the ordnance range and the independence of penetration from velocity in the hypervelocity range above 3 km/s, after [2].

These latter, striking in the velocity range of 1 500-1 800 m/s, are better described by the semi-empirical Lanz-Odermatt equation [3]:

$$P = aL\sqrt{\frac{\rho_p}{\rho_t}}\, e^{-(2S/\rho_p v^2)} \qquad (2)$$

where:

- a is a function of the penetrator length/diameter (L/D) ratio
- S is a measure of target resistance, and
- v is the impact velocity.

Both of the fitting parameters a and S are related to the mechanical properties of both the penetrator and target. It can be seen that, as the impact velocity, v, increases, penetration becomes independent of velocity, as described in Equation (1).

For armour penetrators, then, penetration can be increased by increasing the length, the density and the velocity. While current guns and propellants appear to be at the design limit for muzzle velocities, enhancements continue to the L/D ratio. As for density, the move from steel to tungsten

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