SAND2010-0473C

Commercial and Military Applications of DU

Topics

- Commercial Applications
- Military Applications
- Characterization of aerosols produced from impacts in military applications

Commercial Applications of DU

Cobalt-60 teletherapy unit

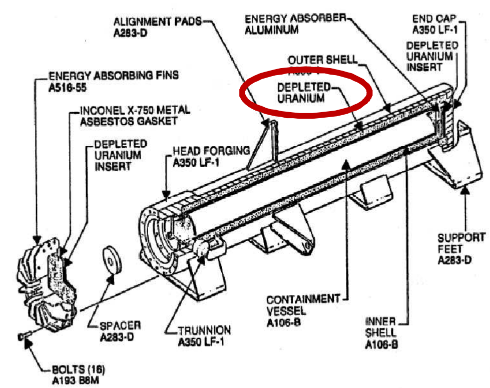
Radiation Shielding

- The density of DU makes it suitable for shielding gamma radiation
- Used extensively in the medical and research sectors as radiation beam collimators
- Used in containers to transport nuclear sources
- Often been used as a shield for radioactive sources in teletherapy units (used in the treatment of cancer) and in linear accelerators
  - Typical quantities of DU used in such equipment range from tens to hundreds of kilograms

Commercial Applications of DU

Radiation Shielding

- Casks used for holding spent fuel in the nuclear power industry - constructed by combining DU with concrete (e.g. DUCRETE™)
  - Increased gamma-radiation shielding with thinner shield walls and much lighter weight casks than traditional storage casks
- Large quantities of DU commonly used as shielding material in casks used for the transport of high-level radioactive sources



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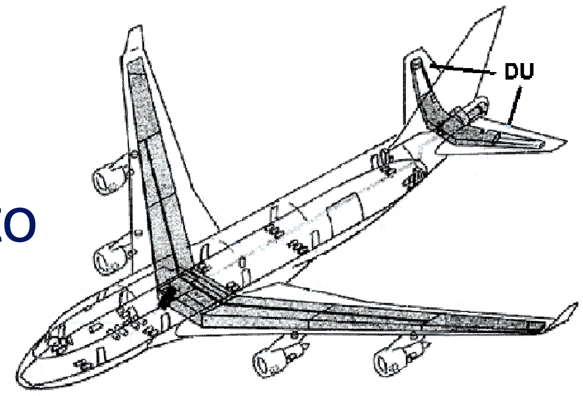
Commercial Applications of DU

<u>Counterbalance Weights</u>



- Wide-bodied aircrafts require heavy counterweights on control surfaces to enable proper flight control
  - These areas often have low surface clearance with insufficient space available for low density materials
- Depleted uranium, lead and tungsten have all been used for counterweights due to their high density
- A typical wide-bodied airplane such as the Boeing 747 ('jumbo jet') requires ~ 1500 kg of counterweights
  - Not all of this material is DU however, and DU is now being replaced retrospectively with tungsten

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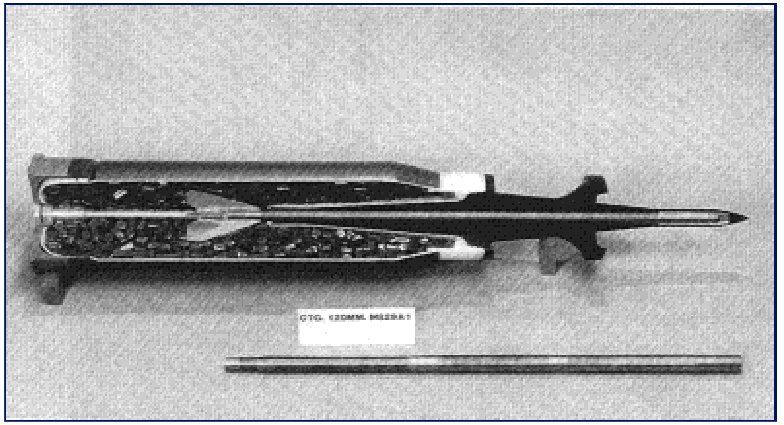
Commercial Applications of DU

- Vessels and equipment, such as boats and satellites require a large amount of weight to be carried in the form of ballast
  - The high density and relative availability of DU make it a potentially suitable material for this use by fulfilling the weight requirements while minimizing the amount of space taken up by the ballast material
- Industries in which the use of DU has been cited for these purposes include the aircraft industry, military aerospace industry, and the oil and gas exploration and production industry

Military Applications of DU

<u>Munitions</u>

- Because of its high density and structural properties, DU can be applied defensively to protect against penetration by projectiles made of less dense metals, such as tungsten carbide sub-projectiles
- DU can be applied offensively as projectiles to defeat armored targets
- Used by:
  - U.S. Abrams tanks
  - Bradley Fighting vehicles
  - AV-8B Harrier aircraft
  - A-10 aircraft



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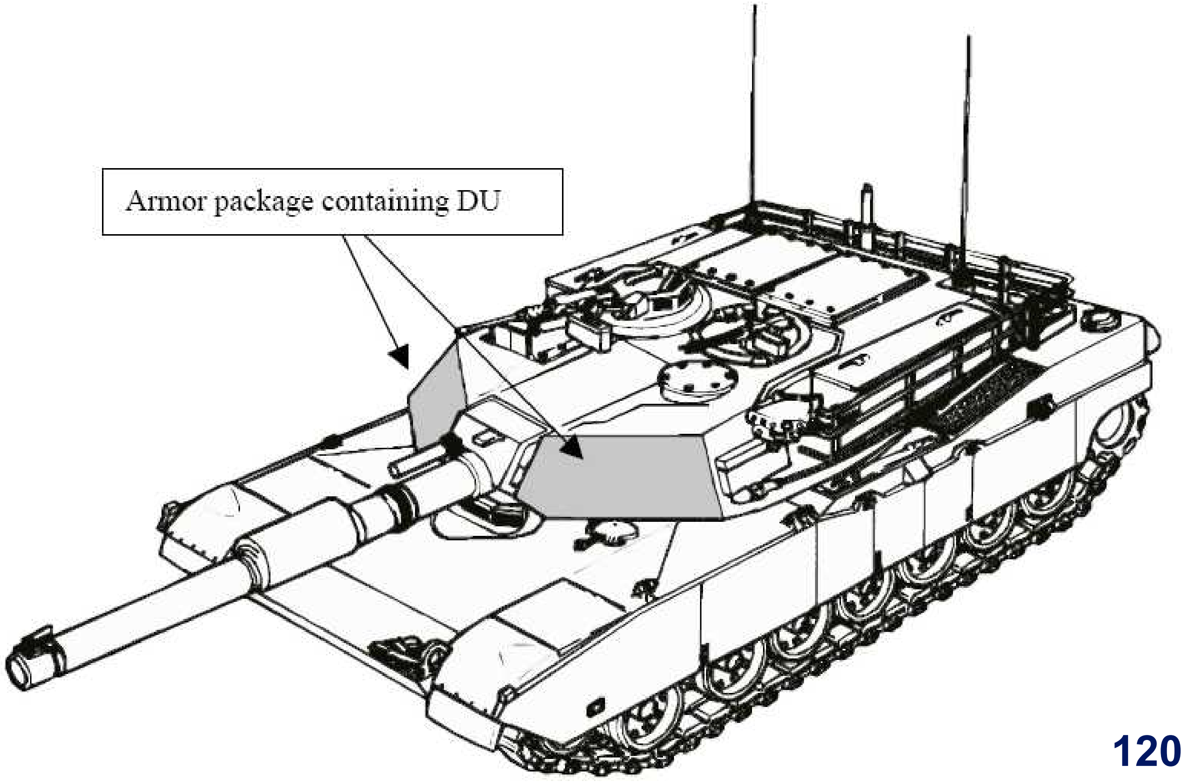
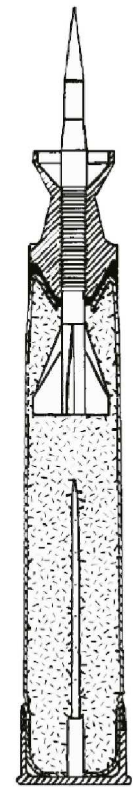
Military Applications of DU

DU Armor and Munitions - Examples



M1 Tank with DU Armor



120mm M829 Sabot-Tracer

Military Applications of DU

<u>Advantages of DU</u>

- Depleted uranium has several advantages over similarly dense alternative materials (e.g., tungsten) because it is:
  - Relatively inexpensive
  - Non-brittle (unlike tungsten)
  - At the high temperatures and pressures involved during the impact of such weapons, DU has been found to adiabatically shear (e.g., self sharpen), giving increased penetration.

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Military Applications of DU

Non-explosive radioactive metallic core bullets:

- DU munitions are made of a non-explosive, solid metallic core bullet (called a penetrator)
- Tanks fire larger caliber rounds (105 and 120mm)
- Aircraft fire smaller caliber rounds (20 - 30 mm)
- DU is not confirmed to be used in bombs or missiles

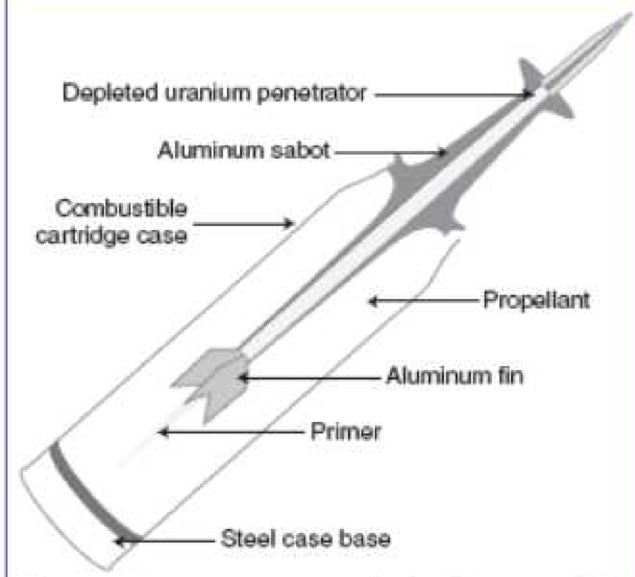

Diagram of an armour-piercing depleted uranium shell

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Military Applications of DU

Anti-Armor Munitions

- DU is used because of its high density (19.0 g/cm^3) (50% higher than lead) and other properties that make it ideal for this purpose

Tank hit by DU munitions

- When a DU penetrator hits armor or a hard surface, the rod self-sharpens - enhancing its ability to pierce the object (casings/jackets do not penetrate)
- DU forms a cloud of finely dispersed particles in air (called an “aerosol”) during penetration
  - Aerosols may cause a dust explosion, since DU ignites spontaneously in contact with air (also called “*pyrophoric*”)

Characterization of Aerosols

- The amount of depleted uranium which is transformed into dust will depend upon:
  - type of munitions
  - nature of the impact
  - type of target
- The number of penetrators hitting a target depends upon many factors, including the type and size of the target
- On average, not more than 10% of the penetrators fired by planes equipped with large machine guns hit the target (20 - 30 mm rounds)

Characterization of Aerosols

- DU munitions which do not hit hard targets will penetrate into the soft ground or remain more or less intact on the surface
- These will corrode over time, as metallic DU is not stable under environmental conditions
- Over time, DU reacts with air and moisture and forms a yellowish green surface
- Lemon yellow uranium oxide particles are therefore often found around target areas

30mm DU munitions: jacket and penetrator

Penetrator lying exposed on the surface

Aerosol Generation
- Combat Conditions -

- Combat Scenarios: When the ammunition / penetrator hits the target, or equipment containing DU is involved in the event
- Types of aerosol exposures in combat scenarios:
  - Combat personnel
  - Combat field rescue personnel
  - Public and environment – If / and due to release of aerosols from combat into the environment
- Exposure and risks associated with ammunitions that missed their target covered separately

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Characterization of Aerosols - Combat Conditions -

- Actual level of aerosols generated during the various impact tests has varied widely
  - Hard target tests in 1979, 1982, and 1990 indicated that <20% of the DU penetrator would turn into aerosol
  - About 90% of the aerosol was less than 10 micron AED (Aerodynamic Equivalent Diameter) - and would be respirable
- Test results conflicted each other - ventilation systems may have impacted data (e.g., total aerosols and size)
- It is very hard to model aerosol generation and inhalation under combat scenarios
- No firm conclusions on DU Oxide generated, or the amount of dust released to environment

Aerosol Generation
- Combat Conditions -

Fires

- During munitions "cook-off," burning propellant does not consume oxygen (propellant supplies its own O_2)
  - Little (if any) oxidation of DU metal occurs because combustion is so rapid
- Very few of the particles generated are small enough to be caught up in thermal currents (without explosion)
  - Most of the particles produced in a tank fire end up deposited on the interior walls of the tanks
- Solubility of any oxides formed during a fire are low

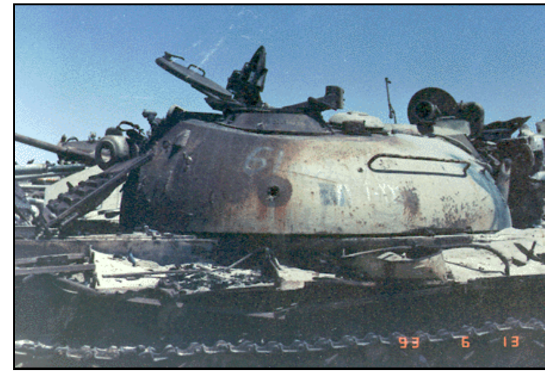
Aerosol Generation
- Combat Conditions -

<u>Vehicles Punctured by DU Projectiles</u>

- Level of oxides formed during impact is largely a function of the "hardness" of the target
- Unless a DU round strikes the vehicle's engine (or similar "hard" obstructions), DU aerosolization is limited if the vehicle is made of light material
- Conversely, harder targets (e.g., Abrams M1A1 Heavy Armor tanks) tend to produce higher levels of DU aerosolization

Aerosol Generation
- Combat Conditions -

Vehicles Punctured by DU Projectiles



- Aerosolization is enhanced if penetrators split into fragments that remain inside the vehicle
- Aerosol levels inside vehicles also depend on such factors as the number of open hatches and other ruptures or openings
- Eventually, particles from inside the tank are either deposited on the inside surfaces of the tank, or are released to the atmosphere through any opening

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Aerosol Generation
- Combat Conditions -

Entry of Contaminated Vehicles

- For Battle Damage Assessment Team personnel, recovery personnel, or souvenir hunters entering damaged vehicles – primary concern is the resuspension of DU dust within the vehicle
- Resuspension depends upon:
  - Air turbulence inside the vehicle
  - Other conditions inside the vehicle (e.g., oily surface walls minimize resuspension)
  - Physical activity inside the vehicle (e.g., lifting or moving equipment or personnel)

Aerosol Generation
- Combat Conditions -

Entry into Contaminated Vehicles

- For emergency rescue personnel who enter a tank shortly after impact, the aerosols generated at impact would be the primary concern
- These impact aerosol levels should be higher than the resuspension levels generated after the aerosols within the tank have had time to settle or to be vented through open hatches, etc.

Aerosol Generation
- Combat Conditions -

<u>Inspection & Repair Activities - Contaminated Vehicles</u>

- Entry into contaminated vehicles for inspection and repair activities can cause significant DU resuspension
- Some of the actual repair activities - like cutting and welding - have the potential to raise resuspension levels even higher
- Cleaning operations can also cause resuspension

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Aerosol Generation
- Combat Conditions -

Routine Combat Activities

- *Evaluation of DU Aerosol Data* indicates potential exposures from DU penetrators that did not penetrate the target or were deflected
  - Penetrator would be hot enough to generate aerosols
  - Oxides would continue to be formed for a while once the penetrator was buried in the soil
  - Some potential exposure to troops near the target at impact, or troops exposed to resuspension from subsequent activities on, in, or near the target