Depleted Uranium

As a result of the Persian Gulf War, there are a number of concerns about destroyed or damaged US Army combat vehicles contaminated by *Depleted Uranium* (DU) munitions. The main concerns resulting from DU contamination are:

[1] Which soldiers were exposed?

[2] To What extent the Army has provided guidance and training in the proper handling and risks in order to minimize exposure.

[3] How effectively the Army has planned for and carried out decontamination and disposal of DU contaminated combat equipment.

[4] Medical evaluation of personnel exposed to DU.

Although the Army does not know the full extent to which personnel were exposed, a General Accounting Office (GAO) review showed that at least several dozen US soldiers, some unknowingly, were exposed to DU by inhalation, ingestion, or shrapnel during the Gulf War.

Army and the Nuclear Regulatory Commission (NRC) officials believe, however, that these personnel were not exposed to levels of DU that exceeded allowable limits established by the NRC. Because there may be **some** risk involved with **any** exposure to radiation, Army regulations require that personnel's exposure to radiation be minimized. During combat and life threatening situations these measures may not be appropriate.

Personnel in noncombat situations should take precautions to ensure that their exposure to DU is as low as reasonably achievable (ALARA).

Post Persian Gulf reviews have determined that although the Army's stated policy is to minimize personnel's exposure to radiation, it has not effectively educated its personnel in the hazards of DU contamination and in proper safety measures appropriate to the degree of hazard. Training on DU has been limited to tank crews, munitions handlers, and EOD personnel.

Its a matter of record that prior to the Gulf War, the Army did not have a formal plan or adequate facilities to decontaminate, dispose of, or quickly repair DU contaminated vehicles.

Risk Low, But Precautions Necessary. According to NRC and Army officials, troops externally exposed to DU radiation, during the Gulf War, were not exposed to external radiation or internal levels of DU that exceeded NRC limits for radiation exposure and toxicity which could cause toxic effects.

In establishing safety controls for DU operations it is important to place the potential hazard of DU in the proper perspective. Safety controls should be consistent with the manner in which the DU is to be used. Where DU and explosive ordnance are utilized, **the potential radiological hazard of DU becomes secondary** to that of the explosive.

Chapter 4
Depleted Uranium

Uranium is actually widely distributed around the world. The crust of the earth, for example, contains a concentration on the average of about four parts per million (PPM). In order to be considered usable, or economically viable as uranium ore, the concentration has to be in the vicinity of 30 PPM or higher. Common foods also contain uranium to a limited extent, about 0.1 - 1.0 PPM. Drinking water in the US contains on the average about 2 millionths of 1 microcurie (0.000000000002 Ci) for each liter.

Uranium has been mined from deposits in the Erz Mountains between Germany and Czechoslovakia since the 1500's. Uranium was originally used in pottery to produce a deep orange color in the glazing applied to the pottery before it was placed in the firing kiln. In fact, this process has remained in the pottery industry up until a few years ago. Bright orange dishes and pottery items made more than ten years ago will still show a reading when measured with a radiac meter.

In the chemically pure state, uranium appears as a shiny, silvery metal. Natural Uranium contains ^{234}U, ^{235}U, and ^{238}U. DU is a by-product of the uranium enrichment process which increases the percentage of the ^{235}U isotope. This enriched uranium is used in the nuclear industry as fuel for nuclear reactors. Uranium which has had a majority of the ^{235}U isotope removed is referred to as "Depleted Uranium" (DU). DU is the waste product left after natural uranium has gone through the enrichment process. The term "depleted" refers to the fact that **most** of the ^{235}U has been extracted, not that the radiation has been depleted. In other words, “depleted” uranium is the opposite of “enriched” uranium.

	Natural Uranium	Depleted Uranium
^{234}U	00.0057%	00.0005%
^{235}U	00.7204%	00.2500%
^{238}U	99.2739%	99.7495%
	100%	100%

Properties which make DU of interest to the military are its high density and strength, ease and relatively low cost of fabrication, and availability.

Student Notes

DU radiation results from spontaneous radioactive decay forming ***daughter atoms***. Uranium, along with a few other radioactive materials, is unusual in that it is a part of a radioactive decay chain. What this means is that when an atom of uranium 238 decays, it converts into a different element called a **daughter product**. The daughter product is also radioactive, and during its process of decay causes a third element to be formed. This process of successive decays from parent to daughter can go on for 17 steps - that is, for 17 generations of ^{238}U radioactive by-products.

Uranium decays by alpha particle emission. The daughter atoms formed during decay emit alpha, beta, and gamma radiation. Therefore the radiation emitted from DU contains alpha, beta and gamma radiation. Because of the long half life of ^{238}U (the major element of DU), the specific activity is unusually low. To help illustrate this, to obtain one curie of radioactivity from DU it would require a single piece weighing 6,615 pounds.

Uranium Decay Series

Nuclide	Half Life	Emissions
Uranium-238	4.5 billion yrs	alpha
Thorium-234	24.1 days	beta / gamma
Proactinium-234	6.7 hours	beta / gamma
Uranium-234	247,000 yrs	alpha / gamma
Thorium-230	80,000 yrs	alpha / gamma
Radium-226	1,600 yrs	alpha / gamma
Radon-222	91.752 hours	alpha / gamma
Polonium-218	3.05 min	alpha / beta
Lead-214	26.8 min	beta / gamma
Astatine-218	2 seconds	alpha
Bismuth-214	19.7 min	beta / gamma
Polonium-214	164 μsec	alpha / gamma
Thallium-210	1.3 min	beta / gamma
Lead-210	21 yrs	beta / gamma
Bismuth-210	5.0 days	beta
Polonium-210	138.4 days	alpha
Thallium-206	4.19 min	beta
Lead-206	**STABLE**	

DEPLETED URANIUM NON-NUCLEAR USES - Because of its high density and structural properties, DU is useful for non-nuclear applications. It can be applied defensively to protect against penetration by projectiles made of less

Student Notes

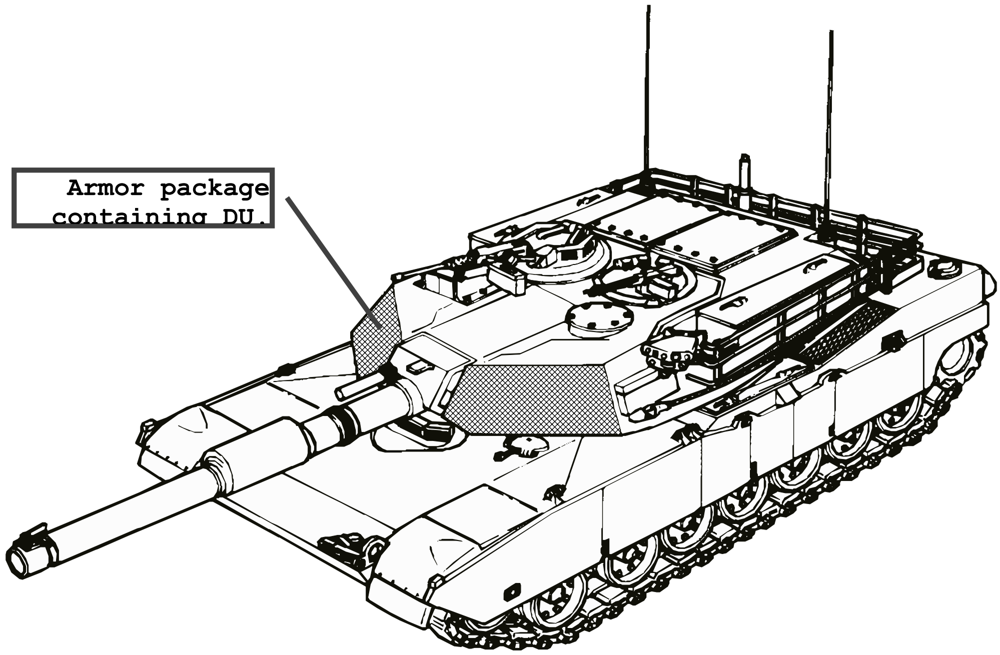
dense metals, such as tungstoncarbide subprojectiles, or offensively to defeat armored targets. US Abrams tanks, Bradley Fighting vehicles, and the Air Force's A-10 aircraft fire DU munitions. DU ammunition is NOT used for training.

DEFENSIVE USE OF DEPLETED URANIUM

RHA ARMOR: Prior to the introduction of the depleted uranium packets, the M1 series armor structure was comprised of *weld fabricated, rolled homogenous steel*. Meaning that it was manufactured and heat treated so that it possessed, as nearly as possible, the same chemical constituents and physical properties throughout.

The Abrams family of tanks consists of four different models; M1, IPM1, M1A1, and M1A2. To ensure maximum crew survivability and provide increased protection against a broad spectrum of anti-tank weapons, the tank plants integrated armor improvements into the manufacturing process for these vehicles.

One such improvement to complete the hull armor envelope was the addition of *ballistic skirts*. This armor is considered "special armor" and is classified but contains no depleted uranium.



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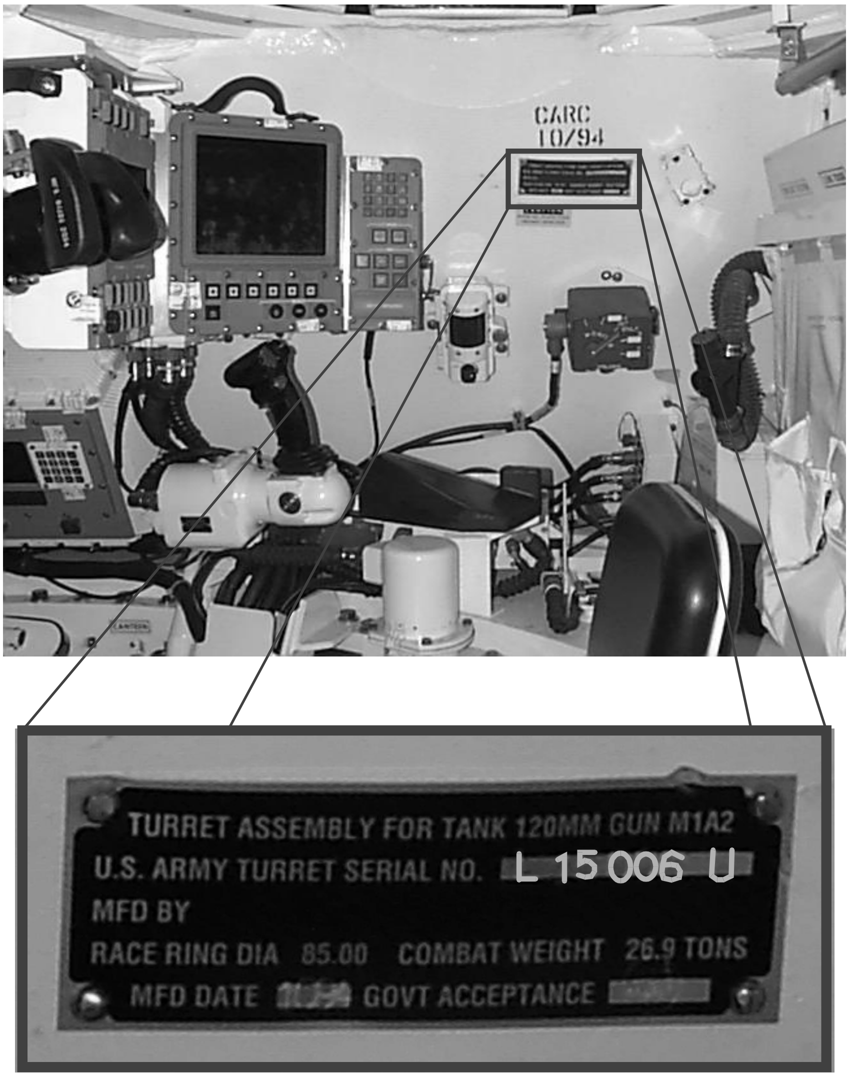
The newest M1A1 tanks, dubbed "Heavies", have depleted uranium packets "molded" into the left and right frontal turret armor. Tanks with this material are identified by a "**U**" at the end of the turret serial number. The M1A2 tanks also contain these DU packets in the turret armor package.



All armor on M1 Abrams series tanks is classified.

Student Notes

REQUIRED NOTIFICATION

Accidents and incidents involving DU armored tanks must be reported immediately (within 4 hours) through the Army accident reporting system to the local RPO or NBC NCO. This individual will in turn report the accident or incident to the TACOM RPO at:

Commander, TACOM
ATTN: AMSTA-CZ
Warren, MI 48397-5000

DSN: 786-7635/6121
Commercial: (810) 574-7635/6121

After duty hours:
DSN: 786-5935/5511
Commercial: (810) 574-5935/5511

These are NOT secure lines. If classified information must be discussed, a call-back from a secure line will be made after the initial notification. The TACOM RPO will then report the accident or incident to the NRC as required. Unless specifically directed otherwise, only unclassified information will be transmitted to the NRC.

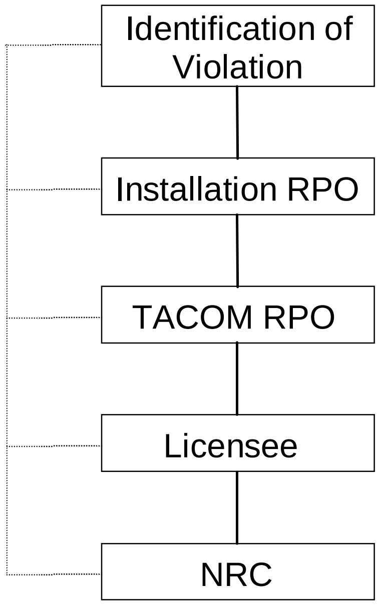


Figure 1 Reporting Chain (DU Armor)

Accidents and incidents that must be reported as soon as possible are:

1. Theft or loss of control of DU armored tanks.
2. Fires, explosions or other types of accidents where DU armored tanks are or could be damaged.
3. Any accident or incident that damages or exposes the DU armor to the environment, or releases DU to the environment.
4. Accidents or incidents that result in an actual or potential radiation exposure from DU material covered under the applicable NRC license that are in excess to limits of exposure to ionizing radiation.

Student Notes

5. Accident/Incident reports will include:

- Name of the person submitting the report.
- The phone number of the person reporting.
- Name and title of the person in charge at the scene.
- Location of the accident/incident.
- Date and time of the occurrence.
- Organizations involved in the accident/incident.
- Equipment involved, to include radionuclide involved.
- List of the property damaged or contaminated.
- Extent of injuries or overexposure.
- Narrative description of the accident/incident.
- Cause of the accident if known.
- Type of accident and vehicle speed
- Was there fire involved
- Did weather conditions contribute to the accident.
- Did defective equipment contribute to the accident.
- List of the individuals and agencies known to have been notified and what actions are being taken.

REPAIR CRITERIA FOR NON SKIRT ARMOR

If the outer skin has been punctured, ripped, or cracked, a patch should be fabricated out of available materials and welded over the opening. The purpose of the patch is to secure the classified armor array and is not intended to improve the ballistic capabilities of the damaged armor. The damage should be evaluated at the appropriate maintenance level and repairs done as required.

NOTE

Personnel making the above type of repair to the armor where the exterior surface has been breached exposing the interior, should be cleared to the level of SECRET. If it is necessary to use uncleared personnel to expedite repairs, the damaged area should be concealed and then evacuated to an authorized repair facility.

Use caution when welding in the area of damaged DU turret armor. Depleted uranium is extremely pyrophoric (it will ignite spontaneously). Additionally DU will emit sparks when scratched or struck with steel. When welding, the patch size should exceed the size of the damaged area by 4 to 5 inches when possible. **DO NOT** weld directly to any exposed DU surface.

Student Notes

Any scrap materials associated with the classified armor shall be stored, safeguarded, and disposed of as ***Secret*** or ***Secret - Special Access Required*** in accordance with established procedures. All scrap will be placed in a metal container and shipped to:

COMMANDER, ABERDEEN PROVING GROUNDS
ATTN: STECS-LI-M
ABERDEEN PROVING GROUND, MD 21005

The shipment should be coordinated with the local Radiation Protection Officer (RPO) and the Live Fire Vulnerability Division, DSN 298-7301 or AC (410) 278-7301. The container will be shipped as classified to the above address under a continuous receipt system. The Special Program Chief:

US ARMY TANK-AUTOMOTIVE COMMAND
ATTN: SFAE-ASM-S-S
WARREN, MI 48397-5000

DSN 786-5453
AC (810) 278-5453

will be notified that the shipment has been made. Armor scrap will NOT be disposed of outside of CONUS.

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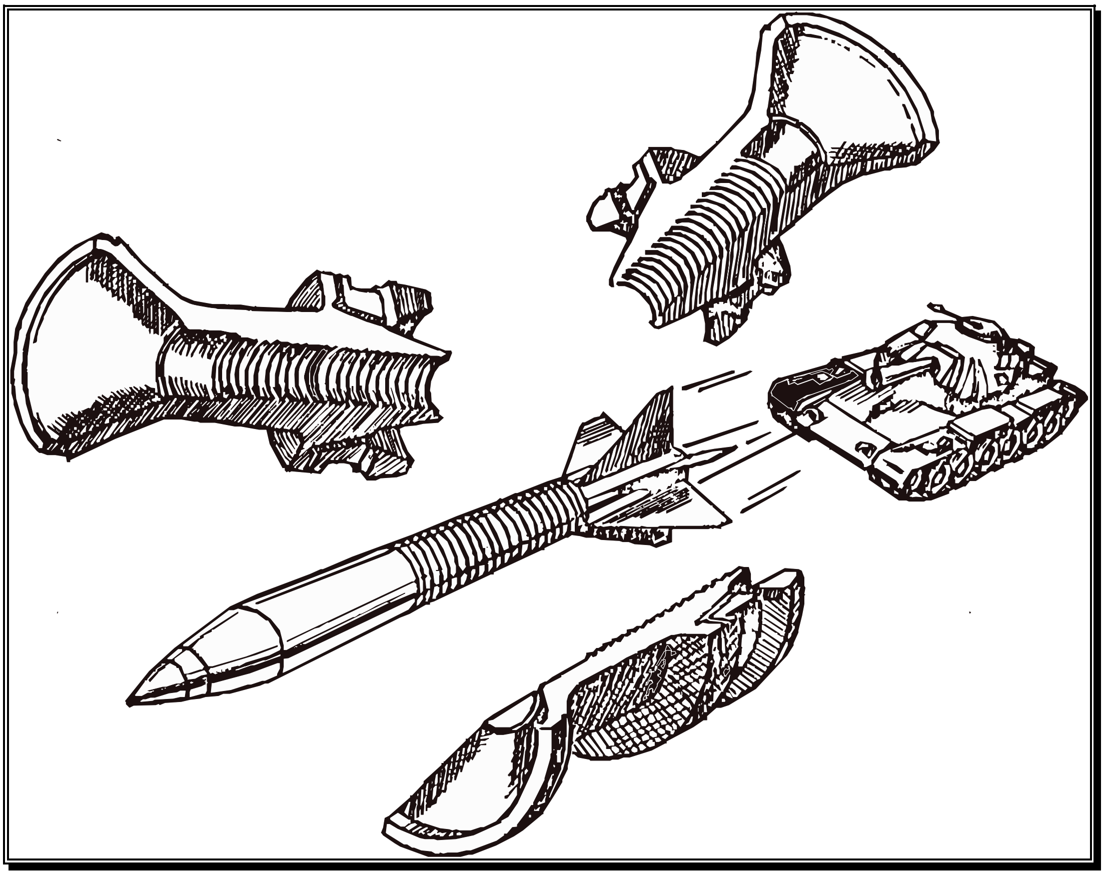
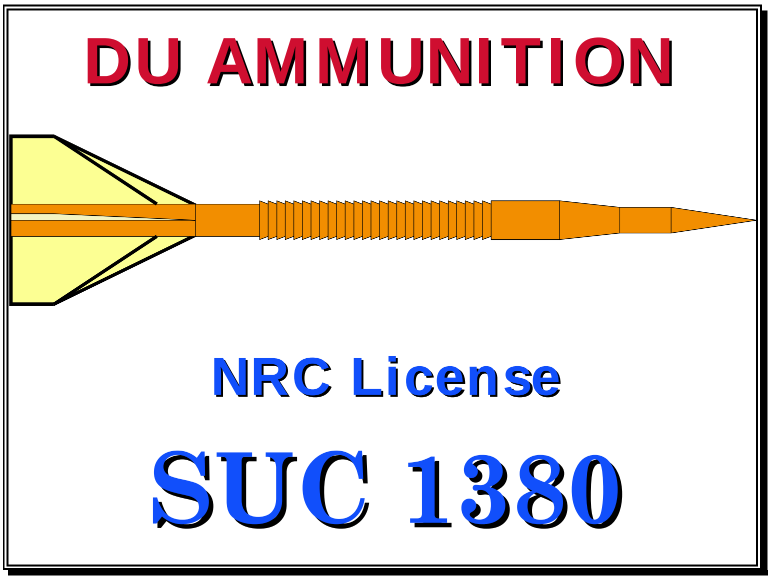
AUTHORIZED AMMUNITION CONTAINING DEPLETED URANIUM



Armor Piercing Projectiles: The combination of high hardness, strength, and density makes DU alloys well suited for armor piercing projectiles. DU costs are competitive with tungsten alloys and tungsten carbides.

Student Notes



The design and material composition of these cartridges represents a departure from previous generations of armor-piercing ammunitions. These rounds employ kinetic energy subprojectiles composed of monolithic (staballoy) depleted uranium cores. The design and material configurations warrant special emphasis during the life cycle of these cartridges. For general military applications, DU ammunition may only be fired during war emergency. All peacetime firings are prohibited except on ranges which are approved and licensed by the NRC and/or have host nation agreement.

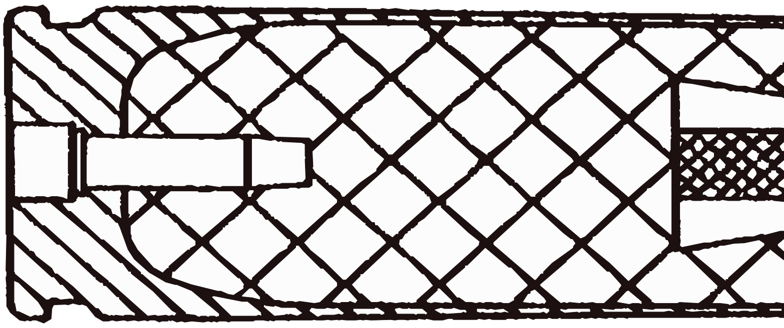
TANK AMMUNITION		**BRADLEY**	**AIRCRAFT**
105mm	120mm	25mm	30mm
M774	M827	M919	PGU-14/B
M833	M829		PGU-14A/B
M900	M829A1		PGU-14B/B
	M829A2		PGU-14A/A

Student Notes

25mm, M919, APFSDS-T

COLOR	MUZZLE VELOCITY
Black w/white obturator	4659 feet/second

The 25mm Armor-Piercing, Fin Stabilized Discarding Sabot with tracer (APFSDS-T) M919 has been designed and developed to replace the currently fielded M791 cartridge as the service armor piercing round for the Bradley. The M919 uses a high length/diameter ratio, depleted uranium penetrator and high energy propellant to achieve improved terminal ballistic characteristics.

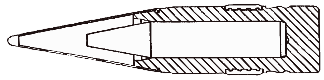


Hazard classification testing was conducted in 1988 at Nellis Air Force Base. Environmental sampling showed no indication that DU oxide had become airborne during the burn test (setting a pallet of ammo on fire). Essentially all of the oxide produced was insoluble when analyzed using a simulated lung fluid test. Only 0.1 to 0.2 percent of the oxide was small enough to be inhaled.

Radiological assessment of the M919 cartridge for external radiation levels was conducted in 1989. The components of the M919 effectively shielded out the predominant alpha and beta radiation. The gamma radiation penetrated the projectiles and the shipping containers. The highest radiation measurement was at the center of the shipping container. Radiation levels at the surface of a single shipping container, measured with field use exposure rate instruments, had a maximum reading of 0.6 mR/Hr. This exceeds the surface exposure rate criteria of 0.5 mR/Hr for excepted material. All other criteria are satisfied by the M919 shipping package.

30mm, API-T and API

The current production API has a boat tail and a shortened windscreen. The projectiles have an aluminum body which holds a depleted uranium penetrator and a hollow aluminum windscreen. Upon impact with the target, the windscreen and body are stripped away allowing the penetrator to continue through

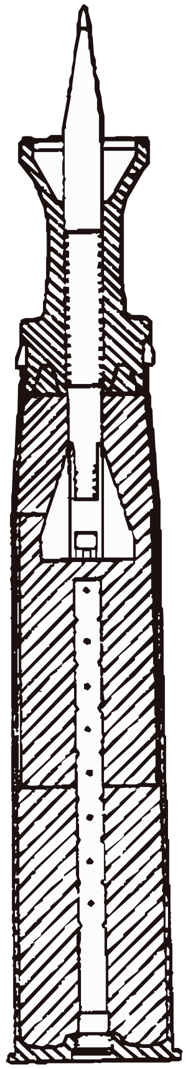


Student Notes

the target. Target friction produces a large amount of heat providing incendiary effects.

Student Notes

105mm, APFSDS-T



The 105mm kinetic energy rounds consist of three models, M774, M833, and M900. These are armor-piercing antitank ammunition and are intended for use in the 105mm, M68 gun and are loaded and fired in the normal manner. The projectile is fin stabilized in flight. In order that only minimal spin is imparted to the projectile when the obturator engages the gun tube rifling, the plastic seal under the obturator produces approximately 80% slippage. Target penetration is effected strictly by the high kinetic energy of the subprojectile impacting the target.

The subprojectile consists of a monolithic staballoy (depleted uranium) core which is fitted with a steel tipped aluminum windscreen and an aluminum fin assembly.

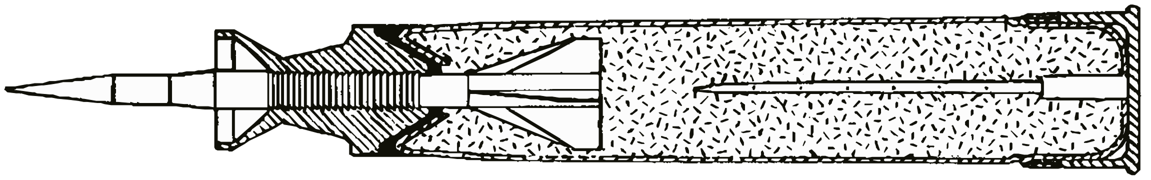
The basic material composition of the ammunition components are as follows:

COMPONENT	MATERIAL
Fin	Aluminum (anodized)
Windshield	Aluminum (anodized) w/ steel tip
Sobot	Aluminum (anodized)
Penetrator	Staballoy (depleted uranium)
Bourrelet	Steel
Sabot Seal	Rubber (Silicon)
Obturator	Nylon
Sealing Band	Polypropylene
Bourrelet Screws	Steel

Student Notes

120mm, APFSDS-T

The 120mm, M829 series, depleted uranium armor piercing fin stabilized discarding sabot-tracer (APFSDS-T) is the primary anti-armor 120mm smooth bore, M256 cannon, tank ammunition in service with the M1A1 and M1A2 Abrams tanks. This second generation kinetic energy projectile is capable of penetrating the frontal slope of all fielded armor systems and it's high technology penetrator and sabot design provides a munition which is accurate at all combat ranges. It's primary function is the destruction of threat tanks and armor fighting vehicles. Target penetration is affected strictly by the high kinetic energy of the DU core when it impacts. Like other DU munitions, these are identifiable by their black color with white markings on the projectile (pointed) end. M829 series ammunition is loaded and fired in the normal manner.



This ammunition will not be fired over the heads of friendly troops unless troops are protected by adequate cover as they may be struck by the discarded sabot.

155mm, Area Denial Artillery Munitions (ADAM)

The Area Denial Artillery Munitions (ADAM) is used for rapid, remote emplacement of point or tactical minefields used to restrict personnel movement. ADAM is a wedge shaped mine that fits efficiently into a 155mm projectile. When the projectile reaches the target area, 36 mines are expelled and shortly after impact with the ground they release trip lines and arm themselves. If not triggered by one of the trip lines, the mines will detonate at a predesignated self-destruct interval or if the battery reaches a level that impairs their proper functioning. When the mine detonates, a small charge propels the kill mechanism upward and then the kill mechanism detonates to optimize its effect against personnel. The ADAM and PDM are not of the kinetic energy "penetrator" type design. These munitions contain an extremely small amount of DU and not categorized as "DU ammunition".

Student Notes

The resin which forms the body of the ADAM mine wedge contains a small amount of DU in the "hardener" portion of the resin. The DU is less than 0.15% (0.024 oz) of the total resin and is present only as a chemical agent that allows the resin to cure at less then 160°F in less then 12 hours. These cure characteristics are required to efficiently produce the mine and to protect the electronic components during manufacture.

Mine, Antipersonnel, M86 Pursuit Deterrent Munitions (PDM)

The M86 PDM is a hand-emplaced anti-personnel mine used by ground forces to rapidly emplace short term minefields. It is activated like a hand grenade and is configured and functions similar to the ADAM mine.

DU Safety

TYPICAL CHARACTERISTICS FOR DU TANK AMMUNITION:

Color ----------------------------Black w/white markings
Muzzle Velocity--------------4925 + ft/sec
Round Weight----------------37.8 - 40.8 lb.
Length -------------------------35.75 - 39.5 in
Tracer --------------------------M13

To help put the radiological hazards of these munitions in their proper prospective, here are some of the warning messages that are associated with various DU ammunition.

WARNING

Firing the M833 at ammunition temperatures above +125°F may result in excessive chamber pressures. Firing at ammunition temperatures below -35°F may result in weapon damage.

Student Notes

WARNING

The M900 is authorized for use in M1 tanks only. Firing the M900 from any other 105mm tank system may result in failure of the gun mount. Firing in unauthorized gun mounts will result in failure of the recoil mechanism hydraulic seals.

WARNING

Do not fire the M900 from 105mm, M68 series cannon equipped with breeches having serial numbers lower than 4804. These breeches can fail catastrophically without warning. Initial quantities may be stenciled with a note indicating a cutoff point at serial number 6000. This number should no longer be considered valid.

WARNING

Do not fire the M900 cartridges where the projectile is loose within the case; i.e., rotating, wobbling, rattling, or any other unsecured manner. This condition may result in excessive pressure during firing resulting in catastrophic breech failure.

WARNING

Hatches must remain closed and the turret vent blower must remain on when firing to prevent buildup of toxic carbon monoxide gas.

Student Notes

All Army munitions containing DU penetrators are full service ammunition which may only be fired during war emergency. All peace time firings are prohibited except on ranges with special NRC license and/or with host nation agreement.

DU is frequently misunderstood which has resulted either in excessive or lack of safety controls. **Although potential users may believe that handling DU presents a complex safety problem, the fact remains that DU is the least hazardous when compared to the hazards presented by the propellant charge.** Sound industry hygiene practices afford adequate protection.

DU ammunition is not to be disposed of by burning, detonation, or buried nor will this ammunition be stored with pyrotechnics or incendiaries.

If cartridges containing DU projectiles are damaged to the point where the internal projectile components are visible, they shall be treated as confidential. The damaged cartridge shall be wrapped in plastic and placed in a container or otherwise covered to prevent exposure. The cartridge shall be returned in a sealed container (as classified material) to the appropriate ASP for disposition.

NOTE

Loss or unauthorized firing of depleted uranium rounds must be reported through the chain of command as soon as discovered (within 4 hours). All transmissions regarding incidents of this nature must be classified at least CONFIDENTIAL. HQ IOC must be notified within 24 hours of the discovery. Violations may result in a personal fine or imprisonment. Failure to report a noncompliance is punishable under federal law. Report to:

Student Notes

COMMANDER; HQ IOC
ATTN: AMSIO-DMW
ROCK ISLAND, IL 61299-6000
DSN 793-0338/2969/1766
AC (309) 782-0338/2969/1766
After duty hours:
DSN 793-1110
AC (309) 782-1110

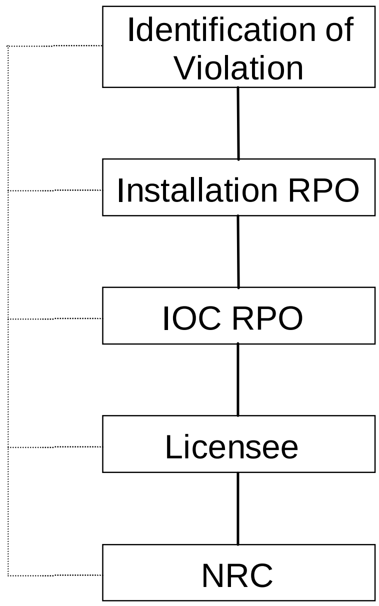


Figure 2 - Reporting Chain (DU Munitions)

Student Notes

DU Hazards

Radiation exposure from DU, in most situations, is of minor significance and is controllable. If in that rare event the dose limits have been exceeded due to exposure to DU, the actual over-exposure is less significant than the fact that safety controls have not functioned as required by law. Minor over-exposures make no significant changes to the individual's total risk situation, but the existence of the over-exposure usually indicates deficiencies or mismanagement which could eventually lead to a complete loss of controls.

DU presents a two fold hazard:

1. **CHEMICAL TOXICITY** The chemical hazard of DU is slightly greater than the radiological hazard. Chemical toxicity is only present after the victim has absorbed the contamination into the blood stream. Normally the body is capable of eliminating over 90% of the radioactive material through the bowels and urine.
2. **IONIZING RADIATION** DU presents an ionizing radiation hazard when:
   - Sufficient quantities are taken into the body.
   - When large amounts of DU with a large surface area are present in a very close proximity to the body for an extended period.

Fortunately, DU is absorbed to a very limited extent through unbroken skin or the gastrointestinal tract; and its specific activity is quite low in comparison with most other radioactive elements. Overexposure to either hazard is rare and easily prevented by maintaining adequate safety controls and training of personnel involved with DU.

EXTERNAL RADIATION

DU contains a series of radioactive elements (daughter products) that commonly emit either alpha or beta particles; this emission may also be accompanied by gamma ray activity. All of the alpha and most of the beta radiation emitted by the DU penetrator is effectively shielded by the shell casing, discarding sabot and aluminum wind screen while the ammunition is intact.

Student Notes

Handling the bare DU penetrator greatly increases the potential for external and internal radiation exposures.

ALPHA EMISSIONS do not present any ***external*** radiation hazard.

GAMMA RAY ENERGY is so low that for practical purposes it constitutes no hazard.

BETA RADIATION accounts for nearly all the penetrating radiation from DU. But, the beta intensity rapidly decrease with distance.

In keeping with NRC and US Army ALARA policies, any vehicle or object struck by DU munitions should be considered contaminated. Any M1A1 Abrams tank which has received combat damage resulting in ignition of stored DU munitions, onboard fires, or has been struck by missiles should be treated as contaminated until inspected by qualified personnel. Fortunately, DU armor and ammunition **does not** constitute a serious external radiation hazard. It is not necessary to use massive shielding or special manipulating devices to decrease exposure in working with DU. There is relatively little radiation exposure at a few feet from the material.

INTERNAL RADIATION

DU can gain access to the body by way of injection, ingestion, or inhalation. Inhalation is the principle safety hazard in dealing with DU compound.

ABSORPTION through unbroken skin is negligible. Absorption via injection is likely to occur in such cases as contamination of open wounds or penetration of the skin by pieces of DU shrapnel.

Absorption by INGESTION is approximately 1% of the intake.

INHALATION of DU is the most significant mode of entry. DU particles can be dispersed in the air from a fire involving DU or from DU ammunition impacting armored surfaces. Only very small particles can be inhaled. Of those inhaled particles, some will be soluble in lung fluid and others will not. Those particles that are *soluble* will be absorbed by the body to become a ***heavy metal*** poison (**chemically toxic**) primarily to the kidneys. The particles in the lungs that are *not soluble* will remain in the lungs and may be a radiation hazard. Insoluble particles that remain in the lungs are dispelled by the body very slowly.

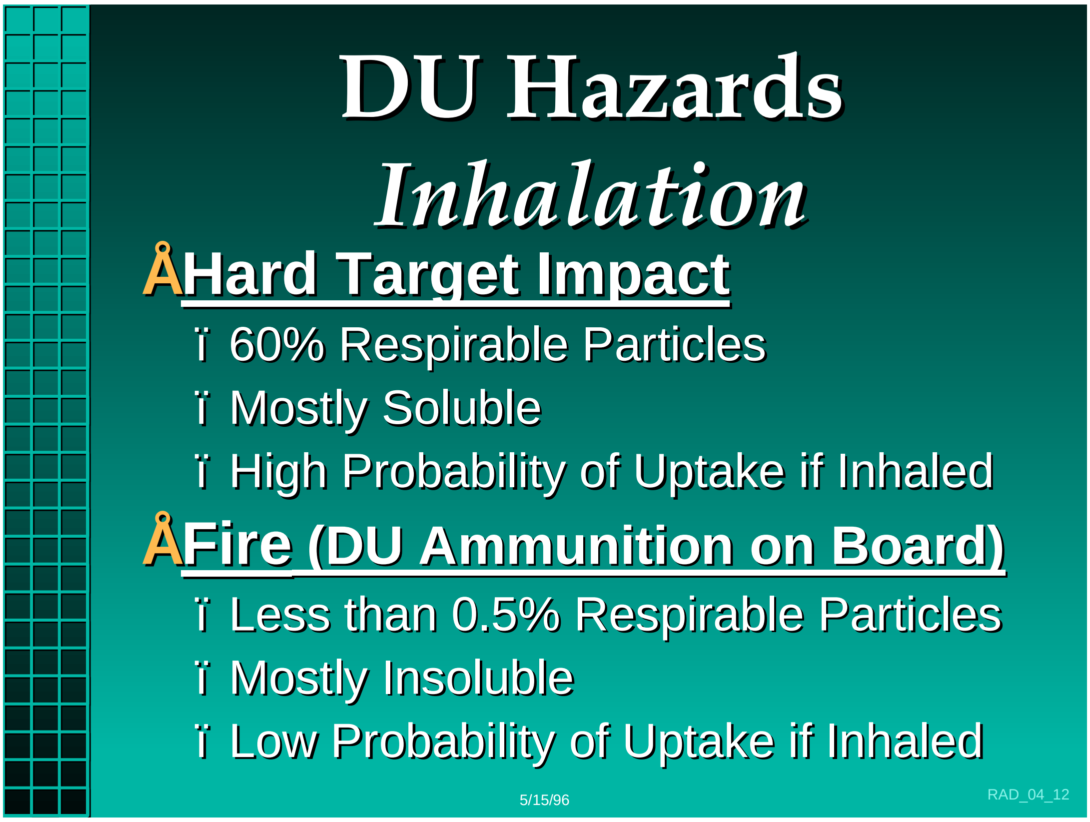
Once in the body, DU can cause damage by ionizing radiation. The principle radiation hazard from internal deposits of DU is the intense ionization in tissue

Student Notes

produced by alpha particles emitted during the radioactive decay process. The energy of the alpha particles is absorbed in the first 0.1mm of tissue, resulting in localized cellular damage while the beta and gamma radiation emissions dissipate their energies in relatively large volumes of tissue and produce comparatively little damage.

CHEMICAL TOXICITY

The more soluble components of DU are quickly taken into the blood stream via the lungs or contaminated wounds and may result in significant deposits in the kidney. Once there, some of the DU combines with the protein of cell walls, poisoning the cells and interfering with the vital functions of waste elimination and maintenance of electrolyte balance. The DU does not remain fixed in the kidney, but is eliminated at a rate of about half every two weeks. Moderately severe damage to the kidney as a result of acute exposure is repairable, and a return toward normal kidney function may occur even during continued exposure.



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Nuclear Regulatory Commission
(NRC)