TAB G -- DU Exposures in the Gulf War

Various scenarios exposed Gulf War veterans to depleted uranium. US Abrams tanks mistakenly fired depleted uranium penetrators into some US combat vehicles, destroying or damaging them. In addition, personnel recovering, repairing, or decommissioning DU-damaged vehicles may have inhaled or ingested residual DU fragments and particles. There were also several accidental tank fires and an ammunition explosion and fire at Camp Doha, Kuwait, which burned, oxidized, and fragmented many DU rounds, creating a potential exposure hazard to soldiers operating in the vicinity. Other personnel entered Iraqi vehicles destroyed or damaged by DU.

A relatively small number of veterans were involved in high-risk exposure scenarios, while a relatively high number of veterans were involved in much lower-risk scenarios. To evaluate the health risks from this spectrum of scenarios, this office adopted a prioritized approach that categorized the scenarios into three levels, depending on the veterans' activities and the severity of the exposure.

FFFFF Level I includes veterans in or near combat vehicles at the time these vehicles were struck by DU munitions, or veterans who entered vehicles immediately after they were struck by DU munitions. These veterans could have been struck by DU fragments, inhaled DU aerosols, ingested DU residues, or had DU particles land on open wounds, burns, or other breaks in their skin -- or any combination of these possibilities. FFFFF

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FFFFF Level II includes veterans and a small number of DoD civilian employees who worked in and around vehicles (mostly friendly-fire wrecks) containing DU fragments and particles. These individuals may have inhaled DU residues stirred up (resuspended) during their activities on or inside the vehicles, ingested DU after transferring it from hand to mouth, or spread contamination on their clothing. Soldiers who were involved in cleaning up DU residues from Camp Doha's North Compound after the July 11, 1991, explosion and fires are also included in this group. FFFFF

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FFFFF Level III is an "all others" group whose exposures were largely incidental or fleeting. This group includes individuals who entered DU-contaminated Iraqi equipment, soldiers downwind from burning Iraqi or US equipment struck by DU rounds, or soldiers downwind from burning DU ammunition (e.g., soldiers at Doha during the July 11 fire). While these individuals could have inhaled airborne DU particles, the possibility of receiving an intake high enough to cause health effects is extremely remote. FFFFF

As research progressed, investigators subdivided the three levels into 13 sub-categories of DU exposure (see Table 1, page 8), which are described below.

A. Level I

During the Gulf War, US Abrams tanks fired DU rounds at occupied US vehicles, destroying or damaging 6 M1/M1A1 tanks and 14 Bradley Fighting Vehicles. A combination of the featureless desert terrain, large, fast-moving armored formations, and low visibility from darkness, heavy rains, sandstorms, etc., were all contributing factors in these incidents. In some instances, a single DU round hit the friendly vehicle; in other instances, multiple rounds hit the vehicle. One incident involved an Apache helicopter that hit an Abrams tank carrying DU rounds igniting an on-board fire. (Tab J, "Tank Fires," discusses this tank which is not included in the 6 tanks mentioned above.) An Abrams also hit a 15th Bradley with DU, but the crew had already evacuated the vehicle. (See Tab H.) [236]

Figure G-1. M1A1 lost to friendly fire

Given the confusion and uncertainty on the battlefield, some of the soldiers in vehicles coming under friendly fire initially believed they had been fired upon by Iraqi armor. It was only after the fact that battle damage assessment experts confirmed that the entrance and exit holes in the struck vehicles exhibited the distinctive radioactive trace left by Abrams DU penetrators. Soldiers involved in these friendly-fire DU incidents found out what actually happened to them from after-action investigations and word of mouth. Most of these soldiers were unaware of the potential health effects associated with DU. Consequently, the investigation of friendly-fire incidents was accompanied by an effort to identify, locate, and contact all surviving soldiers who were in or on vehicles at the time they were penetrated by DU rounds.

104 soldiers on board US combat vehicles struck by DU penetrators survived the attacks; 11 soldiers died. Table G-1 lists the vehicles and the number of soldiers onboard who survived. (See Tab H for a description of each friendly-fire incident.) The "0" entry in the right-hand column reflects the fact that the 2-2 Cavalry Bradley was initially struck by enemy fire, evacuated, and subsequently struck by "friendly" DU rounds.

Table G-1. Summary of US vehicles hit by DU tank rounds

Army Unit	Vehicle Type	Bumper Numbers	Surviving Soldiers Onboard
4-7 Cavalry	Bradley	A-24, A-31, & A-22	15
1-37 Armor	Abrams	C-12	4
1-41 Infantry	Bradley	B-21, B-26, B-33, D-21 & D-26	29
3-66 Armor	Abrams	B-66, B-22, A-14, A-31 & A-33	19
3-15 Infantry	Bradley	C-11, C-22 & C-23	23
4-66 Armor	Bradley	HQ-55 & HQ-54	9
1-34 Armor	Bradley	HQ-232	5
2-2 Cavalry	Bradley	G-14	0*
Total			104
* This vehicle was vacant when it was struck by DU rounds.			

The second sub-category of Level I includes personnel who rushed to the aid of the soldiers in vehicles hit by DU rounds. Investigators have identified 46 veterans fitting this criteria (although as many as 60 soldiers may be in this category). These soldiers often entered damaged or destroyed vehicles moments after they were hit, possibly exposing themselves to DU residues or oxides still airborne from the impacts or stirred up by the rescue activities.

B. Level II

The seven sub-categories of Level II include soldiers who worked in and around DU-contaminated vehicles (mostly friendly-fire wrecks) or who took part in the cleanup of DU contamination at Camp Doha, Kuwait, after an explosion and fire on July 11, 1991, detonated or burned several hundred rounds of DU ammunition.

Table G-2. DU-contaminated vehicles

Reason for Contamination	Abrams	Bradleys
Accidental friendly fire	6	15
Intentional friendly fire	3	0
Tank fire caused by suspected hellfire	1	0
Accidental tank fires	3	0

Tanks burned in Doha fire	3	0
Total	16	15

A total of 16 Abrams and 15 Bradleys (Table G-2) were contaminated with DU in the Gulf during 1990-1991. In addition to the accidental friendly-fire vehicles mentioned earlier, three bogged-down Abrams were deliberately destroyed by other US tanks (after their crews had evacuated) to prevent them from falling into Iraqi hands. The Level II group also includes personnel whose maintenance or salvage duties required them to frequently enter and exit, or spend extended periods of time working in, contaminated vehicles. Finally, soldiers who cleaned up DU residues or spent penetrators inside Camp Doha's North Compound following the July 1991 ammunition supply point explosion/fire, fall into this classification.

1. Removing Munitions

Explosive Ordnance Disposal (EOD) personnel entered DU-contaminated vehicles or surrounding areas to disarm and remove unexploded ordnance. Although the military trained and equipped EOD personnel to operate in a nuclear- and DU-contaminated environment, some EOD personnel may not have been aware in every case that the vehicles they were working in had been struck by DU. Also, explosive ordnance disposal is an extremely dangerous undertaking and worrying about DU contamination was often secondary to EOD personnel disarming and removing unexploded ordnance.

The standard uniform of EOD personnel clearing unexploded ordnance was body armor (flak jacket) and a kevlar helmet. Because of the extreme heat of the Gulf, EOD personnel often wore only T-shirts under the body armor. At Camp Doha, engineer personnel assisted EOD by cleaning up non-explosive debris and identifying unexploded ordnance. Engineers found DU penetrators in the 1st Squadron's motor pool during the initial clearing and clean-up. They initially picked up these penetrators -- often with bare hands -- and tossed them with the rest of the debris into a civilian dump.[237] Some soldiers knew there were DU tank rounds in the Camp Doha stockpile, but were unaware of what DU was or what its properties were. They were not advised of any contamination hazard or protective measures against contamination, but were only ordered to wear kevlar helmets and flak vests for protection against unexploded ordnance.[238]

2. Maintenance and Recovery Operations

Some soldiers entered US equipment contaminated with DU within hours or days of the penetrator impact -- usually to recover weapons, gear and sensitive equipment, a task that sometimes took hours. Many of these soldiers had earlier survived the friendly-fire incidents in those same vehicles.[239] Unit mechanics spent hours, sometimes days, removing reusable parts like engines and transmissions. They were never warned of the dangers of DU. Some of these mechanics noted the dusty condition of the friendly-fire wrecks they worked on.[240] A member of a US Army Battle Damage Assessment Team said that more that 27 major components were removed from the first four Bradleys he inspected (three of which were contaminated with DU).[241] The mechanics performing this work were not only potentially exposed to DU dust, but also may have inadvertently spread parts and equipment containing trace amounts of DU to other vehicles. In fact, a mechanic from the 4-7th Cavalry Squadron reports that after spending several days crawling around dusty friendly-fire wrecks, stripping them of usable parts, a Battle Damage Assessment Team with RADIAC meters arrived and declared the vehicles to be radioactive. They made the mechanics round up all the parts and, after checking each one, assessed most of them to be radioactive and ordered them to be put back into the original vehicles.[242] This office has identified 60 veterans who spent more than a half-hour performing maintenance or equipment recovery inside contaminated tanks or Bradleys.

3. Logistics Assistance Representatives

Some logistics assistance representatives (LARs) also entered damaged or destroyed vehicles. Logistics representatives were civilian systems experts who often determined the disposition of knocked-out equipment. Because the logistics assistance representatives had more direct contact and communication with the Armament

Munitions and Chemical Command (AMCCOM), they were more aware of DU hazards and the proper procedures for mitigating those hazards.[243] A December 20, 1990, message to the logistics assistance representatives advised them on the proper assessment, repair and recovery techniques:

> The number of personnel who take part in the vehicle recovery should be kept to an absolute minimum. They are to be dressed in protective coveralls, gloves, rubberized boots, and they are to also wear the M25 or M17A2 protective mask with M13A2 filter element and the accompanying head covers (i.e., Mission Oriented Protective Posture [MOPP] level 4). The coverall pant legs are to be worn over the rubber boots and sealed with tape at the ankles. Likewise, the sleeves are to be slipped over the gloves and taped. The edges of the hood are to be draped over the coveralls and taped to them and the place where it contacts the respirator. Also, any remaining openings are to be sealed with tape.[244]

Despite this guidance, at least one logistics representative has stated that he entered contaminated systems in a tee shirt and without a respirator.[245] When interviewed, the deputy to the officer in charge of the M1-series tank LARs stated that, despite warning messages that highlighted the potential exposure risks to DU, he had received numerous reports after the war of his personnel entering damaged Abrams tanks without proper protective equipment.[246] At least one representative has indicated that he was unaware of the warning messages until after the Gulf War. He reported that he entered DU-contaminated vehicles at King Khalid Military City without personal protective equipment and with the knowledge and consent of the health physics officer and radiation control personnel at the site.[247] Four out of 16 logistics assistance representatives interviewed to date report working around DU-contaminated vehicles. Efforts are continuing to identify and interview other logistics representatives.

4. Battle Damage Assessment Teams

A group from the US Army Ballistics Research Laboratory (BRL) at Aberdeen, Maryland, conducted battle damage assessments on damaged or destroyed US ground combat vehicles. This 12-man battle damage assessment team (BDAT) looked at damaged and destroyed US combat vehicles to determine how they had been knocked out, what damage had been sustained, the type of weapon or munition used, how well the vehicles' defensive features had worked, etc. These inspections required frequent entry into disabled, often DU-contaminated vehicles. The battle damage assessment team arrived in the Gulf on or about January 21, 1991, and were attached to combat elements prior to the ground war (which began a little over a month later on February 23rd). Because the team's personnel had more technical expertise with DU than most soldiers, they were sometimes called in after the ground war began to help evaluate potential crew and equipment radiation contamination and to assist in friendly-fire investigations.[248]

Investigators have interviewed all twelve members of the Ballistics Research Laboratory battle damage assessment team. Most team members said they were trained in proper handling procedures and safeguards for DU-damaged equipment, but three do not recall receiving this training. Some members of the team followed the prescribed precautions and only entered DU-contaminated tanks after donning yellow radiation suits, including dust masks, gloves, and boots. Other members were not as rigorous in taking protective measures. A few battle damage assessment team personnel have indicated that the wearing of masks and gloves was an impediment to taking accurate measurements. Others indicated that there were not enough masks for everyone and they eventually ran short on gloves as well; apparently the gloves were easily torn on the sharp edges in the close confines of the vehicles. Assessments typically took between six and eight hours to complete, although some team members reported spending less than an hour inside vehicles. They did not consistently adhere to the practice of checking themselves for radioactivity after working in vehicles. While only one team member reported more than marginal levels of DU on him, he indicated that he was unable to get all the DU off and eventually everything in his pack became contaminated. Most team members practiced good personal hygiene, particularly after working in contaminated vehicles.[249]

A seven- or eight-member battle damage assessment team from the US Army Tank and Automotive Command (TACOM) also inspected DU-contaminated vehicles after the ground war. This team, though they knew DU had been used, did not wear masks, gloves, or head cover. One member of this team indicated that he didn't (and doesn't)

consider the DU contamination at that site to be a hazard. Another member said that the wearing of masks would have hindered the team's ability to carry out the tasks inside the vehicles.[250]

Several of the Ballistics Research Laboratory battle damage assessment team members said they wore radiation badges while they were in the Gulf and never received feedback on the readings. In December 1997, the office of the Special Assistant for Gulf War Illnesses requested information on these readings from the Army office responsible for maintaining dosimetry data.[251] In response to that request, the US Army Radiation Standards and Dosimetry Laboratory provided histories of exposure to ionizing radiation for all twelve Ballistics Research Laboratory team members and two members of the TACOM battle damage assessment team.[252] According to these histories, from January 17, 1991, to March 12, 1991, all battle damage assessment team members wore thermoluminescent dosimeters capable of measuring external whole body radiation. All readings were zero, as would be expected from a low-level radiation source such as DU. These devices were not capable of measuring how much DU may have been inhaled or ingested. At the request of the Office of the Special Assistant for Gulf War Illnesses, the Army provided these histories to the battle damage assessment team members.[253]

5. Processing Damaged Equipment

US forces transported disabled or destroyed US combat vehicles to King Khalid Military City, the central receiving and storage site for such vehicles (as well as many Iraqi "trophy tanks"). The Pentagon ordered the 144th Service and Supply Company, a National Guard unit from New Jersey, to assess battle damage and prepare the vehicles for shipment back to the US. Although their mission did not include maintenance or repair, members of the 144th have indicated that they periodically re-entered the contaminated vehicles to cannibalize equipment for other units.[254] The 144th personnel were not familiar with proper procedures for handling DU-contaminated M1-series tanks or Bradleys. Because their original mission did not involve tanks with DU armor, unit personnel were not familiar with Army Technical Bulletin (TB) 9-1300-278,[255] which contained guidance for handling DU-contaminated M1 tanks.[256]

The 144th worked on DU-contaminated equipment without taking any precautions (e.g., wearing dust masks). They reportedly had no knowledge that some of the damaged equipment was contaminated with DU until after March 11, 1991. In many cases, contaminated equipment was mixed with uncontaminated equipment. Until the arrival of a radiation control (RADCON) team from the Armament Munitions and Chemical Command (AMCCOM), no one controlled access to the equipment. As many as 27 soldiers in the 144th worked in or around damaged Bradleys and Abrams without protective gear for an undetermined period of time.[257] Although the battle damage assessment team commander stated that he informed personnel from the unit about the potential hazard from contaminated vehicles on or about March 11, 1991,[258] various members of the 144th have questioned the date they were actually notified, and stated that they continued to enter contaminated equipment after this date.[259] While AMCCOM sent communications to ARCENT addressing DU contaminated equipment, there is no documentation indicating that personnel from the 144th were informed that the equipment in their control was contaminated, therefore the exact date will probably never be confirmed.

Approximately 10-15 maintenance personnel from the 556th Corps Support Company assisted the 144th. According to the team's non-commissioned officer in charge, 556th personnel worked in the storage yard evaluating the extent of damage to the vehicles for approximately two weeks before they were informed of the potential DU contamination hazard.[260]

The 144th ultimately shipped 14 Abrams and 9 Bradleys with DU contamination to the Chem-Nuclear Systems' Defense Consolidation Facility in Snelling, South Carolina for decontamination and disposal. Initially, Chem-Nuclear Systems' (CNS) facilities could not meet security, structural, and environmental requirements to handle the larger equipment such as the Abrams tank. Therefore, after receiving the initial Abrams involved in the December

1991 tank fire, CNS built a new building which was fully licensed by South Carolina's Department of Health and Environmental Controls. CNS instituted appropriate industrial hygiene and radiation protection procedures throughout the entire processing operation, including external dosimetry and pre- and post-urine uranium and blood lead analyses. CNS tailored personal protective equipment to each vehicle. Removable alpha contamination levels inside the vehicles were typically less than 1,000 disintegrations per minute per 100 square centimeters (dpm/cm^2), but CNS detected levels of up to 10,000 dpm/100 cm^2. (Note: NRC guidance for unrestricted use is 1,000 dpm/100 cm^2, i.e., there is no requirement for any protective measures or personnel protective equipment.[261] In addition, personnel protective equipment is generally not required when the removable surface contamination is less than 10,000 dpm. For contamination levels between 10,000 and 1,000,000 dpm, personal protective equipment is required, i.e., shoe covers, gloves, coveralls, and respirator.)[262] Typically, workers wore safety glasses, coveralls, gloves, safety shoes, and booties. CNS performed continuous air monitoring when needed and personnel wore respirators as required. Radiation exposure was minimal and CNS observed no uptake of radioactive or hazardous material in any of the workers.[263]

CNS eventually decontaminated and returned all nine Bradleys to the DoD supply system or for rebuilding at a depot level maintenance site. In addition, CNS returned scrap metal from 11 Abrams to the Aberdeen Proving Ground, and returned two restored Abrams to the active inventory.[264]

6. Radiation Control Activities

After completing their initial battlefield assessments, the Army's battle damage assessment team went to King Khalid Military City (KKMC) on March 11, 1991, to see if any equipment they had missed had been evacuated to the vehicle collection point, which was being managed by the 144th Services and Supply Company. Finding many DU-contaminated vehicles at KKMC, the team requested on-site personnel from the Armament Munitions and Chemical Command (AMCCOM) to arrange for a radiation control team to go to King Khalid Military City.[265]

AMCCOM deployed radiation control teams to identify, assess, and respond to incidents involving DU contamination. Radiation control teams performed their duties primarily at King Khalid Military City (KKMC) and at Camp Doha, although there were some limited excursions to other locations.

On March 24, 1991, a radiation control team of health physicists from AMCCOM arrived at KKMC to assume responsibility for identifying, collecting, and surveying DU-contaminated equipment.[266] Much of this equipment was already at KKMC. The AMCCOM radiation control team segregated the DU-contaminated vehicles, set up a guarded perimeter to restrict access, and instructed 144th personnel in the proper handling of DU. The team examined the vehicles at the site and concluded that their DU radiological and chemical contamination levels, while low, required basic protective equipment, such as surgical gloves and dust masks, and strict personal hygiene measures.[267] Their work, completed around April 12, 1991, cleared the way for contract personnel to inspect, decontaminate, package, and ship the contaminated systems to the US.[268] In all, 15 Bradleys and 10 Abrams at KKMC were contaminated with DU. Some merely had DU "splatter" and could be returned to duty after decontamination. Others had to be sealed to contain the contaminant and then shipped to the US for final processing and disposal.[269]

The AMCCOM personnel also surveyed captured Iraqi equipment being prepared for shipment to the US. According to the person in charge of the survey operation, the most acute radiological hazard on these Soviet-built tanks was the radium used in their gauges, which were often leaking.[270] These gauges had to be removed prior to shipping. One T-72 tank had substantial internal and external DU contamination.[271] It was not shipped, but its ultimate disposition is unknown.[272]

An AMCCOM recovery team deployed to Camp Doha, Kuwait, from July 19 until early August 1991. The team did a radiological survey in and around four M1A1 tanks that were damaged or destroyed in the July 11 fire. After

determining that three of the tanks contained low-level contamination, the AMCCOM team did an initial decontamination of their exteriors and prepared them for shipment to the Saudi Arabian port of Dammam. The team also collected a sizeable quantity of spent DU penetrators and fragments from the 2nd Squadron motor pool pad and deposited them in the tanks' interiors, which were then sealed. On August 6th, the tanks were shipped from Dammam and returned to the US for processing at the Defense Consolidation Facility at Snelling, South Carolina.[273]

On July 24, 1991, a radiation control Emergency Response Team from the US Army's Communications Electronics Command (CECOM) Safety Office at Ft. Monmouth, NJ, arrived at Camp Doha.[274] The Project Director for the US Army Radiological Control Team headed the CECOM team. The team conducted what one member called a "site characterization survey."[275] According to the CECOM team chief, they did a comprehensive radiological survey of the motor pool area and when they detected penetrators or DU "dust," they thoroughly swept the area. The CECOM team was able to survey and clear an estimated two acres of the motor pool (which was the size of several football fields).[276]

Investigators have interviewed several members of the AMCCOM and CECOM radiation control teams. All the individuals interviewed said they used some form of personal protection, although only about half routinely used respiratory protection while working in and around contaminated vehicles. All team members interviewed said that they were careful to monitor each other with a RADIAC meter at the end of each work day to ensure that they were not tracking DU residues away from the cordoned-off portion of the 2nd Squadron motor pool pad.[277] Ten to twelve individuals performed radiation control activities at one time or another. Investigators from the Office of the Special Assistant are continuing their efforts to locate and interview these personnel.

7. Camp Doha Cleanup Activities

A July 11, 1991 fire in Camp Doha's motor pool complex (the North Compound) destroyed or damaged tons of ammunition, as well as 20 to 30 combat-loaded vehicles, dozens of support vehicles, and equipment. The fire externally damaged one M1A1 tank and destroyed three others. Detonated DU rounds inside the three destroyed tanks (approximately 37 rounds per tank) contaminated these vehicles. In addition to the estimated 111 DU rounds in the tanks, the fire also damaged or destroyed more than 500 DU rounds stored in nearby conexes (metal shipping containers). Most of these rounds detonated, leaving behind scorched, exposed DU penetrators. In most cases, these exposed penetrators showed little oxidization, but some were oxidized or fragmented to a significant degree.

Within the North Compound, almost all of the DU penetrators, fragments, and oxides were concentrated in the 2nd Squadron motor pool and wash rack area. Between July 14th and July 23rd, an explosives ordnance demolitions detachment and a company of Combat Engineers cleared approximately a third of the 2nd Squadron motor pool pad. Although AMCCOM and CECOM personnel cleaned up the area with the heaviest concentration of DU -- the burned M1A1s -- the surrounding motor pool pads may have contained residual DU. In addition, the fire and explosions partially burned and scattered many exposed or spent DU penetrators around the conex containers.[278] As the AMCCOM and CECOM teams cleared unexploded ordnance and DU from sections of the concrete pad, regular soldiers were brought in to do a final cleanup using brooms and other hand tools. These soldiers could have inhaled or ingested residual DU stirred up by sweeping and picking up DU penetrators or pieces of DU penetrators with bare hands.[279]

A more comprehensive discussion of the Camp Doha explosion, fires, cleanup, and recovery operations can be found in Tab I.

D. Level III

This group comprises "all others." It includes soldiers downwind of burning DU-contaminated equipment and personnel who entered DU-contaminated Iraqi equipment. It also includes personnel who were present at Camp Doha during and after the motor pool fire, but who did not take part in cleaning operations in the North Compound. Based on existing research, this entire group received minimal exposures.

1. Camp Doha

This group consists of individuals who were at Camp Doha during the fire and subsequent cleanup activities, but were not directly involved in the sweeping operations or with picking up spent DU penetrators, fragments, or oxides in the North Compound. Individuals in the North Compound (motor pool area) when the fire and initial explosions started are also included in this group. An M992 ammunition carrier loaded with non-DU 155mm shells burned for approximately 30 minutes before the explosions started, giving most soldiers time to evacuate the area. Cleanup activities in the South Compound are included in Level III becaus