TECHNOLOGY FOR THE CERTIFICATION OF RANGE RESIDUE

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Introduction

The safe disposal of range residue is one of the most challenging tasks facing Department of Defense (DoD) test and training range managers. Each year, DoD components expend almost 250,000 tons of ammunition to train warfighting forces; test the reliability of ammunition stockpiles; and develop new, more effective weapons to meet the demands associated with evolving military needs. Each of these facets of the range mission generates a corresponding quantity of residue that needs to be cleared from ranges and ultimately disposed of by range operating agencies. Range residue consists of practice munitions; residual scrap from the expenditure of high-explosive rounds; and munitions components such as cartridge cases, flare canisters, bomb fins, or expended rocket motors. It also includes target vehicle residue, dirt from earthen berms and backstops, and concrete or lumber from mockup targets.

Each Military Service establishes range maintenance policies for the ranges it controls. The major range maintenance tasks are locating and destroying unexploded ordnance (UXO), removing munitions residue and expended targets, and restoring targets to serviceable condition. Explosive Ordnance Disposal (EOD) personnel destroy UXO at most DoD ranges. Military or contract maintenance personnel perform munitions and target residue removal tasks and target restoration activities. After removing residue from a range, specially trained personnel must carefully inspect it to ensure that no UXO or other dangerous residue has been overlooked and certify it as safe before the range operating agency finally disposes of it. According to DoD

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policy, all range residue must be handled and disposed of as Ammunition, Explosives, and other Dangerous Articles (AEDA).

Workers that perform inspections of range residue must be specially trained and qualified to identify UXO or dangerous munitions components that may be mixed in munitions scrap or embedded in expended targets. The inspection is largely a visual examination intended to identify dangerous items that were brought in from the range so that they may be safely destroyed. The visual inspection is impeded by the damage munitions sustain on impact with their intended targets, which often makes it impossible to evaluate them effectively. Recyclable metals that pass inspection are usually sold through property disposal pathways of the Defense Logistics Agency (DLA) or through qualified recycling programs. Aside from inert-filled items, which are explosively opened, residue leaves DoD custody virtually unaltered and becomes a tradable commodity on the scrap metal market. Inevitably, some UXO slips through this process.

The DoD Inspector General's Report 97-213, *Evaluation Of The Disposal Of Munitions Items*, recommends a number of management solutions to address the range residue problem. One of the most significant statements in the report is that "physically inspecting AEDA residue for explosive properties was not an adequate method of ensuring it was inert."[1] The Inspector General recommended that DoD explore potentially cost-effective methods for rendering AEDA residue completely free of explosives.[2]

A number of technologies hold promise for enhancing the effectiveness and safety of the residue certification process. Additional research and development may be necessary to advance these technologies and develop systems that are practical, affordable, and environmentally acceptable for employment at DoD ranges. This paper discusses requirements and identifies potential basic technologies that could be developed into systems to improve the AEDA residue certification process.

Background

All range residue is classified as AEDA by DoD directives because it has at one time contained or been exposed to explosives. The terrain around live-fire targets where explosive artillery rounds, cluster munitions, or large explosive bombs are employed is covered with large quantities of heavy munitions case fragments mixed with pieces of live explosive filler and fuze components. Many large munitions case fragments may be found with explosive contamination ranging from trace amounts to several pounds. Large chunks of explosives and live munitions components are normally destroyed by EOD. However, the extent of contamination makes it impossible to check each piece of metal for explosive contaminants.

The AEDA classification also applies to expended inert-filled ordnance that range maintenance personnel remove from target areas and practice munitions designed to be fitted with small spotting charges that produce a flash and a cloud of smoke when the munition hits its

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[1] Department of Defense, Office of the Inspector General, "Evaluation of the Disposal of Munitions Items," Report Number 97-213, September 5, 1997, page 7.
[2] Ibid, page 8.

target. Both inert-filled ordnance and practice munitions present special challenges. Inert-filled munitions, such as inert artillery projectiles or inert aircraft bombs, are often assembled from the same components used to build live explosive rounds. After they hit a target and are exposed to the elements, the color markings that identify them as nonhazardous abrade and corrode, which makes eliminating them as being potentially hazardous items very difficult. On the other hand, sometimes, the colors change. For instance, a large blue bomb encountered in the field is universally understood to be filled with inert material, but the Navy paints some of its explosive aircraft bombs blue gray, a color that is easily mistaken for the inert color code. Practice munitions sustain a significant amount of damage upon impact. This damage makes it difficult to determine if the spotting charges they contain have exploded or been completely consumed. Some examples of troublesome practice munitions include the BDU-33 series practice bomb used by the Air Force, the Navy MK 76 Mod 5 practice bomb, and the Army's M274 practice rocket warhead.

The practice bombs contain red phosphorus and black powder or titanium tetrachloride spotting charge in the nose of the cast steel bomb body. Personnel inspecting impacted bombs on the range insert a flexible probe into the tail of the bomb to determine whether or not the spotting charge fired. The fin set, however, is made of sheet steel that on impact can bend around the bomb body or fill with dirt or mud. Either condition prevents inserting an inspection probe. The rocket warhead contains a live fuze and a spotting charge designed to produce a large flash and a cloud of smoke from two large holes in the sides of the warhead body. Impact can throw the spotting charge out of the warhead, leaving a live fuze behind.

Target residue certification also pose special challenges. Target vehicles include all types of trucks, trailers, armored personnel carriers, and main battle tanks. After a vehicle has been destroyed by weapons fire on a range, it may be contaminated by unexploded ordnance lodged in its frame; tires; armor; or heavy driveline components such as drive axles, transmissions, or transfer cases. The photograph to the right shows the rear drive axle of a large truck removed from an impact range target. Aircraft cannon rounds made the holes in the differential assembly. Small explosive projectiles in the 20-mm to 40-mm class are likely to be found in these locations, making target certification an extremely difficult task.

Inspection and Disposal Process

At most ranges, the inspection of the residue from range operations is a process that relies solely on the judgment of an inspector who certifies that an expended munition or target does not contain any hazard that might preclude its offer for sale as scrap metal. Inspectors have few tools that can be employed, other than their experience with the residue they process, probes, mirrors, flashlights, common hand tools, and ultimately, demolition explosives to destroy dangerous or suspicious items. At times, the quantity of material that must be examined overwhelms the work force. The photograph to the right shows workers in the fourth day of operations to inspect and certify several hundred tons of practice bombs. The task the inspectors perform is critical and offers no room for even a single error. Every piece of residue must be visually inspected to ensure that it does not contain explosives. The process generally involves a small work force engaged for long hours picking up thousands of items under demanding working conditions that include temperature extremes, dust, and the danger and noise of heavy equipment operating nearby. The work has resulted in documented injuries from repetitive motion and from physiologically destructive lifting conditions. Complacency in the work force inspecting the material is a constant concern for supervisors of inspection and certification crews. After inspections and certifications are complete the material is sold through Defense Reutilization and Marketing Service (DRMS).

There are several post-sale factors that may contribute to accidents after AEDA residue leaves government control. DRMS classes AEDA residue as Group 1 or Group 2 based on the hazard potential of the material and the generator's willingness to certify it as explosive-free. Group 1 contains nonhazardous material or items that are certified as explosive-free. Group 2 residue is not certified and may still contain hazards. A generator can offer Group 2 residue for sale, and a buyer may purchase it with the understanding that he or she assumes the associated risks.

Once a certified lot of residue has left DoD control it may be traded and mixed with other material at the whim of the buyer. This material may include other range residue, such as Group 2 material or range residue gathered from illegal scrap-picking activities. Many DoD ranges have remote, unsecured boundaries, and civilians routinely illegally enter some ranges to remove high-value metals that they can dispose of easily on the scrap market. This illegally gathered scrap can enter the recycling stream and be mixed with an inspected and certified lot from a DoD range after it has left DoD control. These two factors can compromise the certification issued by DoD agencies because certified material legally released to the public is not demilitarized after inspection. As a result, without inspections like those described above, it is virtually impossible to distinguish the differences between these types of AEDA scrap. It is easy for an unscrupulous dealer to add munitions from other sources to certified scrap purchased from a DoD range and sell the entire lot to another dealer as Group 1 material covered by a DoD certification document. Large quantities of AEDA residue may change hands on the scrap market several times before being processed for recycling. This places the personnel certifying the AEDA scrap, recycling workers, and the government's interest at risk.

Safety Issues and Accidents

Over the years, accidents and incidents that injure workers in the AEDA inspection work force or downstream in the salvage and recycling business have occurred numerous times. Each Service has established database files that track statistical data on explosive-related accidents, but the accuracy of data collected after the mid-1980's is suspect. A detailed descriptor of each accident is beyond the scope of this paper; however, a few examples are given below to illustrate several key points.

In March 1997, an accident occurred in Fontana, California, which attracted considerable attention in the media and led to a DoD Inspector General (IG) investigation. A civilian scrap metal concern had purchased a certified AEDA lot from the Defense Reutilization and Marketing Office (DRMO) at Barstow, California. While several employees in the yard were working to cut the scrap with a torch, a live, high-explosive antitank round exploded, killing one worker outright and injuring several others. In the aftermath, emergency responders from the Army and contracted cleanup workers found 20 additional live explosive rounds in the yard. Ultimately, San Bernadino County proffered second degree murder charges against the civilian contract inspector who had certified the scrap. In the pre-trial hearings, several irregularities involving the overall management of the AEDA residue before it left government control and the acquisition of munitions residue from other sources by the scrap dealer were disclosed.

There are several parallels between the Fontana accident and a 1975 accident in which in a civilian was killed handling AEDA on the Gila Bend segment of the Luke Air Force Range (now the Barry M. Goldwater Air Force Range) in Southwestern Arizona. Large quantities of scrap munitions had been removed from a tactical range on the complex by a civilian construction firm contracted for the job. The workers were to remove material that supposedly had been inspected by EOD personnel. This material included large practice bombs that had been explosively opened to expose inert fillers. While a salvage contract worker was cutting a sand-filled 750-pound practice bomb with a torch, an internal charge exploded, killing the worker and injuring two co-workers assisting him. The Air Force investigation identified unauthorized entries by the removal contractor into the range, problems with munitions historical and technical data, and management of the entire residue collection process as potentially contributing factors in the accident. The investigator recommended more EOD involvement in the residue collection and disposal process--a strategy that continues on the Goldwater Range to this day. But simply making EOD responsible for the massive amounts of scrap metal recovered from ranges has not been enough to prevent additional accidents.

In another incident that occurred in the late 1970's, a practice bomb from a lot of AEDA scrap exploded in a smelter in California, severely burning a worker standing nearby. The lot of AEDA was traced to the Luke range, where hundreds of thousands of practice bombs had been inspected and certified by EOD personnel.

Because DRMOs have experienced so many accidents with practice bomb explosions in their facilities, they have forbidden their acceptance in DRMO yards. In 1993, a civilian DRMO employee was severely injured when a certified practice bomb he was cross loading from an overweight vehicle exploded in his face. This accident resulted in a temporary moratorium on sales of range residue in some commands and forced ranges to establish off-site sales areas approved by servicing DRMOs.

The most recent incident occurred in California in January 1998. A civilian worker torch cutting a cartridge-actuated device contained in a 59,000 pound lot of AEDA reportedly purchased from the Naval Air Weapons Station China Lake was injured when a small explosive component blew up. This incident, coupled with the Fontana incident and the DoD IG's findings, has driven DoD to develop and implement a corrective action plan to address the deficiencies cited in the DoD IG report.

Technology Requirement

Past actions to apply more manpower, improve the skills of the people responsible for the process, and implement additional regulations have not stopped explosives from entering the AEDA residue recycling stream and causing serious injuries or deaths. The DoD IG recommended that the DoD consider cost-effective technology to help solve the problem. The application of technology in the certification process is needed to help reduce reliance on human decisions and to subject all AEDA residue to treatment that will ensure it is free of explosives and demilitarized.

Some requirements that a successful solution will have to address include the following:

- Improve safety throughout the process, from inspection and certification to disposal and recycling;
- Eliminate hazardous material from range residue;
- Significantly reduce the manpower and cost associated with the overall process;
- Reduce or eliminate reliance on human involvement in the certification process;
- Comply with all applicable DoD, federal, state, and local laws and regulations;
- Demilitarize (cause the range residue to become unidentifiable metal scrap to enable easy recognition of items that have not been inspected, processed, and certified as safe);
- Apply to ranges across the DoD;
- Meet Defense Explosive Safety Board safety and reliability requirements.

Potential Concept

One approach is to develop a system that employs a three-step process to demilitarize and certify munitions residue. First, an operator would cull suspect munitions that cannot be positively identified as inert filled. These would enter an analytical stage where sensor-based tools would be used to confirm that large projectiles and bombs received from range clearance activities are actually inert filled. When inert-filled materials are confirmed, the munitions scrap would enter the second step of the process, where it is cut, crushed, or melted. Practice ordnance, such as small practice bombs, could be placed directly into a processor, where any explosions of low energy spotting charges would be safely contained. If a mechanical process is selected as an initial step to reduce the scrap volume, it may need to be followed by some sort of processing to eliminate any remaining explosive residue. Targets would be cut, crushed, smashed, or shredded after a visual inspection for embedded munitions was completed. In the third step of the process, target residue would be further processed to ensure that no small UXO remained embedded in drive line or frame components. Byproducts of the process would then be released for disposal or recycling.

Basic Technologies

Industrial applications of technology to resolve this problem are either emerging or exist and may be modified and proven to meet the Department's needs. Ultrasonic analysis developed for the chemical warfare community may hold promise for positively identifying the presence of inert fillers in an item before it is subjected to processing. The goal for this step is to eliminate the possibility of main charge explosives, submunitions, white phosphorous, or flares in an ordnance item that has no readily discernible identification features. Any ordnance identified as containing hazardous filler would be removed for demolition in a safe area. Los Alamos National Laboratories has developed a field-deployable sensor that may have promise in meeting this requirement. The presence of a small spotting charge in a practice munition would not present cause to perform demolition procedures. These munitions would be effectively dealt with in the robust equipment employed in the next phases.

The second phase of the process could involve technology to grind, shred, or crush the inert munitions to demilitarize it and prepare it for further processing. The scrap metal recycling industry has several technologies that hold promise for this phase. Commercial metal shredders, cutters, and crushers that may meet requirements are available and have been proven capable of demilitarizing inert-filled munitions in large quantities. The auto wrecking industry has shredders that are capable of consuming an entire light truck. These machines may require further development to prove that they meet requirements to survive an occasional small explosion. Luke AFB validated this concept in 1997 in a groundbreaking effort to crush 3,500 tons of scrap BDU-33 bombs. The machine, contracted from JPJ Munitions Group, validated the concept of machine processing tough munitions casings. During the process, the machine survived 75 spotting charge explosions. The bombs that were crushed had been inspected up to four times by EOD personnel using methods described previously. But, as the DoD IG pointed out, a final phase to thermally treat the crushed metals would have enhanced safety.

The last stage of the process would somehow treat the crushed or shredded munitions and target residue. If thermal equipment were used, it would have to provide the high levels of heat necessary to burn off explosive residue and be sufficiently robust to survive a small explosion or high intensity burn associated with pyrotechnics. Of course, the equipment will need to be compliant with federal and state environmental laws and prove its effectiveness and safety to the Defense Explosive Safety Board. Again, promising technologies that may be competitive to meet this need are available. These include hot gas diffusion units being used to process contaminated materials from explosives and ammunition manufacturing operations, plasma arc furnaces that are being developed for Department of Energy remediation projects as well as for conventional munitions treatment tasks, and flashing furnaces designed for contaminated waste processing.

Summary

Safety problems inherent in the current AEDA residue processing scheme will continue to injure or kill people that inspect or recycle scrap from DoD test and training ranges if the Department does not employ more effective methods to inspect and demilitarize expended munitions and targets. Further regulation of disposal of this material without placing more effective tools in the hands of the personnel who perform residue inspection and certification work will only serve to put more pressure on an overburdened system that has already proven incapable of effectively dealing with the problem.

While some ranges have explored new possibilities, these efforts have been relatively small and isolated. The Range Commander's Council has committed itself to improving the safety and reliability of the AEDA residue-certification process. The Range Commander's Council's Environmental Group (REG) is working with the Office of the Secretary of Defense-led Munitions Residue Disposal Process Review Team chartered on 9 June 1998 to identify specific concerns and make recommendations.

Further development of industrial hardware and sensor technology offers promising solutions. We have only scratched the surface of technologies that can contribute to addressing this critical need. We must work together to identify potential technologies, develop systems, and demonstrate their capabilities.