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ASSAY OF POTENTIALLY CONTAMINATED PROPELLANT

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ABSTRACT

One of the decontamination and decommissioning projects within the Department of Defense is the demilitarization of an aging stockpile of munitions. A large portion of the stockpile contains depleted uranium (DU) as an armor piercing core and so these munitions must be assayed for the presence of uranium in other components. The assay method must be fast and preferably easy to implement. The presence of DU is indicated by its alpha decay. The alpha particles in turn produce ions in the ambient air. If a significant fraction of these ions can escape the quantity of propellant, the ions can be detected instead of the alpha particles.

As a test of the feasibility of detecting alpha emissions from DU somewhere within a cartridge of propellant, the transmission of ions through layers of real propellant was measured. The propellant is in the form of graphite-coated cylindrical pellets. A 105mm cartridge was modified for use as a pellet chamber. A check source served as an ion source. The ion detector consisted of a grid held at 300V coupled to an ammeter. Results confirm that this is a promising technique for testing the propellant for the presence of DU quickly yet with sensitivity.

INTRODUCTION

The Department of Defense maintains a large inventory of munitions which contain depleted uranium (DU) components. The DU component normally forms the core of the projectile assembly of the munitions, and is utilized because of its superior ability to penetrate enemy armor. As the stockpile of DU munitions ages, it will become necessary to safely disassemble the munitions, removing all explosive/combustible components and recovering other components for recycling. This process is known as demilitarization (demil). Of particular interest is the demil of 105mm tank ammunition since this cartridge design has a section of the DU penetrator rod in direct contact with the propellant charge. The propellant consists of solid cylindrical pellets, each 1.5 cm long and 7.6 mm in diameter. Because the level of potential DU migration onto the propellant is expected to be low, a sensitive method of assay is required to segregate contaminated propellant. Given the large volume of propellant to be monitored, the assay method must also be expeditious - preferably in-situ on the demil line - since a lengthy assay time could significantly add to the total cost of the demil project.

One indicator of the presence of DU is the presence of alpha particles emitted by the natural decay of uranium. Alpha particle activity can be detected via the ions that are created in air by the ionizing alpha radiation. The ions can survive much longer - and thus travel much farther from the source uranium - before neutralizing compared to the range of the alpha particles. For assay of a cartridge full of propellant, air is drawn through the pellets, transporting these ions to an ion detector.

An alternative assay would empty the pellets from each cartridge, spread the pellets on a conveyor, and scan the pellets for gamma-ray activity. This process is slower and might spread contamination.

ALPHA DETECTION
The ion detector consists of a metal grid across an air pipe. Ions caught on the grid as air passes through create a very small (femtoamps) current to ground. The response of the detector is on the order of seconds, the time necessary to transport the ions from the alpha particle to the detector. Detector requirements are simply a small voltage supply (300V battery) for biasing the collection grid, and a sensitive ammeter or electrometer. Similar detectors based on long-range alpha detection (LRAD) have been designed (1) and fielded by a team at Los Alamos National Lab (2).

The number of ions reaching the detector is proportional to the amount of DU present on the surface of the pellets. The ions can be absorbed or at least neutralized in collisions with the pellets before reaching the detector. This potential loss of efficiency at ion collection and hence of sensitivity to DU can affect the attractiveness of this non-destructive, in-situ assay.

ION TRANSMISSION TEST

The transport of the ions through the propellant was tested at Savanna Army Depot Activity. Air containing fixed amounts of ionization is drawn through a steel 105mm cartridge case. The loss of ions to attachment to propellant grains is measured as a function of depth of propellant in the case.

Test Apparatus

The test bench is illustrated in Fig. 1. The lower chamber held a \(^{230}\text{Th}\) check source which served as a source of ions. The front door on the chamber had a large cut-out, covered by a generic furnace air filter. The source disk was held in the center of the chamber by a stand. The TMA/Eberline source had an activity level of 6220 disintegrations per minute (dpm) in Sept. 1991 (essentially the same at present) over an active area of 4.4 cm diameter. In order to provide different activity levels, several masks were made. These masks consisted of sheet metal, with circular punch-outs of graduated diameter. Diameters were chosen to provide variations in activity level in 660 dpm steps - assuming the activity was uniform across the original source. The data will call this assumption into question.
The pellet chamber consisted of an empty 105mm cartridge, roughly 60 cm long. The bottom of the cartridge had a large hole, covered by a perforated metal sheet. This mechanical support for the pellets may have acted as an electrostatic filter for the ions passing through.

The pellets are graphite-coated, and therefore normally have a conductive surface. The packing fraction of the 7.6 mm diam., 1.5 cm cylinders was determined to be 60% in random pouring of the pellets. The layer of pellets would act as a grounded, conducting sponge that could filter ions. Qualified personnel transferred the propellant between storage and the cartridge during the operation, and data acquisition was carried out in a separate bay behind 30 cm-thick concrete walls.

The 10 cm diameter pipe monitor was bolted onto the cartridge. The signal grid was nominally 91 cm from the source disk. The sensitivity of the pipe monitor was determined in the lab to be 10 dpm per femtoampere (fA), similar to other LRAD pipe monitors (2). A 300V battery was used to bias the grid. The battery was kept remote in the data acquisition bay in accordance with safety procedures. An Amone electrometer (3) was secured to the monitor body and wrapped with black electrical tape. A BNC cable (and a grounding strap) was run out of the bay to a Keithley electrometer operating as a voltmeter. A PowerBook 180c ran the acquisition software.

A vacuum hose was connected with flanges directly to the top of the monitor. Approximately 1.8 m of this hose ran to a shop vac. A 10 cm diameter chamber was inserted midway along the hose, and contained a probe for measuring air speed. There is some question as to the effect of turbulence within this chamber on the measured air speed, as the chamber was not very long. A sliding opening assembly permitted control of the amount of vacuum and therefore the air speed. Airflow was kept between 30 and 102 cm/s in a 10 cm diameter so that the response was relatively insensitive to air speed (2).
TEST RESULTS

Fig. 2 shows the response of the monitor with no propellant in the chamber. The data set taken at 45 cm/s airflow consists really of two sets, separated by 90 minutes of delay. The lower value of the two points for 6220 dpm goes with the earlier set. Three observations are relevant.

1. The sensitivity (slope) changed during the delay, when the monitor and electrometer were moved and the electrometer was not physically secured. Ignoring the 6220 data (see #2), the slope below 3500 dpm is 66 dpm/fA while above 3500 dpm the slope is 43 dpm/fA.

2. The source disk appears to have non-uniform deposition, with higher activity per unit area towards the periphery of the disk. Within each of the data sets, the 6220 data are consistently above what would be expected extrapolating the lower activity data. This is also true to a lesser extent for the 4905 dpm activity, and the 4247 dpm area. Therefore, source strength must be considered nominal. We suspect that only the total activity of the $^{230}$Th source would be guaranteed to some tolerance by TMA/Eberline.

3. Better sensitivity was obtained with increased air speed. The slope at 74 cm/s is 35 dpm/fA. Moreover, the measured air speed was less stable at the lower setting. This may be a function of turbulence in the measurement chamber at that air speed, or the load on the shop vac when the air vents just upstream of the vac were wide open. The half-minute to half-minute fluctuations in the data definitely appeared to be proportional to the fluctuations in measured air speed.

**LRAD Response vs "Activity" and Airflow**

- 90 fpm
- 145 fpm

Figure 2. Response of the ion monitor as a function of the source activity. The activity is calculated from the unmasked area, assuming uniform deposition of the total activity. Results are given at two different air speeds.
Fig. 3 shows the response of the monitor when 5 cm of propellant covers the bottom of the cartridge. Data were taken for 145 fpm. The ratio of response for 5 cm vs no propellant is graphed in Fig. 4. for those activity levels common to the two sets of data. This ratio represents the average transmission of ions through 5 cm of propellant. The average is 25% with a (one-sigma) range of 21-29%. Thus one could anticipate that transmission of ions through 10 cm of propellant - an additional 5 cm - would be 25% of 25%, or 1/16. This would be close to the background of roughly 20 fA. Indeed, with 10 cm of propellant, a signal was obtained at background level even with an unmasked, 6220 dpm source activity.

LRAD Response vs "Activity" and Pellet Depth

![Graph showing response of the ion monitor to a 5 cm layer of propellant compared to no propellant.](image)

Figure 3. Response of the ion monitor to a 5 cm layer of propellant compared to no propellant.
LRAD Response with 2 inch Depth Relative to No Pellets

![Graph](image)

Figure 4. Transmission through 5 cm of propellant. The average is 25% for every 5 cm layer.

For a 5 cm layer, the air speed was increased to 122 cm/s in an attempt to optimize the monitor sensitivity. The results are plotted in Fig. 5. Not much signal was recovered, and in fact the measurement with a 10 cm layer was checked at air speeds approaching 152 cm/s without observation of any signal above background.

**IMPROVEMENTS IN TECHNIQUE**

Some improvement can be expected that would enable response to approach 10 dpm/fA (without propellant). The ion source/alpha source was separated by the perforated metal sheet, which surely acted as an imperfect electrostatic filter. In real monitoring (and in the next phase of testing), alpha sources will be buried within or directly underneath any propellant.

Moreover, the use of triaxial cable would enable the electrometer to be separated from the detector head. Care should be taken in stabilizing air flow - at least for interpreting test results if not in actual disassembly usage. Lastly, test sources should be better defined as to intermediate activity levels - such as through use of a source set.

The next phase of testing will involve mixing a known amount of DU powder into some M30 propellant. We will learn the effect of reduced ion production by a single alpha particle due to pellets in the path of the alpha. This next phase will be carried out at Picatinny Arsenal in New Jersey.
LRAD Response vs "Activity" and Airflow

Figure 5. Response of the ion monitor as a function of the source activity. Results are given at two different air speeds.

CONCLUSIONS

A sensitive but fast method is needed to assay propellant from the demil of munitions containing DU. Alpha decay of the DU and subsequent ion production in air (the LRAD technique) provides a possible means of assay. In studying this technique we have measured the transmission of ions through overlaying propellant.

A significant fraction of ions (25%) penetrates 5 cm of propellant. Therefore, assaying the DU within a batch of propellant is feasible through detection of the ions produced by the alpha decay of uranium. However, because no ions would penetrate a full 105mm cartridge, the assay process must involve spreading the propellant within some container or conveyor belt. This still offers an improvement in the amount of time required to assay a quantity of propellant. Traditional alpha particle detectors detect the alpha particles directly and so are sensitive to DU contamination only on the top surface.

The next phase is being scheduled to use contaminated propellant to test the true efficiency of the detection method. If the efficiency is large enough, then only engineering problems relating to implementation on the demil line need be addressed.

REFERENCES

"LRAD-Based Airflow Monitors", Los Alamos National Laboratory Manuscript LA-12742-MS (March, 1994).