A White Paper

FULLY CONTAINED TREATMENT OF LEAKING M55 ROCKETS

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Leaking M55 rockets, containing chemical weapons materiel, present the Army with an operational challenge that is inherently more difficult than other munitions awaiting destruction by the Assembled Chemical Weapon Alternatives (ACWA) program. A significant number of the roughly 70,000 M55 rockets at the Blue Grass Army Depot have developed leaks and the number is expected to grow. While these leakers are currently fully contained in overpacks for safe storage, their destruction will require special handling, making them less amenable to the reverse assembly process used at the Blue Grass pilot plant. Rockets are particularly difficult because of the rocket motor which must be removed and which potentially could be contaminated. The Blue Grass pilot plant is expected to come on-line in a few years. However, the leaking M55 rockets will probably remain in storage for a significant period after initial processing begins because of the specialized procedures and extra precautions that will be required. The Army would gain significant safety, operational, and cost advantages from a near-term capability to destroy these munitions in a proven, fully contained process without removing them from their overpacks and without the need for reverse assembly.

Sandia National Laboratories proposes to adapt the proven Explosive Destruction System (EDS) technology to provide that near-term capability. The EDS was developed for the Project Manager for Non-Stockpile Chemical Materiel (PM NSCM) to destroy recovered munitions. As such, it is also ideally suited for non-standard stockpile munitions. Sandia's modified design uses a larger explosive containment vessel to accommodate the M55 rocket ***while still in the overpack container***. This EDS variant can be made ready for Army testing within 1 year. With this system, the Army could process a large fraction of the leaking M55 rockets at Blue Grass before the pilot plant reaches full operational capability. In addition, the Army could optimize the Blue Grass pilot plant for the "normal" M55, thereby reducing the operating costs.

OPERATIONAL ADVANTAGES OF EDS FOR M55 LEAKERS

The EDS/M55 variant should integrate well with the Blue Grass Pilot Plant:

- It is a non-incineration system which, like the planned pilot plant, uses chemical neutralization to treat chemical agents. As such, it can employ any of the neutralization recipes used for all of the chemical agents present at Blue Grass.
- Because the initial treatment process is the same as the Blue Grass production process, the effluent from the EDS can be sent to the pilot plant SCWO treatment process along with the effluent from the other munitions.
- EDS handles both agents and energetic materials; this eliminates the need to disassemble the munition and it eliminates any special problems if the energetic materials are contaminated with agent.

- Because EDS uses explosive shaped charges to access the munition, it can treat the munition without first removing it from the overpack. The shaped charges would penetrate through the overpack into the munition.
- EDS uses a fully contained batch process which is fundamentally better suited for non-standard operations because it provides flexibility, redundancy, and surety of destruction. Operations can be extend or repeated and nothing leaves the system until there is positive confirmation that the agent is destroyed.
- Since the EDS is already qualified, the Army can begin destroying the leaking munitions much sooner than if they wait until the fixed facility is ready, particularly since the leakers will likely be the last to be processed.

Besides its application to the leaking M55 rockets, development of the modified EDS will provide PM NSCM with the capability to destroy larger non-stockpile munitions than they can currently process in the EDS 2 and it will provide PM ACWA with the capability to deal with other non-standard munitions.

ADAPTING EDS TO THE M55

The EDS/M55 variant is an adaptation of the proven EDS P2. It is designed to process leaking M55 rockets in their safety overpack container, or "PIG". Three different containers are currently in use. They are shown in figure 1. The primary design issue for accommodating the M55 + PIG in the EDS is the length of the detonation containment vessel. Two other items to consider for this application are the configuration of the shaped charges that are used to open the munition and the processing rate.

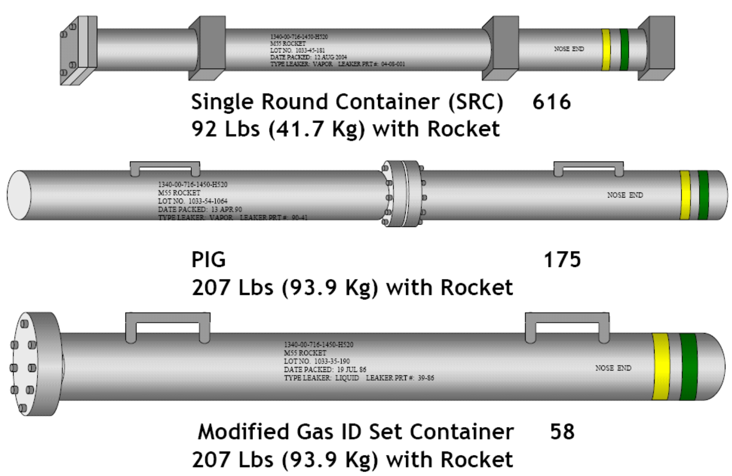

Figure 1. Safety Overpack Containers ("PIG") for Leaking M55 Rockets

Detonation Containment Vessel Size

There are two design requirements that drive the size of the explosive containment vessel. The first is the ability to physically fit the munition inside the vessel. The second is the vessel's structural capacity to contain the detonation of the explosives. The overall length of the M55 rocket is 78 inches while the inside length of the EDS P2 vessel is only 60 inches. There are two options for increasing the length. The most obvious is to simply fabricate a deeper cylindrical cup while keeping the same door and closure system. This option has the least impact on the other components in the system, but makes the vessel more difficult to fabricate. The other option is to replace the door with a second cylindrical cup so that the vessel is twice as long and the clamp and seal are in the middle. This is shown in figure 2. This option provides a 10 foot vessel with minimal effort.

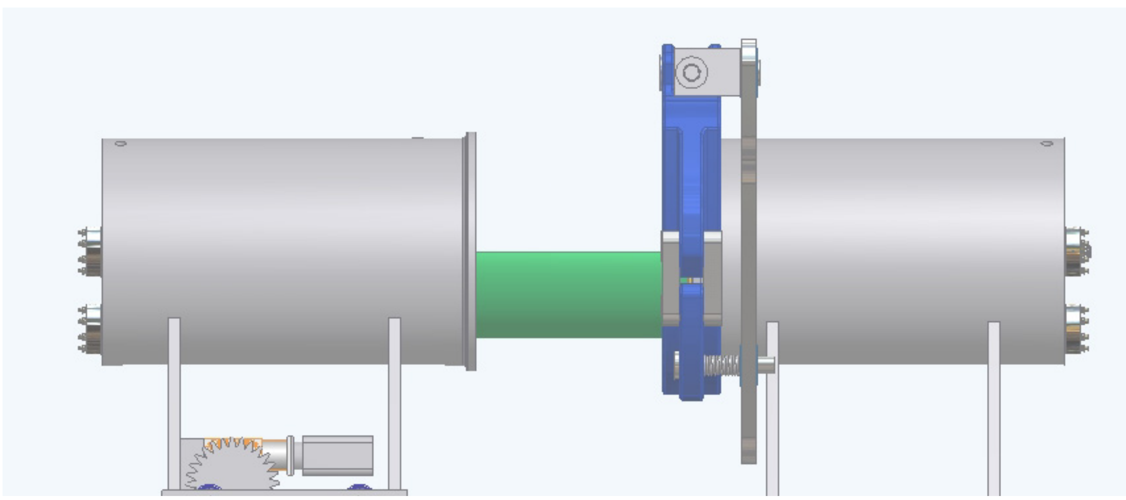

Figure 2. Dual Cylindrical Cup Design for EDS/M55 Detonation Containment Vessel

With either option, our preliminary analysis indicates that the vessel is structurally adequate for this application. The M55 rockets contain a total of 22.5 pounds of energetic materials. Although this is clearly greater than the rated capacity of the P2 vessel, based on our experience with the EDS and other applications we believe we can configure shaped charges to reliably deflagrate, but not detonate, the propellant. If the propellant does not detonate, the impulse load is limited to the detonation of the burster, which is well within the vessel capacity. The static pressure from the gases generated by the propellant will be about 250psi, which is also well within the capacity of the vessel (2000 psi ASME pressure rating).

However, even though we expect to reliably deflagrate the propellant, the possibility of detonation can never be completely eliminated and must be considered as the maximum credible event. A computer simulation based on the detonation of all 22.5 pounds of energetic material indicates that the vessel will experience about one percent plastic strain. This is well below the failure level of the vessel and would not be a problem as a one time, off-normal event. Such an event would be detectable from routine vessel inspection. The vessel would be removed from service and evaluated to determine its fitness for further use.

Munition Opening System

Shaped charges and a fragment suppression system must be configured for each type of munition. Since the EDS was first developed almost ten years ago, Sandia has developed configurations for a large variety of different munitions. The design for the M55 rocket will be similar to those for other large munitions such as the 155 mm or 8 inch artillery shells. However, there are two unique requirements. The first is the need to leave the munition inside of the overpack and the second is the need to deflagrate the propellant. Our plan is to place a linear shaped charge circumferentially around the munition to open the rocket motor and initiate the propellant. A second linear shaped charge will make an axial cut in the munition to access the agent. Simultaneously, a single conical shaped charge will detonate the burster. Since the charges must penetrate both the container and the munition wall, the standoff distance cannot be optimized for both so a compromise is required. Proper alignment will also be a concern. Analysis and testing will be required to optimize the design and demonstrate reliability for each of the three overpack containers.

Process Time and System Throughput

The EDS was designed for processing small quantities of munitions, not for continuous, high-throughput operation. If no other changes are made to the design, the modified EDS would take two days to process each M55 rocket. By using two systems operated in a staggered sequence, as is currently done at Pine Bluff, the Army would be able to process about 200 munitions per year. This is not unreasonable for the expected number of leaking munitions and it would complete the task earlier than what appears likely with the planned facilities.

However, with a few low-risk design changes the process time can be reduced to one day, thereby doubling the throughput. These improvements could be implemented with minimal impact on the time required to fabricate the operational system. These design upgrades are described in the following paragraphs.

Inductive Heating – One of the slowest steps in the EDS P2 is heating the vessel. Heating is done in two steps. First, it is heated to 60°C during the neutralization step. Later it is heated to 100°C as part of the water rinse. The system now uses band heaters that heat the vessel from the outside. The heating rate is limited by the rate of thermal conduction through the wall and by limits on the temperature of the outer surface. Furthermore, most of the energy goes to heat the steel wall. Induction heaters generate heat near the inner surface of the vessel. Consequently, more of the heat reaches the fluid more quickly. The outer surface does not get as hot so higher power heaters can be used. Thermal stresses are less and the vessel cools more quickly. Several companies supply induction heating systems suitable for this application. We understand that PM NSCM has recently had positive experience inductively heating ton containers.

Steam Injection – The second heating step during the water rinse could be shortened substantially by injecting steam instead of water. The latent heat of the steam would help heat the vessel from the inside and the steam would decontaminate the vessel more effectively than liquid water. Commercially available steam generators could easily meet our needs.

Effluent Holding Tank – In the EDS P2 the treatment chemicals remain in the vessel for over four hours. Generally the agent destruction is complete in less than two hours, but a sample must be collected and analyzed before the effluent can be drained to the waste drums. The EDS/M55 upgraded design would drain the effluent to a holding tank after two hours. The effluent would remain there, fully contained, for the final two hours of treatment. Meanwhile, the next step in the explosive containment vessel, which is the hot water rinse, can proceed. Besides saving time, this change would simplify the sample collection because the sample would be drawn from the holding tank rather than the EDS vessel. The tank would also provide more uniform mixing and heating to assist the treatment process.

Active Cooling – The original EDS P2 sits overnight prior to final cleaning and thus has a large amount of time to cool down. To complete the process in one day, the EDS/M55 variant will require active cooling. The inductive heating system described above already includes water cooling for the induction coils. This same cooling system can be used to cool the vessel.

Table 1 shows the effect of these changes on process time. The process could be completed in a single day, which would essentially double the throughput compared to the original EDS P2 design.

Table 1. Comparison of Processing Times for the Original EDS P2 and the EDS/M55 Variant

Process steps	Elapsed time for EDS P2	Elapsed time for EDS/M55
Safety brief, first entry, loading, leak check, and detonation	3:45	3:45
Reagent transfer, vessel heating	6:15	5:30
Complete treatment, drain vessel	8:45	5:45
Transfer water and heat vessel	12:30	8:00
End of day activities	13:00	-
	Day 2	
Next day startup	1:45	-
Drain and clean vessel	3:25	10:25
Post operation activities	6:35	12:40

PROPOSED IMMEDIATE NEXT STEPS

The EDS/M55 variant is based on proven technology and the design upgrades derive from well-understood engineering methods. Therefore the development risk for the EDS/M55 is minimal. Nonetheless, it is recognized that the Army will require time to consider this option and to integrate it into the overall program plan and budget. Meanwhile, Sandia recommends that PM NSCM fund Sandia for several near-term activities to further refine this opportunity. The information and experience from these activities will also benefit ongoing non-stockpile projects with the EDS P1 and P2 systems. The recommended tasks include the following:

- Develop the Fragment Suppression System design and Shaped Charge configuration for the M55 rocket – This action will refine the design and demonstrate the capability to deflagrate the propellant and to attack the munition inside of the overpack container. Both functions will require design and testing. This activity will provide essential design data needed prior to the full engineering design of the EDS/M55 variant system. This can be done with open-air tests using mockup munitions and is expected to take six months and cost about $300K.
- Review with the vendor the options for producing a longer detonation containment vessel. This will involve minimal cost of about $30K for labor and travel to evaluate design details and estimate fabrication costs.
- Perform more thorough analysis of the consequences of detonating the propellant. This will involved additional computer simulation. It will take three months and cost about 75K.

SUMMARY

By using the EDS/M55 variant to treat leaking M55 rockets, the Army can dispose of these hazardous munitions much sooner than currently expected while eliminating the special handling required for reverse assembly of the leaking munitions in the fixed disposal facility. Furthermore, the ability to treat them without first removing them from the overpack would substantially reduce the hazards and complexity of the process. In addition, PM NSCM would gain a system design that can destroy larger munitions at non-stockpile sites and the improvements made to increase throughput will be useful for all non-stockpile applications of future EDS systems.