

# **Army Research Laboratory**

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## **An Efficient Technique for the Collection and Analysis of Fragment Mass Distributions From Fragmenting Munitions**

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## **Abstract**

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A fundamental step in evaluation of warhead performance is the characterization of fragments emitted during warhead detonation. The emitted fragments must be captured, a process made difficult by their high initial speeds; however, the capture must be "soft" to avoid breaking the fragments into pieces, thus changing the mass distribution. Customary techniques involve the capture in sheets of soft building material ("Celotex"), an expensive technique. As a result, a test series customarily consists of only a few rounds.

This report presents a new technique which uses hay for the capture and recovery of fragments for those cases in which the data required include the total distribution of masses, but not the partial distributions by angle. This capture technique does not preserve angular information after capture. On the other hand, the use of hay as a stopping medium provides exceptional savings in materials and labor. As a result, a test series was run at approximately 20% of the cost of a comparable series employing the customary "Celotex" technique.

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Finally, the consultation and support of Mr. James O'Bryon, currently in the Office of the Secretary of Defense, Director of Operational Test and Evaluation, are recognized and appreciated.

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# I. Introduction

A fundamental step in evaluation of warhead performance is the characterization of fragments emitted during warhead detonation. This characterization presents several outstanding experimental difficulties. The emitted fragments must be captured, a process made difficult by their high initial speeds – commonly over 2 km/sec. However, the capture must be “soft” to avoid breaking the fragments into pieces, thus changing the mass distribution. In addition, an overriding consideration is the severe blast environment that accompanies a detonation.

The most commonly used procedure for characterizing fragments uses large stacks of a soft construction material (trade name: “Celotex”) which is commercially available in 1.2 m  $\times$  2.4 m  $\times$  1.27 cm (4 ft  $\times$  8 ft  $\times$  1/2 in) sheets. Approximately 100 such sheets are banded into a unit measuring 1.2 m  $\times$  2.4 m  $\times$  1.2 m (4 ft  $\times$  8 ft  $\times$  4 ft). These units – commonly about 100 of them – are then stacked, 4.8 m (16 ft) high, in a semicircle, called an arena, around the warhead to be detonated. When all is in place, the angular zones with respect to the axis of the warhead are marked onto the units, the warhead is detonated, and the captured fragments are analyzed.

This technique is quite expensive for two reasons. First, the Celotex material itself is quite expensive. In 1992, the cost of Celotex alone for one arena exceeded \$75,000. For this reason, it is necessary to replicate several warhead detonations in an arena before tearing it down and recovering the fragments. Unfortunately, the blast and fragment environment is so severe that an arena with a reasonable radius about the warhead can survive about three detonations. Thus, the number of fragments collected per arena is limited. In addition, the reuse of an arena for multiple shots runs the risk of losing previously collected data should a later detonation go awry.

Another significant expense is incurred in fragment recovery. In order to gather the desired data, it is necessary to manually locate each fragment, manually extract the fragment, manually clean it, weigh it, and record its weight and the polar zone in which it was recovered. Even with technical enhancements (e.g., metal detectors), the man-hour costs to recover fragments from an arena are comparable to the Celotex costs.

As a result of these expenses, it is common for a complete series to consist of as few as five shots to characterize the distribution of fragment masses from a particular type of warhead.

In 1993, the need arose to measure the differences in mass distributions between two sets of M109, 155 mm high explosive (HE) artillery projectiles.<sup>1</sup> Since the phenomenon being investigated may have resulted small differences in large numbers of fragments, the needed confidence in the accuracy of the data required many more than five rounds. In addition, the available funding was significantly less than that required for a typical warhead characterization series. As a result, a new technique was required for the determination of mass distributions.

This report describes the new technique. The purpose and results of the first use of the technique are reported elsewhere.<sup>1</sup>

## II. Considerations and Pre-Testing

It is essential to note that the data required in the M109, 155 mm HE artillery projectile comparison included the total distribution of masses, but not the partial distributions by angle. That is, the angular dispersion was irrelevant, allowing all fragments to be combined into a single mass distribution regardless of their individual angles of emission. Thus, the capture technique did not need to preserve angular information after capture. The technique presented here takes advantage of this loose constraint.

(Extensions of the technique to support coarse angular resolution are discussed below.)

The capture material chosen for the technique is common hay. It is a customary practice in the western United States to harvest hay (for cattle feed) in tightly packed bales measuring 1.2 m (4 ft) high by 1.2 m wide by 2.8 m long with a density of 176 to 192 kg/m<sup>3</sup> (11 to 12 lb/ft<sup>3</sup>). Total mass of a bale is about 680 kg (1500 lb.) Previous experiments performed at the Energetic Materials Research and Testing Center (EMRTC) had shown these bales to constitute a soft recovery medium: fragments do not break during penetration of packed hay. In addition, the cost of a unit (bale) of hay, approximately \$90, is significantly less than the cost of a comparable unit of Celotex.

It remained to demonstrate that the stopping power of a unit of hay was sufficient for fragments from an M109 155 mm artillery round. For this purpose,

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<sup>1</sup>Klopčic, J. Terrence and Lynch, David D. *Static and Dynamic Characterization of the M107 (Composition B Filled) Artillery Projectile*, ARL Report, to be published.

a round was detonated in the configuration shown in Figure 1. Note that the test unit was placed in the zone of the artillery round that contains the fastest and many of the largest fragments. Post-shot analysis showed no perforation of the thin aluminum witness panel. It was therefore concluded that the stopping power of hay was sufficient for the referenced experiments.

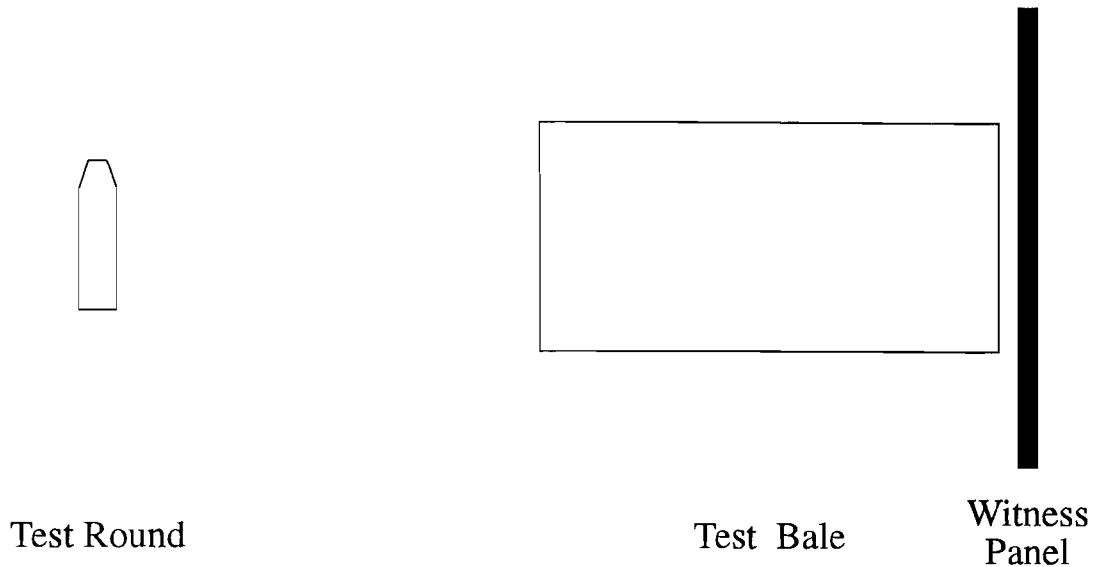


Figure 1: Stopping Power Experiment. Plan View

### III. Experimental Setup and Procedure

The experimental setup for a fragment collection is depicted in Figure 2. Photographs taken during the first application of this technique are included in Figures 3 through 6.

Note that these hay bales can be stacked at least five high, giving a vertical span of over 6 m.

As explained below, it is essential to build the collection stack on a smooth solid surface, as provided by the steel floor plate shown in Figure 2.

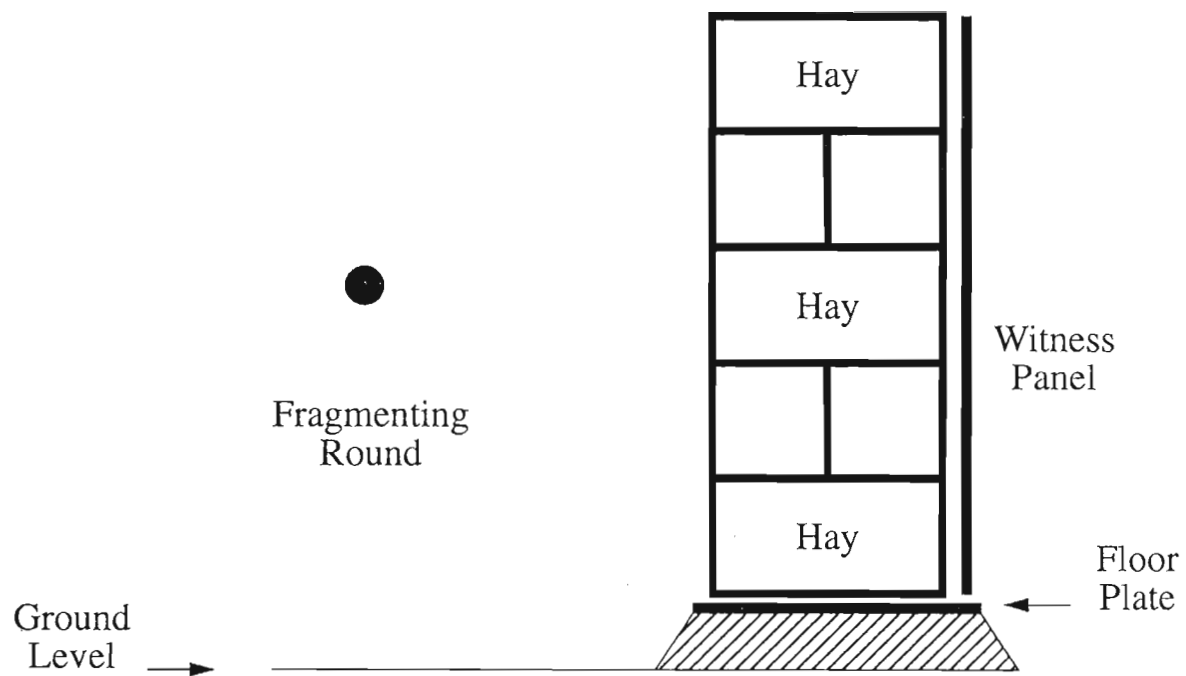


Figure 2: Fragment Collection Setup. Side View



Figure 3: Witness Panel and Floor Plate. Oblique View



Figure 4: Witness Panel and Floor Plate. Front View



Figure 5: Collection Stack. Oblique View



Figure 6: Collection Stack. Front Closeup

It is also desirable to prevent fragments which impact the ground from ricocheting into the collection medium.<sup>2</sup> In this experiment, the collection medium was raised above the ground such that probable ricochet angles were excluded.

Since the fragment collection technique described in this report may be applicable to many different fragmentation experiments, the particulars of round placement and detonation will not be discussed here. In particular, the placement and detonation employed in the first use of this collection technique are reported elsewhere.<sup>1</sup>

Following detonation of the round(s), the procedure continues as follows.

1. Ground plates are laid on the ground surrounding the fragment-containing hay. This is depicted in Figure 7.
2. The hay is then burned, with the residue (ash and fragments) collected by the floor plate and ground plates.
3. After the hay has been completely burned, the residue is carefully swept from the floor plate and ground plates onto plywood sheets.
4. The fragments are then magnetically recovered from the ash.
5. The recovered fragments are then cleaned, weighed, and analyzed using standard techniques.

## **IV. Lessons Learned and Suggested Improvements/Extensions of the Technique**

In the process of conducting the first experiments with this technique, two outstanding errors in procedure were made which caused the need for reruns.

1. When the collection stack of hay is burned, the fire releases the baling bands, allowing the bales to burst open. This action causes some of the

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<sup>1</sup>Klopacic, J. Terrence and Lynch, David D. *Static and Dynamic Characterization of the M107 (Composition B Filled) Artillery Projectile*, ARL Report, to be published.

<sup>2</sup>*Testing and Data Reduction Procedures for High-Explosive Munitions*. Joint Munitions Effectiveness Manual 61A1-3-7, Revision 2, May 1989.

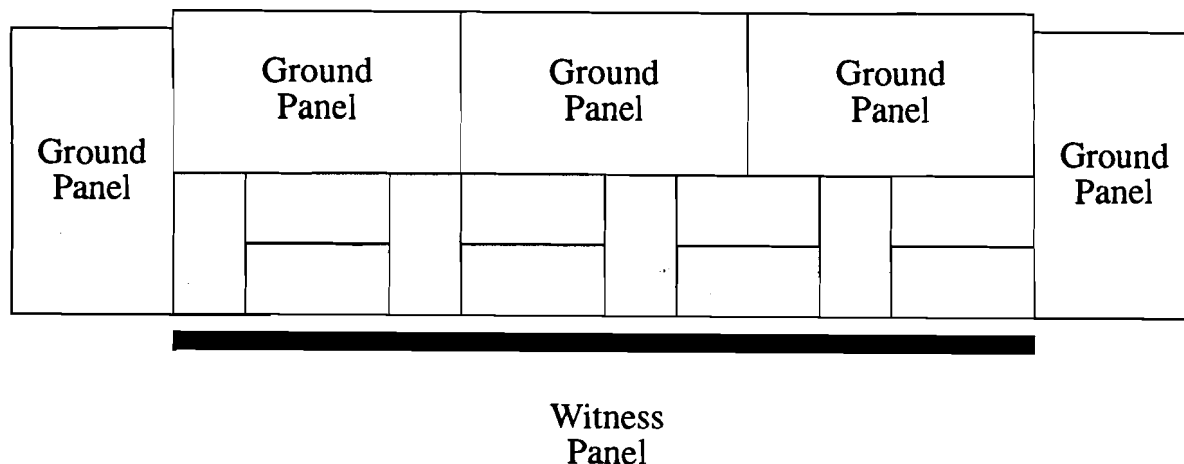


Figure 7: Post-Shot Configuration. Plan View

2. An attempt was made to replace the hay with less expensive/more readily available straw. Although the fragment retardation properties of straw are quite comparable to hay, the burning characteristics are not. Rather, when straw is burned, it produces a sticky residue which solidifies into hard masses in which the fragments are embedded. This phenomenon significantly impedes the subsequent separation and recovery of the fragments.

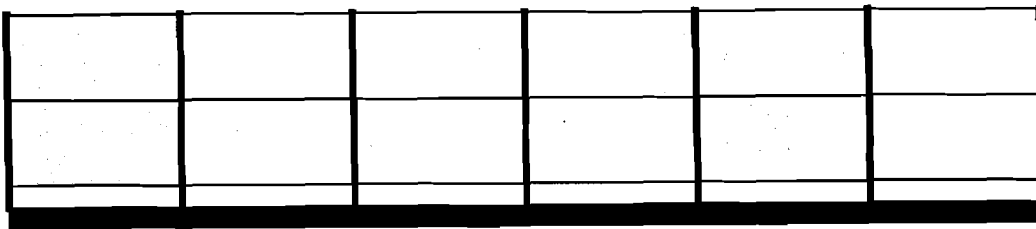
Suggested improvements/extensions of the technique include the following.

1. To avoid the potential loss of fragments due to the tumbling of burning bales beyond the ground plates, the collection stack could be surrounded by heavy wire ("Cyclone") fencing prior to burning.
2. It would be possible to construct bins within the stack as shown in Figure 8. This configuration, in conjunction with use of fencing during the burning process, would allow a coarse separation of fragment collection by angular zone. It is pointed out, however, that construction of angular zones of sufficient resolution to replace traditional Celotex arenas appears highly impractical.

3. A different realization of this fragment collection technique involves a different alignment of test round and collection stack. In this realization, a 2.8 m (8 ft) deep trench is dug into the ground and lined with the witness panel. The collection stack is then laid into the trench such that the upper edge of the stack is at ground level. This variation of the technique avoids the difficulties involved in tumbling bales. However, it introduces difficulties in test round placement, and may increase setup costs.



Fragmenting Round



Witness Panel with  
Zone Separators

Figure 8: A Binned Collection Stack. Plan View

## V. Summary

The technique described in this report was successfully used to collect fragments from explosively detonated M107 155 mm artillery projectiles. The technique proved to be significantly less expensive than the traditional Celotex method of fragment collection. The technique also proved to be highly efficient, resulting in rapid turnaround time. As described in Reference 1, the efficiency and lower cost allowed the collection of four times as much data at approximately one fifth the cost of the standard fragment collection technique.

On the other hand, the application of this technique did not require angular separation of the fragments. Had such information been required, at the common (5 degree) level of resolution, this technique would not apply.

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