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Executive Summary

The objective of this project was to utilize existing knowledge to formulate a testing methodology by which less-lethal kinetic energy munitions can be assessed. In addition, results from testing using these methodologies are presented to allow for law enforcement agents to make informed decisions. Input was garnered from various organizations including, but not limited to: manufacturers, NIST and law enforcement agencies. The goal of this effort was to objectively evaluate kinetic energy munitions in order to ultimately reduce the risk of injury.

Law enforcement personnel rely on less lethal weapons as an alternative to lethal force in situations with an individual or as a method of crowd control. However, as the use of less lethal alternatives has increased, the likelihood of severe or even fatal injuries has increased as well. Currently, it is the responsibility of the manufacturers and the end users to determine whether or not the blunt trauma and penetrating trauma risks are appropriate. The ability to assess the prevalence and associated severity of injuries due to less lethal impacts is essential to ensure that these weapons are not producing undesired effects.

A testing methodology is purposed that will allow for objective evaluations to be made for currently manufactured rounds prior to deployment. In addition, the results of a variety of less-lethal kinetic energy rounds are presented.

1. Introduction

1.1 Background

This report summarizes the results of the less-lethal kinetic energy munitions testing that were conducted as a test of the proposed NIJ less-lethal kinetic energy test methodology. The results reported here represent the most commonly used bean bag style kinetic energy munitions utilized by law enforcement officers. This round style was selected due to its popularity among law enforcement and peace keeping officers. The rounds are meant to be the first of many round types to be characterized by the testing methods.

On December 5, 2005, a meeting was held at National Institute of Standards and Technology (NIST) to discuss the process to move a kinetic energy less-lethal standard forward. Draft standards for both blunt and penetrating impacts were presented. A process previously followed by NIST was identified as the appropriate path to follow and is presented in Figure 1.

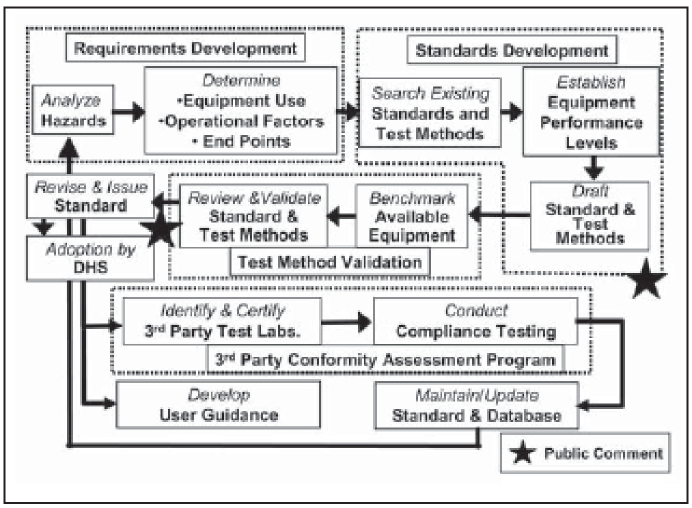


Figure 1: Development of a standard following process established by NIST.

Following this process, the next step involved determining the requirements for kinetic energy less-lethal devices. A meeting was held in conjunction with the Technical Working Group – Less Lethal in Orlando, FL on April 20 and 21, 2006. End users of less-lethal kinetic energy devices were queried as to their experiences with the devices. The following individuals were in attendance: Cynthia Bir, Sid Heal, Chris Myers, Rick Wyant, Al Cannon, Don Kester, Wayne Fryer, and Jim Mahan. Matt Begert, Joe Cecconi and Brian Montgomery were in attendance and represented the National Institute of Justice. In addition, Ed Hughes from Pennsylvania State participated in the discussions.

The current Wayne State University testing procedures for both penetration and blunt trauma assessment were distributed, as well as the Less-Lethal Kinetic Energy Accuracy Program developed by WSU and funded by the NIJ in 2002. Discussions were held in terms of the pros and cons of a standard versus a user's guide. Since the time and logistics for the development of a standard are lengthy, a test methodology and user's guide was thought to be more readily accessible with the ability to be updated.

Again following the guide provided by NIST, the next step was to query the manufacturers to garner their input. A meeting was scheduled, in conjunction with IACP 2006 annual conference, to obtain the manufacturer's feedback regarding the user's guide/standard. All major manufacturers of less-lethal kinetic energy munitions were invited to attend. The attendees included: Cynthia Bir (PI-Wayne State University), Joe Cecconi (National Institute of Justice, Senior Scientist), Kirk Rice (National Institute of Standards and Technology), Paul Ford (Defense Technology), Charlene Schreiner (Wayne State University), Dave DuBay (Non-Lethal Defense, Inc.), Jay Kehoe (TASER International), Lee Tolleson (ALS Technologies, Inc.) and Jim Simonds (Air Force Research Labs).

Information was garnered from all manufacturers regarding the current steps they take when developing a round. Most manufacturers look at two aspects: ballistic clay deformation and accuracy. Quality assurance aspects are also explored, i.e. velocity checks. It was stated that, in order to measure success, both manufacturers and end users need to embrace whatever test methodology is developed. All manufacturers will need to put the methodology in their literature, and end users need to be aware of the standard and push to purchase and replace current rounds with compliant products.

Manufacturers suggested initially defining a simple test protocol, as testing progresses additional testing protocols maybe added. Once this initial data has been acquired, threshold standards could then be set for acceptable passing scores. However, all manufacturers were receptive to having a test methodology that they could use.

As part of these meetings, key areas were identified for assessment including the accuracy of round and risk of trauma (blunt and penetrating). Potential surrogates were identified with initial testing conducted to ensure repeatability. Three different test methodologies were developed as part of the larger less-lethal kinetic energy assessment document. These include: Penetration Assessment, Accuracy/Precision, and Blunt Trauma. The entire testing methodology can be found in Appendix A.

As part of the development of the proposed testing methodology, an evaluation of currently manufactured kinetic energy munitions was conducted. End users and manufacturers were asked to identify the top rounds in terms of utilization in the United States. All rounds were procured and tested according to the testing methodologies established. The results are presented below.

1.2 Goals and Objectives

The goal of this research was to develop a testing methodology for the evaluation of less-lethal kinetic energy munitions. Two key aspects of testing were proposed including performance of the round and injury risk. The parameters evaluated include accuracy, precision, penetration, and the viscous criterion (VC). This methodology was then used to evaluate the most popular rounds currently available.

2. Terminology

Accuracy - A measurement of how closely a measured value agrees with the true value. For the current study, this represents how close the measured X and Y coordinates of the impact are to the center of the target.

Precision - A measurement of how closely measured values agree with each other. For the current study, this represents how close the various impacts for a given round are to each other.

Circle of Precision - The smallest circle in which all ten impacts for a given round fit. The center of the circle of precision is placed on the average X and Y coordinates.

Viscous Criterion (VC) – An injury criterion empirically derived to correlate impact to severity of injury. The VC is calculated based on the amount of sternal deflection and the velocity at which the deflection occurs. VC has been validated as a useful tool in determining injury severity related to blunt ballistic impacts.

3-Rib - The 3-Rib Ballistic Impact Dummy is a biofidelic mechanical surrogate used for evaluating injury risk of blunt ballistic impacts.

Beanbag rounds – Classification of kinetic energy round that resemble a beanbag in terms of size and shape. These rounds are typically filled with lead shot, or fine silica beads and are available in a variety of shapes and weights.

Tail-stabilized beanbag rounds – Classification of kinetic energy round that is similar to the beanbag in terms of the concept of deployment. However, the bags are tied not stitched resulting in a ball-like shape with the addition of a tail. Another type of tail-stabilized beanbag round has a ribbon tied to the back of the round. The tail is used to drag-stabilize the round during flight theoretically increasing accuracy. The tail-stabilized beanbag rounds are also available in a variety of shapes and weights.

Rubber projectiles - This round has several names including “rubber rocket” and “rubber baton”. The basic design is a rubber impacting surface or head that is attached to a tail with stabilizing fins.

3. Materials

3.1 Round Selection

A total of ten different munitions were evaluated for this initial assessment. All of the rounds tested were from the 12 gage platform (Table 1). A variety of manufacturers were consulted as well as end users and the most popular rounds were selected.

Table 1 – Classification of kinetic energy rounds tested.

Model Number	Munition Type
ALS 1202	Flexible baton
ALS 1212	Tail-stabilized Beanbag
ALS 1212T	Tail-stabilized Beanbag
MK Ballistic 4020S	Drag-stabilized Beanbag
MK Ballistic 4023	Drag-stabilized Beanbag
MK Ballistic 4024	Tail-stabilized Beanbag
CTS 2581	Drag-stabilized Beanbag
CTS 2588	Drag-stabilized Beanbag
Defense Technologies 3021	Flexible baton
Defense Technologies 3027	Tail-stabilized Beanbag

3.2 Universal Receiver

A universal receiver was used to launch each of the rounds (Figure 2). This device is able to mount fire a variety of caliber rounds and has an interchangeable barrel. It is controlled remotely with a computerized firing system.

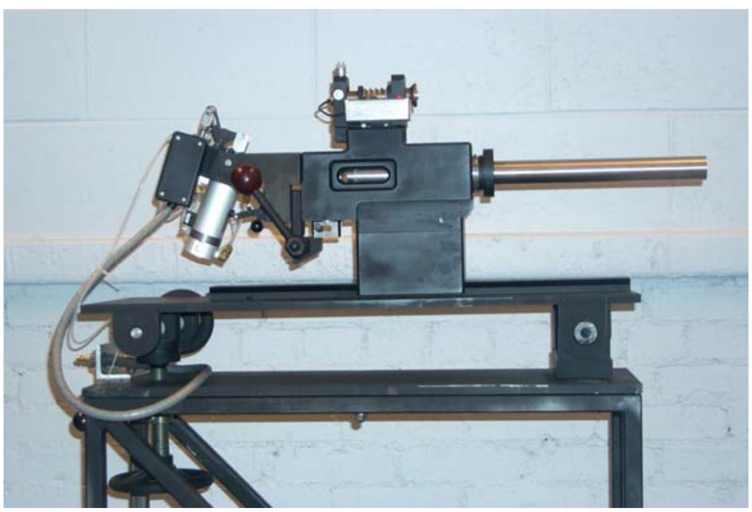


Figure 2: Universal receiver used for firing less-lethal kinetic energy rounds.

3.3 3-rib Ballistic Impact Dummy

A biomechanical surrogate was developed and validated to determine the risk of injury due to blunt ballistic impacts (Bir, 2000). The surrogate or 3-Rib Ballistic Impact Dummy (3-RBID) was developed to provide a portable surrogate to evaluate less-lethal kinetic rounds in terms of risk of injury. Three BioSID ribs are joined to a spine box with a polyurethane sheet joining the ribs in the front. The impact surface measures 4.5 inches in height and 8.5 inches in width. A urethane foam pad was placed in front of the polyurethane sheet to achieve biofidelity.

The 3-RBID was placed on a Teflon coated table to allow for a low friction interface between the dummy and table. A RIB-EYE system (Denton ATD, Inc) was mounted inside the thorax and allows for internal deflection measurements to occur during impact. Based on the output from the sensors, the percent risk of injury can be determined.

3.4 Redlake HG 100K Camera

High-speed video was collected at 20000 fps to determine the exact location of impact and to determine the impact dynamics of the projectile on target.

3.5 Chronograph

The velocity of each round was recorded with two Oehler skyscreens (Model 57) that were positioned 4 feet from the target. The skyscreens were attached to an Oehler 35P chronograph, which provided a printout of each impact velocity.

4. Methodology

This report follows the recommended standards laid out in the draft NIJ less-lethal kinetic energy test standard (Appendix A). The standard calls for the munition to be assessed using three tests; accuracy and precision (impact characteristics evaluated at 16 ft (5 m) and 50 ft (15 m)), blunt trauma (risk of injury to the boney thorax and the underlying soft tissues evaluated at 5 ft), and penetration (risk for the round to penetrate the skin evaluated at 5 ft). Ten good hits for each round were required for each test.

4.1 Accuracy/Precision Testing Methodology

The accuracy testing phase utilized a universal receiver to mount the 12 gauge barrel. A paper target containing a bull's eye and one inch grid marks was mounted down range at distances of 16 feet (5 m) and 50 feet (15 m). After each impact, the target was replaced and key-testing information recorded. X and Y coordinate data was measured from the point of impact to the axis using digital calipers. If the rounds hit very low at the 50 feet distance, then the point of aim was raised to 2 inches, 3 inches, or 4 inches above the origin, depending on how far the round was dropping. If the point of aim was different than the origin, then a note was made and the measurements were later recalculated to adjust for the adjustment.

4.2 Risk of Blunt Trauma Assessment Methodology

Each round was fired at a distance of 5 feet until 10 "successful" impacts were obtained. A successful impact was determined to be one that hit the center (2 inch by 3 inch) of the pad and did not break any of the ribs of the 3-RBID. It should be noted that a broken rib in the surrogate does not correlate to a broken rib in the human. For each successful impact, the injury parameter of VC and percent risk of injury was determined. Based on previous research, it has been determined that a VC of .6 m/s will result in a 25% chance of a thoracic skeletal injury at a level of AIS $\geq$ 2.

4.3 Penetration Methodology

Each round was fired at a distance of 5 feet until 10 impacts were obtained. The rounds were fired at a surrogate that consisted of a penetration assessment layer (PAL) of ballistics gel and a laceration assessment layer (LAL) of foam and chamois. Each component of the surrogate measured approximately 6 inches by 6 inches and was organized so that the chamois was up-range of the foam, which was up-range of the gel. The components were held in place by metal clips attached to elastic straps.

The three degrees of injury used to classify the damage are no injury, laceration and penetration based upon the damage to the three-layered surrogate. No injury is used to describe an impact that results in no visible damage to the surrogate. Laceration defines an impact with resulting damage to one or both LAL layers but no perforation of the PAL layer. Last, penetration describes any impact with resulting visible damage to the PAL layer regardless of the LAL damage status.

5. Results

A total of 10 different rounds were tested. If categorized by round type, there were 2 flexible batons and 8 beanbags. If categorized by manufacturer, there were 3 ALS rounds, 3 MK Ballistics rounds, 2 CTS rounds, and 2 Defense Technologies rounds.

5.1 Accuracy/Precision Testing Results

Shotgun-fired rounds were grouped into three unique designs: beanbags, tail-stabilized beanbags and rubber projectiles. Comparisons were made between the type of round, and individual rounds according to classifications with a significance level set to $p \geq 0.05$.

5.1.1 Accuracy

Table 2: Accuracy at a distance of 5 meters.

Accuracy - 5 m			
Round	Center Point		Distance from Origin (in)
	X-Axis (in)	Y-Axis (in)	
CTS 2588	-0.0341	-0.0592	0.0683
MK 4020S	-0.1764	-0.3724	0.4120
ALS 1212T	-0.2338	-0.3601	0.4293
ALS 1202	-0.2634	0.3628	0.4483
MK 4024	-0.0469	-0.4788	0.4810
MK 4023	-0.1621	-0.6266	0.6472
ALS 1212	-0.2574	-0.7126	0.7577
CTS 2581	-0.4691	-0.7846	0.9141
DT 3027	-0.3997	-1.0726	1.1447
DT 3021	-1.2027	-0.1585	1.2130

The above table lists the 10 rounds in order of greatest accuracy to lowest accuracy when shot from a distance of 5 m. Table # also lists the corresponding center point for each round. The center point is the average x- and y-coordinates of the ten trials. The distance from the center point to the origin is also listed. A small distance corresponds to a great accuracy whereas a great distance corresponds to a small accuracy. In order of most accurate to least accurate rounds at 5 m are: CTS 2588, MK 4020S, ALS 1212T, ALS 1202, MK 4024, MK 4023, ALS 1212, CTS 2581, DT 3027, and DT 3021.

Table 3: Accuracy at a distance of 50 ft.

Accuracy - 50 ft			
Round	Center Point		Distance from Origin (in)
	X-Axis (in)	Y-Axis (in)	
ALS 1202	-0.1507	0.1701	0.2273
DT 3021	0.4691	-1.0885	1.1852
CTS 2588	-0.7696	-2.8566	2.9584
ALS 1212T	-1.8256	-4.1471	4.5311
MK 4020S	-1.8059	-5.1136	5.4231
ALS 1212	-0.9559	-7.0624	7.1268
CTS 2581	-1.4464	-7.0021	7.1499
DT 3027	0.7422	-7.1400	7.1785
MK 4024	-0.2635	-7.5734	7.5780
MK 4023	-0.9255	-8.7798	8.8285

Table 3 lists the 10 rounds in order of greatest accuracy to lowest accuracy at 50 ft. In order of most accurate to least accurate at 50 ft are: ALS 1202, DT 3021, CTS 2588, ALS 1212T, MK 4020S, ALS 1212, CTS 2581, DT 3027, MK 4024, and MK 4023.

Table 4: Statistical Analysis of Velocity from 16 ft (5 m) Accuracy Test

Round	# of Shots	Mean	Std. Dev	Std error	lower95%	upper 95%
ALS 1202	10	700.4	125.69	39.75	610.49	790.31
ALS 1212	10	303.1	19.23	6.08	289.35	316.85
ALS 1212T	10	329.5	8.92	2.82	323.12	335.88
CTS 2581	10	275.9	8.49	2.69	269.83	281.97
CTS 2588	10	329.2	12.33	3.90	320.38	338.02
DT 3021	10	540.6	61.51	19.45	496.60	584.60
DT 3027	10	284.6	12.84	4.06	275.41	293.79
MK 4020S	10	296.8	27.61	8.73	277.05	316.55
MK 4023	10	256.3	10.92	3.45	248.49	264.11
MK 4024	10	285.2	21.39	6.76	269.90	300.50

The above table lists the rounds and the mean, standard deviation, standard error, lower 95% and upper 95% of velocity gathered from the 16 ft (5 m) accuracy test. The first screen of the chronograph was placed 4 ft from the target.

Table 5: Statistical Difference Between Velocities of Rounds from 16 ft (5 m) Accuracy Test

Round					Mean
ALS 1202	A				700.4
DT 3021		B			540.6
ALS 1212T			C		329.5
CTS 2588			C		329.2
ALS 1212			C	D	303.1
MK 4020S			C	D	296.8
MK 4024			C	D	285.2
DT 3027			C	D	284.6
CTS 2581			C	D	275.9
MK 4023				D	256.3

The above table lists the rounds according to their statistical differences, i.e., rounds not connected by the same letter are statistically different.

Table 6: Statistical Analysis of Velocity from 50 ft (15 m) Accuracy Test

Round	# of Shots	Mean	Std. Dev	Std error	Lower 95%	Upper 95%
ALS 1202	10	621.2	82.13	25.97	562.45	679.96
ALS 1212	10	254	14.79	4.68	243.42	264.58
ALS 1212T	10	297.1	11.99	3.79	288.52	305.68
CTS 2581	10	249.7	7.60	2.40	244.26	255.14
CTS 2588	10	312.2	33.24	10.51	288.42	335.98
DT 3021	10	440.8	41.69	13.18	410.98	470.62
DT 3027	12	263.4	21.34	6.16	249.86	276.98
MK 4020S	10	266.4	25.91	8.19	247.87	284.93
MK 4023	10	216.6	37.71	11.92	189.63	243.57
MK 4024	10	223.8	33.29	10.53	199.99	247.61

The above table lists the rounds and the mean, standard deviation, standard error, lower 95% and upper 95% of velocity gathered from the 50 ft (15 m) accuracy test. The first screen of the chronograph was placed 4 ft from the target.

Table 7: Statistical Difference Between Velocities of Rounds from 16 ft (5 m) Accuracy Test

Round						Mean
ALS 1202	A					621.2
DT 3021		B				440.8
CTS 2588			C			312.2
ALS 1212T			C	D		297.1
MK 4020S			C	D	E	266.4
DT 3027			C	D	E	263.4
ALS 1212				D	E	254
CTS 2581				D	E	249.7
MK 4024					E	223.8
MK 4023					E	216.6

The above table lists the rounds according to their statistical differences, i.e., rounds not connected by the same letter are statistically different.

5.1.2 Precision

Table 8 – Precision at 16 ft (5 m)

Precision - 5 m	
Round	Radius of Circle (in)
ALS 1212T	0.43
CTS 2588	0.57
ALS 1202	0.65
MK 4023	0.75
CTS 2581	0.79
DT 3027	0.94
ALS 1212	1.22
MK 4020S	1.30
MK 4024	1.34
DT 3021	1.52

The radius of the circle of precision was calculated by taking the largest circle that encompasses all 10 shots with the center placed on the average of the X and Y coordinates. Table 8 lists the 10 rounds in order of greatest precision to lowest precision, where an increase in the size of the circle of precision results in a decrease in precision. In order of most precise to least precise at 5 m: ALS 1212T, CTS 2588, ALS 1202, MK 4023, CTS 2581, DT 3027, ALS 1212, MK 4020S, MK 4024, and DT 3021.

Table 9: Precision at a distance of 50 ft (15 m).

Precision - 50 ft	
Round	Radius of Circle (in)
CTS 2581	2.07
CTS 2588	3.80
ALS 1212T	4.06
MK 4020S	4.16
MK 4024	4.43
DT 3027	4.74
MK 4023	5.98
ALS 1202	6.52
DT 3021	6.54
ALS 1212	8.33

Table 9 lists the rounds in order of greatest precision to lowest precision. In order of most precise to least precise at 50 ft.: CTS 2581, CTS 2588, ALS 1212T, MK 4020S, MK 4024, DT 3027, MK 4023, ALS 1202, DT 3021, and ALS 1212.

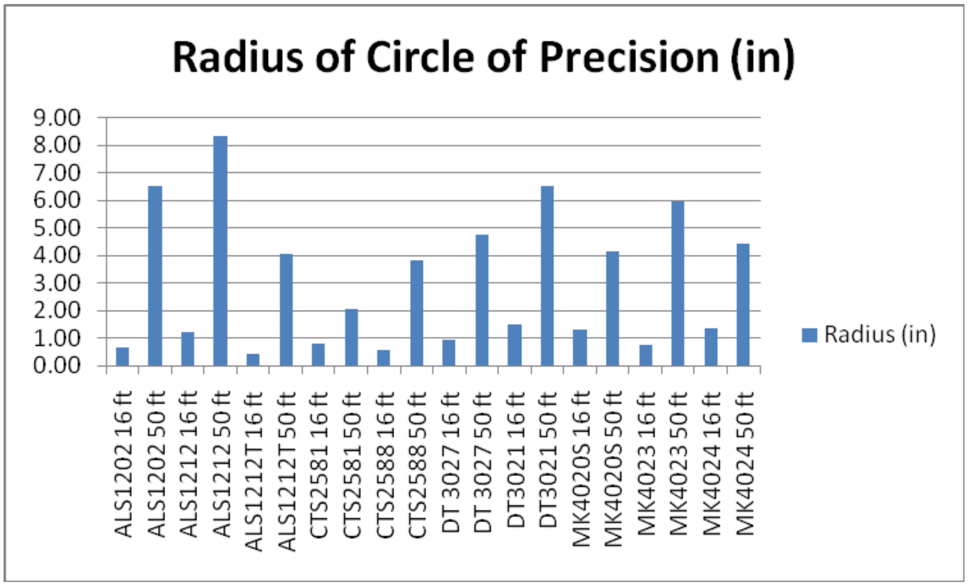


Figure 3: Radius of circle of precision for 10 Rounds at 16 and 50 ft.

Figure 3 shows the rounds as the independent variables and the radius of the circle of precision as the dependent variable. Both the results for the 16 ft test and the 50 ft test are shown.

5.2 3-RBID Results

Table 10: Blunt trauma resutls for less-lethal rounds from 5 feet.

Round	Maximum VC (m/s)	Result	# of shots > 0.6 m/s
DT 3021	0.0932	Acceptable	0
ALS 1202	0.2084	Acceptable	0
MK 4023	0.3243	Acceptable	0
ALS 1212	0.4462	Acceptable	0
DT 3027	0.4905	Acceptable	0
CTS 2581	0.5579	Acceptable	0
MK 4024	0.5935	Acceptable	0
ALS 1212T	0.6188	Partially Acceptable	1
MK 4020S	0.7104	Partially Acceptable	4
CTS 2588	0.9266	Unacceptable	10

10 lists the ten less lethal rounds tested in order of increasing maximum viscous criterion (VC). Ten good sets of data were gathered for each round except for ALS 1212T and DT 3027. For each of these two rounds, only eight shots produced good data due to the surrogate ribs breaking.

Table 10 lists the results for each round as Acceptable, Partially Acceptable, or Unacceptable. A round is considered Acceptable if no shots produced a maximum VC greater than 0.6 m/s which equates to a 25% risk of AIS $\geq$ 2. A round is considered Partially Acceptable if one or more shots, but not all shots, produced a VC greater than 0.6 m/s. A round is considered Unacceptable if all the shots fired produced a VC greater than 0.6 m/s. No shots from DT 3021, ALS 1202, MK 4023, ALS 1212, DT 3027, CTS 2581, or MK 4024 produced a VC of greater than 0.6 m/s. Therefore, they are all classified as Acceptable. One shot from ALS 1212T and four shots from MK 4020S had VCs greater than 0.6 m/s. Only one round, CTS 2588, is classified Unacceptable as it produced a VC of greater than 0.6 m/s in all ten shots.

Table 11: Statistical Analysis of VC from 3-RBID Test

Round	# of Shots	Mean	Std. Dev	Std error	lower95%	upper 95%
ALS 1202	10	0.15	0.05	0.02	0.11	0.19
ALS 1212	10	0.27	0.11	0.04	0.19	0.36
ALS 1212T	8	0.41	0.11	0.04	0.31	0.50
CTS 2581	10	0.47	0.06	0.02	0.43	0.50
CTS 2588	10	0.76	0.09	0.03	0.70	0.83
DT 3021	10	0.06	0.02	0.01	0.05	0.07
DT 3027	8	0.39	0.08	0.03	0.33	0.46
MK 4020S	10	0.54	0.18	0.06	0.41	0.67
MK 4023	10	0.21	0.09	0.03	0.15	0.28
MK 4024	10	0.40	0.16	0.05	0.28	0.52

The above table lists the rounds and the mean, standard deviation, standard error, lower 95% and upper 95% of VC gathered from the 3-RBID test. The muzzle of the barrel was 5 ft from the 3-RBID and the first screen of the chronograph was placed 4 ft from the target.

Table 12: Statistical Difference Between VC of Rounds from 3-RBID Test

Round						mean
CTS 2588	A					0.76
MK 4020S		B				0.54
CTS 2581		B				0.46
ALS 1212T		B	C			0.41
MK 4024		B	C			0.40
DT 3027		B	C			0.39
ALS 1212			C	D		0.27
MK 4023				D	E	0.21
ALS 1202				D	E	0.15
DT 3021					E	0.06

The above table lists the rounds according to their statistical differences, i.e., rounds not connected by the same letter are statistically different.

Table 13: Statistical Analysis of Velocity from 3-RBID Test

Round	# of Shots	Mean	Std. Dev	Std error	lower95%	upper 95%
ALS 1202	10	547.20	72.23	22.84	495.53	598.87
ALS 1212	10	233.80	54.01	17.08	195.17	272.43
ALS 1212T	8	304.63	10.60	3.75	295.77	313.48
CTS 2581	10	264.70	10.75	3.40	257.01	272.39
CTS2588	10	310.90	24.16	7.64	293.62	328.18
DT 3021	10	562.90	57.75	18.26	521.59	604.21
DT 3027	8	282.88	23.70	8.38	263.06	302.69
MK 4020S	10	299.00	27.70	8.76	279.19	318.81
MK 4023	10	211.10	42.03	13.29	181.04	241.16
MK 4024	10	259.90	50.49	15.97	223.78	296.02

The above table lists the rounds and the mean, standard deviation, standard error, lower 95% and upper 95% of velocity gathered from the 3-RBID test. The muzzle of the barrel was 5 ft from the 3-RBID and the first screen of the chronograph was placed 4 ft from the target.

Table 14: Statistical Difference Between Velocity of Rounds from 3-RBID Test

Round					Mean
DT 3021	A				562.9
ALS 1202	A				547.2
CTS 2588		B			310.9
ALS 1212T		B			304.6
MK 4020S		B			299
DT 3027		B	C		282.9
CTS 2581		B	C	D	264.7
MK 4024		B	C	D	259.9
ALS 1212			C	D	233.8
MK 4023				D	211.1

The above table lists the rounds according to their statistical differences, i.e., rounds not connected by the same letter are statistically different.

5.3 Penetration Results

Table 15: Impact results for less lethal rounds at 5 feet.

Round	Result		
	No Injury	Laceration	Penetration
MK 4023	4	6	0
MK 4024	0	5	5
MK 4020S	0	4	6
ALS 1212	0	1	9
CTS 2581	0	1	9
DT 3021	0	1	9
ALS 1202	0	0	10
ALS 1212T	0	0	10
CTS 2588	0	0	10
DT 3027	0	0	10

Table 15classifies the post impact damage for the less lethal munitions tested. For each round ten trials were conducted. The three degrees of injury used to classify the damage are no injury, laceration and penetration based upon the damage to the three-layered surrogate. No injury is used to describe an impact that results in no visible damage to the surrogate. Laceration defines an impact with resulting damage to one or both LAL layers but no perforation of the PAL layer. Last, penetration describes any impact with resulting visible damage to the PAL layer regardless of the LAL damage status.

The table is organized so that severity increases as one reads down the table. If two rounds have the same severity, then they are organized alphanumerically. Only one round, MK 4023, had zero penetration results. It was also the only round to show any no injury results. However, it resulted in laceration in 60% of the trials. There is a large jump in severity to the next round, MK 4024. This round had a 50% penetration result and zero no injury trails. Similar to the MK 4024 in terms of damage was MK 4020S. MK 4020s had one more penetration and one less laceration than MK 4024. This resulted in penetration in 60% of the trials. Another large jump in damage severity occurs for the last seven rounds. Three of them, ALS 1212, CTS 2581 and DT 3021, exhibited a 90% penetration result. The last four, ALS 1202, ALS 1212T, CTS 2588 and DT 3027, resulted in penetration in all trails.

Table 16: Statistical Analysis of Velocity from Penetration Test

Round	# of Shots	Mean	Std. Dev	Std error	lower95%	upper 95%
ALS 1202	16	658.44	169.73	42.43	568.00	748.88
ALS 1212	10	310.30	25.26	7.99	292.23	328.37
ALS 1212T	20	304.80	11.32	2.53	299.50	310.10
CTS 2581	10	275.90	10.97	3.47	268.05	283.75
CTS 2588	10	310.00	7.48	2.37	304.65	315.35
DT 3021	10	541.50	66.74	21.10	493.76	589.24
DT 3027	10	273.90	13.31	4.21	264.38	283.42
MK 4020S	10	266.80	22.81	7.21	250.48	283.12
MK 4023	10	193.70	18.24	5.77	180.65	206.75
MK 4024	10	256.70	15.92	5.04	245.31	268.09

The above table lists the rounds and the mean, standard deviation, standard error, lower 95% and upper 95% of velocity gathered from the penetration test. The muzzle of the barrel was 5 ft from the surrogate and the first screen of the chronograph was placed 4 ft from the target.

Table 17: Statistical Difference Between Velocity of Rounds from Penetration Test

Round					Mean
1202	A				658.4
3021		B			541.5
1212			C		310.3
2588			C		310.0
1212T			C		304.8
2581			C	D	275.9
3027			C	D	273.9
4020S			C	D	266.8
4024			C	D	256.7
4023				D	193.7

The above table lists the rounds according to their statistical differences, i.e., rounds not connected by the same letter are statistically different.

6. Conclusions

This report represents a broad assessment of less-lethal kinetic energy rounds. This assessment was conducted to provide the end-user with the knowledge to make an informed decision. It is recommended that the end-user take the above information in compliment with their existing knowledge and experience. It should also be noted that Wayne State University does not endorse any of the above products.

APPENDIX A - Draft NIJ less-lethal kinetic energy test standard

1. Background

1.1 Overview

Extended-range kinetic energy rounds are utilized in law enforcement activities as well as in military "peace-keeping" missions. Regardless of the scope of their deployment, the rounds always serve the same purpose; they persuade an unwilling party to comply without the use of lethal force. The compliance is often a result of the pain caused by these munitions. The goal is to inflict enough discomfort to solicit compliance without severe injury or fatality. Therefore it is essential to identify and minimize factors contributing to resulting in serious or life-threatening injuries.

1.2 Accuracy/precision

These undesirable effects can be a result of such factors as inaccurate rounds and poorly placed shots. The rounds vary widely in design; however there are several characteristic round types or styles that most manufacturers have developed. This disparity in design, as well as the design itself, contributes to the fact that no two rounds behave exactly the same in flight. Therefore, accuracy is a concern when deploying extended-range kinetic energy rounds.

In addition to the accuracy problem, precision can also be a problem. Two of the same rounds, fired in the exact same manner, have resulted in very different shot placements. This lack of precision makes it difficult for the end user to determine how to aim for the best accuracy. In general terms, accuracy can be described as how close a round is to a given point (i.e. the center of the target) whereas precision refers to how closely two or more rounds impact with respect to each other. Therefore, a given round is most useful when it has both good accuracy and good precision.

1.3 Injury criteria

Another potential risk of injury results from the impact event itself. This assessment relies on impact biomechanics to predict the risk of injury related to a given impact. The tolerance of the human body to a given impact and the determination of the amount of energy or force imparted by the round are key parameters to assess. Determining a risk of injury prior to deployment in the field, allows the end user to make well-informed decisions. Two types of injuries will be assessed: blunt trauma and penetration risk.

1.3.1 Blunt trauma

The risk of blunt trauma to the thorax will be assessed by using an empirically based injury criterion called the viscous criterion (VC). This criterion has used extensively for motor vehicle occupants to predict the severity of injury. The VC is calculated based on the amount of thoracic compression and the velocity at which this compression occurs.

The amount of thoracic compression was defined as the displacement of the chest in relationship to the spine normalized by the initial thickness of the thorax. VC has been validated as a useful tool in determining injury severity related to blunt ballistic impacts to the thorax (JOT).

Cardiopulmonary resuscitation (CPR) has been given as an example of why both the amount of compression and rate at which is occurs is important to consider when predicting the risk of injury (SEARCH). The human body can tolerance relatively large compressions (20%) and a very slow rate (.1m/s) without injury. However, these compression levels at a higher velocity can produce severe or life-threatening injuries. The current tolerance of VC proposed for blunt ballistic impacts is .6 m/s for a 25% risk of AIS $\geq$ 2. The injuries seen in the validation of VC as an injury parameter including skeletal injuries such as rib and/or sternum fractures (JOT). More severe injuries, such as lung contusions, have been correlated to a VC of 2.8 m/s (also 25% risk). (Bir dissertation)

1.3.2 Penetrating trauma

The risk of penetrating trauma is important to assess due to the increase in severity of injuries seen once the munition penetrates into the body cavity. One factor to consider is the amount of energy generated by the munition. In addition, it is important to determine the energy per area of presentation ratio or E/a value. This value takes into account the mass, velocity, and the cross-sectional area of the projectile. Simply reporting energy is insufficient for comparison of different samples and projectiles.

A hypodermic needle provides an example of how the tolerance of the skin to penetration can be based on energy density. The sharpness of the needle provides a very low contact area between the knife and the skin. Therefore, very little force is required to penetrate through the skin.

The current tolerance for penetration is based on the region of concern on the body. Recent research has demonstrated various E/a required to produce a 50% risk of penetration for various regions of the body. The values are as follows:

Location	50% Risk (J/cm^2)
On Anterior Rib	23.99
Between Anterior Rib	33.30
Liver	39.88
Lateral to Umbilicus	34.34
Proximal Femur	26.13
Distal Femur	28.13

2 Scope

The scope of this testing procedure is limited to evaluating the risk of injury related to the proper deployment of kinetic energy munitions. This assessment will include blunt trauma, risk of penetration and accuracy of shot placement.

2.1 Exclusions

This testing procedure will not evaluate the effectiveness of a given munition. This procedure will not evaluate munitions with multiple sub-munitions. At the current time, assessments of blunt trauma are related only to thoracic impacts. Penetrating trauma is assessed only for thigh, thoracic and abdominal regions. Biomechanical threat to the head is not evaluated with this procedure.

2.2 Applicability

2.2.1 This test procedure applies to kinetic energy munitions intended to deter an individual or a group of individuals without the use of lethal force, penetration, or blunt trauma.

2.2.2 This test procedure is intended to evaluate single projectile kinetic energy munitions. Although this procedure can be performed for multiple projectile munitions, it should be noted that the results will be dependent on the number of rounds that impact the target. Therefore, the results could be misleading.

2.2.3 This test procedure is designed to evaluate rounds that are fired per the manufacturer’s specifications. The effects or injuries that may occur when such rounds are fired at distances closer than those tested cannot be determined.

2.2.4 The results of testing conducted in accordance with this procedure shall apply only to the specific model of munition tested. Any change in the construction of a round which has been determined to successfully comply with the requirement of this procedure, including—but not necessarily limited to materials or manufacturing process—shall require retesting of the revised model in accordance with the full range of requirements of this procedure.

2.2.5 The ability to evaluate a specified munition is dependent upon the completion of all three test areas: blunt trauma, penetrating trauma, and accuracy/precision. If an assessment in all three areas is not completed a complete assessment of the injury potential of the munition cannot be determined.

2.2.6 The test procedure does not apply to injuries to the head, including the face and eyes. However, information regarding such injuries is available in previously conducted research [Raymond 2008].

3 Discussion

3.1 Requirements of this test procedure are voluntary in nature, but may be made mandatory by competent authorities responsible for supervising kinetic energy munitions procurements.

3.2 This test procedure is designed to evaluate kinetic energy munitions with respect to accuracy/precision, blunt trauma, and penetrating trauma and to obtain objective, baseline data. Such information will be compiled to provide the user with the overall performance of the individual munition. In addition, the performance of the munition will be assessed based on existing research in the areas of blunt trauma and penetrating trauma with respect to kinetic energy munitions. Inasmuch as no government-issued certification testing currently exists for kinetic energy munitions, this procedure does not establish acceptable and unacceptable limits of munition performance.

3.3 To the maximum extent possible, this test procedure relies on materials, techniques, and processes currently used in ballistic impact testing.

3.3.1 Munitions are fired with a Universal Receiver if possible. If the specific munition is of a caliber which cannot be fired with said receiver then the munition will be fired with a mounted device.

3.3.2 The 3-rib Ballistic Impact Dummy used in this procedure was designed specifically for the evaluation of kinetic energy munitions to evaluate blunt trauma to the thorax. This device was previously validated for a 50th percentile male [Bir, 2000].

3.4 This test procedure is intended to:

3.4.1 Evaluate the injury potential of a specified munition based on three specific areas. Such a determination is based the assessment of Viscous Criterion using the 3-rib in order to determine blunt trauma, the assessment of penetrating trauma, and an accuracy/precision assessment.

3.4.2 Provide objective data with respect to a specific munition design, and its ability to cause serious or lethal injury when fired at manufacturer's specifications.

3.4.3 Provide information regarding the uniformity and consistency of the munition construction and performance.

3.4.4 This procedure is intended as a one-time evaluation of the injury potential inherent in a particular munition design. This initial design compliance test shall be referred to as "design compliance". Continued compliance testing of production units of a munition having previously satisfied the initial design compliance are left to the voluntary discretion of the manufacturer and/or the requirements established by procurement authorities. Compliance testing of production units to the requirements of this procedure shall be termed "performance assurance tests".

4 Glossary of Terms

4.1 Model – A specific design of a munition whose shape, materials, and construction differ from that of other munitions.

4.2 Shot, fair – An un-yawed and un-pitched projectile of the specified construction and specified velocity impacting at the specified angle of obliquity and intended shot impact location, also to include:

4.2.1 An otherwise fair shot but yawed or pitched, which produces a penetration

4.2.2 An otherwise fair shot but striking at a greater angle, which produces a penetration

4.2.3 An otherwise fair shot but striking at a lower velocity than the intended range, which produces a penetration

4.2.4 An otherwise fair shot but striking at a greater velocity than the intended range, which does not produce a penetration

4.3 Shot, unfair – includes the following categories:

4.3.1 Any shot which impacts only one rib on the 3-rib Ballistic Impact Dummy

4.3.2 An otherwise fair shot which impacts the target within one inch of the edge of the target (Blunt Trauma)

4.3.3 An otherwise fair shot which impacts the target within 10 mm of the edge of the LAL (Penetration)

5 Test Sampling

5.1 Rounds submitted for testing in accordance with this procedure may be rounds in development or rounds available for sale by the manufacturer

5.2 Rounds of each design shall constitute a sample for this test procedure

5.3 The rounds of the test sample shall be identical in construction

6 Requirements

6.1 The 3-rib Blunt Trauma Assessment portion of this procedure stipulates that any round tested which produces a VC greater that 0.6 m/s which equates to a 25% risk of AIS $\geq$ 2 injury will be considered unsatisfactory.

6.2 The Penetration Assessment portion of this procedure stipulates that any round tested which produces a penetration will be considered unsatisfactory.

6.3 The Accuracy/Precision portion of this procedure describes the means by which accuracy will be assessed but there is currently no value for a satisfactory/unsatisfactory score.

7 Test Procedures

7.1 3-rib Blunt Trauma Assessment Test

7.2 Penetration Assessment Test

7.3 Accuracy/Precision Test

8 Design Acceptance (Rejection)

9 Data

9.1 Recorded data will include, but will not necessarily be limited to, the following:

9.1.1 Date of test
9.1.2 Shot number
9.1.3 Manufacturer of round
9.1.4 Model of round
9.1.5 Caliber of round
9.1.6 Desired velocity (range)
9.1.7 Actual velocity (at tested distance)
9.1.8 Impact location (X, Y coordinates)
9.1.9 Diameter of the C.O.P. (average)
9.1.10 Mass of fired projectile
9.1.11 "Fair" or "Unfair" characterization for each shot
9.1.12 "Penetration" or "Non-penetration" or each shot
9.1.13 Environmental conditions or temperature conditioning of the test samples

9.2 Data analysis will include, but not necessarily be limited to, the following:

9.2.1 Viscous Criterion
9.2.2 E/a
9.2.3 C.O.P.

10 Reporting

10.1 The Final Test Report shall include a narrative of the test, including the identity of the party requesting the test, the results of the testing, and the data records of Paragraph 1.2, above.

10.2 If such criteria does exist, the Final Test Report shall include a statement certifying or denying compliance of the performance of the munition design with the applicable requirements

10.3 If such information has not been furnished or previously agreed upon, the Final Test Report will document results without comment

11 Availability

11.1 Additional copies of this procedure may be obtained from:

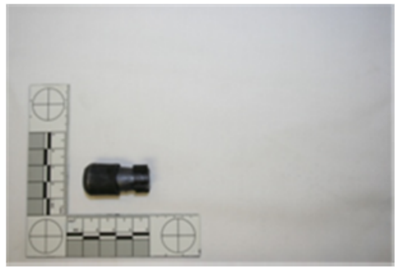
Ballistic Impact Research Laboratory
Bioengineering Center
Wayne State University
818 W. Hancock
Detroit, MI 48201
Tel 313.577.3830 or 313.577.8322
Fax 313.577.8333

12 Revisions

12.1 It is anticipated that changing technologies and the availability of new knowledge may require revision of this procedure.

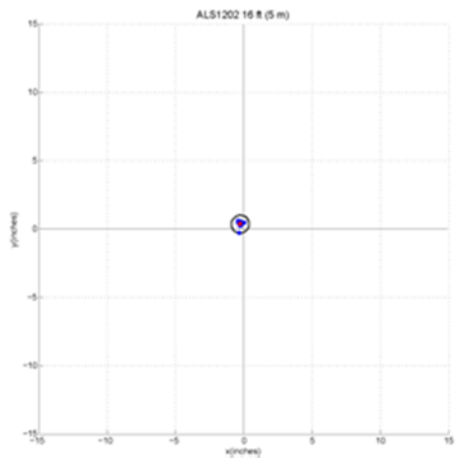
APPENDIX B – Individual Round Results

ALS 1202

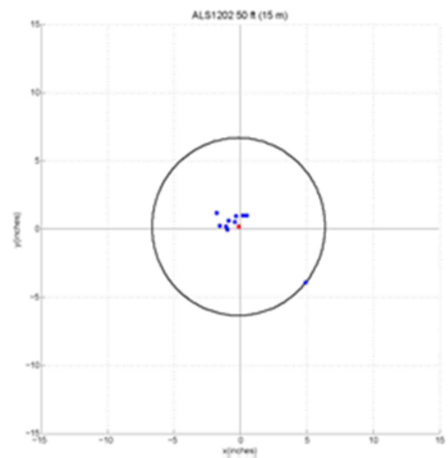


Manufacturer Specs	
Type	Rubber Baton
Suggested Range (Min ft - Max ft)	60-120
Mass (g)	9.0
Color	Black

Photographs of round in (left) and out (right) of shell



16 ft (5 m). Center (-0.26,-0.36), Radius 0.65



50 ft (15 m). Center (-0.15,0.17), Radius 6.52

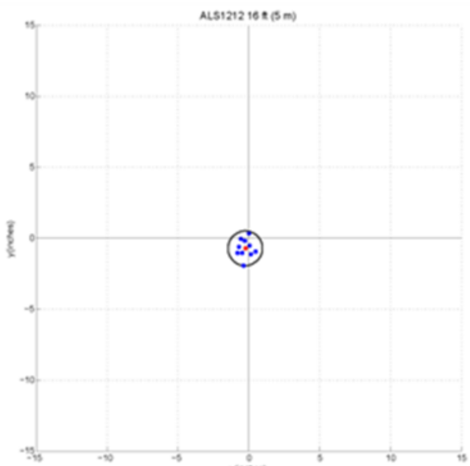
3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
ALS1202-1	507	0.0989	2%
ALS1202-2	543	0.1959	4%
ALS1202-3	567	0.2084	4%
ALS1202-4	454	0.1518	3%
ALS1202-5	448	0.0839	2%
ALS1202-6	488	0.0662	2%
ALS1202-7	565	0.1417	3%
ALS1202-8	648	0.1964	4%
ALS1202-9	625	0.1902	4%
ALS1202-10	627	0.1754	3%
Max		0.2084	4%
Result		Acceptable	

Penetration Results		
Velocity (FPS)	Damage	Comments
679	Penetration	
708	Penetration	
787	Penetration	
834	Penetration	
698	Penetration	
666	Penetration	
775	Penetration	
731	Penetration	
828	Penetration	
843	Penetration	
Result	No Injury	0%
	Laceration	0%
	Penetration	100%

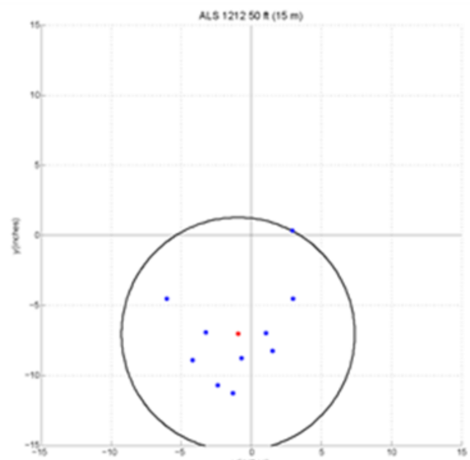
ALS 1212

Manufacturer Specs	
Type	Tail-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	20-60
Mass (g)	40.3
Color	White/Black

Photographs of round in (left) and out (right) of shell



16 ft (5 m). Center (-0.26,-0.71), Radius 1.22



50 ft (15 m). Center (-0.96,-7.06), Radius 8.33

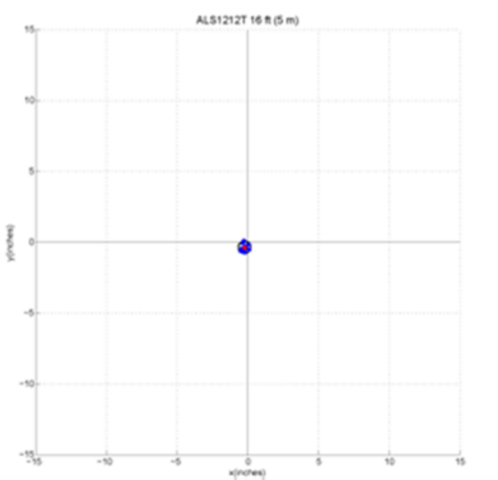
3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
ALS1212-1	275	0.2899	6%
ALS1212-2	249	0.2876	6%
ALS1212-3	116	0.0321	2%
ALS1212-4	320	0.4462	14%
ALS1212-5	230	0.2611	5%
ALS1212-6	228	0.2535	5%
ALS1212-7	197	0.2160	4%
ALS1212-8	214	0.2244	4%
ALS1212-9	268	0.4239	12%
ALS1212-10	241	0.3112	7%
Max		0.4462	14%
Result		Acceptable	

Penetration Results		
Velocity (FPS)	Damage	Comments
267	Laceration	
277	Penetration	No video
317	Penetration	
298	Penetration	
316	Penetration	
343	Penetration	
339	Penetration	No video
296	Penetration	
324	Penetration	
326	Penetration	
Result	No Injury	0%
	Laceration	10%
	Penetration	90%

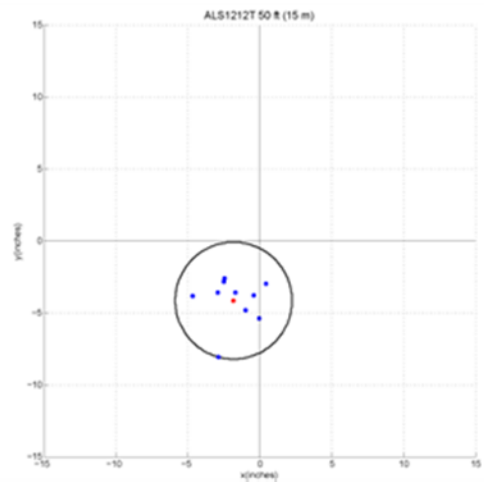
ALS 1212T

Unavailable

Manufacturer Specs	
Type	Tail-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	unknown-unknown
Mass (g)	40.5
Color	Yellow



16 ft (5 m). Center (-0.23,-0.36), Radius 0.43

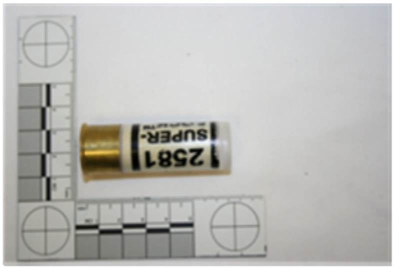


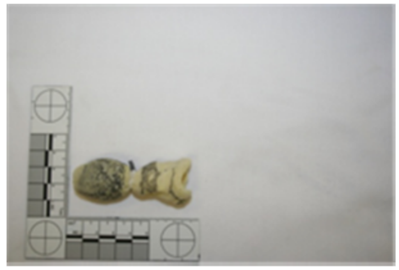
50 ft (15 m). Center (-1.83,-4.15), Radius 4.06

3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
ALS1212T-1	296	0.2632	5%
ALS1212T-2	315	0.2978	6%
ALS1212T-3	311	0.4653	15%
ALS1212T-4	306	0.4157	12%
ALS1212T-5	293	0.3382	8%
ALS1212T-8	289	0.4052	11%
ALS1212T-9	317	0.4712	15%
ALS1212T-10	310	0.6188	29%
Max		0.6188	29%
Result		Partially Acceptable	

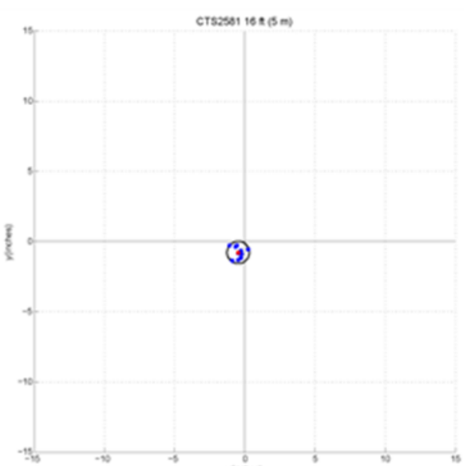
Penetration Results		
Velocity (FPS)	Damage	Comments
298	Penetration	
295	Penetration	
297	Penetration	
332	Penetration	
301	Penetration	
312	Penetration	
293	Penetration	
317	Penetration	
297	Penetration	
305	Penetration	No video
Result	No Injury	0%
	Laceration	0%
	Penetration	100%

CTS 2581

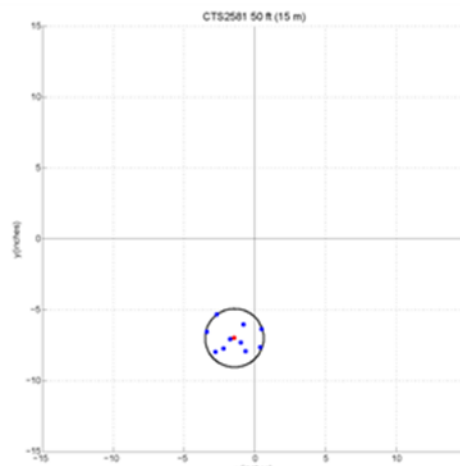




Manufacturer Specs	
Type	Drag-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	15-60
Mass (g)	41.5
Color	Yellow



16 ft (5 m). Center (-0.47,-0.78), Radius 0.79

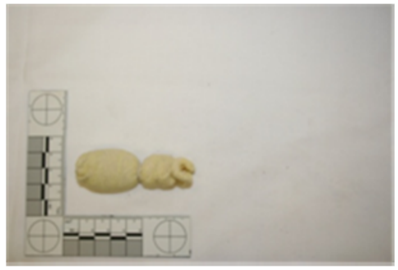


50 ft (15 m). Center (-1.44,-7.00), Radius 2.07

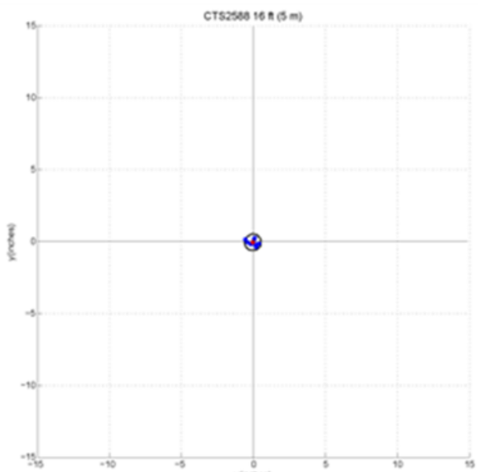
3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
CTS2581-1	246	0.3669	9%
CTS2581-2	276	0.5579	23%
CTS2581-3	273	0.4855	16%
CTS2581-4	273	0.5055	18%
CTS2581-5	255	0.4316	13%
CTS2581-6	266	0.4431	13%
CTS2581-7	268	0.4033	11%
CTS2581-8	272	0.4734	16%
CTS2581-9	249	0.4864	16%
CTS2581-10	269	0.4987	17%
Max		0.5579	23%
Result		Acceptable	

Penetration Results		
Velocity (FPS)	Damage	Comments
284	Penetration	
277	Penetration	
277	Penetration	
275	Penetration	
269	Penetration	No video
295	Penetration	
260	Penetration	
267	Laceration	
289	Penetration	
266	Penetration	
Result	No Injury	0%
	Laceration	10%
	Penetration	90%

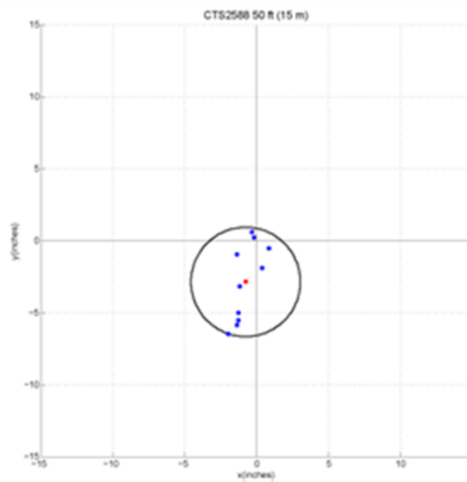
CTS 2588



Manufacturer Specs	
Type	Drag-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	15-60
Mass (g)	43.2
Color	Yellow



16 ft (5 m). Center (-0.03,-0.06), Radius 0.57

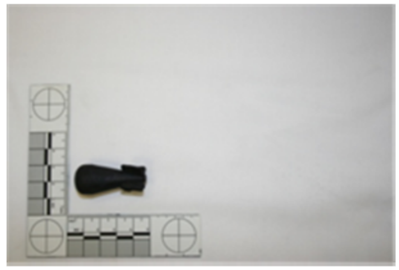


50 ft (15 m). Center (-0.77,-2.86), Radius 3.80

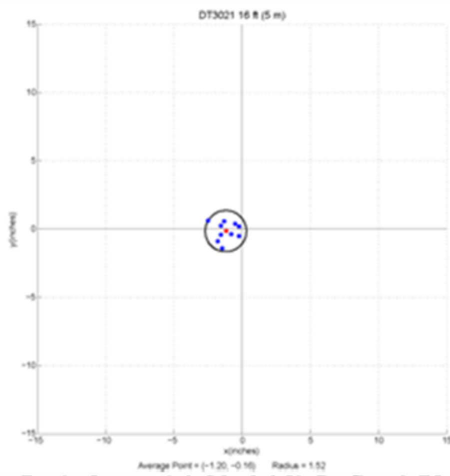
3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
CTS2588-1	327	0.8820	64%
CTS2588-2	312	0.8032	54%
CTS2588-3	334	0.7043	40%
CTS2588-4	304	0.6240	30%
CTS2588-5	309	0.6810	37%
CTS2588-6	309	0.7808	51%
CTS2588-7	333	0.9266	70%
CTS2588-8	320	0.7551	47%
CTS2588-9	249	0.6918	38%
CTS2588-10	312	0.7947	53%
Max		0.9266	70%
Result		Unacceptable	

Penetration Results		
Velocity (FPS)	Damage	Comments
319	Penetration	
311	Penetration	
317	Penetration	
312	Penetration	
301	Penetration	
297	Penetration	
312	Penetration	
305	Penetration	
319	Penetration	
307	Penetration	
Result	No Injury	0%
	Laceration	0%
	Penetration	100%

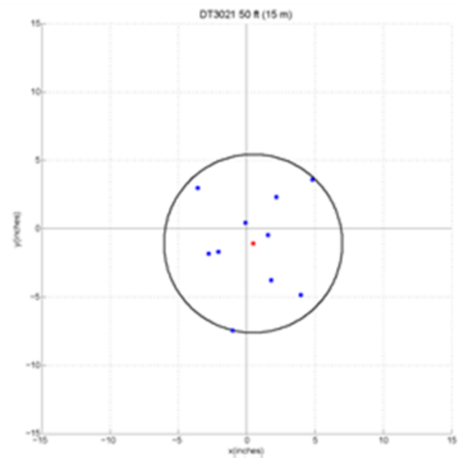
DT3021



Manufacturer Specs	
Type	Rubber Baton
Suggested Range (Min ft - Max ft)	15-35
Mass (g)	5.7
Color	Black



16 ft (5 m). Center (-1.20,-0.16). Radius 1.52



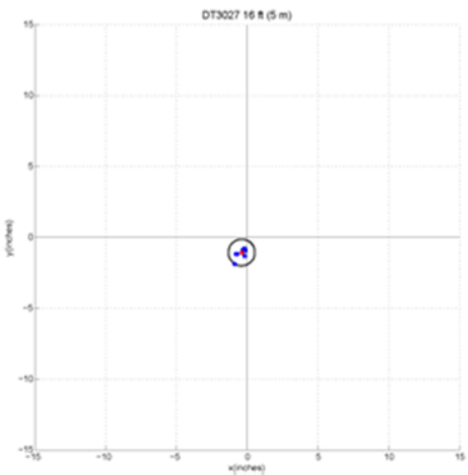
50 ft (15 m). Center (0.47,-1.09). Radius 6.54

3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
DT3021-1	487	0.0388	2%
DT3021-2	524	0.0503	2%
DT3021-3	497	0.0418	2%
DT3021-4	542	0.0480	2%
DT3021-5	573	0.0669	2%
DT3021-6	558	0.0545	2%
DT3021-7	624	0.0736	2%
DT3021-8	555	0.0586	2%
DT3021-9	591	0.0643	2%
DT3021-10	678	0.0932	2%
Max		0.0932	2%
Result		Acceptable	

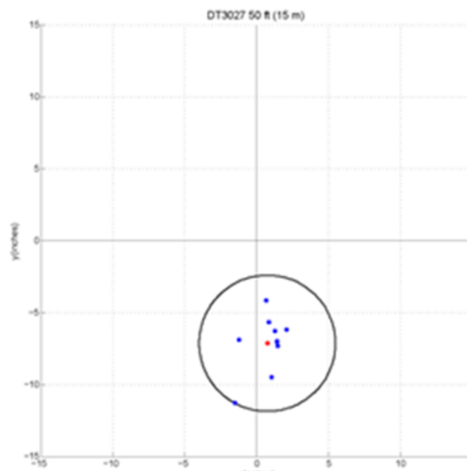
Penetration Results		
Velocity (FPS)	Damage	Comments
497	Penetration	
511	Penetration	
592	Penetration	
411	Laceration	
549	Penetration	
597	Penetration	No video
480	Penetration	
600	Penetration	
552	Penetration	
626	Penetration	
Result	No Injury	0%
	Laceration	10%
	Penetration	90%

DT3027

Manufacturer Specs	
Type	Tail-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	20-50
Mass (g)	39.3
Color	Yellow



16 ft (5 m). Center (-0.40,-1.07), Radius 0.94

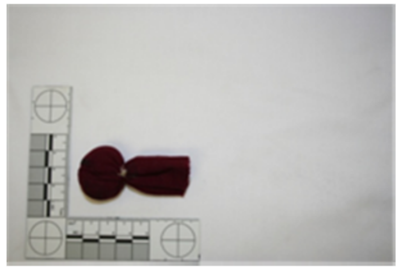


50 ft (15 m). Center (0.74,-7.14), Radius 4.74

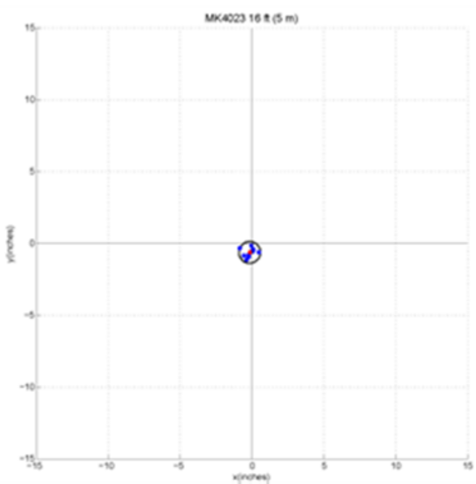
3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
DT3027-1	281	0.3932	11%
DT3027-2	305	0.4905	17%
DT3027-5	268	0.2930	6%
DT3027-7	293	0.4603	15%
DT3027-9	292	0.3368	8%
DT3027-10	303	0.3932	11%
DT3027-11	289	0.4691	15%
DT3027-12	232	0.2962	6%
Max		0.4905	17%
Result		Acceptable	

Penetration Results		
Velocity (FPS)	Damage	Comments
278	Penetration	
265	Penetration	
287	Penetration	
281	Penetration	
275	Penetration	
261	Penetration	
296	Penetration	
249	Penetration	
273	Penetration	
274	Penetration	
Result	No Injury	0%
	Laceration	0%
	Penetration	100%

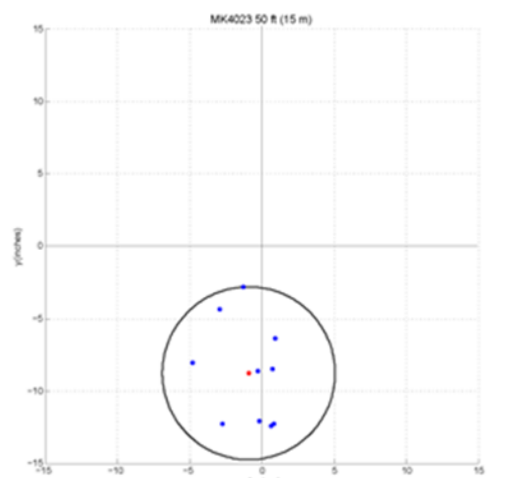
MK 4023



Manufacturer Specs	
Type	Drag-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	20-90
Mass (g)	39.9
Color	Red



16 ft (5 m). Center (-0.16,-0.63), Radius 0.75

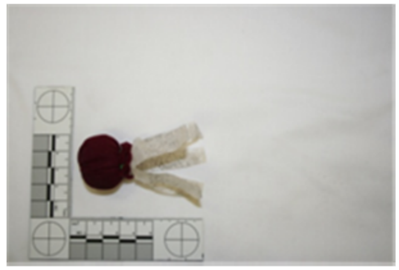


50 ft (15 m). Center (-0.93,-8.78), Radius 5.98

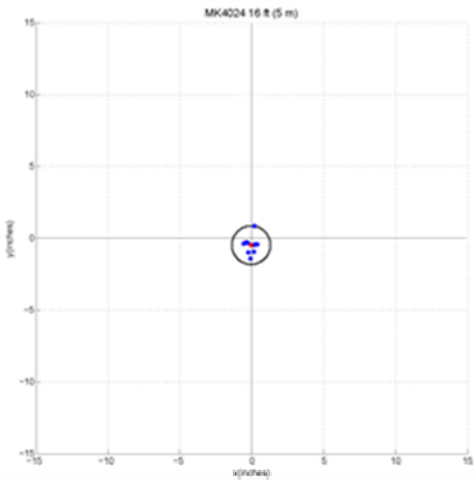
3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
MK4023-1	214	0.2063	4%
MK4023-2	142	0.0701	2%
MK4023-3	177	0.1562	3%
MK4023-4	162	0.1010	2%
MK4023-5	257	0.3243	7%
MK4023-6	259	0.3180	7%
MK4023-7	234	0.2807	6%
MK4023-8	254	0.3074	7%
MK4023-9	225	0.2197	4%
MK4023-10	187	0.1407	3%
Max		0.3243	7%
Result		Acceptable	

Penetration results		
Velocity (FPS)	Damage	Comments
173	No Injury	
182	No Injury	
175	Laceration	
181	No Injury	
197	Laceration	
223	Laceration	
208	Laceration	
210	No Injury	
177	Laceration	
211	Laceration	
Result	No Injury	40%
	Laceration	60%
	Penetration	0%

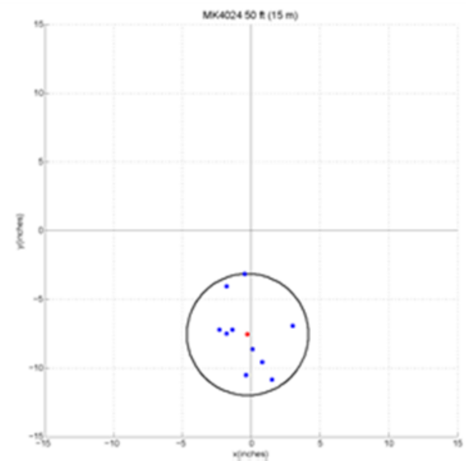
MK 4024



Manufacturer Specs	
Type	Tail-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	20-90
Mass (g)	40-8
Color	Red/White



16 ft (5 m). Center (-0.05,-0.48), Radius 1.34

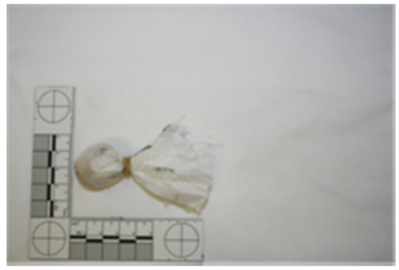


50 ft (15 m). Center (-0.26,-7.57), Radius 4.43

3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
MK4024-1	267	0.4001	11%
MK4024-2	294	0.5513	22%
MK4024-3	293	0.5557	23%
MK4024-4	308	0.5935	26%
MK4024-5	260	0.3666	9%
MK4024-6	165	0.1286	3%
MK4024-7	187	0.1773	3%
MK4024-8	300	0.4863	16%
MK4024-9	297	0.4620	15%
MK4024-10	228	0.2704	6%
Max		0.5935	26%
Result		Acceptable	

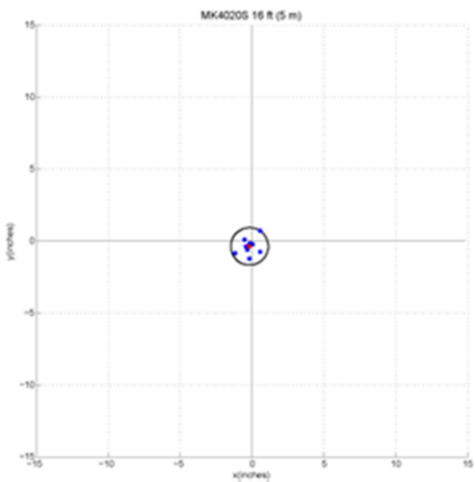
Penetration Results		
Velocity (FPS)	Damage	Comments
228	Penetration	
255	Penetration	
285	Laceration	
257	Laceration	
251	Penetration	
267	Penetration	
251	Laceration	
242	Laceration	
258	Laceration	
273	Penetration	
Result	No Injury	0%
	Laceration	50%
	Penetration	50%

MK 4020S

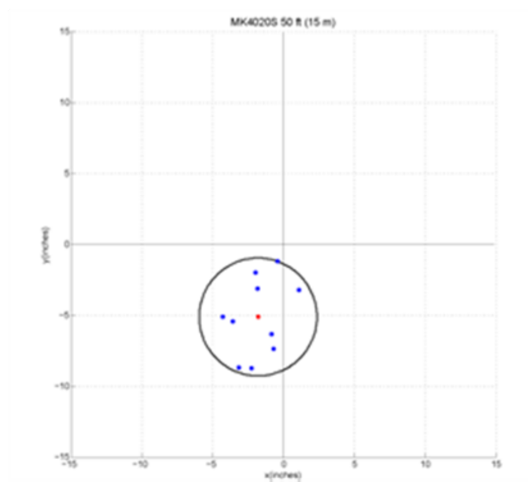



Manufacturer Specs	
Type	Drag-Stabilized Beanbag
Suggested Range (Min ft - Max ft)	30-75
Mass (g)	39.4
Color	White

Photographs of round in (left) and out (right) of shell



16 ft (5 m). Center (-0.18,-0.37), Radius 1.30



50 ft (15 m). Center (-1.81,-5.11), Radius 4.16

3-RBID Results			
Filename	Velocity (fps)	Middle Rib VC	% Risk of Injury
MK4020S-1	279	0.4437	13%
MK4020S-2	322	0.7104	41%
MK4020S-3	317	0.6826	37%
MK4020S-4	317	0.6950	39%
MK4020S-5	311	0.5503	22%
MK4020S-6	298	0.5517	22%
MK4020S-7	320	0.6358	31%
MK4020S-8	231	0.5329	20%
MK4020S-9	290	0.4884	17%
MK4020S-10	305	0.0840	2%
Max		0.7104	41%
Result		Partially Acceptable	

Penetration Results		
Velocity (FPS)	Damage	Comments
280	Penetration	
247	Laceration	
228	Laceration	
287	Penetration	
243	Laceration	
277	Penetration	
290	Penetration	
289	Penetration	
248	Laceration	
279	Penetration	
Result	No Injury	0%
	Laceration	40%
	Penetration	60%