A TEST METHODOLOGY FOR THE COMPLETE CHARACTERIZATION OF THE TASER® XREP MUNITION

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Objectives

A tripartite group of the Home Office Scientific Development Branch (United Kingdom), the Canadian Police Research Center (Canada) and the National Institute of Justice (USA) agreed to jointly fund an independent third party assessment of the mechanical, electrical and physical characteristic of the TASER XREP munition. Wayne State University (WSU) in Detroit, Michigan was selected as the independent test facility and work began in the February of 2008. Key test parameters were discussed among the funding agencies and a total of 10 tasks were identified to measure the desired test parameters.

The goal of this research is to characterize and evaluate the XREP round. The characterization will include physical, mechanical and electric properties and the evaluation will be in terms of accuracy, precision and potential risk of injury. The parameters evaluated include accuracy, precision, mass, length, electrical output (voltage, current and frequency spectrum) velocity risk of penetration and the viscous criterion or VC.

Background

Many times in tactical situations there exists a need to deploy a restrained amount of force. In these instances, less lethal weapons are a popular choice, with extended-range kinetic energy rounds being the most common choice among law enforcement agencies. The term extended-range kinetic energy round describes an entire class of less-than-lethal munitions. These munitions, by definition, use kinetic energy as the means of transferring an incapacitating force in the form of a ballistic impact.

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.

Historically, accuracy and precision have been problematic with extended range kinetic energy munitions. 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.

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.

One of the disadvantages of kinetic energy based munitions is their reliance on pain to achieve an effect. The inclusion of other techniques of incapacitating a subject within the round will add to the chances of a successful outcome following use. In the fall of 2007 Taser International announced a pilot program for the eXtended Range Electronic Projectile or XREP munition which offers this additional capability. The XREP is a 12 gauge round has two modes of incapacitation, kinetic energy and neuro-muscular incapacitation (NMI). The round was initially marketed as having "the same NMI bio-effect as the handheld X26 but with a range of 20 meters."

Materials

Round Supply

At the time of testing the XREP round was in a pilot program and not commercially available although the rounds tested were described as being representative of production rounds by the manufacturers. All rounds were supplied directly to WSU from Taser. The rounds were shipped in six batches. The batch numbers and quantities shipped are listed below in Table 1.

Batch #	Quantity
1	20 (plus 5 with no combustible charge)
2	40
3	55 (plus 15 with no combustible charge)
4	40
5	50
6	70
Total	275 (plus 20 with no combustible charge)

Table 1 – XREP Inventory List

Universal Receiver

A table mounted universal receiver (HS Precision Model UR01 Rapid City, SD) was used to fire all rounds. The receiver was fitted with an 18 inch smooth bore cylindrical barrel and a laser sight. The receiver was pneumatically driven and computer controlled to allow the testing to be completely repeatable and user independent. The receiver's laser sight was sighted in at each firing distance using a 12 gauge bore sight.

3-rib Ballistic Impact Dummy

A biomechanical surrogate was recently 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 non-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 6.0 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 non-contact RibEye system is used to measure the location of each of the three ribs independently in three dimensions. The RibEye was attached to a data collection system, which collected data at 20 kHz. Data collected from each impact was used to obtain the magnitude and velocity of rib deflection.

High Speed Video

High-speed video (Redlake HG 100K Video Camera) was collected at 20,000 fps to determine the exact location of impact and to determine the in-flight characteristics and impact dynamics of the projectile.

Velocity

The velocity of each round was recorded with three Oehler skyscreens (Model 57). The skyscreens were attached to an Oehler 35P chronograph, which provided a printout of each measured velocity.

Mass

All masses were measured on an Ohaus scale (Model E0D120).

Methodology

Testing was performed in three phases. Phase one assessed the physical characteristics of the munitions, including physical design, electric output, and durability. Phase two assessed the in-flight characteristics, including the aerodynamics, the deployment of the cholla barbs, as well as the accuracy and precision of the round. Phase three assessed the probability of injury from the munition, including the risk of penetration and the blunt trauma effects.

Physical/ Electrical Characteristics Methodology

Task 1. Physical Design

The assessment of physical characteristics included a characterization of the physical properties of the overall munition as well as the sub-munition pieces. Ten rounds were procured for this task and the values for the physical dimensions were averaged. The properties which were assessed included overall dimensions and mass in addition to the dimensions and mass of the chassis and nose assembly separately. Additional dimensions were recorded for the torsion spring fins, the frontal electrodes and the cholla barbs.

Physical characteristics were recorded using rounds that had been fired. First total mass was measured and then the hand trap wire and tether were cut as close to the nose section as possible and the nose and chassis sections were weighed independently. Next the munitions were fitted together and total length was measured and then individual section lengths were measured. Total diameter was recorded at the largest point, the rear faring while nose diameter was recorded at the nose frame and chassis diameter was recorded at the middle of the chassis. Fin area was calculated using the equation for the area of a trapezoid (1/2 x h x (a +b)) where h is the height, a is the short leg and b is the long leg of the trapezoid.

An assessment of the force required to break the nose section free from the chassis was also performed. The nose section of a live, electrically discharged munition was secured to the crosshead of a uni-axial test machine (Instron) and the chassis was compressed about the longitudinal axis at a constant velocity (0.5 mm/s). A digital output of the force/time was recorded.

Task 2. Assessment of Electrical Output

The assessment of the electrical output of the munition included four separate tests to measure the electrical output of the three most likely discharge modalities. These were; discharge across the front barbs, discharge from a front barb to a rearward facing barb, discharge from a front barb to a cholla barb and discharge from a front barb to the conductive hand trap wire. A total of 20 rounds were to be used for this assessment, five for each of the four discharge modalities.

Digital Oscilloscope leads (Tektronix Inc., model TDS 3012B, Beaverton OR) were connected to both sides of a 1/100 voltage divider which was connected to the discharge points of the munition in each scenario. The munition was then be activated by removing the insulator placed between the battery and the chassis electronic housing. Determination of electrical output for each scenario will include recording the duration, waveform, voltage, current, for each individual round as characterized by oscilloscope recording. Oscilloscope data was recorded at 1.25 GS/sec.

Task 3. Durability

The durability of the XREP munition was assessed at two different temperatures and in two different initial orientations. Twenty live rounds were tested at 23°C (room temperature) and twenty live rounds were tested at -20°C. Ten rounds at each temperature were dropped from an initial horizontal orientation and ten rounds were dropped from an initial vertical (barbs facing downward) orientation. Testing began from an initial height of 1 meter. If the round did not break then the height was increased by 50 centimeters and it was dropped again. This incremental increase continued until the round broke or a height of 3 meters was reached. The impact surface was a solid concrete surface. Breakage was considered a crack in the chassis, separation of the nose assembly from the chassis or any permanent deformation which could cause the round to malfunction. The aerodynamics and accuracy of the drop tested XREP rounds was measured using the same methods described below in sections 4.2.1 and 4.2.3.

In-flight Characteristics Methodology

Task 4. Overall Aerodynamics

The aerodynamics of the XREP round was studied using two high speed video cameras (Redlake Inc., model HG 100K, Tucson AZ) recording at 10,000 frames per second each. Cameras were positioned at various distances from the barrel to record flight characteristics at a range of deployment distances. Rounds were fired at the target from 4 different distances (5, 10, 15 and 20 meters). Ten rounds were fired at each distance. This allowed the overall aerodynamics to be recorded at a range of distances from the barrel. The aerodynamics were recorded at the muzzle, at impact as well as 5, 7.5, 10, 12, 15 and 20 meters. Data recorded included attitude of the round (in degrees of pitch above or below horizontal), rotations per second and velocity.

Task 5. Deployment of Cholla Electrodes

The deployment of the cholla electrodes at impact was recorded during the 40 impacts used to assess the overall aerodynamics of the munition. Video of each impact was recorded using a high speed video camera (Redlake Inc., model HG 100K, Tucson AZ) recording at 10,000 frames per second. Images show the orientation of the round at impact, decoupling of the chassis from the nose section (via breakage of the fracture pins), and deployment of the 6 cholla barbs from the chassis.

Eight (no additional rounds were available) rounds were used to determine cholla barb placement and post impact discharge potential. An anthropomorphically correct, shielded test surrogate served as the target to determine actual cholla barb placement. Shots were aimed at the center of the thoracoabdominal mass. A resistive wire mesh vest was placed on to the surrogate to measure electrical activity.

Task 6. Accuracy and Precision

The inherent accuracy of the round was assessed using a fixed position firing system. The fixed position firing method will utilize a universal receiver for repeatable firing conditions. A paper target containing a bull's eye and one inch grid marks was mounted down range at distances of 5, 10, 15 and 20 and meters from the barrel. Ten rounds were fired at each distance. The universal receiver was aimed using a laser sight prior to each impact. Rounds traveled through 3 infrared light screens (Oehler Research Inc., Model 57, Austin TX) which will determine the velocity.

After each impact the target paper was changed and the munitions. After each impact, X and Y coordinate data were measured from the point of impact to the axis using digital calipers.

Task 7. Temperature Effects

Temperature effects were determined by repeating the tests for accuracy and precision as well as recording the aerodynamics of the round at 50°C and -20°C. Rounds were placed in a temperature controlled chamber (Espec model ESL-2CA) for 24 hours prior to testing. Aerodynamics, accuracy and precision were measured as discussed previously in sections 4.2.1 and 4.2.3 respectively with the exception of the 20 meter distance which was ruled out after the initial testing showed a significant vertical drop at this distance.

Probability of Injury

Task 8. Risk of Penetration

The skin penetration test protocol required the use of a combination of 20% ordnance gelatin, 0.60 cm foam, and natural chamois. The Laceration Assessment Layer (LAL) which consists of the foam and chamois was placed on the front face (towards the munition) of the gelatin. The LAL layer was secured to the gelatin with adjustable elastic straps. The front face of the surrogate was positioned at a 0-degree angle of incidence. The gelatin was cut to expose a flat surface free from damage for each subsequent test.

Penetration effects were assessed at 2 distances; 2 and 5 meters. Ten fair hit impacts were completed as part of each test distance. Test round velocities were determined independently using three light screens (Oehler Research Inc., Model 57, Austin TX). After completion of each test, the surrogate was visually inspected and evaluated for penetration. Test round masses were recorded using digital balance (Ohaus, model E0D120, Pine Brook NJ).

Task 9. Risk of Blunt Trauma

The blunt trauma assessment was conducted to determine the probability of injury from the impact of the XREP munition. This testing protocol required the use of the 3-RBID thoracic surrogate to measure the viscous criteria (VC) for each impact. The 3-RBID was positioned on a Teflon coated table to allow for a low friction interface between the surrogate and table. For the purposes of this testing, a laser displacement (Robert A. Denton Inc. model RibEYE, Rochester Hills MI) system was integrated into the surrogate. This system allowed for non-contact deflection measurements to be made over a wide region of the sternum. Data were collected using a TDAS (Diversified Technologies, Seal Beach CA) data acquisition system at 10,000 Hz. Data collected from each impact were used to obtain the magnitude and velocity of rib deflection.

Blunt trauma effects were assessed at 2 meters. Test round velocities were determined independently using three light screens (Oehler Research Inc., Model 57, Austin TX). Ten "successful" impacts were completed. A successful impact is one that hits no less than one inch from any edge. For each impact that fell within the specifications, the injury parameter of VC was determined. Based on previous research, it has been determined that a VC of 0.8 m/s will result in a 50% chance of sustaining a thoracic skeletal injury at a level AIS > 2. This injury level correlates to multiple rib fractures.

Results

Initial testing of the XREP revealed significant differences in the rounds from one batch to the next. The first two batches were shipped electrically dead. Further batches revealed the electrical activity of the round was intermittent and some rounds tested remained electrically active more than 5 minutes after being activated. The rounds were also found to drop considerably from the point of aim at the 20 meter mark. The drop was more than twice the drop recorded for rounds tested at 15 meters.

Shortly after testing of the rounds was completed, TASER sent a letter to WSU indicating that the rounds which were tested were not going to be released for commercial sales and that the XREP platform was being re-designed. The second generation of the XREP munition was intended to be available for testing in late 2008 but as of the date of the writing of this paper (March 2009), they were still not available to be re-tested.

Conclusions

The testing methodology described above was established as a means to fully and completely characterize the XREP munition. The methodology was developed with input from the funding agencies, end-users and research personnel. It represents lessons learned through years of research experience and is designed to provide end-users and law enforcement administrators with accessible, easy to use results that will assist them in their decision on if and when to use the XREP munition.

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

Penetration Assessment Layer (PAL) – The internal component of the penetration surrogate used to assess the occurrence of penetration. The PAL is composed of 20% ballistic gelatin.

Laceration Assessment Layer (LAL) – The external covering of the PAL used to assess the occurrence of laceration. The LAL is composed of an outer layer of natural (Sheep skin) chamois and an inner layer of 0.60 cm closed cell foam.