# Raising the Standards for Protective Equipment used by Public Order Police Officers

**D. Longhurst**[1], J. Horlick[2], B. Montgomery[2], C. Robinson[2], R. Schauf[3], R. Kinsler[4]

[1] *RTI, 3040 E. Cornwallis Road, Research Triangle Park, NC 27709 (dlonghurst@rti.org)*

[2] *National Institute of Standards and Technology (NIST), 100 Bureau Drive, Gaithersburg MD 20899, USA*

[3] *U.S. Capitol Police, 119 D Street NE, Washington, DC 20510*

[4] *Sydor Technologies, 105 Shell Cove Ct. Joppatowne, MD 21085*

**Abstract.** Law enforcement officers in the United States are facing increased acts of violence and aggression while protecting the First Amendment rights of citizens and communities to assemble in peaceful protests and demonstrations. Public order police officers may not know in advance what threats they will encounter during an incident, but their equipment must protect against the most likely and injurious hazards. A multi-discipline collaborative effort, initiated by the National Institute of Justice, was begun in 2017 to guide the development of performance standards for protective equipment worn by these officers, and the first equipment to be addressed was helmets. Public order officers defined their operational and functional requirements and described the threats and hazards they face. Those requirements and hazards were then considered by technical experts, researchers, manufacturers, and officers, working together through the ASTM International E54 Committee on Homeland Security Applications. The group adapted or developed new standard test methods to address officer head protection needs, which include protection against multiple blunt impacts with hard surfaces or thrown/launched objects, hand-swung penetrating weapons, slingshot projectiles, flammable liquids, and more. Those test methods have been incorporated into a specification for officer head protection that gives performance requirements and acceptance criteria. The two published standards are:

- ASTM E3343/E3343M – 22, *Test Methods for Nonballistic-resistant Helmets Worn by Law Enforcement and Corrections*
- ASTM E3342/E3342M – 22, *Specification for Nonballistic-resistant Helmets Specifically Designed to be Worn by Law Enforcement and Corrections Officers When Maintaining Order in Violent Situations*

These standards are being used by a newly formed *ASTM Verification Program for Law Enforcement Equipment*, which will help to raise the bar for protective equipment used by officers. This paper will introduce the officer-specified needs; detail the decisions, research, and testing upon which the standards were established; and provide a description of the ASTM Verification Program.

## 1. INTRODUCTION

United States (U.S.) law enforcement officers are facing increased acts of violence and aggression while protecting the First Amendment rights of citizens and communities to assemble in peaceful protests and demonstrations. These officers may not know the threats they will encounter until they are on scene, and their equipment must protect against the most likely and injurious hazards. The protective equipment officers wear includes helmets with face shields, supplemental eye protection, hearing protection, torso and limb protectors, gloves, and protective footwear.

## 2. NATIONAL INSTITUTE OF JUSTICE SPECIAL TECHNICAL COMMITTEE

In 2017, the National Institute of Justice (NIJ) was requested by public order police officers and their agencies to assist with the development of standards for personal protective equipment. A review of available standards revealed a gap in performance standards and test methods addressing the specific U.S. law enforcement requirements. NIJ is facilitating the development of baseline performance requirements, standardized test methods, and conformity assessment requirements for equipment used by U.S. public order police. An NIJ Special Technical Committee (STC) of public order police officers, stakeholder organization representatives, and technical experts from across the U.S. was convened and has been working collaboratively for three years. Officers defined their operational and functional requirements and described the threats and hazards they face, and using that information, technical experts worked together to address their needs through standard test methods and specifications.

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Standards are being developed through the ASTM International E54 Committee on Homeland Security Applications, with the participation of U.S. law enforcement public order practitioners, testing laboratories, product certifiers, researchers, as well as manufacturers and industry.

## 3. IDENTIFYING OFFICER NEEDS AND REQUIREMENTS

As the starting point for developing standards, officers were asked to identify their needs and requirements in terms of threats, hazards, and other issues of concern. They provided a list of 75 threats ranked from frequently experienced to rarely experienced. Those threats were then separated into nine categories to indicate the type of hazard to the officer: blunt impact, puncture, cut, thermal and flame, biological, chemical, respiratory, and distraction. Appendix A, Table 1 contains a brief listing of these hazard categories with examples of hazards. It is emphasized that the listing gives examples of hazards within each category, but many hazards fall within multiple categories. For instance, slingshot projectiles may be blunt impact, cut, and/or puncture hazards. The officers also noted whether the threats were typically wielded by hand, swung by hand, thrown, or launched.

According to NIJ STC public order police representatives, head and face protection were the number one priority, and the most immediate and injurious threat to an officer during an event is blunt impact to the head and face. The impact and resultant injury may be caused by a launched, thrown, or swung blunt object. The swung blunt object may also penetrate due to embedded spikes or other protruding secondary threats.

The second threat of concern to the officer's head and face is harmful fluids, which may be of any configuration, caustic, biohazard, or toxic or it may be on fire. Specific concerns were raised about fluids running off the helmet shell onto skin or into eyes, pooling of flammable fluids on the shell, and the helmet components burning or melting when exposed to flaming materials.

Another threat of concern is high-powered, hand-held lasers that are frequently used against law enforcement officers to distract, disorient, or injure them. These lasers are inexpensive, easy to obtain, easy to conceal and carry, and easy to use. Some can cause temporary or permanent blindness with only momentary exposure. It is recommended personnel be equipped with eye protection against laser light at wavelengths of concern based on risk assessment.

Another threat used against officers is use of devices making extremely high decibel noises, primarily to distract and disorient officers but that can also damage hearing in a short amount of time.

Officers expressed additional needs beyond the threats listed above. The retention system holding the helmet to the head must be secure and easily released but have parts that allow for it to be snapped off in the event of a forcible removal by a protestor. The helmet will be worn for long periods of time, and the interior padding should be easy to clean.

## 4. PUBLIC ORDER POLICE HELMET STANDARDS

Because of its importance to officer safety, head protection was selected as the first item of protective equipment to be addressed by the STC. After identifying the hazards to be protected against, an effort was initiated to develop test methods and performance requirements for public order helmets, including face shields, and address those hazards. Technical experts, researchers, manufacturers, and officers, working through ASTM International's E54 Committee on Homeland Security Applications, began with a review of relevant existing public order head protection standards:

- *Protective Helmets – Test Methods,* BS EN 13087, 2000. [1]
- *Riot Helmets and Faceshield* Protection, CSA Z611-02, (Reaffirmed 2012). [2]
- *PSDB Protective Headwear Standard for UK Police*, HOSDB 21-04, 2004. [3]
- *NIJ Standard for Riot Helmets and Face* Shields, NIJ 0104.02, October 1984. [4]

A related resource reviewed by the group was a report done at the request of NIST: *Research Leading to Revised NIJ 0104.02 Standard for Riot Helmets and Face Shields*, Biokinetics Report R08-18B (Re-released July 2019). [5]

The review also included standards addressing blunt impact and eye protection for sports helmets, such as those for hockey and horseback riding, and industrial head protection.

The testing and performance requirements from each standard were analyzed and compared, and decisions were made to adapt existing test methods, where possible, and to develop new test methods as needed to address officer operational requirements and concerns. These test methods are included in ASTM E3343/E3343M, *Test Methods for Nonballistic-resistant Helmets Worn by Law Enforcement and*


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*Corrections* [6], which provides a collection of test methods that may be used. The performance requirements and additional testing requirements are included in ASTM E3342/E3342M, *Specification for Nonballistic-resistant Helmets Specifically Designed to be Worn by Law Enforcement and Corrections Officers When Maintaining Order in Violent Situations* [7]. Appendix A, Table 2 provides a list of ASTM E3342/E3342M [7] performance requirements and associated test methods.

This paper focuses on three standard test methods of ASTM E3343/E3343M that were modified to address specific concerns of U.S. public order police: (1) protection against multiple blunt impacts in a single location on the helmet shell, (2) face shield impacts by thrown objects, and (3) face shield impacts by slingshot projectiles.

## 5. HELMET SHELL IMPACT ATTENUATION TESTING

Most existing public order helmet standards require a blunt impact attenuation test that simulates an officer being shoved or otherwise impacted that results in falling and hitting the head on a solid object, such as pavement or a curb. The test typically requires a single impact in each of several locations on the outer shell. The impact, at a specified energy, is usually achieved by dropping the helmet, mounted on a headform, onto an anvil of specified shape. The performance criterion is typically specified in terms of maximum linear acceleration, which predicts the maximum force acting on the head, and the pass/fail limit is typically 300g [5].

Officers have expressed concerns that their helmets must protect against multiple impacts that could occur during one event or over years of use. Helmets are not typically replaced following blunt impacts unless there is visible damage to the shell. The problem is that most currently available helmets use crushable foam inner materials (such as expanded polystyrene), and protection-reducing damage can occur with a single impact but not be visible on the outer helmet shell. These factors led to an obvious need to modify existing test methods to assess multiple locations on the helmet shell, with more than one impact in each location.

A reduction in the pass/fail acceleration limit was recommended in a NIST-funded research report to be 250g because it advances the protection offered by the helmet and respects the technology of modern energy absorbing materials and construction methods [5].

As a demonstration of the modified test methods, technical experts proposed that, according to the helmet impact attenuation method of ASTM E3343 [6], three impacts at 120 J should be done in each of five locations on the shell, and the three impacts should be done sequentially on a flat anvil, a triangular anvil, and a corner anvil. To evaluate how different helmets might perform, testing was done on five commonly used riot helmets, one ballistic-resistant helmet, and a football helmet, with the non-riot helmets providing points of comparison.

Figure 1 shows a graph of peak acceleration (g) for each impact on each helmet, with the pass/fail acceleration value of 250g shown.

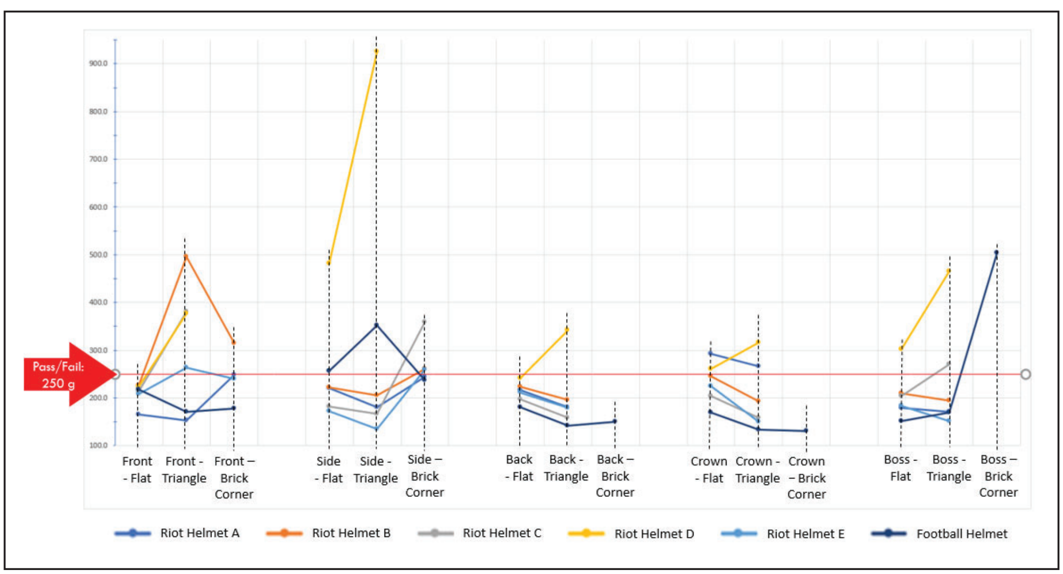


**Figure 24.** Graph of maximum recorded acceleration for each helmet impact by anvil

Observations based on these results shown in Figure 1 and examination of the impacted helmets are summarized below:

(1) Two impacts, once each with the flat and triangle anvils, in a single location do not appear to be too severe for the riot helmets tested, and a third impact may not be too severe, depending on the anvil chosen.

(2) The brick corner anvil penetrated many helmet shells as shown in Figure 1, brick corner impacts were omitted for some helmets due to concerns of damaging the test equipment. See Figure 2 for an example of shell puncture.

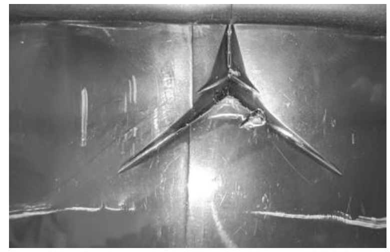

**Figure 25. Brick corner anvil puncture**

Because the test was too severe and not realistic, the task group made the decision to replace the brick corner anvil with the hemispherical anvil and conduct another round of testing that focused on anvils.

Subsequent testing was done on three helmets of a single model, rotating the order of the anvils and placing six impacts on each side of the sample (right and left). To obtain as many impacts as possible on three helmets, testing was done with side impacts only, based on the assumption that the sides are identical and would respond the same; other locations were not impacted because they are known to respond differently when impacted (as may be seen in Figure 1). See Appendix A, Table 3, for the impact locations and order of anvils.

Figure 3 provides two graphs of results showing the maximum recorded acceleration for each impact. Figure 3(a) shows impacts on the left side of three helmets using a single anvil. Six impacts were done; the first three are important for this test, and the second three were done for information. It can be seen from the first three impacts that the flat anvil impacts yield greater peak acceleration values. Figure 3(b) shows impacts on the right side of three helmets using an ordered sequence of three anvils. This figure indicates that impacts with the flat anvil yield greater acceleration values overall, regardless of the order of anvils. Evaluation of the test data led to the task group deciding to require three anvils (flat, triangle, and hemisphere) for each location and specify a different anvil order for each subsequent location on each helmet. The anvil order is listed in ASTM E3342/E3342M [7].

## 6. FACE SHIELD IMPACT AND DEFLECTION TESTING

Two existing public order helmet standards (NIJ 0104.02, PSDB 21/04) require procedures to test whether a known impact to face protection will cause deflection and contact to the wearer's face. Both procedures require that the helmet be mounted on a facially featured headform (positioned horizontally and nose facing up) with the face shield in the lowered position. Per these standards, assessing the face shield involves a single drop of a hemispherical impactor aligned with the headform nose, at a specified energy, onto the face shield. Contact between the headform nose and the face shield, via electrical connection, is determined during the impact.

Officers agreed with the above procedure for assessing face shield deflection; however, they also expressed their need to assess face shield integrity. The consensus of officers was that the face shield should be impacted in four locations, in the order listed: the nose, the upper edge center, the lower edge center, and at least one attachment point. After the final impact, the face shield integrity will be assessed, and the test result is considered a pass if each face shield tested does not contact the headform nose, has no visible cracks or splitting, is able to be raised and lowered, and remains fully attached. To support the inclusion of this test method and requirements, testing in accordance with ASTM E3343/E3343M [6] was done on three previously tested riot helmets. Deflection and impact testing revealed that some helmets showed no contact with the nose, while others did show contact; some helmets had visible structural damage, while others did not; and all helmet face shields remained functional and could be raised and lowered after impact. See Appendix A, Table 4, for the results of the test.

This testing supported the inclusion of the improved face shield deflection and impact test in the ASTM standard.

## 7. PROJECTILE TESTING OF FACE SHIELD

One of the concerns of public order police in the U.S. is protection against a projectile impact to the face shield, and the specific threat is a projectile fired from a wrist-supported slingshot. The *PSDB Protective Headwear Standard for UK Police* includes a procedure for assessing the face shield's ability to


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withstand an impact from a low mass, high velocity projectile. While the general test was determined to be appropriate for U.S. purposes, the test projectile and its velocity (6 mm ball bearing at 200 m/s) were not appropriate because they are intended to address the threat UK police face from a projectile fired from an airsoft gun. Therefore, testing was required to determine a more suitable test threat and velocity.

NIST performed testing to determine a recommended projectile size, type, and velocity. Three commonly available wrist-supported slingshots were tested using five readily available slingshot ammunition types (See projectile details in Appendix A, Table 5).

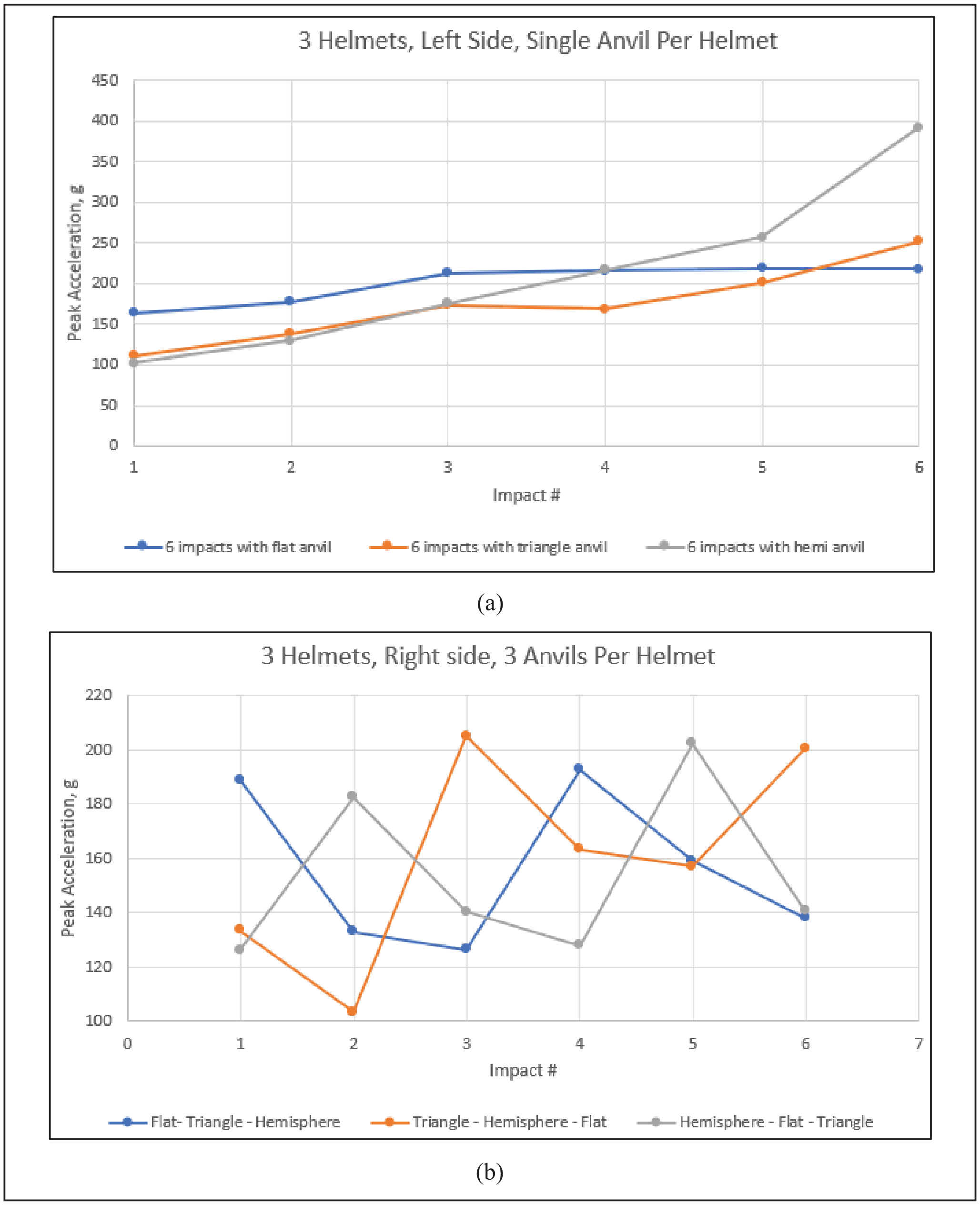


**Figure 26.** Test Results for Determination of Anvils and Order

For the test, the slingshot was mounted in a fixture, and the projectiles were shot through Oehler light screens to measure velocity (See Figure 4 for the test setup). Based on the abilities of several people to pull back and aim the slingshots, the draw length by the largest male, 81.3 cm, was selected as the draw length for the test. Five of each projectile were shot, and the average kinetic energy for each is shown in Figure 5. The ½-inch steel sphere achieved a maximum velocity of 47 m/s and delivered the greatest kinetic energy of all projectiles: 9.2 J. Based on this testing result, the ½-inch steel sphere was chosen as the projectile to require in the standard.

**Figure 4.** Two Views of Test Setup

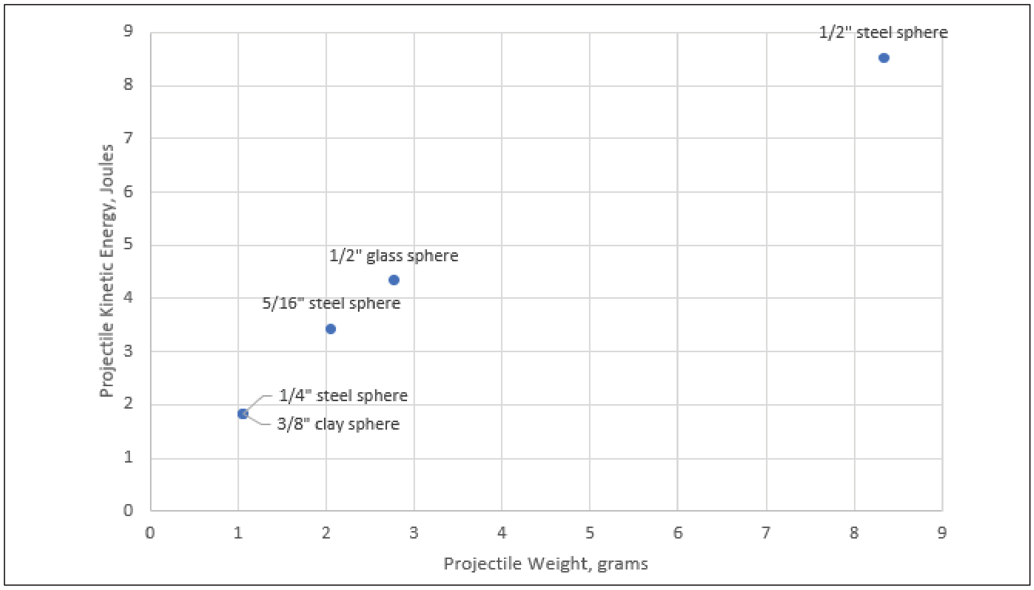


**Figure 5. Projectile Mass vs. Kinetic Energy**

The velocity was measured at different draw lengths as shown in Figure 6(a) and 6(b), and the relationship between draw length and velocity/k inetic energy can be seen. Both Figure 6(a) and 6(b) show extrapolated trendlines. This was done estimate the draw length of a larger adult male, size 40R, according to ASTM D6240 [8], having a length from wrist to opposite shoulder of 100.1 cm. Using that measurement (rounded up to102 cm (~ 40 inches)) to simulate one arm outstretched holding the slingshot, and the other hand at the opposite shoulder holding the projectile in the band (there is some hand length not taken into account) yields a corresponding velocity of 61 m/s (KE = 15.5 J). Adding in

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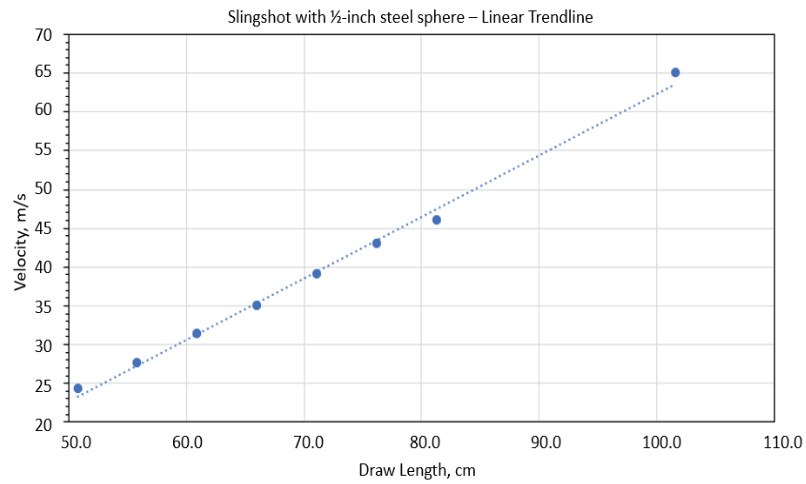
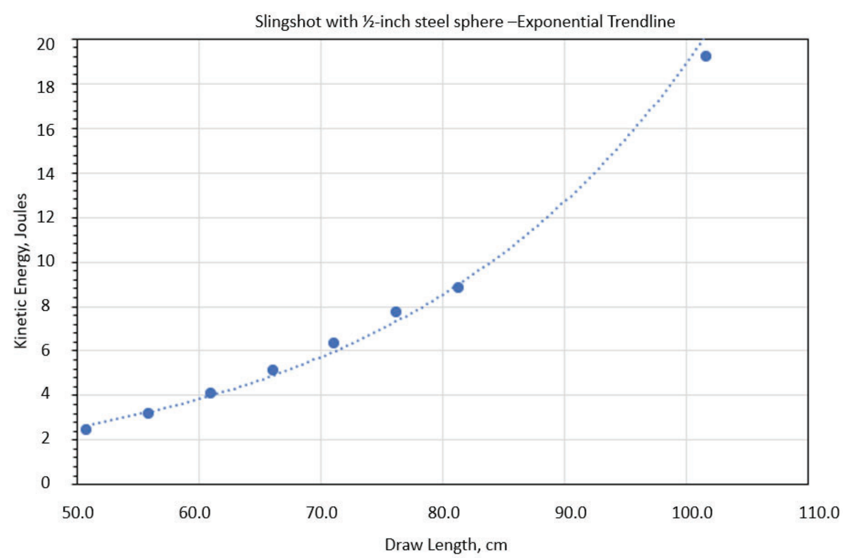
a safety factor, the task group decided to set the required velocity for the ½-inch steel sphere at 65 m/s (KE = 19.2 J).

ASTM E3342/E3342M [7] requires testing with the "1/2-inch" steel sphere at 65 m/s. An impact is called a complete penetration if any part of the test projectile, or any part or fragment of the face shield, has damaged a witness panel such that the light from a light source can be seen through the witness panel. The test result shall be considered a pass if *(1)* each face shield shows no visible cracks or splitting and *(2)* the witness material has no complete penetrations.




(a)




(b)

**Figure 6. Graphs for Slingshot with ½-inch Steel Ball**

## 8. ASTM VERIFICATION PROGRAM

The task group collaborating on these public order helmet standards recognized that published standards alone are not sufficient for improving the safety of law enforcement officers. There must be a method of conformity assessment to demonstrate that specified requirements are fulfilled, and it must provide both confidence in the helmet's performance but also be cost-effective for manufacturers and purchasers.

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To meet this need, an ASTM Verification Program has been established to evaluate and verify that public order helmets meet the requirements of ASTM E3342/E3342M. The program is managed by the Safety Equipment Institute (SEI, an ASTM affiliate), which is an independent, third-party conformity assessment body, and requires testing by a laboratory accredited to ISO 17025 [9] with the relevant ASTM standards in their scope of accreditation. The laboratory will submit test reports to SEI for evaluation against the appropriate standard. Those products that are successfully verified will be included in an online listing of verified products (www.seinet.org), will receive authorization to have the ASTM-verified Mark placed on them (See Figure 7), and will undergo annual testing to assess continued compliance. Key benefits are listed below:

**Figure 7. ASTM-verified Mark**

- For purchasers, the program will greatly simplify the purchasing process by eliminating (or at least reducing) challenges caused by (1) unverified supplier claims of equipment performance; (2) incomplete, confusing, or misleading information about equipment performance; (3) and false advertising about equipment performance. A purchaser can require ASTM verification as a condition for purchasing a product and then check the online verified products list to see whether the product(s) being offered by a supplier has been verified.
- For manufacturers, the program will enable them to distinguish their ASTM-verified products from those that do not meet standards.
- For end users, the program will allow them to check their individual helmets to see whether the ASTM-verified Mark is present.

## 9. CONCLUSIONS

The work described in this paper began with identification of the needs and requirements of public order police officers in the U.S. The most pressing concern was protection of the head and face, which led to the effort to identify relevant existing test methods that could be applied as written or modified as needed. Fifteen existing test methods were determined to potentially be relevant, and three of those were modified to meet the officer-expressed needs, with the modifications supported by testing of commonly used helmets. ASTM E3342/E3342M specifies 11 performance requirements and test methods that the NIJ STC officers stated were their priorities (See Appendix A, Table 2 for a listing).

The ASTM Verification Program will help to ensure that U.S. public order police officers have access to helmets verified to meet ASTM E3342/E3342M and protect them against the threats they are likely to encounter during an incident or event.

## 10. ACKNOWLEDGMENTS

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## REFERENCES

[1] *Protective helmets – Test methods*, British Standard 13087, 2000.
[2] *Riot Helmets and Faceshield* Protection, CSA Z611-02, (Reaffirmed 2012).
[3] *PSDB Protective Headwear Standard for UK Police*, Publication No. 21/04, 2004.
[4] *NIJ Standard for Riot Helmets and Face Shields,* NIJ 0104.02, October 1984.
[5] *Research Leading to Revised NIJ 0104.02 Standard for Riot Helmets and Face Shields*, Biokinetics Report R08-18B (Re-released July 2019).
[6] *Test Methods for Nonballistic-resistant Helmets Worn by Law Enforcement and Corrections*, ASTM E3343/E3343M-22.
[7] *Specification for Nonballistic-resistant Helmets Specifically Designed to be Worn by Law Enforcement and Corrections Officers When Maintaining Order in Violent Situations,* ASTM E3342/E3342M.


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[8] *Standard Tables of Body Measurements for Mature Men, ages 35 and older, Sizes Thirty-Four to Fifty-Two (34 to 52) Short, Regular, and Tall*, ASTM D6240.
[9] International Standardization Organization/International Electrotechnical Commission (ISO/IEC) 17025, *General requirements for the competence of testing and calibration laboratories*.

## Appendix A. Supporting Data Tables

**Table 9. Categories and Examples of Hazards of Concern**

| Category of Hazard | Examples of Hazards |
|---|---|
| **Blunt impact** | Glass bottle, brick, rock, sign post, bike rack, rebar, mace, crowbar, bat, hammer, frozen soda can, slingshot projectile (e.g., marble, spark plug, ball bearing) |
| **Puncture** | Knife, sharpened dowel, bat with embedded spikes, improvised shiv, club |
| **Cut** | Glass, knife, box cutter, ax, machete, saber, bike chain, razor |
| **Thermal/flaming** | Flare, firework mortar, Molotov cocktail, flammable aerosols, fuel |
| **Biological** | Blood, urine, feces, saliva |
| **Chemical & Respiratory** | Pest repellant, hairspray, acetone, vinegar, bleach, ammonia, acids, lye, drain cleaner |
| **Distraction** | Visual: Paint, laser, strobe light, firework, mortar, Molotov cocktail<br>Auditory: Yelling, loudspeaker, siren, air horn, whistle, trumpet, firework, mortar |

**Table 10. Performance Requirements and Associated Test Methods**

| ASTM E3342/E3342M Section | Associated Test Method | Purpose of Test: To assess |
|---|---|---|
| Section 7, Helmet Impact Attenuation | ASTM E3343/E3343M, Helmet Impact Attenuation Test | helmet's capability to attenuate an impact caused during a fall in which the head is hit on a flat, edged, or corner surface |
| Section 8, Helmet Shell Penetration Resistance | ASTM E3343/E3343M, Helmet Shell Penetration Resistance Test | helmet's ability to resist a thrown object, such as a brick |
| Section 9, Face Shield Deflection and Impact | ASTM E3343/E3343M, Face Shield Deflection and Impact Test Method | integrity of the face shield and its attachments and to assess whether a known impact to the face shield will cause deflection and contact to the wearer's face |
| Section 10, Face Shield Projectile Resistance | ASTM E3343/E3343M, Face Shield Projectile Resistance Test | face shield's ability to withstand an impact from low mass, moderate velocity projectiles, such as those launched from wrist-supported slingshots |
| Section 11, Flammable Liquid Trap | ASTM E3343/E3343M, Flammable Liquid Trap Test | whether there are liquid traps on the exterior of the helmet and whether the helmet is self-extinguishing within the defined period of time |
| Section 12, Liquid Penetration Resistance | ASTM E3343/E3343M, Liquid Penetration Resistance Test | helmet's ability to protect the wearer from contact with liquids |
| Section 13, Dynamic Retention System | ASTM E3343/E3343M, Dynamic Retention System Test | integrity of the retention system when subjected to a dynamic force as a drop weight delivers an impact load to the retention system |
| Section 14, Face Shield Optics | ANSI/ISEA Z87.1, Section 9.4, Refractive Power, Astigmatism and Resolving Power Tests, and, Section 9.5, Prismatic Power | whether the face shield distorts wearer's vision due to spherical and astigmatic aberration, and prismatic effects |
| Section 15, Accelerated Corrosion | ASTM E3343/E3343M, Accelerated Corrosion Test | ability of metallic components to resist corrosion |

| | | |
|---|---|---|
| Section 16, Helmet Shell Spike Penetration | ASTM E3343/E3343M, Helmet Shell Spike Penetration Resistance Test | helmet's ability to resist a sharp weapon swung at the head, such as a board with an embedded nail |

**Table 11. Impact Testing Details**

| Impact Series | Helmet and Location | Order of Anvil Impact | |
|---|---|---|---|
| **1** | Helmet #1 – Left side | Impacts 1 through 6 | All flat anvils |
| **2** | Helmet #1 – Right side | Impact 1, 4<br>Impact 2, 5<br>Impact 3, 6 | Flat anvil<br>Triangle anvil<br>Hemisphere anvil |
| **3** | Helmet #2 – Left side | Impacts 1 - 6 | All triangle anvils |
| **4** | Helmet #2 – Right side | Impact 1, 4<br>Impact 2, 5<br>Impact 3, 6 | Triangle anvil<br>Hemisphere anvil<br>Flat anvil |
| **5** | Helmet #3 – Left side | Impacts 1 - 6 | All hemisphere anvils |
| **6** | Helmet #3 – Right side | Impact 1, 4<br>Impact 2, 5<br>Impact 3, 6 | Hemisphere anvil<br>Flat anvil<br>Triangle anvil |

**Table 12. Face Shield Deflection and Impact Testing Results**

| Impact No. | Impact Type | Sample | Riot Helmet B | Riot Helmet C | Riot Helmet E and Ballistic Helmet |
|---|---|---|---|---|---|
| 1 | Deflection | 1 | Contact to Nose | Contact to Nose | No Contact |
| 2 | Deflection | 2 | Contact to Nose | Contact to Nose | No Contact |
| 3 | Impact at nose | 1 | Visible Dent and crack | Visible Dent | No Visible Damage |
| 7 | Impact at nose | 2 | Visible Dent and crack | Visible Dent | No Visible Damage |
| 4 | Impact 2" below upper edge | 1 | Visible Dent | Visible Dent | No Visible Damage |
| 8 | Impact 2" below upper edge | 2 | Visible Dent | Visible Dent | No Visible Damage |
| 5 | Impact at chin | 1 | Visible Dent | Visible Dent and crack | No Visible Damage |
| 9 | Impact at chin | 2 | Visible Dent and crack | Visible Dent and crack | No Visible Damage |
| 6 | Impact within 1" of attachment point | 1 | No Visible Damage | No Visible Damage | No Visible Damage |
| 10 | Impact within 1" of attachment | 2 | Attachment pin broke; face shield fully functional | No Visible Damage | No Visible Damage |

**Table 13. Projectile Types, Weights, and Sizes**

| Projectile Type | Weight, grams | Diameter, mm |
|---|---|---|
| "3/8-inch" clay sphere | 1.05 | 9.7 |
| "¼-inch" steel sphere | 1.06 | 6.4 |


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| | | |
|---|---|---|
| "5/16-inch" steel sphere | 2.06 | 7.9 |
| "½-inch" glass sphere | 2.77 | 13.2 |
| "½-inch" steel sphere | 8.33 | 12.7 |