

NIJ Standards for Ballistic Resistance of Body Armor and Stab Resistance of Body Armor: New Developments

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Abstract. The U.S. National Institute of Justice (NIJ) is revising their standards for body armor that protects law enforcement and corrections personnel against gunshots and stabbing weapons. The seventh revision to the NIJ standard for Ballistic Resistance of Body Armor, NIJ Standard 0101.07, includes many improvements that have been previously presented at the Personal Armour Systems Symposium. This paper focuses on new improvements to test methods for nonplanar armor designed for women and new test threats that take into account the changing landscape of policing and corrections in the U.S. Some improvements to the test methods for armor designed for women include new clay appliques to ensure better contact of panels with the clay backing material and new shot requirements to assess shaping features. Shot placement has also been reconfigured to explore potential vulnerabilities due to unique construction elements in the panel and nonzero angles of incidence in the proximity of edges. NIJ Standard 0101.07 requires testing with three rifle threats that were not previously required. One of the rifle threats new in NIJ Standard 0101.07 is a 7.62x39mm mild steel core (MSC) round, which is known to have variabilities in manufacturing and performance. A factory round was identified as an appropriate MSC test threat based on lot assessments and confirmed through a separate study conducted by an adjacent U.S. Government agency. The first revision to the NIJ standard for Stab Resistance of Body Armor, NIJ Standard 0115.01, has been extensively updated to include two protection categories, new test threats representing improvised weapons typically seen inside correctional facilities, updated test equipment, improved test procedures to better assess armor performance, and new methods for nonplanar armor designed for women. This paper will provide an overview of NIJ's body armor activities, describing the improvements to both standards, the changes to the NIJ Compliance Testing Program, and guidance for agencies, purchasers, and end users.

1. U.S. LAW ENFORCEMENT AND CORRECTIONS ARE DANGEROUS PROFESSIONS

Law enforcement and corrections are dangerous professions. The United States (U.S.) Bureau of Labor Statistics reports that in 2018 police and sheriffs' patrol officers in the U.S. experienced a fatality rate on the job of 13.7 in 100,000 officers—four times higher than the overall fatality rate on the job of 3.5 in 100,000 workers across all industries in the U.S. that year [1]. A majority of the accidental fatalities each year are traffic-related, while a majority of the felonious fatalities are due to assaults with firearms. Analysis of the Federal Bureau of Investigation's (FBI) Law Enforcement Officers Killed and Assaulted (LEOKA) statistics show that from 1987 through 2019, over 80,000 officers were assaulted with firearms. Furthermore, of the 1,923 officers feloniously killed in the line of duty by all means over that time span, 1,773 were feloniously killed by firearms. That equates to *over 92% of all felonious deaths* in the line of duty being due to firearms. Handguns alone accounted for at least 1,320 of those firearms fatalities [2].

Fewer law enforcement officers are killed by stabbing and cutting weapons than by firearms, but these assaults are also of concern to law enforcement. Analysis of LEOKA statistics show that from 1987 through 2019, over 38,000 officers were assaulted with knives with 20 officers feloniously killed [2]. Data to provide national estimates on assaults on correctional officers is harder to come by in the U.S., so much of what is known about the hazards in corrections is collected at the state and local levels in addition to anecdotal information. The Federal Bureau of Prisons in the U.S. publishes monthly serious assaults on its correctional staff [3], which totals several incidents per year, some of which involve stabbing or cutting weapons. For corrections officers, stabbing and cutting with inmate manufactured weapons are much greater concerns because those weapons are often intentionally contaminated with body fluids containing biohazards. While the assault may not result in immediate death, the long-term effects of infection can be deadly.

2. NIJ STANDARD 0101.07: BALLISTIC RESISTANCE OF BODY ARMOR

NIJ published its first performance standard for ballistic-resistant police body armor in 1972 [4]. The current revision is the seventh, NIJ Standard 0101.07, *Ballistic Resistance of Body Armor*, which includes improved test methods for female body armor and updated body armor protection levels that incorporate additional rifle threats faced by U.S. law enforcement, as discussed previously [5]. This revision takes into consideration the changing landscape of policing in the U.S. and implements lessons learned over the past decade of testing using NIJ Standard 0101.06, published in 2008 [6]. The improvements include more widespread stakeholder engagement, improved test methods and procedures, and updated test threats and protection levels, all of which result in better protection for officers wearing body armor.

NIJ Standard 0101.07 was developed with the guidance and input of a large group of end users and technical experts. Unlike previous revisions of the NIJ body armor standard which have been comprehensive, standalone documents, NIJ Standard 0101.07 references ten ASTM standards developed through the open and inclusive ASTM standards development process, with the participation and input from a wide range of stakeholders, including materials and equipment producers. These include standardized methods for laboratory measurements, ballistic testing, and data collection, among others [7].

In 2013, the U.S. Army, NIJ, and the National Institute of Standards and Technology (NIST) began a partnership to harmonize the standards and their implementation for ballistic-resistant vests. The federal agencies chose to work through ASTM's E54 Committee on Homeland Security Applications to develop standard test methods and practices for the purpose of improving and validating methods, increasing consistency among test laboratories, and ultimately increasing confidence in ballistic-resistant equipment. Incorporation of relevant ASTM standards into NIJ standards and U.S. Army requirements and testing documents affords the opportunity to harmonize laboratory test procedures and practices for both law enforcement and military ballistic-resistant armor and other ballistic-resistant equipment while allowing those end user communities ultimate control over product specifications, such as the specific threats against which their equipment must protect.

3. NEW NIJ STANDARD 0123.00 DEFINES BALLISTIC PROTECTION LEVELS AND TEST THREATS

NIJ's new test threats specification, NIJ Standard 0123.00, *Specification for NIJ Ballistic Protection Levels and Associated Test Threats*, is published as a companion to NIJ Standard 0101.07. NIJ Standard 0123.00 specifies the test threats—including projectiles and reference velocities—identified by U.S. law enforcement as representative of prevalent threats in the United States which will be used to test ballistic-resistant equipment for U.S. law enforcement applications. It is referenced by NIJ Standard 0101.07 for body armor and may be incorporated into future NIJ standards for ballistic-resistant helmets and ballistic-resistant shields. NIJ opted to develop a standalone specification of ballistic protection levels and associated test threats rather than specify the information directly in NIJ Standard 0101.07, as had been done in NIJ Standard 0101.06 and prior revisions. As a standalone specification, it may also enable testing of a variety of ballistic-resistant equipment, not just ballistic-resistant body armor, against contemporary U.S. law enforcement threats. However, NIJ Standard 0123.00 itself does not define any test methods.

The test threats in the inaugural version of NIJ Standard 0123.00 have been updated from section 2 of NIJ Standard 0101.06 to reflect the evolving threats faced by U.S. law enforcement end users, including a wider range and more severe ballistics threats, as shown in Table 1. The ballistic protection levels have been modified accordingly, with the protection level nomenclature also changed for better clarity and to reduce officer and end user confusion. Several new rifle test threats were added to the 7.62x51mm M80, including 5.56mm M193, 5.56mm M855, and 7.62x39mm mild steel core (MSC), which is commonly seen by officers but is known to have huge variability in performance. That variability in the MSC round has driven the development of surrogate test round designs to ensure consistency in testing; however, NIJ Standard 0123.00 specifies a factory round until surrogate test round development activities are completed and validated, and the surrogate is commercially available.

NIJ Standard 0123.00 specifies a range of acceptable bullet dimensions, bullet mass, core dimensions, core mass, and core hardness for the factory 7.62x39mm MSC projectiles as well as audit procedures to assess ammunition lots to determine suitability for testing. NIJ previously engaged ammunition experts to investigate the possible solutions to define a 7.62x39mm MSC test round suitable to include in NIJ standards for the purposes of NIJ certification testing and Follow-up Inspection Testing (FIT) testing through its NIJ Compliance Testing Program (CTP) for ballistic-resistant body armor [8].

Physical characteristics of the ammunition as well as factors, such as availability of supply, were considered in the assessment of the various factory rounds available. The audit procedures were developed to conduct a multi-laboratory evaluation of the candidate ammunition, which performed consistently across the NIJ-approved laboratories. In addition, a factory round was identified as an appropriate MSC test threat based on lot assessments and confirmed through a separate study conducted by an adjacent U.S. Government agency.

Table 1. NIJ ballistic protection levels in NIJ Standard 0123.00.

NIJ Ballistic Protection Level	Test Threat	Ammunition Identifier	Reference Velocity
NIJ HG1	9mm Luger FMJ RN 124 grain	Remington #23558	1305 ft/s (398 m/s)
	.357 Magnum JSP 158 grain	Remington #22847	1430 ft/s (436 m/s)
NIJ HG2	9mm Luger FMJ RN 124 grain	Remington #23558	1470 ft/s (448 m/s)
	.44 Magnum JHP 240 grain	Speer #4453 or #4736	1430 ft/s (436 m/s)
NIJ RF1	7.62x51mm M80 ball NATO FMJ steel jacketed 147 +0/-3 grain	U.S. military supply or rounds meeting NATO specifications	2780 ft/s (847 m/s)
	7.62x39mm MSC ball ammunition Type 56 from Factory 31	Factory 31 Ammunition evaluated and meeting the requirements of NIJ 0123.00 Appendix A	2400 ft/s (732 m/s)
	5.56mm M193 56 +0/-2 grain	U.S. military supply or rounds meeting NATO specifications	3250 ft/s (990 m/s)
NIJ RF2	7.62x51mm M80 ball NATO FMJ steel jacketed 147 +0/-3 grain	US military supply or rounds meeting NATO specifications	2780 ft/s (847 m/s)
	7.62x39mm MSC ball ammunition Type 56 from Factory 31	Factory 31 Ammunition evaluated and meeting the requirements of NIJ 0123.00 Appendix A	2400 ft/s (732 m/s)
	5.56mm M193 56 +0/-2 grain	U.S. military supply or rounds meeting NATO specifications	3250 ft/s (990 m/s)
	5.56mm M855 61.8 ± 1.5 grain	U.S. military supply or rounds meeting NATO specifications	3115 ft/s (950 m/s)
NIJ RF3	30.06 M2 AP 165.7 +0/-7 grain	U.S. military supply or rounds meeting NATO specifications	2880 ft/s (878 m/s)

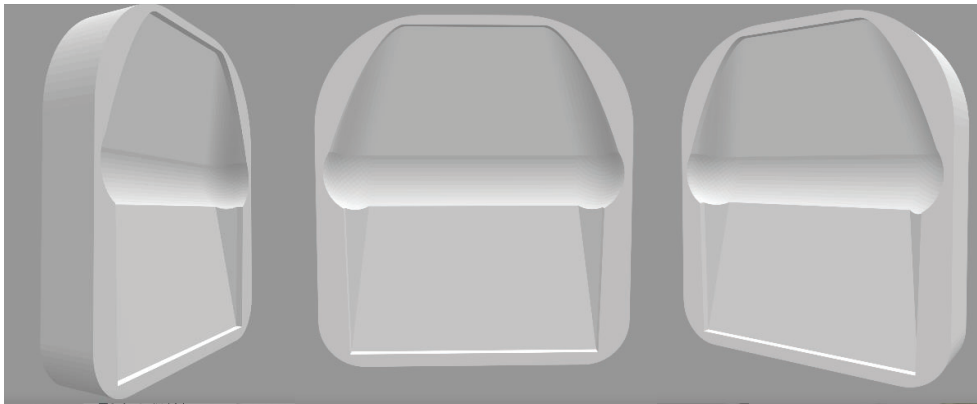
4. UPDATED LABORATORY PRACTICE FOR TESTING NONPLANAR BODY ARMOR DESIGNED FOR WOMEN OFFICERS

NIJ Standard 0101.07 includes many improvements that have been previously presented at the Personal Armour Systems Symposium [5]. Some improvements to the test methods for armor designed for women include new clay appliques to ensure better contact of panels with the clay backing material and new shot requirements to assess shaping features. Women comprised about 14% of full-time sworn officers employed by local police departments in the U.S. in 2020 [9]. Shot placement has also been reconfigured to exploit potential vulnerabilities due to unique construction elements in the panel and nonzero angles of incidence in the proximity of edges.

NIJ Standard 0101.07 initially referenced ASTM E3086, *Standard Practice for Creating Appliques for Use in Testing of Nonplanar Soft Body Armor Designed for Females*. This ASTM standard specified a procedure for creating appliques (e.g., build-up of clay) for use behind nonplanar soft armor panels and affixing the appliques to the clay block. The purpose was to specify critical parameters for creating appliques in order to improve consistency of the test setup between laboratories. The practice described a single applique shape applicable only to nonplanar, soft body armor designed for women. Implementation of this practice proved more challenging than expected, including difficulty creating the specific applique shapes described in ASTM E3086 and ensuring proper contact with the armor panel once mounted on the clay block, which required reconsideration of how to build up clay behind nonplanar soft armor panels.

A more simplified applique was developed to ensure that the panels are fully filled in with clay before mounting on the clay block. This applique is more monolithic in form with the general contours of a female torso in cross-section. It is created using one of two standardized mold sizes along with a procedure to shape its form once affixed to the clay block. The result is a better substrate to ballistically test nonplanar armor.

Figure. 1. Different views of the mold used to form the clay appliques for testing nonplanar soft armor in NIJ Standard 0101.07.



5. UPDATED P-BFD METHODS: ANGLED SHOTS ON SOFT ARMOR NEAR EDGES AND SHOTS ON THE CROWN OF MULTI-CURVED HARD PLATES

NIJ has updated perforation-backface deformation (P-BFD) testing to include an additional shot on soft armor panels. How soft armor responds to handgun projectiles striking very near the top edge of a front armor panel has been explored by an adjacent U.S. Government agency through experimental testing efforts. This involved mounting a ballistic vest with soft armor panels in an external carrier onto a model female torso made of molded ballistic gelatin. In this configuration, the top of the panel is naturally slanted back toward the torso in the carrier, creating an angle of obliquity between the armor panel the trajectory of the incoming bullet. Shots striking the top center edge at angles of obliquity in excess of approximately 40° have been demonstrated in some exploratory tests to not fully engage all layers of the armor panel and deflect off a middle layer into the neck region of the gelatin torso.

For planar soft armor, NIJ has added a shot located at the top center at the minimum shot-to-edge distances (2 in. or 3 in.) for the specific NIJ HG1 and NIJ HG2 threats at a 45° angle of incidence, which is achieved by rotating the clay block. For nonplanar soft armor, the built-up clay of the applique introduces an approximately 15° angle of obliquity by slanting the top of the armor panel back toward the clay block. The clay block is rotated an additional 30° angle of incidence to yield an overall 45° angle between the shot and armor surface. This new shot will provide minimum performance for soft armor for handgun projectiles striking that location.

NIJ has also reconfigured P-BFD testing on hard armor plates to include striking the crown on curved plates. The crown is defined as the location of the highest point of the strike face of the plate when the plate is lying horizontally on a flat surface, at the intersection of multiple different curvatures. The placement of a shot on the crown probes the performance of hard armor in a location that may be more vulnerable to penetration due to characteristics of the materials or construction methods used to

manufacture plates. This shot location is consistent with testing conducted by the U.S. Army on hard armor to meet its specifications, bringing the NIJ standard into better alignment with DoD testing.

6. NIJ STANDARD 0115.01: STAB RESISTANCE OF BODY ARMOR

The first revision to NIJ Standard 0115.00, *Stab Resistance of Body Armor*, has been extensively updated to address law enforcement and corrections officer needs and requirements and to improve the standard based on lessons learned in the years since the previous publication [10]. NIJ published a draft of the new standard in 2020 through the *Federal Register* to request comments and input from the public, a practice commonly used by U.S. Government agencies to seek input on important guidance, policy, or regulations they plan to publish [11].

Stabbing is a major concern for officers working inside controlled-access facilities, such as jails, detention centers, and prisons. Inmates are well known to make improvised stabbing weapons from materials found in their environment and sharpened on concrete or other rough surfaces. Due to metal detectors and other detection methods at entrances and other key points, it is difficult to introduce weapons into a controlled-access facility, so firearms and commercial knives are not considered to be typical threats. Therefore, the revised standard NIJ Standard 0115.01, a *Stab Resistance of Body Armor*, includes two NIJ stab protection categories that are more descriptive of stab threats and the environments in which they are likely to be encountered: NIJ-STAB-Commercial and NIJ-STAB-Improvised.

The NIJ-STAB-Commercial threats address commercially made knives and spikes, typically encountered outside of controlled-access facilities or within the jail intake area. Within the commercial protection category, there are three test threats as shown in Table 2. These are the same threats specified in NIJ Standard 0115.00, but the test threat designator has been updated for clarity. The impact energy level for this test threat was derived from prior research [12]. The primary energy of 24 J corresponds to the 85th percentile of the population that was studied, and the 36 J energy corresponds to 1.5 times the primary energy value and is intended to ensure that the armor material performs in a linear fashion and does not suffer catastrophic failure at, or near, the primary energy level.

The NIJ-STAB-Improvised threats address improvised or inmate-made weapons, typically encountered inside controlled-access facilities, such as jails, detention centers, and prisons. Because improvised weapons are not as sharp or durable as commercial weapons, having an improvised weapon category will likely result in lighter-weight, more comfortable armor for corrections officers. Developing the parameters for improvised weapons required research to understand and analyze the types of improvised weapons found inside controlled-access facilities. NIJ funded an effort to characterize common improvised weapons and develop exemplars for testing [13, 14]. The research and development effort resulted in three test threats within the improvised protection category as shown in Table 2. The impact energy level for the improvised test threat was derived from the same study as for commercial weapons [11]. The primary impact energy of 43 J corresponds to the 96th percentile of the population that was studied, and the 65 J energy corresponds to 1.5 times the primary energy value.

NIJ requires that body armor within each stab protection category be tested with all three test threats. The performance requirements for resistance to penetration by commercial threats have been kept the same as “protection level 1” in NIJ 0115.000, namely: (1) 7 mm (0.28 in) at E1, for fair hits at angles of incidence of 0° and 45° and (2) 20 mm (0.79 in) at E2, for fair hits at angles of incidence of 0°. The penetration limit at E1 was determined through research indicating that internal injuries to organs would be extremely unlikely at 7 mm (0.28 in). The performance requirements for resistance to penetration by improvised threats are the same as for commercial threats, except that no penetration is allowed at the primary impact energy. This is intended to protect officers from exposure to infectious diseases when shanks and shivs are intentionally contaminated with body fluids or feces.

NIJ has added new testing requirements and procedures for effectively assessing shaped armor designed for women. Manufacturers are required to submit all test samples in NIJ template size NIJ-C-4, and female armor front panels must be submitted with cup sizes of B and E. The revised standard requires a build-up of backing material behind the front panel and impacts in specific locations to test potential weak point caused by stitching or other design features.

NIJ has improved all test procedures to better assess armor performance and to reduce interlaboratory variability in testing. Major improvements include an increased sample quantities from 3 to 16 samples and 16 more for shaped armor designed for females. Requirements were added for conditioning by submersion in water prior to impact testing and for sample panels to be rotated at several angles (0°, 45°, 90°, >30°). Multiple impact locations per sample panel were also added as were increased specificity for depth of penetration measurements and use of cut length for both commercial and improvised blades. To further reduce interlaboratory variability, NIJ increased the specificity in

requirements for the stab testing apparatus and had a new sabot designed and fabricated for the testing laboratories currently participating in the NIJ CTP.

Table 2. Stab protection categories, stab threats, and associated impact kinetic energies proposed for NIJ Standard 0115.01.

NIJ Stab Protection Category	Test Threat	Test Threat Designator	Impact Kinetic Energy, E1	Overtest Impact Kinetic Energy, E2
NIJ-STAB-Commercial	Commercial single-edged (SE) blade	Com-SE	24 ± 0.50 J (17.7 ± 0.36 ft-lbf)	36 ± 0.60 J (26.6 ± 0.44 ft-lbf)
	Commercial double-edged (DE) blade	Com-DE		
	Commercial spike (SP)	Com-SP		
NIJ-STAB-Improvised	Improvised single-edged (SE) blade	Imp-SE	43 ± 0.60 J (31.7 ± 0.44 ft-lbf)	65 ± 0.80 J (47.9 ± 0.59 ft-lbf)
	Improvised double-edged (DE) blade	Imp-DE		
	Improvised spike (SP)	Imp-SP		

7. NIJ COMPLIANCE TESTING PROGRAM

The NIJ CTP is a body armor certification program to provide U.S. law enforcement and correctional agencies and personnel confidence that the body armor they purchase and use performs according to minimum performance requirements to protect against common handgun and rifle threats as well as stab threats. Use of NIJ-certified body armor is ubiquitous among U.S. law enforcement and corrections agencies, and many agencies outside the U.S. make use of NIJ standards and NIJ-certified armor. Since the NIJ CTP began accepting armor submissions to meet the requirements of NIJ Standard 0101.06 in 2009, over 1,800 unique models of ballistic-resistant body armor have been submitted to the CTP for compliance testing through the end of 2022, with an overall failure rate of approximately 38% of models submitted for initial testing. Currently there are over 400 models of ballistic-resistant body armor listed on NIJ's Compliant Products List (CPL) [15,16].

Industry participation in the program by manufacturers is voluntary; however, it is recognized by manufacturers as the standard in body armor quality assurance. At the end of 2022, the NIJ CTP had 82 participants worldwide, with 127 manufacturing locations representing 73 locations in the continental U.S. and 54 manufacturing locations outside the U.S. The NIJ CTP also recognizes Body Armor Quality Management System Requirements called BA9000, which are optional quality assurance requirements to which body armor manufacturers can choose to have their manufacturing locations certified. There are 16 manufacturing locations certified to BA 9000 operated by 15 of the NIJ CTP participants, representing 228 models, or 55%, of the ballistic-resistant body armor currently listed on the CPL.

While NIJ will begin to certify body armor to the new NIJ Standard 0101.07 and will publish a new CPL for those armor models, it will also continue to accept armor for certification to NIJ Standard 0101.06 during a transitional period. NIJ will also continue to maintain its CPL for armor models compliant with NIJ Standard 0101.06 for a period of time and will continue to require FIT on these models. This will allow law enforcement agencies the time needed to transition their equipment as smoothly as possible over a reasonable amount of time. NIJ will also begin to certify body armor to the new NIJ Standard 0115.01 and will publish a new CPL for those armor models, it will also continue to accept armor for certification to NIJ Standard 0115.00 during a transitional period.

8. CONCLUSION

NIJ Standard 0101.07, *Ballistic Resistance of Body Armor*, includes improved test methods for female body armor and updated body armor protection levels that incorporate additional rifle threats faced by

U.S. law enforcement. NIJ Standard 0101.07 references ten ASTM standards, including standardized methods for laboratory measurements, ballistic testing, and data collection. NIJ's new test threats specification, NIJ Standard 0123.00, *Specification for NIJ Ballistic Protection Levels and Associated Test Threats*, specifies the test threats, including projectiles and reference velocities, identified by U.S. law enforcement as representative of prevalent threats in the U.S., including a 7.62x39mm MSC factory round. Improvements to the test methods for armor designed for women include new clay appliques to ensure better contact of panels with the clay backing material and new shot requirements to assess shaping features. NIJ has added a P-BFD shot located at the top center of soft armor panels at the minimum shot-to-edge distances to provide minimum performance for handgun projectiles striking that location and has reconfigured P-BFD testing on hard armor plates to include striking the crown on multi-curved plates.

The revised NIJ Standard 0115.01, *Stab Resistance of Body Armor*, includes two NIJ stab protection categories that are more descriptive of stab threats and the environments in which they are likely to be encountered: NIJ-STAB-Commercial and NIJ-STAB-Improvised. NIJ has added new testing requirements and procedures for effectively assessing shaped armor designed for women and has improved all test procedures to better assess armor performance and to reduce interlaboratory variability in testing. While NIJ will begin to certify body armor to the new NIJ Standard 0101.07 and NIJ Standard 0115.01 and will publish new CPLs for those armor models, it will also continue to accept armor for certification to NIJ Standard 0101.06 and NIJ Standard 0115.00 during a transitional period.

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