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Selection and Application Guide to Police Body Armor

NIJ Guide 100–87

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Technology Assessment Program

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FOREWORD

The Law Enforcement Standards Laboratory (LESL) of the National Bureau of Standards (NBS) furnishes technical support to the National Institute of Justice (NIJ). This document was produced as part of the Technology Assessment Program of NIJ. A brief description of the program appears on the inside front cover.

LESL is: 1) Subjecting existing equipment to laboratory testing and evaluation and 2) conducting research leading to the development of several series of documents, including national voluntary equipment standards, user guides, and technical reports.

Additional guides as well as other documents are being issued under the LESL program in the areas of protective equipment, communications equipment, security systems, weapons, emergency equipment, investigative aids, vehicles, and clothing.

Technical comments and suggestions concerning this guide are invited from all interested parties. They may be addressed to the author or to the Law Enforcement Standards Laboratory, National Bureau of Standards, Gaithersburg, MD 20899.

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INTRODUCTION

Lightweight body armor has been widely available for use by law enforcement personnel for well over a decade. The dramatic reduction in officer homicides following the introduction of soft body armor, as shown in figure 1, gives testimony to the protection that it provides. The story of success extends far beyond protection from handguns—it has been estimated that as many as 1200[1] lives that have been spared, including cases where body armor has prevented serious injuries to officers from other types of assaults or accidents.

The National Institute of Justice (NIJ)[2], the developer of the current generation of soft body armor, has issued standards for body armor performance through its Technology Assessment Program. In addition, NIJ established the Technology Assessment Program Information Center (TAPIC) to disseminate test results and other pertinent information. Body armor has been tested as a part of the TAPIC equipment testing program to determine compliance with the NIJ standard. A list of armor models that comply with the requirements of the standard is available from TAPIC.[3]

While body armor is a household word in the law enforcement community, questions about its selection and use are frequently asked. This guide responds to commonly expressed concerns. It provides information to assist in determining the level of protection required for individual officers consistent with the threats to which they are exposed. The selection of armor from the variety of styles that are available is discussed together with the proper care of armor in service. The NIJ standard is discussed in detail, as well as the use of the standard in armor-procurement. In addition, administrative concerns including the issue of replacing in-service armor are discussed and other sources of information are described.

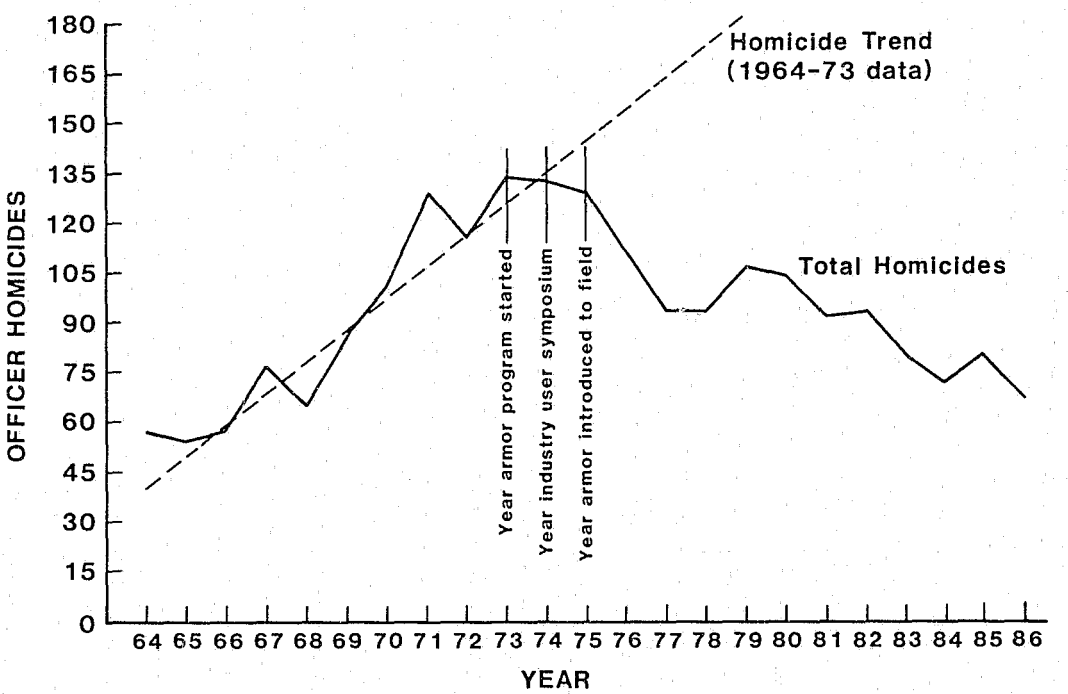

FIGURE 1. RECENT TRENDS IN OFFICER HOMICIDES.

[1] Based on E. I. Du Pont De Nemours Co., Inc. estimates.

[2] The National Institute of Justice is the successor to the Law Enforcement Assistance Administration (LEAA), National Institute of Law Enforcement and Criminal Justice (NILECJ).

[3] Write to the Technology Assessment Program Information Center, Box 6000, Rockville, MD 20850 or call 1-800-24-TAPIC (301-251-5060 in Maryland or the Washington, DC Metro Area).

We ask all departments to exercise prudent judgment in the selection of armor appropriate to their needs. In so doing, we urge proper attention to those factors that affect the wearability of armor to encourage routine full-time use by all officers when on duty. The temptation to order armor that provides for more protection than realistically needed should be avoided, for to do so increases the likelihood that the armor will not be worn.

BACKGROUND

Body armor, widely used during the time of hand-to-hand combat, became obsolete with the advent of the crossbow and firearms. Technology had advanced sufficiently by World War II to permit the development of armor constructed from ballistic nylon with metallic inserts. This armor, the flak jacket, was intended primarily to protect against munitions fragments and, to a limited extent, weapon fire. Unfortunately, the armor was heavy and bulky and saw only very limited use by law enforcement personnel.

During the 5-year period from 1966 to 1971 the number of law enforcement officers killed each year in the line of duty more than doubled from 57 to 129. The NIJ staff was concerned with the rapid increase in officer fatalities. Recognizing that a majority of the homicides were inflicted with handguns, NIJ initiated a research program to investigate the possibility of developing lightweight body armor that could be worn by police full-time while on duty to protect against this threat.

The NIJ investigation quickly identified new materials that could be used to weave lightweight fabric with excellent ballistic resistant properties. Following initial laboratory research, NIJ concluded that the objective of producing body armor suitable for full-time police use was possible. In a parallel effort, the National Bureau of Standards' Law Enforcement Standards Laboratory (LESL), a part of the NIJ Technology Assessment Program, developed a performance standard [1][4] that defined ballistic-resistant requirements for police body armor.

A full-scale development effort was launched by NIJ in 1973; although quickly accomplished, it was highly complex and involved several government agencies. The Biophysics Branch of the Chemical Systems Laboratory at the U.S. Army Edgewood Arsenal took the lead in developing armor designs and in medical research, while the Natick R&D Command, Body Armor Group, Natick, MA focused on research concerning wearability and comfort. The development effort had progressed sufficiently by 1974 to hold a conference with the manufacturing industries to completely discuss the details of the research findings and garment design.

Since body armor previously had not been used routinely by police, NIJ felt that it was important to implement a demonstration project to obtain information on wear experiences and to prove that full-time wear was possible.[5] In 1975, 5000 sets of body armor purchased by NIJ were issued to volunteer officers in 15 cities throughout the United States. The first instance of saving a participating officer's life occurred less than 6 months after the armor was distributed and less than 2 weeks after it was issued to him. During the 1-year demonstration period, there were 18 shooting incidents in which soft body armor successfully protected the officers. The demonstration project armor issued by NIJ was designed to ensure a 95 percent probability of survival after being hit with a 38 caliber bullet at a velocity of 800 feet per second. Further, the probability of requiring surgery if hit by a projectile was to be 10 percent or less. **Note that the armor protection is rated in accordance with a specific threat—there is no such thing as "bullet proof" armor.** For practical purposes it is impossible to construct wearable armor that will protect against all possible weapon threats.

Private industry was quick to recognize the potential market for the new generation of body armor, and soft body armor became commercially available in quantity even in advance of the NIJ demonstration program. Since then, many communities have staged fund-raising events to purchase armor for its officers, police departments have purchased armor from operating budgets, and individual officers have purchased their own. It is estimated that armor is currently available to more than half of the nation's police officers. **Regrettably, it appears that many who possess body armor do not use it routinely.**

[4] Numbers in brackets refer to references in appendix A.

[5] For detailed information concerning the overall NIJ development effort, refer to the publications listed in appendix B.

The selection of armor has become increasingly complex as manufacturers have developed numerous models and designs, the variety of ballistic fabric styles has increased, and the protection requirements of police agencies have changed. All of these factors have necessitated changes in the NIJ body armor standard. The current edition, which was issued April, 1987 [4] is the third revision of the 1972 base document.

The sections of this guide that follow discuss the factors that must be considered when selecting armor, the NIJ standard and how to use it, as well as the capabilities and limitations of body armor.

THE THREAT

The use of weapons of all types, particularly handguns by those with criminal intent, poses a constant threat to police officers, whether responding to a domestic quarrel or to an armed robbery. All too frequently, a domestic disturbance erupts into violence when one or more of the family members redirect their anger toward the officer who is attempting to effect a peaceful resolution of the problem. Similarly, routine traffic stops too often result in an unexpected armed confrontation. At times like these, an officer most needs the protection provided by body armor. The possible occurrence of one of these unexpected incidents is a principal reason for wearing the armor at all times.

Logic dictates the routine use of soft body armor—still there are those who do not, often in spite of departmental regulations to do so. Those who ignore the protection of armor constantly expose themselves to unnecessary pain and suffering or even death. Officers should also consider the potential impact of their actions upon their families, who must suffer the anxiety of awaiting the uncertain outcome of surgery, the burden of caring for the injured or permanently disabled officer in the home, or worse the anguish of the person's death and the problems of raising a family alone.

The current generation of soft body armor was developed specifically to protect against injury from assault with handguns. A review of the statistics concerning weapons confiscated nationwide during the period from 1964 to 1974 identified the 38 caliber handgun, firing bullets at a velocity of 800 ft/s, as the most common weapon threat to officers—in fact, caliber 38 and smaller handguns accounted for more than 85 percent of the confiscated weapons.

When an individual is hit by a bullet, the extent of the injury sustained depends upon where the bullet strikes the body and the path or trajectory of the bullet into or through the body. Injury to the vital organs is most often fatal. The primary purpose of armor is obviously to prevent a bullet from penetrating into the torso.

In the case of hard armor, such as metal, rigid reinforced plastic, or ceramic materials, it is possible to use armor of such a thickness that the armor does not appreciably deform from the bullet impact. If, however, the armor that covers the torso deforms from a bullet impact, the surface of the armor against the body at the point of impact will be forced against or into the skin and flesh. Unlike a penetrating wound, in which the skin is broken and the bullet tears through the body, the deformation of armor from the bullet impact results in blunt trauma. This type of nonpenetrating injury (blunt trauma) can cause severe contusions (bruises) and/or internal damage, and can even result in death. Figure 2 shows a photograph of a plaster cast of the cavity formed in clay backing material when soft body armor is struck by a test bullet.

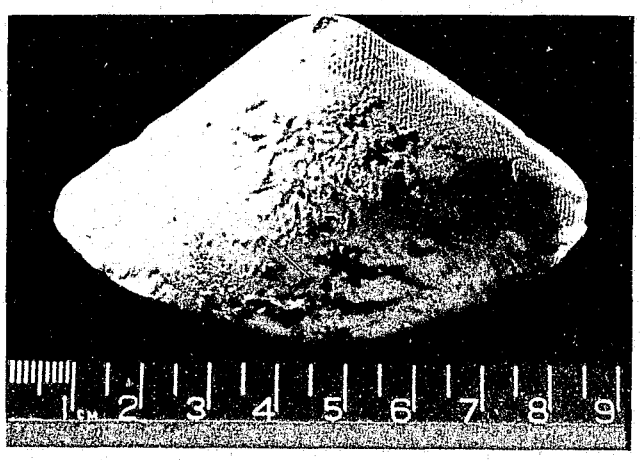

FIGURE 2. PLASTER CAST OF DEFORMATION IN CLAY BACKING FOR PROTECTIVE GARMENT FOLLOWING FIRING OF THE TEST ROUND.

Simplistically speaking, the design of ballistic-resistant armor consists of identifying the threat (bullet type, caliber, impact velocity), selecting a material that will resist that threat, and determining the thickness of material necessary to prevent both penetration and blunt trauma injury. In designing armor, the final weight of the armor is an important factor in the selection of the ballistic-resistant material to be used. For body armor, the obvious goal is to design the lightest possible unit that achieves the desired protection while still providing comfort and without restricting movement.

Anyone familiar with weapons knows that protection from the threat of a bullet fired from a 44 Magnum revolver requires armor with significantly greater ballistic-resistant capabilities than that required to protect against bullets fired from a 32 caliber short barrel revolver. The degree of threat from handguns depends upon caliber, bullet configuration (i.e., lead round nose, hollow point, jacketed, weight, composition and shape) and impact velocity. Thus, armor that defeats a specific projectile at one impact velocity may not defeat the same caliber projectile at a higher velocity or of different composition or configuration.

On the whole, there undoubtedly exists a continuous range of threat levels for the different weapon and ammunition combinations that are available. As with clothing, which allows one to select from a limited range of garment type and weight depending upon the climate and season, it has proven to be satisfactory to establish six armor types (protection level classifications) that enable the selection of armor to protect against most common threats—including sporting and armor-piercing rifle bullets.

The details of armor classification and selection are discussed later in this guide. For the moment, it is sufficient to **recognize the importance of being realistic in assessing the firearm threat to your officers.** The weight and bulk of soft body armor increases significantly as greater threat protection is demanded; both of these factors discourage full-time use of body armor.

The original NIJ effort to develop the current generation armor focused solely on the urgent need to protect law enforcement personnel from handgun assault. As with most new technology, soft armor has proven to be useful in ways not thought of when first put into service. The same properties that provide ballistic protection—resistance to penetration and blunt trauma—combined with abrasion resistance have saved many officers from serious physical injury in vehicle accidents.

During the course of a routine patrol, an officer was negotiating a sweeping right-hand curve (at a high rate of speed) when the vehicle ran off the edge of the pavement. As the vehicle was brought back onto the pavement the officer lost control; after fishtailing several times, the vehicle became airborne and crashed head-on into a rocky earth hillside. The officer suffered a fractured sternum, sprained right thumb, possible concussion and pain in the area of the neck. There is every reason to believe that the body armor that the officer was wearing saved the officer's life.

In another incident, an officer in a patrol car was following a slow moving vehicle and was struck from behind by a vehicle moving at approximately 60 mph. Again, body armor was credited with preventing serious injury.

Medical experts have concluded without question that body armor mitigates injury in head-on collisions when the driver is thrown against the steering wheel, particularly when the seat belt is fastened.

The officers assigned to motorcycle duty are very vulnerable to injury in vehicular accidents. The officer shown in figure 3, a member of the California

FIGURE 3. PHOTOGRAPH OF THE BACK OF AN OFFICER WHO WAS WEARING BODY ARMOR WHEN INVOLVED IN A MOTORCYCLE ACCIDENT. PHOTOGRAPH COURTESY OF CALIFORNIA HIGHWAY PATROL.

Highway Patrol, was traveling at about 45 mph when he heard the sound of a vehicle approaching rapidly from the rear. He was attempting to move to the right when struck by the vehicle in the left rear. The motorcycle spun counter clockwise; he was thrown from it, landing on his back and sliding on the pavement for approximately 100 feet before coming to rest. He sustained only minor injuries (complained of pain) to his right elbow and right leg.

Body armor has also protected numerous officers from injury from physical assault with two-by-fours, baseball bats, and other rigid objects.

It should be noted that soft body armor is potentially vulnerable to knife attack, hence all officers should avoid such confrontations. However, there are numerous incidents in which soft body armor has lessened injury from knives.

BODY ARMOR CONSTRUCTION

The current generation of soft body armor can provide protection from handguns and even 9 mm submachine guns. It is not, however, practical at the present time to make soft body armor that will withstand high-powered rifle fire.

Body armor to protect against rifle fire, discussed later, is of either semirigid or rigid construction. It is intended only for tactical situations where it will be worn for short periods of time when confronted with high level threats.

Soft body armor is constructed of multiple layers of ballistic fabric or other ballistic-resistant materials, assembled into a ballistic panel. The ballistic panel is inserted into a carrier of conventional garment fabrics, such as nylon or cotton. The ballistic panel may be permanently sewn into the carrier or may be removable. The ballistic protection is determined by the number of layers in the ballistic panel.

The design of a ballistic panel is considerably more complex than this description implies. Ballistic fabric is available in at least four styles, determined by the thickness of the yarn and manner in which the fabric is woven. Each style of fabric has unique ballistic resistant properties. The manufacturer of soft body armor may construct a given model of ballistic panel from a single fabric style, or two or more styles in combination. The location and number of layers of each style within the multiple layer ballistic panel influence the overall ballistic performance of the panel. In addition, some manufacturers coat the ballistic fabric with various materials. In some cases, the manufacturers add a layer of nonballistic material for the sole purpose of increasing blunt trauma protection. As a consequence, it is not possible to compare one product with another solely on the basis of the number of fabric layers in the ballistic panel. There are even composites of two or more different ballistic materials.

The manner in which the ballistic panels are assembled into a single unit also differs from one manufacturer to another. In some cases the multiple layers are bias-stitched around the entire edge of the panel; in others, the layers are tack-stitched together at several locations. Some manufacturers assemble the fabrics with a number of rows of vertical or horizontal stitching, or may even quilt the entire ballistic panel. There is no evidence that stitching impairs the ballistic resistant properties of a panel; rather, stitching tends to improve the overall performance depending upon the style of fabric used.

The differences between ballistic panels in the products of various manufacturers result from individual design concepts to achieve a given level of ballistic performance with minimum weight and maximum comfort or wearability. If armor has been demonstrated to provide the desired level of protection, the user should not be concerned with the design, but should look for proper fit and comfort.

Soft body armor intended for routine use is most often designed to be worn beneath the normal uniform shirt. Again, manufacturer's tend to design different methods of attaching the armor to the body. Hook and pile fasteners are common, as are "D" ring tightening straps. With the exception of metal fasteners of any type (which can deflect a bullet on impact and pose a hazard), the method of attachment is a matter of personal preferences.

The number of body armor configurations available (including armor designed specifically for female officers) assuredly makes it possible for any officer to find comfortable armor suitable for routine use, consistent with his or her personal taste in appearance.

BODY ARMOR PERFORMANCE STANDARD

NIJ Standard-0101.03, "Ballistic Resistance of Police Body Armor," dated April 1987 [4], is the current edition of the standard. The base document (0101.00) [1], issued in March 1972, did not address blunt trauma protection and had only a limited number of armor classifications. Subsequent research established requirements for blunt trauma protection, which were included in the 0101.01 edition dated March 1978 [2]. The decimal number (.01) indicates the number of the revision to the standard. The .01 edition classified armor into five types in accordance with the level of protection provided. The standard was revised again in March 1985 [3], at which time the number of armor classifications was expanded to six and the test methods were also modified. Anyone purchasing body armor should ensure that it complies with the current edition of the NIJ standard (0101.03).

NIJ Standard-0101.03 was developed by the National Bureau of Standards' Law Enforcement Standards Laboratory (LESL) and issued by the National Institute of Justice as a voluntary national standard. This is a performance standard (rather than a design standard) as are almost all standards that LESL develops. Performance standards clearly present requirements that specify a minimum satisfactory level of performance for each attribute that is critical to the manner in which the equipment accomplishes its intended use. In contrast, design standards specify the manner in which an item of equipment must be manufactured. Performance standards encourage design innovation and the use of advanced technology, addressing critical requirements only and not such attributes as comfort, color or style that are generally a matter of user perception or preference.

Armor Classification

NIJ Standard-0101.03 establishes six formal armor classification types, and a seventh special type as follows:

Type I (22 LR; 38 Special)

This armor protects against 22 Long Rifle High Velocity lead bullets, with nominal masses of 2.6 g (40 gr), impacting at a velocity of 320 m (1050 ft) per second or less, and 38 Special round nose lead bullets, with nominal masses of 10.2 g (158 gr), impacting at a velocity of 259 m (850 ft) per second or less. It also provides protection against most other handgun rounds in calibers 25 and 32.

Type I soft body armor is light, weighing approximately 0.9 kg (2 lbs). **This is the minimum level of protection that any officer should have, and the armor should be routinely worn at all times while on duty.**

Type II-A (Lower Velocity 357 Magnum; 9 mm)

This armor protects against 357 Magnum jacketed soft point bullets, with nominal masses of 10.2 g (158 gr) impacting at a velocity of 381 m (1250 ft) per second or less, and 9 mm full metal jacketed bullets, with nominal masses of 8.0 g (124 gr), impacting at a velocity of 332 m (1090 ft) per second or less. It also provides protection against threats such as 45 Auto., 38 Special +P, and some other factory loads in caliber 357 Magnum and 9 mm, as well as the Type I threats.

Type II-A body armor weighs approximately 1.6 kg (3-1/2 lbs); it is well suited for full-time use by police departments, particularly those that use 357 Magnum service weapons with lower velocity ammunition or 38 special service weapons with high velocity (+P) ammunition.

Type II (Higher Velocity 357 Magnum; 9 mm)

This armor protects against 357 Magnum jacketed soft point bullets, with nominal masses of 10.2 g (158 gr), impacting at a velocity of 425 m (1395 ft) per second or less, and 9 mm full jacketed bullets, with nominal velocities of 358 m (1175 ft) per second and protects against most other factory loads in caliber 357 Magnum and 9 mm, as well as the Type I and II-A threats.

Type II body armor, heavier and more bulky than either types I or II-A, weighs slightly more than 1.8 kg (4 lbs). It is worn full-time by some departments, but may be considered unsuitable for full-time use in hot, humid climates.

Type III-A (44 Magnum; Submachine Gun 9 mm)

This armor protects against 44 Magnum, lead semi-wadcutter bullets with gas checks, nominal masses of 15.55 g (240 gr), and impacting at a velocity of

426 m (1400 ft) per second or less, and 9 mm full metal jacketed bullets, with nominal masses of 8.0 g (124 gr), impacting at a velocity of 426 m (1400 ft) per second or less. It also provides protection against most handgun threats, as well as the Type I, II-A, and II threats.

Type III-A body armor, which provides the highest level of protection currently available as soft body armor, weighs 2.3 kg (5 lbs) or more, and is **generally considered to be unsuitable for routine wear**. However, individuals confronted with a terrorist weapon threat may often be willing to tolerate the weight and bulk of such armor while on duty.

Type III (High-Powered Rifle)

This armor protects against 7.62 mm full metal jacketed bullets (U.S. military designation M80), with nominal masses of 9.7 g (150 gr), impacting at a velocity of 838 m (2750 ft) per second or less. It also provides protection against threats such as 223 Remington (5.56 mm FMJ), 30 Carbine FMJ, and 12 gauge rifled slug, as well as the Type I through III-A threats.

Type III body armor, normally of hard or semirigid construction, is clearly intended only for tactical situations when the threat warrants such protection, such as barricade confrontations where sporting rifles are involved.

Type IV (Armor-Piercing Rifle)

This armor protects against 30-06 caliber armor-piercing bullets (U.S. military designation APM2), with nominal masses of 10.8 g (166 gr) impacting at a velocity of 868 m (2850 ft) per second or less. It also provides at least single hit protection against the Type I through III threats.

Type IV body armor provides the highest level of protection currently available. Since this armor is intended to resist "armor-piercing" bullets, it often utilizes ceramic materials. Such materials are brittle in nature and may provide only single-shot protection since the ceramic tends to break up when struck.

Special Type

A purchaser having a special requirement for a level of protection other than one of the above astandard threat levels should specify the exact test rounds and minimum impact velocities to be used, and indicate that this standard shall govern in all other respects.

Model/Style Designation

A manufacturer can, and frequently does, use identical ballistic panel construction to produce several different configurations of armor such as an undergarment or a sport coat, each of which provides the same level of ballistic protection.

For the purposes of the Technology Assessment program body armor certification procedures, the following definitions have been adopted.

> A body armor MODEL is a manufacturer designation that identifies a unique ballistic panel construction; i.e., a specific number of layers of one or more types of ballistic fabric and or ballistic-resistant material assembled in a specific manner.
>
> A body armor STYLE is a manufacturer designation (number, name, or other descriptive caption) usedto distinguish between different configurations of a body armor product line each of which includes the same model of ballistic panel

The distinctions between body armor model and style were established to eliminate the necessity of retesting a given body armor model for compliance with the NIJ Standard each time a manufacturer incorporates the model into different style of armor.

Requirements

The performance requirements of NIJ Standard-0101.03, which were developed with the active participation of the Personal Protective Armor Association, ensure that each armor type will provide a well defined minimum level of ballistic protection.

Table 1, reproduced from the standard, identifies the specific bullets and impact velocities that each armor type must withstand.

Types I, II-A, II, and III-A armor are required to prevent penetration from the impact of six bullets at specified velocities and locations for two types of

TABLE 1. TEST SUMMARY.

Armor type	Test variables				Performance requirements		
	Test Round	Test ammunition	Nominal bullet mass	Minimum required bullet velocity	Required fair hits per armor part at 0° angle of incidence	Maximum depth of deformation	Required fair hits per armor part at 30° angle of incidence
I	1	38 Special RN Lead	10.2 g 158 gr	259 m/s (850 ft/s)	4	44 mm (1.73 in)	2
	2	22 LRHV Lead	2.6 g 40 gr	320 m/s (1050 ft/s)	4	44 (1.73 in)	2
II-A	1	357 Magnum JSP	10.2 g 158 gr	381 m/s (1250 ft/s)	4	44 mm (1.73 in)	2
	2	9 mm FMJ	8.0 g 124 gr	332 m/s (1090 ft/s)	4	44 mm (1.73 in)	2
II	1	357 Magnum JSP	10.2 158 gr	425 m/s (1395 ft/s)	4	44 mm (1.73 in)	2
	2	9 mm FMJ	8.0 g 124 gr	358 m/s (1175 ft/s)	4	44 mm (1.73 in)	2
III-A	1	44 Magnum Lead SWC Gas Checked	15.55 g 240 gr	426 m/s (1400 ft/s)	4	44 mm (1.73 in)	2
	2	9 mm FMJ	8.0 g 124 gr	426 m/s (1400 ft/s)	4	44 mm (1.73 in)	2
III		7.62 mm (308 Winchester) FMJ	9.7 g 150 gr	838 m/s (2750 ft/s)	6	44 mm (1.73 in)	0
IV		30–06 AP	10.8 g 166 gr	868 m/s (2850 ft/s)	1	44 mm (1.73 in)	0
Special requirement (see sec. 2.2.7)*		*	*	*	*	44 mm (1.73 in)	*

* These items must be specified by the user. All of the items must be specified.

Notes: Armor parts covering the torso front and torso back, with or without side coverage, shall each be impacted with the indicated number of fair hits. Armor parts covering the groin and coccyx shall each be impacted with three fair hits at 0° angle of incidence. The deformation due to the first fair hit shall be measured to determine compliance. No fair hit bullet or one impacting at a velocity lower than the minimum required bullet velocity shall penetrate the armor.

Abbreviations:
AP — Armor Piercing
FMJ — Full Metal Jacketed
JSP — Jacketed Soft Point
LRHV — Long Rifle High Velocity
RN — Round Nose
SWC — Semi-Wadcutter

ammunition. Two of the impacts in each six-shot sequence must be at an angle that is 30° from the line perpendicular to the plane tangent to the armor surface. Further, the deformation of the backing material (a measure of blunt trauma protection) must not exceed 44 mm (1.73 in). The armor must meet these requirements while both dry and wet.

Type III armor requirements are identical to those above, except that only one type of ammunition is specified, and all six test rounds are fired perpendicular to the surface of the armor.

Type IV armor is required to resist penetration from only a single type of ammunition, and is only required to prevent penetration from a single perpendicular impact.

In addition to the ballistic requirements, the NIJ standard requires quality workmanship, and specifies the minimum information that must be included on the label of the armor.

The maximum allowable deformation of the clay backing material, permitted by the standard was determined through an extensive series of ballistic gelatin measurements and animal experiments conducted by a team of medical experts. This limit ensures protection from blunt trauma arising from an impact occurring over vital locations. Even at this level of protection, however, there is no absolute guarantee of protection against internal injuries.

The rationale for the requirement that armor resist bullet penetration is obvious. The reasons for other ballistic requirements may not be apparent.

The current generation of soft body armor is constructed primarily from fabric woven from yarn of Kevlar®[6] Aramid Fiber. Kevlar® is remarkably durable and has exceptional ballistic resistant properties, but it also has some undesirable attributes.

Fabric woven from Kevlar® and certain other ballistic fabrics lose ballistic resistant efficiency when wet, **but fully returns to normal ballistic efficiency upon drying.** Laboratory tests of untreated Kevlar® vests soaked in water have shown a reduction in ballistic efficiency of more than 20 percent compared to that of dry vests. The cause of this phenomenon is not known, but the problem has been circumvented by using a water repellent treatment such as Zepel D[6] fabric fluoridizer or Scotchguard®[7] on the Kevlar® fabric; alternatively, the fabric may be protected from moisture by encasing it in a moisture-proof container.

An officer may confront an armed assailant in the rain, and body perspiration can also significantly reduce the ballistic efficiency of untreated Kevlar® fabric. Laboratory tests conducted by the U.S. Army Natick R&D Command using a manikin that simulates human perspiration verified that vests will absorb perspiration in amounts comparable to a vest that has been allowed to drain following immersion in water. A series of tests were conducted by a research team from the Department of Justice in which officers wearing untreated vests were subjected to strenuous exercise on a hot humid day. The amount of perspiration in the vests agreed well with the Natick experiments and, when ballistic tests were conducted, a significant reduction in the efficiency was noted. In view of this, the NIJ standard requires that a vest continue to provide the rated level of ballistic protection when wet.

All soft body armor types are required to resist the penetration of bullets striking at an angle to the surface: the probability of being hit exactly perpendicular to the surface is low. Certain styles of Kevlar® fabric are as much as 20 percent less efficient ballistically when a bullet strikes at an angle. Armor must provide the rated level of protection regardless of the angle of impact.

It should be noted that Kevlar® is subject to degradation from ultraviolet light. Tests have shown that the ballistic efficiency of Kevlar® is significantly degraded by exposure to sunlight for extended periods of time. The ballistic efficiency of Kevlar® can also be degraded through exposure to various chemicals, such as bleach or, some dry cleaning fluids.

On balance, the exceptional ballistic efficiency of Kevlar® fabric compensates for these few limitations—therefore, aware of them, the user can easily care for and properly maintain soft body armor and ensure that it provides the rated protection throughout its service life.

[6] Registered trade name of the E. I. Du Pont De Nemours Co., Inc.

[7] Registered trade name of the 3M Manufacturing Company.

Performance Testing

Figure 4, from NIJ Standard-0101.03 [4], shows the test setup for ballistic testing of police body armor. The chronograph is required to measure the bullet velocity to ensure that each test round is within the range required by the standard. The armor that is being tested is mounted on a clay backing material whose consistency is controlled.

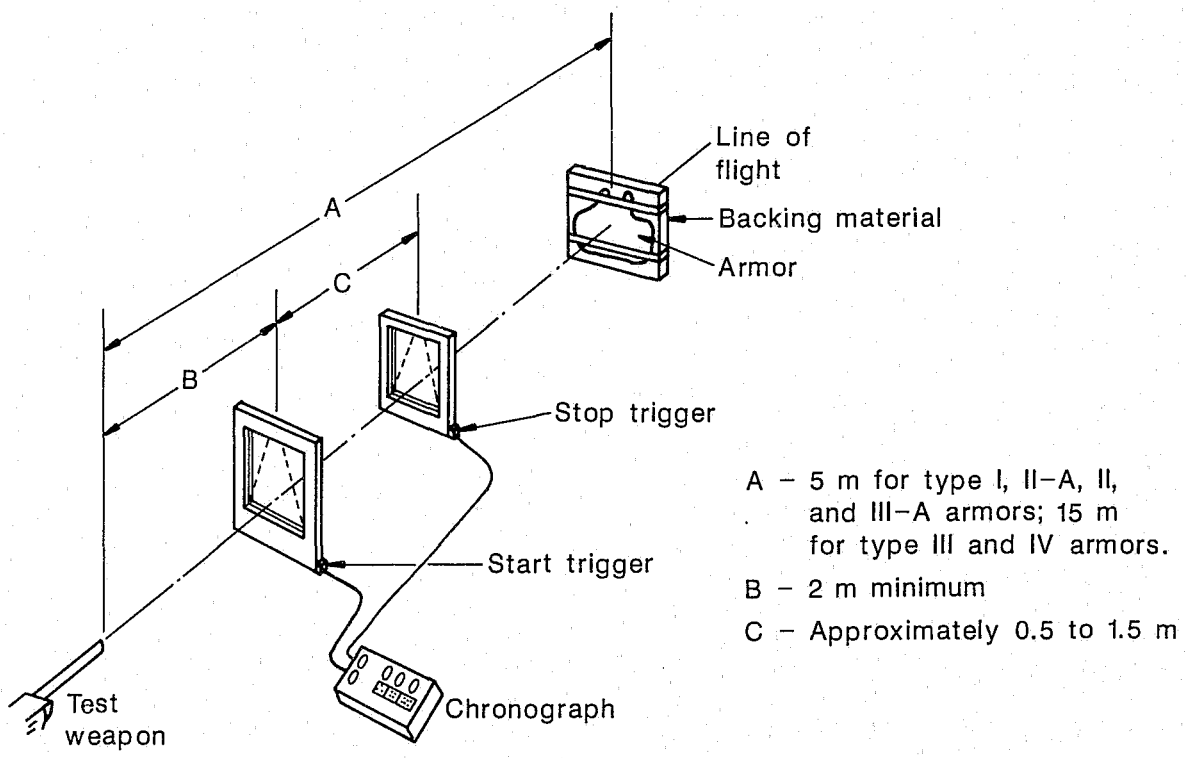

FIGURE 4. BALLISTIC TEST SETUP.

Figure 5, also from NIJ Standard-0101.03 [4], shows the general locations of point of impact for each round fired in the six-shot sequence for each type of ammunition as specified in table 1 for the type of armor being tested. The deformation of the clay behind the impact of the first shot (location 1) is measured to determine compliance with the blunt trauma requirement. Following the deformation measurement, the armor is repositioned on the clay and is not smoothed or otherwise disturbed for the remaining five bullet impacts, two of which (locations 5 and 6) are fired at an angle of 30° to the armor surface. The armor is not disturbed during the last five firings in order to evaluate protection from multiple hits.

The armor is tested both while dry and after being sprayed with a measured quantity of water for three minutes and allowed to drain before being mounted on the clay.

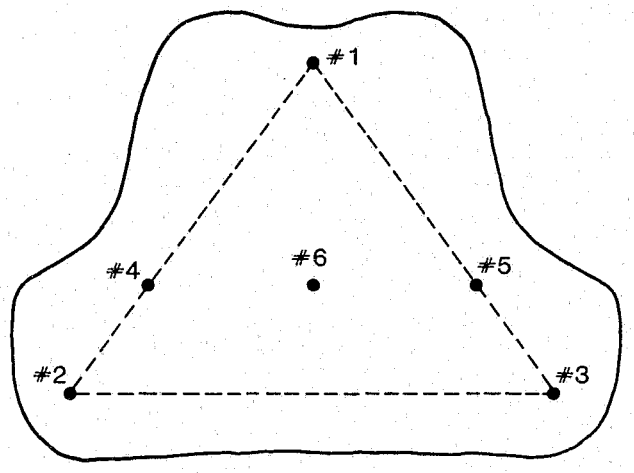

FIGURE 5. TEST AMMUNITION SHOT SERIES.

Both the front and back of the armor are tested and, if present, tests are conducted on groin and coccyx (end of spine) protection panels.

The clay backing material must be properly conditioned and must meet the requirements specified in the standard, as the only current means of relating deformation to blunt trauma protection. Some departments attempt to conduct their own tests using a variety of backing materials, including thick stacks of newspapers, wood, or even steel plate. This practice should be avoided, for the bullet interacts differently than when the armor is mounted on the proper clay backing material. Further, other backing materials can be unsafe—in several cases bullets have bounced back and injured the officer shooting at the armor.

V_{50} Ballistic Limit Testing

Performance testing, using the method specified by the NIJ standard verifies whether a specific armor will protect from a known threat; however, it does not provide a measure of the absolute level of protection that a given armor is capable of providing. Manufacturers frequently provide an extra margin of safety by using more layers of fabric than the minimum number required to prevent penetration by a given round.

In order to obtain a more quantitative knowledge of the ballistic resistant capabilities of armor, the military and some research laboratories conduct tests known to determine the V_{50} ballistic limit of the armor, the theoretical velocity at which a specific type of bullet is expected to penetrate the armor one-half of the time. In this test, the armor is mounted on the clay backing material and specified bullets are fired to determine the velocities at which the bullets do and do not penetrate the armor. A sufficient number of bullets are fired at various velocities to obtain groups of five nonpenetrating bullets and five penetrating bullets, with a velocity range of no more than 38 m/s (125 ft/s) between the lowest velocity nonpenetrating bullet and the highest velocity penetrating bullet. The V_{50} ballistic limit is calculated as the average velocity of the 10 bullets.

The V_{50} ballistic limit test, while useful in research studies, is not suited for use in a performance standard. It is described here for completeness of discussion, since recent research into the effects of aging and use upon body armor has relied upon V_{50} determination rather than performance testing.

GETTING THE RIGHT PROTECTION

Threat Level Selection

The first step in selecting appropriate body armor is to establish the level of protection that meets the needs of the user based on the realistic weapon threat. It is impossible to completely protect a law enforcement officer from all possible threats with a body armor that can be worn continuously. It is therefore necessary to select a reasonable level of ballistic protection accepting some risk of injury even when the armor is worn. Type I armor is considered to be the minimum level of protection that any officer should have throughout his working shift. This level of protection was established in 1972 based on nationwide statistics for all confiscated weapons. At that time, 85 percent of the weapons on the street were 38 special or a lesser threat.

The weapons and ammunition commonly found on the street vary significantly with geographical location. It is, therefore, essential that one consider the information concerning weapons and ammunition that are confiscated in both the local jurisdiction and nearby surrounding areas, as well as statistics concerning gun sales of sporting goods stores. Such data will permit an assessment of the current threat from street weapons. We strongly recommend the selection of an armor that protects against both the street threat and the handguns the officers themselves use. A review of reports on officers killed during the period from 1970 to 1986 shows that, on the average, one in five victims was assaulted with his or her own service weapon. Type II-A body armor will protect against the weapons commonly used by many police departments.

Information from the Uniform Crime Reports, Law Enforcement Officers Killed and Assaulted [5], provides some insight into the overall threat to officers nationwide. Not all weapons are fully described and the assaults may not be representative of typical

threats to police. Table 2 compiled from this report presents a summary of the handguns used to kill police during the period from 1981 through 1986. Type I armor protects against the first group of weapons, 38 caliber and smaller, which accounted for more than 50 percent of the fatalities. Less than 10 percent of the weapons (the 41 and 44 Magnums), require the level of protection afforded by Type III-A armor; the remaining handguns, the 357 Magnum and 9 mm (many of which were service weapons), cannot be directly related to threat level based upon caliber alone. On the whole, Type II armor protects against over 90 percent of the identified weapons. Taking service weapons into account, it appears that Type II-A armor would provide appropriate protection against nearly 70 percent of all weapons listed in table 2.

TABLE 2. HANDGUNS USED IN OFFICER HOMICIDES. (COMPILED FROM UNIFORM CRIME REPORTS, OFFICERS KILLED AND ASSAULTED, 1981 THROUGH 1985)

Handgun	Year					
caliber	1981	1982	1983	1984	1985	1986
22	3	5	5	4	3	5
25	3	2	4	1	4	0
32	4	5	3	6(1)	3	1
380	0	3	0	0	3	0
38	32(6)*	19(1)	24(6)	17(7)	17(3)	20(5)
45	1	0	1	1	3	5(1)
357 Mag	17(6)*	12(4)	11(5)	13(4)	15(6)	14(8)
9 mm	4	6	3	6(1)	3	4(1)
41 Mag	0	0	0	1	1(1)	0
44 Mag	3	1	2	2	1	1
NR**	2	7	1	1	4	1

*Numbers in parentheses identify service weapon fatalities.
**Handgun caliber not reported.

In analyzing potential weapon threats a given police force will probably identify several threat levels, depending on the nature of specific assignments. Specialized armor will be required for SWAT team operations, but these armors will be issued and only used as needed. As noted earlier, armor that provides protection against high level threats is heavy and bulky, and is unsuitable for full-time use.

NIJ believes that it is in the best interst of all police departments to promote the routine full-time use of body armor. Quite aside from armor sparing officers and their families from pain and suffering, the economic impact on a department when an officer is killed in the line of duty is staggering. Several departments have calculated the cost associated with an officer homicide, including replacing the officer—their estimates range from a low of several hundred thousand to well over one million dollars.

As previously stated, avoid the temptation to purchase armor that provides protection far in excess of realistic needs, for such action not only increases the cost, but there is a greater likelihood that it will not be worn. Overspecification of protection levels has been alleged as the most common reason that armor is not worn.

The individual department must carefully consider the selection of armor appropriate to its needs, recognizing that it may not be practical to protect against all possible handgun attacks. In the final analysis, those responsible for selecting the level of protection for armor to be used routinely must exercise prudent judgment and decide whether the overall benefits of limited protection (purchasing a less-protective armor type than the maximum level of protection indicated by threat analysis) outweigh the complete loss of protection if the armor is not worn.

Types of Armor

The protective undergarment, the most widely used police body armor, is worn under the normal uniform shirt. Properly designed, these garments are relatively comfortable, lightweight [approximately 2 kg (4 1/2 lbs) or less], and do not unduly restrict movement. These are available in a variety of designs.

Figures 6 and 7 show typical male and female undergarment body armors. In this case, it is designed to provide full front, side, and rear protection. In one case, the armor uses a "D" ring fastening system while the other uses hook and pile. The ballistic panel is often contained in pouches in a polyester/cotton carrier. When purchasing undergarments of this type, two carriers should be ordered to permit one to be laundered while the other is worn. Metal fasteners should be avoided, for they can become secondary missiles. Hook and pile tape fasteners, such as those manufactured by Velcro Corp., should be at least 1-1/2 in wide and should provide approximately 2 in of adjustment. In addition, the fasteners should be anchored to a good quality elastic, about 3 in long, to facilitate

FIGURE 6. MALE UNDERGARMENT ARMOR.

FIGURE 7. FEMALE UNDERGARMENT ARMOR.

proper adjustment and to compensate for body movement.

Many manufacturers market loose weave undershirts, such as shown in figure 8, to be worn with body armor. These undershirts appear to improve airflow over the armor to minimize heat build-up and perspiration.

The protective undergarments are also available with special pouches that allow additional ballistic protection by inserting armor panels in the front and, in some cases the rear. These panels may be metal, ceramic, or rigid plastic. It should be recognized that the increased protection applies only to the portion of the torso behind the insert. Thus far, NIJ has not conducted research to determine the effectiveness of such inserts. In general, NIJ believes that armor should provide the rated level of protection over the entire area of coverage, not just isolated areas.

The soft body armor materials permit the design of various other armor configurations, which are sometimes used by police officers when out of uniform. These include the ballistic protective sports

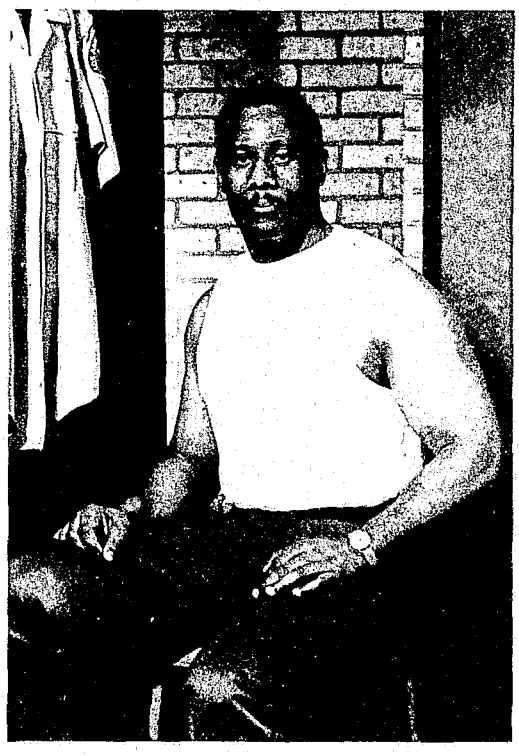

FIGURE 8. LOOSE WEAVE UNDERSHIRT.

coats and vests. In addition, raincoats, and a variety of jackets, all with ballistic liners, such as shown in figures 9, 10, and 11 are available. One can even purchase shirts with ballistic protection, of the type shown in figure 12. Figures 13 and 14 show even more casual appealing protective vests such as a simulated down outer vest and a denim work jacket. There are also numerous designs of tactical protective vests of fabric of the type shown in figure 15. All of these styles of body armor can meet the requirements for NIJ Standard-0101.03.

Body armor to provide protection against the higher threat levels (III and IV), as specified in NIJ Standard-0101.03, will be of either semirigid or rigid construction. Semirigid armor can consist of a somewhat flexible material with impregnated ballistic fabrics or a garment composed of small articulated plates of ballistic material such as steel or plastic reinforced with glass or Kevlar® (GRP and KRP), borrowing from the naturally occurring armor design of the armadillo. Semirigid vests, are difficult to conceal, allow the use of dense materials (high areal density), while retaining limited movement.

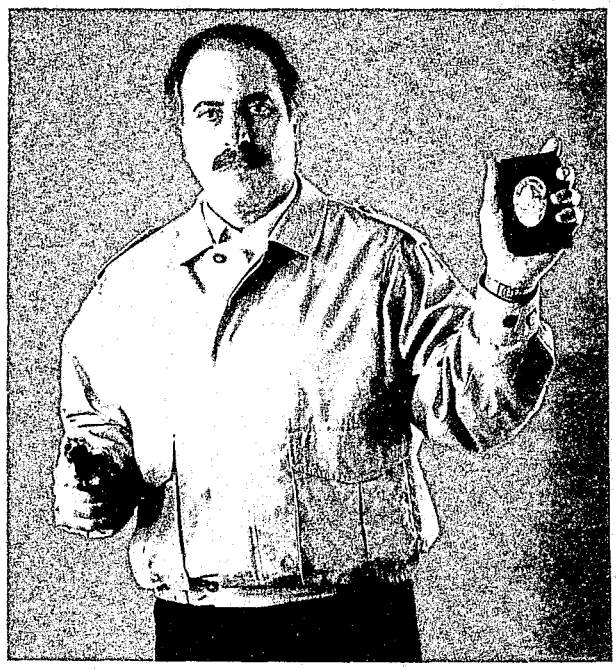

FIGURE 10. MARKSMAN JACKET.

FIGURE 9. RAINCOAT WITH BALLISTIC LINER.

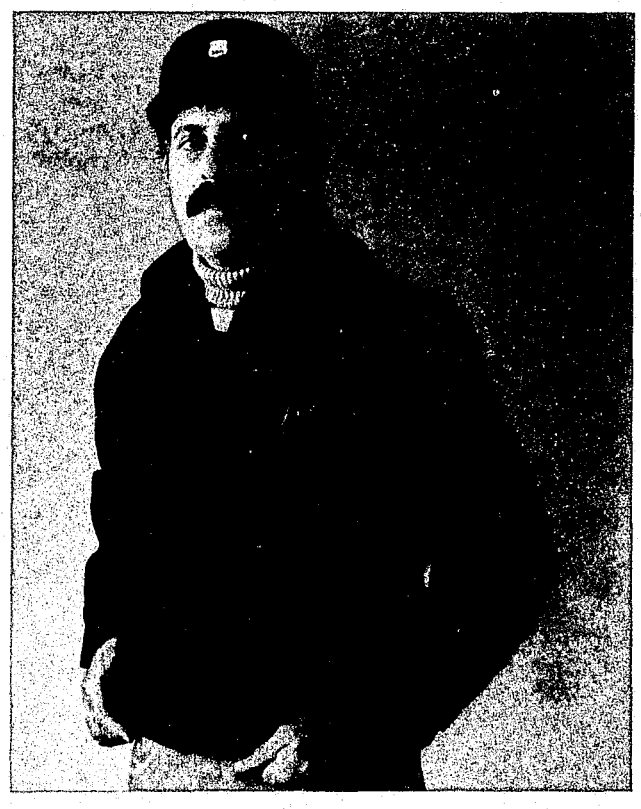

FIGURE 11. POLICE STREET JACKET WITH BALLISTIC LINER.

FIGURE 12. SHIRTS WITH BALLISTIC LINER.

FIGURE 14. DENIM WORK JACKET WITH BALLISTIC LINER.

FIGURE 13. SIMULATED DOWN VEST WITH BALLISTIC LINER.

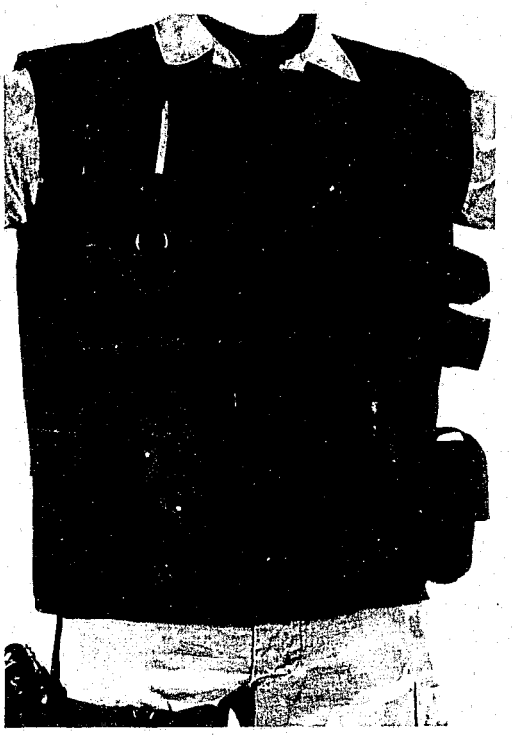

FIGURE 15. SOFT BODY ARMOR TACTICAL VEST.

Rigid body armor is composed of molded ballistic material (GRP, KRP, metals, or ceramics) designed to cover selected portions of the body. Rigid body armor is perhaps the most restrictive of body movement and is also difficult to conceal. Figure 16 shows a typical tactical vest, which incorporates a panel of rigid armor. In general, semirigid and rigid body armors would be used only for short periods when expecting confrontation with high level threats.

GRP and KRP, which will delaminate when struck by a bullet, and ceramic armor constructed as a mosaic with a GRP or KRP backing, have multiple hit capability. Laboratory tests of blunt trauma with respect to use of GRP, KRP and ceramic/GRP or KRP armor have been made. Both materials should significantly reduce the hazard from blunt trauma.

FIGURE 16. TACTICAL VEST WITH RIGID BALLISTIC PANEL.

Comfort And Fit

When selecting armor for full-time routine use by an officer, comfort is a major factor. Armor that is set aside or relegated to the trunk of a cruiser is of no benefit when needed most. The NIJ development effort recognized this as a real world problem, and emphasized comfort in the design of lightweight body armor for police use. Two fundamental factors were considered; fit—from the standpoint of mobility and the weight distribution of the armor, and heat discomfort. Both of these armor characteristics were evaluated by the U.S. Army Natick R&D Command with instrumented anatomical models of the human body. The stresses measured relative to weight distribution resulted in an improved design for the garments. Similarly, the dissipation of body heat through body armor was measured. Those tests demonstrated that, during normal activities, an individual wearing body armor would not suffer unduly from reduced dissipation of body heat; for example, the long sleeve police uniform has about the same heat dissipation as utility army fatigues. Adding the original NIJ vest to the police uniform prevented about the same amount of heat loss as adding a helmet liner to the Army's fatigue uniform.

Comfort, either with respect to fit or heat dissipation, is at best subjective and a matter of individual sensation. However, there are adequate data to suggest that body armor is suitable for full-time use and that an officer should accept minor discomfort in exchange for the protection that is afforded. To resolve questions concerning comfort, members of the department might wear samples of armor on a trial basis before making a major purchase.

Laboratory tests and comments from officers who wear body armor during their daily shifts have identified a number of factors that bear upon the comfort of body armor when worn for extended periods of time. These are illustrated in figure 17.

Coverage

It is possible to purchase armor that covers only the front torso, with a separate section that can be added to protect the rear torso and the sides. An officer that spends nearly the entire duty shift in a vehicle may be tempted to wear only chest protection, but this is not advisable. The statistics bear grim testimony to the importance of using armor that provides FULL COVERAGE. There have been a number of instances, the most recent in 1983, in which officers wearing front-only protection died from wounds to the back. The Uniform Crime Report has provided statistics concerning the use of body armor by officers killed only since 1981. Since then, at least one officer was killed each year as

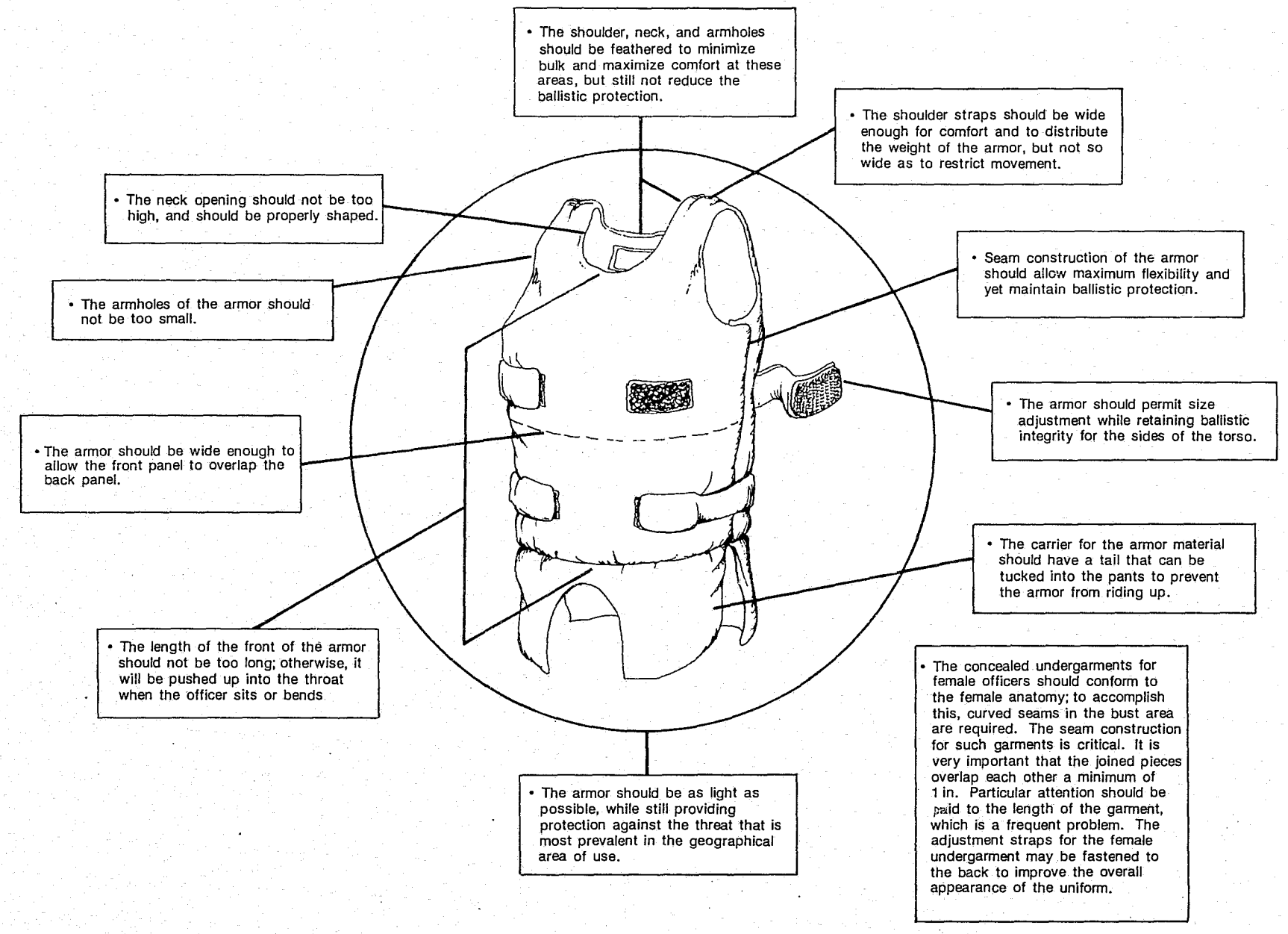

FIGURE 17. DESIGN ELEMENTS THAT CONTRIBUTE TO ARMOR COMFORT.

the result of a bullet entering the body through the side in the open area between front and rear armor panels. There were four such fatalities in both 1982 and 1984 and two in 1983.

Purchasing Body Armor

Any department that is purchasing body armor should require that it comply fully with NIJ Standard-0101.03. In using the standard as the basis for a procurement, determine the threat protection level desired, then the appropriate style of armor. For example, a typical purchase order might be worded:

> "The body armor shall meet all requirements of NIJ Standard-0101.03 (or current edition[8] if a new revision is available), 'Ballistic Resistance of Police Body Armor,' dated April 1987. It shall be of Type II (Higher Velocity 357 Magnum-9 mm), as defined in that standard, and shall afford protection to the torso front, torso back, and sides."

Other characteristics of body armor not addressed by the standard, such as size, weight, launderability, type of carrier and type of fasteners, should be evaluated in terms of what is available and what is needed or desired by the intended users of the body armor. Any additional characteristics of concern to the user as well as sampling plans for product inspection should also be specified in the purchase order.

Although some manufacturers will custom fit each set of armor to the individual officer, most armor is purchased in stock sizes that will reasonably accommodate most police officers. It is recommended that one or more garments in each size be obtained from the supplier for fitting purposes to determine size range prior to ordering in quantity.

Note: The standard also provides a basis for procuring body armor to meet unique protection requirements that are not included within the standard threat level classification. A purchaser needing special ballistic protection should specify the exact test rounds to be used (i.e., caliber, bullet shape, bullet mass, configuration, and velocity) and state that NIJ Standard-0101.03 shall govern in all other respects.

Whenever a department purchases body armor in quantity the procurement should be competitive. TAPIC makes available a list of armor that has been tested by independent laboratories and certified to comply with NIJ Standard-0101.03. The department should select several models from different manufacturers that suit its needs and solicit bids from each. Experience has shown that substantial savings accrue from competitive procurement regardless of the item of equipment.

When a department develops a purchase specification, two actions should be avoided. The first common mistake is to characterize a particular product, equivalent to "rigging" the procurement and ignoring the benefits of a truly competitive procurement. Instead, the department should request bids for armor that has been certified to comply with the standard with specified optional, nonballistic features only if essential. In so doing, reserve the right to purchase vests from the manufacturer that offers armor which the department's officers find most comfortable, even if that manufacturer is not the lowest bidder.

A second, more serious mistake is to go beyond performance requirements and include elements of armor design in the purchase specification; e.g., "the armor shall be NIJ Type II-A, be constructed of X layers of ballistic fabric, and/or weigh a maximum of Y lbs." Realistically, once a manufacturer has developed a specific ballistic panel and has certified that panel to provide the level of protection required of a given NIJ armor type, the manufacturer has little control over the final weight of the armor. The only way to alter the weight is to make the length or width of the panel smaller or larger, or otherwise alter the panel shape. Similarly, if a department specifies fewer layers of ballistic fabric than incorporated in an armor type design, the manufacturer cannot remove layers and still certify that that armor type will conform to the standard for the given armor type. Aside from difficulty in obtaining bids to meet ballistic element design parameters in a specification, the department then must assume liability for the level of ballistic protection of that armor.

Quality Control

There is no present method of determining the ballistic resistant properties of armor other than testing

[8] Prior to using the NIJ standard in a procurement, contact TAPIC (1-800-24-TAPIC or (301) 251-5060 in the DC metropolitan area) to ensure that the most current edition of the standard is used.

it against bullet impact. Commercial testing is expensive, causing many departments to attempt to conduct tests of their own armor—occasionally for quality control purposes, but most frequently in an effort to determine if armor in use for an extended time is still serviceable.

A department that chooses to do some or all of its own armor testing must have proper facilities and qualified personnel and should adhere rigidly to the methods described in NIJ Standard-0101.03. The use of a reliable chronograph and properly conditional clay is MANDATORY. Tests performed without proper equipment (using inadequate substitutes for backing material such as telephone books or Duxseal and commercial ammunition of unknown velocity) are certain to provide erroneous and unreliable information. Further, such test results cannot be related to that obtained through the NIJ Technology Assessment Program certification testing. With the exception of those few departments that can afford research laboratories, we recommend contracting with approved independent testing laboratories for armor testing.

Because ballistic testing is expensive and destructive in nature, it is difficult to provide guidance in the establishment of a quality control program for departments purchasing soft body armor. As a minimum, all departments regardless of size should inspect armor when received and prior to issue. Any evidence of poor workmanship or visible differences from the samples shown before purchase should be discussed with the manufacturer.

Small departments, or those purchasing only a few sets of armor at one time can rely upon manufacturer certification of compliance with NIJ Standard-0101.03 as verification of the level of ballistic protection that the armor provides. Departments that purchase armor in large quantities may wish to conduct quality control testing of representative samples of the armor purchase lot.

A department that elects to establish a quality control program should include full details of the sampling plan in the purchase specification, as well as the acceptance and rejection criteria agreeable to the manufacturer. It will be necessary to increase the purchase quantity by the number of samples to be tested. It will also be necessary to reach advance agreement with the manufacturer on who will do the testing and who will pay for it, whether or not the armor is found to be acceptable.

The complexities and expense of establishing a formal quality control program for armor are such that each department should thoroughly analyze its needs and resources before deciding whether to put one in place.

MAINTAINING BODY ARMOR

When an individual purchases body armor for personal use, or is issued body armor by a law enforcement agency, the first suggestion is obvious—use it all of the time. Body armor can save an individual's life because assaults occur without warning, many under circumstances that would not be expected to result in an attack on the officer, and a vehicle accident can happen at any time.

The proper care of present-day body armor includes precautions when cleaning the garment. Every garment should have a label with instructions on how to clean the components. Follow these instructions, and make sure that your spouse is also aware of correct cleaning procedures. Most armor should be hand washed in hot water with any mild home laundry detergent. **DO NOT USE BLEACH OR STARCH AND DO NOT WASH AT A COMMERCIAL LAUNDRY.** Rinse thoroughly to remove all traces of soap and drip dry **indoors** away from sunlight. Rinsing properly is important, for the accumulation of a residual film of soap can absorb water and reduce the ballistic resistance of the fabric. Perchloroethylene is the only dry cleaning solvent found so far that does not significantly degrade the ballistic protection afforded by current soft body armor. However, to eliminate the possibility of accident, it is recommended that armor not be dry-cleaned. Moreover, **NEVER DRY ARMOR ON AN OUTDOOR CLOTHESLINE, EVEN IN THE SHADE.**

Each time that body armor is washed, it should be inspected for any signs of wear. If it appears that the thread used to sew layers together is wearing badly, or if there is evidence that the fabric is unravelling, the vest should be returned to the manufac-

turer for repair. Officers should never attempt to repair armor themselves under any circumstances.

Some manufacturers market soft body armor with the ballistic panel sealed within a moisture barrier, such as thin plastic or coated cloth, rather than chemically waterproof the fabric. The owner of such armor must routinely inspect it to be sure that the cover of the ballistic inserts has not been cut or damaged so as to allow moisture to penetrate into the ballistic panel. Even if the outer covers have not been cut or otherwise damaged, it is still possible for the moisture barrier to be damaged. When plastic rubs over the ballistic panel as a consequence of the normal flexing of the body armor in use, it can wear through the barrier and expose the armor to moisture penetration. It should also be noted that the plastic overlay tends to make the armor much warmer to wear, for it significantly reduces the rate at which perspiration can evaporate or be absorbed.

Ceramic materials such as boron carbide, aluminum oxide, or silicon carbide are extremely brittle. Such armor should not be dropped on hard surfaces and, when used, the ceramic must serve as the striking (exterior) surface. Hard body armor, particularly the ceramic material, must be handled carefully because it is fragile, and should be inspected first before each actual use to ensure that there are no surface cracks since they degrade ballistic performance.

EXISTING BODY ARMOR

When the current generation of soft body armor was first introduced, the limits of deformation to evaluate blunt trauma protection had not yet been established, and there was obviously not sufficient historical data to enable the establishment of a reasonable service life during which the armor would continue to provide the rated level of ballistic protection.

The performance requirements for deformation were first established in 1978 when the NIJ standard was first revised. As a consequence, armor purchased prior to 1978 was not tested for compliance with the current deformation requirement. Similarly, soft armor manufactured prior to 1985, when the NIJ standard was revised for the second time, was not tested for penetration resistance when struck at an angle. Thus, any department with armor in its inventory that was purchased prior to the issuance of NIJ Standard-0101.03, April 1987, might wonder whether it is suitable for current use, or if it should be replaced. There is no simple answer.

One aspect of body armor replacement is unambiguous: All departments should periodically review the information used to select the level of protection (armor type classification) when the armor was purchased. Changes in service weapon and/or ammunition should be evaluated with respect to the type of armor used by the officers. Equally as important are changes in the weapons or ammunition of the local criminal population. If changes have occurred and increased the threat to the officers, the department should consider upgrading its armor.

To the present time, there are no known instances in which soft body armor has failed to prevent the penetration of a bullet constituting a threat equal to or less than the protection rating of the armor. Also, there are no known instances in which an officer shot under the above circumstances has required surgery for blunt trauma.

There have, however, been instances of officer fatalities resulting from wounds received from weapons/ammunition exceeding the rated protection of the armor. A large East coast police department upgraded all armor to a higher protection level, following two shooting incidents in 1985 in which officers' armor was penetrated; one officer was killed, the other survived.

If the armor issued to officers was not tested to determine if it complies with NIJ Standard-0101.03, even if its rated level of protection (armor type) is consistent with current needs, it would be advisable to verify its performance.

Armor manufacturers changed their model designations at the time samples were submitted to TAPIC for independent laboratory testing to determine compliance with the requirements of NIJ Standard-0101.03. As a result, it is impossible to relate the armor models contained in the current TAPIC Consumer Product List to previously manufactured armor. In the case of armor purchased prior to the 0.1 edition of the standard, it was not tested for blunt trauma protection, and armor found to comply with the .01 edition of the standard was not tested for penetration resistance when impacted at an angle.

Most manufacturers had their armor tested for compliance with the requirements of NIJ Standard-0101.02. Unfortunately, such testing occurred at a time when TAPIC was not operational; testing records are incomplete and the samples tested were not retained in archival storage. Consequently, TAPIC, now operated by a new grantee, cannot validate the results of testing done in accordance with NIJ Standard-0101.02. This means that TAPIC cannot verify that a given armor model was found to comply with the standard, or is identical to that which was tested should the manufacturer certification of compliance to NIJ Standard-0101.02 come into question.

The only way to ensure that armor purchased to a prior edition of the NIJ Standard conforms to the current requirements of NIJ Standard-0101.03 is to test the armor. The names of TAPIC approved independent testing laboratories, together with the individuals to contact to arrange such tests are available from TAPIC.

Since the ballistic testing of body armor is destructive, we would suggest that you test the oldest and most heavily worn set of armor still in service. Give the officer that was issued the old vest a new one that conforms to the current edition of the standard. If the armor fails the test, additional testing will probably be required to determine the extent to which replacement is necessary. If the armor passes the test, you still need to ensure that your officers are aware of the sharp instrument vulnerability, if the armor label does not contain a warning. In fact, it may be prudent to consider placing a cautionary notice on the cover of each set of armor with a permanent marking pen. If you do so, remove the ballistic panels until the ink has dried. DO NOT write over the existing label attached to the armor by the manufacturer.

Even though a department has verified that its armor is of the proper type and conforms to the standard, there are other reasons to consider replacement. The first of these is the individual officer. Bodies can and do change significantly over the years, and armor that is properly sized when purchased may no longer fit. If an officer's body has changed to the point that the armor is so uncomfortable that it is no longer worn, it is time to provide new armor.

The physical condition of individual armor may also influence the decision to replace. If armor has been worn extensively and the edges of the fabric in the ballistic panel are fraying, or if the stitching is beginning to unravel, it should be inspected by the manufacturer to determine whether repair is in order or if it should be replaced. A department should never attempt to repair armor itself. Stains or discoloration of the ballistic panels may be evidence of exposure to bleach, excessive sunlight, or chemicals that could reduce the ballistic resistant properties of manufacturer recommendations concerning the necessity of replacement.

All departments should routinely inspect all armor issued to its officers—this should be done at least annually to assess the overall condition of the entire inventory and to determine whether an individual officer's armor fits properly, has been properly maintained, or is in poor physical condition.

Every set of armor will eventually have to be replaced for one reason or another. Since no two sets of armor are exposed to identical wear or care, it is unreasonable to expect each set of soft body armor to "wear out" in exactly the same period of time.

Limited studies of the ballistic resistant capabilities of armor used for extended periods of time were initiated in 1983, at which time some of the armor that was tested had been in service for more than 8 years. The earlier E. I. du Pont de Nemours Co., Inc., testing [7] and a 1986 study by NIJ [8] both found that **age alone does not degrade the ballistic properties of armor.** Armor manufactured in 1975, but that remained in inventory without issue, exhibited ballistic resistant properties identical to those at the time of manufacture. Both research studies included armor that had been in use for as long as 10 years with ballistic properties that were indistinguishable from that of unused armor manufactured at the same time.

The NIJ tests failed to demonstrate any significant differences in 10-year-old armor regardless of the extent of use or apparent physical condition. In contrast, data from the du Pont study identified used vests with ballistic efficiencies less than that of unused vests. Some of the vests with marginal performance had been in use for periods of time as short as 3 to 5 years. The du Pont researchers concluded that, regardless of age, use and abuse can cause ballistic decay. For example, one poorly performing 3-year-old vest appeared to have been exposed to excessive ultraviolet radiation.

Independent of the above research studies, some departments have established formal replacement policies based solely on the length of time since the date of issuance. Those that we are aware of have selected 5 years for an automatic replacement cycle—possibly because the NIJ guide to body armor issued in 1980 stated that 5 years was a practical service life. The original statement was based on the fact that armor had then been in service for 5 years and was known to provide acceptable performance for *at least* that period of time. We have now ascertained that armor properly cared for retains its ballistic capability even after 10 years of use.

All departments should recognize that a replacement policy should be consistent with the manner in which its officers use their armor. If armor is worn only occasionally (a poor practice at best), the policy might well be limited to budgeting for the purchase of armor for new recruits when hired and replacement of a defined percentage for accommodating problems of fit or excessive wear and tear. Those departments with a high wear rate, however, may wish to select a routine cycle based on length of service.

For most departments, with normally austere budgets, it is desirable to use the longest replacement cycle possible to conserve funds without endangering the officers. Unfortunately, the limited data available prevent the recommendation of a "reasonable life" expectancy based upon age alone. Further, the duPont data suggest significant differences in service life of armor among departments.

It appears that, until further studies are conducted and nondestructive test methods developed, departments have little choice but to conduct ballistic tests of their armor on a routine basis. Departments should initiate test programs to evaluate the ballistic resistant protection provided by existing armor if they can afford to—particularly those with armor six or more years old. We also recommend that tests be conducted while the armor is in the wet condition. If the ballistic properties of armor are questionable, the department should consider replacement.

During the NIJ testing of used vests, two vests were found to exhibit marginal V_{50} ballistic limit when tested wet. Upon retest dry, the ballistic limit was satisfactory. Chemical analysis substantiated the fact that the fabric lacked proper waterproofing—hence, the suggestion of wet testing.

ADMINISTRATIVE CONSIDERATIONS

Training

It is the responsibility of the department to provide suitable training and to inform officers about proper care and use of specific equipment to protect against avoidable injury. All departments should seek to increase the routine use of body armor throughout the entire shift of duty. Some 1200 lives have been saved by body armor as of the summer of 1987. Moreover, of the 191 officers killed between 1981 and 1986 as the result of wounds to the torso, the majority would probably be alive if they had been wearing body armor. An additional 13 officers killed during this period would also be alive if the armor they were wearing at the time of assault had provided full coverage of the sides and back.

A number of departments have issued administrative mandates that armor shall be worn at all times while on duty. In some cases, the orders are properly enforced and the officers do wear their armor. In other cases, the officers ignore the orders and relegate their armor to the cruiser trunk or locker.

Some departments have found that they can increase the routine use of body armor by taking advantage of the tighter control over officers in the police academy setting. These departments issue body armor to each recruit when he or she reports to the academy and require that they wear it at all times throughout the training period. While there are no firm statistics, it appears that such action does promote the routine use of body armor when the recruits are assigned to duty.

Another approach that seems to work is to obtain the officer's commitment to try wearing the armor routinely for a period of 1 month or even longer. If the officer does so, he or she realizes that the armor is not as uncomfortable as expected and continues to wear the armor routinely thereafter.

While we are not aware of documented studies, there appears to be a consensus among most officers that following a short period of wear the armor "softens" and becomes more pliable and comfortable.

When an officer wears body armor routinely, the knowledge of protection against the common threats that will be encountered should be reassuring. However, the officer must keep in mind that the armor was selected on the basis of limited threat protection. There is no "bulletproof" armor, so the officer should not tempt fate. When responding to a call, and it is known that the officer may be exposed to a weapon threat in excess of the known protection provided by normal armor, it is only prudent to obtain additional protection, including ballistic helmets.

The importance of using good judgment at all times cannot be overemphasized in any training program. All departments should require the reading of the Uniform Crime Report, Law Enforcement Officers Killed and Assaulted by all officers. The incidents described in that report each year reinforce the importance of routine use of body armor, to protect against unexpected assaults. Further, they encourage officers to recognize that seemingly routine assignments, such as serving warrants can, and often do, end in armed confrontation.

The department must make sure that each officer knows the level of ballistic protection provided by the armor at the time of issue relative to various weapon threats, and how to maintain the armor. Equally as important, the department must ensure that each officer knows that body armor manufactured from Kevlar® is vulnerable to attack by a knife or other sharp instrument, such as an ice pick, and will not be completely effective against such an attack. All officers should be frequently reminded of these factors during regularly scheduled training sessions.

Issuing Body Armor

Although body armor has been in use for more than a decade, it is still a relatively new technology when compared to other types of police equipment. Much remains to be learned concerning its service life, and efforts continue to devise nondestructive methods of assessing the ballistic efficiency of armor that has been worn extensively.

The first obligation is to ensure that armor fits the officer to whom it is issued, for fit determines whether it will be comfortable, and to a large extent, whether it will be worn. Armor can be special ordered or tailored for those officers with unusual body dimensions.

The NIJ standard requires that body armor provide a blank line for the date of issuance. This should be filled in with a permanent marking pen or stamp when issued to the officer.

It is important to maintain accurate property records for all armor in inventory. The department should at any time be able to determine which armor was issued to each officer together with the name of the manufacturer, model number, armor type, production lot number, and date of issuance.

Proper records will be invaluable if a production lot should be found to be defective after issuance. If armor is purchased from several manufacturers, it will be possible to compare officer satisfaction and use experience over the different products. Good records can also assist in planning for the purchase of new and replacement body armor.

Soft body armor will be frequently returned to inventory, often as the result of an officer retiring or accepting other employment. Armor may sometimes be removed from service because it no longer fits the individual to whom originally issued. Unless the armor shows signs of abuse, it may be reissued to another officer. In one known instance, an officer's life was spared only a matter of days after acquiring armor. That armor had been purchased privately by an officer who sold it on leaving the department. The officer whose life was saved was the fifth owner.

In addition to reissuing armor to full-time police, a number of departments issue to members of their volunteer corps the used armor that has been returned to inventory. Any department that has used, but serviceable, armor in its inventory should try to issue it to someone who will wear it.

Disposing of Soft Body Armor

When soft body armor has reached the end of its useful life and is no longer serviceable, it is important that the department dispose of it in a manner that will prevent inadvertent use.

Current soft body armor will not burn, so incineration is not possible. It is also difficult to cut. As a result, it must be disposed of intact, relegated to landfill burial. For obvious reasons, armor should not be sent to a public, uncontrolled landfill.

E. I. du Pont de Nemours Co., Inc. maintains a controlled disposal site as part of its Wilmington, Delaware facilities and will accept armor from any department, offering a practical means of disposal.

Liability

All administrators are painfully aware of frequent suits against police departments. In the case of body armor the liability issue centers on the protection ballistic-resistant body armor does or does not provide. One officer wearing a vest was killed from ambush with a high-powered rifle. The survivors suit alleged that the officer did not know that the armor, intended to protect against handguns only, was not capable of protecting against a bullet from a high-powered rifle.

Another individual made the fatal mistake of participating in a live demonstration of body armor. The individual encouraged an "assailant" to attack with a knife and subsequently died from wounds received when the knife penetrated the armor. The distributor had covered the armor manufacturer's label with a second label, which stated that the armor would protect against lesser threats than the rated threat level. This resulted in a major suit for compensation against several parties based on the mistaken assumption that a knife is a lesser threat than the ballistic threat specified on the armor label. The NIJ Standard (NIJ Standard-0101.03, Ballistic Resistance of Police Body Armor) defines levels of ballistic protection only. A knife is not a ballistic threat, and when considered in the context of the level of protection provided by ballistic-resistant body armor, it is not a LESSER THREAT, it is an **ENTIRELY DIFFERENT TYPE OF THREAT.**

The claims that have been filed to date involving the loss of life while wearing ballistic-resistant body armor range up to $1 million. A proliferation of claims on the part of survivors can only increase your department's operating costs. Successful claims are likely to increase not only the cost of the body armor, but insurance as well.

Due to incidents such as those described above, the NIJ Standard requires that the manufacturer clearly label the level of ballistic protection that the armor is capable of providing in accordance with the types classified in the standard. In addition, the standard requires that the label on Type I through Type III-A armor include a warning notice that the armor is not intended to protect the wearer against rifle fire and if appropriate, that the armor is not intended to protect the wearer from sharp-edged or pointed instruments.

All administrators should insist on full compliance with the labeling requirements of the standard. The information required by the standard is essential for the officer to know the level of protection provided by the armor, and that it is properly maintained. In addition, the specific manufacturing data are very important. If a given set of armor is found to be defective, the department should inspect all armor from the same production lot, for the entire lot may be defective.

When an Officer Is Shot

The individual officer and the police administrator must be aware of the possibility of blunt trauma. Any officer shot while wearing armor should receive a medical examination as soon as possible. Even though the officer shows no after effects other than soreness or a bruise, the possibility of serious internal injury exists. Prompt medical attention will minimize the risk of serious complications.

The medical staff of the Maryland Institute for Emergency Medicine, Baltimore, Maryland, recommends the following examinations for officers shot while wearing body armor.

- All victims of assault should be hospitalized for observation in spite of apparent state of good health and minimal skin lesion.
- Strikes to the chest should be monitored with serial chest X-rays.
- Strikes to the precordial region require cardiac monitoring and serial ECG's and enzyme determinations.
- Strikes to the abdomen require frequent examinations for signs of peritoneal irritation. Impacts over the liver should be viewed with great suspicion of underlying hepatic injury.

Before the officer returns to duty, replace the life-saving armor with a new set. Retire the armor to a trophy case to advertise gratefully the protection that it afforded. An officer once protected will undoubtedly wear body armor routinely.

APPENDIX A – REFERENCES

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