Aged Body Armour Testing in Development of a Replacement Protocol

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Abstract. At the present time, police forces across Canada do not follow any common guidelines on the safe life expectancy of personal body armour. Some forces automatically replace armour at the expiry of the manufacturer's five-year warranty while others extend service life to ten years and beyond. In the absence of meaningful sample selection and proper laboratory testing of aged armour, any degradation of performance may not be detected, leaving the true ballistic resistance of in-service armour largely unknown. The Canadian Police Research Centre (CPRC) was requested by the Canadian Association of Chiefs of Police (CACP) to investigate this issue towards the development of an Aged Armour Replacement Protocol. This guideline will help to ensure that the body armour worn by Canadian police officers is known to be effective.

In support of this effort, police forces across Canada were contacted to determine their body armour procurement, distribution and replacement practices. Numerous participating forces also provided decommissioned body armour that had been removed from active service to help determine age-related ballistic degradation through laboratory testing. One hundred and fifty NIJ Level II used panels have undergone testing at Biokinetics to the NIJ standard indicated on their certification labels. Beyond supporting the above protocol development, this testing program responded to a request by the Ontario Association of Chiefs of Police (OACP) to investigate age related armour performance degradation.

The development of the Aged Armour Replacement Protocol and the test results of the 150 samples of aged body armour are the integrated topics of this paper.

1. INTRODUCTION

A question exists regarding the "safe" life expectancy of ballistic body armour worn by Canadian police officers. There is currently no accepted practice to determine the proper replacement interval for this essential item. The most commonly cited guideline is to simply replace armour every five years. In the NIJ guide to selection of body armour [1] it suggests that this 5-year period stems from early research begun in 1983 by DuPont [2] as well as an independent 1986 National Institute of Justice (NIJ) evaluation of aged armour [3]. Both research studies included exclusively Kevlar armour and both included vests that had been in use for as long as 10 years. While the NIJ found the used vests had ballistic properties that were indistinguishable from those of unused armour manufactured at the same time, DuPont researchers found reduced performance among poor condition armour and recommended re-evaluation of vests in the 3-5 year range. Nevertheless, the NIJ suggested that for properly maintained armour with no visible signs of wear it should not deteriorate within a five year period of use [3].

In 2003 a police officer in Forest Hills, Pennsylvania was shot in the abdomen and his vest, less than a year old and made with Zylon ballistic material, was perforated. The Forest Hills shooting was the first case where a certified vest failed to prevent perforation by a round it was designed to defeat. The incident prompted the Body Armour Safety Initiative [4]. The NIJ was directed to examine degradation issues associated with Zylon as well as to review the existing process by which bullet-resistant armour was certified.

While significant developments have since been made toward test methods that simulate accelerated ageing, the NIJ stated that there "is no accepted test protocol to evaluate the performance of used body armour over a period of years of typical law enforcement use."[5] However, it requires that a manufacturer's product "demonstrates to satisfaction of NIJ that the model will maintain ballistic performance (consistent with its originally declared threat level) over its declared warranty period."

Canadian police armour replacement policies range from five years (to coincide with the typical manufacturer's warranty) to indefinite service life, replacing a vest only after obvious physical damage, a sizing change requirement, or an officer's departure from service. The NIJ research in the wake of the Zylon incident has drawn much attention to the issue of aged body armour and the need for a scientific basis for replacement.

The Canadian Association of Chiefs of Police (CACP) asked the Canadian Police Research Centre (CPRC) "to investigate the issue of life expectancy of soft body armour with respect to issues including the manufacturer's warranty period and replacement time". Subsequently, the Ontario Association of Chiefs of Police (OACP) requested CPRC to pilot a three year program to investigate "the degradation of ballistic armour material over time" by testing used body armour "in a consistent scientific manner". The OACP volunteered to assist where possible in arranging for the supply of aged armour from Ontario police services to use as test samples, and the CACP similarly encouraged support from other forces in Canada. The work described herein grew out of these two initiatives. One hundred and fifty samples of aged soft body armour retired from active police duty across Canada were laboratory ballistic tested to determine whether the performance of the armour had deteriorated with age. All ballistic testing was conducted at Biokinetics' facility in Ottawa, ON.

2. CONTACT WITH POLICE SERVICES

Initial contact with police services was made via the CPRC booths at the CACP Conference (Montreal 2008) and the OnScene First Responders Conference (Regina 2008). The Ontario Ministry of Community Safety and Correctional Services (MCSCS), in cooperation with the OACP and the Ontario Policing Standards Advisory Committee Body Armour Working Group, prepared an All Chiefs Bulletin in support of the program (2009). Further personal contact was made with major city and provincial police forces across Canada. The objectives were twofold. First was to obtain aged armour decommissioned from use for testing purposes. Second was to solicit information on their armour service intervals and replacement policies.

By the end of testing, samples of aged soft body armour were received with both front and rear ballistic panels for each from twenty two police services from across Canada.[1] Other forces contacted were unable or unwilling to contribute aged armour, but nevertheless contributed information on their purchase and replacement policies.

3. ARMOUR PURCHASE AND REPLACEMENT POLICIES

To clarify, "armour" in this study consists of the ballistic inserts, or shot packs, which are fitted into front and rear pockets in non-ballistic carriers. The armour inserts are made up of a number of layers of high tensile strength woven materials such as Kevlar, Spectra, Dyneema, and Twaron. These layers of fabric are enclosed typically in water resistant nylon pouches. Ballistic armour inserts may rotate through a number of carriers with any one police officer to allow wearing of a clean carrier while a second is being laundered. In addition, the inserts may well continue to be used with a number of different carriers and users over the lifetime of the armour inserts.

The availability of information on armour purchase, service and retirement policy varied considerably among the police services. Nevertheless, a number of common traits were evident:

All of the services feel they are buying armour to an appropriate standard which for the most part is NIJ Level II. Tactical Teams are, of course, regularly issued armour with higher levels of protection, typically NIJ Level III.

There is no coherent, country-wide methodology used to determine when to retire body armour from service. In some cases, an attempt is made to regularly replace body armour at or near the expiration of the typical manufacturers' five year warranty period, without consideration as to whether continued usage

[1] Note that since this initial testing of 150 samples, several other forces listed have contributed armour towards this continuing program.

might be possible. In most cases, armour migrates on an informal basis from its initial issuance to new recruits, through various years of service in active front line duty to a position with an officer assigned to desk duty. This may be as a result of the natural career cycle of an officer or through reassignment of the armour to non front line personnel. Retired armour which appears in good shape is sometimes retained for use in emergency replacement situations where in-service armour has become unserviceable, or for use by VIPs and visitors in ride-along scenarios.

In some cases, armour is regularly inspected and will be replaced if it shows evidence of abnormal wear such as fraying or persistent folds, or if it is subject to unusual events (such as a vehicle crash or immersion in water).

A few forces test samples of their aged armour by subjecting them to firing range shots from service weapons. However, only one police service regularly tests aged armour in a controlled laboratory setting to its initial purchase specification and bases the retirement decision on that testing. As a result, original armour is in service for as few as five years in some forces to in excess of fifteen years in others. With the exception of the one force mentioned, no other force tracks armour issued to officers in terms of purchase lot or manufacturing batch number.

Retired armour is disposed in a number of ways. In some cases the armour is destroyed by cutting or incineration or is shipped to a recycler who cuts it into fine particles for reuse in other products. Otherwise armour may be transferred to another police service that has less stringent policy on the age of armour. This is usually to a developing country but occasionally occurs within Canada as well.

Very few of the multitude of forces interviewed were able to give clear estimates of the quantities of armour purchased and decommissioned on an annual basis.

4. CONSIDERATIONS FOR AN AGED ARMOUR REPLACEMENT PROTOCOL

Since body armour testing is destructive, it is necessary in practice to select a small sample of vests and assume that the test results of this sample reflect the larger population of users. It is, therefore, critical to consider a representative sample in the testing. For example, if attempting to make a statement about used armour in Canada, testing a large number of armour samples donated by a northern force would not be adequate because it would fail to include armour that is subject to the humidity of areas such as the British Columbia coast or the Canadian Maritimes, which may be an important factor. Ideally these factors should be identified up front such that stratified random sampling can help ensure the desired representation.

Such factors may include the manufacturer, armour material and construction, age, number of service years, number of years in storage, type of storage facility (e.g. climate controlled), region (climate) of use, gender of user, user activities (e.g. patrol car, foot patrol, marine duty) and user maintenance practice (e.g. always hung away from sunlight, thrown in back seat of car).

These factors may or may not have a marked effect on performance degradation of a garment. Consultation with the Office of Law Enforcement Standards (OLES) and the National Institute of Science and Technology (NIST) Statistical Engineering Division (SED) confirms that there is little science available at this time to answer which are relevant factors. Most experience in this area stems from the research following the recall of Zylon ballistic fabric from the marketplace, because it was found to suffer degradation of tensile strength under exposure to heat and humidity. However, the factors affecting Zylon do not necessarily affect other ballistic fabrics the same way. Even if the influence of the above factors on ballistic degradation was well understood, the interviews with police forces have revealed that this information is not available on in-service armour.

There exists, as a result, a confounding situation. With respect to armour currently in service, a test sample can not be selected because it might not be relevant. The factors affecting body armour degradation are not known, and even if they were, one can’t tell if the armour has been exposed to them. Furthermore, other than the fact that the armour claims to be NIJ certified, the initial test results of new armour are not available, so there is limited ability even to identify performance degradation.

Consequently a *retrospective* approach applied towards the group of in-service armour will not be feasible. Rather an aged armour replacement protocol for Canadian police services will need to be *prospective*. A similar approach has been adopted in the UK by the Home Office Scientific Development

Branch (HOSDB) whereby armour performance is checked at purchase, then tracked throughout its lifetime and samples are selected periodically for continued compliance testing [6]. Should there be concern that a model has degraded unacceptably, the affected lot may be recalled and new armour issued.

At the time of this writing, work toward such a protocol for Canadian Police Services is underway.

5. TESTING AGED BODY ARMOUR

Samples were photographed and all data pertaining to each armour sample was recorded in a database including manufacturer, model, size, date of manufacture, serial number and where possible material construction and layers of fabric. Any additional information available from the supplying force was also recorded. Since date of retirement from service was not available in all cases, age for our purposes was defined as the time span from date of manufacture to date at testing. By this definition, the age of samples tested ranged from two to seventeen years.

All tested samples were designated NIJ Type II meant to protect against 9mm FMJ 8.0 g and .357 magnum JSP 10.2 g handgun rounds. Manufacturer's labels indicated compliance to standards NIJ-0101.03, NIJ-0101.04 and the NIJ 2005 Interim Standard.[2] A number of samples indicated compliance to "NIJ-0101.03 (To Canadian Testing Procedures)".[3] Only the front panel from each pair was tested. The back panel is held in reserve for future study.

In a cooperative effort with the OLES, the bottom 5 cm was cut from each tested panel and sent to them, along with the confidential test results, for their analysis and materials research. No results are reported at this time.

5.1 Modified and Abbreviated NIJ Testing Protocol

Standardized NIJ ballistic test procedures include a host of criteria related to size, shape, workmanship, labelling and ballistics. Ballistic tests include both Perforation - Backface Signature (P-BFS) and Ballistic Limit (BL) or V50. V50 is a statistical process whereby the speed at which a projectile is likely to perforate 50% of the time is discovered. This is generally found by an iterative convergence of speeds that do and do not perforate. A P-BFS, or V-proof test, checks that the panel can defeat a projectile at a given speed.

For this program only V-proof testing was done. V50 testing would not have been instructive because there was no new armour data for comparison. V-proof testing gives clear feedback to the supplying forces on the performance of their aged armour. Furthermore, the back face signature (BFS) was measured, which is the indent left in the flat clay backing block upon which NIJ ballistic tests are done. The limit is 44 mm for any projectile. Wet conditioning and oblique shots were omitted.

NIJ standards 0101.03 and 0101.04 define primary and secondary projectiles for level II panels. Three shots of the primary projectile form the NIJ "triangle" pattern on the panel, shown in Figure 1. A fourth primary projectile is shot between 1 and 2. A secondary projectile (shot 5) is fired on the line between shots 1 and 3, and again within the triangle (shot 6). The outer shots must not be closer than 75 mm to the outer edge, nor closer than 50 mm to each other. Additional shots may be necessary in the case of speeds that were out of range, as long as the spacing criteria are met. For all testing on aged armour the .357 was the primary round and the 9mm the secondary round.[4]

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[2] Note that NIJ 2005 adopts the same test procedures and failure criteria as the 0101.04 standard.

[3] NIJ-0101.03 (To Canadian Testing Procedures) allows for the smoothing of the garment on the clay-backed ballistic testing surface between shots. Otherwise the garment might become puckered and disheveled after several shots, thus unduly influencing the test outcomes. Later versions of the NIJ standard specifically addressed this issue.

[4] NIJ-0101.03 and NIJ-0101.04 define the primary and secondary rounds differently. However, since the .357 were the dominant threat of perforation in this testing, it was taken to be the primary round for all tests.

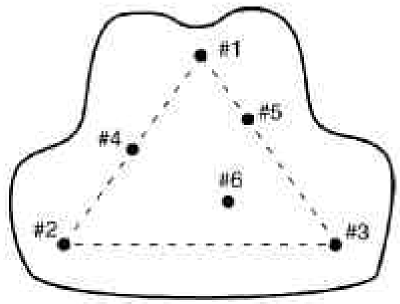

Figure 1: NIJ shot triangle pattern on ballistic panel.

5.2 Bullet Velocity and Overspeed Tests

The test sequence and projectile speeds are provided below in Table 1.

Table 1: Standard and overspeed tests.

STANDARD	LEVEL	CARTRIDGE	PROJECTILE	SPEED m/s	SHOT NO.	*	ANGLE OF INCIDENCE	SHOT SPACING
NIJ 0101.03 (1987)	II	357 MAG	10.2 g JSP	425 - 440	1, 2, 3	BFS	0 degrees	75mm from edge 50mm from previous shot
				446 - 462	4	P		
		9 mm	8.0 g FMJ	358 - 373	5	P		
				412 - 429	6	P		
NIJ 0101.04 (2000)		357 MAG	10.2 g JSP	427 - 445	1, 2, 3	BFS		
				448 - 467	4	P		
		9 mm	8.0 g FMJ	358 - 376	5	P		
				412 - 432	6	P		

*data recorded: BFS = back face signature (44mm max)
P = penetration (yes or no)

Because it is not possible to fire a bullet at a precise speed, the standards allow an acceptable test speed range called "fair".[5] Above the fair speed, a panel might still stop a bullet, but any perforation is not deemed a failure. For certification testing a bullet moving within fair speed range and below must not perforate.

NIJ-0101.03 references a Minimum Required Bullet Velocity[6] of 425 m/s, and defines a fair hit as "an impact velocity no more than 50 ft (15 m) per second greater than the minimum required test velocity".[7] This gives a .357 range of 425 to 440 m/s, but the defining speed is the minimum 425 m/s, not some higher reference number. NIJ-0101.04 on the other hand defines a reference velocity plus or minus a tolerance. For .357 this is 436 ± 9.1 m/s or in other words from 427 to 445 m/s.[8] A similar distinction in the definition of fair speeds for 9 mm projectiles exists between the standards.

Additionally, we introduced the concept of the 'overspeed' test. The idea was that if armour was indeed degrading over time, a failing V-proof test would only tell you that it had degraded to an unacceptable level. However, testing above the V-proof speed could act as an 'early warning' indicator. In

[5] Note that rounds used in standardized testing are hand loaded according to precise recipes. Bullet speeds are carefully verified prior to testing to ensure that the desired speeds are achieved. Yet despite this, there remains some variability in the final projectile speed.

[6] Reference NIJ-0101.03 Table 1.

[7] Reference NIJ-0101.03 section 3.5.

[8] Reference NIJ-0101.04 Table 1.

preliminary shots, the overspeed was set to 10% for both rounds, but it was found that every .357 at this overspeed would perforate, but not any 9mm's. Subsequently .357 overspeed was reduced to 5%, and 9mm overspeed increased to 15%.

Back face signature (BFS) refers to the depth of the depression in the clay backing material upon which the panel is positioned when fired upon. In standard testing, 44 mm is the maximum allowable depth of indentation. In this testing, BFS was only measured for the standard speed .357 projectiles.

6. RESULTS OF FIRST 150 AGED ARMOUR SAMPLES

Test results relating to specific vests have not been disclosed. Makes and models of tested garments are not reported here. The intention is not to single out particular designs or manufacturers but rather to learn about aged armour from the field in general.

6.1 Perforation Data

A summary is provided in the Table 2 below for the 150 front panels tested. With the .357 at standard speed, there were 24 perforations among 18 panels and 175 cases of BFS > 44mm among 105 panels. Fifteen of the panels were perforated within the fair hit speed range. Three were below the minimum speed. At .357 over-speed, there were 66 perforations among 63 panels. There were no 9mm failures at standard speed and only 4 at over-speed. Back face signature was not measured for 9mm rounds.

Because 9 mm failures were non-existent at standard speed, 9mm performance will not be discussed further.

Table 2: Summary test results for 150 panels

Standard	Qty. Panels	Round	Panels Perforated			BFS>44mm
			slow	fair	over-speed	***
NIJ 0101.03*	136	.357	1	12	57	95
		9 mm	0	0	3	n/a
NIJ 0101.04**	14	.357	2	3	6	10
		9 mm	0	0	1	n/a

* includes "To Canadian Testing Procedures"

** includes NIJ 2005 which is functionally identical

*** fair speeds only

For either .03 or .04 panels, it is unknown what number might have perforated at sub-standard speeds, because only errant shots occurred there.

6.2 Perforation Risk vs. Projectile Velocity

The overall data set of .357 shots is illustrated below in Figure 2. Dichotomous data (either perforation or stop) with a general overlap as seen here can be generalized using binomial logistic regression. This generates a probablility function to relate the risk of perforation to the .357 projectile's speed. The equation takes the form of $p(x) = (1+exp(-B_0-B_1x))^{-1}$ and from SPSS data analysis software B_0=0.108 and B_1= -49.399. These factors are used to generate the logist risk curve in Figure 2. The curve suggests that the risk of perforation is approximately 3% at the low end of the fair speed range, which the reader is reminded corresponds to the minimum performance indicated on the armour's stitched label.

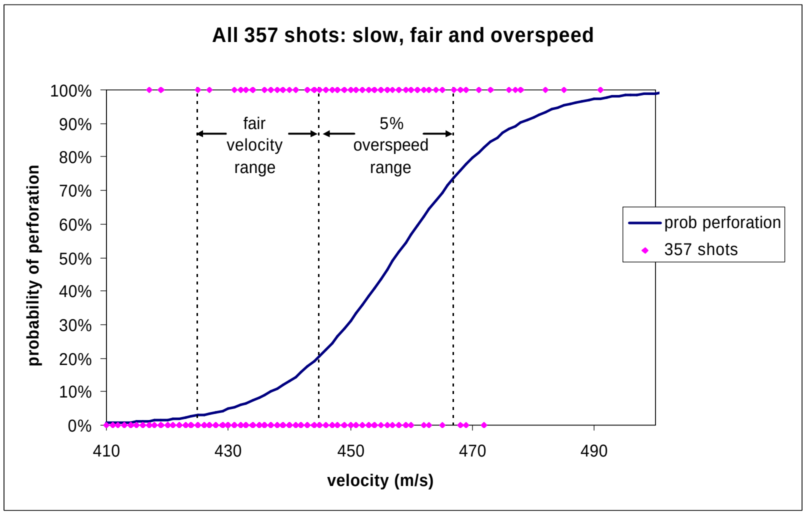

Figure 2: Probability of perforation versus speed for .357 projectile.

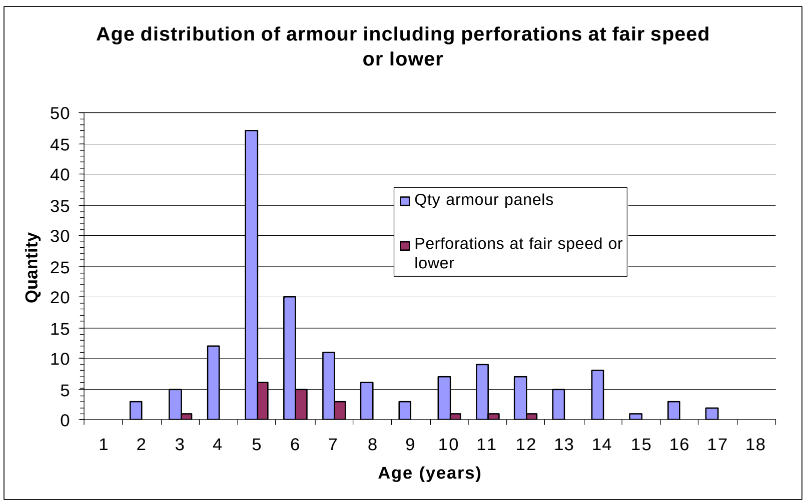

Figure 3: Age distribution of tested armour as well as the fair speed (or lower) perforations.

6.3 Perforation Relative to Age of Armour

The armour tested in this series ranged from 2 to 17 years old. The age is presented from the date of manufacture to the date of testing, rounded down to the nearest whole year. Perforations of .357 rounds at fair speed or lower were experienced in armour as young as 3 years and as old as 12 years.

The age distribution of the armour tested in this series is presented above in Figure 3. Also presented in this figure are the numbers of .357 perforations experienced among the age ranges. The highest failure rates were among the 6-year old (25%) and 7-year old (27%) armours. However, because this particular group of samples does not necessarily correspond to makes and models of current in-service armour, these failure rates are not necessarily indicative of the entire population of products in the field.

Here a logist calculation relating perforation risk to age was not mathematically feasible due to the non-overlapping nature of the data, confirming that there was no clear correlation relating the age of the tested armour to its performance.

6.4 Early Warning Overspeed Indicator

Of the 18 samples that allowed .357 perforations, 11 samples had corresponding .357 overspeed perforations (61%). However, 7 samples allowed .357 perforations at fair velocity and below but *defeated* the overspeed rounds (39%). This implies that the result of an overspeed test is not a reliable indicator of fair speed performance. It further implies that the overspeed test is not effective as an "early warning indicator" of body armour degradation.

6.5 Ballistic Materials

Of the 18 samples that allowed .357 perforations at fair velocity or below, 11 comprised 22 layers of Kevlar fabric, 6 comprised 24 layers of Kevlar fabric and one comprised 27 layers of a hybrid Twaron-Kevlar composite. Areal density was not measured.

6.6 Influence of Garment Size on Perforation

Perforations at fair speed or below occurred in front panels with chest sizes from 34 to 52 inches (mean 44.06 inches, s.d.3.67 inches). There was no apparent correlation of perforation risk with garment size.

7. DISCUSSION

At the outset of this program, two key assumptions were made. The first was that all armour when new would exceed the minimum requirements of the test standard. The second was that armour's bullet resistance would deteriorate over time until at some point its performance was no longer acceptable. While this second assumption is undoubtedly true eventually, the extent of degradation due to time and use alone remains poorly understood. In this testing some 17 year old samples performed as required by the standard for new armour and some 3 year old samples did not.

It is evident that not all armour is created equal, despite claiming compliance with a test standard. Equally built products do demonstrate differences in performance. Ideally there would be a margin of safety to ensure that the band of variation remains above the minimum allowable performance. For ballistic armour this would typically be accomplished by adding extra layers of fabric. This increases cost, increases weight and decreases wearer comfort. Where products are often compared by price and specifications (the purchaser presuming that all perform equally well to the standard), there is little benefit to the manufacturer in adding a substantial safety margin.

This in turn challenges the first assumption. Given a projectile speed range for a fair shot, one would hope that a product would withstand the highest of that range. But it is conceivable that a product may never have actually proven itself at the high end of the fair speed range, but rather the mid or low end. Given the inherent variability of a bullet's interaction with the armour, and the benefit of chance, a design may have been certified without being maximally tested.

Table 3: Confidence level for each version of NIJ standard.

	P-BFS tests		Ballistic limit tests
Standard	Allowed number of perforation per number of shots, for perpendicular impacts*	Calculated confidence level for 5% penetration probability	Number of shots used to calculate ballistic limit
NIJ 0101.03	0/8 shots	34%	N/A
NIJ 0101.04	0/16 shots	56%	12
NIJ 0101.06	0/32 shots	81%	120

* note that angled shots have been omitted from the shot totals

Analysis of the number of shots required to pass the previous NIJ 0101.03 and NIJ 0101.04 standards shows low statistical confidence due to the low number of shots used to assess the ballistic capability of the armour. These early standards would indeed seem to allow for acceptance of armour based on chance alone rather than on the fact that the low probability of penetration observed is genuine. Recognition of this poor statistical power in earlier NIJ standards is shown in NIJ-0101.06, where the statistical sampling has been increased significantly for P-BFS and ballistic limit tests as presented above in Table 3. For completeness, the confidence level for 5% perforation probability is calculated for each version of the standard. For the

NIJ 0101.06, the confidence that the probability of perforation is 5% or less is 81%, whereas it is much less for the other versions. Based on this information, it is possible that some of the aged armours tested would not have passed the more rigorous test methodology in NIJ-0101.06 even if they had been brand new.

In the aged armour testing in this program, we observed in many cases that armour which stopped a bullet sustained tearing of the last layers of fibre, indicating that it was at the cusp of failure. In overspeed tests, a 5% increase in .357 bullet speed was sufficient to cause perforation in 63 of 150 panels (42%).

Of course this does not necessarily mean that the product is safe or unsafe, just that it might not always be "certifiable" to new performance requirements at any stage in its life. In only three cases did we experience perforations below the stated minimum speed stitched on the panel.

To put the test results into context, this brief review of armour ballistic standards is offered. All of the armour tested was produced to meet standards developed by the Office of Law Enforcement Standards and issued by the National Institute of Justice, both based in the United States. The standard which governs ballistic performance of body armour is NIJ-0101. Various versions of this standard have been issued over the years, beginning with NIJ-0101.00 in 1972 and progressing through to the current version NIJ-0101.06 which was issued in July 2008. All of the armour tested was in compliance with the .03 and .04 versions of the standard.

At each revision of the standard a number of changes were made to reflect the additional knowledge which was gained in the subject area in the intervening years. One of the most notable additions to the .06 version was the concept of differing performance requirements for "new" and "conditioned" armour. The latter samples are conditioned by being tumbled for ten days in a controlled heat and humidity environment, as the standard says "…to subject test armours to conditions that are intended to provide some indication of the armour's ability to maintain ballistic performance after being exposed to conditions of heat, moisture, and mechanical wear." New armour is tested with bullet speeds which are elevated above expected street speeds. Armour which has been through the conditioning protocol is tested with reduced bullet speeds.[9] This reduced speed is less than required for new armour but still greater than a street speed of approximately 376 m/s (for the .357 Magnum) [7]. No previous version of the standard included such a performance requirement for conditioned armour.

During the testing of the first 150 armour samples, which was carried out in accordance with the .03 and .04 standards, we experienced some .357 shots which perforated the armour at bullet speeds below that which should have been stopped by the armour when new. However, the speeds were beyond expected performance for the "conditioned" armour in the .06 version of the standard and thus also above expected street speeds for the particular threat, the .357 magnum 10.2 g JSP.

Since there was no change for the new armour test speed for this threat from the .04 to the .06 version of the standard, it is reasonable to review the test results on aged .03 and .04 compliant armour in comparison to the reduced performance level permitted for conditioned armour incorporated into the .06 standard. In this context the aged armour performed acceptably.

A similar rationale may be applied to the backface signature results. While our testing resulted in numerous cases of BFS exceeding the requirement of 44 mm for new armour, the current .06 version of the standard both increases this new armour limit to allow for some BFS up to 50 mm and states under Performance Requirements for conditioned samples that "an excessive BFS measurement will not constitute a failure".

8. CONCLUSIONS

The following conclusions are based on communications with Canadian Police Forces and this initial testing of 150 front panels of aged body armour. The program is planned to continue on additional samples. As more aged armour panels are tested in the future, some of these conclusions may change:

- There is no commonly accepted practice among Canadian Police Forces to replace in-service body armour. Only one force conducted scientific testing as the basis for armour replacement.

[9] For conditioned armour NIJ 0101.06 defines a .357 fair velocity range of 399-417 m/s.

- There is insufficient information available about the causation of armour degradation and there is insufficient information about the usage history of in-service armour to recommend a *retrospective* sampling and testing protocol for armour presently in the field. A successful replacement protocol will need to be *prospective* in nature.
- One hundred and fifty samples of decommissioned police body armour were obtained from Canadian police departments. Of the 150 panels tested, eighteen (12%) failed in .357 perforation within the fair velocity range of certification testing. Only three panels (2%) failed to defeat a projectile below the stated minimum speed of protection. These armours were certified to the NIJ-0101.03 and .04 standards. If these results are reviewed within the context of the new NIJ-0101.06 standard which allows a margin for performance degradation for conditioned samples, overall performance remains within current requirements.
- Of the 150 panels tested, one hundred and five panels (70%) exceeded the minimum back face signature of 44mm. Again, when reviewed in light of the new NIJ-0101.06 standard for conditioned samples, these results are within current requirements.
- Based on the particular makes, models and ages in this test series there is insufficient evidence to suggest that bullet resistance necessarily decreases in a predictable way with age, beyond some initial change as reflected in the new standard. More likely the aged performance of a particular armour is most related to the quality and robustness of its initial design and materials and thus its initial performance when new. This hypothesis is supported by the low statistical confidence of perforation resistance in NIJ-0101.03 and .04.
- The concept of ballistic testing at elevated speeds to provide some advance warning of deteriorating armour appears to be ineffective.
- Further testing of aged armour should continue with target speed centred on the minimum allowable speed for new armour. In this fashion, some shots will be too slow and some within the low end of the fair range. Most will be above the .06 requirements for conditioned armour. Any perforations in this regime will be a clearer indicator of an armour's true aged performance as related to officer safety.
- The armour samples tested in this report were *not specifically selected* as representative samples of armour in continued use by police forces. This was armour already decommissioned from service and otherwise slated for disposal. There is no way to know how this tested armour relates to the population of armour currently being worn in active police service.

Acknowledgements

The authors would like to thank sincerely all of the Canadian Police Forces who supplied aged body amour and/or otherwise contributed to this program.

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