

Aged Body Armour Testing: Further Results

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Background

- Police forces across Canada and USA do not follow any common guidelines on the safe life expectancy of personal body armour
 - No such guidelines exist
 - Some automatically replace armour at the expiry of the manufacturer's five-year warranty
 - Others extend service life to ten years and beyond.
- The Canadian Association of Chiefs of Police (CACCP) and the Ontario Association of Chiefs of Police (OACP) asked the Canadian Police Research Centre (CPRC) to investigate this issue
 - Intent to develop an Aged Armour Replacement Protocol.

Objectives

- Assess if there is degradation of armour performance due to aging using Vproof tests and ballistic limit tests (V50)
- Investigate if there is failures of NIJ compliant armours

Phase I study

- Results presented at PASS 2010
- Vproof tests on 150 armours (0101.03, 0101.04 & 0101.05 Level II)
- All armour withdrawn from police forces inventory
- Aged between 2 and 17 years old
- Shots done within and below the fair range for NIJ Level II
- All shots done with 0.357 Magnum JSP round

Phase 1 study results

		Phase 1		
		Qty.	Failure Rate (%)	CI
NIJ 03	Perforations below fair range	1	1.2	0.0
	Number of shots below fair range	83		4.8
	Perforations within fair range	15	5.1	2.0
	Number of shots within fair range	293		8.5
NIJ 04 & 05	Perforations below fair range	3	37.5	12.5
	Number of shots below fair range	8		75.0
	Perforations within fair range	5	15.2	6.1
	Number of shots within fair range	33		27.3

Phase II study

- Additional objective: Try to explain failures observed in Phase I
- Divided into two parts:
 - Execute Vproof test on another series of 150 armours retired from police force
 - Execute V50 tests on the back panel of the first 150 armours
- Same procedure as in Phase I

Armour samples

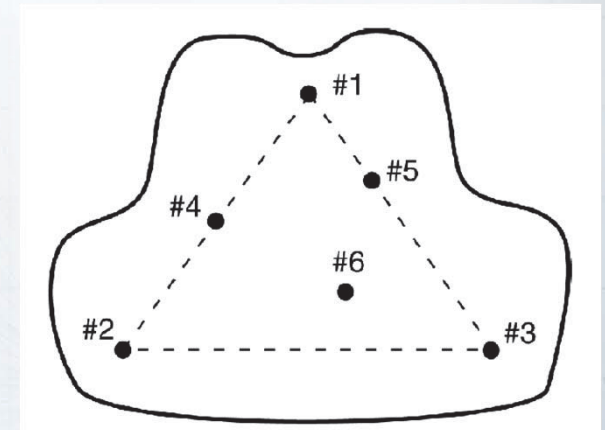
- Twenty two police forces across Canada (Alberta, Ontario, Nova Scotia and Saskatchewan) donated soft body armour removed from service.
- All compliance to either NIJ-0101.03, NIJ-0101.04 and the NIJ 2005 Interim Standard with a number of samples indicating compliance to “NIJ-0101.03 (To Canadian Testing Procedures)”.
- All armour were rated NIJ level II.
- The age of the armour ranged from 1 to 17 years old.
- All armours were made from 18 to 35 layers of Aramid.
- Not feasible to obtain complete information on the service history of each garment

Age statistics	Phase 1	Phase 2
Average	7.9	7.7
Standard deviation (SD)	3.59	4.13
Maximum	17.6	16.2
Minimum	2.1	1.3
Median	6.6	6.2
Number of samples	150	157

Test method (1)

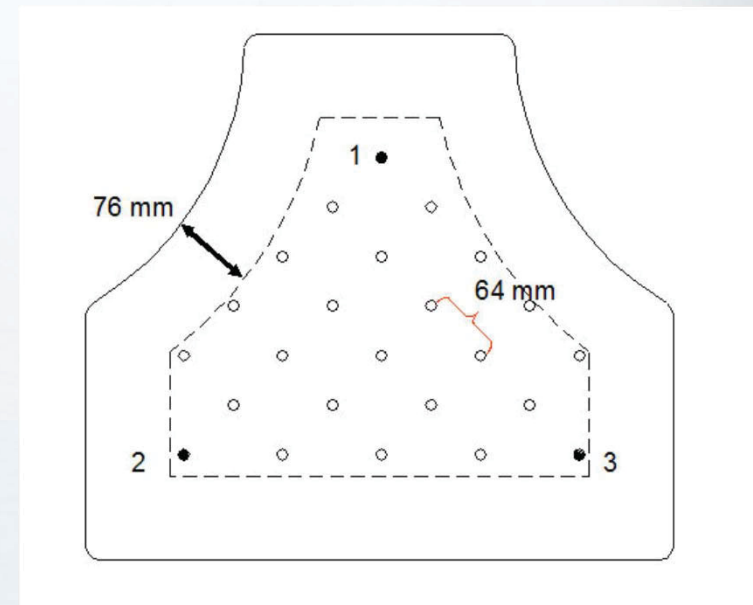
- Vproof tests

- Triangular shot pattern as described in the NIJ 0101.03, 0101.04 and NIJ 2005 standards for NIJ level II body armour was used
- All 6 shots were done perpendicular to the body armour (within $\pm 5^\circ$) and
- All shots done with the .357 Magnum JSP round.
- Shot spacing was 75 mm from any edges and 50 mm minimum from previous shots.
- All armours were backed with calibrated Roma Plastilina, as per NIJ standard
- Measurements included impact velocity and backface signature (BFS) for each shot that impacted the armour within fair range
- All shots were done at ambient temperature.
- Fair velocity ranges for the .357 Magnum were:
 - NIJ 0101.03: between 425 and 440 m/s
 - NIJ 0101.04 and 05: between 427 and 445 m/s

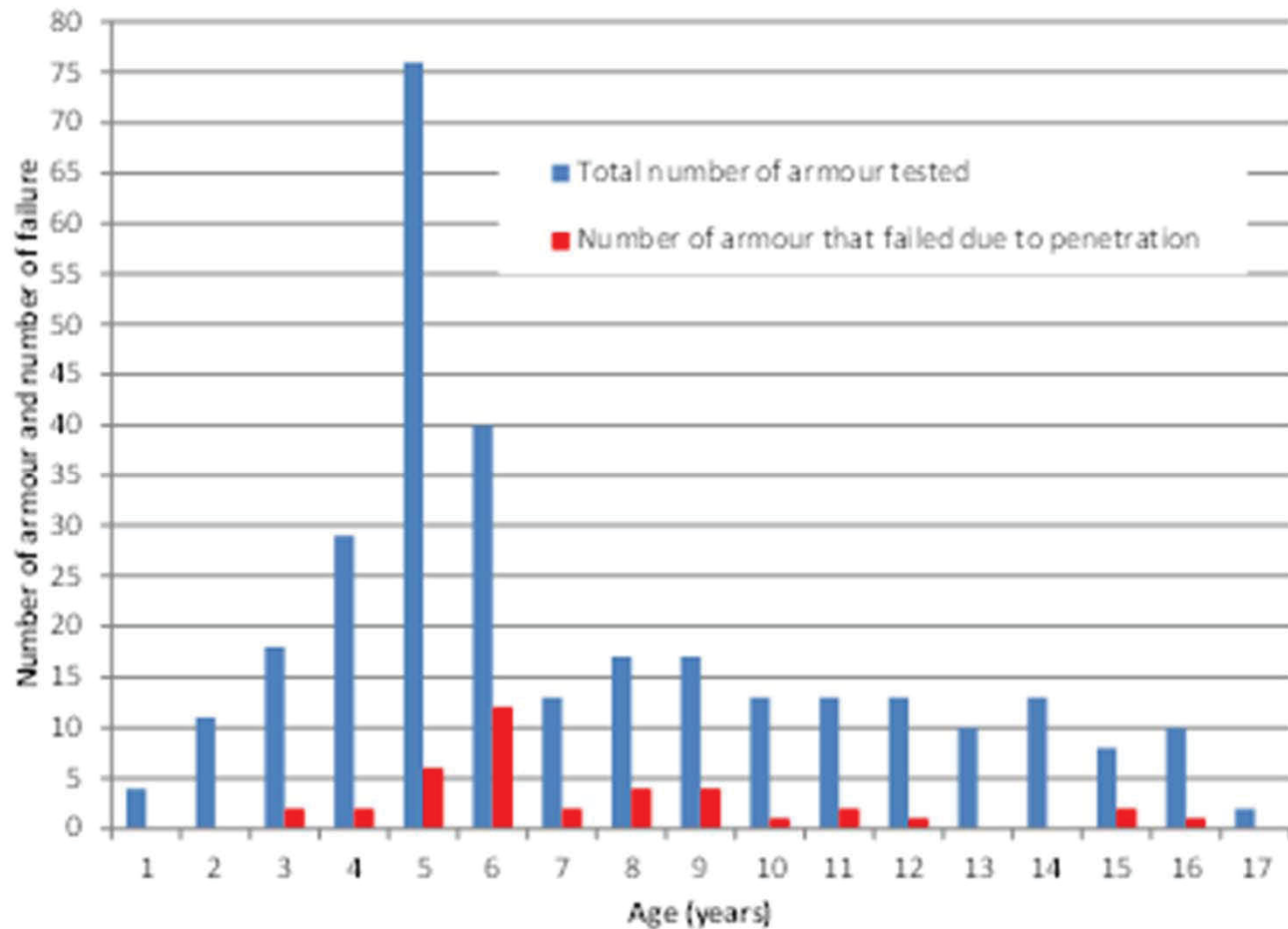


Test method (2)

- Ballistic limit tests
 - Followed methodology defined by MIL-STD 662F
 - Up-and-down method
 - The V50 was calculated using the arithmetic mean based on six shots (3 “highest partial” and 3 “lowest complete” impact within a velocity spread of 45 m/s.
 - In some cases up to ten shots were necessary to achieve this criterion.
 - Backing material used was Minicel® instead of Plastilina to facilitate testing.
 - Shot spacing was 76 mm from any edge and a minimum of 64 mm between shots (Figure 1).
 - The first shot was the topmost point on the armour, and the second and third shots were in the bottom corners. The next shots were directed at the interior dots, spacing them apart from each other as specified.
 - All shots done at ambient temperature and perpendicular to the armour (within $\pm 5^\circ$)



Results: Failure histogram



Results: Failure rates

		Phase 1			Phase 2		
		Qty.	Failure Rate (%)	CI	Qty.	Failure Rate (%)	CI
NIJ 03	Perforations below fair range	1	1.2*	0.0	5	1.9*	0.0
	Number of shots below fair range	83		4.8	262		4.2
	Perforations within fair range	15	5.1*	2.0	17	3.8*	1.8
	Number of shots within fair range	293		8.5	449		6.2
NIJ 04 & 05	Perforations below fair range	3	37.5**	12.5	1	0.8**	0.0
	Number of shots below fair range	8		75.0	129		2.3
	Perforations within fair range	5	15.2***	6.1	2	1.8***	0.0
	Number of shots within fair range	33		27.3	110		4.5

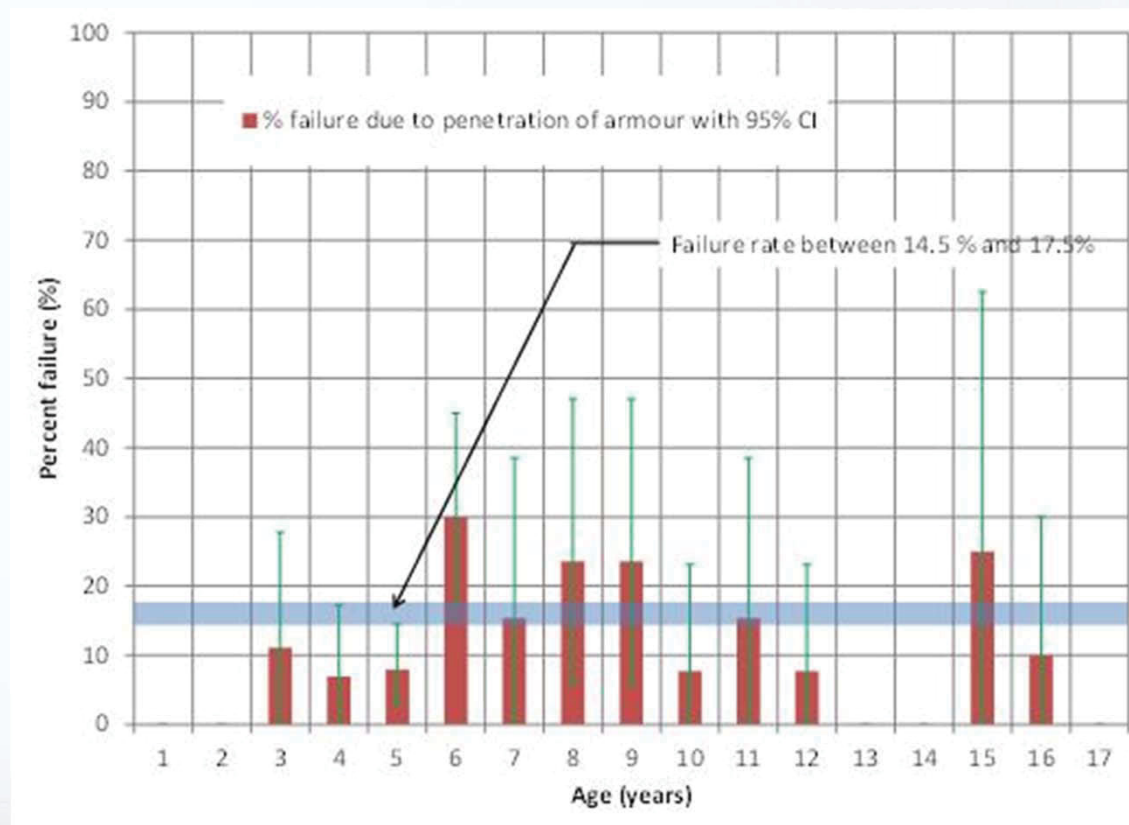
* Confidence interval: 99%

** Statistical difference between Phase 1 and Phase 2 (at confidence level p=95%)

*** Statistical difference between Phase 1 and Phase 2 (at confidence level p=90%)

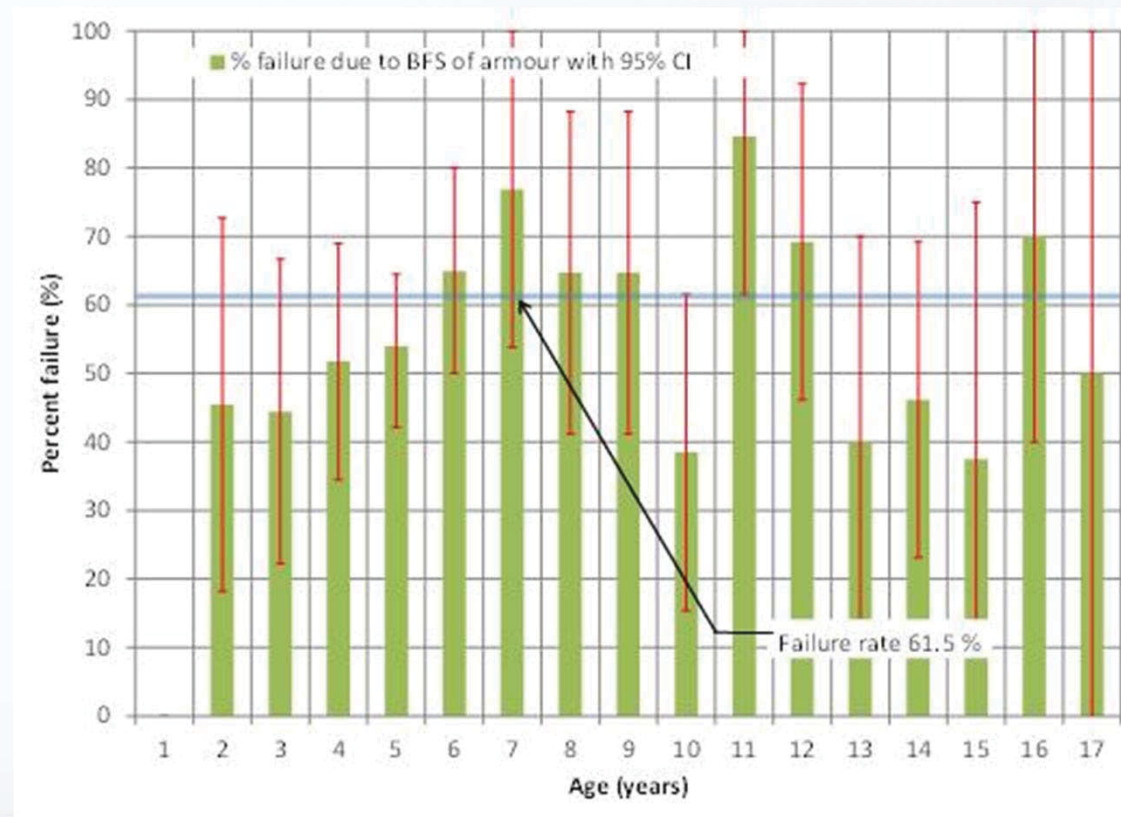
Failure rates due to penetration versus age

- No correlation with age
- Error bars are large
- Failure rate between 14.5% and 17.5%



Failure rates due to BFS versus age

- No correlation with age
- Error bars are large
- Failure rate 61.5%



Ballistic limit tests

- Fair velocity ranges for the .357 Magnum are:
 - NIJ 0101.03: between 425 and 440 m/s
 - NIJ 0101.04 and 05: between 427 and 445 m/s
- Vproof tests done on clay – V50 tests done on minicell
 - Minimum V50 value quite close to fair velocity range

	V50 values measured	SD values measured
Average	479.4	13.9
SD	13.7	3.0
Maximum value	528.8	20.2
Minimum value	449.2	5.9
Average error on V50*	± 14.6	
Maximum error on V50*	± 21.2	
Minimum error on V50*	± 6.2	
Number of armour tested	120	

* At the 95% confidence interval

Discussion

- No correlation between
 - Age and test failure
 - Age and V50
 - Possible explanation: variation in make, manufacturer and police force requirements are quite large, although they all claim certification to some version of NIJ Level II
- Attempt to refine the process by selecting data applicable to a single manufacturer or for one particular police force did not show any trends.

Discussion

- Failures:
 - Analysis of the Vproof data for Phase 2 confirms the observations that were made in Phase 1
 - Possible explanation:
 - Safety margins seem quite low
 - Process to approve armours (number of shot done) resulted in low confidence level that observed sample actually represents reality

Standard	BFS tests		Ballistic limit tests
	Allowed number of perforations per number of shots, for perpendicular impacts	Calculated confidence level for 5% perforation 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

Conclusion & Way ahead

- No correlation between
 - Age and test failure
 - Age and V50
- Failures:
 - Process to approve armours (number of shot done) resulted in low confidence level that observed sample actually represents reality
- Way ahead
 - This study might have been affected by many uncontrolled variables: samples from many sources, different material, variability of service use, sample from different manufacturers, etc.
 - To mitigate these effects
 - Study a batch of 7 years old armours from one manufacturer and from the same lot (naturally aged armours).
 - Acquire 100 new armours made from the same manufacturer with the same material
 - Execute V50 tests on the 50 naturally aged armours and compare to V50 tests on 50 new armours and 50 new armours environmentally degraded as specified in NIJ 0101.06 standard

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