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SKIN PENETRATION ASSESSMENT OF NON-LETHAL PROJECTILES

Edition B, Version 1
JULY 2021

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NORTH ATLANTIC TREATY ORGANIZATION (NATO)

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NATO LETTER OF PROMULGATION

15 July 2021

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS

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RECORD OF SPECIFIC RESERVATIONS

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CHAPTER 1 INTRODUCTION

1.1. SCOPE

The scope of this document is to define an assessment method, in line with the current state of science, to quantify the risk of skin penetration of non-lethal projectiles. The method is based on impacts on a surrogate. The penetration criterion comes from non-lethal projectile impacts on PMHS [1, 1, 3, 3, 3]

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CHAPTER 2 METHOD USING A SURROGATE

2.1. DEFINITIONS

2.1.1. Surrogate

The internal component of the surrogate used to assess the occurrence of penetration is composed of 20% by mass ballistic gelatine.
The external covering is composed of an outer layer of natural chamois and an inner layer of 6 mm closed cell foam.

2.1.2. Penetration

A test will be categorized as a penetration if the test results in visible damage to the gelatine, after careful examination. Visible damage is defined as cracks or penetration of the projectile into the gelatine with or without perforation of the layers.

2.2. REQUIREMENTS

2.2.1. Criteria

A kinetic energy projectile is considered not to cause penetration at the specified shooting distance if zero penetration occurs during the test (see section 2.5.4). If a penetration occurs during the test sequence, the remaining rounds will be tested in the sequence and all results will be recorded.

2.3. TEST FACILITY AND EQUIPMENT

This section describes the equipment to be used for the assessment of the skin penetration.

2.3.1. Test facility and arrangement

The test facility employed for the skin assessments shall provide the necessary conditions to meet the requirements stated in the following sections. The skin injury test arrangements shall be similar to those shown in Figure 1.

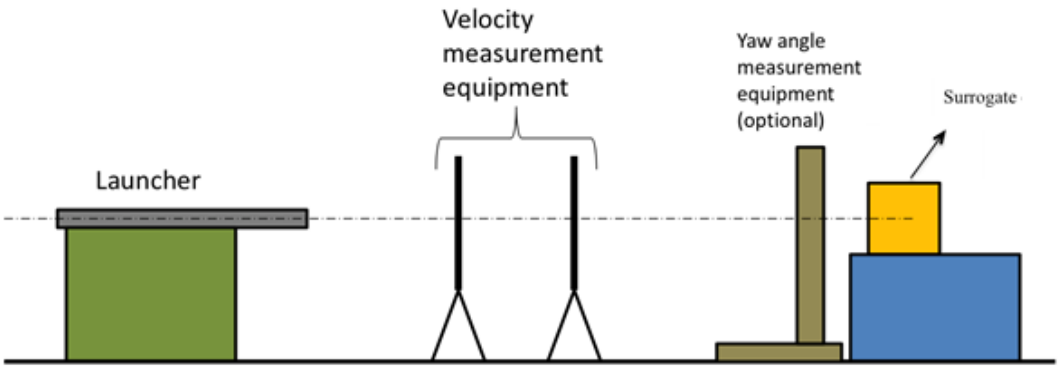

Figure 1 Example of experimental arrangement used for ballistic testing

2.3.2. Launching system

The test weapon/launcher shall be the original system or as close as possible. If for any reason (e.g. shooting distance, hit probability) the original system cannot be used, a proof barrel may be used. In this case, the National Authority has to verify that the impact conditions (velocity, yaw) are equivalent to the original system.

2.3.3. Characteristics of the surrogate

The distance between launcher and target should be chosen on the following parameters:

- User's requirements
- Manufacturer's instructions

1. Gelatine

Gelatine blocks will be made in 20% concentration by mass (80% water) and will be stored at 10°C prior to use. In order to offer a maximum surface for the ballistic test procedure, it is advisable to use a gelatine cube with an edge length of 25 cm. All faces of the cube can be used for the ballistic test. The gelatine recipe is presented in **Error! Reference source not found.**.

2. Foam

The foam used in this test procedure is 6 mm Darice closed cell foam available from DollDoo, 8521 Spencer Court, North Ridgeville, OH 44039-4493, USA; www.dolldoo.com.

3. Natural chamois

Natural chamois has to be used. The area density should be between 233 and 339 g/m^2.

4. Surrogate construction

The external covering will be placed on the front face of the gelatine (Figure 2). The layers will be secured to the gelatine with adjustable elastic straps.

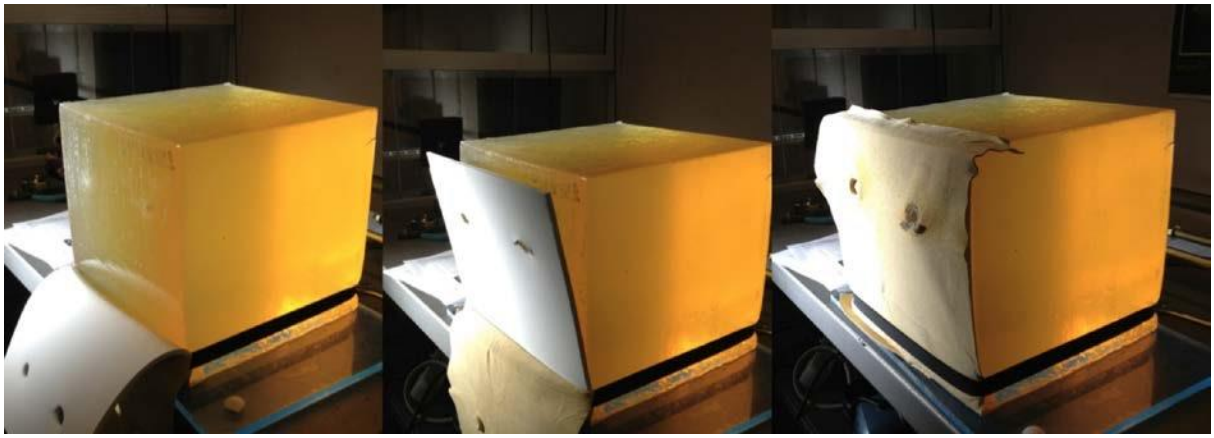

Figure 2 Surrogate construction

5. Launcher to target distance

The launcher to target distance should be chosen based on the following parameters:

- User's requirements
- Manufacturer's instructions

6. Projectile velocity measurement system and method of correction

The velocity of each projectile shall be measured and if necessary corrected to give the striking velocity. Recommended measurements systems are:

- Doppler Radar
- Optical Screen
- High speed camera

When a velocity other than striking velocity is being measured, this will be corrected, using any accepted method, to allow for the distance between the point at which the velocity is measured and the point at which the projectile was expected to strike the target, using the velocity decrement, in order to give the striking velocity.

7. Impact angle control equipment

The equipment used to position the target shall ensure that the required impact angle to the line of fire is achieved at the intended point of aim on the target (Target obliquity).

8. Projectile yaw measurement

The laboratory should have a method for the yaw measurement. Any suitable method (e.g. yaw card, orthogonal photographic system or flash X-ray system, etc.) that does not in itself cause projectile instability can be used.

2.4. EQUIPMENT CALIBRATION

Before the start of the test, the gelatine has to be properly calibrated. The procedure is described below.

2.4.1. Gelatine

Before ballistic testing a calibration shall demonstrate that the support material has met the homogeneity requirements. The calibration shall be carried out in the same ambient conditions that are used for the ballistic testing.

Calibration of the gelatine shall be in accordance with standard gelatine calibration procedures. Calibration will be completed for each gelatine block used prior to the test.

A lead 4.5mm (0.177”) caliber projectile with a mass of 0.53 g (8.17 gr) travelling at velocity between 120 m/s and 230 m/s is used for calibration. At least 3 shots per blocks should be performed. The impact locations should be at least 3 cm from the border of the block, and at least 3 cm from one another. The impact velocity and the depth of penetration should be measured for each test. The setup and the velocity measurement devices are the same as those described in section 2.3.1 and 2.3.3.6. The tests results in term of penetration depth as function of the velocity should fall within the corridors defined by the following coordinates (Table 1):

Impact velocity [m/s]	Penetration depth [cm]
122.4	2.1
122.4	5.9
228.8	7.6
122.4	11.4

Table 1 (Impact velocity - Penetration depth) Coordinates of the corridor of validation for performing the validation of the gelatine

The calibration should be performed not earlier than 3 hours before the test. The block should be reconditioned at 10°C at least 1 hour between the calibration and the test.

2.5. BALLISTIC TEST PROCEDURE

This section describes in chronological order the conditions, materials and test procedure for the ballistic testing.

2.5.1. Target description and inspection

Prior to testing, each target shall be visually examined to verify that no defect or other damage exists at the impact location.

2.5.2. Test area ambient conditions

The ballistic testing shall be carried out at a temperature of 20°C with a tolerance of ± 5°C. All testing has to be completed within 45 minutes upon removal of the sample from the test facility. The temperature and relative humidity values of the test area shall be measured within five minutes before and after each test. The average temperature shall be stated in the final report.

2.5.3. Conditioning of the target and material

Gelatine shall be conditioned to 10°C ± 2°C between 24 hours and 48 hours prior to the calibration test sequence.

Cartridges shall be conditioned for a minimum of 24 hours at a specified temperature with a tolerance of ± 2°C.

2.5.4. Number of impacts

To achieve 95% confidence that the true failure probability is about 10% or lower, the number of impacts shall be 28 (assuming a normal distribution).

2.5.5. Shot patterns

To obtain a reproducible and fair assessment the impacts shall respect certain minimum distances edges, and previous impacts.

The minimum shot-to-edge distance shall not be smaller than 2 calibers. The minimum shot-to-shot distance shall be 3 calibers.

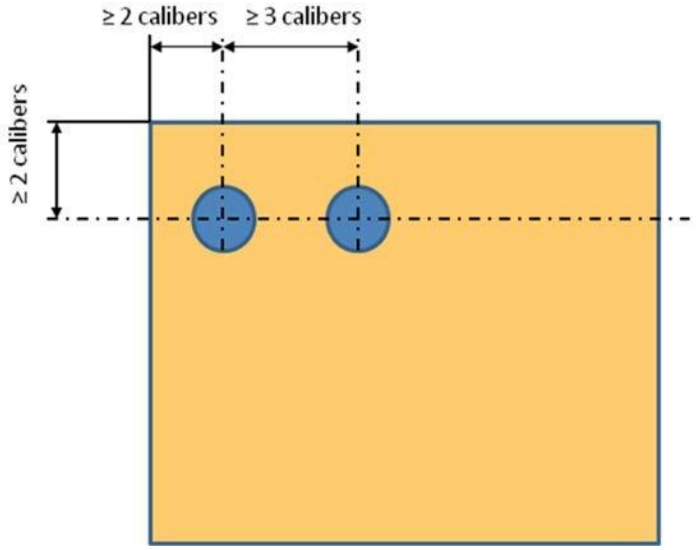

Figure 3 Shot pattern

2.5.6. Projectile velocity measurement

The velocity of each projectile shall be measured and if necessary corrected to give the striking velocity.

2.5.7. Results

Visually inspect the surrogate to determine the result (criteria: see section 2.1.2). Measure and record the result on the Test Data Sheet.

1. Impact validity assessment (fair shots)

All impacts, which are included in the assessment of the skin, shall be fair shots. An impact is only to be considered fair when the following conditions are met:

- The positions of the impacts are in accordance with values described in Section 2.5.5.
- If the original system is used, the impact conditions are considered to be fair.
- If the original system is not used, the impact conditions should match the one from the original weapon.

After each shot, a visual inspection of the surrogate has to be performed to avoid the presence of shreds of projectile between the gelatine and the chamois or foam; or to avoid deformation of foam or chamois, which could influence the result.
The launcher to target distance is in accordance with the definition in section 2.3.3, point 5.

2. Observations and records

For each assessment the following minimum observations are to be made and records kept.

- Target identification
- Shooting distance
- The date of testing
- Conditioning temperature and duration
- Test area ambient conditions (TPH)
- Details of the weapon/launcher
- Details of projectile used (type designation, manufacturer, batch or id number)
- Description of the shot impact location
- Result of Yaw measurement – if required
- For each shot:
    - Impact location on the block
    - Fairness of shot
    - Shot number (traceable to the target)
    - Projectile velocity
    - Impact angle and yaw angle – if required
    - The shot information shall be reported in the order fired
    - The penetration result
    - The nature of any other reactions by the test item
- Calibration results of the surrogate (or a reference to it) used in the assessment
- Striking velocity vs measured velocity

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CHAPTER 3 REFERENCES

[1] C. Bir, S. J. Stewart and M. Wilhelm, "Skin Penetration Assessment of Less Lethal Kinetic Energy Munitions," *Journal of Forensic Sciences,* vol. 50, no. 6, pp. 1426-9, 2005.

[2] "STANAG 2920 - Classification of Personal Armour, Edition 4," NATO Standardization Office, 2015.

[3] L. Koene, M. L. van Essen, A. Oukara and A. Papy, "Assessment of skin penetration of kinetic non-lethal projectiles using the surrogate method," in *28th International Symposium on Ballistics*, Atlanta, GA, USA, September 22-26, 2014.

[4] M. J. van der Horst, S. R. Meijer and M. Philippens, "Test and Injury Assessment Methods for Non-Lethal Kinetic Energy Projectiles," in *6th European Symposium on Non-Lethal Weapons*, Ettlingen, Germany, 2011.

[5] I. Horsfall, T. Ringrose and C. H. Watson, "A Statistical Approach to Proof Testing," in *Personal Armour Systems Symposium (PASS)*, Brussels, Belgium, 2008.

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ANNEX A GELATINE RECIPE

The 20% gelatine manufacturing process for one block is the following:

1. Prepare 3.125 kg of powdered gelatine and fill the Bain-marie container with 12.5 l of water at a temperature between 20°C and 25°C;
2. Incorporate the gelatine slowly and in small quantity so that it soaks properly with water and to avoid the foaming. Mix continuously using an appropriate mixer;
3. After incorporation, leave the mixture at rest for 15 to 20 minutes so that all the particles are well impregnated;
4. Heat the mixture to 50 °C and let the mixture rest for a certain amount of time in order to obtain a homogeneous liquid mixture;
5. Pour the mixture into a mold and remove the remaining foam at the surface;
6. Leave at rest for 10 min so that the air bubbles disappear;
7. Put the mold in a cold room at 10°C for at least 16 hours;
8. To facilitate the unmolding, immerge the block in 70°C water for a few seconds, then turn them over on a flat surface in order to unmold them;
9. Remove the excess of liquid gelatin and smooth the faces of the block;
10. Put the block in a cold room during 24 hours before the test.

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ANNEX B REVISION HISTORY

Various changes have been made to the document for consistency purposes between all AEPs.

1. Phraseology and format

AEP94 has been made consistent with AEP103 regarding chapters, sections and table of contents and accordingly few sentences have been adapted according to the AEP103.

2. Projectile velocity measurement system and method of correction

High speed camera has been added as mean of measurement.

3. Force wall method

The force wall method is currently removed, pending a potential update.

4. Gelatine recipe

Gelatine recipe has been added.

5. Gelatine calibration

The method has been adapted.

AEP-94(B)(1)