PROBLEMY MECHATRONIKI
UZBROJENIE, LOTNICTWO, INŻYNIERIA BEZPIECZEŃSTWA

PROBLEMS OF MECHATRONICS
ARMAMENT, AVIATION, SAFETY ENGINEERING

ISSN 2081-5891; E-ISSN 2720-5266 **https://promechjournal.pl/**

Analysis of the Possibility of Elimination of Threats Resulting from the Modification of Bullet Trajectory after Hitting the Target in Garrison Shooting Ranges

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Received: July 11, 2022 / Revised: August 7, 2022 / Accepted: November 4, 2022 / Published: June 30, 2023.

2023, 14 (2), 109-126**;** https://doi.org/10.5604/01.3001.0053.6674

Cite: Chicago Style

Gacek, Józef, Wojciech Koperski, Dariusz Tymiński, Bronisław Marciniak, Ryszard Woźniak, Ewa Morzyk, Konrad Suska, Przemysław Sidelnik, and Przemysław Lewandowski. 2023. "Analysis of the Possibility of Elimination of Threats Resulting from the Modification of Bullet Trajectory after Hitting the Target in Garrison Shooting Ranges". *Probl. Mechatronics. Armament Aviat. Saf. Eng.* 14 (2) : 109-126. https://doi.org/10.5604/01.3001.0053.6674

Abstract. During shooting operations in garrison shooting ranges, a phenomenon of random deflection of the bullet flight path was noticed which may cause secondary reflections from accidentally hit technical and ballistic shooting range elements and the ground of the actual plane of the shooting range (ricochets posing a threat to people and property within the shooting range and safety zones). Minimisation of this phenomenon must be considered during the design and operation of the shooting ranges. In 2020–2022 the Military Institute of Armament Technology (Zielonka, Poland) carried out tests with the aim of determining the impact of the shooting target or military target material or design (hereinafter referred to as the targets) on the risk of occurrence of modifications of bullet trajectory that cause the bullets to leave the shooting zone. The paper presents example results of these tests that show, but are not limited to, that the reasons to modify the direction of the bullet path after target penetration and any ricochets include: target material (flat or corrugated sheet metal, cardboard, plywood, etc.), target wooden legs, and even metal elements fixing the legs to the target. On the basis of the test it was shown that the metal targets prohibited on intermediate lines may cause significant deflections of the bullet flight path after penetration and dangerous ricochets. Due to the reason presented above, the metal targets are placed on the last line of targets before the main bullet trap only where the technical and ballistic parameters of the bullet trap ensure that any ricochets are captured. It was stated that the contact targets used on intermediate target lines and provided with wooden legs may cause bullet trajectory changes comparable to or even greater than in the case of the prohibited metal targets. To this end it is advisable to establish legal framework covering the ballistic inspection of the target materials to be used in garrison shooting ranges.
Keywords: ballistics, shooting range, ricochet

1. INTRODUCTION

According to [1], the design of garrison shooting ranges must minimise the possibility of ricochets. For this purpose units holding a relevant authorisation of the Polish Minister of National Defence, Military University of Technology (MUT, Warsaw, Poland) and Military Institute of Armament Technology (MIAT, Zielonka, Poland) carry out verification shooting in each newly commissioned (reconstructed or extended) shooting range and provide an opinion in terms of the safety of use of the shooting range with particular attention paid to the bullets — whether they leave the shooting range and the determined safety zones. Establishing the design conditions of the shooting ranges, the legislator included such protective elements as:

- target traps;
- side and top protections;
- vertical panels.

The legislator also specified additional requirements for the very shooting zone and its equipment, e.g.:

a) Within the shooting zone, up to a depth of 0.20 m, there shall be no hard elements, particularly stones, debris, steel and concrete elements, or other materials causing the bullets to ricochet.

b) Target lifts should be located, subject to par. 3, not less than 0.20 m below the level of actual plane of the garrison shooting range, in a manner ensuring their proper operation.
c) Lighting fixtures used to illuminate targets should be located below the level of actual plane of the shooting range.

The majority of the shooting range equipment, such as lifts, target lighting, or hit counters, can be located in cavities below the level of actual plane of the shooting range to protect them from direct firing, and to prevent the bullets (and their fragments) from ricocheting from hard elements. Targets used in shooting ranges should ensure the minimisation of the bullet path deflections by utilising proper materials and design solutions.

The results of the tests carried out in recent years indicate that the development of the provisions relating to the kinds and types of materials approved for use in the design of the targets intended for garrison shooting ranges and/or the implementation of certification of the targets under the new regulation to be introduced in September of the current year is reasonable.

2. DEFINITIONS

Modification of bullet trajectory — deflection from the original path before hitting the target in the direction of the bullet after penetrating the target. As a result of such a deflection, the bullet hitting an obstacle along its flight path may penetrate the obstacle, may remain in the obstacle, and may reflect from the obstacle (ricochet).

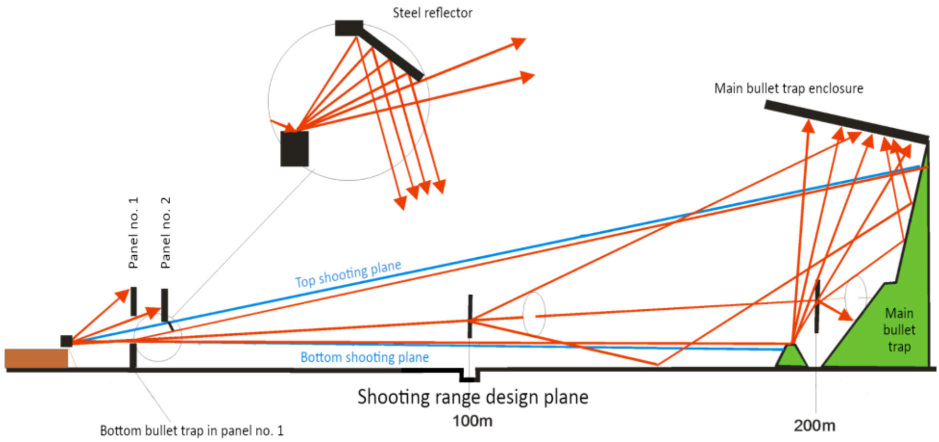

Fig. 1. Technical limitations of the possibility of the bullets leaving the garrison shooting range or ricocheting (example).

Ricochet — a bullet or its fragment reflected from a hard element or from the shooting zone ground. In this case the subject matter is the bullet and its farther flight after target penetration. The bullet that penetrates the obstacle loses some portion of its kinetic energy and the direction of its farther flight is modified. The flight of a series of bullets in space has the form of a cone with an angle of inclination of its longitudinal section up to 80°. The phenomenon of flight of the bullets after target penetration is presented in Fig. 1 with a deflection cone. In this figure the flight and stoppage of the bullets after ricocheting from the obstacle (target) are marked.

3. DIAGRAM OF BULLET FLIGHT DIRECTION MODIFICATION AFTER TARGET PENETRATION

The literature indicates that there are four basic factors affecting the bullet behaviour after hitting an obstacle (and thus the probability of ricocheting):

- bullet design;
- obstacle material;
- impact velocity;
- impact angle.

This study does not include the issue of the impact of the bullet design and impact velocity that has already been widely described in the literature — it should be considered as being in an as-is condition resulting from the properties of the weapons and ammunition used at the Armed Forces of the Republic of Poland. In view of the above reservation, it can be assumed that the typical reasons for the modification of the bullet flight path (direction and loss of a portion of kinetic energy) during firing in garrison shooting ranges include:

a. low angle impacts at a material with a high density (ground, steel, concrete, ice, water, etc.);
b. bullet reflection from a hard surface;
c. penetration of a material having significant ballistic resistance (tree and bush trunks, wooden beams, thin sheet metal, plastic, etc.).

4. PREVENTING RICOCHETS IN GARRISON SHOOTING RANGES IN VIEW OF THE APPLICABLE PROVISIONS

The applicable Regulation [1] contains provisions that require the reasons for ricocheting in newly constructed garrison shooting ranges to be limited. To prevent the bullet from hitting the actual plane of the shooting range by direct fire, a bottom bullet trap is installed under the vertical panel no. 1 to restrict the “visibility” of the actual plane for the aiming shooter and the weapon. To avoid bullet reflection from hard surfaces within the shooting zone, any hard elements that may cause ricocheting are eliminated up to a depth of 0.2 m.

Target equipment, such as lifts or lighting, are located below the bottom plane of the shooting range. The only exception from this principle are the provisions pertaining to special-purpose shooting ranges where it is acceptable to use mobile bottom bullet traps or ballistic covers. They must be resistant to bullet penetration and have anti-ricochet panels.

Furthermore Regulation [1] indicates the proper shape of the front surface of the main bullet trap as well as the side protections of the shooting range which must have no hard elements to eliminate the risk of ricocheting .

Another shooting range protection against bullets or ricochets that might leave the shooting range area covers vertical or inclined panels. To minimise the risk of ricocheting from the panels, they are constructed perpendicular to the shooting range axis and protected with anti-ricochet materials (wood, polyurethane and rubber, etc.).

If areas to determine normal safety zones (dangerous zone and hazard zone) have sufficient dimensions, the number of the vertical panels within the shooting zone is limited to two vertical panels (or even one vertical panel). If there is no such area, safety should be compensated with the proper design number of vertical panels (single or dual covered).

The data derived from the literature [3, 4] indicate that the ricochets may occur even when the bullets hit the targets under fire. The legislator seems to notice this issue by limiting the possibility to use metal targets in class I and II garrison shooting ranges where they are acceptable only at the last line of targets before the main bullet trap, and by indicating contact targets as relevant for use on all target lines. At the same time the type of contact target material is not defined, and this is the factor influencing the ballistic resistance of the targets.

5. TARGETS USED IN GARRISON SHOOTING RANGES

The term "contact targets" with regard to the Polish Army covers those targets in which momentary short-circuiting of the electrodes by the bullet penetrating the target's active plane is used to record hits. The electrodes are separated by an insulator. The electrodes may include steel sheet, aluminium sheet, or steel mesh, and the insulator may include foamed polystyrene or polyurethane foam. The target is attached to wooden legs used to mount the target on the lift.

Currently the following several contact target designs are available on the market:

a. made of two sheet metals separated by insulation;
b. made of two pieces of metal mesh separated by insulation;
c. made of foam with metal foil electrodes.

Moreover, as far as shooting ranges of other safety classes, having normal safety zones (dangerous zone and hazard zone) corresponding to the technical condition requirements are concerned, the provisions do not indicate which targets may be used therefore the following targets may also be installed:

a. metal targets made of sheet metal;
b. paper targets on support frames;
c. fibreboard targets with wooden legs.

The shooting experimental tests were carried out to determine the impact of the commercially available target materials with particular emphasis on the contact targets influencing the magnitude of deflection of the bullet flight path after target penetration and the risk of secondary ricochets.

The above test scope was focused on the material factor, and the remaining factors were considered as as-is conditions pursuant to the provisions on the weapons and ammunition used by the Polish Army as well as to the Regulation [1] in which target firing angles in garrison shooting ranges are provided.

6. RISK POSED BY BULLETS PENETRATING TARGETS USED IN GARRISON SHOOTING RANGES AND THEIR RICOCHETS

According to the analysis of the technical, construction, and operating documentation of the existing garrison shooting ranges, it can be concluded that when B1 operational firing using a military pistol (Fig. 2), as described in the Small Arms Firing Programme (Ref. no. 857/2012), carried out in a 200 m shooting range, for example, under the main bullet trap there is a risk of critical (maximum) deflections of the bullet path that may cause the bullet to go above the vertical panel active plane or above the main bullet trap enclosure.

This covers target firing from 10 m and 25 m, using additional open lines of fire (LOO) within the shooting zones before the main bullet trap, such as in a 200 m shooting range. The output line (LW) is determined at a distance of 50 m from the last line of targets (LC), aiming towards the shooting range's initial line. B1 firing using a military pistol is carried out as follows. When the firing director gives a "Go" command, the shooter takes the firing position, standing at LOO50, chambers the pistol and fires at target 1 (at a distance of 10 m).

After firing three bullets at target 1, the shooter replaces the magazine, releases the lock, secures the gun and relocates to the height of target 1, unlocks the gun and fires at target 2. Then the shooter secures the gun and relocates towards the next target, and when this target appears, the shooter kneels, unlocks the gun and fires at the last target .

Assuming that behind target 2 (e.g. in a 200 m shooting range), at 25 m, there is a panel with a height of 5.4 m above the actual plane of the shooting range (Fig. 2), when the bullet flight trajectory after hitting target 1 at a distance of 10 m from the LOO is changed by 17° or more, the bullet will leave the shooting range.

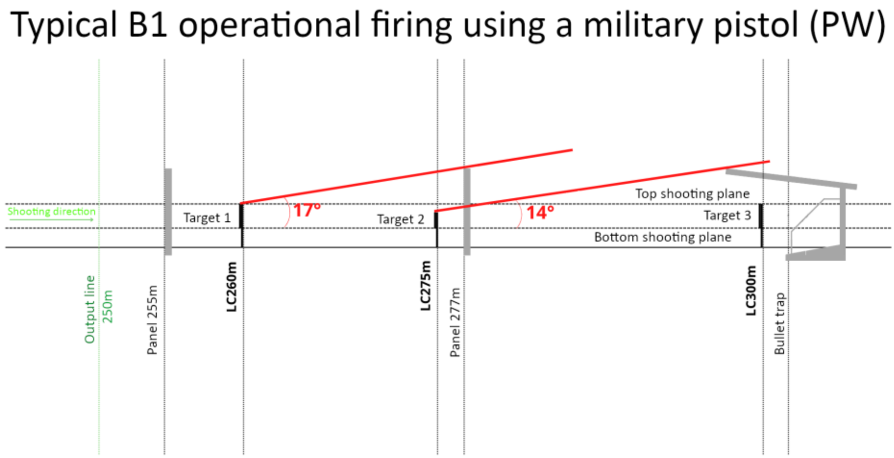

Fig. 2. Diagram presenting critical deflections of the bullet flight path at B1 firing using a military pistol

Similarly, when the bullet flight trajectory after hitting target 2 at a distance of 25 m from the LOO is changed by 14° or more, the bullet may penetrate the opening in the panel, not hitting the main trap, but flying above it.

For testing purposes B1 operational firing was carried out using a machine pistol. It was stated that as small deflection of the bullet flight path as 7° may cause the bullet to leave the shooting range (Fig. 3).

For target 1 located behind the second panel at LC 75 m, when the bullet is deflected upwards by 7°, the subsequent panel located at a distance of 105 m with a normal bottom edge height of 4.5 m above the actual plane of the shooting range will not capture such a ricochet.

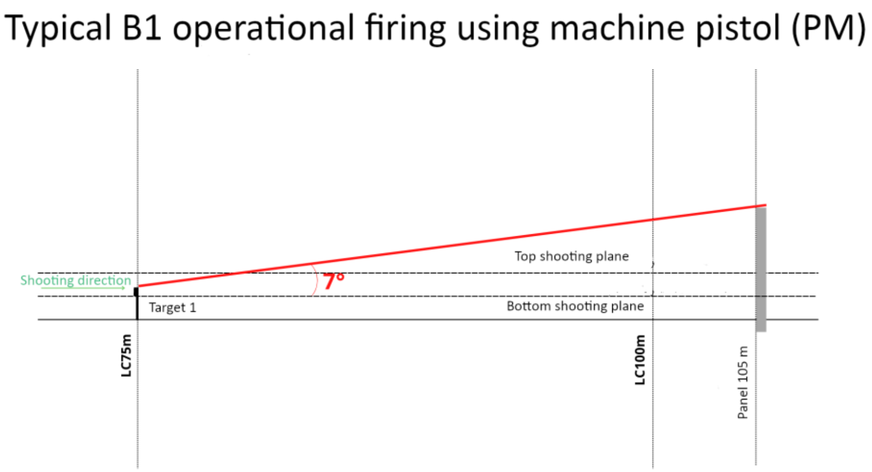

Fig. 3. Diagram presenting deflections of the bullet flight path at B1 firing using a machine pistol

The risk of the bullets leaving the shooting range may also occur during B1 operational firing using a machine gun (Fig. 4 and Fig. 5) for flight deflections of 12° for a target located at 100 m — assuming that directly behind them there is a panel, the second panel is located 25 m farther — and for deflections above 9° for a target located at 150 m.

To maintain safety and to ensure efficient capturing of the bullets after target penetration and ricochets by the main bullet trap and the side protections, the bullet flight path deflections caused by the targets for a pistol cartridge should be below 7° and for intermediate cartridge should be below 9°.

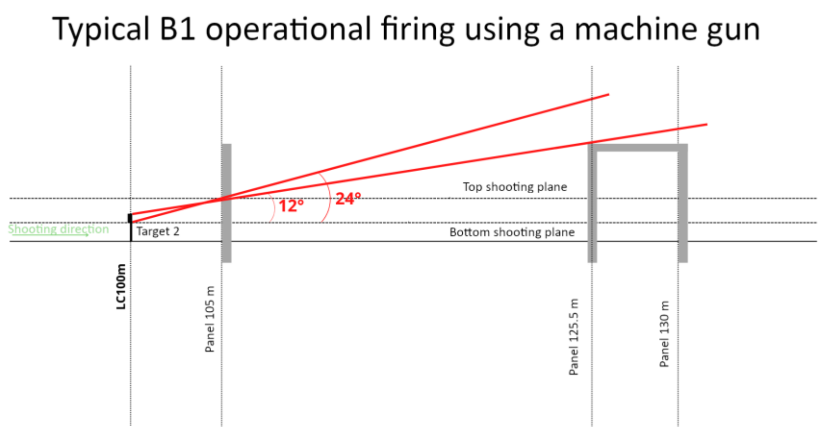

Fig. 4. Diagram presenting deflections of the bullet flight path at B1 firing using a machine gun for a distance LC of 100 m

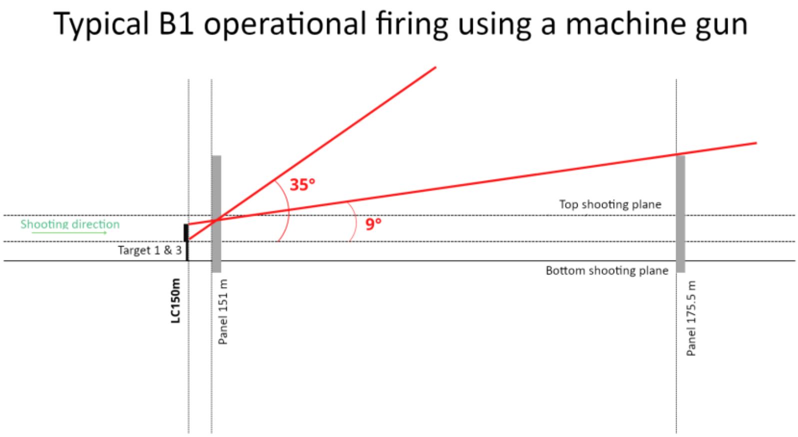

Fig. 5. Diagram presenting deflections of the bullet flight path at B1 firing using a machine gun for a distance LC of 150 m

7. TEST METHODOLOGY AND LABORATORY RESOURCES

9 × 19 mm pistol cartridge with an initial energy of 600 J, and 5.56 × 45 mm intermediate cartridge with an initial energy of 1800 J and 7.62 × 39 mm with an initial energy of 2000 J were used for firing tests. Four types of objects were tested:

1. metal targets with grooves on wooden legs (Photo 1);
2. contact targets made of two pieces of metal mesh separated by insulation, with wooden legs (Photo 2);
3. contact targets made of two pieces of metal mesh separated by insulation, on foam supports (Photo 3);
4. targets with aluminium sheet metal electrodes, on wooden legs (Photo 4).

Photo 1. Metal target with wooden legs

Photo 2. Contact target with two pieces of mesh separated by foam, with wooden legs

Photo 3. Contact target with two pieces of mesh separated by foam, with foam support

Photo 4. Contact target with two aluminium sheet metals separated by form, with wooden legs

Silhouette targets no. 23 were used for testing. The targets were fired at from the stand. Prior to testing the aiming point was determined using a laser installed on the stand both on the target and on a paper screen recording the deflections. The paper screen penetrated by the bullet after hitting the tested target was positioned at a distance of 5 m from the targets. The test stand photos are provided below (Photo 5 and Photo 6).

The tests were carried out on technical equipment of the MIAT ballistic laboratory.

Photo 5. Test stand — gun support with aiming laser

Angles of deflection from the firing axis that show whether the bullet flight trajectory was modified were measured based on the location of the bullet hole in the paper screen relative to the bullet hole in the target.

Photo 6. Test stand — target and paper screen (“witness”)

8. EXAMPLE TEST RESULTS

Test tests were carried in 2019–2022. Several firing series were performed in the above period. At least 15 basic shots for every cartridge type were fired at all tested targets. Moreover additional series of shots were fired in locations suspected of causing greater deflections of the bullet flight path, including, but not limited to, the connection between the targets and the (wooden and foam) legs/supports and to the wooden material of the target legs.

The exception included the contact targets made of two aluminium sheet metals separated by a polystyrene foam core — 10 shots using 9 × 19 mm cartridge were fired at them. Example results of the tests carried out in 2020–2022 are summarised in Table 1.

Table 1. Metal target firing results. The bullet flight path deflection angle (in degrees) depending on the type of cartridge and hit location

	Sample maximum value			Average value for a series of 15 shots		
Cartridge	9 × 19	5.56 × 45	7.62 × 39	9 × 19	5.56 × 45	7.62 × 39
Bullet energy [J]	600	1800	2000	600	1800	2000
Penetration of flat sheet metal only	15.8	2.6	4.5	6.9	0.9	1.6
Penetration of sheet metal and wooden leg	41.6	28.0	25.6	23.1	11.7	10.7
Penetration of sheet metal on the groove	22.7	16.4	11.7	15.0	4.6	2.9
Penetration of wooden leg only	28.6	9.3	8.9	22.8	4.9	4.5

Note: If the bullet hit mark was not confirmed on the paper screen (victim) and the bullet flew outside the paper, a deflection of 50 degrees was recorded

On the basis of the test results it was claimed that for the metal targets the bullet deflections depend on their energy — 9 m cartridges are deflected much more than 7.62 mm and 5.56 mm cartridges. The bullet path deflection is even greater when the bullet hits the grooves on the sheet metal. An average deflection for the cases when the 9 mm bullet hit the groove was 15°, whereas the maximum deflection was 22.7°. At the contact with the groove bullet fragmentation also occurred. An average deflection for 5.56 × 45 mm intermediate cartridge was 4.6°, whereas the maximum deflection was 16.4°. An average deflection for 7.62 × 39 mm cartridge was 2.9° and the maximum deflection was 11.7°.

Penetration of the metal target and the leg to which the target is attached by a single bullet significantly increases the bullet flight path deflection. The maximum deflections identified for the connection of the steel target to the wooden leg (sheet metal inlet, wood outlet) were, respectively: 41.6° for 9 × 19 mm cartridge; 28° for 5.56 × 45 mm cartridge; and 25.6° for the 7.62 × 39 mm cartridge. Moreover when the 9 × 19 mm cartridge penetrated the steel target with the wooden leg, several cases of bullet fragmentation were identified.

Table 2. Mesh and polyurethane foam contact target firing results. The bullet flight path deflection angle (in degrees) depending on the type of cartridge and hit location

	Sample maximum value			Average value for a series of 15 shots		
Cartridge	9 × 19	5.56 × 45	7.62 × 39	9 × 19	5.56 × 45	7.62 × 39
Bullet energy [J]	600	1800	2000	600	1800	2000
Target penetration only	1.3	2.2	1.0	0.5	0.6	0.5
Penetration of target and wooden leg	48.7	16.9	14.6	12.4	7.8	10.3
Penetration of target and foam leg	4.6	2.3	2.3	2.2	0.9	0.8
Penetration of wooden leg only	28.6	9.3	8.9	22.8	4.9	4.5
Penetration of foam leg only	3.5	5.8	1.4	1.8	0.8	0.5

As far as firing at the polyurethane foam contact targets with embedded metal mesh electrodes are concerned, significant path deflections were found after penetration of the target at the connection to the wooden legs. They were particularly visible for hits at the leg edge — the deflections even amounted to 48.7 ° for the 9 × 19 mm cartridge. The contact target itself did not generate significant deflections — the maximum deflection values were 1.3° for pistol cartridge and did not exceed 2.2° for the intermediate cartridge.

Table 3: Firing at aluminium sheet metal contact targets with wooden legs. The bullet flight path deflection angle (in degrees) depending on the type of cartridge and hit location

	Sample maximum value			Average value for a series of 10 shots		
Cartridge	9 × 19			9 × 19		
Bullet energy [J]	600			600		
Target penetration only	1.2			0.5		
Penetration of target and wooden leg	40.7			23.7		
Penetration of target, screw and wooden leg	80.9			62.8		
Penetration of wooden leg only	28.6			22.8		

The greatest bullet flight path deflections were relatively caused by simultaneous penetration of the contact target with aluminium sheet electrodes with the wooden leg by the 9 mm bullet at the location where the fixing screw was hit.

The maximum deflection was 80.9° and the average deflection was approx. 62.8°. The penetration of this type of target, as in the case of the foam target, did not cause great deflections — the maximum deflection was 1.2°.

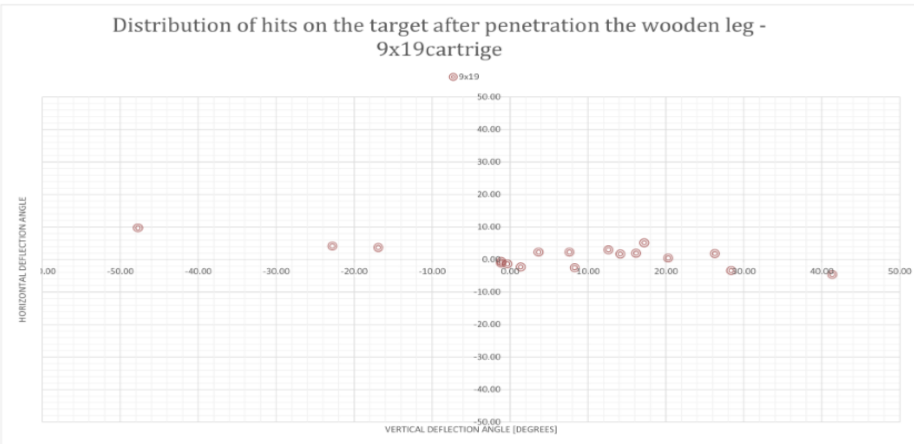

Fig. 6. Distribution of hits after penetrating the wooden leg — 9 × 19 cartridge

The test results cast doubts as to the properties of ballistic wooden legs used in the majority of targets, and therefore the wood itself was also tested.

The results recorded indicate that it deflects the bullets to an even greater extent than the steel sheet metal that was not hit. The maximum deflection for the wooden legs hit by the 9 × 19 mm cartridge was 28.6°.

It should be noted, however, that it was the maximum deflection [traces of path deflection recorded on the paper (victim)]. For a single bullet, the deflection was so high that there was no bullet hole in the screen (victim). The maximum deflections for the intermediate cartridge of 5.56 × 45 mm was 9.3° and for the intermediate cartridge of 7.62 × 51 mm was 8.9°.

The above indicates that the wood-target connection increases the bullet path deflections, in particular when the target was penetrated with an incomplete bullet bore (slipping or rubbing at the edge of the wooden leg).

Foam contact targets with polyurethane legs were also tested — no significant deflections were identified. The maximum deflections for the pistol cartridge were 4.6° and for an intermediate cartridge were 2.3°. One of the 7.62 × 39 mm bullets penetrating the foam target with the foam support hit the power supply cable. In this case the path of the bullet was modified significantly compared to the foam target — the deflection was 8.4°. The results of the tests clearly indicate that the greatest deflection of the bullet flight path for the military targets occurs when wooden legs are used to set the targets in the lift.

The greatest deflections of the bullet paths for the sheet metal targets and for the contact targets were identified in locations where the bullets hit the target material and the wooden leg. This effect did not occur for the target made entirely of foam (both the target itself and the support). During the tests it was claimed that the path of the bullet that penetrated the foam target on the foam support is only subject to slight deflections, not exceeding 5°. It was also confirmed that the prohibition on the use metal targets in garrison shooting ranges (except for the last line of targets before the main bullet trap) is justified — deflections of the bullet flight paths for the metal targets, in particular for the metal target with grooves, were significantly greater than for the contact targets.

9. CONCLUSIONS

1) The existing structures of the designed garrison shooting range equipment (shooting targets and military targets) do not include the aspects of the bullet flight path deflections caused by target penetration; however in practice this phenomenon was observed in the form of hit traces in the areas near the top and bottom panel edges.
2) The tests confirmed that the prohibition on the use of metal targets (excluding the last line of targets before the main bullet trap) in class I and class II garrison shooting ranges is justified. After penetration the metal surface of the target causes great deflections of the bullet flight path. As a result the bullets may not be captured by the shooting range safety infrastructure and may leave the shooting range, posing a threat to the life and health of people and to the property within the range of the bullet.

3) The applicable provisions of law do not include any regulations regarding the materials that can be used to manufacture the contact shooting and military targets. In view of the above it is acceptable to provide them with electrodes in the form of steel sheet metals to ensure that such a contact target will be as efficient in terms of the bullet flight path deflection after penetration as the steel target. It was confirmed, however, that the deflection of the bullet flight path after penetration of the foam contact targets with electrodes with metal mesh embedded in the foam was significantly reduced. In this case the bullet flight path deflections did not occur or were acceptable — they did not exceed 5°. At the same time it was claimed that even the use of this type of targets did not guarantee the complete elimination of the deflections of the bullet flight path as these deflections resulted from the use of wooden legs to set the targets in the lift. Despite being considered as an anti-ricochet material in the shooting ranges used to protect panel and bullet traps, the wood when used for target legs caused significant deflections of the bullet flight path, ranging up to several dozen degrees. There was no deflection-related issue when the foam support was used instead of the wooden legs as an element set in the lift.
4) All tested types of contact targets, excluding the targets with electrodes with mesh embedded in the polyurethane foam on the foam support, caused deflections of the bullet path that exceeded the safe angles as defined in a section of the study Risk posed by ricochets from targets used in garrison shooting ranges.
5) Therefore the conclusion that the targets intended for garrison shooting ranges should not be attached to wooden legs is justified. The legislator, following the right path and prohibiting on the use of steel targets in garrison shooting ranges and imposing the use of contact targets, did not foresee that in some circumstances the latter may also deflect the bullet flight path.
6) As a result a suggestion to create a catalogue of materials accepted for use in the contact targets intended for use in garrison shooting ranges is worth considering.
7) Alternatively it seems reasonable to certify the contact targets by an appropriate scientific unit (MIAT, MUT, and Military Institute of Armored and Automotive Technology in Sulejówek, Poland) in terms of safety of use in garrison shooting ranges. Such certification should cover the materials used to manufacture the targets and to carry out test firing for the safety of use of the targets.
8) The deflections of the bullet flight paths caused by the targets should not exceed several degrees — analyses show that the critical deflection angle of the bullet flight path is 7°.

FUNDING

The authors received no financial support for the research, authorship, and/or publication of this article.

REFERENCES

[1] Rozporządzenie Ministra Obrony Narodowej dnia 4 października 2001 r. *w sprawie warunków technicznych, jakim powinny odpowiadać strzelnice garnizonowe oraz ich usytuowanie* (Dz.U.2001.132.1479 z dnia 2001.11.19) ze zmianami Dz.U. 2016 poz. 363, Dz.U. 2008 nr 61 poz. 380 i Dz.U. 2018 poz. 113

[2] *Program Strzelań z Broni Strzeleckiej* – Szkol 857/2012. Warszawa: Wydawnictwo MON.

[3] Gacek, Józef, Bronisław Marciniak, Ryszard Woźniak. 2015. "Wybrane zagadnienia bezpieczeństwa konstrukcji i eksploatacji strzelnic garnizonowych". *Problemy Techniki Uzbrojenia* 44 (133) : 103÷133.

[4] Stępniak, Wiesław, Przemysław Sidelnik, Bartosz Kozera. 2010. „Metody badania zjawiska rykoszetowania amunicji, na przykładzie badań amunicji o ograniczonym rykoszetowaniu". *Problemy Techniki Uzbrojenia* 39 (114) : 57÷68.

[5] Rozporządzenie Ministra Obrony Narodowej *w sprawie warunków technicznych, jakim powinny odpowiadać obiekty budowlane niebędące budynkami, służące obronności Państwa oraz ich usytuowanie* (Dz.U. 2017 poz. 711)- tekst jednolity.

Analiza możliwości eliminacji zagrożeń wynikających ze zmiany trajektorii pocisków po trafieniu w tarczę na strzelnicach garnizonowych

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Streszczenie: Podczas prowadzenia strzelań na strzelnicach garnizonowych zaobserwowano zjawisko losowego odchylania toru lotu pocisków, które może powodować wtórne odbicia od przypadkowo trafionych elementów techniczno-balistycznych strzelnicy oraz gruntu płaszczyzny rzeczywistej strzelnicy (rykoszety stanowiące zagrożenie dla ludzi i mienia na strzelnicy i w strefach ochronnych). Projektowanie i eksploatacja strzelnic musi uwzględniać minimalizację tego zjawiska. W latach 2019÷2022 przeprowadzono w Wojskowym Instytucie Technicznym Uzbrojenia badania, których celem było ustalenie wpływu materiału i konstrukcji tarcz lub figur bojowych (dalej nazwanych tarczą) na zagrożenie wystąpienia zmian trajektorii pocisków, skutkujących opuszczeniem przez pociski strefy strzelań. W artykule przedstawiono przykładowe wyniki tych badań, które pokazują m.in., że przyczynami zmiany kierunku lotu pocisku po przebiciu tarczy i ewentualnego powstawania rykoszetów są: materiał, z którego wykonano tarcze (blacha płaska lub falista, tektura, sklejka, itp.), nogi drewniane tarczy, a nawet metalowe elementy mocujące nogi do tarczy. Na podstawie przeprowadzonych badań wykazano, że zakazane do stosowania na pośrednich liniach celów tarcze metalowe mogą powodować znaczne odchylenia toru lotu pocisku po przebiciu oraz niebezpieczne rykoszety. Z tego powodu tarcze metalowe ustawiane są wyłącznie na ostatniej linii celów przed kulochwytem głównym, gdzie parametry techniczno-balistyczne kulochwytu zapewniają wychwycenie ewentualnych rykoszetów. Stwierdzono, że stosowane na pośrednich liniach celów tarcze kontaktowe, posiadające nogi drewniane, mogą powodować zmiany trajektorii pocisków porównywalne lub nawet większe niż w przypadku zakazanych tarcz metalowych. Z tego powodu wskazane jest stworzenie ram prawnych dla kontroli balistycznej materiałów, z których wykonywane są tarcze przeznaczone do stosowania na strzelnicach garnizonowych.

Slowa kluczowe: strzelnice, balistyka zewnętrzna, obiekty szkoleniowe, strzelnice garnizonowe