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Examination of low-energy bullets velocity

Summary

This article presents the overall results of research performed under the project entitled: "Examination of low-energy bullets velocity" financed by the National Centre for Research and Development, carried out by a scientific consortium led by the Central Forensic Laboratory of the Police.

Keywords bullet, velocity, measurements, energy, ballistics

In the period from 18 December 2012 until 17 March 2015, a project in the field of national defense and security entitled "Examination of low-energy bullets velocity" financed by the National Centre for Research and Development was carried out at the Firearms Examination and Ballistics Unit of the Central Forensic Laboratory of the Police.

To this end, a scientific consortium was established led by the Central Forensic Laboratory of the Police (CLKP), and including the following partner institutions:

- Institute of Security Technologies "Moratex",
- Military Institute of Armament Technology (WITU),
- Police Academy in Szczytno (WSPol),
- Research and Development Centre of Research and Didactic Equipment (COBRABiD).

Each of the partner institutions was assigned the tasks adequate for its specific field of activity and the existing equipment. CLKP, WITU and Moratex focused on researching and measuring ricochets, shooting ranges and the targets mimicking the human body. COBRABiD built measuring equipment, e.g. measurement gate, target fixing device and ricochet testing device. Finally, the main tasks of WSPol were to gather information on criminal cases involving the use of low-energy bullets, publish research results and organize the project closing conference.

In accordance with the adopted schedule, the project was divided into 4 stages comprising a total of 21 tasks:

1. Stage I (scientific research) – implementation period from 18.12.2012 until 17.06.2013:
   - task 1.1 – verification of information concerning criminal cases around the country, involving the use of low-energy bullets, injury risk analysis,
   - task 1.2 – specification of research objects (types of projectiles and launching devices),
   - task 1.3 – verification of the concept and designing the test stand,
   - task 1.4 – identification of a substrate mimicking the human body, including its encasement,
   - task 1.5 – identification of obstacles for the ricochet study,
   - task 1.6 – determination of requirements for measuring instruments,
   - task 1.7 – development of a research methodology(-ies),
   - task 1.8 – development of a research programme.
2. Stage II (development works) – implementation period from 18.06.2013 until 17.04.2014:
   - task 2.1 – modernization of measuring instruments, purchase of sub-assemblies,
   - task 2.2 – construction of a measurement gate,
   - task 2.3 – construction of a target fixing device,
   - task 2.4 – construction of a ricochet testing device,
   - task 2.5 – development of validation procedure for test stand elements,
   - task 2.6 – test method validation.
3. Stage III (development works) – implementation period from 18.04.2014 until 17.10.2014:
   - task 3.1 – test shooting and measurements,
   - task 3.2 – determination of trajectory characteristics (compilation of ballistics tables),
   - task 3.3 – setting up test substrate, encasements and obstacles,

- task 3.4 – test shooting and measurements,
- task 3.5 – visualization and description of the impact of projectiles on the substrate (uncovered and covered).

4. Stage IV (development works) – implementation period from 18.09.2014 until 17.03.2015:

- task 4.1 – evaluation and publication of research results,
- task 4.2 – organization of a seminar presenting research results.

Within the framework of Stage I, the main focus was placed on scientific research with the aim of analyzing the greatest possible number of documented cases involving the use of various launching devices for low-energy bullets, based on the data available in the National Police Information System (KSIP), press releases and specialist (mainly medical) literature. Based on the data obtained, the launching devices and projectiles suitable for the study were selected and the concept of the test stand was developed. It was decided that the velocities of the launched projectiles will be measured using three different devices simultaneously, e.g. a Doppler radar, a photogate and a high-speed camera.

Stage II involved development works oriented at constructing the test stands in CLKP, WITU and Moratex, adequate for the study planned. Since all the above institutions have been conducting similar studies and have the appropriate research facilities, the test stands to be constructed required only minor upgrades and modernization in line with planned research. Preparation of the test stands involved the purchase of a high-speed camera for CLKP, a Tema Motion software for contactless motion analysis and a ballistic gelatin preparation kit for Moratex as well as modernization of a Doppler radar owned by CLKP and high-speed cameras owned by WITU and Moratex. COBRABiD built a photoelectric measurement gate, a ricochet testing device and a target fixing device.

During Stage III, the scheduled tests and measurements were carried out.

The test shooting was carried out at CLKP and it was followed by measurements of ricochet parameters for the projectiles bouncing off three surface types, e.g. concrete, metal sheet and laminate particle board, for the impact angles of 5°, 10°, 20°, 30°, 40°, 50° and 60°. The tests involved the following launching devices and projectiles:

Table 1 Launching devices and projectiles tested at CLKP

Item #	Launching device	Projectile
1.	4.5 mm Hammerli 850 air rifle	COBRA 500 pellets, weight 0.5 g Hammerli Field Target pellets, weight 0.5 g Round Ball pellets, weight 0.55 g Walther high power pellets, weight 0.35 g Monster Diabolo pellets, weight 0.87 g,
2.	4.5 mm Walther PPQ pistol	COBRA 500 pellets, weight 0.55 g Hammerli Field Target pellet, weight 0.55 g Monster Diabolo pellets, weight 0.87 g, Walther high power pellet, weight 0.35 g Round Ball pellets, weight 0.55 g
3.	4.5 mm Ranger air rifle	COBRA 500 pellets, weight 0.55 g Hammerli Field Target pellets, weight 0.55 g Monster Diabolo pellets, weight 0.87 g, Walther high power pellets, weight 0.35 g Round Ball pellets, weight 0.55 g
4.	5.5 mm Zoraki HP01 air pistol	Hammerli super speed pellets, weight 0.65 g Walther copper impact pellets, weight 1.0 g Umarex classic pellets, weight 0.85 g, Exact Jumbo Monster Diabolo pellets, weight 1.64 g Torpedo pellets, weight 1.3 g
5.	5.5 mm FX air rifle (at two velocity settings)	Hammerli super speed pellets, weight 0.65 g Walther copper impact pellets, weight 1.0 g Umarex classic pellets, weight 0.85 g, Exact Jumbo Monster Diabolo pellets, weight 1.64 g Torpedo pellets, weight 1.3 g
6.	6.35 mm AT44-10 air rifle	JSB Exact King pellets, weight 1.65 g Baracuda pellets, weight 2.01 g
7.	6.0 mm ASG HK 416 D air pistol	plastic balls, weight 0.2 g steel balls, weight 0.3 g

Item #	Launching device	Projectile
8.	6.0 mm ASG HK MP5 A3 air pistol	plastic balls, weight 0.2 g steel balls, weight 0.3 g
9.	Paintball BT Omega .68 Cal.	rubber balls, diameter 17.3 mm, weight 3.73 g
10.	6/10 mm Ekol Viper 2.5" revolver	rubber balls, diameter 10 mm, weight 0.75 g

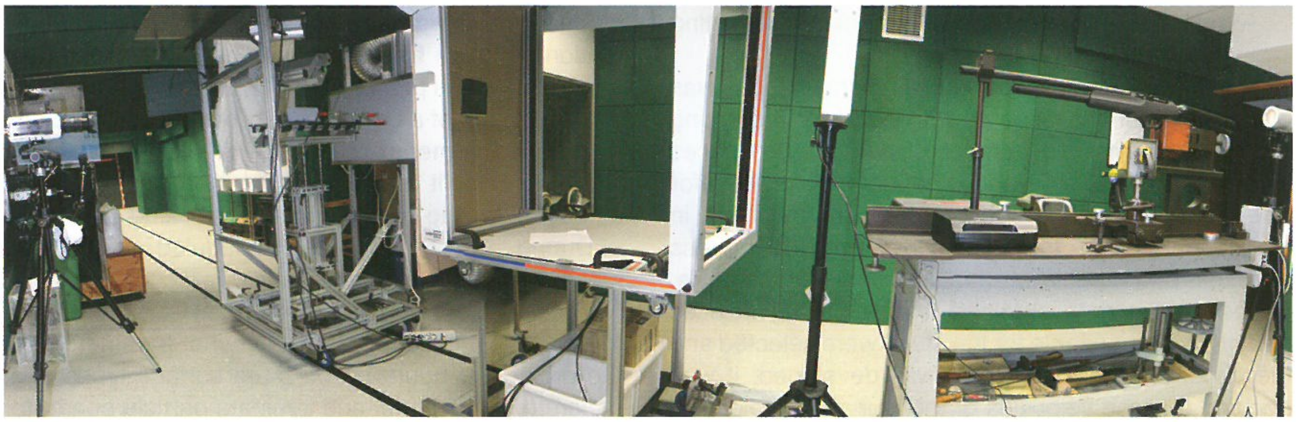

Fig. 1. Test stand in CLKP (ricochets).

The surfaces to be tested were affixed to the ricochet testing device constructed during Stage II by COBRABiD. Each of the ricochets was recorded using a Phantom v.711 high-speed camera. The recordings were analyzed with the Tema Motion software for contactless motion analysis. The velocity of each launched projectile was measured prior to ricocheting using a measurement gate built by COBRABiD as part of Stage II. For some of the elements, the velocity was determined using Doppler radars Weibel SL520/W700 and DRS-1 (Fig 1).

Based on the results of the tests carried out, the ricochet tables were compiled, containing the values of impact velocity, velocity after ricochet, angle of impact and angle of reflection, for each pellet type / surface type combination.

The exemplary table with test results for a 6/10 mm Ekol Viper 2,5" revolver and 10 mm rubber ball projectiles is shown below.

Table 2 Ricochets – 6/10 mm Ekol Viper 2,5" revolver, 10 mm rubber balls

TABELA STRZELNICZA (RYKOSZETY)
Rewolwer Ekol model Viper 2,5" kal. 6/10 mm: – kulka gumowa o średnicy 10 mm i masie 0,75 g.

a) beton

Kąt st.	Vu	Vo	Kąt u	Kąt o
5	115	104	7	3,5
10	130	108	12	6
20	124	76	22	17
30	119	62	32,5	23
40	140	56	43,5	29
50	120	40	51	37,5

b) płyta

Kąt st.	Vu	Vo	Kąt u	Kąt o
5	120	116	7,5	3,6
10	113	105	13	5,2
20	134	120	22	7,8
30	130	104	31,6	10,2
40	127	86	42,2	13,4
50	132	64	52,6	25,2

c) blacha

Kąt st.	Vu	Vo	Kąt u	Kąt o
5	132	125	8	3,2
10	120	110	12,5	8
20	120	100	23	9
30	124	91	32	11
40	123	52	43	28
50	130	44	54	34,7
60	125	34	63	44,5

The tests carried out at WITU involved the shooting, followed by measurements of range-related parameters. The following launching devices and projectiles were used:

Table 3 Launching devices and projectiles tested at WITU

Item #	Launching device	Projectile
1.	Tenpoint Titan HLX crossbow	bolt length 48 cm, bolt weight 30.6 g bolt length 53 cm, bolt weight 31.3 g.
2.	Cobra bow	arrow length 78.5 cm, arrow weight 35.5 g
3.	4.5 mm Hammerli 850 air rifle	COBRA 500 pellets, weight 0.5 g Hammerli Field Target pellets, weight 0.5 g Round Ball pellets, weight 0.55 g Walther high power pellets, weight 0.35 g Monster Diabolo pellets, weight 0.87 g,
4.	4.5 mm Walther PPQ pistol	COBRA 500 pellets, weight 0.55 g Hammerli Field Target pellets, weight 0.55 g Monster Diabolo pellets, weight 0.87 g, Walther high power pellets, weight 0.35 g Round Ball pellets, weight 0.55 g
5.	5.5 mm Zoraki HP01 air pistol	Hammerli super speed pellets, weight 0.65 g Walther copper impact pellets, weight 1.0 g Umarex classic pellets, weight 0.85 g, Exact Jumbo Monster Diabolo pellets, weight 1.64 g, Torpedo pellets, weight 1.3 g
6.	6.35 mm AT44-10 air rifle	JSB Exact King pellets, weight 1.65 g Baracuda pellets, weight 2.01 g
7.	6.0 mm ASG HK 416 D air pistol	plastic balls, weight 0.2 g steel balls, weight 0.3 g
8.	6.0 mm ASG HK MP5 A3 air pistol	plastic balls, weight 0.2 g steel balls, weight 0.3 g
9.	Paintball BT Omega .68 Cal.	rubber balls, diameter 17.3 mm, weight 3.73 g
10.	6/10 mm Ekol Viper 2,5" revolver	rubber balls, diameter 10 mm, weight 0.75 g

The trajectory characteristics were determined on the basis of measurements taken with a Doppler ballistic set Dr-5000 from Terma Elektronik AS. Radial velocities of the projectiles were measured along their trajectories. At least 10 velocity measurements were taken for each type of projectile, followed by a calculation of the mean initial velocity V_0, which served as a reference for the determination of trajectory characteristics. The equations of motions described in STANAG 4355 (MPMTM) were applied to analysis of measured radial velocity vectors that were subsequently used to calculate the drag coefficient C_D= f(Mach) and to compile the ballistics tables. The exemplary table with test results for a Tenpoint Titan HLX crossbow and bolts of 48 cm of length and 30.6 g of weight as projectiles is shown below.

Table 4 Range – TenpointTitan HLX crossbow, bolt length 48 cm, bolt weight 30.6 g

TABELA STRZELNICZA (CHARAKTERYSTYKI TORU LOTU)

Broń: Kusza Tenpoint Titan HLX
Element miotany: Bełt dług. 48 cm, m = 30,6 g
Prędkość początkowa V_0= 81 m/s
Tabela C_D = f(Mach):

Mach	0,140	0,150	0,160	0,170	0,180	0,190	0,200	0,210	0,220	0,230	0,240
C_D	1,220	1,227	1,350	1,311	1,270	1,323	1,328	1,331	1,372	1,300	1,400

Θ0 [°]	tc [sec]	X [m]	Y [m]	Vc [m/sec]	ΘC [°]
1	0,286	22,7	0,1	77,9	1,0
2	0,569	44,3	0,4	75,1	2,1
3	0,848	64,9	0,88	72,5	3,2
4	1,123	84,4	1,54	70,2	4,4

Θ0 [°]	tc [sec]	X [m]	Y [m]	Vc [m/sec]	ΘC [°]
5	1,395	103,0	2,38	68,0	5,6
6	1,663	120,6	3,39	66,1	6,9
7	1,928	137,5	4,54	64,3	8,2
8	2,189	153,6	5,87	62,6	9,5
9	2,447	168,9	7,35	61,2	10,8
10	2,701	183,5	8,96	59,9	12,2
15	3,927	247,0	18,91	54,4	19,5
20	5,077	296,2	31,64	51,4	26,9
25	6,150	333,7	46,82	50,0	34,0
30	7,159	360,5	63,32	49,5	40,7
35	8,105	377,1	81,41	49,6	46,8
40	8,986	384,0	99,82	50,1	52,4
41*	**9,155**	**384,3**	**103,09**	**50,2**	**53,5**
45	9,801	381,6	118,91	50,9	57,4
50	10,547	370,1	137,45	51,8	61,9
60	11,821	321,0	171,82	53,6	69,7
70	12,776	239,3	200,45	55,0	76,5
80	13,373	129,3	218,18	55,9	83,1

* kąt, przy którym uzyskano max donośność

ITB Moratex accomplished a series of tests concerning the penetration capability of low-energy bullets against obstacles (gelatin) imitating the human body, both covered and uncovered. The tests involved the following launching devices and projectiles:

- 4.5 mm Walther PPQ pneumatic air pistol,
- 4.5 mm Hammerli 850 air rifle,
- 4.5 mm Ranger BT65 air rifle,
- 5.5 mm Zoraki HP-01 air pistol,
- 5.5 mm FX Gladiator/Cutlas air rifle with adjustable pressure,
- 6 mm ASG HK MP5 A3 air rifle,
- 6.35 mm Ranger AT 44 W-10 air rifle,
- 6 mm Ekol Viper K10 revolver,
- and the following 4.5 mm, 5.5 mm and 6.35 mm projectiles in different designs:
- 4.5 mm Umarex 500 cobra,
- 4.5 mm Diabolo H&N Barakuda,
- 4.5 mm Diabolo JSB Exact Monster,
- 4.5 mm Diabolo H&N Rabbit magnum,
- 4.5 mm H&N lead balls (BBs),
- 4.5 mm Diabolo JSB Exact,
- 5.5 mm Hammerli Superspeed,
- 5.5 mm Umarex 250 flat head pellet,
- 5.5 mm Baracuda hunter extreme,
- 5.5 mm H&N Sport Baracuda Power copper plated pellet,
- 5.5 mm Diabolo H&N Rabbit Magnum,
- 5.5 mm Exact jump diabolo JSB,
- 5.5 mm Tomitex lead ball (BB),
- 6.36 mm Exact King Diabolo JSB,
- 6.25 mm H&N Sport Baracuda.

Projectile velocities were registered by a photoelectric gate. Gelatin penetration process was recorded using a PHANTOM v711 high speed camera. The measurements were based on the PHANTOM – Vision research v1.33.697.0 software, whereas an analysis was carried out by using the TEMA MOTION – Image Systems v 3.7 software intended to describe dynamic events.

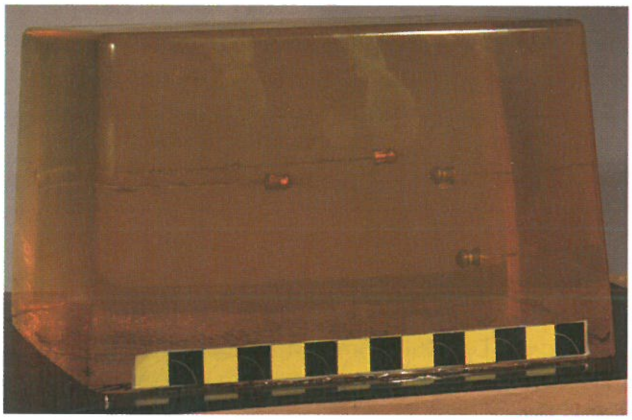

Fig. 2. Tests carried out at MORATEX (targets imitating the human body).

The firearms listed above were used in a series of tests assessing the penetration of projectiles in the form of 4.5 mm, 5.5 mm and 6.35 mm cal. pellets into gelatin (uncovered and covered with a cotton t-shirt). The weights of pellets ranged from 0.5 g to 1.02 g for 4.5 mm cal., from 0.835 g to 1.75 g for 5.5 mm cal. and from 1.64 g to 2.01 g for 6.35 mm cal., respectively.

The velocity of 5.5 mm pellets depended on the type of pellet and it ranged from 76.7 m/s for Baracuda hunter extreme type to 323.7 m/s for Hammerli Superspeed type. Energy values varied according to the weight of the projectile and ranged between 3.32 J and 44 J for Hammerli Superspeed and Baracuda hunter extreme pellets, respectively. The maximum penetration depth – 151 mm – was recorded for 5.5 mm Rabbit Magnum II pellets, weight approx. 1.63 g.

The depth of pellet penetration into gelatin is not only dependent on the velocity. Another determinant is the pellet shape – the more pointed the pellet grains are, the deeper penetration can be expected. Finally, the depth of penetration depends on the weight, which in turn determines the kinetic energy. Covering the obstacle with a cotton t-shirt does not affect the penetration. In the case of 5.5 mm Baracuda Power copper plated pellets fired with the energy of 17 J (allowed for pneumatic weaponry), the penetration equals more than 80 mm (Fig. 3). Hence, it is sufficient to inflict damage on any human internal organ.

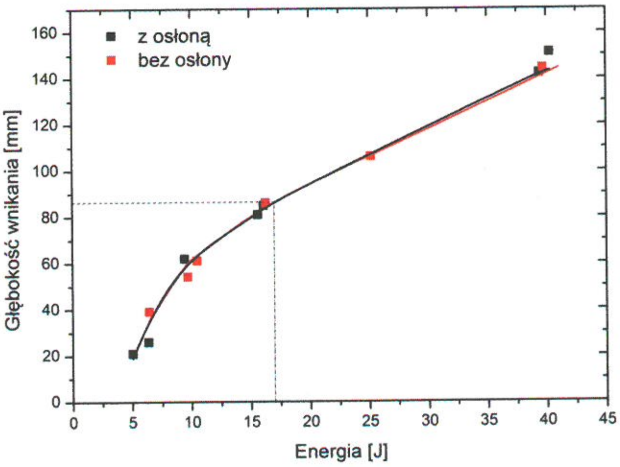

Fig. 3. Relationship between penetration depth and kinetic energy for 5.5 mm Baracuda Power copper plated pellets.

Equally serious injuries may be caused by Baracuda hunter extreme pellets which, at speeds above 200 m/s, tend to rotate upon impact with a gelatin block. The rotation inside the block reduces the penetration depth and at the same time causes an increase in cavity size.

Reasearch and development work carried out as part of the project have delivered vast quantities of data such as statistics,comparisons and ballistics tables. Another valuable result consisted of unique validation procedures developed for the particular elements of the test stand as well as testing methodologies. In order to disseminate the results into research, police, forensic and judicial pragmatics, the Publishing and Printing Division of the Police Academy in Szczytno published an item entitled "Examination of low-energy bullets velocity" consisting of 121 pages of narrative material and 44 pages of annexes.

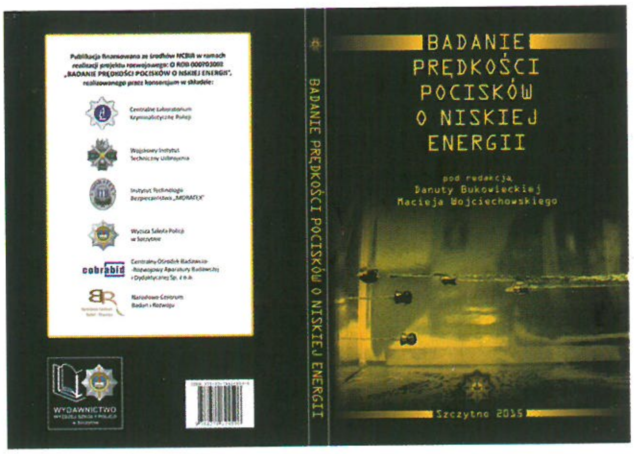

Fig. 4. Publication cover design.

In order to further propagate the results, a scientific and practical seminar entitled: "Examination of low-energy bullets velocity as a challenge of contemporary forensics" was organized at the Przystań Hotel in Olsztyn. Among the invited participants were representatives of research institutions and police academies, firearms and ballistics experts as well as the members of the supervisory team, whose presence facilitated the exchange of comments and experiences related to the issues studies under the above project.

The participants had an opportunity to listen to multimedia presentations addressing the particular stages of research along with the corresponding results as well as received advertising materials, including a volume entitled "Examination of low-energy bullets velocity" published by the Police Academy in Szczytno.

Fig. 5. Attendants of scientific and practical seminar entitled: "Examination of low-energy bullets velocity as a challenge of contemporary forensics".

Sources of figures and tables

Tabs. 1–4: autors
Figs. 1–6: autors

Translation Rafał Wierzchosławski

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