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Comparative analysis of different types of ballistic barrels used in ammunition investigations

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Abstract. Manufacturers offer different types of ballistic barrels made according to various standards. The paper presents comparison of three types of ballistic barrels: pressure, velocity, and accuracy barrels made according to C.I.P. and NATO EPVAT standards. Projectile velocities in several measuring points on the flight path and propellant gas pressures in the barrels were measured and then compared. The main aim of the article is to discuss whether all types of barrels to conduct most ballistic tests are needed, or whether one, the most universal in a specific calibre is enough.
Keywords: mechanical engineering, ballistics, firearm, ammunition tests, ballistic properties
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1. Introduction

One of crucial parts of ammunition investigations is focused on measuring pressures, projectile velocity along the flight path, and terminal effect on a target. To provide repeatable test conditions and the possibility of conducting pressure measurements, specialised ballistic barrels are needed. Most of manufacturers offer ballistic barrels made according to C.I.P., SAAMI or NATO EPVAT standards [2-4].

Among the used three different types of barrels, the following ones can be highlighted: pressure barrels (PB), velocity barrels (VB), and accuracy barrels (AB). What is interesting, despite the fact that C.I.P. standard does not include velocity and accuracy tests, C.I.P. velocity and accuracy barrels are offered too. Barrels construction analysis provides the conclusion that excluding gauge sockets in pressure barrels there is no difference between them. The question arises - is it economically reasonable to apply velocity and accuracy barrels?

The main subject of this paper is to compare different types of ballistic barrels made according to C.I.P. and NATO EPVAT standards. Moreover, the paper presents a comparison of results of pressure measurements between the barrels made according to these two standards. All the percentage differences between the results, presented throughout the paper, refer to mean values.

The paper does not deal with an issue of certified laboratories where the use of different types of barrels is imposed by standards.

2. Experimental stand and methods

Eighteen ballistic barrels with five types of cartridges were tested:

1. .300 Blackout C.I.P. standard pressure (no. 6000), velocity (no. 6002) and accuracy (no. 6004) barrels. Barrel length: 508 mm, gauge socket located 17.5 mm from breech face (pressure barrel). Cartridges used: .300 Blackout HP 125 gr — bullet weight: 8.1 g, manufacturer: Hornady.
2. .300 Blackout NATO EPVAT standard pressure (no. 6001), velocity (no. 6003) and accuracy (no. 6005) barrels. Barrel length: 406.4 mm, gauge socket located 37 mm from breech face (pressure barrel). Cartridges used: same as point 1.
3. 5.56 × 45 mm C.I.P. standard pressure (no. 5946), velocity (no. 5948) and accuracy (no. 5950) barrels. Barrel length: 600 mm, gauge socket located 25 mm from breech face (pressure barrel). Cartridges used: 5.56 × 45 mm Pb (lead core) — bullet weight: 3.54 g, manufacturer: MESKO S.A., 5.56 × 45 mm RS (steel core) — bullet weight: 4 g, manufacturer: MESKO S.A.
4. 5.56 × 45 mm NATO EPVAT standard pressure (no. 5947), velocity (no. 5949) and accuracy (no. 5951) barrels. Barrel length: 508 mm, gauge socket located 46.5 mm from breech face (pressure barrel). Cartridges used: same as point 3.
5. 7.62 × 51 mm C.I.P. standard pressure (no. 5970), velocity (no. 5972) and accuracy (no. 5974) barrels. Barrel length: 600 mm, gauge socket located 25 mm from breech face (pressure barrel). Cartridges used: 7.62 × 51 (BALL) — bullet weight: 9.45 g, manufacturer: Hirtenberger, 7.62 × 51 (BALL) — bullet weight: 9.46 g, manufacturer: MESKO S.A.
6. 7.62 × 51 mm NATO EPVAT standard pressure (no. 5971), velocity (no. 5973) and accuracy (no. 5975) barrels. Barrel length: 562 mm, gauge socket located 54 mm from breech face (pressure barrel). Cartridges used: same as point 5.

The same laboratory stand as in [1] was used. Seven tests (shots) were carried out for each barrel and cartridge type. Several parameters were measured: propellant gas pressure in a barrel, projectile muzzle velocity (Vm), projectile velocity at 2 m (V2), 25 m (V25), and at 50 m (V50). Projectile velocities obtained with different barrel types (pressure, velocity, accuracy) were compared under the same standard and barrel calibre. Propellant gas pressures were compared under the same barrel calibre but for different standards.

In order to compare the results obtained for different barrel types, an analysis of statistical significance of the differences, based on T-Student's distribution, for a confidence level of 0.95, was carried out.

Due to only 50-m length of the laboratory shooting range and slight differences between measurements, often less than coordinates estimation inaccuracy of target system, shooting accuracy was not taken into account.

3. Results

3.1. Hornady .300 Blackout

At first, .300 Blackout ballistic barrels were investigated. The results shown in Fig. 1, regarding the C.I.P. standard barrels, provide slight difference in projectile velocities between different types of barrels. The greatest difference of 2.26% occurs between the pressure barrel and the velocity barrel (PB-VB). In case of comparing the pressure barrel to the accuracy barrel (PB-AB), the difference amounted to 1.33%. The difference of less than one percent was observed between the velocity and accuracy barrels (VB-AB).

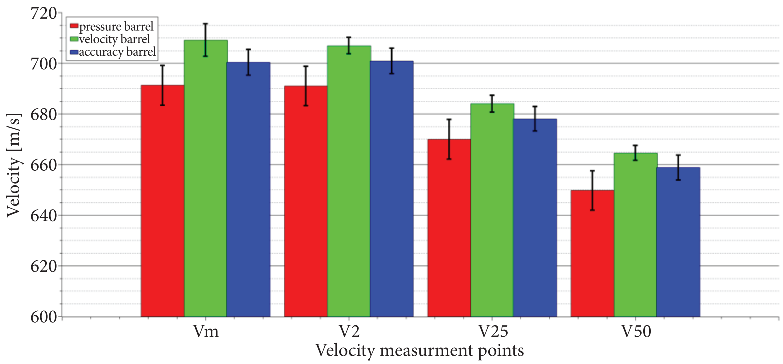
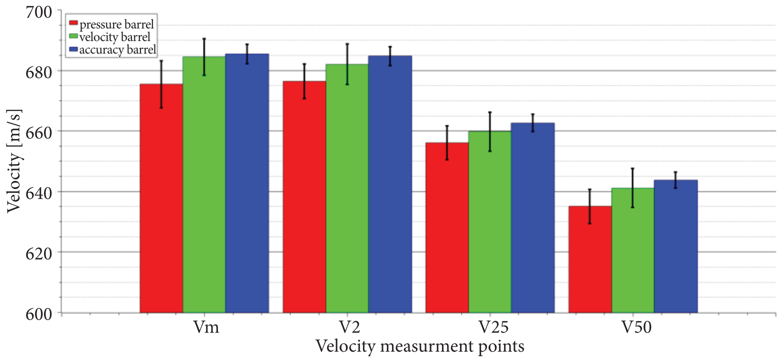


Figure 1. Comparison of velocities of .300 Blackout projectiles fired from different types of ballistic barrels made according to C.I.P. standard

In Fig. 2, the results from NATO EPVAT standard barrels are presented. Only for PB-AB comparing, 1.26% — difference was observed. The differences between PB-VB and VB-AB were statistically insignificant.



Fgure 2. Comparison of velocities of .300 Blackout projectiles fired from different types of ballistic barrels made according to NATO EPVAT standard

3.2. MESKO 5.56 × 45 mm Pb

Further measurements were conducted for 5.56 × 45 mm round equipped with a lead core bullet. The results for C.I.P. standard barrels were shown in Fig. 3. A high value of standard deviation in case of the pressure barrel can be noticed. Again, the greatest difference of 2.02% values occurs between the pressure barrel and the velocity barrel. A lower variance of 1.66% occurred between PB-AB. The results for VB-AB are statistically insignificant.

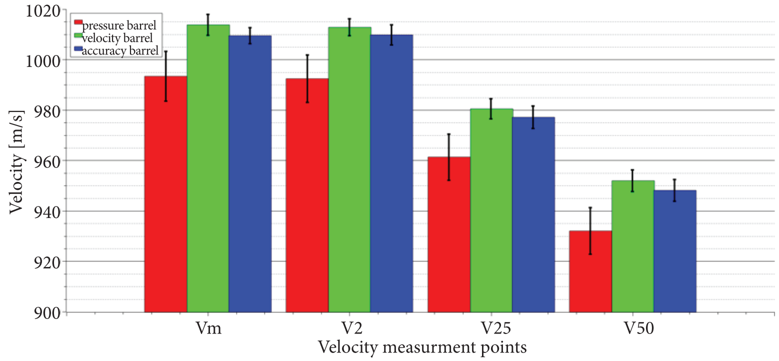


Figure 3. Comparison of velocities of 5.56 × 45 mm Pb projectiles fired from different types of ballistic barrels made according to C.I.P. standard

Similar results to the C.I.P. standard barrels were obtained for NATO EPVAT standard which are shown in Fig. 4. The greatest difference of 1.44% occurs between PB-VB. The differences between VB-AB and PB-AB are below 1%.

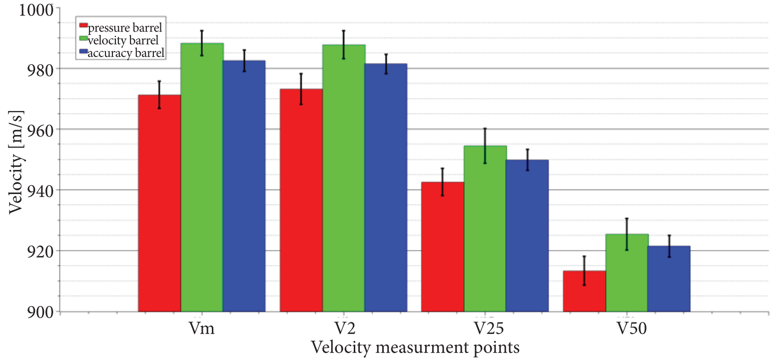


Figure 4. Comparison of velocities of 5.56 × 45 mm Pb projectiles fired from different types of ballistic barrels made according to NATO EPVAT standard

3.3. MESKO 5.56 × 45 mm RS

Figures 5-6 show the results for 5.56 × 45 mm RS (steel core) cartridges. In case of barrels made according to C.I.P. standard, the projectile velocity differences of 1.24% (PB-VB) and 1.73% (PB-AB) were observed. From statistical point of view, the difference between velocity and accuracy barrels was not observed.

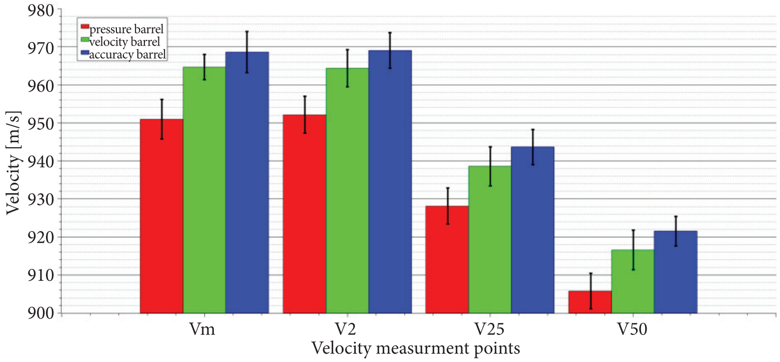


Figure 5. Comparison of velocities of 5.56 × 45 mm RS projectiles fired from different types of ballistic barrels made according to C.I.P. standard

In the case of barrels, made according to the NATO EPVAT standard, the observed differences are even smaller. The projectile velocity differences between the pressure barrel and two others are less than 1%. The results for velocity and accuracy barrels are statistically indistinguishable.

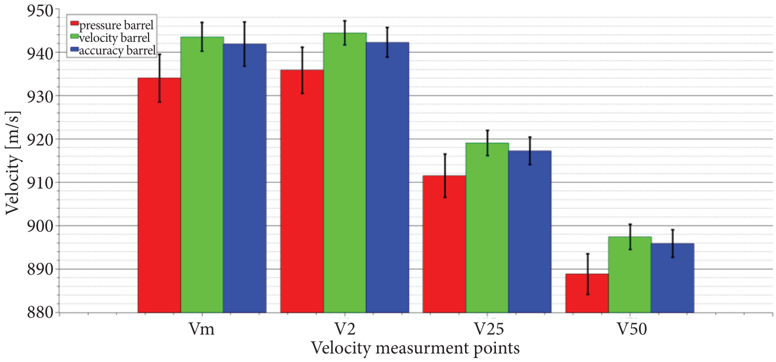


Figure 6. Comparison of velocities of 5.56 × 45 mm RS projectiles fired from different types of ballistic barrels made according to NATO EPVAT standard

3.4. Hirtenberger 7.62 × 51 mm BALL

The first of the two rifle cartridges used was 7.62 × 51 mm with the BALL projectile manufactured by Hirtenberger. Very similar differences in projectile velocities between different types of barrels as in the case of intermediate cartridges can be observed. The velocity of projectile fired from the pressure barrel is less than 1% slighter than the velocity of projectile fired from the velocity barrel and 1.46% slighter than the velocity of projectile fired from the accuracy barrel. Again, no statistically significant differences between velocity and accuracy barrels were observed.

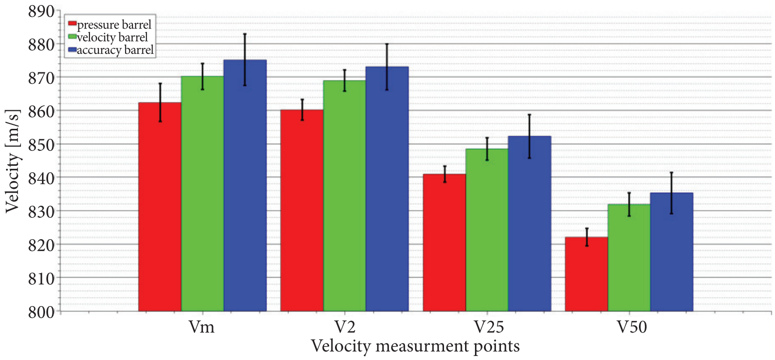


Figure 7. Comparison of velocities of 7.62 × 51 mm (Hirtenberger) projectiles fired from different types of ballistic barrels made according to C.I.P. standard

Curious results, presented in Fig. 8, in the case of NATO EPVAT barrels were observed. Only PB-AB velocities difference is statistically significant, but its value is less than 1%. However, unlike the other cases, where the projectiles shot from the pressure barrels were characterised by similar but lower velocities than the others, in this case it was reversed. The authors suspect that the reason for obtaining such results was the heterogeneity of parameters in the batch of ammunition.

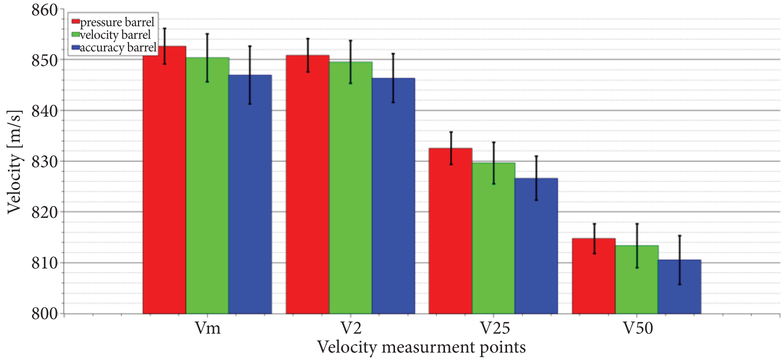


Figure 8. Comparison of velocities of 7.62 × 51 mm (Hirtenberger) projectiles fired from different types of ballistic barrels made according to NATO EPVAT standard

3.5. MESKO 7.62×51 mm BALL

Another ammunition used for tests was 7.62 × 51 mm with the BALL projectile manufactured by MESKO. The results are presented in Figs. 9-10. In the case of C.I.P. standard barrels, the differences between PB-VB and VB- AB are statistically insignificant. For PB-AB, the difference is less than 1%.

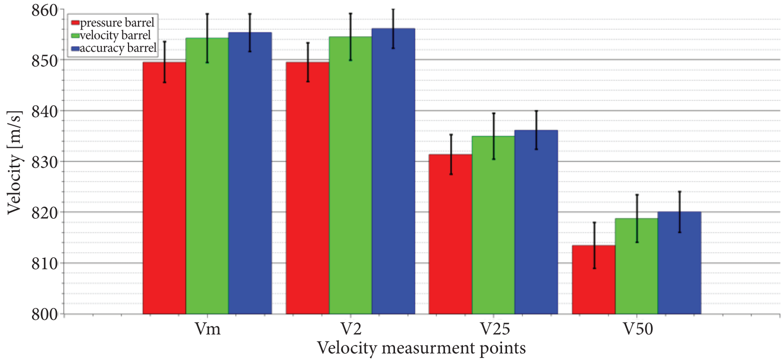


Figure 9. Comparison of velocities of 7.62 × 51 mm (MESKO) projectiles fired from different types of ballistic barrels made according to C.I.P. standard

For NATO EPVAT barrels all differences are statistically insignificant or less than 1%.

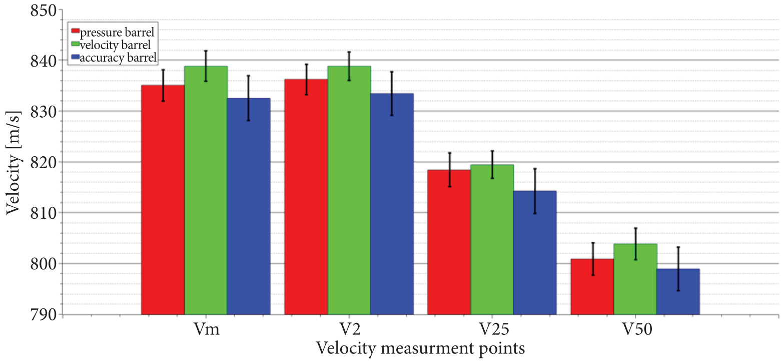


Figure 10. Comparison of velocities of 7.62 × 51 mm (MESKO) projectiles fired from different types of ballistic barrels made according to NATO EPVAT standard

3.6. Summary

In Table 1, the summary results of the carried-out tests were presented. Relatively large dispersion of the pressure measurement results in the case of .300 BLK ammunition (both standards of barrels) and 5.56 × 45 mm Pb for the barrel made according to the C.I.P. standard is noticeable. In these cases, correlation with the projectile velocity spreads is observable too.

The pressures obtained for pressure ballistic barrels, obtained for various cartridge types, are presented in Fig. 11. It was assumed that the higher pressures would be measured in the barrels made according to the C.I.P. standard, where the pressure is measured in the case. In general, the measurement results indicate such a trend. However, in the case of intermediate ammunition, the differences are statistically insignificant. For rifle ammunition, the pressures obtained in the C.I.P. barrels were 5% greater than these in the NATO EPVAT barrels. Similar results were obtained in the paper [5].

TABLE 1

Summary of results

Ammunition type	Standard	Barrel type	Velocity				Pressure [MPa]
			V_m [m/s]	V_2 [m/s]	V_{25} [m/s]	V_{50} [m/s]	
Hornady .300 Blackout	C.I.P. 508 mm* 17.5 mm**	pressure	691.23 ± 7.84	691.04 ± 7.83	669.94 ± 7.76	649.73 ± 7.84	361.69 ± 13.04
		velocity	709.10 ± 6.44	706.94 ± 3.27	683.96 ± 3.28	644.53 ± 2.86	-
		accuracy	700.30 ± 5.07	700.81 ± 4.99	678.01 ± 4.86	658.70 ± 4.93	-
	NATO EPVAT 406.4 mm* 37 mm**	pressure	675.43 ± 7.78	676.40 ± 5.67	655.97 ± 5.57	634.97 ± 5.63	361.91 ± 10.90
		velocity	682.79 ± 6.09	682.04 ± 6.69	659.74 ± 6.51	641.11 ± 6.45	-
		accuracy	685.43 ± 3.15	684.69 ± 3.10	662.57 ± 2.91	643.69 ± 2.58	-
MESKO 5.56 × 45 mm Pb	C.I.P. 600 mm* 25 mm**	pressure	993.41 ± 9.93	992.44 ± 9.38	961.34 ± 9.21	931.96 ± 9.19	323.93 ± 11.59
		velocity	1013.77 ± 4.13	1012.84 ± 3.30	980.49 ± 3.95	952.00 ± 4.26	-
		accuracy	1009.51 ± 3.18	1009.83 ± 4.01	977.14 ± 4.55	948.21 ± 4.33	-
	NATO EPVAT 508 mm* 46.5 mm**	pressure	971.23 ± 4.46	973.14 ± 5.15	942.50 ± 4.47	913.26 ± 4.68	316.04 ± 4.13
		velocity	988.17 ± 4.06	987.69 ± 4.60	954.36 ± 5.70	925.30 ± 5.21	-
		accuracy	982.49 ± 3.55	981.41 ± 3.22	949.76 ± 3.48	921.44 ± 3.63	-
MESKO 5.56 × 45 mm RS	C.I.P. 600 mm* 25 mm**	pressure	950.86 ± 5.24	952.09 ± 4.76	928.11 ± 4.66	905.73 ± 4.72	344.91 ± 7.56
		velocity	964.60 ± 3.26	964.26 ± 4.87	938.53 ± 5.10	916.46 ± 5.17	-
		accuracy	968.64 ± 5.45	968.97 ± 4.65	943.63 ± 4.55	921.51 ± 3.86	-
	NATO EPVAT 508 mm* 46.5 mm**	pressure	933.97 ± 5.47	935.83 ± 5.28	911.50 ± 4.96	888.77 ± 4.65	340.63 ± 8.30
		velocity	943.53 ± 3.30	944.36 ± 2.82	919.03 ± 2.95	897.39 ± 2.93	-
		accuracy	941.77 ± 5.07	942.24 ± 3.40	917.24 ± 3.19	895.76 ± 3.19	-

cont. tab. 1

Hirtenberger 7.62×51 mm BALL	C.I.P. 600 mm* 25 mm**	pressure	862.31 ± 5.68	860.09 ± 3.07	840.94 ± 2.42	821.97 ± 2.64	337.59 ± 7.62
		velocity	870.06 ± 3.91	868.87 ± 3.17	848.40 ± 3.34	831.80 ± 3.50	-
		accuracy	875.07 ± 7.68	872.99 ± 6.91	852.20 ± 6.54	835.24 ± 6.11	-
	NATO EPVAT 562 mm* 54 mm*	pressure	852.64 ± 3.53	850.84 ± 3.28	832.54 ± 3.18	814.71 ± 2.89	321.10 ± 5.70
		velocity	850.34 ± 4.69	849.51 ± 4.21	829.60 ± 4.14	813.33 ± 4.33	-
		accuracy	846.89 ± 5.70	846.33 ± 4.75	826.59 ± 4.33	810.50 ± 4.78	-
MESKO 7.62×51 mm BALL	C.I.P. 600 mm* 25 mm**	pressure	849.53 ± 3.95	849.49 ± 3.80	831.27 ± 3.94	813.44 ± 4.53	332.50 ± 6.93
		velocity	854.19 ± 4.83	854.50 ± 4.58	834.86 ± 4.46	818.73 ± 4.68	-
		accuracy	855.26 ± 3.65	856.09 ± 3.88	836.10 ± 3.83	820.03 ± 3.98	-
	NATO EPVAT 562 mm* 54 mm*	pressure	835.03 ± 3.14	836.21 ± 3.03	818.40 ± 3.34	800.79 ± 3.15	318.03 ± 5.02
		velocity	838.83 ± 3.05	838.76 ± 2.82	819.36 ± 2.75	803.84 ± 3.06	-
		accuracy	832.46 ± 4.42	833.40 ± 4.31	814.23 ± 4.38	798.90 ± 4.34	-

* barrel length
** gauge socket location measured from breech face

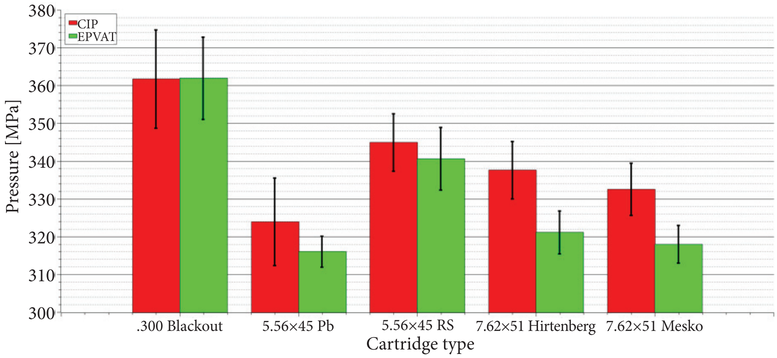


Figure 11. Comparison of pressures received for pressure barrels made according to the C.I.P. and NATO EPVAT standards

4. Conclusions

- If average values of the velocities of projectiles, shot from different types of ballistic barrels, are taken into account, small differences can be observed. The differences are especially noticeable with regard to the pressure barrels compared to other types of barrels. In every case, differences between velocity and accuracy barrels are statistically insignificant or they are less than 1%.
- In order to more precisely compare the velocity and accuracy barrels, long-range accuracy tests are required.
- Excluding certified laboratories, purchase of barrels of other type than pressure barrels is economically and practically unjustified. Pressure barrels are sufficient to conduct almost the entire spectrum of ballistic investigations.
- Despite different gauge socket distance from a breech face depending on the standard, in case of intermediate ammunition, propellant gas pressures ale almost equal. Gas pressures, measured in C.I.P. standard barrels for rifle ammunition, are approximately 5% greater than these measured in NATO EPVAT standard. Different results between these two classes of cartridges occur probably from greater length of a case in rifle ammunition. That causes greater distance of the gauge socket from the breech face in the barrel made according to the NATO EPVAT standard.

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DAWID GOŹDZIK, BARTOSZ FIKUS, JACEK KIJEWSKI

Analiza porównawcza różnych typów luf balistycznych wykorzystywanych w badaniach amunicji

Streszczenie. Producenci oferują różne typy luf balistycznych wykonanych według różnych standardów. W artykule przedstawiono porównanie trzech typów luf balistycznych: ciśnieniowej, prędkościowej i skupieniowej wykonanych według norm C.I.P. i NATO EPVAT. Zmierzono i porównano prędkości pocisków w kilku punktach pomiarowych na torze lotu oraz ciśnienie gazów prochowych w lufach. Głównym celem artykułu jest omówienie, czy do przeprowadzenia większości badań balistycznych potrzebne są wszystkie rodzaje luf, czy wystarczy jedna, najbardziej uniwersalna w danym kalibrze.
Słowa kluczowe: inżynieria mechaniczna, balistyka, broń palna, badania amunicji, właściwości balistyczne
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