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Correct and Effective Characterization of Fire-arms Noise: a Basic Aspect to Provide Reliable Input Data for the Reduction of Emitted Noise from Shooting Ranges in Urbanized Area

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A large number of noise sources in urbanized areas involve health impairment risk or important annoyance, and characterization and control techniques have been developed to improve the safety and wellbeing of dwellers. But there is a large variety of gun shots due to both the gun and the used cartridges, and it is almost impossible to dictate a general rule to manage in detail this topic. A clear example of this situations is represented by a shooting range, a limited and well defined installation in which shooting activities are practiced. The shooting ranges, which were since a long time usually located in former military facilities, are nowadays in proximity of densely dwelled areas, due to the recent impressive urbanization rate. Hence, this situation makes necessary that a number of shooting ranges must nowadays accomplish the urban noise classifications. The situation appears to be quite complex in Italy since the national regulations for the measurement and management of the environmental noise problems associated with the activity of shooting ranges appear to be somehow not exhaustive, this involving administrative and legal problems. The source simulation methods (e.g. continuous pink or white noise) and the propagation models upon which the common computer assisted techniques are usually based can reduce to a large extent the quality of the control measures, due to poor prediction of the emitted sound power and estimates of the noise propagation pattern.

1. Noise due to Firearms Shooting

Some measures for health protection in relation to noise may relate to:

- Production activities, where the noise is calculated through the standard ISO 9613-2 (1996);
- Aircraft near airports, whose noise is estimated through the method described in the document 29 ECAC-ECAC (1997);
- Traffic noise, calculated through the French method NMPB (1996);
- Rail traffic, estimated with the Dutch methods (1996).

These are all continuous noise or noise that have a long duration in time, and it is relatively easy to get representative values. However, the noise generated by a gun shot isn't continuous, but impulsive, consisting of a series of energy pulses of short duration and high sound pressure peaks. This topic was discussed by ISO 17201 (1-2-4) proposing a series of calculations and data standardization for an empirical estimation of the generation and propagation patterns.
The noise generated by a firearm is an impulsive noise, which consists of a series of energy pulses of short duration and high sound pressure peaks (Maher R. C., 2007). Noise related to the gun shots is due to:

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- Noise associated with the expulsion of the air, the bullet and the gases from the barrel;
- Noise associated with the movement of the bullet in the air and its impact on the target. So, in a shot's noise we can find three fundamental components:
- Precursor wave, caused by the fact that the bullet, travelling in the barrel, accelerates and compresses the air, so that it is preceded by a wave that reaches the pressure of several atmospheres;
- The wave caused by the displacement of the air in the barrel due to the movement of the bullet. It is usually negligible;
- The wave caused by the hot gases of the explosion. The pressure wave depends only on the pressure of the gas, a function of the barrel length and of the characteristics of the powder. Short barrels and progressive powders have as consequences high pressures at the muzzle; the opposite occurs with long barrels or lively powders. To estimate the shot's noise it is necessary to identify the various components (Freytag J.C., Begault D.R., Peltier C.A., 2006).

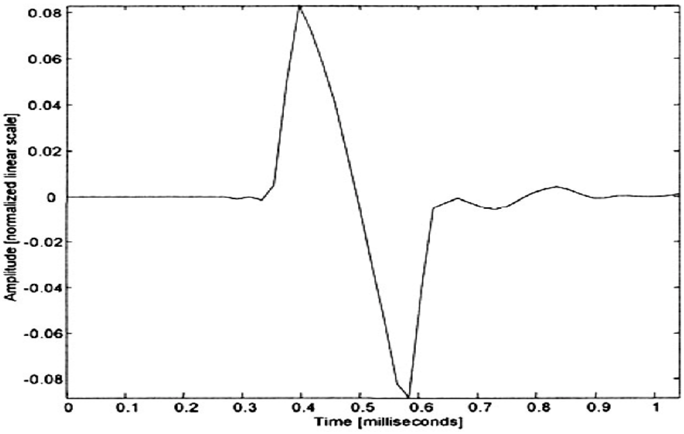

Figure 1: Shock wave recording (R.C. Maher) – left – and a typical shooter – right

2. National Shooting Range and Environmental Noise Regulations

The National Shooting Range is an institution of the State – governed by public law, as described by the constitutive law No. 883 of 7/2/1882, and it doesn't represent neither a business activity or a productive activity, nor a commercial activity according to art. 2195 of the Civil Code.
The noise problems, for this case, are regulated by the environmental noise control official regulations:
- Law n° 447/1995 and other similar (l. 426/98, l. 448/98, l. 205/99, l. 179/02);
- President of the Council of Ministers decree (11/14/1997);
- Circular No. 00000348-1-inq-rum1 of the Ministry of the Environment and Land Protection (9/6/2004).

The concepts of absolute and differential noise are introduced, and the characteristics of the source, in particular in terms of emitted sound duration must be taken into account. With special reference to the noise environmental pollution from shooting ranges, even if the application of the differential criteria can be controversial for the aforesaid reasons, it can be stated, as a common result, that the problem usually does not exist, since the two criteria (differential or absolute approaches) don't show substantial differences in terms of criticality.

3. The noise sources and their location

According to the standard regulations the source (the gun) should be placed at 1.50 m above ground level with barrel parallel to the ground level. The guns used for the present research work were chosen on the basis of the available ammo calibers (Courtney M., 2007), and are listed as follows (Table 1):

Table 1: Guns used in the tests

Ruger pistol 6"barrel Cal 357 Magnum			rolling block pistol 9.5" barrel Cal 357 Magnum
Winchester M1car rifle 45 cm barrel Cal 357 Magnum			Winchester rifle 60 cm barrel Cal 357 Magnum
DWM P08 pistols 4 ", 6", 8" barrel Cal 7.65 P (30L):			Beretta CX4 rifle 41 cm barrel Cal 9 x 21 (9 IMI)
Tecnema TCM2 pistol 5.5" barrel Cal 9 x 21 (9 IMI)			Beretta 98 pistol 12,5 cm barrel Cal 9 x 21 (9 IMI)
SW 617 revolver 6" barrel Cal 22 LR Stinger			Beretta Unione/Olimpia Car 52/60 cm barrel Cal 22 LR Stinger

4. Measurement Campaigns

The shooting range where the tests have been carried out is characterized by a rectangular shape, with 12 lines. Its dimensions are 24 * 30 meters. It is bordered by three concrete walls, lined with sound proofing material. In accordance to a Technical Directive of the Defence Ministry, the overall shooting range layout can be sketched as follows (Figure:2):

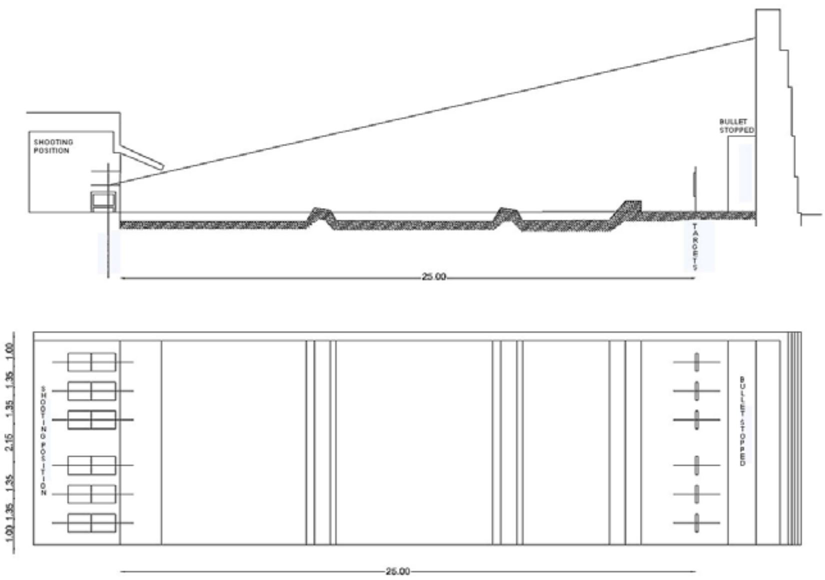

Figure 2: Simplified sketches of the Shooting range layout

5. The Measurement Layout and Instrumentation

The measurement campaigns were carried out in 2009-10. The following instruments were used:

- Bruel & Kjaer integrating sound level meters fitted at the purpose with a B&K 4941 ¼" microphone (specially designed for measurement of very high levels, gunshot noise measurements included);
- Bruel & Kjaer 4220 pistonophone calibrator;
- Larson & Davis 2900 real time analyzer;
- Edirol R – 09 digital recorder.

Asides, a bullet speed Shooting Chronograph and environmental conditions recorders were used (Maher R.C., Shaw S.R., 2008). The microphones were positioned (Figure 3) at the shooting bench, in the proximity of the barrel muzzles (the use of windscreens was unfortunately unavoidable for protection from sparks).

The sound level meter was connected to the real time analyzer for both the evaluation of the energy content in the 20Hz – 16 kHz range, and to make immediately detectable any saturation phenomena. A backup system for further analysis is based on the use of the digital recorder.

Figure 3: The 1/4" Microphone position (left) and Real Time Analyzer (right)

6. Preliminary Results

6.1 Ammo Quality and Measurement Reproducibility

Some preliminary tests were carried out with the use of both commercial factory -quality checked- and handloaded ammo of different powder charge and reaction velocity, and bullet material and weight (and, in some cases, shape). Even if in a number of cases the results in terms of target scoring achieved using handloaded ammo specially designed for the used gun proved to be quite satisfying, the common rule suggesting the use of high quality target grade ammunition, purchased in bulk so all ammunition comes from the same manufacturing lot since even minor changes can result in changing the point of impact. So it was indirectly confirmed that an important dispersion in the resulting data was, as expected, recorded both in the bullet velocity (from 3 % for factory to more than 8 % for handloaded ammo) and in the noise emitted level. In Table 2 the difference is shown in the case of subsonic noise generated by commercial and handloaded ammo in 7.65 P caliber (measurements carried out at 1m distance from the barrel muzzle).

Table 2: Mean dispersion in the measurement results for shots with factory and handloaded cartridges

Production	Cartridge	Pistol	Recorded noise dispersion
Factory	*7.65 P - LRN*	*DWM P08 4" barrel*	*± 0,5 dB*
Handloaded	*7.65 P - LRN*	*DWM P08 4" barrel*	*± 2 dB (*)*
(*) some results varied of more than 3 dB from the mean value			

6.2 Barrel length Influence on the Bullet Velocity and the Characteristics of a Gunshot Noise

The tests carried out with commercial - quality checked - ammo confirmed the relationship between the bullet velocity -and expectable emitted noise characteristics- and the barrel length: in Table 3 and

Figure 4 the transition is shown from subsonic to supersonic velocity in the case of identical pistols fitted different barrels of increasing length:
The recorded shot noise values (measurements carried out at 1m distance from the barrel muzzle) ranged from 143.5 to 147.5 dB in the case of subsonic cartridges, and from 152.0 to 155.5 dB for the supersonic cartridges (in both cases the aforementioned dispersion of ± 0.5 dB must be considered) .

Table 3: Results got with 7.65 P (30 Luger) commercial cartridges

Cartridge	Bullet Type	Bullet [grains]	Powder type	Powder [grains]	Pistol	Barrel length [inches]	Av.Bullet Velocity [m/s]
7.65 P 30 Luger	*Full Metal Jacket*	*93*	*Balistite 1*	*4.01*	*DWM*	*4*	*348*
						6	*391*
						8	*411*
7.65 P 30 Luger	*Lead Round Nose Teflon - coated*	*110*	*3N37*	*4.86*	*DWM*	*4*	*303*
						6	*324*
						8	*344*

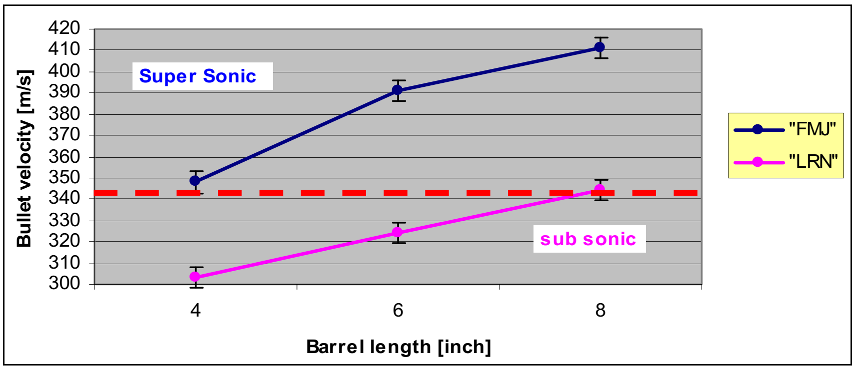

Figure 3: Bullet velocity in the case of DWM pistols fitted with 4", 6" and 8" barrels and commercial cartridges in 7.65 P caliber

6.3 Considerations on the emitted Noise Frequency Distribution in the proximity of the Source
Even if the imprecision due to the unavoidable presence of the windscreen must be remembered (the authors were not able to find in literature suggestions for such special measurements), the frequency distributions recorded appear to be acceptable, at least to a first approximation: in Figure 4 an example is provided, from a subsonic 7.65 P cartridge shot by a DWM P08 pistol with a 4 inch barrel

7. Conclusion

The characterization of the gunshot noise in practical situations typical of shooting ranges in urbanized areas is both and important and a quite complex problem, the standards and technical literature providing precious information but leaving some practical aspects not completely solved. Some attempts to define the source characteristics on the basis of theoretical relationships based on the

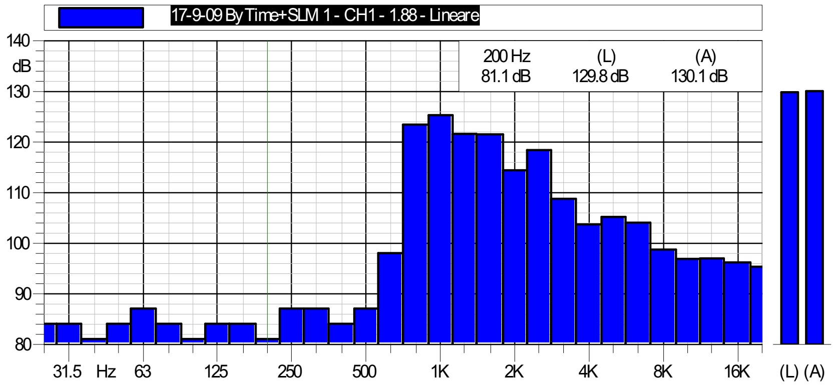

Figure 4: Frequency spectrum of the noise from a 7.65 Luger P LNR cartridge (DWM pistol, 4" barrel)

results of measurements at different distances according to a widely used approach provided poor results due both to the large number of parameters conditioning the emitted noise from the source (powder quantity and characteristics, bullet mass and shape, gun characteristics, etc.) and to the complexity of the noise propagation pattern in the shooting ranges. Hence, the research work here discussed can be considered a quite preliminary approach, the main results being a valuable definition of the instrumentation set and of the measurement layout (with some problems still existing), but further work is clearly necessary – and we are continuing both study and measurements - to get the result of an effective collection of input data of the quality necessary where the goal is a scientific control design of the emitted noise towards dwelled areas in the immediate proximity of the shooting range, able to go beyond the present approach based on rough empirical solutions.

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