COLT C8A2 CARBINE IMPULSIVE NOISE AUDITORY HAZARD ASSESSMENT THROUGH TESTING IN A REVERBERANT ENVIRONMENT

Sebastian Ghinet*, Andrew Price, Anant Grewal, Yong Chen, and Viresh Wickramasinghe
NRC-Aerospace, Flight Research Laboratory.

1 Introduction

Exposure to high levels of gunfire impulsive noise is potentially hazardous to human hearing and may lead to permanent auditory as well as non-auditory damage in the unprotected ear. A client approached NRC Aerospace to address a concern for potential hearing damage from discharging of firearms within enclosed spaces, characterized as reverberant acoustic environments.

In order to address this concern, a reconfigurable room was built by NRC on a shooting range and this test setup was used to measure the impulsive noise time trace waveforms. The measured waveforms were analyzed in accordance with the updated standard procedure MIL-STD-1474E (revision 15 April 2015) [1] using the algorithm suggested by the standard: Auditory Hazard Assessment Algorithm for Humans (AHAAH) [2]. This algorithm enabled the assessment of the auditory hazard risk to which personnel would be exposed during a Colt C8A2 carbine discharge. Three different geometry and floor area configurations were considered for the room. Moreover two different window configurations where considered, namely: a) armored window with a narrow slit gun port opening surrounded by ballistic glass and b) wide open large window.

The paper presents the results and conclusions of the data analysis of the testing campaign aimed at evaluating the noise exposure and assessing the auditory hazard of personnel using the Colt C8A2 carbine.

2 Measurement procedure

The test procedure developed for this study took into consideration several technical challenges related to the high complexity and specific technical requirements.

Most of the impulsive noise measurements presented in literature are conducted in free field conditions such as a shooting range, which provide ideal conditions. Depending on the nature of the study in the literature, a part of the measurements was conducted using a firearm fixture while other studies were conducted with a human subject operating the firearm [3].

The present work differentiates from any previous studies because the major part of the complexity of the problem arose from the large number of shock wave reflections involved in this measurement procedure. In the present work the emphasis was on determining the importance of the shock wave reflections and influence of reverberation behavior of the partially enclosed room on the auditory hazard assessment.

In the present setup the spherical shock wave centered on the carbine mussel (situated outside the control post) was expected to impinge the ballistic glass of the window and penetrate through the 2-inch wide gun port slit opening. The diffracted component, through the slit opening, of the shock wave was expected to propagate towards the shooter's body. One part of the wave was expected to impact the body and reflect back towards the window. The shock wave was expected to experience a number of reflections between the shooter's body (head, arms and torso in shooting representative position) and the window/wall in front of the shooter. A second part of the shock wave was expected to propagate inside the room and experience the reverberation behavior of the room.

In order to provide a realistic testing environment and address the challenging test specifications, NRC proposed to design and build a reconfigurable reverberant room on the premises of a shooting range. Impulsive noise measurements were performed on the shooting range of the Eastern Ontario Shooting Club (EOSC) in Cheney, Ontario.

2.1 Configurable room

A configurable room as shown in Figure 1, having the footprint and floor area of representative small (green), medium (red) and large (blue) size control posts was built on one of the long range EOSC shooting ranges. The small size room had a hexagonal shape and a floor area of $8m^2$. The medium size room had a polygonal 6 sided shape and a floor area of $13.5m^2$. The large size room had an octagonal shape and a floor area of $18m^2$. The three room configurations and the wall dimensions are shown in Figure 1 (a=1.93m; aa=1.93m; b=2m; c=2.44m; d=2.22m). All walls of the rooms were 2.44m in height.

2.2 Instrumentation

The impulse noise waveform record duration was 0.5s. The data acquisition system was set to record 50msec of data prior to the trigger. The sampling rate of the recorded signal throughout the present measurement campaign was 1 M-Samples/s.

The data acquisition system was composed of a National Instruments (NI) front-end (NI PXIe-8840 Core i5-4400E 2.7GHz, Dual Core, Win 7 (64)-bit) with a high sampling rate data acquisition card PXIe-6124 Simultaneous Sampling Multifunction DAQ which provided 4 simultaneously sampled analog inputs, at up to 4 MS/s per channel, 16 bits of resolution, and a PXI Express interface for dedicated bandwidth from module to controller. The NI hardware was used in conjunction with an in-house developed LabVIEW computer program application with microphone calibration capability as well as trigger control. The microphone used in the present measurement campaign

*Sebastian.Ghinet@nrc-cnrc.gc.ca

was a 1/8-inch GRAS Type 46DP with a frequency range of 6.5Hz – 140KHz, a dynamic range of 46dB(A) – 191dB and a sensitivity of 0.85mV/Pa.

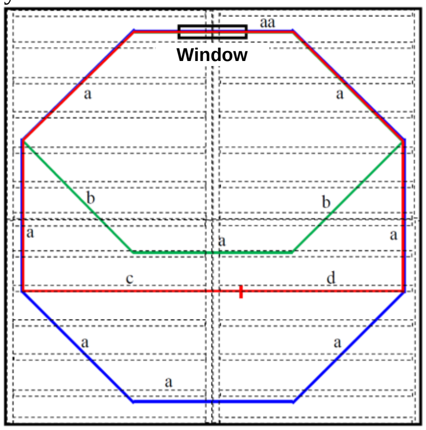

Figure 1. The three configurations of the room: Green (hexagon); Red (polygon, 6 sides); Blue (octagon),

3 Results

3.1 Free-field

Measurement configurations conducted in a free field condition were performed to facilitate comparisons and highlight specific behaviours governing the results measured within the room. Those measurements were conducted with the microphone placed at the following locations: 2m from the carbine at the height and azimuth position of the muzzle - the peak impulsive noise level Lpk was 162.8dBP; 0.5m from the carbine at the height and azimuth position of the front sight of the carbine (0.6m from shooter's right ear) - Lpk was 173dBP; 0.5m from the carbine at the height and azimuth position at the half length of the carbine (0.38m from shooter's right ear) - Lpk was 168.5dBP; 0.5m from the carbine at the height and azimuth position of the shooter's right ear - Lpk was 163dBP; 0.1m from the shooter's left ear - Lpk was 160dBP and 0.1m laterally from the shooter's right ear - Lpk was 159dBP.

An example of free field time-domain waveform measured at a lateral position 0.5m from the carbine axis and 0.6m from shooter's ear (front sight of the carbine) is shown in Figure 2.

3.2 Reverberant Environment

For each of the three configurations of the room, the impulsive noise wave pressure was measured at a distance of 0.1m from the right ear and left ear of a shooter. As an example, the time-domain waveform measured at 0.1m from the right ear of the shooter in room Configuration A is shown in Figure 3.

Using the AHAAH algorithm, the estimated number of allowed occasional exposures (single shots), within a 24-hour sliding window period, without wearing a hearing protection, was found to be very limited e.g. maximum of 3 (three) rounds for two smaller control posts configurations A and B and 4 (four) rounds for the largest control post configuration C. Exceeding these limits may result in noise induced hearing loss (NIHL) as per the MIL-STD-1474E standard.

4 Conclusion

The auditory hazard risk for personnel exposed to gunfire noise as a result of discharging a Colt C8A2 carbine from within a reverberant environment of a room was assessed in this study. The measured waveforms were analyzed in accordance with the updated standard procedure MIL-STD-1474E using the algorithm suggested by the standard: Auditory Hazard Assessment Algorithm for Humans (AHAAH). The data analysis provided the estimated number of allowed occasional (no more than once per week) impulsive noise exposures, within any 24-hour sliding window period.

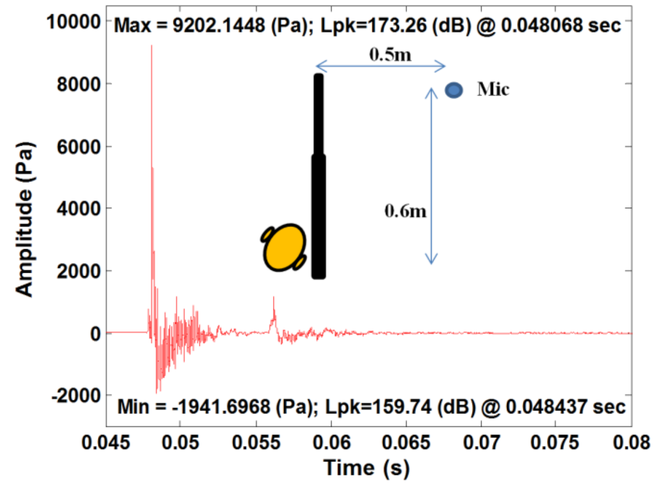

Figure 2. Free field time-domain waveform measured at a lateral position 0.5m from the carbine axis and 0.6m from shooter's ear

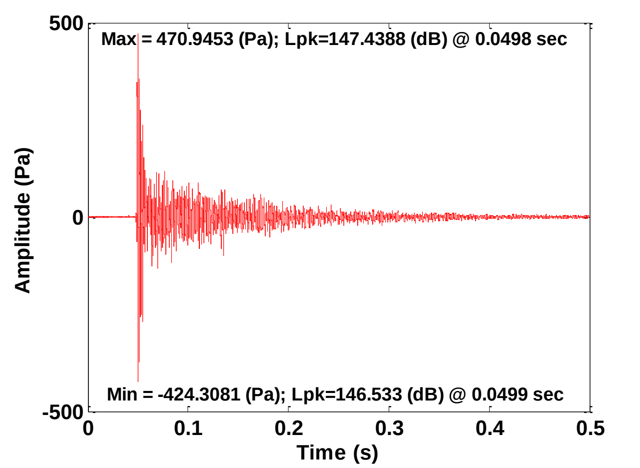

Figure 3. Time-domain waveform measured at 0.1m from the right ear of the shooter in Control Post Configuration A.

References

[1] MIL-STD-1474E, "Department of Defense Design Criteria Standard Noise Limits".

[2] G. Richard Price, "The Auditory Hazard Assessment Algorithm for Humans (AHAAH): Hazard Evaluation of Intense Sounds", July 2011, ARL-TR-5587.

[3] P. Rasmusen, G. Flamme, M. Stewart, D. Meinke, J. Lankford, "Measuring Recreational Firearm Noise", Sound & Vibration, August 2009, pp14-18.