2023 SILENCER SUMMIT SOUND TEST RESULTS

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Introduction

The 2023 SILENCER SUMMIT sound test was a sound testing event that took place August 8, 9, & 10th, 2023 at TMC's indoor test facility in Cheyenne, WY.

The purpose of the sound test was threefold:

1) to test as many silencers as possible in one place at one time with the exact same setup;
2) to share sound testing best practices and test additional issues on the PLICSI;
3) to provide a "proof of concept" for a new sound test method, the PLICSI, that allows for platform to standard critiques (aka: yet "Another" test?), thereby also analyzing the applicability of that test protocol for future testing.

The event was primarily organized by SAC, TMC, was the host, scientific equipment operator, did the post-processing of the data, and provided the overall technical direction and administration. Silencers from: Ace Suppressors, Alex Engineering, Grand Defense, Gray Ops, Gwinn Arms, Gwinnup Innovations, Griffin Armament, JK Armament, Radical Defense, Revolver, Sage, TMC, YHM, Atlas Arms, Silencer Shop, and Hampton Products were the test silencers.

Results

Approximately 300 gun/silencer combinations were tested over the three days. The bulk of the testing was done on an AR platform, and some of each silencer with 5.56 & 7.62x51 although there were some pistol caliber silencers tested on pistols, rifles, and MP5 platforms.

For each test, all shots were recorded on the three microphones and all waveform files were saved. These waveform files were used in post analysis to determine the following parameters for each mic position: peak pressure (Pa), peak pressure (dB), peak pressure (dBC), impulse (Pa*ms), impulse (dB*ms), and impulse (dBC*ms).

The crux of the reporting contains:

1) the tables in this HTML document, which are dynamically sortable on all columns;
2) the "Sound Test Results" Excel file, which has the raw data, the sortable tables, and charts that contains a pivot for each unit, for each mic, for each test parameter (peak, impulse, and dual for a total of 18 graphs per test unit);
3) a CSV file that can be easily imported into a spreadsheet for your own sorting;
4) Excelpies that for an entire file, let you pull up the entire dataset as output by the PLICSI. This dataset is approximately 5.5 GB once compressed.

The Excel file has a pivot table and chart calculation for every shot in the tables below. This means that if there's some other analysis you want to do to the waveforms, you're welcome to run it and graph it yourself.

At the bottom of this page is a link to the "Jamovi_string.txt" Grizzer Function that was used to generate the values in the tables from the waveform files.

Experimental Setup and Procedure

1. Test Setup

1. Decorated
   a. Test Unit: SAC, BRS, & CR
   b. Stand-Off Tube: BRS
   c. Pro Ignitions: SAC, BRS, & CR
   d. Muzzle Device: SAC & CR
   e. Pro-Ignition Lubricant: Gun Tools, L.

FIGURE 1: MICROPHONE LOCATIONS

2. Test Location Properties

Data was obtained inside of the TMC Bun with approximate range and bullet flight location, see Figure 2.

FIGURE 2: RANGE LAYOUT

3. Post Analysis Definitions

1. **Peak** - The maximum value in the curve, approx 0.1s, 40 and dB.

2. **LZE** - Less is a "sound energy metric" = Less defined as equivalent constant sound energy for a fluctuating curve. It is calculated by averaging the SPL (sound pressure level) over the defined time frame and then converting that value back to decibels. The LZ3 curve becomes a flat average sound level. If our (see above) 0.1s curve averaged to 1 second, then the LZ1 would be a flat line at the 1 second level.

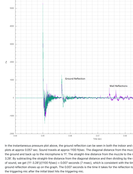
3. **Impulse** - Statistical using the total overload where any under the curve is calculated by multiplying the value and the time interval, applies to Pa*ms and dB*ms.

4. **Pa dB calculation** - 20*log(Pa) where Pa is the Pa Pascal equivalent of 1dB.

5. **dB to dBA** - In this document, dB is used to refer to unweighted dB. dBA is used to refer to A-weighted dB.

LINSUPPRESSED GUNSHOTS

FIGURE 3: RAW MUZZLE INSIDER VS. OUTSIDER: PRESSURE



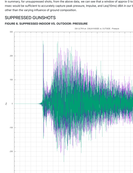
In the instantaneous pressure plot above, the ground reflection can be seen in both the indoor and outdoor plots at approx 0.001 sec. Sound travels at approx 1100 ft/sec. The diagonal distance from the muzzle to the ground is approx 1.5 feet, and the distance from the muzzle to the ceiling is approx 3 feet. Thus, 1.5ft/1100 ft/s = 0.0014s, subtracting the straight line distance from the diagonal distance and then dividing by the speed of sound, we get (1.5ft-3ft)/1100 ft/sec) = 0.001 seconds (1 msec), which is consistent with the time the ground reflection is seen in the plot. The wall reflections, on the other hand, do not have the reflections to get to the first trigger/zero line after the initial blast like the triggering mic.

The intensity of the ground reflections is affected by the ground composition, i.e., concrete will reflect more than dirt, and by the angle of incidence. Measurements for outside reflected sound of the pressure wave that used floor of the indoor range.

The reflections from the walls shown up well before 0.075 seconds in Figure 3 above. The wall reflections are affected by the composition of the wall, the angle of incidence, and the distance. The wall reflections show up sooner and more distinct in the pressure wave vs. the sound wave. On the outside, the reflections show up to a higher equivalent sound level (Pa) when they come back to the mic position.

FIGURE 4: RAW MUZZLE INSIDER VS. OUTSIDER: IMPULSE

FIGURE 5: RAW MUZZLE INSIDER VS. OUTSIDER: Log(Abs) dB

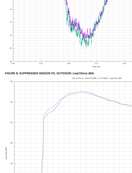


Note in the Log(abs), the ground reflection on the outdoor plot is a higher intensity than the ground reflection on the indoor. This is because the composition of the outdoor "ground" is more reflective (compared to dirt).

In summary, for unsuppressed shots, from the above data, we can see that a window of approx 0 to 75 msec captures the "important" pressure, impulse, and intensity data and captures BM or run-ups better than the outgoing influence of ground composition.

SUPPRESSED GUNSHOTS

FIGURE 6: SUPPRESSED INSIDER VS. OUTSIDER: PRESSURE

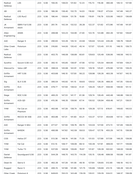


The various reflection events of the indoor and outdoor plots are harder to identify and differentiate when shooting suppressed. The suppressor extends the pressure release time which causes the ground reflections to be lost in the noise of the event. In other words, the time it takes for the muzzle report from the suppressor to reach the ground and return to the mic is longer than the time it takes for the muzzle report without a silencer and the muzzle to wall reflections to be lost in the noise.

For sound pressure, the peaks to split strength the entire waveform is evaluated in the search for the peak value. The peak value is typically the muzzle report and not the ground reflection. For the data in Figure 6, the peaks are automatically assigned to the point and it's clear the peak value is the muzzle report, sometime before 0.005 sec. Thus, the reflections are coming back to the mic at least 10 msec after the muzzle report. The ground reflection is not affecting the peak pressure measurement. Therefore, the "sound case" in terms of retaining pressure longer (due to the volume and the gas volume and pressure) of 556.mp4.

FIGURE 7: SUPPRESSED INSIDER VS. OUTSIDER: IMPULSE

FIGURE 8: SUPPRESSED INSIDER VS. OUTSIDER: Log(Abs) dB



Accentuated by the suppressor blast, ranging pressures (dBc, Pascals) etc. the wall reflections are still there to identify in the impulse and pascals. Figures 7 and 8 show that an operator whistle can be set to shift the maximum value to the impulse and without those waves being affected by wall reflections.

In Figure 7 (MP5-SD), the large negative curve and the second positive curve of the impulse calculation is affected by the ground reflection and therefore, the maximum value is affected by the ground. The wall reflection is enough to include the first positive portion and its return to zero (at approx 0.005 sec). Impulse plots used throughout various laboratories are typically truncated since they cross zero on the way down the first time. Thus, the ground reflection would not be included in the impulse calculation. In Figure 8, the wall reflections are also dynamically adjusted for each waveform by finding the minimum value of impulse that is -75 msec before the maximum value. The wall reflections are included in the impulse calculation for the suppressed case before the maximum value was found.

For cals, specifically Log(Abs) dBA, the data analysis window was set at -0.0125 sec after the shot, or 75 msec. This correlates with the time we have already determined that reflections come back. In Figure 8, it is clear that the wall reflections are lost in the noise. The ground reflection is about 2300 dBA (mic), so we capture the maximum value of the gunshot with the process.

Also note that the cals graph from approx 0.005 to 0.075 is higher for the outside plot primarily because of increased ground reflection.

Environmental Factors When Testing Outdoors

Outdoor sound testing is affected by many environmental factors such as weather on the test day, primarily wind. Gross wind events need to be taken into advisement when considering the efficacy of a sound mitigating upgrade/ mod. Nevertheless the current has a direct effect on how difficult or easy it is to walk. Wind has the potential to increase the ambient sound, thereby forcing the mic to be closer to the gunshot and the noise to be relatively louder and vice versa.

SUMMARY

By analyzing unsuppressed and suppressed gunshot data from indoors and outdoors, we determined that accounting, finding peak pressure, impulse, and Log(Abs) dB was possible by ordinating the data to the muzzle report. Ordinating the data to the muzzle report minimizes the influence of the ground reflection and wall reflections and allows for the use of each sensor (mics) to correlate the reflections recorded to the muzzle report.

HOST/CARTRIDGE NOTES

The following tables are broken out by combinations of "suppressor caliber" and "cartridge and host." For example, the first table served .223 caliber suppressors shooting cartridge 5.56* on — corresponding to all the .223 caliber suppressors shooting 5.56 ammunition from our 5.56 host.

Here is a list of the different cartridges/hosts in the test:

1. **5.56** - LC M193 5.56, Grizzly Win 55 JHP, PMC 55 JHP, and Free Mil 55 FMJ
2. **.300 BLK** - Grizzly 110 SMK, Grizzly 125 OTM, Grizzly 125 FMJ
3. **.308** - LC M118 LR, Sig Match Black 175 MTM, Sig Elite Hunter 150 SP
4. **.338 LM** - Sig Elite Hunter 250 SP
5. **.45 ACP** - Hornady JCP(Revolver) 230gr FTX, and Free to Bleed 185G W/ TMC
6. **9mm** - Sig Elite Hunter 115 JHP, Free to Bleed 124G W/ TMC, and Free to Bleed 147G W/ TMC
7. **Brass** - 223 Remington Brass 55gr, Aero Precision 6 Flanged Brass
8. **9mm MP5K** - 223 Remington Brass 124gr, Free Bleed 124 W/ MP5K/SD9
9. **9mm MP5SD** - Free Bleed 124 W/ MP5K/SD9, Free Bleed 147G W/ MP5K/SD9
10. **9mm P320 MPX** - Aero Ammo 124gr FMJ, Free Bleed 124 W/ MP5K/SD9
11. **9mm G17** - 223 Remington Brass 124gr, Free Bleed 124 W/ MP5K/SD9
12. **Tested** - Not reported on header/ key

RESULTS

The following results are grouped so that the tests done on the same host/cartridge are together. In the column headers, TMC, "SR", and "CER" refer to test positions, left, to mitigate left, SR, to "Shooter's ear", and CER, or to the JK CER Adaptor.

The tables are responsive, so you can click on any column header to sort by that field.

This is best viewed on a wide monitor. You can also zoom out if your browser causes "Control+WHEEL".

COLUMN ABBREVIATIONS: "Imp" = Impulse, "Loud" is Log(Abs), "Pa" is Pressure in Pa, "Int" is weight (cal) Intensity, "Dur" is Duration, "Pa*ms" is Pressure in Pascals multiplied by the duration in ms, "Int*ms" (cal)Int, is Int. "Pa*ms" is "Impulse."

.223 CALIBER SUPPRESSORS SHOOTING CARTRIDGE/HOST: 5.56

Search:

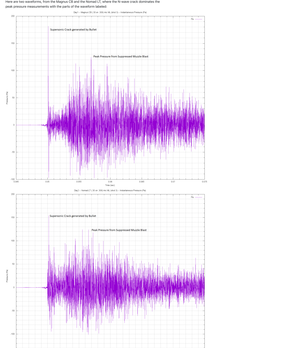
SUPPRESSOR	5.56	LOUD	Imp Pa	Imp dB	Imp dBC	Imp Pa*ms	Imp dB*ms	Imp dBC*ms	LOUD	Imp Pa	Imp dB	Imp dBC	Imp Pa*ms	Imp dB*ms	Imp dBC*ms	LOUD	Imp Pa	Imp dB	Imp dBC	Imp Pa*ms	Imp dB*ms	Imp dBC*ms	Comments	Date Updated
762 Suppressor	.223	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	Tested	2023-08-08
Ace Suppressors AR-15 Rifle	.223	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	Tested	2023-08-08
AMERICAN DEFENSE MFG Omega 7	.223	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	159.8	1,000.0	154.0	154.0	1,000.0	154.0	154.0	Tested	2023-08-08
Griffin Armament

| | | |

What about supersonic crack? Was that included or excluded?

Supersonic crack (also known as the Kerr effect) was not included in the calculations. Other than the embedding described in the "Experimental Setup and Procedure" section, no parts of the waveform were excluded. If supersonic crack was present, it would be included in the calculations. In the case of the Model 2 Mega-Joule DE 3D-Jet, 200" Air Shot 1, just after 0.05 a peak just under 100 PSI. That is the 3D-crack. The second highest peak at approx 0.001 is the peak from the muzzle discharge. The following supplement in the "Pressure Vs Time" section shows the waveform for Shot 1 in full. The 3D-crack is the peak just after 0.05, about equal to the discharge peak, highpass or Mega, Normal 12, dated. In this dataset, supersonic shot as 5.56 still never have their peak less than the 0.5 crack because the action noise ("pop pop") on the MK18 dominates.

Here are two waveforms, from the Magnus CSI and the Normal 12, where the 5.56 wave crack dominates the peak pressure measurements with the peak of the muzzle discharge being much smaller.



Why didn't you calculate any exposure metrics or damage risk criterions (DRC)?

There are two principal reasons and one ancillary reason why:

(1) As anyone who has fired a firearm - even suppressed - inside a building or tight tent is a well-known, well-documented, and well-understood fact, the pressure waves from firearms can cause hearing damage, especially hearing loss and tinnitus. Shooting inside a building is a kinetic experiment that shooting outside in the middle of a field because of all the reflections that come back. They, exposure risk increases. Because of the increased risk, the Department of Defense (DoD) has a vested interest in a standard upon the local physical environment. A tent's dome is the middle of an open field, or even better, one taken while suspended 20' off the ground to prevent the ground reflections, would literally only be valid as a DRC for that tent. Any other tent, building, or even a tent on a different day with a slight breeze would be a well-or-shooting-inside-a-building or tattoo or similar, would have a vastly different damage result.
(2) There is significant disagreement and/or discussion in the academic literature about the validity of various DRC's with respect to their applicability to gunshots, see these papers as a start: Fletcher Martin 2022 Interpreter Noise OPC relationships and Knowledge gaps; Acoustic Impact on Livestock Of Military Training Activities; Hamme Gerkin Table Top Gunshot Study; Hamme Gerkin Gunshot at 600M; Lenzuolo 2016 JASANN; Lei 108 Jul 2 2001; Hamme Gerkin Table Grass 2007; Pen-testers of Lenz NNSC 2007-08; Hamme Gerkin Table Susceptibility to impulsive noise 434; Hamme Gerkin Table Susceptibility to impulsive noise 435; Hamme Gerkin Table Susceptibility to very high level, low frequency sound ; Includes noise injury prediction based on the Lombardi energy Zwaldo Chart 2006 Hess ; Mazzilli An Analysis of the Blast MICIN SPIE Report No 359 ; Bellanca Blast Overpressure Workshop v5.pdf ; Bellanca et al 2012 effects of unfiltered and filtered impulsive noise on hearing protection
(3) Short #1 and #2, it would be irresponsible to publish a metric that implies "safety" when actual damage is not known and cannot be guaranteed.

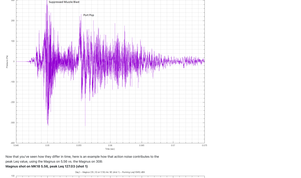
What's the deal with ground reflections and ground composition?

Per the discussion around Figure 5, the reflectivity of the ground depends on its material and composition. In that figure, from about 0.08 to about 0.087 seconds, the use value of the Outside weather is higher. This is because the compacted dirt from the outside test location reflects more sound energy than the grass, which absorbs more sound energy. The ground reflection is also "later" in time because it is further away (ever step in Figure 5). In the suppressed case, the ground reflection is now in the time window where the peak (say a highpass, sa it contributes to the peak (say, for example, Figure 8 at approx 0.0042 sec). Because the ground is softer, the ground reflection is not as powerful and thus contributes less to the physical value of firearms and microphones, ground reflection contributes to the peak (say and highpass. As a result, the same exact floor, or a floor with the exact same sound reflectivity, would be needed to reproduce the same peak for a given shot, all else being equal. Note that this limitation exist also apply to any damage risk criterion (DRC) or exposure metric.

Why are some of the 5.56 Hot numbers so much higher than the .30 cal numbers?

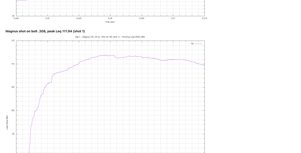
What about gas gun port pop on the 5.56?

Using one high volume TRIAD, can as an example, the Magnus when shot on .308 has numbers @ 50 of 16.35 LeqTrimp (MK Leverage on the bolt action .308 but on the DD MK18 SIR gas port, it has 127.78 LeqTrimp, a difference of 111.43 LeqTrimp. Yet, the 5.56 Hot Shot 1 has numbers of 100 PSI and the .308 numbers being much lower than the .308 numbers, for the 30 and 200 positions, especially when looking at the Impulse and Leq numbers happens because of port pop, that is, gas pressure escaping from the port before the bullet exits the muzzle. The port pop is "noise" that is not related to the shot, but it is in addition to the Hot Shot compared to its distance from the action noise ("the port pop can be distinguished from the muzzle report easily in this example.

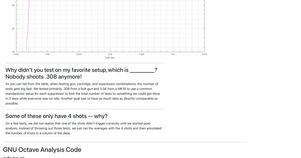


Now that you've seen how they differ in time, here is an example how that action noise contributes to the peak pressure. Note the "bump" in the Mk18 Burst, Port Pop, Shot 1.

Magnus shot on MK18 (5.56), peak Leq 127.5 (shot 1)



Magnus shot on bolt (.308, peak Leq 16.35 (shot 1)



Why didn't you test on my favorite setup, which is _____?

Nobody shoots .308 anymore!

As you can see from the table, when taking gun, cartridge, and suppressor combinations, the number of tests gets big fast. We tested primarily .308 from a bolt gun and 5.56 from a MK18 to use a common standardized setup for each suppressor to limit the total number of tests to something as could get done in 2 days while everyone was on site. Another goal was to have as much data as directly comparable as possible.

Some of these only have 4 shots -- why?

Into these tests, we did not realize that one of the shots didn't trigger correctly until we started post-analysis. Instead of throwing out those tests, we just ran the averages with the 4 shots and then annotated the number of shots in a column of the table.

GNU Octave Analysis Code

adsgn.m

```
clear all;
pkg load signal;
pkg load statistics;
% ALL.3-BOBCAT Weapon & Ammunition Technical Data
% ALL.3-BOBCAT Weapon & Ammunition Technical Data
% Sound Pressure Level Calculation IAW MIL-STD-1474D, Table XIV.
% Sigma = 1.5 dB
%
% Requires the Signal Processing Package.
%
% ver.xlsx.0001.2008.1000.
%
% Author: Christopher Hansen, Pacific Psychological & Neur. Methods
% Last Modified: 2008-10-20
% Last Modified by: PSC, 2008.
%
% Revision History:
%  1. 20 Oct 2010: Fixed/Implemented Band Level Meas. SNR.

ALL.FMT.SNRT
% Minimum A-weighting triangular filter bandwidth in dB(A) SNR.
% Default: 10.
%
ALL.FMT.SNRT = 10;
% Minimum C-weighting triangular filter bandwidth in dB(C) SNR.
% Default: 10.
%
ALL.FMT.SNRTC = 10;
% Minimum Z-weighting triangular filter bandwidth in dB(Z) SNR.
% Default: 10.
%
ALL.FMT.SNRTZ = 10;
% Minimum Peak-weighting triangular filter bandwidth in dB(Peak) SNR.
% Default: 10.
%
ALL.FMT.SNRTPK = 10;
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% Default: 10.
%
ALL.FMT.SNRTBL = 10;
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% Default: 10.
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ALL.FMT.SNRTBLC = 10;
% Minimum Band Level Meas. Triangular Filter Bandwidth in dB(Z) SNR.
% Default: 10.
%
ALL.FMT.SNRTBLZ = 10;
% Minimum Band Level Meas. Triangular Filter Bandwidth in dB(Peak) SNR.
% Default: 10.
%
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% Default: 10.
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ALL.FMT.SNRTSPLIMPTPKPKC = 10;
% Minimum Sound Pressure Level Meas. Triangular Filter Bandwidth in dB(Impulse) SNR.
% Default: 10.
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ALL.FMT.SNRTSPLIMPTPKPKZ = 10;
% Minimum Sound Pressure Level Meas. Triangular Filter Bandwidth in dB(Impulse) SNR.
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% Default: 10.
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% Minimum Sound Pressure Level Meas. Triangular Filter Bandwidth in dB(Impulse) SNR.
% Default: 10.
%
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% Minimum Sound Pressure Level Meas. Triangular Filter Bandwidth in dB(Impulse) SNR.
% Default: 10.
%
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% Default: 10.
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% Minimum Sound Pressure Level Meas. Triangular Filter Bandwidth in dB(Impulse) SNR.
% Default: 10.
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% Minimum Sound Pressure Level Meas. Triangular Filter Bandwidth in dB(Impulse) SNR.
% Default: 10.
%
ALL.FMT.SNRTSPLIMPTPKPKPKPKPKZ = 10;
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% Default: 10.
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