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Six-Inch Shock Tube Characterization

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Auditory Protection and Performance Division

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14. ABSTRACT

The U.S. Army Aeromedical Research Laboratory (USAARL) Auditory Protection and Performance Division (APPD) owns, operates, and maintains a 6-inch inner diameter shock tube to create shock waves in a controlled environment. Firing parameters such as diaphragm material, diaphragm thickness, and transducer location can alter the properties of the produced shock wave. The measured shock wave properties in this study are peak level and A-duration. The shock tube produced more consistent peak levels and A-durations as cylinder pressure approached the natural membrane burst pressure or 80 psi limit. With enough space in the exposure room, the 6-inch shock tube satisfies the requirements in American National Standards Institute/Acoustical Society of America (ANSI/ASA) standard S12.42-2010 for impulse peak insertion loss value (IPIL) calculations.

15. SUBJECT TERMS

shock tube, shock wave, peak sound pressure level, A-duration, ANSI/ASA S12.42-2010

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Introduction

Research associated with exposure to shock and blast wave phenomenon is of significant interest within the Auditory Protection and Performance Division (APPD) of the U.S. Army Aeromedical Research Laboratory (USAARL). Waves such as those created by explosions and gunfire are of particular relevance in defining required hearing protection for an operational environment. In some cases, it is useful to be able to create a shock wave in a controlled environment. The auditory division owns, operates, and maintains several shock tubes to create shock waves in a controlled environment. These shock tubes allow APPD to test hearing protection devices against impulse noises similar to those that military weapon systems produce and follow standards for hearing protection device testing.

Operation of the APPD 6-inch (6-in.) diameter shock tube, shown in Figure 1 below, involves filling a driver section with compressed air separated from the rest of the tube by a frangible diaphragm and rupturing that diaphragm. On command, a mechanical knife ruptures the diaphragm to release the air from the driver into the barrel, down the expansion section, and into the exposure room. Alternatively, pressurizing the driver section to a certain point will cause the diaphragm to naturally burst and produce a shock wave. Variations in the material used for the diaphragm, the pressure in the driver section, and the measurement location in the exposure room all affect the observed pressure waveform.

Figure 1. Six-inch shock tube.

Different materials can act as the diaphragm in the shock tube, including paper and aluminum foil. The most abundant material currently available for the 6-in. shock tube is DuPont Mylar®, which has different thicknesses and breaks under different pressures. Mylar® of thickness 92A (0.001 in.), 200A (0.002 in.), 200S (0.002 in.), 500A (0.005 in.), 1000A (0.010 in.), and 1400A (0.014 in.) are currently available for use with the 6-in. shock tube.

American National Standards Institute/Acoustical Society of America (ANSI/ASA) standard S12.42-2010 uses on the peak level and A-duration of an impulse for the calculation of the impulse peak insertion loss (IPIL) value of a hearing protection device. Ideally, the shock tube should comply with American National Standards Institute/Acoustical Society of America (ANSI/ASA) standard S12.42-2010 in the ability to produce impulses in the level ranges of 130-134, 148-152, and 166-170 decibels (dB) with enough distance between the shock tube opening and the transducers (American National Standards Institute, 2010). The two higher ranges are comparable to the noise levels produced by military small arms fire. Additionally, these impulses should have A-durations within the acceptable range of 0.5 to 2.0 milliseconds (ms).

A series of measurements taken to characterize the performance of the shock tube will aid in predicting the parameters of the waveform generated by the system. These measurements vary the Mylar® thickness of the diaphragm for the tube and the pressure in the driver section. These measurements will aid in ensuring proper compliance with ANSI/ASA S12.42-2010 concerning shock tube impulse generation.

Methods

The shock tube produced impulses using Mylar® membranes 92A, 200A, 200S, 500A, 1000A, and 1400A. The shock tube was pressurized to a maximum of 80 pounds per square inch (psi) or until the membrane naturally ruptured. The cylinder pressure decreased by 5 psi for subsequent sets of shots until the membrane no longer ruptured. The characterization fired five shots for each of the Mylar® and pressure configurations: 92A at 5 to 10 psi; 200A at 5 to 22 psi; 200S at 5 to 15 psi; 500A at 40 to 80 psi; 1000A at 25 to 80 psi; and 1400A at 40 to 80 psi. Five transducers placed 2 meters (m) away from the expansion horn opening recorded the fired shots.

Materials

A Brüel & Kjær (B&K) LAN-XI module collected data at a sample rate of 262144 samples per second. A G.R.A.S. 67SB blast probe, a B&K 4138 ¼- in. microphone set, a B&K 4198 ⅛-in. microphone attached to a B&K 2669C preamplifier, a G.R.A.S. 46BG ¼-in. microphone set, and a PCB 113A27 pencil probe were used to collect data. MATLAB analyzed the data to determine peak levels and A-durations.

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Results

92A

Figure 2 summarizes the peak levels for shots using 92A Mylar® as a membrane with a linear trend line overlaid on the data, which produced the highest R^2 value. Figure 3 provides a boxplot of the recorded shock waves' A-durations.

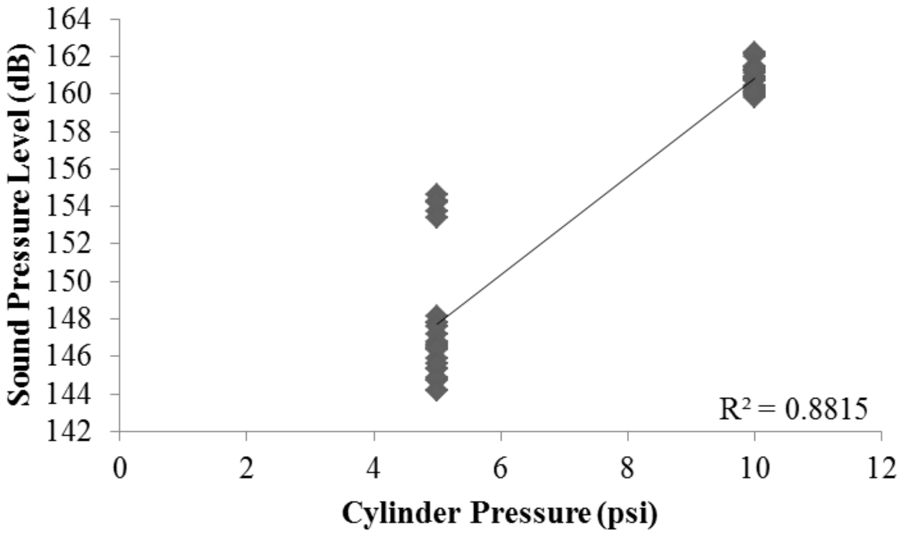

Figure 2. Peak Sound Pressure Levels (92A).

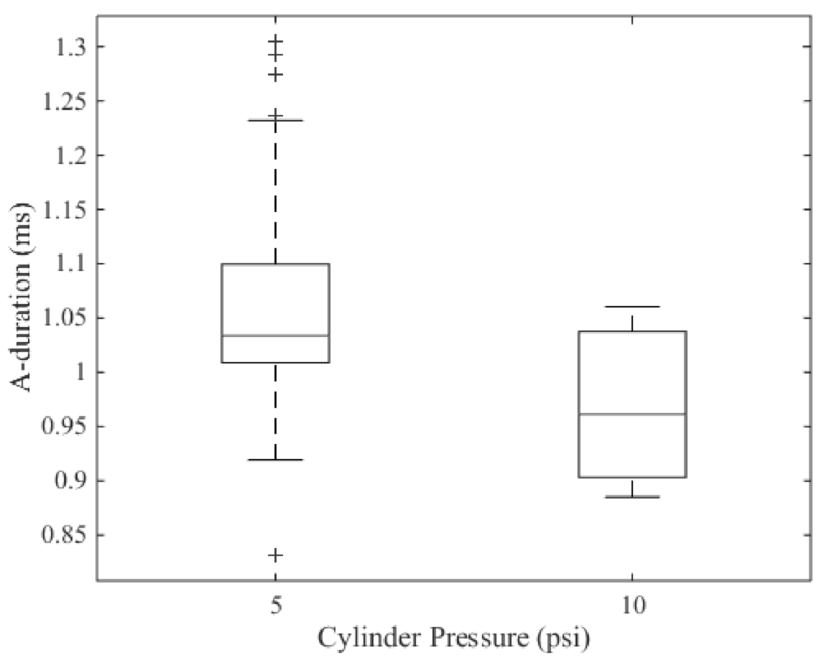

Figure 3. A-duration Boxplot (92A).

200A

Figure 4 summarizes the peak levels for shots using 200A Mylar® as a membrane with a 4th-order polynomial trend line overlaid on the data, which produced the highest R^2 value. Figure 5 provides a boxplot of the recorded shock waves' A-durations.

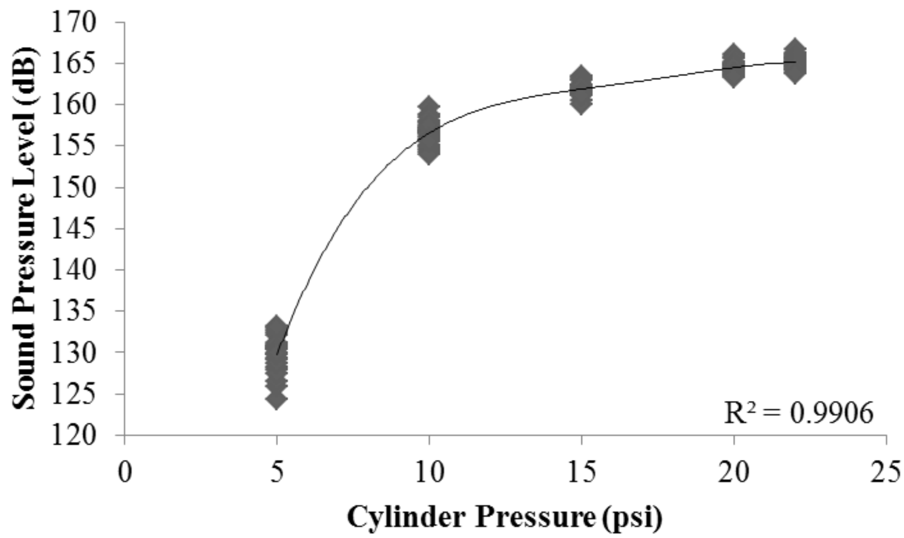

Figure 4. Peak Sound Pressure Levels (200A).

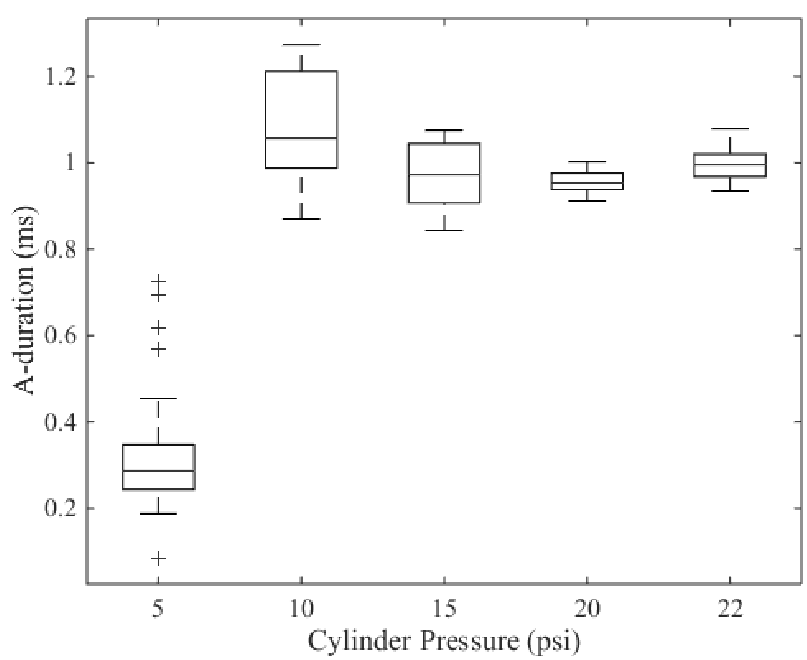

Figure 5. A-duration Boxplot (200A).

200S

Figure 6 summarizes the peak levels for shots using 200S Mylar® as a membrane with a 2nd-order polynomial trend line overlaid on the data, which produced the highest R^2 value. Figure 7 provides a boxplot of the recorded shock waves' A-durations.

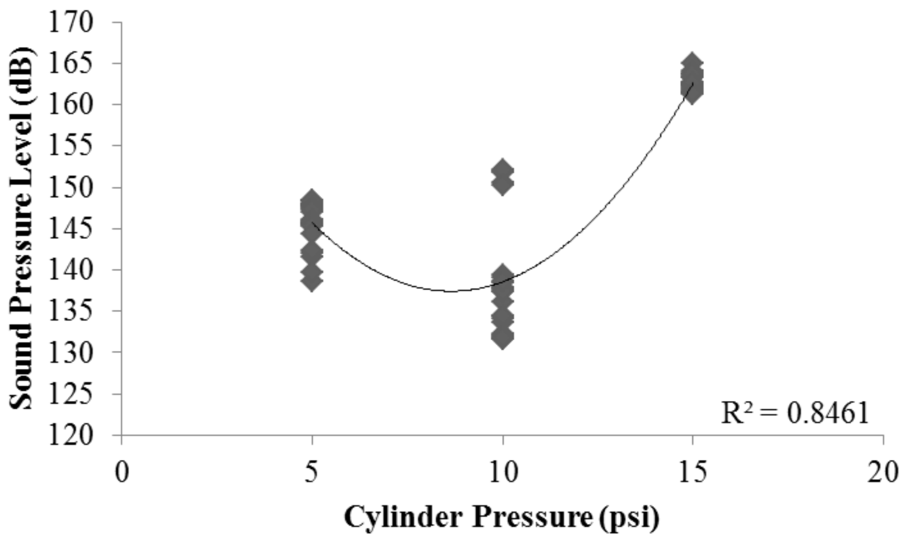

Figure 6. Peak Sound Pressure Levels (200S).

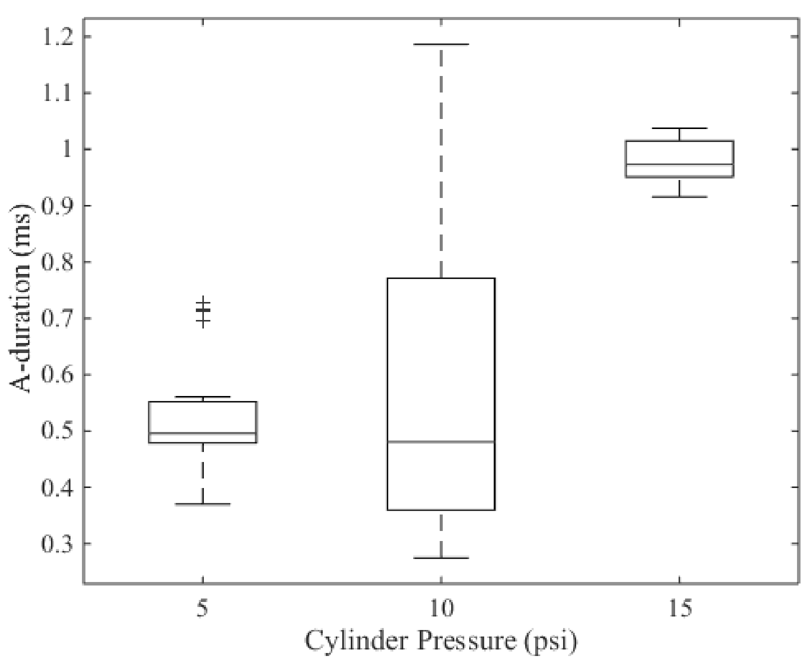

Figure 7. A-duration Boxplot (200S).

500A

Figure 8 summarizes the peak levels for shots using 500A Mylar® as a membrane with a 6th-order polynomial trend line overlaid on the data, which produced the highest R^2 value. Figure 9 provides a boxplot of the recorded shock waves' A-durations.

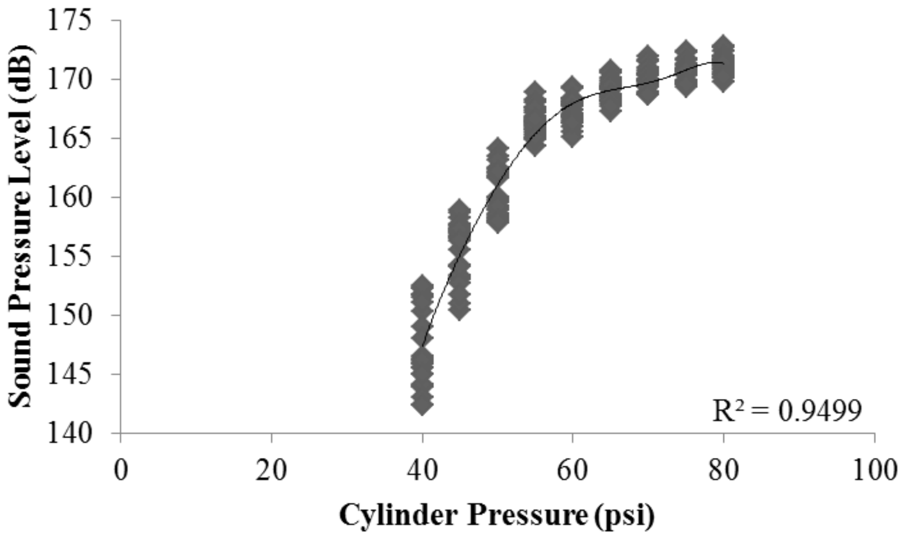

Figure 8. Peak Sound Pressure Levels (500A).

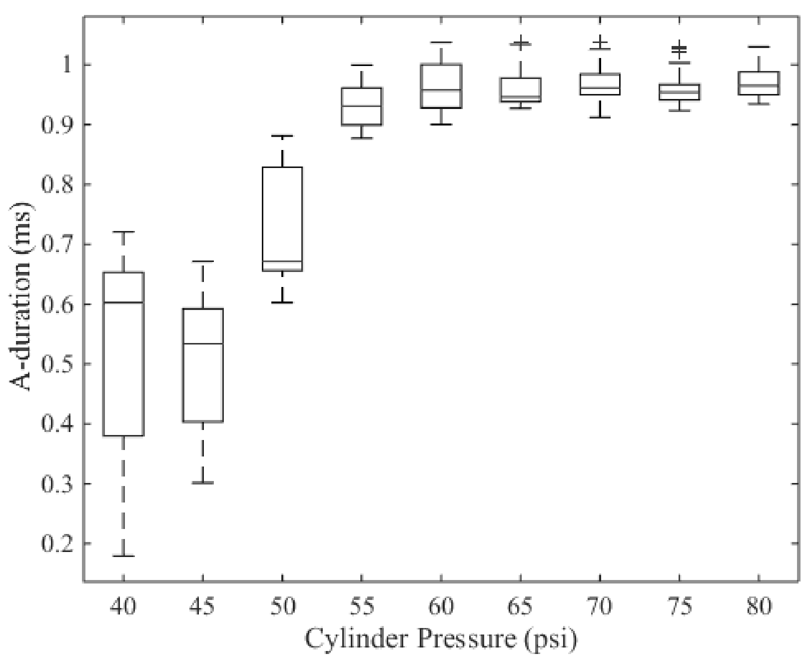

Figure 9. A-duration Boxplot (500A).

1000A

Figure 10 summarizes the peak levels for shots using 1000A Mylar® as a membrane with a 6th-order polynomial trend line overlaid on the data, which produced the highest R^2 value. Figure 11 provides a boxplot of the recorded shock waves' A-durations.

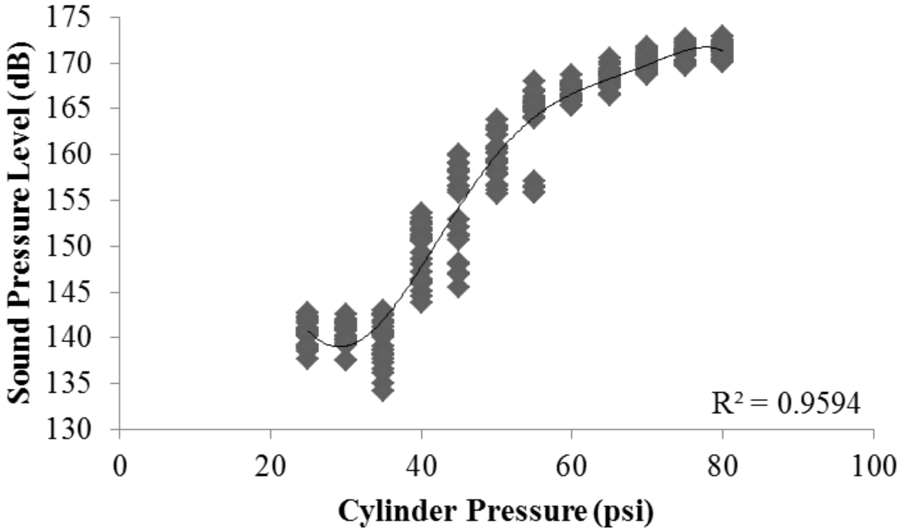

Figure 10. Peak Sound Pressure Levels (1000A).

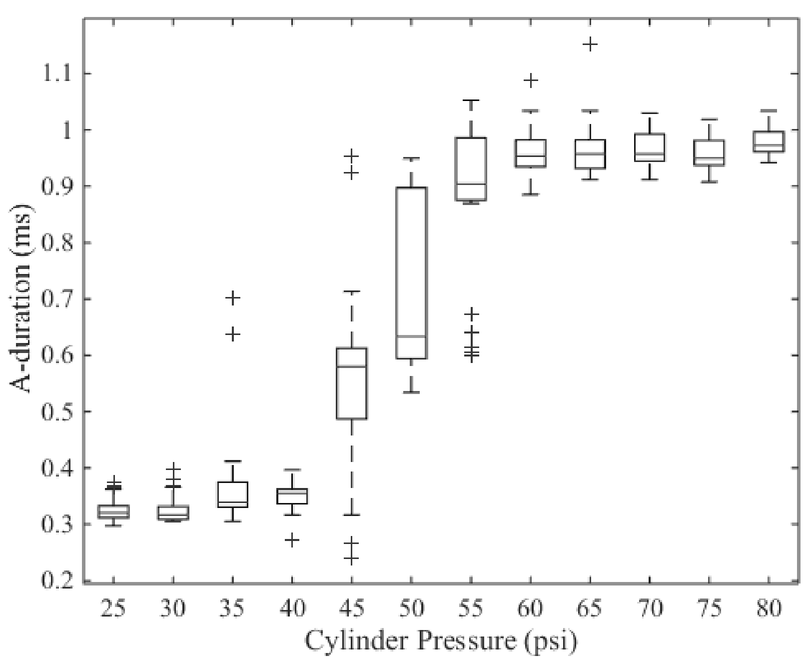

Figure 11. A-duration Boxplot (1000A).

1400A

Figure 12 summarizes the peak levels for shots using 1400A Mylar® as a membrane with no added trend line, as there is no apparent trend. Figure 13 provides a boxplot of the recorded shock waves' A-durations.

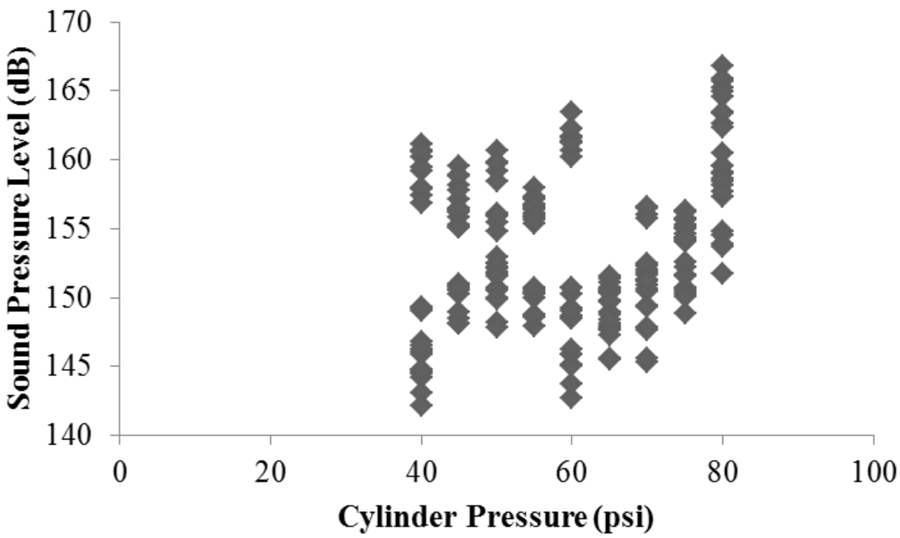

Figure 12. Peak Sound Pressure Levels (1400A).

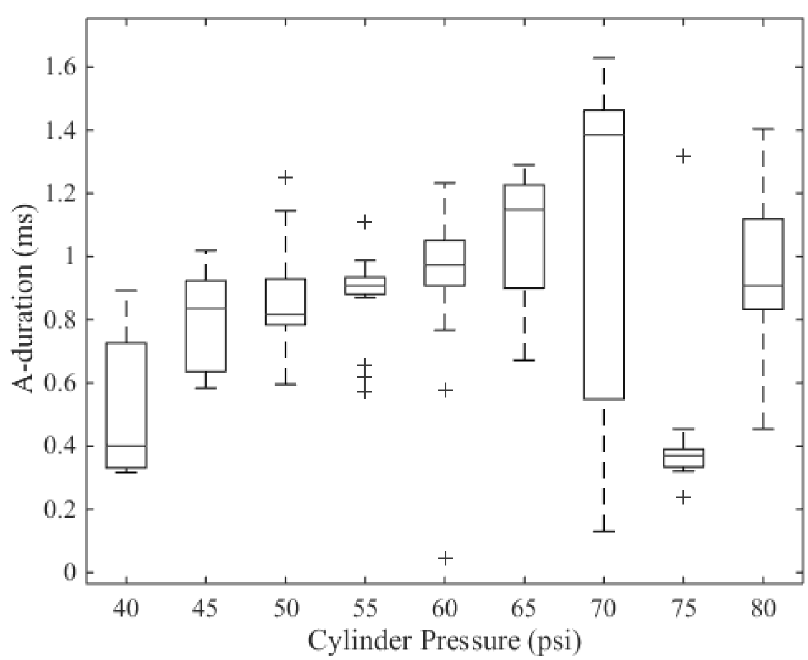

Figure 13. A-duration Boxplot (1400A).

Discussion

The data, presented quantitatively in Appendices A and B, generally suggest more consistent peak levels as the cylinder pressure approaches the natural burst pressure of the membrane or the 80 psi limit. There is a general increasing trend in peak level as cylinder pressure increases across all the membranes, except for shots generated with 1400A. Additionally, the A-durations follow a similar consistency trend as depicted graphically in the previous figures and quantitatively in Appendices C and D.

The 6-in. shock tube will be able to meet the desired peak level ranges of 148-152 and 166-170 dB listed in ANSI/ASA S12.42-2010. Both the 500A and 1000A membranes will produce impulses in the 166-170 dB range when fired with a cylinder pressure of at least 55 psi and 60 psi, respectively. Many membrane and pressure configurations are able to reach the 148-152 dB range. The 500A and 1000A membranes do so when fired with a cylinder pressure of 40 psi, as well as the 92A membrane at 5 psi. Lastly, firing with 200A at 5 psi yields peak levels that can meet the 130-134 dB range.

The shots must also comply with the 0.5 to 2.0 ms A-duration range listed in ANSI/ASA S12.42-2010. Firing the 500A and 1000A membranes at cylinder pressures of at least 55 psi or 60 psi, respectively, yield A-durations that fall in the acceptable range. The 92A membrane at 5 psi yields A-durations that fall into the acceptable range. While the 200A membrane can match the 130-134 dB range, only a few of the test shots met the 0.5 ms lower limit and may need multiple shots to meet the requirements in future studies. The firing conditions that match the peak level and A-duration ranges may change as the transducer distances change.

Recommendations

The large variations in peaks and A-durations suggest that 1400A Mylar® should not be used when firing the shock tube. Transducers should be placed at the farthest position to enable firing with higher cylinder pressures and more consistent A-durations and peak levels. Additionally, the shock tube should be re-characterized whenever it is modified in the future.

Conclusions

When operating the 6-in. shock tube, it is better to fire it as close as possible to the natural burst pressure for any given Mylar® to produce the most consistent results. This testing aided in ensuring the quality of USAARL APPD hearing protection testing through compliance with impulse generation conditions outlined in ANSI/ASA S12.42-2010. Provided enough space, the 6-in. shock tube can produce shock waves in the three SPL ranges used to calculate a hearing protection device's IPIL in accordance with ANSI/ASA S12.42-2010.

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Appendix A. Mean Peak Sound Pressure Levels

Table A1. 92A Mean Peak Sound Pressure Level

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	146.7800	148.1938	147.9648	148.2043	147.4392
10	161.7179	161.0269	160.3744	161.0776	160.1084

Table A2. 200A Mean Peak Sound Pressure Level

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	128.0170	129.5444	130.2181	130.3823	131.0009
10	157.2289	156.9363	156.3339	156.7821	155.7305
15	162.9112	162.0316	161.4174	162.1381	161.0075
20	165.5226	164.6578	164.0689	164.7084	163.5493
22	166.1215	165.3474	164.6411	165.2389	164.2101

Table A3. 200S Mean Peak Sound Pressure Level

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	144.2467	146.4433	146.8152	146.7489	144.2243
10	137.6646	138.6373	139.0389	139.0316	138.5023
15	163.9020	162.6744	162.0928	162.7294	161.6753

Table A4. 500A Mean Peak Sound Pressure Level

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	146.8972	147.8273	148.2707	147.5343	145.9166
45	156.0780	155.6501	155.5528	155.6312	154.3471
50	161.2608	160.5457	159.7286	160.2870	159.5072
55	167.5341	166.7337	165.9176	166.5053	165.3920
60	168.3534	167.6400	166.9823	167.4564	166.3628
65	170.2575	169.3228	168.5186	169.0225	167.8516
70	171.2297	170.3161	169.5893	169.9886	168.8830
75	171.8352	170.9219	170.0974	170.6634	169.5206
80	172.4915	171.7049	170.9710	171.3874	170.1506

Table A5. 1000A Mean Peak Sound Pressure Level

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
25	139.3089	141.5912	141.2495	140.9125	139.4918
30	139.5524	141.6653	141.1439	140.8847	139.1496
35	137.6708	140.6744	140.3290	140.2024	138.5745
40	149.8308	149.8897	149.6241	149.6616	148.4217
45	155.4588	154.8093	153.8079	154.5296	153.7793
50	160.1243	159.8800	159.3904	159.7770	158.8463
55	164.8090	163.8831	163.0641	163.9133	162.8753
60	167.7792	167.1646	166.3746	167.0045	165.7853
65	169.5287	168.5099	167.8828	168.3443	167.0840
70	171.3407	170.4682	169.5479	170.1945	169.0418
75	172.0954	171.3601	170.6517	171.0374	169.8792
80	172.4993	171.6714	170.9588	171.4046	170.2829

Table A6. 1400A Mean Peak Sound Pressure Level

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	150.7661	151.5811	151.6813	151.6605	149.9194
45	153.7735	154.5101	154.1991	154.5778	153.0782
50	153.5336	154.0525	153.8932	154.1867	152.5051
55	153.6199	154.1574	153.8339	154.3280	152.88466
60	152.5928	153.5740	153.1709	153.7610	152.0594
65	147.9067	149.8507	150.1234	150.1936	147.9983
70	150.5876	151.9848	151.6449	152.0217	150.4927
75	153.1175	153.7079	153.5576	153.9397	152.7241
80	160.7796	160.2877	159.7802	160.3524	159.0675

Appendix B. Peak Sound Pressure Level Standard Deviation

Table B1. 92A Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	3.9373	3.6959	3.6564	3.5927	3.5465
10	0.5936	0.2912	0.4598	0.2312	0.1350

Table B2. 200A Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	3.0593	2.5410	1.9453	1.3326	1.1868
10	1.8225	1.3741	1.3373	1.1955	1.3050
15	0.6414	0.4659	0.5789	0.4118	0.5292
20	0.4132	0.2540	0.1174	0.1928	0.1709
22	0.3924	0.3726	0.3947	0.3114	0.3702

Table B3. 200S Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	3.1219	2.7611	2.6816	2.5266	2.5958
10	7.6506	7.8373	7.7712	7.9017	7.0904
15	0.7275	0.5324	0.6680	0.5638	0.5716

Table B4. 500A Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	4.0202	3.8987	3.3633	3.2485	3.6330
45	3.6859	2.3360	1.6534	2.1094	2.7947
50	1.9230	2.0065	2.1684	2.1537	2.1868
55	1.0316	1.0056	0.7581	0.8816	0.9081
60	1.0500	0.8080	0.9529	0.9444	0.7674
65	0.5926	0.5121	0.3934	0.3989	0.3793
70	0.6405	0.4248	0.2354	0.2581	0.2447
75	0.4463	0.1841	0.4089	0.1303	0.1335
80	0.3674	0.2345	0.2580	0.3542	0.2735

Table B5. 1000A Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
25	1.2823	0.8672	1.0281	0.9117	0.7898
30	1.2130	0.6422	0.6698	0.6706	0.9931
35	2.8973	2.0590	2.3294	2.2785	2.3481
40	2.5811	2.6783	3.3672	4.0055	3.4352
45	4.9519	4.9935	5.5392	4.9625	4.8231
50	2.2564	2.3184	2.4450	2.4456	2.3298
55	4.3950	4.2353	4.1229	4.1721	4.0181
60	0.6245	0.6070	0.4301	0.5055	0.4973
65	0.8870	0.8399	0.8973	0.6216	0.5423
70	0.3655	0.3929	0.5173	0.4049	0.3359
75	0.3592	0.1279	0.3654	0.2269	0.2050
80	0.3123	0.2655	0.3476	0.3069	0.1898

Table B6. 1400A Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	8.6729	7.2820	6.7676	7.2084	7.7208
45	5.3602	3.8799	3.2154	3.6590	4.1404
50	4.9364	3.8901	3.4453	3.6665	4.2054
55	4.9787	3.6493	3.2254	3.3473	3.8131
60	9.4285	7.7739	7.3575	7.6397	8.0986
65	1.6118	1.3249	1.3103	1.4671	1.5215
70	3.9937	3.1743	2.9086	3.1225	3.6849
75	2.2981	2.7601	2.2748	2.6093	2.4630
80	4.9550	4.3903	4.4039	4.5957	5.0234

Appendix C. Mean A-durations

Table C1. 92A Mean A-duration

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	1.0719	1.1032	1.0780	1.0567	1.0185
10	0.9506	1.0208	0.9369	0.9979	0.9224

Table C2. 200A Mean A-duration

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	0.3777	0.3128	0.3174	0.3937	0.2670
10	1.0284	1.1406	1.1093	1.1040	1.0010
15	0.9651	1.0429	0.9758	0.9880	0.9125
20	0.9453	0.9888	0.9438	0.9682	0.9338
22	0.9537	1.0521	0.9834	1.0071	0.9880

Table C3. 200S Mean A-duration

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	0.6470	0.5653	0.4395	0.4883	0.4654
10	0.6401	0.6386	0.5974	0.6004	0.5653
15	0.9697	1.0315	0.9590	1.0040	0.9323

Table C4. 500A Mean A-duration

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	0.5798	0.5318	0.5333	0.5318	0.4829
45	0.5013	0.4974	0.5157	0.5020	0.4776
50	0.7088	0.7164	0.7568	0.7378	0.7172
55	0.9109	0.9636	0.9308	0.9537	0.8980
60	0.9415	1.0208	0.9529	0.9705	0.9335
65	0.9453	1.0193	0.9460	0.9628	0.9399
70	0.9514	1.0246	0.9560	0.9720	0.9476
75	0.9399	1.0094	0.9468	0.9628	0.9438
80	0.9453	1.0201	0.9651	0.9819	0.9483

Table C5. 1000A Mean A-duration

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
25	0.3677	0.3250	0.3113	0.3151	0.3159
30	0.3769	0.3265	0.3128	0.3151	0.3105
35	0.5135	0.4089	0.3334	0.3326	0.3242
40	0.3647	0.3448	0.3418	0.3571	0.3311
45	0.6165	0.6165	0.5150	0.5470	0.5013
50	0.7355	0.7393	0.7202	0.7591	0.7019
55	0.8713	0.9171	0.8629	0.9132	0.8598
60	0.9361	1.0193	0.9552	0.9712	0.9277
65	0.9377	1.0490	0.9560	0.9697	0.9262
70	0.9468	1.0208	0.9537	0.9758	0.9430
75	0.9392	1.0117	0.9521	0.9666	0.9247
80	0.9651	1.0254	0.9689	0.9903	0.9590

Table C6. 1400A Mean A-duration

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	0.6729	0.5249	0.5028	0.4974	0.5089
45	0.8820	0.8080	0.8492	0.7721	0.7332
50	0.8873	0.8385	0.8621	0.8705	0.8240
55	0.8568	0.8980	0.8980	0.9621	0.8293
60	0.8255	1.0338	0.9987	0.9926	0.8575
65	1.0078	1.1314	1.0841	1.2138	0.9064
70	0.7805	1.1917	1.1650	1.2573	1.1887
75	0.3830	0.3967	0.5432	0.5402	0.3281
80	0.9514	0.9743	0.9605	0.9872	0.9338

Appendix D. A-duration Standard Deviation

Table D1. 92A A-duration Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	0.1293	0.0992	0.0985	0.1457	0.1424
10	0.0539	0.0554	0.0690	0.0620	0.0261

Table D2. 200A A-duration Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	0.1569	0.1516	0.2258	0.1925	0.0691
10	0.1429	0.1005	0.1372	0.1255	0.1345
15	0.0685	0.0231	0.0724	0.0695	0.0845
20	0.0091	0.0099	0.0088	0.0083	0.0156
22	0.0204	0.0169	0.0294	0.0097	0.0353

Table D3. 200S A-duration Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
5	0.0845	0.0937	0.0638	0.0097	0.0377
10	0.3202	0.3024	0.3576	0.3511	0.3402
15	0.0165	0.0058	0.0225	0.0130	0.0174

Table D4. 500A A-duration Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	0.1812	0.1750	0.1603	0.1293	0.1955
45	0.1353	0.1388	0.1562	0.1089	0.0916
50	0.0933	0.1076	0.1066	0.1026	0.1073
55	0.0215	0.0391	0.0299	0.0333	0.0163
60	0.0359	0.0165	0.0193	0.0268	0.0403
65	0.0265	0.0156	0.0108	0.0122	0.0064
70	0.0159	0.0079	0.0144	0.0197	0.0235
75	0.0134	0.0268	0.0122	0.0197	0.0165
80	0.0057	0.0064	0.0027	0.0058	0.0079

Table D5. 1000A A-duration Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
25	0.0043	0.0099	0.0113	0.0099	0.0063
30	0.0125	0.0099	0.0097	0.0058	0.0058
35	0.1727	0.1284	0.0218	0.0119	0.0195
40	0.0213	0.0136	0.0180	0.0174	0.0382
45	0.2045	0.2200	0.1744	0.1669	0.1475
50	0.1590	0.1711	0.1729	0.1531	0.1825
55	0.1544	0.1797	0.1563	0.1427	0.1271
60	0.0366	0.0468	0.0165	0.0212	0.0125
65	0.0268	0.0582	0.0043	0.0154	0.0133
70	0.0218	0.0084	0.0129	0.0285	0.0195
75	0.0063	0.0050	0.0099	0.0144	0.0113
80	0.0187	0.0068	0.0076	0.0122	0.0088

Table D6. 1400A Peak Sound Pressure Level Standard Deviation

Cylinder Pressure (psi)	G.R.A.S. 67SB	B&K 4138	B&K 4198	G.R.A.S. 46BG	PCB 113A27
40	0.1787	0.2608	0.2470	0.2317	0.2377
45	0.0591	0.1807	0.1428	0.1536	0.1489
50	0.0747	0.1646	0.1688	0.2388	0.2150
55	0.1122	0.1768	0.0356	0.0300	0.1441
60	0.4437	0.0789	0.1361	0.1604	0.1584
65	0.1353	0.1707	0.1858	0.0429	0.1821
70	0.5905	0.4961	0.5213	0.5105	0.4820
75	0.0264	0.0381	0.4326	0.4342	0.0561
80	0.3595	0.1432	0.1783	0.2342	0.1841

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