Acoustical Breadth

Acoustics in regards to ranges is very interesting because of the extremely high sound source level created by a firing gun. Occupation Safety and Health Administration says that peak impulse sound pressure levels should not be higher than 140dB. However, the peak sound pressure level that a fired bullet makes when it breaks the sound barrier can be significantly higher than that.

Peak sound pressure level cannot be negated in the firing range since the sound travels in a direct path from the gun to the shooters ear. Precautions such as double ear protection should be taken, but architecturally, this source sound cannot be reduced. The recommendation for minimizing the effect of peak sound pressure level is that "all reflecting walls should be covered with high efficiency sound absorbing material such as fiberglass insulation covered with perforated aluminum or steel sheets with openings equivalent to 10-15% of the area to permit sound absorption." (Noise Exposure Assessment and Abatement Strategies at an Indoor Firing Range, NIOSH)

The existing design incorporates such a material into the design in the form of tectum wall panels. The acoustical absorptivity of the space cannot realistically be improved very much, so it will not be the focus of this breadth.

There is a concern, however, with the adjacency of spaces. Classroom 'A' is directly adjacent to and shares a wall with the firing range. An examination, audio/visual presentation, and lecture space is an area where loud background noise should be avoided. Transmission loss (TL) and noise reduction (NR) of the common wall is of particular interest to ensure that adequate noise criterion for the classroom is being achieved.

Goals of Classroom Noise Criteria

The classroom should be less than NC-35 as determined from the chart with NC values listed below for a classroom greater than 750 ft^2. The basic general equations for noise reduction used in calculations are listed below.

$$NR = TL + 10 \log (A_{rec}/S_{common\ wall})$$

Noise reduction is a function of transmission loss of the wall assembly as well as the absorptivity of materials of the receiving room. If the receiving room has soft, absorptive materials, it will aid the transmission loss and the noise reduction for the space will be higher than the transmission loss values. If the receiving room has hard, reflective materials, sound will be reflected and noise reduction will be lower than the transmission loss values.

Below is a bar chart displaying the dB level created by three different firearm sources (an M4 rifle, a Beretta pistol, and a Remington shotgun) for octave-band frequencies.

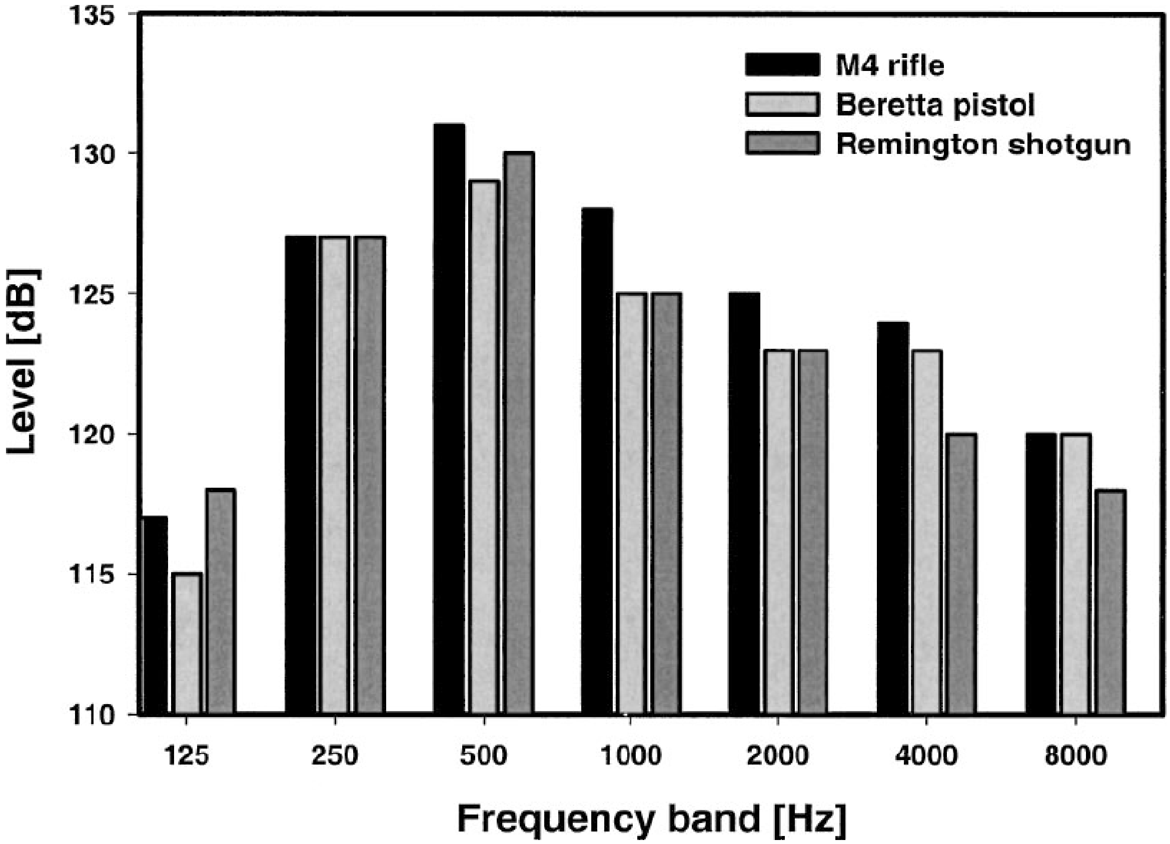


FIGURE 5
Octave-band spectra from three firearms.

The values on the chart were used as the source sound levels in the range that must be reduced by the wall assembly for the firing range to meet the recommended NC value of less than 35.

Two different wall assemblies will be examined.

- A more conventional noise reducing wall assembly consisting of painted hollow (8") CMU and 5/8" gypsum board on resilient channels with 1-1/2" fiberglass furring.
- A proposed wall assembly consisting of painted hollow (8") CMU, a 3" inch air gap, and a 6" 20 gauge metal stud wall with resilient channels on one side with 5" fiberglass insulation with a double layer of 5/8" gypsum board on the classroom side of the wall.

Space	Recommended RC (N) value	Recommended NC value	Approximate dBA value
Private residence, apartment, condominium	25-30	25-35	33-43
Hotels or motels:			
Individual rooms, meeting rooms	25-35	25-35	33-43
Halls, corridors, lobbies	35-45	35-45	43-53
Office buildings:			
Executive and private offices	25-35	25-35	33-43
Open plan offices	30-40	30-40	38-48
Circulation areas	40-45	40-45	48-53
Hospitals and clinics:			
Private rooms and operating rooms	25-35	25-35	33-43
Wards, corridors and public spaces	30-40	30-40	38-48
Performing arts spaces:			
Drama theaters, music teaching spaces	25 (max)	25 (max)	
Music practice rooms	35 (max)	35 (max)	
Concert and recital halls	Consult an acoustical consultant		
Laboratories (with fume hoods):			
Testing/research with minimal speech communication	45-55	45-55	53-58
Research with extensive telephone use	40-50	40-50	48-58
Group teaching	35-45	35-45	43-53
Churches, mosques and synagogues	25-35	25-35	33-38
Schools:			
Classrooms up to 70 m^2 (750 ft^2)	40 (max)	40 (max)	
Classrooms over to 70 m^2 (750 ft^2)	35 (max)	35 (max)	
Libraries	30-40	30-40	38-48
Courtrooms:			
Unamplified speech	25-35	25-35	33-43
Amplified speech	30-40	30-40	38-48
Indoor stadiums and gymnasiums	40-50	40-50	48-58

NC Values	Frequency (Hz)						
	125	250	500	1000	2000	4000	8000
NC-35	52	45	40	36	34	33	32
NC-40	56	50	45	41	39	38	37
NC-45	60	54	49	46	44	43	42
NC-50	64	58	54	51	49	48	47
NC-55	67	62	58	56	54	53	52
NC-60	71	67	63	61	59	58	57
NC-65	75	71	68	66	64	63	62
NC-70	79	75	73	71	69	68	67

Existing (Conventional) Solution

Transmission loss values for the wall assembly listed below are shown in this table.

Transmission Loss Between Firing Range and Classroom						
Wall Assembly	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Hollow (8") CMU Painted 5/8" Gypsum Board on Resilient Channels 1-1/2" Fiberglass Furring	41	49	58	66	69	72
Total Transmission Loss	**41.0**	**49.0**	**58.0**	**66.0**	**69.0**	**72.0**

Sound source dB levels extracted from the bar chart above are shown below.

Sound Source dB Levels in Firing Range						
Source	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
M4 Rifle	117	127	131	128	125	124
Beretta Pistol	115	127	128	125	123	123
Remington Shotgun	118	127	130	125	123	120

Absorption of the classroom was calculated to determine the effectiveness of the transmission loss.

Classroom Absorption Coefficients						
Material	**Frequency (Hz)**					
	125	**250**	**500**	**1000**	**2000**	**4000**
Gypsum Wall	0.14	0.06	0.04	0.03	0.03	0.03
VCT	0.02	0.04	0.05	0.05	0.1	0.05
ACT	0.27	0.6	0.64	0.8	0.91	0.99

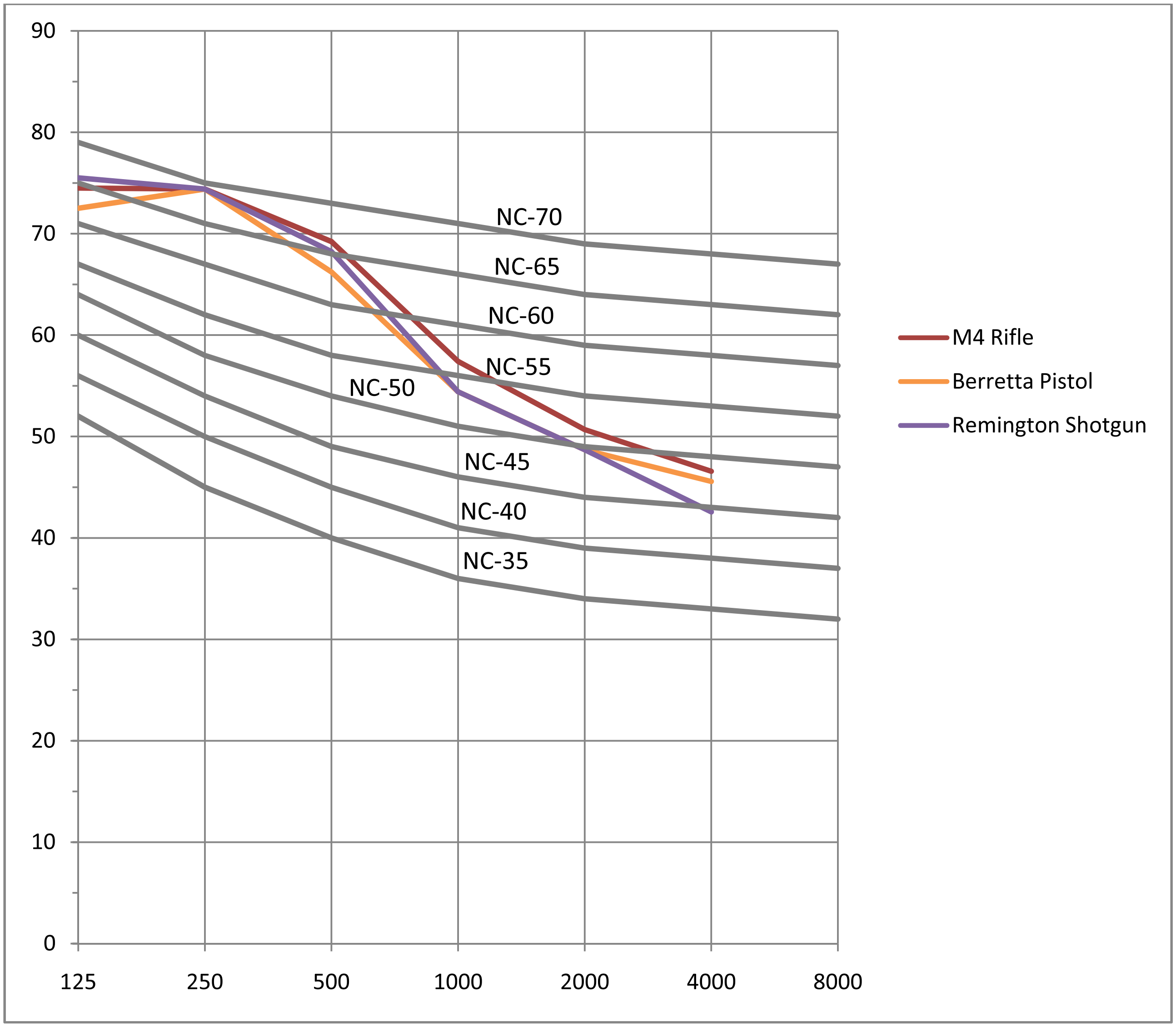
Classroom Total Absorption (Sabins)						
Surface Area	**Frequency (Hz)**					
	125	**250**	**500**	**1000**	**2000**	**4000**
1260	176.4	75.6	50.4	37.8	37.8	37.8
1240	24.8	49.6	62	62	124	62
1240	334.8	744	793.6	992	1128.4	1227.6
Absorption (Sabins)	536	869.2	906	1091.8	1290.2	1327.4

The following equation and the data from the tables above were used to determine the resulting dB levels in the classroom.

$$NR = TL + 10 \log (A_{rec}/S_{common\ wall})$$

Resulting dB Levels in Classroom						
Source	**Frequency**					
	125 Hz	**250 Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**
M4 Rifle	74.5	74.4	69.2	57.4	50.7	46.6
Beretta Pistol	72.5	74.4	66.2	54.4	48.7	45.6
Remington Shotgun	75.5	74.4	68.2	54.4	48.7	42.6

Below is a graph of the resulting dB levels in the classroom with the existing/conventional wall assembly for the three firearm sources. The values are plotted on top of the NC curves.



All of the source lines fall completely below the NC-70 curve. The recommended level for classrooms is no greater than NC-35. This means that this design does not come close to meeting the NC requirements.

Proposed Solution

Transmission loss values for the wall assembly listed below are shown in this table.

Transmission Loss Between Firing Range and Classroom						
Wall Assembly	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Hollow (8") CMU Painted	38	38	45	50	52	55
3" Air Gap	-6.2	-9.6	-10.0	-10.0	-9.2	-9.5
6" 20 Gauge Metal Stud Resilient Channel on One Side 5" Fiberglass Insulation 1 + 2 Layers of 5/8" Gypsum Board	38	51	58	60	62	64
Total Transmission Loss	**69.8**	**79.4**	**93.0**	**100.0**	**104.8**	**109.5**

Transmission losses of wall assemblies are not additive because the transmission of vibrations through adjoining materials decreases the overall effectiveness of each individual material. In this case, though, the materials are not adjoined and are separated by the 3" air gap. They are not necessarily additive because of the 10 log ($A_{rec}/S_{common\ wall}$) factor. The 3" air gap was treated as a small room and the function

$$10 \log (A_{rec}/S_{common\ wall})$$

from the equation

$$NR = TL + 10 \log (A_{rec}/S_{common\ wall})$$

was used to determine the transmission loss within the air gap. Essentially, because of the volume and hard surfaces surrounding the air gap, the space reflects the sound within the cavity and decreases the overall effectiveness of the transmission loss.

The tables below include the values utilized in the calculation of the effectiveness of transmission loss in the 3” air gap.

3" Air Gap Absorption Coefficients						
Material	Frequency (Hz)					
	125	250	500	1000	2000	4000
CMU	0.1	0.05	0.06	0.07	0.09	0.08
Gypsum Wall	0.14	0.06	0.04	0.03	0.03	0.03
Concrete Floor	0.01	0.01	0.01	0.02	0.02	0.02
Concrete Ceiling	0.01	0.01	0.01	0.02	0.02	0.02

3" Air Gap Total Absorption (Sabins)						
Surface Area	Frequency (Hz)					
	125	250	500	1000	2000	4000
380	38	19	22.8	26.6	34.2	30.4
380	53.2	22.8	15.2	11.4	11.4	11.4
10	0.1	0.1	0.1	0.2	0.2	0.2
10	0.1	0.1	0.1	0.2	0.2	0.2
Absorption (Sabins)	91.4	42	38.2	38.4	46	42.2

Sound source dB levels extracted from the bar chart above are shown below.

Sound Source dB Levels in Firing Range						
Source	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
M4 Rifle	117	127	131	128	125	124
Beretta Pistol	115	127	128	125	123	123
Remington Shotgun	118	127	130	125	123	120

Absorption of the classroom was calculated to determine the effectiveness of the transmission loss.

Classroom Absorption Coefficients						
Material	Frequency (Hz)					
	125	250	500	1000	2000	4000
Gypsum Wall	0.14	0.06	0.04	0.03	0.03	0.03
VCT	0.02	0.04	0.05	0.05	0.1	0.05
ACT	0.27	0.6	0.64	0.8	0.91	0.99

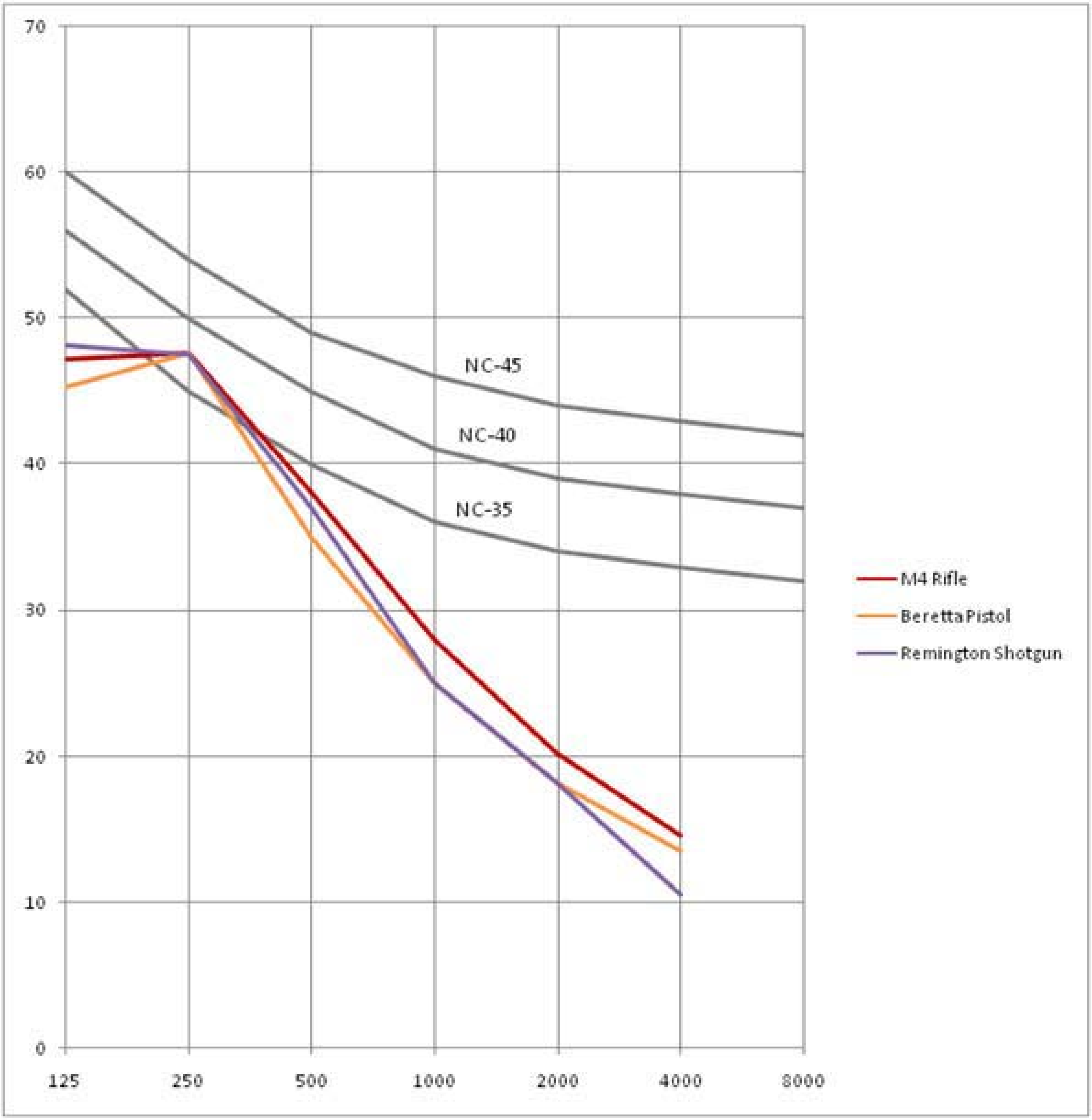
Classroom Total Absorption (Sabins)						
Surface Area	Frequency (Hz)					
	125	250	500	1000	2000	4000
1260	176.4	75.6	50.4	37.8	37.8	37.8
1240	24.8	49.6	62	62	124	62
1240	334.8	744	793.6	992	1128.4	1227.6
Absorption (Sabins)	536	869.2	906	1091.8	1290.2	1327.4

The following equation and the data from the tables above were used to determine the resulting dB levels in the classroom.

$$NR = TL + 10 \log (A_{rec}/S_{common\ wall})$$

Resulting dB Levels in Classroom						
Source	Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
M4 Rifle	47.2	47.6	38.0	28.0	20.2	14.5
Beretta Pistol	45.2	47.6	35.0	25.0	18.2	13.5
Remington Shotgun	48.2	47.6	37.0	25.0	18.2	10.5

Below is a graph of the resulting dB levels in the classroom with the proposed wall assembly for the three firearm sources. The values are plotted on top of the NC curves.



All three of the sources fall between the NC-35 and NC-40 curves. Recommended NC value for classrooms is a maximum of 35. While the wall assembly does not quite meet the recommendation, it is very close. Considering the magnitude of the sound source in the adjacent firing range, it may not be appropriate to expect to fully meet the standard conditions. Obtaining values that are with a few dB of the target values will be accepted as adequate for the purpose of this assessment.