Acoustic Associates

Specialists in Hearing and Acoustics

PO Box 218, Palatine, Illinois 60078
Office: *847-359-1068* • Fax: *847-359-1207*
Website: www.AcousticAssociates.com
E-mail: info@AcousticAssociates.com

Tom Thunder, AuD, FAAA, INCE – *Principal*
Roger Harmon, BSEE, PE – *Senior Field Engineer*
Steve Hallenbeck, AuD – *Audiologist*
Steve Thunder, BSE, COHC – *Acoustical Engineer*

August 29, 2011

City of Rochelle
419 N. 6th Street
Rochelle, IL 61068

Attn: Sam Tesreau, P.E. - City Engineer

Re: Train Noise Evaluation

We have completed our analysis of the sound data that we collected at Railroad Park in Rochelle on July 6, 2011. We understand that people in the community have voiced concerns about the negative impact of train noise in the area, in particular the loudness of the horns. This study was conducted to initiate an assessment of the noise from the trains that pass through Rochelle, especially the horn sounding. Recall from our discussion that the FRA requires that horns generate a sound level of at least 96 decibels on the A-scale (dBA) at a distance of 100 feet in front of the train in the direction of its travel. More recently, a maximum sound level of 110 dBA was established.

As we discussed, because of the acoustic directivity of horns, the Doppler effect of a moving train, reflective surfaces, and the need to establish a precise distance reference, it is difficult to accurately determine the sound level of a horn from a moving train relative to the frontal, 100-foot reference distance. The aim or our study then was to obtain a preliminary understanding of the impact of the train horns in the area relative to the overall train noise.

Measurement Procedure

To accomplish this, our field engineer, Roger Harmon, set up equipment in Railroad Park to record the passing of several trains. His equipment was located as marked in **Figure 1**, which was 50 feet east of the large gazebo. At this location, the equipment was about 60 feet from the north tracks and 50 feet from the south tracks. Figure 2 shows a perspective of a westbound train approaching our recording station along the north tracks. For the 6th and final train, the equipment was relocated to a location near the small gazebo about 40 feet from the north tracks.

Figure 1 - An aerial view showing where the sound recording equipment was set up.

We used two sets of recording equipment for redundancy to ensure a good signal was captured. Each set consisted of a precision grade sound level meter connected to a professional digital recorder. A 94 dB signal was placed on the recording to calibrate the sound recording to ensure a proper lab analysis.

In our lab, we ran an analysis of the recordings to generate a 1/3-octave band frequency spectrum (from 20–20,000 Hz) at 1-second intervals. From this large amount of data (112,000 data points), we calculated the overall (total) C-weighted and A-weighted sound levels. The C-network filters out the very low and very high sounds so that just the audible noise is measured. The A-network filters out much of the low-pitched sound so that it correlates with how humans judge the loudness of the noise. This is because the ear is much less sensitive to sounds in the lower frequency range (i.e., below 500 Hz).

RESULTS

Six trains were captured in our recording over a nominal 1½-hour time-frame in the early afternoon hours. The trains travelled in different directions on different tracks at different speeds. Each train consist included a different type and number of cars. Each train also had a different number of locomotives – some with an additional locomotive at the rear of the train. Accordingly, the sound level time-histories, as shown in Figures 3-8, were each different.

In each profile, the upper (blue) trace shows the C-weighted sound level over time while the lower (red) trace shows the A-weighted sound level. The relative elapsed time is shown on the horizontal axis. Each recording lasted over the primary portion of the pass-by event, nominally 2-6 minutes. The A-weighted trace is always lower than the C-weighted trace because, as noted above, the A-network filter cuts out most of the low frequency noise from the locomotives, whereas the C-network is a measure of all the audible sound.

Since the A-network correlates best with loudness as judged by the human ear, the A-scale is the most often used metric for noise. The C-network, however, is a good measure of how much low frequency noise is present in the spectrum. In essence, when the C-A difference is large (e.g., > 20 dB), there is a lot of low frequency sound in the spectrum. When the C-A difference is small, most of the noise is in the mid- to high-frequency range.

Figure 2 - A view of a westbound train on the north tracks as it approaches the recording station.

When a horn sounds, it appears as a spike on the graphs, especially in the A-weighted trace. When the spike nearly touches the C-weighted trace (i.e., the C-A difference is small), it means the sound has no low frequency components. In fact, train horns normally generate 2-4 tones in the mid-frequencies where the ear is sensitive. This is why the A-weighted level is so high and why people judge these types of horns to be very loud.

The following is a short discussion of each graph as shown below:

Train No. 1 – (Figure 3) This graph shows the general increase in noise as the train approaches the recording location. In addition, the horns (shown by the spikes in the A-weighted trace) get louder as well because the distance decreases. The graph shows that the maximum level reached was 104 dBA.

Train No. 2 – (Figure 4) This was a slow moving train - and therefore was relatively quiet. It sounded its horns at a far distance from the gazebo and was, therefore, relatively quiet. At this greater, but unknown distance, the horns reached a level of 90 dBA.

Train No. 3 – (Figure 5) The horn on this train was only sounded three times during our recording. However, as the train passed, the horn reached a level of 110 dBA. Because of the nature of the cars, there was a significant amount of rolling stock noise following the horns as the train passed the recording station.

Train No. 4 – (Figure 6) A distant horn was sounded on its approach, but as it passed, the engineer sounded three horn blasts with the loudest one occurring at 107 dBA. A high and variable noise level occurred after the horns due to rolling stock noise.

Train No. 5 – (Figure 7) A number of horns were sounded from this train. As the train approached, its horns got louder with the loudest one occurring at 107 dBA followed by significant rolling stock noise.

Train No. 6 – (Figure 8) This train sounded several horn blasts on its approach with the highest one occurring at 107 dBA. For this specific recording, the equipment was located about 40 feet from the tracks near the small gazebo at the northwest corner of the parking lot.

EXPOSURE ANALYSIS

From the data, we calculated two metrics. One was the time-averaged sound level of the whole event. This is called the **Equivalent Level or LEQ**. The LEQ is not an arithmetic average, but rather an average of the energy in the noise. Although the LEQ is always higher than the arithmetic average, it is the metric endorsed by the Environmental Protection Agency because it correlates the best with human response to noise and the annoyance experienced by a community.

Another metric, called the **Sound Exposure Level or SEL**, has been used to compare the effect of different events. For example, how would the noise event from a fast moving motorcycle compare to the distant noise from jetliner flyover? In the case of the motorcycle, the maximum sound level could be very high, but its pass-by duration very short. On the other hand, the jet airplane might generate a much lower maximum sound level, but its duration would be much longer. The SEL is the metric used to compare two dissimilar events such as these.

The SEL normalizes all the sound energy of an event to 1 second. In essence, the SEL reflects the sound energy generated by the entire. By normalizing this to a 1-second period, we are able to compare the two different events. We used the SEL in this study to compare the impact of the train pass-by (which was variable from one train to the next) to that of the horns alone.

As shown in **Table 1**, the typical time-averaged sound level of a passing train at 40-60 feet was around 87-91 dBA. Train 2 at 70 dBA was much lower, but this train was moving slower and blew its horns at a much greater distance than the other trains.

The important statistic from Table 1 is the SEL as calculated for the whole event versus the much shorter duration of several horn soundings. In each case, the SEL of the horn was essentially the same as that of the whole train pass-by. This means that although the rolling stock noise is high, the horns themselves comprise the greatest impact to the area.

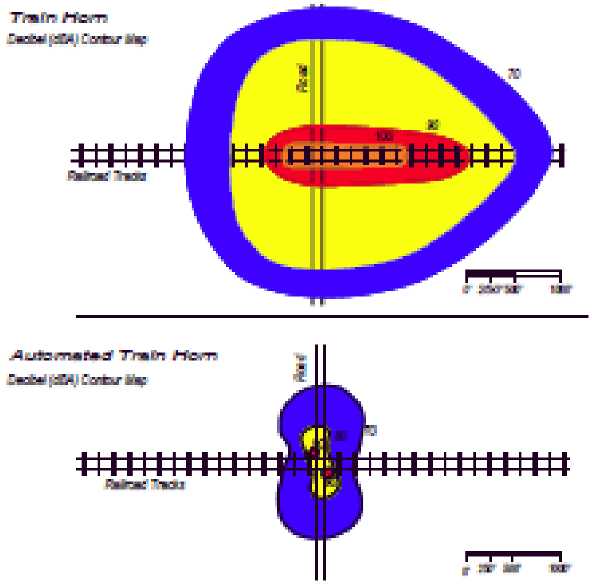
Table 1 - Effective pass-by duration of each train along with the calculated time-averaged sound level (LEQ) and the sound exposure level (SEL) of the whole train compared to that of the horns alone.

	Train 1	Train 2	Train 3	Train 4	Train 5	Train 6
Duration	119 sec	361 sec	137 sec	138 sec	286 sec	210 sec
LEQ Train (dBA)	89	70	91	90	84	87
SEL Train (dBA)	110	95	113	111	109	110
SEL Horn (dBA)	110	94	113	111	108	110

CONCLUSION and DISUCSSION

Based on this study, the horn soundings are the chief impact of noise from the passing trains. Aside from establishing a “Quiet Zone,” another method to reduce the impact of horn soundings is to install wayside horns, also known as Automated Train Horns. These would be installed at the 9th Street crossing and at the 1st Avenue crossing for westbound train traffic.

As seen in the photo to the right taken in Mundelein, Illinois, wayside horns are essentially outdoor loudspeakers placed on tall poles at the crossing and pointed down the road to warn motorists and pedestrians of an oncoming train. These devices mitigate noise in the community because they direct the warning sound down the road where it is needed the most - not into the community. In contrast, because conventional horns on a locomotive start sounding some 1,500 feet from the crossing up until the engine enters the intersection, there is a broad impact area in the community along this entire 1,500-foot path - despite the fact that most people in this area are not on the road and not in danger.



The relative impact of both types of horns is shown in a color plot to the left (taken from a paper by John Redden entitled “Is Train Horn Noise a Problem in your Town”.) The area outside the colored contours is below 70 dBA. As you can see, the “footprint” of noise in the community is greatly reduced with the use of wayside horns. In my experience with assisting Northwestern University in a study of three intersections in Mundelein, Illinois, the wayside horns proved effective at minimizing community noise impact while maintaining the safety of pedestrians and motorists at the intersection. (see Raub R., Lucke, R., and Thunder, T. "Improving the Quality-of-Life for Residents Living near Highway Crossings," Transportation Quarterly, 57(4), Fall, 2003.)

The signal used in a wayside horn is a recording of an actual train horn sound. This is important so that motorists and pedestrians properly identify the potential danger. Since different make and models of train horns sound different, the City may be able to select the type of sound they prefer.

In using a wayside horn, I recommend the horn signal ramp up in loudness as opposed to using a signal with a sudden onset. A ramp-up is a more natural replication of train horn soundings since a horn at 1,500 feet is substantially quieter compared to a horn as sounded as a train approaches the crossing. In our research work in Mundelein, the signals supplied by the Railroad Industry had a sudden onset. Such quick onsets lead to cases of auditory startle, which in turn caused some pedestrians to drop their bags, fall on their bikes, or lose their balance. Increasing the loudness of the signal over the first several seconds allows pedestrians to prepare for the louder part of the signal.

In addition, a ramp-up produces a psychoacoustic effect called "auditory looming." This is where the brain perceives the source as a moving source. A moving source – especially one that sounds like it is quickly approaching – is interpreted by the brain as a dangerous situation.

If the wayside horn approach is pursued, we recommend that the City conduct a survey to document the community sound levels <u>before</u> the installation of the horns. This would be accomplished by setting up recorders at 3 or 4 locations in the community to sample horn levels as generated from passing trains. Then, after the wayside horns are installed, a follow-up study at the same community locations can be conducted to document the reduction in community impact.

This completes our report. Let us know if there are any questions you have or any follow-up work you would like us to conduct.

Sincerely,

Thomas Thunder, AuD, INCE
Principal Audiologist and Acoustical Engineer

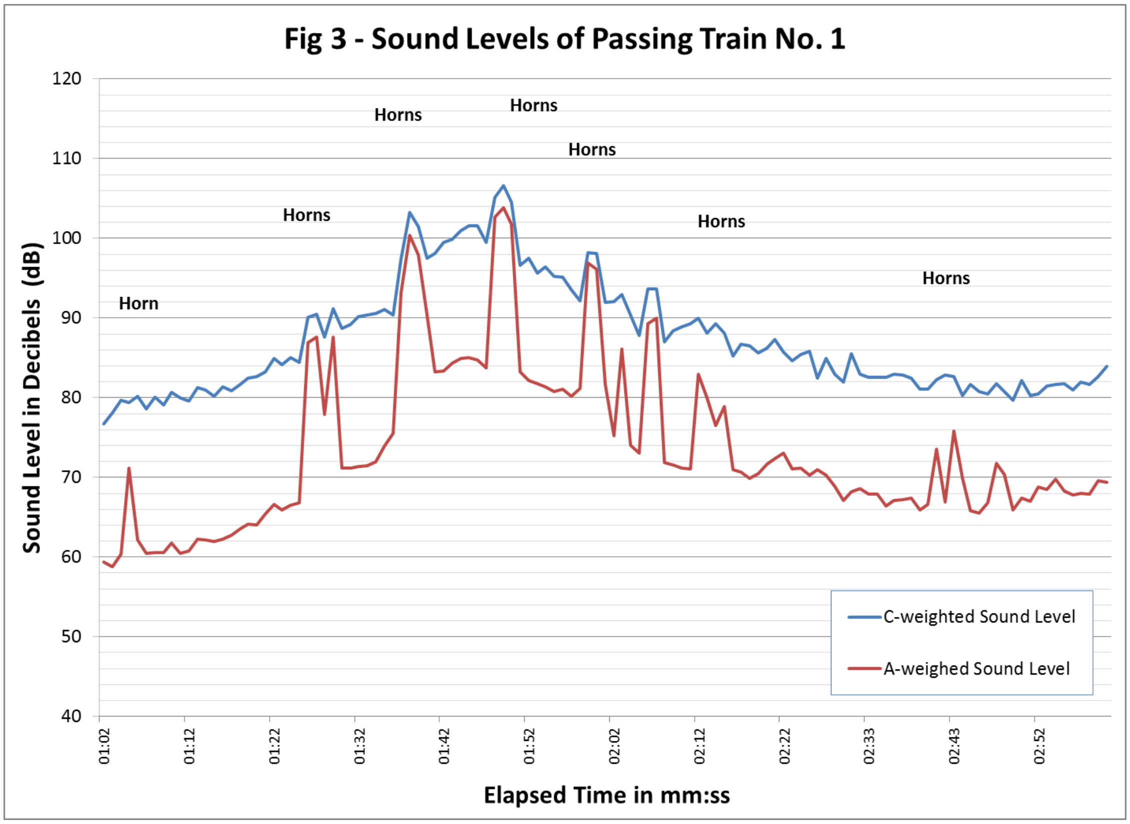


Fig 3 - Sound Levels of Passing Train No. 1
Sound Level in Decibels (dB)
120
110
100
90
80
70
60
50
40
Horn
Horns
Horns
Horns
Horns
Horns
Horns
C-weighted Sound Level
A-weighed Sound Level
01:02
01:12
01:22
01:32
01:42
01:52
02:02
02:12
02:22
02:33
02:43
02:52
Elapsed Time in mm:ss

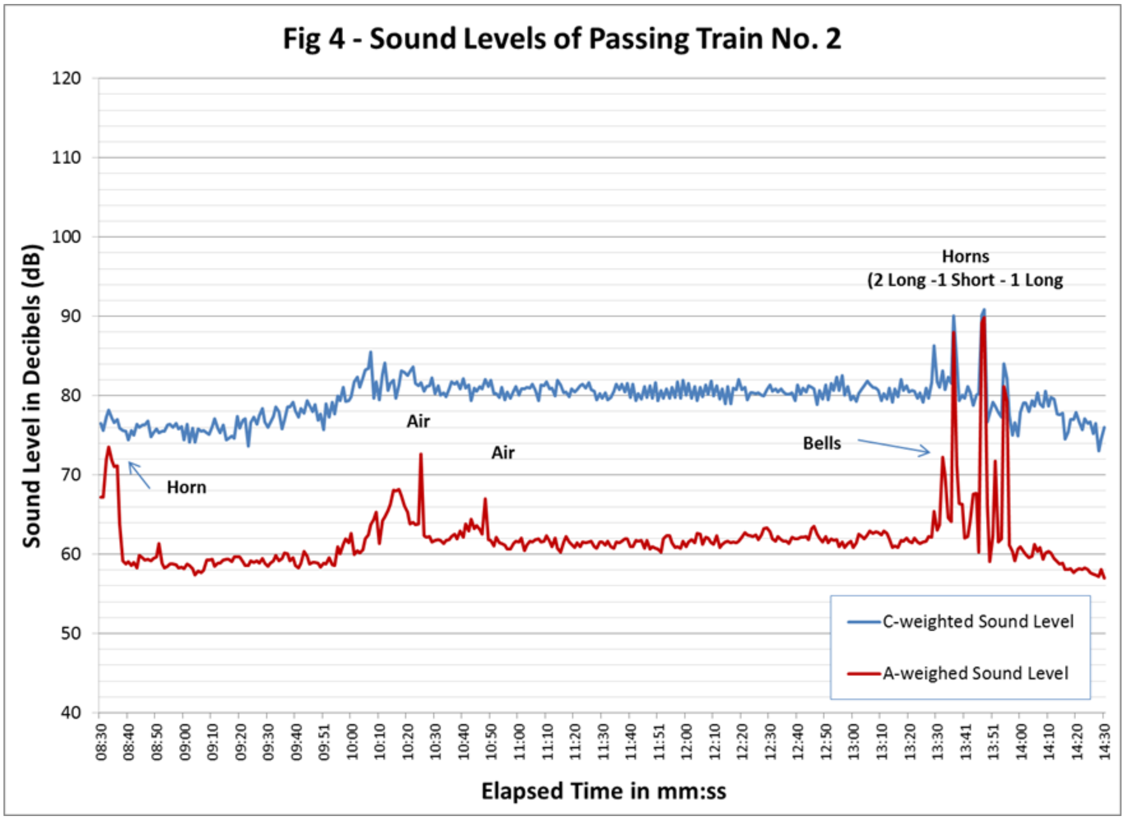


Fig 4 - Sound Levels of Passing Train No. 2
Sound Level in Decibels (dB)
120
110
100
90
80
70
60
50
40
Horns
(2 Long -1 Short - 1 Long
Air
Air
Bells
Horn
C-weighted Sound Level
A-weighed Sound Level
08:30
08:40
08:50
09:00
09:10
09:20
09:30
09:40
09:51
10:00
10:10
10:20
10:30
10:40
10:50
11:00
11:10
11:20
11:30
11:40
11:51
12:00
12:10
12:20
12:30
12:40
12:50
13:00
13:10
13:20
13:30
13:41
13:51
14:00
14:10
14:20
14:30
Elapsed Time in mm:ss

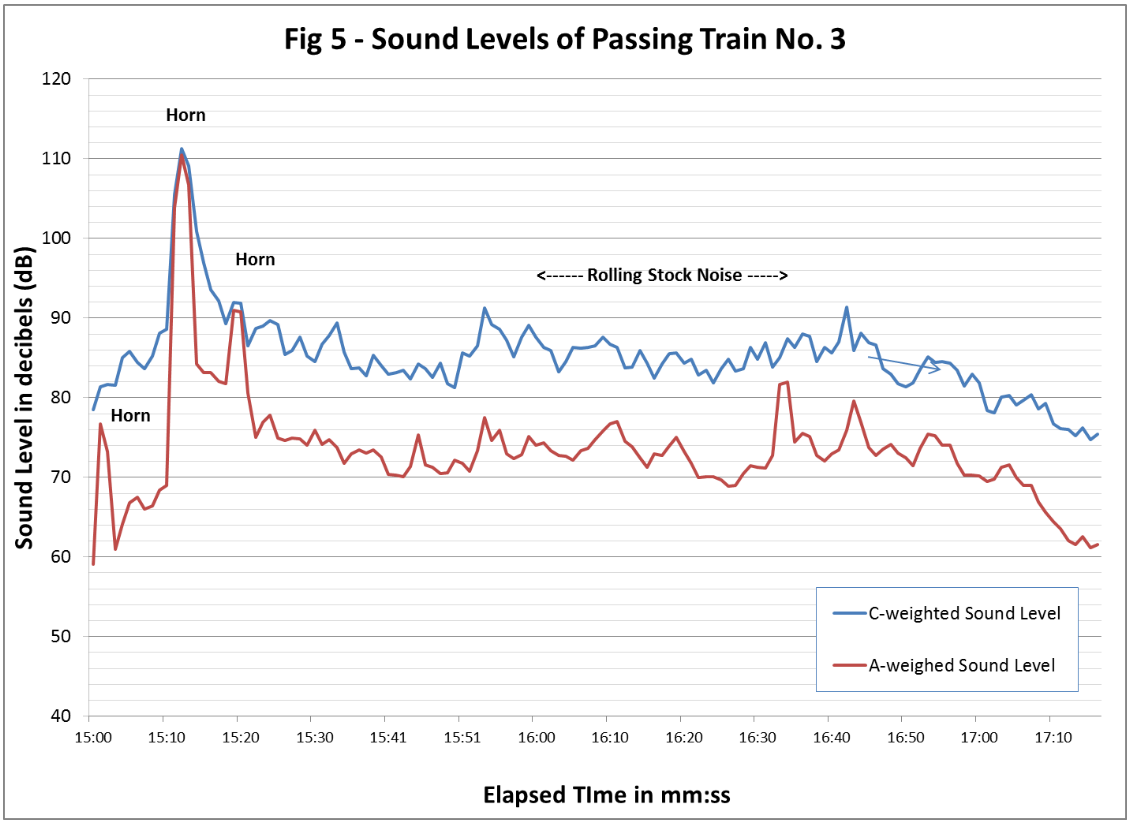


Fig 5 - Sound Levels of Passing Train No. 3
Sound Level in decibels (dB)
120
110
100
90
80
70
60
50
40
Horn
Horn
Horn
<------ Rolling Stock Noise ----->
C-weighted Sound Level
A-weighed Sound Level
15:00
15:10
15:20
15:30
15:41
15:51
16:00
16:10
16:20
16:30
16:40
16:50
17:00
17:10
Elapsed TIme in mm:ss

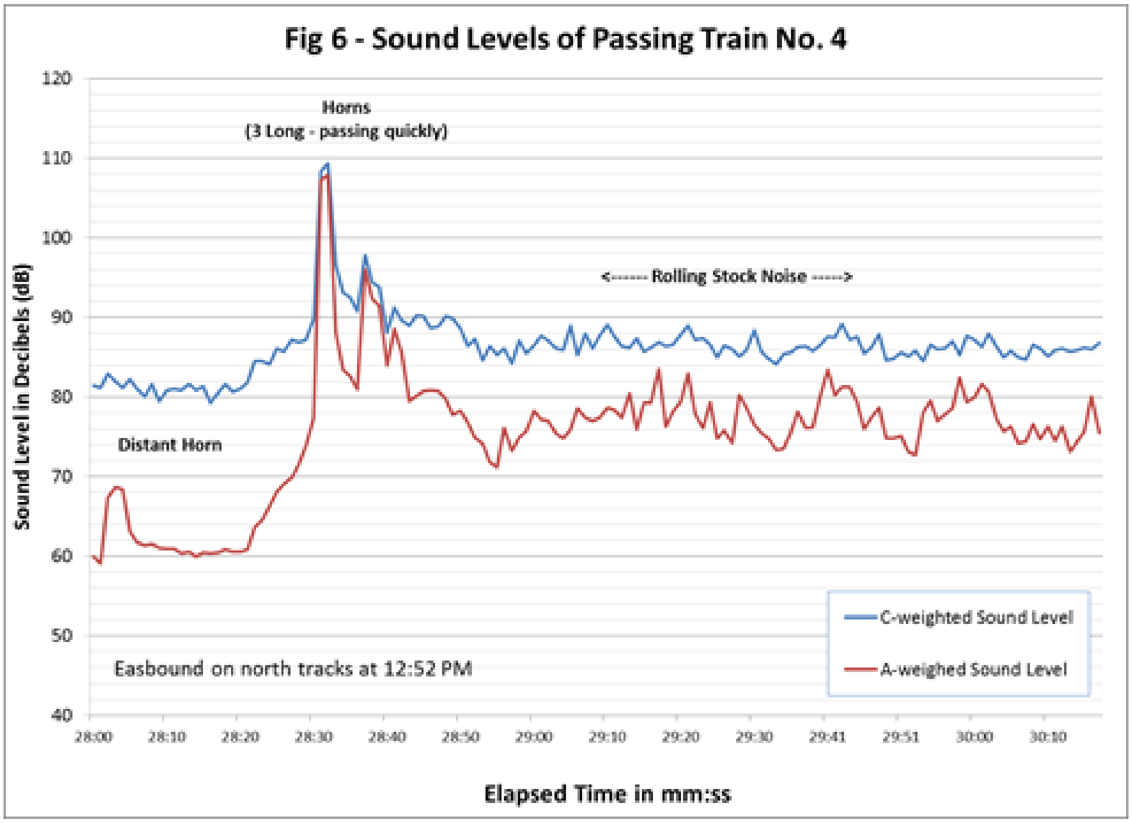


Fig 6 - Sound Levels of Passing Train No. 4
Sound Level in Decibels (dB)
120
110
100
90
80
70
60
50
40
Horns
(3 Long - passing quickly)
<------ Rolling Stock Noise ----->
Distant Horn
Easbound on north tracks at 12:52 PM
C-weighted Sound Level
A-weighed Sound Level
28:00
28:10
28:20
28:30
28:40
28:50
29:00
29:10
29:20
29:30
29:41
29:51
30:00
30:10
Elapsed Time in mm:ss

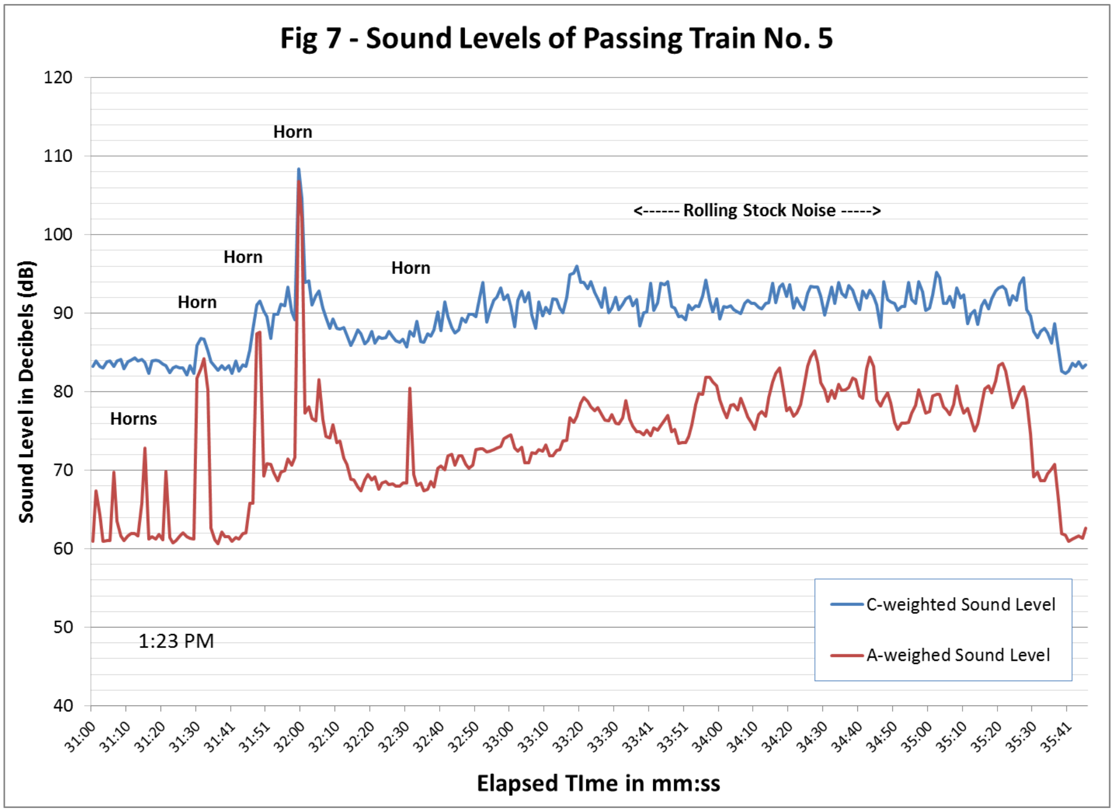


Fig 7 - Sound Levels of Passing Train No. 5

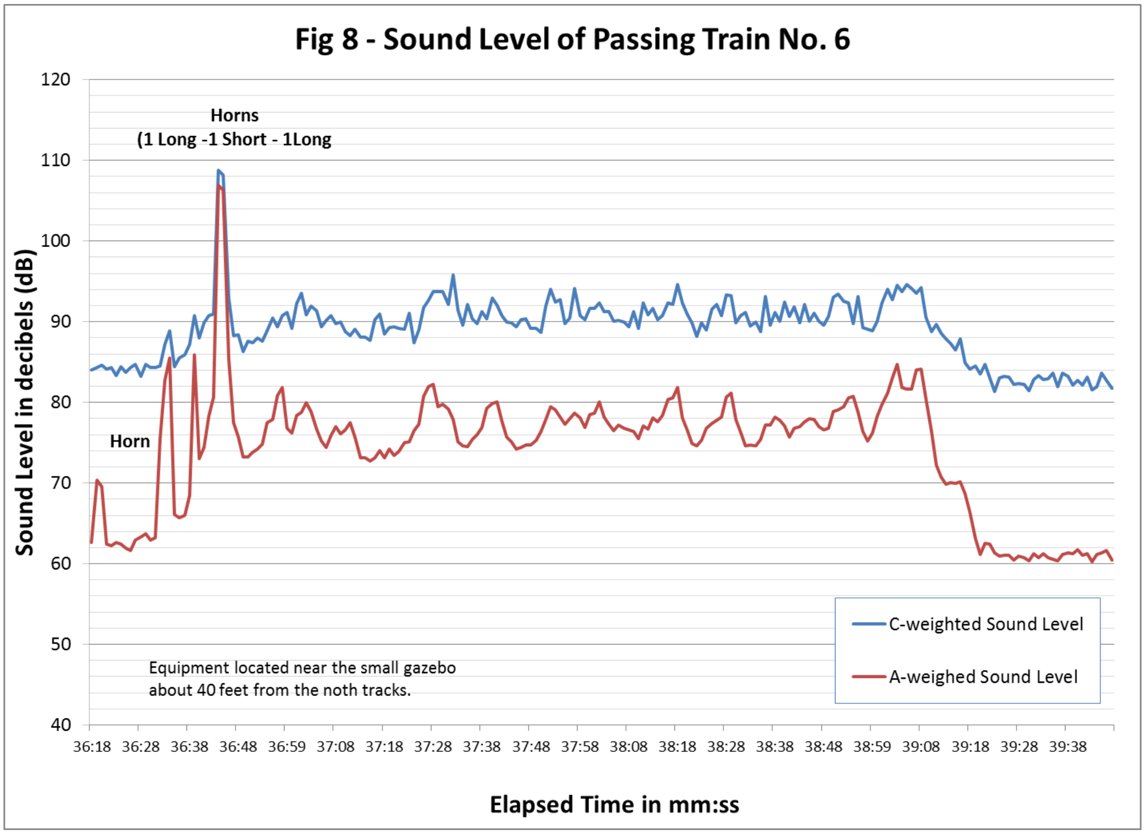


Fig 8 - Sound Level of Passing Train No. 6