NATIONAL TRANSPORTATION SAFETY BOARD
Vehicle Recorder Division
Washington, DC 20594

August 20, 2016

Sound Study

Specialist's Study Report
Addendum 1
By George Haralampopoulos

1. EVENT

Location:	Valhalla, New York
Date:	February 3, 2015
Vehicle #1:	2011 Mercedes ML350
Vehicle #2:	Metro-North Train #659 – 8 Car Train
NTSB Number:	DCA15MR006

2. SUMMARY

For a summary of the accident, refer to the *Crash Summary Report*, which is available in the docket for this investigation.

2.1. Details of Addendum

This addendum contains additional details about the procedures and results from the sound study, as well presents the plotted data in a distance based axis instead of a time based axis.

3. SOUND STUDY

A test was conducted on April 1, 2015, at the Commerce Street grade crossing in Valhalla, New York, to assess the audibility of a typical Metro-North train's horn inside and outside the Mercedes ML350. An exemplar 2011 Mercedes ML350 vehicle was used as the test vehicle, along with regularly scheduled trains on an active track.

3.1. Test Procedure

Prior to the test, ambient measurements were taken while positioned at the test location inside the exemplar vehicle under three different vehicle settings as a baseline: engine off, idle, and idle with air conditioning setting on maximum.

Figure 1 shows an overview of the grade crossing and its approach. A test point consisted of measurements collected from the activation of the grade crossing lights to when the entire train consist passed the crossing.

Approximate accident conditions were recreated by placing the exemplar vehicle as close to the west side crossing gate as possible without fouling the track. A track sign known as a whistle post was located about 1,340 feet from the grade crossing for northbound trains. This sign signals the train engineer to begin the horn cadence.[1] Two sound level meters were used to measure the sound level of the horn as the train passed the crossing. One meter was placed inside the vehicle and the other was placed outside. A total of 4 data points were captured using this procedure. [2]

A similar test was performed on the east side of the track to determine the difference in outside sound pressure profiles from the east side of the track against the west side of the track (figure 2). Only one sound level meter was used and it was relocated to the outside area of the east track. A total of 2 data points were captured using this procedure.

[1] A horn cadence consists of a long, long, short, long sequential horn activation.
[2] The outside meter was placed in way to limit sound reflections from the exemplar vehicle disturbing the readings.

Figure 1. Overhead and street view of west side of test area.

Figure 2. Equipment set up on east side of test area.

3.2. Equipment Used

Two Extech SDL600 sound level meters were used during the testing. Both meters were set up to measure 'A-Weighted' sound pressure[3] using a fast time weighting time constant to account for quickly changing sound events such as a train's horn. A tri-pod and appropriate wind screen was used for the outside device. Each device was calibrated using the SDL600's included 94 dB potentiometer.

A LIDAR speed detection device was used to measure the speed of the passing trains. All LIDAR measurements were taken in line with the passing trains on the east side of the track.

Two video cameras were used; one was used to film the LIDAR readings and the other captured the outside sound level meter readings. The video recordings were also used to provide a common time reference between the two sound level meters.

[3] A-weighting applies a filter to unweighted sound measure to more closely approximate the frequency response of the human ear.

3.3. Car Ambient Condition Test Results

Table 1 shows the car's measured ambient sound pressure levels under three conditions without a train present:

- Engine off
- Engine idle
- Engine idle with maximum air conditioning

Table 1. Ambient sound pressure level readings inside car.

Number	Condition	Sound Pressure dB(A)
1	Engine Off	31.4
2	Engine Idle	43.0
3	Idle with A/C	48.7

The duration of each sample was averaged at least 10 seconds. All conditions were measured with the car windows up.

3.4. Completed Test Points

All trains used for testing were regularly scheduled northbound local and express Bombardier M-7 trains. The car's configuration used for all test points was windows up, and engine in idle. The speed of the train, as measured from the LIDAR, was constant for the duration of each test point. All samples taken from the sound level meter are recorded at one sample per second.

The train's distance was calculated using the speed captured by the LIDAR, multiplied by the elapsed seconds before and after passing the crossing. In the plotted data below, a negative distance implies before the crossing, a positive distance implies after the crossing, and zero indicates the grade crossing. The zero point was determined using sound signatures from the recorded video and indicates when the train passed the test equipment.

The data from test point 4 was omitted due to sampling errors introduced to the sound level meters by passing vehicle traffic near the test area.

3.4.1. Passing Train East Side Results

Table 2 summarizes the train's measured speed at the grade crossing, horn activation time in feet before the grade crossing, and maximum recorded sound level measurement from each meter in dB(A).

The horn was consistently applied at nearly the same distances for all three test points except for test point 2. Each horn activation of test point 2 occurred closer to the crossing when compared to the other test points.

Table 2. Outside and inside sound pressure readings for west side of crossing.

Test Point	Speed (ft/sec)	Horn 1 (ft)	Horn 2 (ft)	Horn 3 (ft)	Horn4 (ft)	Max in-car dB(A)	Max outside dB(A)
1	82.133	1232.0	739.2	328.5	164.3	95.9	119.5
2	80.67	968.0	484.0	161.3	80.7	102.9	117.0
3	80.67	1290.0	806.7	322.7	161	102.6	120.2

Figures 3 through 5 show the inside vehicle vs outside sound level meter readings during each test point taken on the west side of the track. Dashed lines denote where the horn was heard with respect to the recorded video. The x-axis shows time in eastern daylight time, while the y-axis shows weighted sound pressure in dB(A).

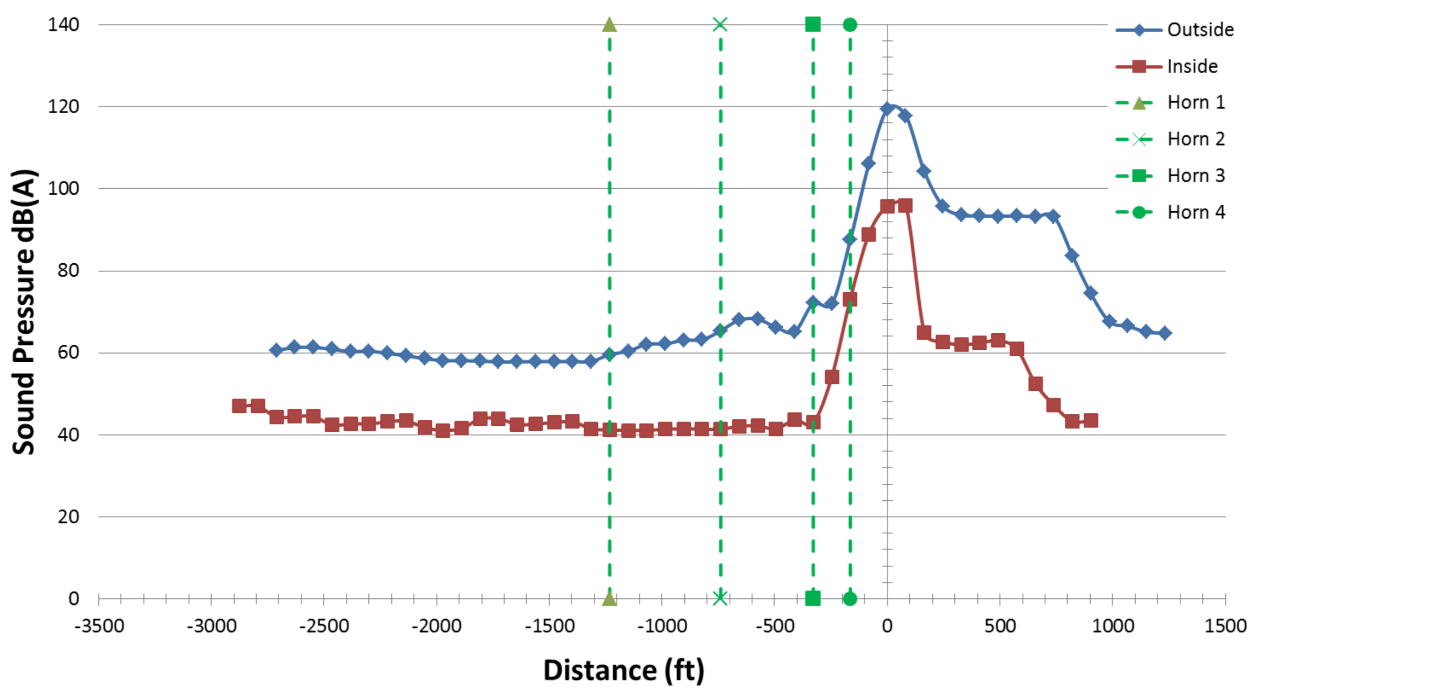

Figure 3. Summary of sound meter results from Test Point 1.

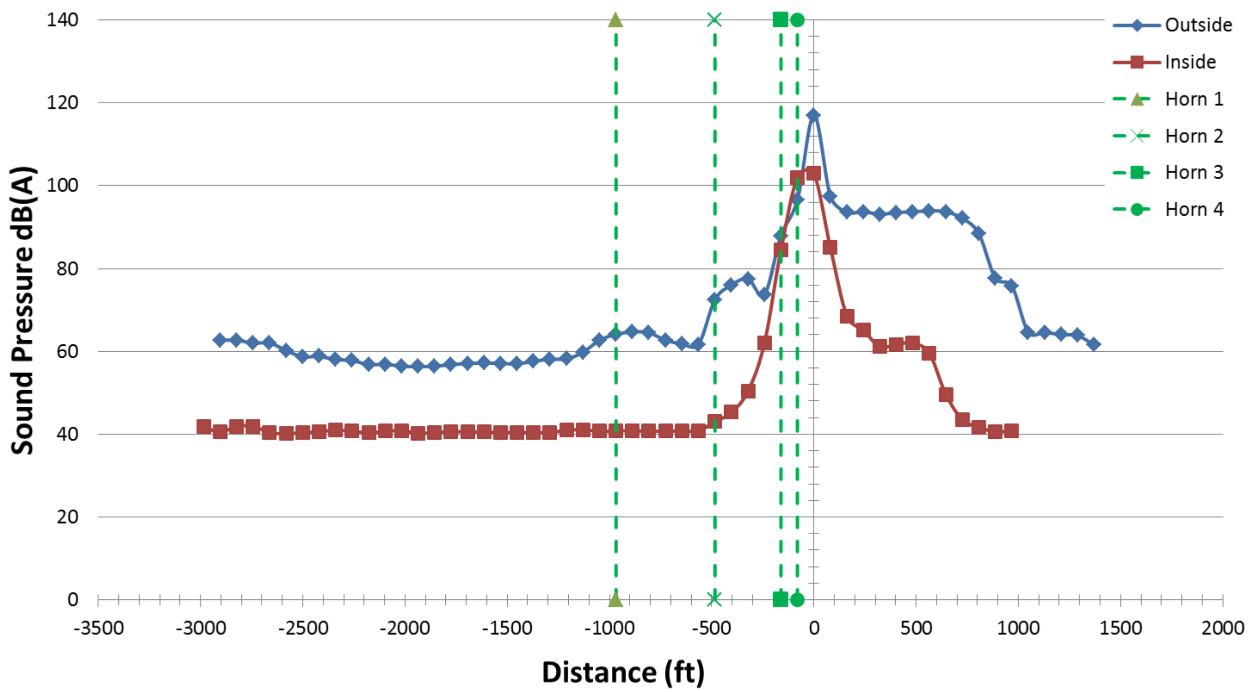

Figure 4. Summary of sound meter results from Test Point 2.

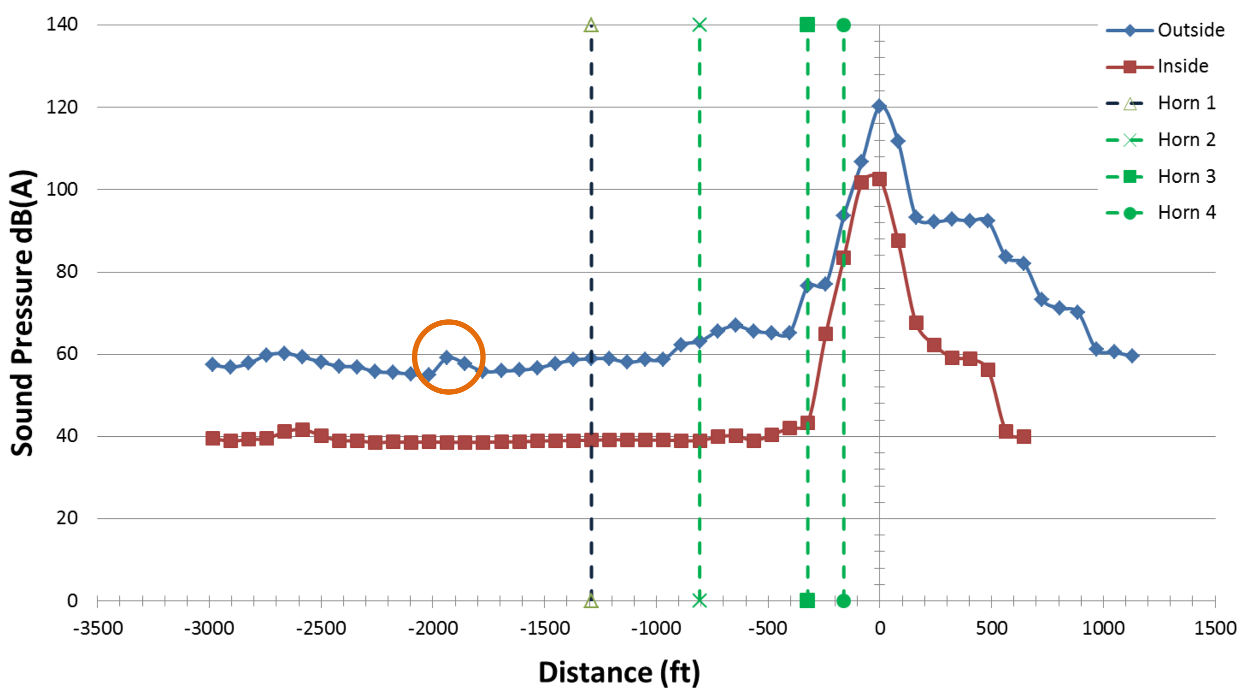

Figure 5. Summary of sound meter results from Test Point 3.

An orange circle denotes an increase in the ambient noise from passing vehicles during the test point.

3.4.2. Passing Train West vs East Side Results

Test points 5 and 6 were conducted using only one outside sound level meter. Data from test point 6 was omitted due to sampling errors introduced by excessive wind that occurred during the test point.

Figure 6 compares the sound profile readings from test point 3 and test point 5 from the outside sound level meter. Test point 5 experienced a max dB(A) reading of 120.4. Both test points had a similar horn cadence that began about 1291 feet prior to the train passing the crossing.

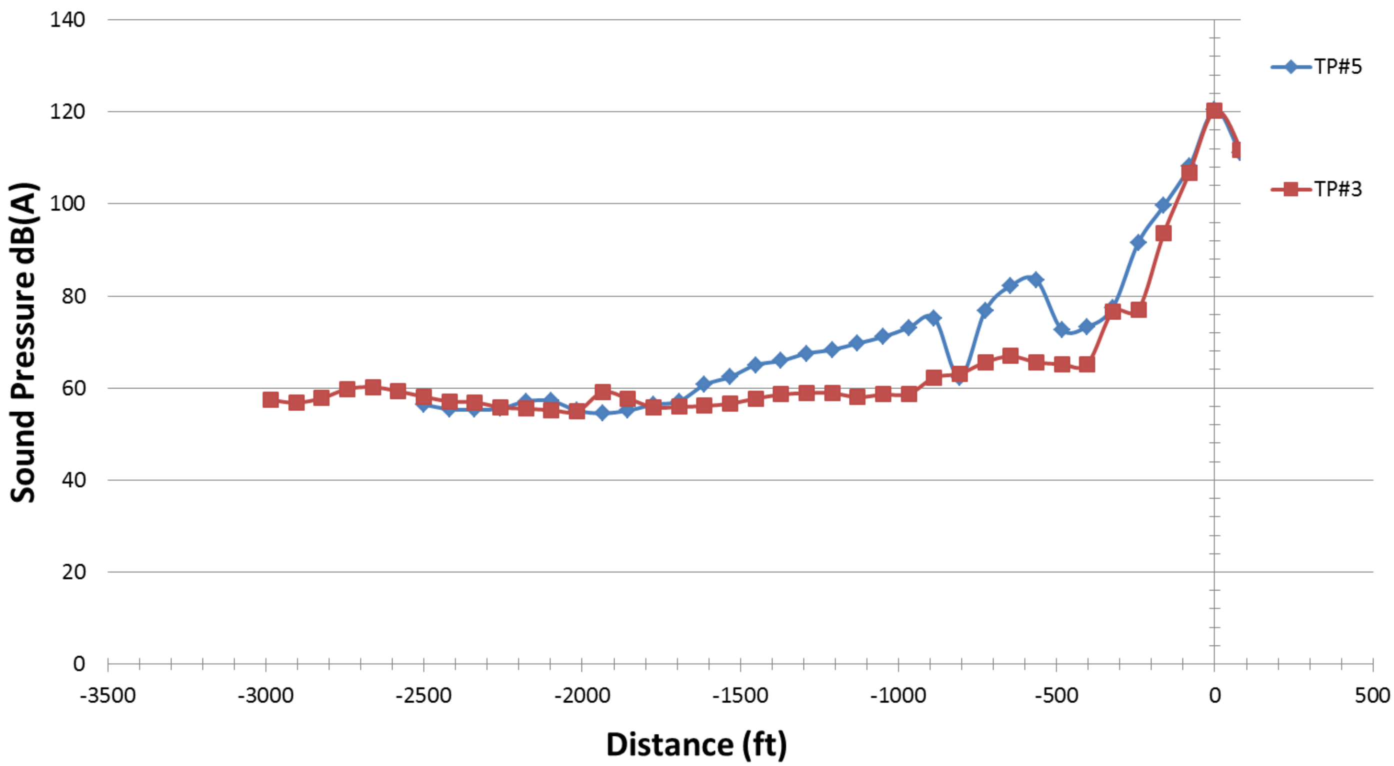

Figure 6. Test Point 3 vs Test Point 5.

3.5. Results and Limitations

The following results were determined when comparing the inside vs outside sound level meter data from test point 1 through 3 conducted on the west side:

When looking solely at the inside vehicle sound level meter data, a consistent trend was noticed between all three test points. The data showed engine-idle ambient readings until the train was about 350 feet from the crossing, where the dB(A) increased rapidly to its maximum recorded dB(A). For test point 1 and 3, this was at the 3rd horn activation. Because test point 2 had a much later start to its horn cadence, this was around the 2nd horn activation, although comparatively, the rise began around the same distance.

When looking solely at the outside vehicle sound level meter data, all three test points showed a progressive rise in dB(A) after the first horn activation.

Data from test point 5 plotted against test point 3 showed an earlier and more pronounced rise in dB(A) from the east side when compared to the west side. In order for a train horn to be effective, it must be 10 dB above ambient noise to attract attention. Therefore, it can be concluded that a train would have been audible earlier from the east side of the track vs the west side of the track with the substation. At 400 feet from the crossing, the plots merged to their respective max recorded dB(A) reading indicating no difference in audibility. [4]

Table 3 lists the calculated dB(A) value for each test point at 100 feet from the crossing. This value was interpolated between the first and second point before the crossing for each test point.

Table 2. Interpolated dB(A) values 100 feet from crossing for outside and inside test points.

Test Point	in-car dB(A) @100 ft	outside dB(A) @100ft
1	85.5	102.0
2	97.8	94.5
3	97.3	103.63
5	---	106.0

The following were identified as limitations to the test:

Use of the horn was at the discretion of the train operator, a significantly shorter cadence was noticed in test point 2.

The vehicle was set up behind the crossing arm adding an estimated 10 feet of distance between the center of the crossing to the location of the vehicle.

[4] "Driver Behavior at Highway-Railroad Grade Crossings: A Literature Review from 1990-2006" U.S. Department of Transportation Federal Railroad Administration, October 2008, Cambridge, Massachusetts."

The use of the vehicle’s heater or radio was not factored into the test, therefore, the car configuration was assumed to be a best case scenario for a driver to detect the horn.

George Haralampopoulos
Aerospace Engineer
Vehicle Recorder Division