Wayside horn noise investigation

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ABSTRACT

Warning horns are used by trains and sounded when approaching a level crossing to warn of its presence. The functional requirement of the horn is to be loud, so that it is audible when sounded at a large distance from the level crossing. Due to this, the use of warning horns can sometimes result in complaints from nearby noise sensitive receivers, for whom the horn noise is not intended. The wayside horn concept replaces the use of the loud train horn, with a lower noise, permanent horn installation at the level crossing. Therefore, an audible sound to warn of the trains' presence can be produced at the level crossing focusing on the area in which the audible sound is required, and significantly reducing the potentially disturbed area. This paper presents the results of a trial study of a wayside horn installation undertaken at a level crossing in Whyalla, South Australia. The wayside horn noise has been compared with the noise of a train horn, and both were compared against criteria for the assessment of the audibility of danger signals and also sleep disturbance.

INTRODUCTION

The wayside horns idea was developed in response to complaints from residents living nearby to the level crossing site regarding the noise from train horns. The wayside horn concept replaces the use of the loud train horn, with a lower noise, permanent horn installation at the level crossing. Therefore, an audible sound to warn of the trains' presence can be produced at the level crossing focusing on the area in which the audible sound is required, and significantly reducing the potentially disturbed area.

This paper presents the results of measured noise levels from the proposed wayside horns and the existing train horns for comparison with each other and against relevant assessment criteria; in this case the World Health Organisation (WHO) sleep disturbance criteria and audibility criteria provided by International Standard ISO 7731.

The study focussed on the comparison of external noise levels against the noted standards. This paper however also considers the audibility assessment inside a vehicle.

ASSESSMENT CRITERIA

Audibility noise criteria

To the best of the author's knowledge, there are no applicable standards in Australia for the assessment of the audibility of train horns. As such, International Standard ISO 7731:2003, titled *Ergonomics — Danger signals for public and work areas – Auditory danger signals* was used for determining criteria for assessing the audibility of noise levels due to the train and wayside horns at the level crossing.

ISO 7731 prescribes that "when using one-third octave-band analysis, the sound level shall exceed the masked threshold by at least 13 dB in one one-third octave-band or more in the range". The noise generated by the audible warning device should be within the frequency range 500 to 2500 Hz.

In addition, the overall A-weighted sound pressure level of the signal shall not be lower than 65 dB at any position in the signal reception area.

For measuring the ambient noise and the signal under ISO 7731, the slow time weighted maximum (L_{ASmax}) should be used.

Environmental noise criteria

The World Health Organisation (WHO) has reviewed research of sleep disturbance caused principally by transportation noise such as traffic, aircraft and railway noise. They conclude that for short duration variable noise sources the onset of sleep disturbance commences at internal fast time weighted maximum (L_{AFmax}) noise levels of 45 dB(A).

It is normal practice when considering internal noise levels from an external source to assume that windows may be partially open, as could be the case. Based on the windows being partially open, the WHO suggests that to achieve the internal levels described above, the L_{AFmax} noise levels outside a bedroom window should be limited to 60 dB(A).

SITE DESCRIPTION

The level crossing is located on the OneSteel site on the Pellet Plant to Blast Furnace train line, as shown in Figure 1. The nearest noise sensitive receivers to the level crossing site are located approximately 400 metres to the south-east.

Two wayside horns have been installed permanently on the north-eastern side of the crossing. The horns are mounted at approximately 4–5 metres above ground level and are oriented towards the hold line points on the western and eastern sides of the crossing. An image of the wayside horn installation is provided in Figure 2.

Figure 1. Level crossing and sensitive receiver locations

Figure 2. Wayside horn installation

MEASUREMENT PROCEDURE

Audibility noise measurements

The audible warning alarm noise levels were measured at each of the hold line points for vehicles on the western and eastern sides of the crossing in terms of one-third octave-band L_{ASmax}. The wayside horn noise levels were measured over a number of short blasts of the horns. The train horn noise levels were measured for a number of train pass-bys in each direction.

Environmental noise measurements

The L_{AFmax} noise level was measured at each of the predetermined measurement locations in the residential area for direct comparison with the WHO sleep disturbance criteria.

ASSESSMENT AND RESULTS

Audibility noise assessment

The noise levels that were measured at each location were compared with the calculated masked threshold, and assessed for whether they achieved an excess of at least 13 dB(A) in at least one one-third octave band.

The masked threshold, according to ISO 7731 is based on the one-third octave bands of the background noise at the crossing. The background noise was measured in terms of the L_{ASmax} in one-third octave bands.

The masked threshold $L_{Ti,\ 1/3oct}$ for one-third octave band analysis is calculated by the following procedure:

Step 1: In the lowest one-third octave band, i = 1

$$L_{T1,\ 1/3oct} = L_{N1,\ 1/3oct}$$

Step i: (i > 1)

$$L_{Ti,\ 1/3oct} = \max.\ (L_{Ni,\ 1/3oct};\ L_{T(i-1),\ 1/3oct} - 2.5\ \mathrm{dB})$$

Repeat step i for i = 2… up to the highest one-third octave band.

Table 1 provides results of the assessment of the wayside horn noise against ISO 7731. The test results are presented for the wayside horns set to approximately ¼ setting on the volume control, which was been fixed within the control cabinet. The masked threshold was calculated from a measurement during a train pass-by at the level crossing and includes noise from warning bells installed at the crossing. The results indicate that the noise level at both sides of the crossing is compliant (entries marked in **bold** where the excess equals or exceeds 13 dB). Note that the results have been rounded to the nearest whole decibel integer and as such the signal level minus the masked threshold may not always equal the excess presented in the table. All signal levels exceeded 65 dB(A), with L_{ASmax} 93 dB(A) and 92 dB(A) being measured on the eastern and western sides of the crossing respectively.

Table 1. Wayside horns noise measurements

Eastern side of crossing	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**
Masked Threshold	71	72	70	69	70	71	75	73
Signal Level	82	76	87	86	88	84	79	74
Excess	11	4	**16**	**17**	**18**	**13**	4	1
Western side of crossing								
Masked Threshold	71	72	70	69	70	71	75	73
Signal Level	86	76	83	81	86	84	79	76
Excess	**15**	4	12	12	**16**	**13**	4	3

Table 2 and Table 3 provide results of the assessment of the train horn noise. The test results are presented for the train horn sounded from each side of the level crossing. The results indicate that the noise level at the eastern side of the crossing with the train from the south is compliant (entries marked in **bold**); however the noise on the western side of the crossing is non-compliant with the train from either side of the crossing (the train horn was not audible on the western side with the train from the north) and was also non-compliant on the eastern side with the train from the north. Signal levels exceeded 65 dB(A) with the train from the south, with L_{ASmax} 84–86 dB(A) being measured on each side of the crossing. Signal levels with the train from the north were not audible on the western side of the crossing and achieved L_{ASmax} 65 dB(A) on the eastern side of the crossing.

Table 2. Train horn noise measurements from the south

Eastern side of crossing	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**
Masked Threshold	71	72	70	69	70	71	75	73
Signal Level	65	74	73	82	78	75	75	75
Excess	0	2	2	**14**	8	3	0	2
Western side of crossing								
Masked Threshold	71	72	70	69	70	71	75	73
Signal Level	73	76	75	78	76	71	74	71
Excess	1	4	4	10	6	0	0	0

Table 3. Train horn noise measurements from the north

Eastern side of crossing	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**
Masked Threshold	71	72	70	69	70	71	75	73
Signal Level	54	51	52	58	54	54	55	54
Excess	0	0	0	0	0	0	0	0

There was a light southerly wind present during the measurements, hence the train horn noise from south was audible but not from the north. During more favourable meteorological conditions the train horn may be audible from the other, or both directions. However, the measurements demonstrate that there will be times when the train horn is not audible.

The wayside horns are not subject to such variations due to meteorological effects due to the much smaller propagation distance, and hence provide a more consistent noise level at the level crossing. As such, the wayside horns are likely to be compliant with the ISO 7731 audibility criteria over a much larger range of weather conditions, thus providing a better warning of an oncoming train at the level crossing.

Environmental noise assessment

Maximum noise levels due to the wayside horns were measured at three locations in the residential area located to the south of the site. Measurements were undertaken under two wind conditions from separate visits.

Measurement results for the first visit are presented in Table 4. Based upon the measurements, the train horn has the potential to cause sleep disturbance at locations 2 and 3, and is significantly louder than the wayside horns.

Table 4. Measured environmental noise levels

Measurement location	**Train horn L_{AFmax} dB(A)**	**Wayside horns L_{AFmax} dB(A)**
Location 1	~50 dB(A)[1]	Not audible
Location 2	64 dB(A)	Just audible, could not be measured in background noise environment
Location 3	61–69 dB(A)	~50 dB(A)[1]

Note 1 Noise level was difficult to measure due to the background noise environment and as such has been approximated based upon the instantaneous L_p observed on the sound level meter.

There was a light southerly wind present during the noise measurements which has the effect of reducing noise at the measurement locations. Therefore, it is expected that under worst case weather conditions for the propagation of noise from the horns to the residential area, the noise from the horns will be louder. In order to determine the noise from the wayside horns under worst case conditions, a noise model of the site was prepared. The wayside horns were modelled as a simple point source in SoundPlan V7.0 software, using the CONCAWE model (weather category 6 for worst case conditions). The results of the model are presented in Table 5.

Table 5. Predicted environmental noise levels due to the wayside horns

Measurement location	**Wind direction under measurement conditions L_{AFmax} dB(A)**	**Worst case conditions L_{AFmax} dB(A)**
Location 1	43 dB(A)	54 dB(A)
Location 2	51 dB(A)	59 dB(A)
Location 3	50 dB(A)	57 dB(A)

Measurements were later repeated under northerly wind conditions for the wayside horns only. Results are presented in Table 6.

Table 6. Measured environmental noise levels

Measurement location	**Wayside horns L_{AFmax} dB(A)**
Location 1	53 dB(A)
Location 2	59 dB(A)
Location 3	50 dB(A)

There was a north north-westerly wind present during the noise measurements (4-5 m/s) which is generally the worst case direction for the propagation of noise towards locations 1 and 2. In order to verify the noise model of the site, the revised noise measurement conditions were input into the model. The results of the model are presented in Table. It is noted that there is a very good correlation between the predicted and measured noise levels.

Table 7. Predicted environmental noise levels due to the wayside horns

Location	Wind direction under measurement conditions L_{AFmax} dB(A)	Worst case conditions L_{AFmax} dB(A)
Location 1	54 dB(A)	54 dB(A)
Location 2	59 dB(A)	59 dB(A)
Location 3	49 dB(A)	57 dB(A)

The results of the noise modelling indicates that the noise from the wayside horns, when assessed under worst case conditions for the propagation of noise from the horns to the receivers, is unlikely to exceed 60 dB(A) and as such, the likelihood of sleep disturbance for the nearest residents is low. Furthermore, the wayside horns provide an increased warning signal noise level at the crossing whilst reducing the environmental noise level in the residential area.

Effect of vehicle on wayside horn audibility

The audibility assessment and comparison of noise emissions between the existing train horns and wayside horns were based on external noise measurements only. This was due to the added complexity of analysis of the outside to inside noise reduction and internal noise level for a wide range of vehicles. Furthermore, the audibility requirements for train horns in Australia are not clear.

Since then, the author has undertaken an audibility assessment based on subsequent measurements of a typical passenger vehicle. The vehicle measurement results are summarised in Tables 8 and 9.

Table 8. Passenger vehicle outside to inside noise reduction

	Outside to inside noise reduction dB(A)							
Passenger vehicle	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**
Windows closed	24	35	36	38	43	44	44	45
Drivers window open	4	14	18	18	14	12	9	9

Table 9. Idling passenger vehicle internal noise level measurements

	L_{ASmax} Sound Pressure Level dB(A)							
Passenger vehicle	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**
Inside windows closed	42	42	38	37	34	31	27	25
Inside drivers window open	44	40	40	42	42	38	34	32
Inside radio on “normal” volume	57	61	56	53	59	59	59	56

Based on the outside to inside passenger vehicle noise reduction and internal noise level measurements, the masked threshold, signal levels and audibility were re-calculated using the following methodology:

- Calculate the revised internal background noise level based on the higher noise level in each 1/3 octave band of 1) the internal vehicle noise level (Table 9), and 2) the ambient background noise level less the outdoor to indoor vehicle noise reduction (Table 8).
- Using the calculated internal background noise level from the step above, calculate the revised masked threshold.
- Calculate the revised signal level based on the measured signal level less the outdoor to indoor vehicle noise reduction (Table 8).

The results are summarised in Table 10.

Table 10. Wayside horn audibility calculations inside of a passenger vehicle

Windows closed, radio off	**500 Hz**	**630 Hz**	**800 Hz**	**1000 Hz**	**1250 Hz**	**1600 Hz**	**2000 Hz**	**2500 Hz**
Masked Threshold	47	45	42	40	37	35	32	30
Signal Level	60	41	49	46	44	40	35	30
Excess	**13**	0	7	6	7	5	3	0
Drivers window open, radio off								
Masked Threshold	67	65	62	60	57	59	66	64
Signal Level	80	62	67	66	73	72	70	66
Excess	**13**	0	5	6	**16**	**13**	4	2
Windows closed, radio on								
Masked Threshold	57	61	59	56	59	59	59	57
Signal Level	60	41	49	46	44	40	35	30
Excess	3	0	0	0	0	0	0	0
Drivers window open, radio on								
Masked Threshold	67	65	62	60	59	59	66	64
Signal Level	80	62	67	66	73	72	70	66
Excess	**13**	0	5	6	**14**	**13**	4	2

The results show that the wayside horns will generally be compliant with the ISO 7731 audibility criteria within a vehicle with closed windows and with the drivers’ window opened, providing that the radio is not operating. The exception is that with the windows closed the signal level within the vehicle is 61 dB(A) and therefore not strictly compliant due to the required overall noise level of 65 dB(A), however the required signal-to-noise ratio is achieved.

If the vehicle radio is operating at what the author considers being a “normal” volume, then the wayside horns will be compliant with the ISO 7731 audibility criteria with the drivers' window opened, however will not achieve the requirements of ISO 7731 with windows closed.

Upon review of the results, the signal level would need to be increased by at least 10 dB(A), subjectively doubling the noise level. This may not be considered to be reasonable due to the following:

- Non-compliance with ISO 7731 does not necessarily mean that a signal is not audible.
- Increasing the signal level may not achieve compliance with ISO 7731 in all circumstances as it is dependant on the noise level within the vehicle; and this may be highly variable.
- The train driver still has the option of sounding the train horn in addition to the wayside horns to signal its presence.
- Environmental noise levels would be increased significantly and possibly exceed applicable sleep disturbance criteria in the neighbouring residential area.
- Alternative visual and audible signals are already present at the level crossing (this being the level crossing lights and bells).

Whilst the audibility requirements in Australia are unclear, it appears that there are differing requirements for train horns in the USA and the UK, with the USA concerned with the drivers of road vehicles hearing the horns while in the UK the warning horns are most significant at crossings for pedestrian only.

In the USA, where there is a desire for the train horns to be audible within vehicles, the specification for a train horn is to achieve a minimum noise level of 96 dB(A) at 100 feet (33 metres). The location of the whistle board is required to be approximately 400 metres from level crossing, therefore the noise level of the train horn at the level crossing, assuming geometric spreading will be 74 dB(A). This noise level is significantly lower than the 92-93 dB(A) achieved by the current wayside horn installation at the OneSteel level crossing. The current noise levels produced by the wayside horn at the OneSteel level crossing would be equivalent to a train at an approximate distance of 45-55 metres from the level crossing, assuming geometric spreading.

CONCLUSION

The measurements indicate that the permanent wayside horn installation is achieving the International Standard ISO 7731:2003, titled Ergonomics — *Danger signals for public and work areas – Auditory danger signals* criteria at the level crossing.

Whilst the wayside horns do not necessarily satisfy the ISO 7731 audibility requirements for every scenario of a receiver within a vehicle, they do provide a significant improvement to the audibility of the train horn at the existing level crossing, and also an improvement when compared to the audibility of a train sounding its horn at the whistle board of most other level crossings.

Furthermore, environmental noise measurements and modelling indicate that the maximum noise level criterion of 60 dB(A) from the wayside horns is not being exceeded in the residential area to the south of the site in conditions conducive to the propagation of noise from the OneSteel site to the residential area.

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