Evaluation of occupational noise exposure levels on the Wellington Suburban Tranz Metro Rail Service

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Abstract

An occupational noise evaluation study was carried out by Massey University students on locomotive engineers and on-board staff on the two main train sets operating on the Wellington Rail Suburban Network. All measurement results conducted as part of the study show full compliance with the criteria for workplace noise exposure prescribed within the Health and Safety in Employment Regulations 1995. The health and safety noise criterion level permits a maximum dose of 100% which is equivalent to 85 dB L_{Aeq} for a normalised 8 hour working day. The highest measured sound exposure was 13% of the total permitted exposure. All occupational noise measurements were observed and written accounts were taken by the three person investigation team. Observations revealed atypical behaviour of one participant which likely compromised one set of readings. This atypical result was removed from the analysis and therefore did not alter the study conclusions. Regardless, such observed behaviour from the study team, reinforces the value of observed real time field monitoring during collection of data.

Original peer-reviewed student paper

About Ka'isa Beech

Age 23, is training to be a Train Traffic Controller with KiwiRail. She first developed an interest in workplace Health and Safety after joining KiwiRail in 2011, becoming a Health and Safety representative on the Health and Safety Action Team, as well as volunteering for various positions within the Rail and Maritime Transport Union (RMTU). She is currently the elected Assistant Secretary of the Wellington Branch of the RMTU. Her other interests include music. She graduated from the New Zealand School of Music in 2014 with a Bachelor of Music specialising in Ethnomusicology and performs with various groups around Wellington.

Kaisa recently participated in a project to undertake a comprehensive assessment of the Palmerston North heavy engineering KiwiRail workshops and has also developed and delivered a training and education seminar to at risk workers in KiwiRail.

She has now met all the prescribed criteria to be recognised and certified as a "Competent Person" in noise management and assessment under the Approved Code of Practice for Management of Noise in Workplace.

1. Introduction and purpose of assessment

The Tranz Metro Rail Passenger Service is operated by KiwiRail and funded by the Greater Wellington Regional Council [1]. This paper includes summary details of a field investigation and related sound pressure level measurements into an Occupational Health and Safety investigation into the sound pressure levels employees of the Tranz Metro Rail Passenger Service are typically exposed to while performing their duties. This investigation was carried out on five locomotive engineers (also commonly known as '*train drivers*') and five on-board staff (also commonly known as conductors or ticket collectors) while working on the trains. Measurements were based on exposure to staff while predominately inside the train cabin or engineers cabin, however limited periods outside for on board staff while performing platform based duties was also collected.

The investigation was undertaken in general accordance with the Australian/New Zealand Standard 1269:1:2005 *Measurement and Assessment of Noise Immission and Exposure* [2]. The study compares the measured sound pressure level data gathered in order to assess whether the two selected staff types of Tranz Metro staff (Engineers and On-Board Cabin Crew) when exposed to occupational noise (throughout a typical 8 hour working shift) comply with the criteria of Regulation 11 of the Health and Safety in Employment Regulations 1995. This requires that all practicable steps must be taken to ensure employees are not

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exposed to a time average sound pressure level exceeding 85 dB $L_{Aeq\ 8h}$ over normalised 8 hour working day, and not exposed to any single sound pressure level in excess of 140 dB L_{Cpeak} at any time, regardless of their daily sound exposure. Unlike the of 85 dB $L_{Aeq\ 8h}$ exposure limit, the peak level is not based on the daily noise exposure but an absolute exposure limit at any time throughout the working day. The reasoning behind this is that any sound event equal to and in excess of 140 dB L_{peak} level can potentially cause permanent hearing loss.

2. Method of investigation

The method of investigation involved measurement of sound pressure levels via the use of personal sound exposure meters. The method chosen was to place one single personal sound exposure meter on the shoulder of each of the five locomotive engineers as well as on each of the on-board staff members. The field measurements took place over the working day on Thursday 10th April 2014 between the hours of 10.40am and 6.40pm (10.40 hrs-16.40 hrs).

Tranz Rail, operate two types of electrically powered train units, the older 'Ganz Mavag Units' and the recently acquired 'Matangi Units'. As both types of units are operated in service, measurements focused on sampling sound pressure levels across both types of units. Measurements were conducted across five return passenger train trips across the network of four lines (Kapiti, Johnsonville, Meilling and Hutt valley). The Ganz Mavag Units have been in service for more than 50 years and are gradually being decommissioned and replaced by the modern Matangi Units which will make up the entire Wellington based passenger fleet as the older Ganz Mavag Units are phased out. Remodelled units from the older Ganz Mavag units known as the SuperGanz Unit are also in operation, but were not studied because there are very few in operation. There are also two regional passenger services being the "*Wairarapa Line*" operating between Wellington and Masterton and a "*Capital Connection*" commuter service operating between Wellington and the Palmerston North. These regional passenger services were also not included in the study due to time constraints. Both the Wairarapa and Capital Connection Lines are of rolling stock pulled by diesel locomotives and hence further study would be worth investigating.

3. Overview of units tested

Matangi is the Maori word for wind. The Korean built Matangi Units are technically called the "*FP/FT Matangi Units*" which are a class of electric multiple units consisting of a single FP unit and FT unit. The FP Unit is the power car and an FT is trailer or dummy car. The units were built by Hyundai Rotem especially for New Zealand. The Matangi Units were progressively introduced from 2004 to allow for the retirement of the remaining DM/D class "English Electric" multiple units that were introduced between 1949 and 1954. Multiple units can be coupled together depending upon demand such as peak hour. The passenger compartment of one unit can seat up to 147 people. Figure 1 is a composite photo set of the exterior, interior passenger carriage area and locomotive engineer's cabin of the Matangi Unit.

Figure 1: Matangi unit

The Ganz-Mavag Units are technically called the "*EM/ET Class Units*" which are a class of electric multiple units consisting of a single EM unit and ET unit. The EM Unit is the power car and an ET trailer or dummy car. The Ganz-Mavag units are named after the manufacturer being the Ganz-Mavag of Budapest, Hungary. As with most units, multiple units can be coupled together depending upon demand such as at peak hour usage. The passenger compartment of one unit can seat up to 148 people. Figure 2 is a composite photo set of the exterior, interior passenger carriage area and locomotive engineer's cabin of the Gavz -Mavag unit.

Figure 2: Ganz-Mavag unit

4. Overview of internal wagon noise

There are two types of internal wagon or compartment noise - airborne and structure borne transmission.

Airborne noise sources include:

- Air-conditioning (Matangi units)
- Bogies
- Engine and auxiliary equipment

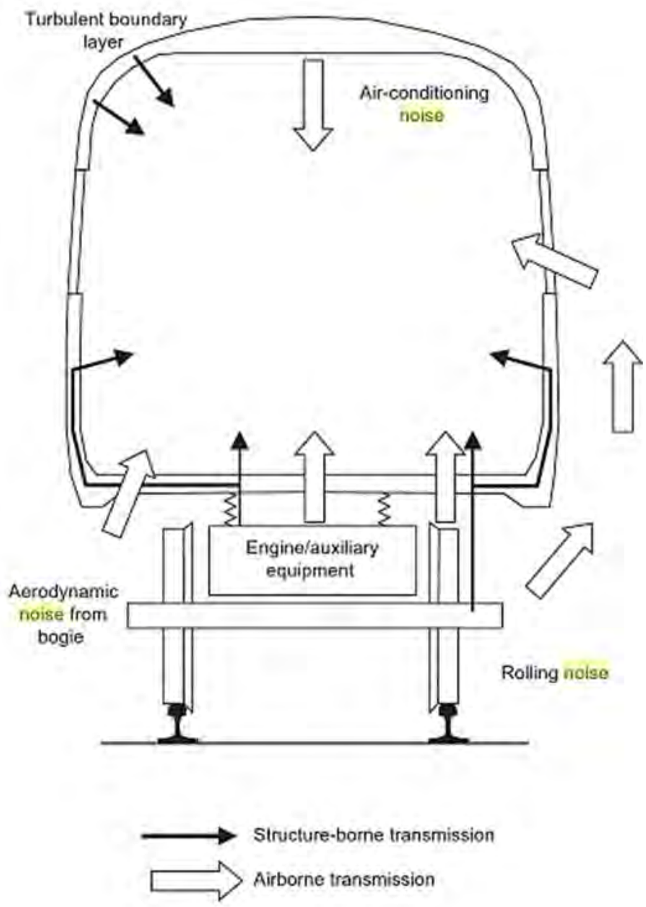

Figure 3: Noise transmission pathways

- Rolling noise noting that which enters through windows especially if the unit has opening windows (Ganz-Mavag units)

Structure borne noise conduction includes

- Engine and auxiliary equipment
- Bogies
- Noise from turbulent boundary layer
- Rolling noise from wheels, track and bogies

The new Matangi units have no opening windows due to air conditioning being fitted except in the engineer's cabin and areas where passengers do not have access. The non-air-conditioned Ganz Mavag Units have windows throughout which can be opened.

Other noise sources will include that generated by occupants such as passengers and crew, external noise sources such as passing over bridges, through tunnels, and warning signals such as horns and sirens. As much the testing was done at off peak hours, the trains were not crowded, with less than half the seated capacity occupied at any one time.

The most noticeable noise in all the trips carried out was the track squeal on the Johnsonville line which is due to the tight curvature of the tracks. While it was not of sufficient sound pressure level to be an occupational noise issue, the audible characteristic of this noise has been reported as causing annoyance to nearby residences. Similar issues have been reported in Australia where Transport for New South Wales (TfNSW) has undertaken an intensive study on track squeal which has been reported by Hanson et al. [3].

5. Measurement equipment

Four Digitech QM1599 Class 2 sound level meters were used to collect data for the study. While these instruments were not specifically designed as personal sound exposure meters (dosimeters) they were able to be adapted as screening student training meters by building a shoulder mount with a leather pouch which was pinned to the shoulder. Prior to beginning the assessment, the dosimeters were calibrated using a Pulsar101 Calibrator (set at 93.7 dB). Measurements were taken in general accordance with the Australian/New Zealand Standard AS/NZS 1269.1:2005 Occupational Noise Management. While the instruments were not independently certified as required by AS/NZS 1269.1, the calibrators used were internally calibrated under laboratory conditions with a certified Class 1 sound level meter with current laboratory verification. Comparative tests have shown that these instruments had +/- 3 dB accuracy for L_{Aeq} dB measurements which is what can be expected from a Class 2 instrument. These instruments were unable to give true L_{Cpeak} dB levels but a non-standardised peak value was given. We have assumed that this is reasonably close to a true peak level for the purposes of this study. Regardless, there are no apparent noise sources in this work environment that would create a peak level at or above 140 dB L_{Cpeak}.

The dosimeters were attached to the shoulder of the individual and were placed as close to the ear as possible. All the staff members we approached were willing to participate. Staff were selected based on the type of unit and line they were working on and to fit into the limited time available for the testing schedule. Each measurement period was typical of a return train trip from the Wellington Railway Station terminal.

As the instruments did not automatically calculate sound exposure, these were calculated by converting the L_{Aeq} dB values to their linear equivalents (Pa^2 values) and multiplying by the run time (in hours) to give sound exposure in pascal squared hours (Pa^2h). Conversion to a percentage gave the % dose values.

A comprehensive log was recorded by the investigators who were seated in the passenger areas on all the trips. It was not possible for the investigators to be present in the driver's cabin due to a strict the health and safety policy while the units are in operation. Sources of noise only heard by the locomotive engineers could therefore not be identified but observations proved invaluable in describing the types of noise in general and detecting any

actions or atypical behaviour which might compromise results/ or tapping the device. If such actions were clearly observed occurring, recordings were discarded.

6. Weather conditions

The weather conditions during the field testing on Thursday 10th April 2015 were overcast with rain and light wind while at Wellington Station. It is possible for the microphone to also pick up the sound of rain and wind (especially wind shear across the microphone) and this may interfere with measurements. While weather conditions can be variable to where the train travels, changes were not sufficient enough to remove dosimeters to prevent damage from the weather or to a cause undue interference from rain and wind noise.

7. Measurement and Assessment

7.1 Individual Trip Data

The following presents measurement data collected on Thursday the 10th of April 2015 between 10.40 am and 6.40 pm.

7.1.1 Trip One

10.44 am train to Waikanae (terminal), all stops to Waikanae. 12:00 pm train from Waikanae, all stops to Wellington; Matangi 4 car set.

Table1: Results for Trip One

Time / run-time Sound measurement	Locomotive engineer One	On-board staff member One*
	1041 – 1304 (2 hours 23 mins)	1047 – 1301 (2 hours 14 mins)
L_{Aeq}	75 dB	85 dB
L_{peak}	115 dB	119 dB
Dose %	3 %	28 %

* The staff member concerned was observed continually singing and talking into the dosimeter in an abnormal way. These results were not included in the study but listed here to demonstrate the value of observed monitoring where such incidents would otherwise go undetected.

The L_{peak} value of 115 dB for locomotive engineer one, appears high and is probably a false peak due to the dosimeter accidently touching a wall or other object while being worn.

7.1.2 Trip Two

11.02 am train to Johnsonville (terminal), all stops to Johnsonville. 11.30 am train to Wellington all stops to Wellington. Matangi 4 car set.

Table2: Results for Trip Two

Time / run-time Sound measurement	Locomotive engineer Two	On-board staff member Two
	1055 – 1157 (1 hour 2 mins)	1047 – 1301 (2 hours 14 mins)
L_{Aeq}	69 dB	73 dB
L_{peak}	101 dB	101 dB
Dose %	0.3 %	1.8 %

7.1.3 Trip Three

3.57 pm train to Upper Hutt, express to Waterloo/express to Taita/all stops from Taita. 4.45 pm from Upper Hutt, express to Wellington. Ganz Mavag 4 car set.

Table3: Results for Trip Three

Time / run-time Sound measurement	Locomotive engineer Three 1553 – 1713 (1 hour 20 mins)	On-board staff member Three 1541 – 1714 (1 hours 33 mins)
L_{Aeq}	74 dB	73 dB
L_{peak}	100 dB	101 dB
Dose %	1.3 %	1.5 %

7.1.4 Trip Four

4.17 pm train to Melling, all stops to Melling. 4.41 pm train from Melling, all stops to Wellington. Matangi 4 car set.

Table 4: Results for Trip Four

Time / run-time Sound measurement	Locomotive engineer Four 1555 – 1648 (54 mins)	On-board staff member Four 1552 – 1648 (56 mins)
L_{Aeq}	75 dB	69 dB
L_{peak}	115 dB	101 dB
Dose %	1.1 %	0.3 %

7.1.5 Trip Five

5.50 pm train to Taita, all stops to Taita. 6.07 pm train from Taita, all stops to Wellington. Ganz Mavag 4 car set.

Table5: Results for Trip Five

Time / run-time Sound measurement	Locomotive engineer Five 1748 – 1842 (54 mins)	On-board staff member Five 1749 – 1841 (52 mins)
L_{Aeq}	74 dB	74 dB
L_{peak}	98 dB	102 dB
Dose %	0.8 %	0.8 %

7.1.6 Results summary

The results across all trips can be summarised as follows:

Locomotive Engineers

L_{Aeq} 69 -75 dB
L_{peak} 98 – 115 dB
% Dose 0.3 – 1.1%

On – board staff

L_{Aeq} 69 -74dB
L_{peak} 98 – 115 dB
% Dose 0.3 – 1.8 %

The sound exposure (% dose) calculation for Locomotive Engineer (worst case scenario):

$L_{Aeq\ 2.4h}$ = 75dB => 0.0126 Pa^2
0.0126 x 2.4 = 0.0302 Pa^{2}h
Sound exposure ($E_{A\ t}$) = 2.4 x 0.0126 = 0.030 Pa^{2}h
%Dose = 0.03 x 100 = 3.0 %

Dose corrected for an 8 hour working day = 3.0 x 8/2.4 = 10 % (assuming that the same level of noise was received over a full 8 hour working day).

7.2 Health and Safety in Employment Legislation

The Health and Safety in Employment Act 1992 (HSE 1992) was the principal health and safety statute in force when the investigation was carried out. The object of the Act is to promote the prevention harm occurring in the workplace, including potential harm from noise. Duty holders [employers] are required to take all practicable steps to remove, control, or otherwise manage hazards in the workplace including noise.

The Health and Safety in Employment Regulations 1995 (Regulation 11) requires that employers must take "*all practicable steps*" to ensure employees aren't exposed to a noise exposure level $L_{Aeq\ 8h}$, of 85 dB(A) and a peak noise level, L_{peak}, of 140 dB, regardless of whether the employee is wearing hearing protection.

Sub-clause (3) of Regulation 11 states that where an

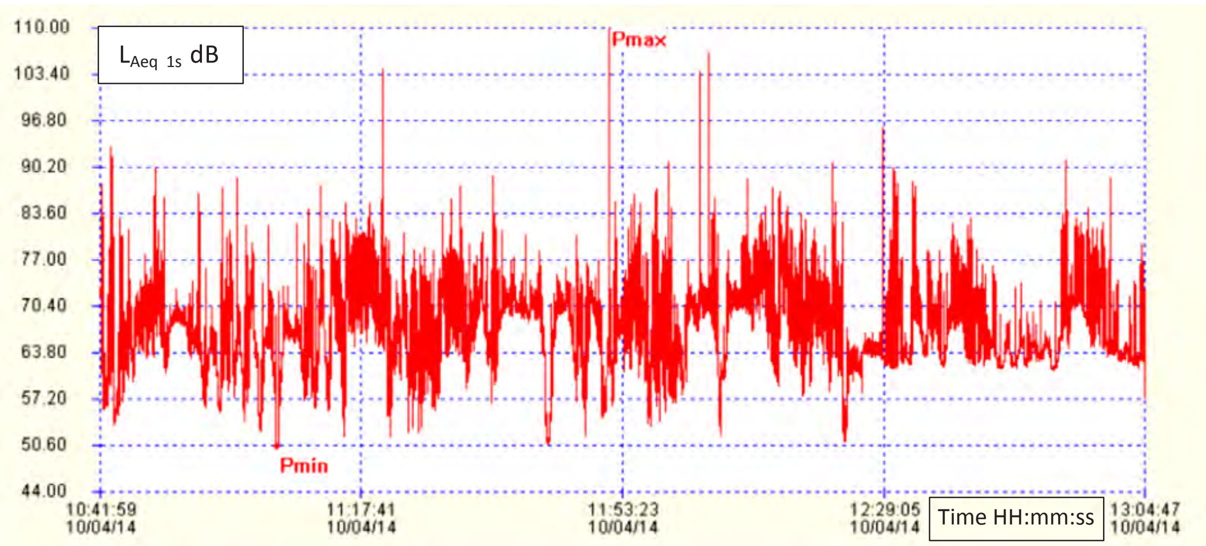

Figure 4: Time history for locomotive engineer (Trip One - 10.44 am return trip to Waikanae)

employer has taken all practicable steps to ensure that no employee at any place of work under the control of that employer is exposed to noise above the levels specified in subclause (1) but has not eliminated the risk that any employee may be exposed to noise above those levels, the employer shall communicate clearly, by way of signs, labelling of machinery, or other appropriate means:

a) the fact that noise levels at the place of work are or are likely to be hazardous; and
b) the sort of personal hearing protection device that is suitable to protect against the noise levels
c) where such a device may be obtained.

8.3 Assessment

Based on the selected testing, all results were well within the criteria of Regulation 11 the Health and Safety in Employment Regulations 1995. While the equipment was of Class 2 specification, it is likely that there is full compliance with the legislation on these units and operations, as sound levels recorded were well below the above legal criteria.

The sample results indicate a highest L_{Aeq} dB value of the locomotive engineers was measured at 75 dB L_{Aeq}, and for on-board staff this was 74 dB L_{Aeq}. The highest peak level of the locomotive engineers was 115 dB L_{peak} and of the on-board staff at 98 dB L_{peak}. It is however noted that these levels are an estimate due to the limitations of the Class 2 equipment and actual L_{peak} levels would be expected to be well below the 140 dB L_{peak} criterion in a test environment such as this. Even taking the worst case scenario of an estimated daily noise dose reaching 10%, this is well below the maximum permitted dose of 100% which is equivalent 85 dB $L_{Aeq\ 8h}$. It is worth noting that if occupational noise levels approached the criteria prescribed in Regulation 11, it would be extremely uncomfortable for passengers and a serious hindrance to staff in carrying out their duties.

During the running of the units, locomotive engineers predominantly stay within the driver's cabin, it is possible to open the window and the locomotive engineers carried out this function during some of the assessments. The locomotive engineers also leave the cabin and walk outside the units for inspection before departing the station. As this occurs before each departure, this exposure is included within the measurement results. Staff were briefed to carry out their duties as normal and not do anything different while wearing the dosimeters.

When considering the operation of the train for on-board staff, although staff members are seated within the passenger compartment in between stations, they are required to step off the train at each station to check that passengers have completely disembarked or boarded the train. They are also required to walk in between the sets when the train is moving to collect fares. A comprehensive log was recorded by the investigators who were seated in the passenger areas on all the trips, but it was not possible for the investigators to be present in the driver's cabin due to the health and safety policy. Sources of noise only heard by the locomotive engineers could therefore not be easily identified.

Observations can be invaluable in describing the types of noise in general and also detecting any actions or atypical behaviour which might compromise results. These include deliberate talking, singing into the microphone or otherwise tampering with the dosimeter being worn.

In regards to the typical operations and noise exposure, the units may stop at all stations and in some cases only stop at selected stations.

7.4 Second tier health effects (Non-auditory effects)

It is well documented that there are additional health risks relating to both health and productivity that should be managed in terms of occupational noise that may not cause auditory damage [4]. Non-auditory effects of noise may be defined as all those effects on health and well-being which is cause by the exposure of occupational noise with the exclusion of effects on the hearing organ [ear]. These non-auditory effects can themselves have a host of second tier health effects including sleep disturbance and also inducing physiological and physiological stress. In all cases, the level of effect depends on a host of factors including levels of sound, types of sound and also exposure times. However annoyance and stress, for example, do not necessarily relate to or depend on the absolute sound pressure level. The potential of annoyance from occupational noise may need to be considered in regard to health effects. Such potential effects can be compounded by a host of other factors including age, existing hearing disabilities or other medical conditions.

7.5 Limitations

These results presented here were undertaken as a student project and had various limitations including the type of equipment and limited sample size. Results included only the Tranz Metro employees operating the Ganz Mavag and Matangi Units for only a limited test time. No other measurements were taken while undertaking other typical other duties that are performed over an average working day, due to time constraints. Based on the sound exposures recorded and the length of time of the typical shifts, there are unlikely to be any significant non-compliance issues with these units, as all measurement were well within the criteria prescribed in the legislation.

These measurements also excluded the regional services, Wairarapa and Capital Connection service (to Palmerston North) which use locomotives and carriages which are a completely different type of train to the Matangi and Ganz Mavag electric multiple units. The SuperGanz train, a

remodelled version of the Ganz Mavag was also excluded from this assessment.

Equipment used was a limitation of accuracy, as the dosimeters did not fully meet the Occupational Noise Management standard AS/NZS1269:2005, as they are provided as training equipment. However internal calibration and verification under laboratory conditions revealed an accuracy of +/- 3 dB which is an acceptable tolerance for a Class 2 meter. The dosimeters were unable to record true peak levels, however the equipment was able to give a reasonable estimation suitable for screening purposes that both L_{Aeq} and L_{peak} levels were unlikely to be exceeded.

8. Conclusion

The results gathered from assessing the noise exposure of locomotive engineers and on-board staff performing limited duties on the Tranz Metro Rail Passenger service showed full compliance with the noise criteria set within Regulations 11 of the Health and Safety in Employment Regulations 1995. An unexpected finding of the study reinforced the value of carrying out observations with personal sound exposure measurements as a participant was observed singing and talking into the dosimeter – something that may have otherwise not been detected.

9. Recommendations

After completing this investigation and considering the limitations and findings of the results it is recommended that:

1. An investigation is carried out on the Wairarapa line, Capital Connection and on the SuperGanz train sets. These include train sets which staff had identified as being reasonably loud and there were no measurements taken on these trains.
2. Measurements need to be taken to measure the other duties that locomotive engineers and on-board staff members are required to carry out during their average day of work. This assessment only measured the levels of noise employees were exposed to while they were running the passenger service. However, it is important to measure the other duties. The employees work on a rotating shift, which means some days they may mainly be driving trains, while other days they are mainly relaying trains between the yard and the platform.
3. It would be important to measure the noise on-board staff are exposed to on the “school trains.” Staff members have reported noise levels as quite loud and find it hard to concentrate. If this is identified, practicable measures to minimise the noise could be investigated.

10. Acknowledgments

We would like to thank all the staff who contributed to this study by wearing personal sound exposure meters (dosimeters). In addition we would like to thank the management team Scott Sargent, (Health and Safety Advisor), Patrick Maney, (Injury Prevention and Wellness Manager), Rob Gordon (Metro Manager), Scott Brooks (Former Metro Manager), Natalie Thompson,(Tranz Metro On-Board Manager), and Mike Fenton (Tranz Metro Operations Manager) for their assistance and permission to undertake this study.

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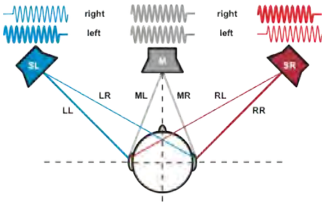
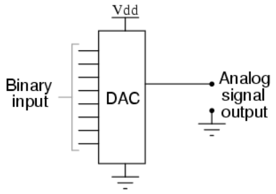
Fifteen Question Quiz

"The hammer never complains of the noise"





Q1. What is the symbol for acoustic impedance and what are its SI units ?

Q2. In Building Acoustics, what do the two terms "STC" and Rw stand for?

Q3. True or False, L_{peak} and L_{max} mean the same thing?

Q4. Why might two crying babies be perceived as being more than twice as loud as one?

Q5. Briefly describe the differences between an '*anechoic chamber*' also referred to as 'Full anechoic chambers' and a 'semi-anechoic chamber' and give an example of when a semi-anechoic chamber may be used.

Q6. The 'incus' is a term used for the middle of the three bones in the middle ear, what is another name for 'incus'

Q7. True or false 'sone' and 'phon' are both units of loudness?

Q8. What does the term "DAC" stand for?

Q9. Briefly explain what is meant by the term "Sound Insulation".

Q10. Briefly explain what is meant by the term "Frequency Weighting".

Q11. Briefly explain what is an "audiogram".

Q12. What are the key factors that limit the practicable attenuation of an acoustic barrier to about 15 dB?

Q13. Name the two basic forms of sound level meter (SLM) design approved under IEC 61672.

Q14. Two small and extremely quiet sound sources with a measured sound pressure level of 7 dB each, are placed next to each other. What is the notional combined sound pressure level of the two sources?

Q15. What is facade correction and when would you apply it?

Find the answers on Page 37