

Which is Safer – Tonal or Broadband Reversing Alarms?

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ABSTRACT

Tonal reversing alarms have been identified as a source of noise annoyance to the community (DEC 2012). There has been a drive to replace tonal reversing alarms with broadband alarms. However, there has also been resistance in replacing the tonal with broadband alarms, due to perceived safety concerns. Many owners and operators of heavy vehicles believe that their tonal reversing alarm provides a safety system superior to the broadband alarm. Recently SafeWork Australia (2011a) issued their document *Managing Noise and Preventing Hearing Loss at Work*, within which ISO 9533:2010 is selected as the standard to measure audible reversing alarms on vehicles. In order to address the above safety concerns, the Noise Regulation Branch of WA's Department of Environment and Conservation (DEC) studied 21 DEC vehicles with tonal reversing alarms against the ISO 9533 Standard. Also tested were 5 vehicles from the City of Subiaco. The investigation found that a large proportion of the tonal reversing alarms tested failed to comply with the ISO 9533. Some of the tonal reversing alarms were then replaced with broadband alarms with the similar sound power levels. The test results demonstrate that all these broadband reversing alarms are able to meet the requirements of ISO 9533, when properly installed. This study also indicates that broadband reversing alarms are much less annoying at the distances further away (say further than 100 m), where the sound of the alarm is substantially merged in the background noise.

INTRODUCTION

Audible reversing alarms have been in use in Australia for many years in mine sites, construction sites and industrial and commercial premises to warn persons nearby that a vehicle is reversing. Most of these alarms operate by emitting a pulsing 'tonal' sound that may be described as a 'beep-beep' sound. Aside from reversing mobile plant, beeper alarms are also used as start-up or movement alarms for some fixed plant.

Reversing alarms are necessarily loud, and the single frequency sound is not easily attenuated by transmission with distance, thus the noise can be annoying for receivers at considerable distances from the source where safety is not at risk. Noise Regulation Branch of the Western Australian Department of Environment and Conservation (DEC) has been encouraging consideration of 'broadband' reversing alarms as an alternative to the use of the more common 'tonal alarms'. The sound of a broadband alarm, although covering a range of higher frequencies where the ear is more sensitive, is much less intrusive by nature than the sound of a tonal alarm and tends to be masked by the background noise at a lesser distance. Broadband alarms by virtue of using a range of frequencies may provide improvements from a safety point of view, as they overcome some of the inherent limitations of single frequency tonal alarms, see Nélisse et al (2011).

This paper presents the results of a series of trials of reversing alarms on DEC vehicles at the Mundaring and Wanneroo Depots in June and September 2011 and further testing carried out in 2012 both on DEC and local government vehicles. The paper presents comparisons between the existing tonal beepers and newer broadband alarms and assesses the occupational safety performance of both types against the ISO 9533:2010 Standard. Additional assessments of audibility at various distances are used for comparison of environmental intrusiveness.

Beepers as an Environmental Noise Source

Community noise complaints often involve the intrusive noise of alarms (DEC 2012), however the number of complaints alone is likely to underestimate community concern as it is likely that there is a general assumption that the alarms are required by legislation.

Audible safety warning devices currently have a conditional exemption from the WA environmental noise regulations (DEC 2003). Regulation 3 (c) states:

Nothing in these regulations applies to...

(c) *noise emissions from safety warning devices fitted to motor vehicles, mining and earth moving machinery, vessels and buildings if –*

(i) *it is a requirement under another written law that such a device be fitted, and*

(ii) *it is not practicable to fit a safety warning device that complies with the written law under which it is required to be fitted and emits noise that complies with these regulations...*

With regard to vehicle reversing alarms, only the Mines Safety and Inspection Regulations 1995 (Department of Mines and Petroleum 2011) (Regulation 13.3) specifically requires an audible safety warning system; in other words the exemption under regulation 3(c) only has clear application on mine sites.

Despite the tenuous link to the exemptions in regulation 3, beepers are commonly regarded as exempt from the environmental noise regulations on non-minesites, making it difficult for industry, the community and enforcement officers to determine their status and deal effectively with environmental noise complaints whilst ensuring safety considerations are not compromised.

Beepers as a Safety System

The occupational safety and health legislation in WA requires a safe working system, but (apart from mine sites) does not specifically require mobile plant to be fitted with audible warning systems. The legislation does prohibit interfering with safety equipment. A review by Burgess & McCarty (2009) concluded that the occupational health and safety regulations in the various States of Australia only require that an effective warning device be incorporated, but not that it needs to be an audible alarm.

The national Model Work Health and Safety Regulations (Safe Work Australia 2011b) require powered mobile plant to have a warning device to warn persons who may be at risk from movement of the plant, but do not require audible reversing alarms. The Australian Design Rules for vehicles (Commonwealth of Australia 2006) do not require an audible reversing alarm, but (if one is fitted) excludes certain types of sound and specifies that the signal should be no louder than is necessary as a warning.

Given that tonal reversing beepers are not required as part of the workplace safety system, the question arises as to their effectiveness as a safety system. Nélisse et al (2011) states:

Two important factors may affect the effectiveness of backup alarms on workers safety. Firstly, the uniformity of the sound field behind the vehicle is not guaranteed, in particular for tonal alarms. Secondly, spatial localization of the alarm can be a problem, particularly for workers wearing hearing protectors.

This is a compounding issue because people who rely on sound for their safety - blind and visually impaired - have stated that the current 'tonal' beepers cause them distress and hinder them from concentrating on the process of navigating without the aid of sight. The Association for the Blind WA stated in communications to the DEC (Carol Solosy, Director Corporate Services, 2 June 2011):

Based on the anecdotal evidence, our O&M [Orientation & Mobility] Instructors are of the opinion that the tonal reversing signals currently used on vehicles don't provide much useful audio information; whilst they can be heard; listeners with a vision-impairment can't detect the proximity of the vehicle nor the direction in which it's travelling. Furthermore, our O&M Instructors have observed that clients either ignore the signal, believing it provides no relevant information or worse, are distracted by it, which then interferes with their ability to attend to other environment clues around them, with the potential to compromise their safety. Such responses can be influenced by a person's personality and travel skills.

There is a range of alternatives to the traditional 'beeper' capable of providing a safe system of work, while also reducing environmental noise impacts. Apart from broadband alarms, these include variable-level audible alarms ('smart alarms'); focused tonal alarms; non-audible warning systems (e.g. flashing lights, reversing cameras); proximity alarms; spotters or observers; and exclusion zones (Burgess & McCarty 2009). The above methods could be combined, where appropriate.

Burgess & McCarty considered that there may be two International Standards that are relevant for audible movement alarms. The two standards specify considerable difference in the levels of the alarms. The International Standard *ISO 7731:2003 Ergonomics- Danger signals for public and work*

areas –Auditory danger signals is intended to call attention to hazards or dangerous situations in public and work areas and essentially specifies levels that exceed the ambient noise level by 10 to 15 dB. This is considerably higher than the levels specified in *ISO 9533:2010 – Earth-moving machinery – Machine-mounted audible travel alarms and forward horns – Test methods and performance criteria* which requires the alarm to be equal to or greater than the ambient level and equates to a rise in the ambient level of 3 dB when the alarm is on. Details of the ISO 9533 criteria are below.

The difference in the emergence levels above ambient that the two alarm standards require would lead to considerable differences in their impact as environmental noise pollution on receivers other than those for whom the alarm is intended.

Burgess & McCarty (2009) consider that ISO 7731 is applicable to serious hazards such as fires, when 100% reliability is required for all those in threat and that ISO 9533 appears to apply to warnings near mobile plant on workplaces. It is possible that while ISO 9533 is more relevant for reversing alarms on general vehicles, ISO 7731 may also apply to DEC fire trucks in emergency situations.

TEST METHODOLOGY

A series of tests were conducted on reversing alarms, starting with the DEC heavy fleet. The fleet consists of vehicles mainly used for fire control including trucks, front end loaders, bulldozers and graders; see Table 1 below for vehicle details. Each individual vehicle is numbered and T and B indicate whether a tonal or broadband alarm is fitted. Alarms are classified as Tonal or SA BBS which indicates a self-adjusting broadband alarm. The numeral is the highest alarm level at 1 m in dB(A).

Table 1. Vehicle/alarm List

No.	Vehicle	Alarm
01T	Lt/Med Fire Truck	Tonal
01B	Lt/Med Fire Truck	97SA BBS
02T	Lt Truck	Tonal
02B	Lt Truck	97SA BBS
03T	Prime Move & Trailer	Tonal
03B	Prime Move & Trailer	97SA BBS
04T	Front-end Loader	Tonal
04B	Front-end Loader	107SA BBS
05T	Bulldozer	Tonal
05B	Bulldozer	107SA BBS
06T	Grader	Tonal
06B	Grader	107SA BBS
07T	Lt/Med Fire Truck	Tonal
07B	Lt/Med Fire Truck	97SA BBS
08T	Lt/Med Fire Truck	Tonal
08B	Lt/Med Fire Truck	97SA BBS
09T	Medium Tipper	Tonal
09B	Medium Tipper	97SA BBS
10T	Front-end Loader	Tonal
10B	Front-end Loader	107SA BBS
11T	Medium Tipper	Tonal
12T	Light Fire truck	Tonal
13T	Light Fire Truck	Tonal
14T	Light Fire Truck	Tonal
15T	Front-end Loader	Tonal
16T	Light Truck	Tonal
17T	Lt/Med Fire Truck	Tonal
18T	Lt/Med Fire Truck	Tonal
19T	Medium Fire Truck	Tonal

20T	Medium Fire Truck	Tonal
21T	Multi-use Tractor	Tonal
22T	Path Sweeper	Tonal
23B	Rubbish Truck 1	87 BBS
24B	Rubbish Truck 2	87 BBS
25B	Rubbish Truck 3	87 BBS
26B	Rubbish Truck 4	87 BBS

In the initial set of tests on the DEC fleet the original tonal alarms fitted to ten different vehicles from the DEC heavy fleet were measured for existing sound levels, then new self adjusting (“smart” or “context sensitive”) broadband alarms were fitted in the same locations on the vehicles (where possible) and the measurements were repeated. The broadband alarms were Brigade Electronics bbs-tek SA series alarms and were chosen to approximate the level of the original alarms as estimated by the fleet safety officer, although the original alarms levels are unknown. The replacement models used were BBS 97SA which produces a range of levels from 77 dB to 97 dB; and BBS 107SA which produces a range of levels from 87 dB to 107 dB. These initial tests were specifically to gain experience in the placement of the alarms and to identify any obvious changes in level due to replacement with broadband alarms both in the vicinity of the vehicle and at a distance.

A recent publication (Safe Work Australia 2011a) has specified the use of ISO 9533:2010 as the appropriate standard for measuring how well an audible warning device is suited to a specific application when fitted to a vehicle. This standard was adopted as a measurement guide throughout this study.

ISO 9533 recommends that to work safely, workers must be able to hear warning signals above any other noise (ambient noise) at the workplace. For reversing alarms on mobile plant, Figure 1 below from ISO 9533 identifies the measuring locations to be used.

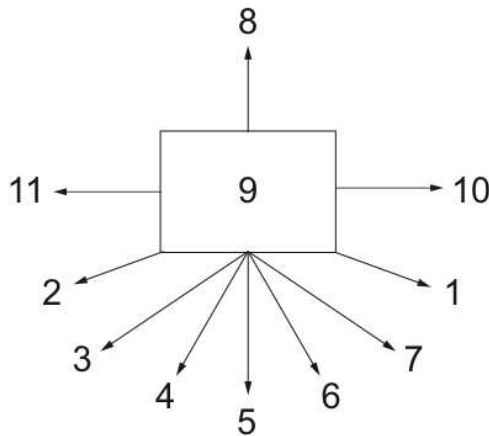


Figure 1. ISO 9533:2010 test measurement locations

Measurements were made in locations 1 to 7 as required in ISO 9533 for reversing alarms, measurements were also made at locations 10 or 11 and at two more positions at 25 m and 40 m directly behind the vehicle.

The exact position of the ISO 9533 measuring locations are as shown in the Table 2 below:

Table 2. ISO 9533:2010 test measurement locations.

Location ¹	Coordinate distances and direction m				As measured from
1	0.7	Right	0.7	Rear	Right rear corner
2	0.7	Left	0.7	Rear	Left rear corner
3	4.9	Left	4.9	Rear	Rear centre
4	2.7	Left	6.5	Rear	Rear centre
5	0.0	Centre	7.0	Rear	Rear centre
6	2.7	Right	6.5	Rear	Rear centre
7	4.9	Right	4.9	Rear	Rear centre
8	0.0	Centre	7.0	Front	Front centre
9	Location of operator				Ear height
10	0.0	Centre	7.0	Right	Right-side centre
11	0.0	Centre	7.0	Left	Left-side centre
NOTE Text in bold italic indicates travel warning alarm test points					
¹ As per Figure 1					

There are two methods and performance criteria specified in ISO 9533. They both essentially require the noise level of the alarm at potential reception points to be at least as high as the noise from the engine under high idle.

Criteria Method 2 was chosen from this standard as the broadband alarms being substituted in these tests were self-adjusting types:

7.5.1 General

For tests conducted in accordance with 7.2 to 7.4, the criteria given in 7.5.2 to 7.5.4 shall be met for each test measurement location and alarm type.

7.5.2 Reverse and travel warning alarm - Exterior test

7.5.2.1 General

The A-weighted sound pressure level determined at test measurement locations 1 to 7 [see Figure 1] for the alarm activation test shall meet the sound pressure level criterion given in 7.5.2.2 to 7.5.2.3 as appropriate.

7.5.2.2 Method 1 – Fixed sound level alarm

The recorded values from “Alarm On” shall be greater than or equal to the recorded values from “Alarm Off” at each test measurement location.

7.5.2.3 Method 2 – Self-adjusting sound level alarm

The recorded values from “Alarm On” shall be a minimum of 3 dB greater than the measured values from “Alarm Off” at each test measurement location.

The standard also requires that the sound being measured be ‘spatially averaged’ by rotating the measuring device through a circle of approximately 260 mm radius approximately 1.2 m above the ground. In the first set of tests on DEC fleet this was not done as the meters were mounted on fixed tripods. In subsequent testing the method required by the standard was approximated by the measuring operator using the top of a tripod as a reference point and rotating the meter in their hand through a radius of approximately 260 mm whilst keeping the meter generally pointed at the vehicle under test. The standard describes a jig that can be constructed to achieve the spatial averaging however the method used is quicker and seemed to produce the expected results.

Observations and measurement results from the first set of tests indicated that the second set of tests should strictly follow the ISO 9533 spatial averaging requirement. These tests were done on further DEC heavy vehicles and rubbish trucks and a path sweeper from the City of Subiaco. The rubbish trucks all were fitted with broadband alarms while the sweeper was fitted with a tonal alarm.

The third set of tests were done using two tonal alarms and four broadband alarms set up on an area consisting of a num-

ber of large grassed playing fields. The alarms were mounted on a t-piece 1.2m above the ground with measurements made at 1m, 25 m 50 m 100 m, 200 m, 300 m and 400 m directly in front of the alarms.

The measurements were performed using up to seven Brüel & Kjær types 2250, 2260 and 2270 sound level meters each recording one second logs, with full broadband and spectral statistics for each log. The standard requires L_{Amax} Fast measurement values and the statistical levels were also measured as Fast. Broadband 100 ms samples of Fast time-weighted levels were also obtained. The type 2250 and 2270 meters all had sound recording enabled.

The logged data measurements were extracted and tabulated to allow for a number of different analyses. Field notes and replaying of audio data (at the appropriate level) in the laboratory also enabled subjective assessments.

RESULTS

Examples of the spectral characteristics of the two different alarm types can be seen from the graphs in Figures 2 and 3.

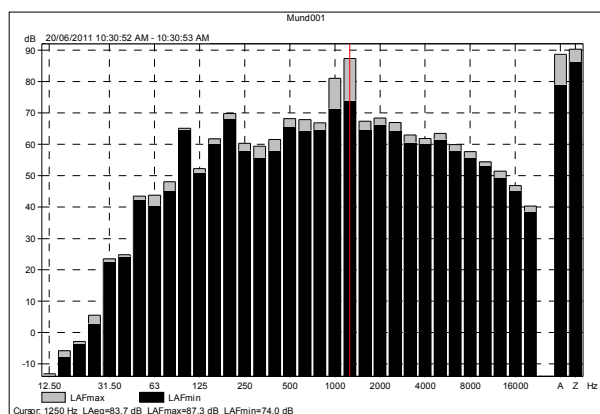


Figure 2. Loader with tonal alarm spectrum (7m directly behind vehicle)

As the measurements were made with the vehicle engines running under high idle the bulk of the spectrum is due to the vehicle noise, with the tonal beeper in this case showing an obvious peak in the 1 kHz and 1.25 kHz bands.

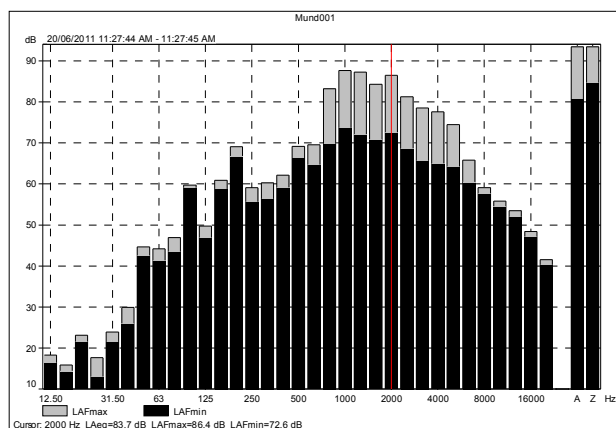


Figure 3. Loader with broadband alarm spectrum (7m directly behind vehicle)

Figure 3 contains the same vehicle idling noise as in Figure 2 but shows that the spectral output of the 'broadband' alarm is spread over a range of frequencies from approximately 800 Hz upwards.

The results of the initial tests on the first ten vehicles listed in Table 1 (numbers 01 to 10, T and B indicates tonal or broadband alarms), which had their tonal alarms replaced with broadband alarms, are presented in Figure 4. This shows the level of the alarms in relation to a pass or fail of the criteria in ISO 9533. To simplify the results of measurements taken over a number of locations, in Figure 4 the alarm level is the level measured at location 5 (directly to the rear) and the ISO criteria measurement is the worst case value measured of all the positions measured.

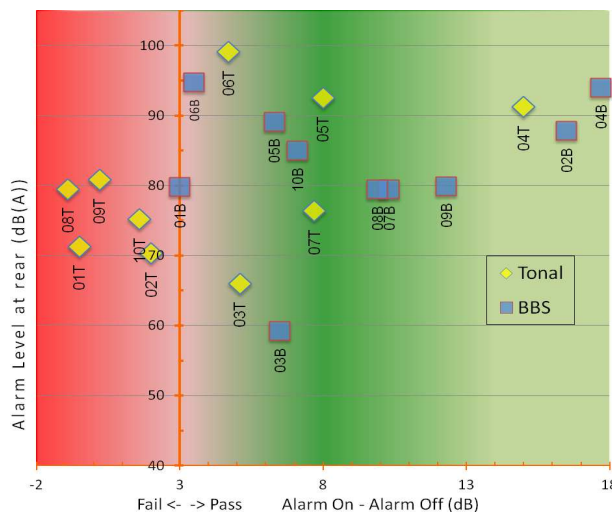


Figure 4. Worst case ISO 9533 result compared with alarm level directly to the rear (Location 5).

These initial measurements indicate that:

- Five of the ten tonal alarms tested failed to meet the requirements of ISO 9533 that the alarm be 3 dB(A) above the noise level of the vehicle, and
- Seven of the ten broadband alarms performed better in terms of drop-off behind the vehicles. Of these broadband alarms six alarms were actually louder than the original alarms but five of these six still had better drop-off over the distance from 7 m to 25 m.

Significantly, initial tests found that a number of alarms were poorly mounted on the vehicles and included - in addition to the ubiquitous off-centre rear mounting - mountings at locations inside almost completely sealed engine cowlings, at locations facing forwards under the vehicle in front of a cross member and on the side of the vehicle. Reversing alarms were also found located on the prime mover with the end of the attached trailer some 10 m further behind. Table 3 presents notes on poorly placed alarms from all test sets.

Table 3. Alarm placement information

No.	Alarm
02T	Tonal alarm was a taillight mounted unit
03T	Alarm fitted to prime mover only
04B	New alarm significantly louder than original.
09B	New alarm 10 dB(A) louder than original alarm
11T	Tonal Alarm facing forwards
12T	Tonal Alarm facing forwards
16T	Tonal Alarm in tail light fitting
19T	Tonal Alarm surrounded by machinery & baffles
21T	Tonal Alarm mounted in very heavy engine cowling with very few sound outlets

22T	Tonal Alarm mounted in engine cowling but directionally correct
23B	Alarm mounted near rear, facing sideways
24B	Alarm mounted in 'sealed box' by construction methods
25B	Alarm facing forwards from rear bumper
26B	Alarm mounted correctly but not centred

Initial comparison between measurements made to the rear and to the side of the vehicle for both tonal and broadband alarms showed little value under Method 2 of ISO 9533 as the measurements to the side can be significantly affected by noise from the engine, the varied placements of the alarms and the replacement of the original alarms with alarms of different overall level. Method 1 would produce a better result as the engine would be off, however would not test the ability of a smart alarm to adjust to the background levels.

The second set of tests was done only on the original alarms mounted on an additional set of DEC heavy fleet vehicles (numbers 11 to 21) and vehicles from the City of Subiaco (numbers 22 to 26). This set of measurements utilized spatial averaging performed according to ISO 9533 and showed the marked difference in the range of levels experienced with small changes in location. Figure 5 shows the modulation of the alarm pulses obtained while spatially averaging.

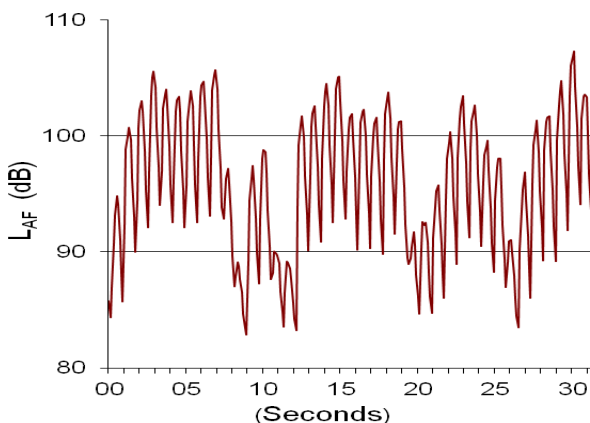


Figure 5. Variation in level shown while spatially averaging (tonal alarm at 7 m).

Figure 6 below shows the range of the modulation obtained while spatially averaging for a set of vehicles carrying tonal or broadband alarms. This chart is from measurements made at Location 5, 7 m directly behind the vehicle. It can be seen that the variation is significantly larger, up to 18 dB, for the tonal alarms than for broadband alarms and that the variation of the order of 10 dB found by Nélisse et al (2011) within the short range of approximately 1 m is an underestimation. It also can be concluded that the range easily extends out to at least 7 m behind the vehicle. It seems clear that that the pattern of sound behind a vehicle is very uneven for 'tonal' alarms and much more even for 'broadband' alarms.

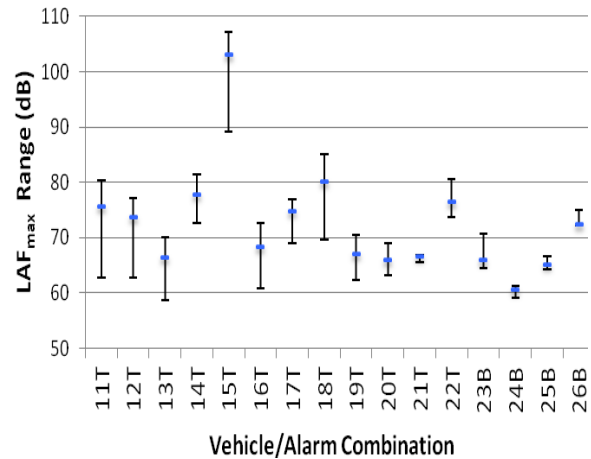


Figure 6. Modulation of spatially averaged signals of different alarms (7 m directly behind vehicle)

The variance found in the second set of measurements also indicates that the results of the first set of measurements, (without spatial averaging) may have resulted in an overestimation of the incidence of non-compliance with ISO 9533 as the static measurement location may have coincided with an alarm low point.

Following the second set of tests the proportion of alarms failing to meet the requirements of ISO 9533 (that the alarm be 3 dB(A) above the noise level of the vehicle) was found to be a possible eight out of twenty two tonal alarms, with a ninth and tenth being borderline. This represents a failure rate of 36% or more.

The third test, with the alarms set up on the playing fields, shows the effect of the two types of alarms as an environmental noise source. The measurements were made with a breeze of approximately 3 m/s, with occasional gusts up to 6 m/s, towards the measurement locations from the alarms. This is close to the wind speed chosen as part of the "default meteorological conditions" in the EPA Guidance Note No.8 (2007) for use in noise modelling for acoustic assessments in Western Australia. Extreme variation in level of the alarms with respect to the background under real environmental conditions proved difficult to quantify and field notes and listening tests of the recorded data in laboratory conditions provided a more useful result. Figure 7 shows the difference in rate of disappearance of the alarms with distance. Note that the assessments are done by active listeners and the level of perception by a casual listener is likely to be somewhat less.

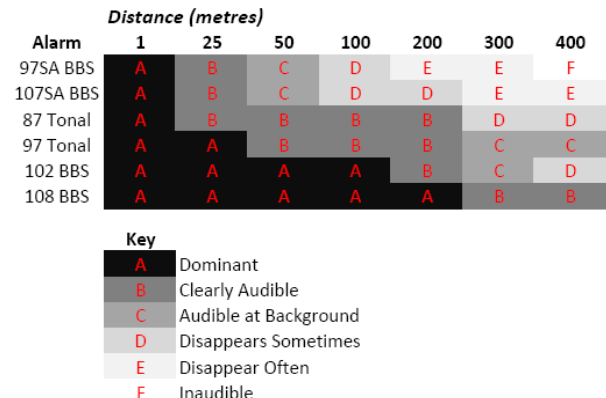


Figure 7. Rate of various alarms merging into the background with increased distance.

Broadband alarms were much more effective at reducing noise pollution when compared with tonal alarms. A broadband alarm operating at 97 dB was only just audible at 200 m and not at all audible at 400 m, while a tonal alarm at 97 dB was rated 'audible at background'. A tonal alarm at 87 dB rated 'disappears sometimes' at 400m – the same rating as a broadband alarm at 102 dB. However the louder broadband alarms were still audible at 400m, indicating that attention should be given to selecting alarms that are not unnecessarily loud.

DISCUSSION

The results of the tests can be divided into two broad categories: occupational safety performance; and environmental noise performance. These are discussed below:

Compliance with ISO 9533 (Movement Alarms)

To ensure that the replacement alarms meet acceptable standards, the existing tonal and replacement broadband alarms have been compared against the ISO 9533:2010 standard. The tests addressed two requirements of this standard: alarm level emergence above ambient and directional variability.

Some 30% of the tonal alarms failed the requirement that the alarm-on sound level pressure must be at least 3 dB higher than the alarm-off value for at least one location required by the standard. None of the 'broadband' alarms failed this test but it must be acknowledged that the 'broadband' alarms were the 'self-adjusting' type and hence would change their output to suit the background noise.

In many cases the placement of the alarms on the vehicles is likely to compromise the efficiency of the alarm as a warning device. Inspection of the locations of alarms on the vehicles indicates that their placement with regard to safety seemed to be secondary to the ease of placement and might have been forgotten with the later addition of purpose-specific equipment. This placement is critical regardless of the alarm type.

The high variability of the tonal alarm levels around the vehicles compared to broadband alarms hinders the ability of the hearer to locate the moving vehicle; this would presumably be compounded in situations where multiple vehicles are operating. As tonal alarms comprise a single frequency, the sound level is susceptible to additions and cancellations due to different signal pathways and the variations can occur over a dimension similar to a human head. For example, the wavelength at 1.25 kHz (the dominant frequency in the tonal alarm in Figure 2), is 27 cm. Presumably the spatial averaging procedure required in ISO 9533 is employed to deal with this variation, but would therefore imply a reliance on movement of the head (or the vehicle) to improve the signal source location in relation to a particular vehicle. Due to the wide range of frequencies in the sound source the variability of broadband alarms is much more limited and would seem to indicate an increased ease in their spatial perception.

It must be noted however that the tonal alarms, due to their prevalence and wide exposure, are already associated with danger by the general public and any alternative sound source will likely need an education program to achieve the same level of association with danger. This is easier to do for vehicles that are site-based than for areas accessed by the general public. The recent review by Burgess & McCarty (2009) concluded that broadband alarms have been successful on construction and mining sites both within Australia and internationally from the safety viewpoint.

It must be noted that it may be that, in a very noisy environment or an environment which contains similar broadband sources, the broadband alarm may prove to be ineffective under the criteria of ISO 9533 and the criteria in ISO 7731 may thus have more relevance for DEC fire trucks in emergency situations. This needs further investigation.

Although the tests were made with only a small number of vehicles a failure rate possibly up to 36% is a concern. The implication is that many 'tonal' alarms fitted to vehicles do not meet the ISO 9533 requirements. The fact that an alarm is fitted to a vehicle is therefore not necessarily an indication that a safe work system is being employed.

Environmental Noise

The exemption for audible warning devices in the Western Australian noise regulations applies only where there is another written law which specifically requires an audible device and there is no practical alternative that complies. It is a common misunderstanding that all transport vehicles in WA have to be fitted with a reversing alarm, but this is only true of vehicles covered by the Mines Safety and Inspection Regulations 1995. Therefore in most circumstances in the instance of a complaint regarding reversing alarms the WA noise regulation metrics are relevant.

The WA noise regulations, as is similar in other jurisdictions, have penalties for noise sources that are considered to have certain annoying characteristics, such as tonality and modulation. These characteristics tend to persist in the noise emission over long distances and have no value to distant receivers as an alert to imminent danger. Broadband alarms tend to exhibit only modulation, while tonal alarms exhibit both modulation and tonality.

The range of frequencies in broadband alarms extends upwards towards the higher frequencies; these frequencies have a greater attenuation with distance through absorption in air. This, and the absence of tonality, means that a broadband alarm is more likely than a tonal alarm to comply at distant 'noise sensitive premises'.

Figure 4 shows that some of the replacement broadband alarms seemed unnecessarily loud for normal commercial use, even on heavy equipment. Selection of the appropriate level of alarm for the vehicle and its working environment is therefore important in managing environmental noise emissions. Further, manufacture of alarms with a wider self-adjusting range would be highly beneficial from an environmental noise point of view.

Figure 7 shows the relative attenuation of various alarms at distances from 1 m to 400 m. This diagram shows how the broadband alarms are quickly masked by the background noise, as long as they are appropriately selected (suited to purpose). On the other hand the tonal alarms were still clearly audible at great distances.

CONCLUSIONS

The presence of a reversing alarm on a vehicle is not indication that a safe working system is being employed if compliance with the criteria in ISO 9533:2010 is an indication of the safety value of an audible alarm. Poor placement can diminish the effectiveness of any alarm and inspection of the alarm location can provide a first indication of whether the safety value has been compromised.

Relocation of an ill-placed alarm would be the appropriate time to consider its replacement with a broadband alarm as there are benefits both for safety and for the reduction of environmental noise.

The following should be considered during replacement:

- Use the lowest possible output 'broadband' alarm.
- Use a 'self-adjusting 'broadband' alarm.
- Ensure that the mounting position of the new alarm is 'ideal'.
- Consider installation of a second (possibly quieter) alarm at the back of the trailers attached to semi-trailers or indeed any long trailer as well as one on the prime mover.
- An alternative standard such as ISO 7731:2003 may apply to vehicles operating in high ambient noise or emergency situations.

ACKNOWLEDGEMENTS

The assistance of various staff members at DEC Depots in Wanneroo, Mundaring and Jarrahdale, and the assistance of the City of Perth, the City of Subiaco and the Grounds Department of the University of WA is acknowledged. A special acknowledgement is given to Jason Dixon & Kelvin Liu for assistance in collecting all the data at various DEC and other sites.

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DEC – see Department of Environment and Conservation
 EPA – see Environmental Protection Authority