

**Review of alternatives to ‘beeper’ alarms for
construction equipment**

AVU 01209

for

**Department of Environment and Climate Change
NSW Government**

by

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EXECUTIVE SUMMARY

This study into alternatives 'beeper' alarms used for warning of vehicle or plant movement has been prepared for the Department of Environment and Climate Change NSW (DECC). The need for the study was identified from the responses during the public review period to the section in the draft *NSW Construction Noise Guideline* on alternatives to reversing alarms. Noise from the standard 'beeper', or pulsed tonal alarm, can lead to considerable annoyance in the surrounding community. Alternatives need to provide the necessary warning to those in the vicinity of a moving item of plant but without producing the same level of annoyance in the surrounding area. This study aims to investigate the range of alternatives with a view to recommending an approach to assist with selection of movement alarms that are effective on site while not causing annoyance in the surrounding community.

The options for movement alarms include spotters, visual alarms, audible alarms and proximity sensors plus alarms. The most common form of alarm is an audible alarm. Pulsed tonal alarms (normally referred to as 'beeper' alarms) are widely accepted as hazard alerts. Advances in audible alarms include those which adjust the level to be above the background, those which focus the sound in the area where persons may be potentially at risk and those with a pulsed broadband signal.

While there is no independent verification of all of the features of broadband alarms as promoted by the suppliers, the alarms have been used on many construction sites following assessment that they provide an effective warning. The alarm signal is more focussed on the area where a person is potentially at risk and there is less risk of confusion from multiple alarm signals on the site.

Note that the study highlights that where a risk assessment is required as part of the project approval, the person responsible for undertaking this assessment may use a variety of means to support their decision making. Further work may be required to assist with guidance material for those undertaking such risk assessment. However some key features for effective implementation of the alternative alarms on a construction site include:

- Use of the same type of alarm sound for all vehicles on site - to ensure association of the sound with the warning and to avoid confusion caused by a mix of warning signals
- Selection of appropriate sound level – this is not necessarily obvious and trials of different models may be necessary
- Correct location of the alarm on the item of plant – so that the sound is heard clearly in the area where a person is potentially at risk
- Appropriate training for all site personnel and signage - to ensure association of the sound with a hazard.

'Beeper' alarms frequently cause annoyance for the community surrounding construction sites. Broadband alarms have been demonstrated to reduce noise complaints from the community due to the character and nature of the sound.

This review has shown that there is a range of alternatives to 'beeper' alarms that are feasible - ie are available and can be used with appropriate worker training. These alternatives are also reasonable – ie do not impose a significant cost per item of plant on industry and, subject to appropriate selection, do not reduce on-site worker safety. It is up to industry to consider these alternatives, along with any other relevant factors, when designing their system of work to minimise noise impact on the community surrounding the site – particularly when planning to work at night.

GLOSSARY OF TERMS FOR MOVEMENT ALARMS

A range of terms are used in the industry to describe movement alarms and the following summarises some of these terms:

Acoustic alarm alarm that has an **audible** signal which means it can be heard.

Broadband alarm pulsed acoustic signal that comprises a range of frequencies and sometimes referred to as '**quacker**' or '**woosher**' – see section 6 for further details.

Focussed alarm alarm with an audible signal which incorporates design features to achieve a greater sound level in the area of potential danger.

Movement alarm alarm to warn of any movement of an item of plant.

Proximity alarm combination of proximity sensor for which the output is used to activate an alarm – usually an acoustic alarm.

Proximity sensor system that only produces an output when an object is detected in a defined area.

Reversing alarm alarm activated when reverse gear on the plant is selected and are also called '**back up**' alarm.

Self adjusting alarm alarm for which the output level automatically adjusts to be higher than the noise level in the area until the output limit of the alarm is reached and is sometimes referred to as '**smart**' alarm.

Tonal alarm pulsed acoustic signal that comprises one or two main frequencies and normally referred to as '**beeper**' – see section 6 for further details.

Travel alarm alarm activated by vertical or horizontal movement of plant like lifts, hoists etc.

Review of alternatives to 'beeper' alarms for construction equipment

Review of Noise Implications of Alternatives

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1. INTRODUCTION

This report has been prepared by the Acoustics and Vibration Unit (AVU) of the University of New South Wales at the Australian Defence Force Academy (ADFA), following the request from the Department of Environment and Climate Change NSW (DECC) for a study into alternatives to reversing 'beeper' alarms. The aims of this study were to:

- Investigate the current world-wide technology alternatives to the 'beeper' style movement alarms on construction equipment;
- Review and summarise the literature available on the range of community reactions to noise from these alternative alarm technologies;
- Review the current NSW work safety legislative requirements for audible movement alarms;
- Compile a list of examples that indicate the extent of construction projects that have applied less annoying audible movement alarms in Australia, and
- Recommend a preferred approach to movement alarms for consideration by environmental and OH&S authorities in NSW.

In this report the terms 'reversing alarm' or 'back up alarm' can be considered to also applicable to 'movement alarm'. Noise impact on the surrounding community can arise from the use of some audible alarms on moving plant at construction sites as

well as on extractive projects. Consequently this report includes a brief discussion of alternative audible reversing alarms used on extractive projects.

2. BACKGROUND

The use of tonal or 'beeper' style alarms on vehicles and mobile plant is widespread across Australia and around the world as a means of providing warnings of moving plant on work sites. The alarms are designed to warn anyone in the vicinity of the moving plant to take appropriate safety action. Many vehicles and mobile plant, in particular the large ones used on construction sites, have poor visibility for the driver of the ground area immediately to the rear of the vehicle. Also the driver is concentrating on the job at hand and may be not fully aware of the other work on the site nor may the driver be able to stop the movement in time to avoid collision.

The most commonly used alarm is a 'reversing alarm' and much of the literature relating to movement warning alarms uses the term 'reversing alarm' or 'back up alarms'. On plant such as hoists, cranes etc, warning alarms are often referred to as 'travel alarms'.

The 'beeper' alarm comprises a pulsed sound comprising one or two alternating frequency tones, usually higher pitched, that are clearly louder than the background noise in the area. The noise from 'beeper' alarms is a common noise source on construction sites and can cause annoyance to the surrounding community. DECC and other regulators often receive complaints about noise from 'beeper' alarms, particularly from the use of such alarms on night works.

Some factors associated with the commonly used 'beeper' reversing alarms include:

- the pulsing nature of the signal draws attention to the sound.
- they can be clearly heard and recognised both within proximity of the mobile plant and also at some distance from the site.
- they operate whenever the mobile plant is reversing, regardless of whether there is a person in the vicinity.
- the tone is an unnecessary alert for those outside the site
- the frequencies used for the tone can be easily heard by those with normal hearing

Many of these factors are desirable for a warning signal to those in danger but for those outside the site the sound can be an annoying alert signal to which they do not need to respond.

Within the site there can also be annoyance for the site workers who hear the alarm signals but who may not be in the danger zone. The sheer number of beeping sounds on larger construction sites can lead to confusion as workers may not be able to properly identify which signal actually indicates a hazard to them at that moment.

The draft *NSW Construction Noise Guideline*, introduced for public comment in August 2008 [DECC, 2008], includes in Table 6.4 "Options for work practices – on site", a section on "Alternatives to reversing alarms" which states that:

Avoid use of reversing alarms by designing site layout to avoid reversing, such as by including drive-through for parking and deliveries.

Examine less annoying alternatives to the typical 'beeper' alarms; examples are smart alarms that adjust their volume depending on the ambient level of noise and multi-frequency alarms that emit noise over a wide range of frequencies.

In all circumstances, the requirements of the relevant Occupational Health and Safety legislation must be complied with. For information on replacing audible warning alarms on mobile plant with less annoying alternatives, see Appendix C.

In Appendix A of the Draft Guideline, Case study 4 on a major road construction includes use of

... 'smart' (less annoying) movement alarms on mobile cranes

Case study 5 in the final version of the Guideline is expected to include reference to 'arranging the work site to minimise the use of movement alarms on vehicles'.

Appendix C of the Draft Guideline on "Audible movement alarms on powered plant", discusses the requirements for audible alarms in more detail. It refers to the relevant clauses in the NSW Occupational Health and Safety Regulation 2001. While this regulation states that danger warning devices are required it does not specify the style of device. It is important to note that this regulation does not mandate either the use of tonal audible warning devices or even the use of audible alarms.

A number of the responses to the Draft *NSW Construction Noise Guideline* commented on the section on alternatives to reversing alarms. DECC summarised these comments as:

“Although there are some examples where less annoying alarms have been used while meeting OH&S legislation, there are still a number of organisations in NSW that do not support their use. There is a need to identify best practice for audible movement alarms that meets the relevant OH&S legislation and also minimises environmental noise impacts.”

This study aims to address that need.

3. STANDARDS FOR AUDIBLE WARNING ALARMS

Two International Standards may be relevant to audible movement alarms. One is “Ergonomics— Danger signals for public and work areas— Auditory danger signals” [ISO 7731, 2003] and the other is “Earth-moving machinery — Machine-mounted audible travel alarms — Test methods and performance criteria” [ISO 9533, 1989]. Australian Standard 4742 – 2003 was identical with ISO 9533, 1989 but is currently listed by Standards Australia as ‘withdrawn’ in December 2008. Each of these two ISO standards is discussed in the following sections.

3.1. ISO 7731 2003

International Standard *Ergonomics— Danger signals for public and work areas— Auditory danger signals* [ISO 7731, 2003] defines the acoustic characteristics and performance testing requirements for danger signal alarms. The introduction of this standard states that

Correctly designed signals can reliably call attention to a hazard or a dangerous situation, even when hearing protection is worn, without causing fright.

An acoustic alarm warning needs to be audible, distinctive, unambiguous and recognizable. The standard states that the signal must not be lower than 65 dB(A) and not greater than 118 dB(A) anywhere in the reception area and at least one of the following three specifications must be followed:

....the difference between the two A-weighted sound-pressure levels of the signal and the ambient noise shall be greater than 15 dB

or

.. the sound pressure level of the signal in one or more octave-bands shall exceed the effective masked threshold by at least 10 dB
or

.. the sound pressure level of the signal in one or more 1/3 octave-bands shall exceed the effective masked threshold by 13 dB

In regard to frequency characteristics, the standard states that

The danger signal should include frequency components in the 500 Hz to 2,500 Hz frequency range. However, generally two dominant components from 500 Hz to 1,500 Hz are recommended.

NOTE 1 The more the centre frequency of the octave-band, where the danger signal is highest in level, differs from the centre frequency of the octave-band where the ambient noise is highest in level, the easier it is to recognize the danger signal.

In the case of persons wearing hearing protection or having a hearing loss, sufficient signal energy should be present in the frequency range below 1,500 Hz

As well as the frequency of the signal, the standard recommends a pulsating signal is preferable to steady signals and that the repetition frequency shall be between 0.5 Hz and 4 Hz.

3.2. ISO 9533 1989

International Standard *Earth-moving machinery — Machine-mounted audible travel alarms — Test methods and performance criteria* [ISO 9533, 1989]. This standard applies to alarms

mounted on earth-moving machines intended to warn personnel of the hazards of a machine travelling under its own power...on work sites and for travelling on public roads

and it defines a travel warning alarm as

an audible signal intended to warn personnel, especially those near the machine, that the machine has been activated to travel under its own power

This standard is currently under revision with a draft version for comment released by ISO in September 2008. The draft revised ISO standard is essentially the same as the 1989 version but with additional sections to allow for the testing of self adjusting alarms.

The ISO 9533 test method involves measurements at 7 locations to the rear of the vehicle (see Figure 3.1 and Table 3.1). It is relevant to note here that the measurement locations 2 to 7 are 5 to 7 m from the centre rear of the vehicle yet the

noise level data from the alarm manufacturers are generally given for 1 m from the alarm.

The assessment to meet the requirements of ISO 9533 is that the difference between the maximum noise levels for measurement conditions (a) and (b) at each measurement point should be equal to or greater than zero.

- a) alarm off with engine at maximum governor speed and
- b) alarm on with engine at low idle or off

A self adjusting alarm relies on the noise level of the engine for effective operation, so a different procedure is required. The proposal in the draft is that the difference between the maximum noise levels for measurement conditions (c) and (d) at each measurement point should be equal to or greater than 3 dB

- c) alarm off with engine at maximum governor speed and
- d) alarm on with engine at maximum governor speed

Thus for minimum compliance the level of the alarm alone needs to be equal to the level of the engine i.e. a engine level of 92 dB plus an alarm level of 92 dB would lead to an overall level for the engine plus alarm 3dB higher i.e. of 95 dB.

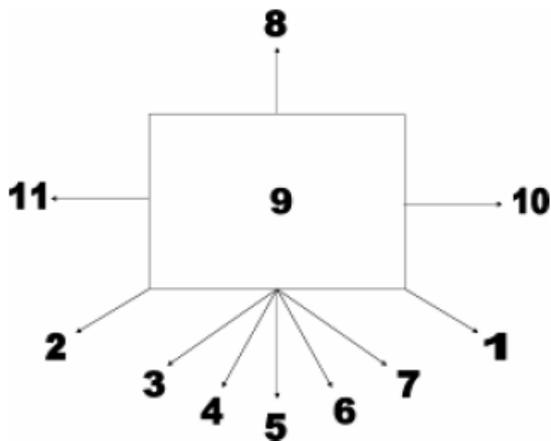


Figure 3.1: Measurement locations [ISO 9533 1989]

Table 3.1: Specifications for measurement locations in ISO 9533.

Test location	Coordinates and directions (m)			As measured from the MRB
1	0,7	Right	0,7	Rear Corner
2	0,7	Left	0,7	Rear Corner
3	4,9	Left	4,9	Rear Centre
4	2,7	Left	6,5	Rear Centre
5	0,0	Centre	7,0	Rear Centre
6	2,7	Right	6,5	Rear Centre
7	4,9	Right	4,9	Rear Centre

3.3. Summary

Two different international standards could apply to construction sites:

- If the alarm is considered as 'auditory warning signals' then ISO 7731 would likely apply, requiring the level of the signal to be 15 dB above the background noise level in the area, not to exceed 112 dB and recommending the alarm to have dominant tones.
- For movement alarms on earth moving equipment, then ISO 9533 would likely apply, requiring the alarm to be at least as loud as the engine under full power.

ISO7731 could be considered applicable to serious hazards, such as fires, when 100% reliability is required for all those in threat, including untrained personnel and those who may need some time to move from the area of potential risk. ISO9533 appears to apply to warnings for persons near mobile plant on worksites. Such personnel should have received a safety induction and so be alerted to the audible warnings used for the potential hazard.

4. MOTOR VEHICLE DESIGN RULES

Motor vehicles must comply with Australian Design Rules (ADRs). ADR 42/00 – General Safety Requirements specifies the requirements for warning alarms as:

42.18. WARNING DEVICES - AUDIBLE

42.18.1. General

No siren, repeater horn, bell, exhaust whistle or compression whistle or other device capable of producing a sound resembling that produced by any such

siren, repeater horn, bell or whistle must be attached to a motor vehicle other than an emergency community service vehicle.

42.18.1.1. For the purpose of this clause, a repeater horn is any device which generates an audible sound (to be emitted) alternating between different tones or frequencies on a regular time cycle.

42.18.2. Warning Device

Every motor vehicle must be fitted with a least one warning device capable of giving sufficient audible warning, of the presence of the vehicle. It must give an audible signal having constant amplitude and frequency characteristics. It may be powered by any energy source including compressed air.

42.18.3. Reversing Alarm

Notwithstanding clauses 42.18.1 and 42.18.2 a further device may be fitted which when and only when reverse gear is selected emits an intermittent audible signal on a regular time cycle. It must not emit a signal louder than is necessary to warn persons of the proximity of the reversing vehicle.

The ADRs do not mandate the use of an audible reversing alarm, instead they describe the nature of such an alarm should it be fitted. In particular it should be noted that compliance means the sound level of the alarm should be no louder than necessary to warn persons near to the reversing vehicle.

5. OCCUPATIONAL HEALTH AND SAFETY REGULATIONS, STANDARDS AND CODES

5.1. NSW Occupational Health and Safety Regulation

Various clauses of the NSW Occupational Health and Safety Regulation 2001 require that mobile plant incorporate measures that effectively warn persons in danger from its operation. This applies to those designing, selling, leasing and ultimately to the employer bringing the item into the work area.

Under Clause 136(A), "Use of plant—particular risk control measures" of the Regulation 2001 there are also requirements on employers in relation to the use of plant which include:

(c) if safety features or warning devices are incorporated into plant, the features or devices are used as intended...

and

(l) measures are provided to prevent, as far as practicable, unauthorised interference with or alteration or use of plant that may make the plant a risk to health or safety...

So if items of plant have a particular type of warning device incorporated within the plant, that is fitted as part of the plant provided by the manufacturer or supplier, on-site modifications should not be undertaken without consultation with the manufacturer or without a risk assessment to demonstrate that the change will not reduce safety to those likely to be affected. This assessment needs to review the information available and check that the modification is appropriate for use on the work site, bearing in mind relevant factors including work practices, site conditions employee acceptance etc.

It is relevant to note at this point that the supply of reversing alarms with items of plant is not consistent across the industry. Some items have an alarm fitted as standard and others available as an accessory. For example many of the items from the Caterpillar range include a fitted reversing alarm, whereas Case Construction Equipment specifications have no mention of a fitted reversing alarm for their plant. Komatsu has an extensive range of products for the construction industry and there is no consistency in the supply of reversing alarms, even within the same product type as indicated in Table 5.1. Case Construction Equipment specifications (www.casece.com) have no mention of a fitted reversing alarm for their plant. Komatsu has an extensive range of products for the construction industry and there is no consistency in the supply of reversing alarms, even within the same product type. The specifications for each of the types of plant have been viewed from the Komatsu website and Table 5.1 provides a summary of those supplied with and without reversing alarms.

Table 5.1: Summary of models of construction equipment from Komatsu that are supplied with and without reversing alarms. The standard fitted alarm is a tonal alarm [from www.komatsu.com/ce/ at March 2009].

Type of equipment	Number of models		
	Total	Reversing alarm fitted as standard	Reversing camera optional
Backhoe loaders	3	0	0
Crushers	4	1	0
Dozers-Crawler	11	7	0
Dozers-Wheeled	2	2	0
Dump trucks-Articulated	2	2	2
Dump Trucks-Rigid	11	9	5
Graders	3	3	0
Excavators	14	8 (Travel alarm)	2
Face Shovels	5	5 (Travel alarm)	0
Skidsteer loaders	5	2	0
Wheel loaders	17	12	0

5.2. OHS Regulations in Other States in Australia

The OHS regulations in the other States are essentially the same as for NSW and only require an effective warning device be incorporated but not that it needs to be an audible alarm.

5.3. OHS National Standards

The *National Standard for Construction Work* [NOHSC 1016, 2005] aims to "protect persons from the hazards associated with construction work" and discusses strategies for the control of hazards but does not make any specific mention of motion alarms. The hierarchy for the strategies are:

- (a) *eliminate the risk; or*
- (b) *if elimination of the risk is not reasonably practicable, minimise the risk through measures which must be considered in the following order:*
 - (i) *first, substitute the hazard giving rise to the risk with a hazard that gives rise to a lesser risk;*
 - (ii) *secondly, isolate the hazard from persons who might be put at risk;*
 - (iii) *thirdly, minimise the risk by engineering means;*

- (iv) fourthly, apply administrative measures such as the adoption of safe systems of work; and*
- (v) fifthly, use personal protective equipment*

Some form of motion alarm could either be considered as an engineering or as an administrative control strategy.

The similarity in the occupational health and safety regulations across the States is because the *National Standard for Plant* [NOHSC 1010] which was declared in 1994 by the National Occupational Health and Safety Commission provides the underlying basis for the regulations. This standard has no specific mention of motion alarms. The Australian Safety and Compensation Council (ASCC, formerly known as the National Occupational Health and Safety Commission, NOHSC) is currently reviewing this standard for Plant and a public comment document, February 2009, [ASCC, 2009] includes Section 5.8.1 on 'Signs, signals and warnings states' stating:

Without prejudice to the provisions of road traffic regulations, plant with a ride-on driver must have the following equipment:

- an acoustic warning device to alert persons*
- an acoustic warning device when the plant is reversing.....*

So the public review national standard is prescriptive in that it requires an acoustic reversing signal but does not give any guidance to the loudness or nature of the signal.

5.4. Codes of Practice in NSW

WorkCoverNSW has a number of Codes of Practice applying to construction sites of which two refer to reversing alarms.

Section 3.2 of *Code of Practice for Moving Plant on Construction Sites* [WorkCoverNSW, 2004] has the following relevant clauses:

- using audible reversing alarms and/or other technologies or other safe work practices.*

Note: reversing alarms may cause confusion where multiple plant is using the same area; other systems of work may be required. They may also be inappropriate where work is to be carried out at night near residential areas and

- implementing systems of control and notices at all entrances and exits where construction vehicles or plant enter or leave the work area by public roads, to protect and warn all persons approaching or in the vicinity*

- *identifying designated delivery and turning areas. The movement of delivery vehicles on construction sites often presents a hazard, particularly when reversing, loading and unloading. Procedures should be implemented to warn all workers of the potential hazard. These procedures should include:*
 - *the requirement for truck drivers to report to a suitably signposted area on the site and/or the requirement for a designated worker to act as an observer to ensure all persons are clear of the reversing vehicle, and*
 - *a system of communication and warning to persons near the delivery point.*

A Safety Alert, *Moving Plant On Construction Sites* [WorkCoverNSW, 2006] highlights concerns about injuries and fatalities caused by reversing plant. It lists a range of options to reduce the hazard that include; audible reversing alarms, reversing sensors, reversing cameras and flashing lights. This alert also states that:

The use of technology such as sensors or reversing cameras is a useful aid to the plant operator but has limitations (eg blind spots) and must always be used with an effective warning system for persons at risk from the movement of the plant.

The *Code of Practice Excavation* [WorkCoverNSW, 2000] refers to alarms in Section 3.15 on "Work near traffic or moving plant" and states:

(g) the use of audible reversing alarms and/or other technologies or other safe work practices. Note: reversing alarms may cause confusion where multiple plant is using the same area and other systems of work may be required.

Both of these Codes of Practice require some form of warning for reversing vehicles but not that it has to be an audible alarm. The Oxford dictionary defines 'audible' as "*that which can be heard*". So compliance with the codes places the responsibility with the person responsible for safety on the site to assess that the alarm can be heard.

5.5. Australian Standards for Specific Items of Plant

Australian Standards that govern the manufacture and operation of specific items of plant often make reference to motion alarms, for example those for scissor lifts and elevated work platforms. For elevated work platforms, AS 1418.10 [2004] states that

"Scissor-actuated elevating work platforms shall be fitted with audible or visible warning devices to warn of raising or lowering movements."

The standard also outlines the ongoing functional tests that must be performed and that include a check that all the safety devices work correctly. Note that in a Standards Australia document, the word 'shall' indicates a statement that is mandatory. So alarms need to be supplied by the manufacturers as part of their

engineering controls to minimise the risks from moving plant and once on the item there is an obligation for their use without alteration or interference.

Another standard that prescribes the use of movement alarms is AS 2150[2005] *Hot Mix Asphalt-a guide to good practice* that states that

“All trucks should be equipped with reversing alarms”.

Note the word 'should' in this statement indicates a recommendation, not a mandatory requirement. This standard does not prescribe the type of alarm.

5.6. Industry and Union Guidelines

Some industry associations also produce safety guides. One association particularly concerned about safety for large reversing vehicles is the Australian Asphalt Pavement Association but their guides do not specifically require any special alarm for reversing plant.

The Union applicable for the majority of workers on construction sites is the Construction and General Division of the Construction, Forestry Mining and Energy Union (CFMEU). Discussions with representatives from the Union indicated that they had not been involved with any assessment of the suitability of alternatives to tonal reversing alarms. However they commented that there would be a benefit if such assessments showed that alternatives could reduce the confusion and annoyance from multiple alarms on a site while still providing the same level of safety for those on site.

Discussions with Civil Contractors Federation representatives indicated that they had not been involved with any assessment of the suitability of alternatives to tonal reversing alarms but would support alternatives that were shown to be safe.

5.7. Health and Safety Executive (HSE) UK

Recommendations on safety for reversing vehicles [HSE 2009] first highlights that “*Nearly a quarter of all deaths involving vehicles at work occur during reversing*” and then summarises a range of options for greater safety around reversing vehicles, one of which provides some guidance on the assessment of audibility for an alarm:

Reversing alarms can be fitted:

These should be kept in working order.

Audible alarms should be loud and distinct enough that they do not become part of the background noise.

where an audible alarm might not stand out from the background noise, flashing warning lights can be used.

5.8. Summary

The OHS regulations do not require an audible reversing alarm but if one is fitted then it should not be modified without consultation with the manufacturer or without a risk assessment to demonstrate that the change will not reduce safety to those likely to be affected.

Codes of Practice require a warning device and if it is an acoustic alarm then the only guidance is that it should be audible. Industry guides for safe work require compliance with the Regulations and Codes of Practice and do not include anything specific about reversing alarms. Similarly guidance from industry and union groups does not specifically refer to any one type of alarm. Their primary goal is to provide a safe working environment.

6. OPTIONS FOR REVERSING WARNING ALARMS

As the items of plant used on construction sites increase in sophistication so do the options for warning movement alarms. This section summarises some of the features of the main options for such alarms. Any validation of information or promotional material available from manufacturers or suppliers is outside the scope of this study.

6.1. Spotters/observers

The use of spotters or observers to provide warning of a potential hazard is labour intensive and requires constant vigilance. However there are specific situations when spotters are required. One such situation is on railway projects where there is risk of a fast moving train requiring early evasive action by those in the area. Although the use of spotters may eliminate the need for additional warning such as from visual or audible alarms, diligence is required on the part of the spotter and this becomes difficult to implement on sites with a large number of moving plant.

Spotters are used extensively in "big box" retail stores in the U.S that have forklifts operating in an environment that includes retail shoppers. However this is not always reliable as one documented case describes a situation where a person was nearly struck by a speeding forklift in a store at the time the spotter was running behind the vehicle trying to get in a position to advise the driver on any possible hazards [Miller, 2007].

6.2. Visual warning

Visual warnings take the form of a flashing light or stroboscope on the top or side of the vehicle. On some large sites such visual warnings are required to be on top of all vehicles on site and operating all the time the vehicle is in motion. Generally a flashing light is rarely used as the sole means of warning of a reversing vehicle. They can be fitted in conjunction with an audible reversing alarm, as for example, most of the Komatsu earth-moving machinery comes with a standard back-up audible alarm as well as a back-up light [Komatsu].



Figure 6.1: Example of strobe warning light
[Australian Warning Systems, 2008a]

6.3. Proximity Sensor Alarms

A proximity sensor system is similar to sonar in that a beamed signal is transmitted when the vehicle is reversing. Any object in the range of the beam will reflect the signal and this reflected signal is detected and some form of warning signal activated. Proximity sensors on vehicles normally use an ultrasonic signal which is above the frequency range for human hearing. Proximity sensors are becoming common for larger domestic vehicles which may not have good rear vision at ground level. A study for NSW Motor Accident Authority on reducing the risks to young pedestrians from reversing vehicles [Paine and Henderson, 2001] examined the application of proximity sensors for some domestic vehicles. They found that:

Individually, none of the evaluated proximity sensors and visual aids provided complete coverage of the critical blind spots. An analysis was therefore conducted into the potential for combining proximity sensors and visual aid for a complete detection system.

and

With such a system in place it is important that drivers realise that they must still reverse very carefully.

Correct installation of the sensor system is essential to its effective operation. The installation needs to be adjusted so that the presence of objects only in the range of concern behind the vehicle is covered but that the beam is not too wide that it will indicate an excessive number of objects as these can lead to desensitisation of the driver to the real warnings. Figures 6.2 and 6.3 provide a recommended alignment from one supplier. From Figure 6.2 it can be seen that there is the risk that while the sensor may be adjusted properly for substantially level surfaces when a vehicle pitches as it travels over sloped terrain, which could be the case on construction sites, the beam may well not detect an object or person until it is too late for the evasive action. Also there is a greater risk for some types of construction equipment

that the sensors and/or the alignment of the sensors will be damaged during the course of site work.

It is also possible that the operation of the vehicle – such as unloading or spreading material – can interfere with the operation of the sensor. RTA Orange District Works has been trialling the proximity sensors with the primary goal to avoid rear collisions with their aggregate spreading trucks. The proximity sensor as supplied was found to not operate correctly and it is surmised this was due to spurious signals from the falling and dispersing aggregate. The supplier is in the process of modifying the sensor before undertaking further trials [private communication, John Harrison, RTA Orange District Works February 2009].

A proximity sensor can be used to activate a warning device, most commonly an audible warning. An audible warning in the cabin can alert the driver to check the rear using the mirrors or via a reverse camera if one is fitted. An example of such a combined system is shown in Figure 6.4.

A proximity sensor can also be connected to an external audible alarm. In this case the external audible alarm is only activated when the proximity sensor identifies that an object or person is within the detection range. One benefit of this system is that the audible alarm is only activated when there is a hazard in the area. This can assist to reduce the confusion from multiple signals on a site. It can also provide some respite to the duration of the audible movement alarms for those in the surrounding community.

It is important to note that the alignment of the sensors and their effective functioning is critical for a person or object in the area of potential hazard to be identified. This requirement may limit the widespread use of proximity movement sensors on construction sites.



Figure 6.2: Example of a proximity detector fitted to a normal vehicle [Reverse Camera, 2009] Note the sensors are fitted within the rear bumper bar of the car.

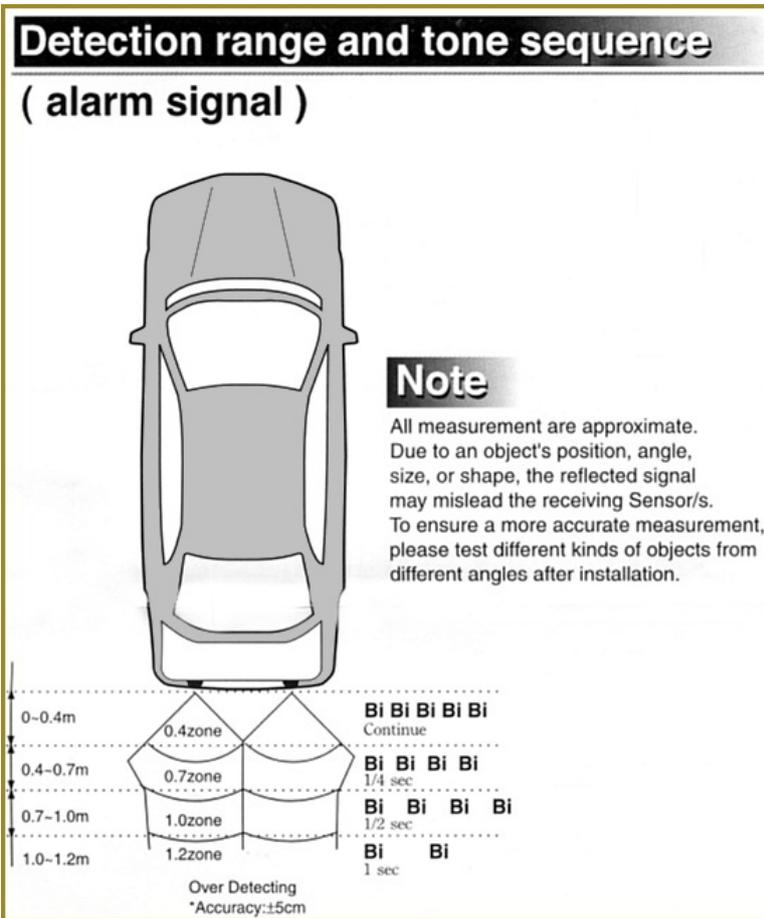


Figure 6.3: Example of the alignment of the detection range in the horizontal plane for a two sensor proximity detector. The audible pulsed sequence heard within the vehicle cabin increases in pulse repetition rate the closer the object to increase the urgency of the warning for the driver to take evasive action. [Australian Warning Systems, 2008b]

Installation Model No: DG-007

Figure 6.4: Example of a proximity detector combined with an in cabin camera display [Animedia Corporation, 2008]

6.4. Acoustic Alarms

Movement alarms in the form of an acoustic signal have been used for decades as a warning. The signal has conventionally been a pulsed tone with either one or two alternating frequencies – commonly called “beeper” alarms. While the “beeper” alarm has been universally used as a warning signal for many decades, with increasing technology there have been three important improvements; self adjusting or “smart” alarms, focussed alarms and pulsed broadband alarms (also called “quackers”).

The sound levels for acoustic alarms are normally quoted in terms of decibels (dB) and, while it is not always stated, the commonly accepted distance is 1 metre. The levels for occupational and environmental noise are normally quoted in terms of A-weighted decibels - dB(A). The A-weighting aims to approximate the response of the human ear. Humans with normal hearing can most easily hear frequencies around those which the majority of audible alarm signals occur, so the difference between the dB and dB(A) levels at these frequencies is small. To demonstrate the range of specifications for tonal alarm used on mobile plant and equipment, data for a selection of alarms has been extracted from manufacturer data sheets and are listed in Table 6.1.

Table 6.1: Data for a sample of audible movement alarms extracted from the specifications for each model accessed from the manufacturer specifications on the Internet in March 2009. This table highlights the more common frequency is around 1200 Hz but there are some that are below and some above this frequency.

Alarm model	Manufacturer	Type of alarm	Applications as stated by manufacturer	Frequency	Sound level at 1m, dB/dB(A)
SA800	bbs-tek	Single Tone	Heavy machinery, earth moving vehicles	1900 Hz	82-112 (Self-adjusting)
SA400	bbs-tek	Single Tone	Heavy commercial vehicles, light earth-moving machinery	1250 Hz	82-102 (Self-adjusting)
DF470	bbs-tek	Dual Tone	Cranes/lifts, heavy vehicles/equipment	1250 Hz	102
FEAVR80	Fleet Electrical	Single Tone	Trucks, buses, fork-lifts, plant	2500 Hz	102
FEAVR92D V	Fleet Electrical	Single Tone	Trucks, buses, fork-lifts, plant	900 Hz	80-98 (Self-adjusting)
FEAVR100	Fleet Electrical	Single Tone	Large earth-moving machinery	1200 Hz	122
220	Preco Safety Products	Single Tone	Not specified	1200 Hz	87
270	Preco Safety Products	Single Tone	Not specified	1200 Hz	107
380	Preco Safety Products	Single Tone	Not specified	1200 Hz	112
3002	Preco Safety Products	Single Tone	Not specified	1330 Hz	97, 107 (Manually switchable)
610	Ecco	Single Tone	Not specified	1040 to 1560 Hz	97
830	Ecco	Single Tone	Not specified	60-1440 Hz	107
SA914	Ecco	Single Tone	Not specified	960-1440 Hz	87-112 (Self-adjusting)

6.4.1. 'Self adjusting' or 'smart' alarms

'Self adjusting' or 'smart' alarms include a mechanism to detect the local noise level and automatically adjust the output of the alarm is so that it is 5 to 10 dB above the noise level in the vicinity of the moving plant. The range of sound level output for the "smart" alarm varies with the supplier and the model but they can be as low as 82 dB and as high as 112 dB. [e.g. Aust warning Systems 2008b, Ecco,-]. Note that the adjustment can only be within the output range of the particular model and once the

upper limit is reached there can be no further increase in output level, even if the background noise level increases. The promotional material for some smart alarms does state that the ability to adjust the level of the alarm is of advantage to those sites '*with low ambient noise level*'.

An extension of the basic smart alarm is to incorporate a proximity sensor so that the reverse alarm is normally only 5 dB above background noise but then increases greatly when there is an object in the area of potential risk. In the case of the Preco Safety Alert System the noise level is 5 dB above background noise then jumps to 112 dB irrespective of the surrounding sound level, when something is detected in the hazard zone [from Preco, 2007]. This sudden increase in noise level may well be effective as a warning for those on site but it may well increase the annoyance in the community.

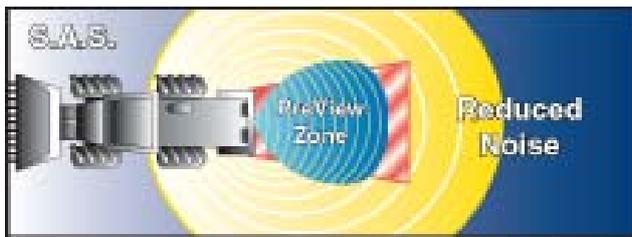


Figure 6.5: Example of the combination of a smart alarm plus proximity sensor [from Preco, 2007].

6.4.2. Focussed tonal alarms

These use the 'beeper' signal but incorporate multiple transducers in an attempt to cancel the sound around the side and so focus the sound to the rear of the vehicle. This feature is available for some Ecco model alarms and produces levels from 97 to 112 dB [Ecco,-]. Figures 6.6 and 6.7 from the data sheet from Ecco for a focussed tonal alarm show the distribution of the sound and comparison with a conventional tonal alarm.

The effectiveness of the focussing technique of the alarm itself can be seen from Figure 6.7. This comparative benefit would apply similarly for a focussed alarm that was fitted on an exposed vehicle surface. The comparative benefit may not be so great if the focussed alarm was fixed to a recessed part of the rear of the vehicle. Even for a conventional alarm the recessing could provide some shielding of the signal to the side. However the focussed alarm does provide an option to minimise unnecessary noise to the side and above a reversing vehicle.

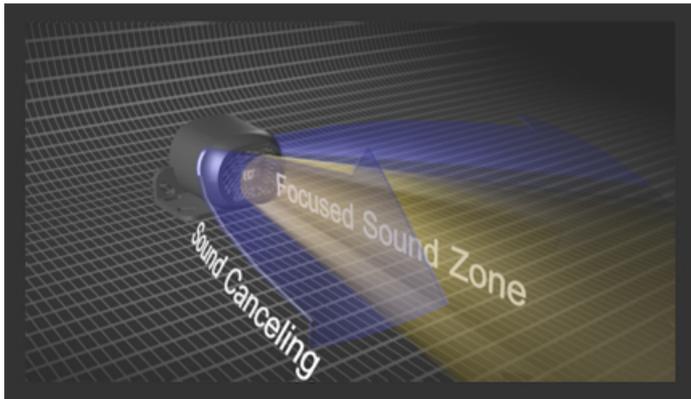
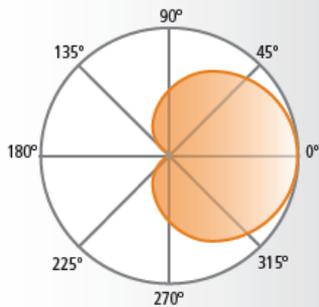


Figure 6.6: Example of focussing of the sound from an alarm using sound cancelling to restrict the distribution zone [Ecco, -]

Focused SoundVector™ Sound Pattern
 Sound is confined to specific area at rear of vehicle.



Centre Point = Alarm Position

Conventional Back-Up Alarm Sound Pattern
 Sound is omni-directional and travels outside the hazard zone.

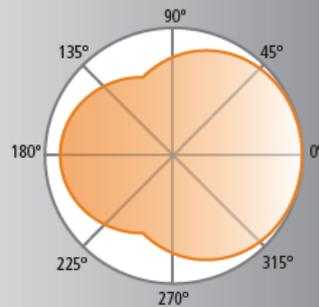


Figure 6.7: Comparison of the distribution of sound around a focussed alarm to that for a conventional alarm. Note that this data appears to be obtained under test conditions for the alarm alone and not fitted to a vehicle [Ecco,-]

6.4.3. Broadband alarms

Broadband signals are promoted by the suppliers as providing an effective warning while being more directional as well as less annoying to the surrounding community than the 'beeper' alarms. Currently Brigade Electronics PLC is the sole manufacturer of these alarms, holding the patent rights [Brigade, Yamaguchi, 2001]. They are marketed as the bbs-tek range of broadband alarms which has models from as low as 62 dB to as high as 107 dB [Brigade Electronics,-]. Comparative data on the current range of broadband alarms is summarised in Figure 6.8.



Heavy Duty



Ideal for dump trucks, bulldozers, loading shovels and all heavy earthmoving machinery.

- Conform to SAE J994 environmental standards
- Tough, durable, guaranteed waterproof (IP68)
- Solid-state, spark-free electronics, epoxy-sealed against mud, water and vibration
- Can be steam-cleaned and pressure-hosed
- CE and 'e' marked (EMC)

STOCK CODE	MODEL	VOLTS DC	SOUND LEVEL dB(A)@1m	FREQUENCY KHZ	CURRENT AMPS	SOUNDER UNIT	SIZE mm (WxHxD)	HOLE CENTRES (mm)
A0899	BBS-107	24	107	Multi	1.0	Driver	173x80x95	152
A0898	BBS-102	24	102	Multi	1.0	Driver	173x80x95	152



Medium Duty



Ideal for trucks, buses and coaches, light mobile plant, forklift trucks and industrial vehicles.

- Conform to SAE J994 environmental standards
- Tough, durable, guaranteed waterproof (IP68)
- Solid-state, spark-free electronics, epoxy-sealed against mud, water and vibration
- Can be steam-cleaned and pressure-hosed
- CE and 'e' marked (EMC)

STOCK CODE	MODEL	VOLTS DC	SOUND LEVEL dB(A)@1m	FREQUENCY KHZ	CURRENT AMPS	SOUNDER UNIT	SIZE mm (WxHxD)	HOLE CENTRES (mm)
A0935	BBS-97	12-24	97	Multi	0.5	Speaker	127x65x76	98-108
A0934	BBS-92	12-24	92	Multi	0.5	Speaker	127x65x76	98-108



Light Duty



Ideal for forklift trucks, light commercial vehicles, MPVs and cars.

- Conform to SAE J994 environmental standards
- Tough, durable, guaranteed waterproof (IP68)
- Solid-state, spark-free electronics, epoxy-sealed against mud, water and vibration
- Can be steam-cleaned and pressure-hosed
- CE and 'e' marked (EMC)

STOCK CODE	MODEL	VOLTS DC	SOUND LEVEL dB(A)@1m	FREQUENCY KHZ	CURRENT AMPS	SOUNDER UNIT	SIZE mm (WxHxD)	HOLE CENTRES (mm)
A0897	BBS-87	12-24	87	Multi	0.5	Speaker	90x49x39	76
A0896	BBS-82	12-24	82	Multi	0.5	Speaker	90x49x39	76
A1397	BBS-77	12-24	77	Multi	0.5	Speaker	90x49x39	76

Figure 6.8: Summary of the details and suggested applications for the BBS alarms Reproduced from 'Broadband sound back-up alarms and movement alarms', [Brigade bbs-tek,-]

A paper by Dr Geoff Leventhall, Brigade Electronics PLC, of October 2007, on "The Loudness of Broadband Alarms and Audibility over Machine Noise" [Leventhall 2007] reports on listening tests at two sand quarries which provides useful information on the characteristics of the broadband. Figure 6.9, from the Leventhall paper, shows the typical spectrum for a tonal alarm with the peak for the fundamental around 1500 Hz and for the harmonics at multiples of the fundamental frequency. Figure 6.10, also from the Leventhall paper, shows the typical spectrum for the broadband alarm which extends from around 1000 Hz dropping gradually in the higher frequencies with none of the peaks present in the spectrum for the 'beeper' alarm.

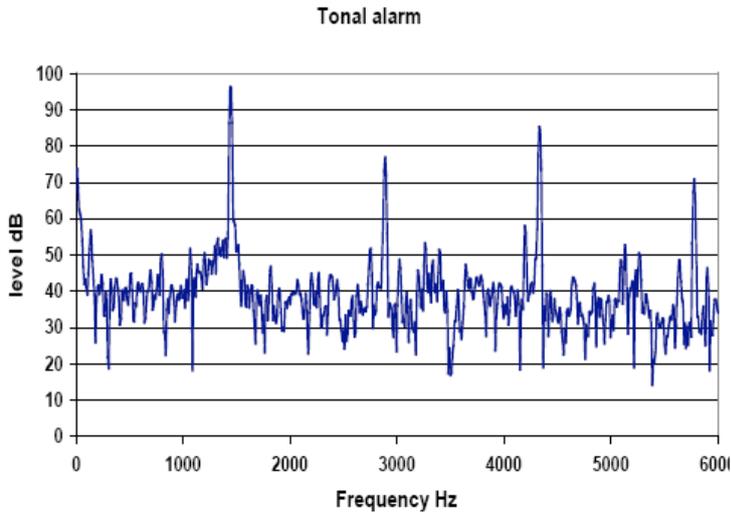


Figure 6.9: Typical frequency spectrum of a tonal alarm [Leventhall, 2007]. The paper does not state which specific alarm this spectrum applies to.

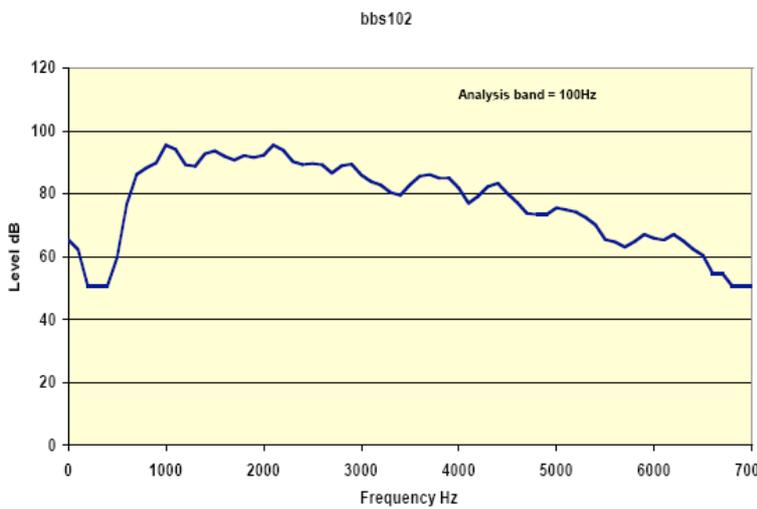


Figure 6.10: Frequency spectrum for a bbs-tek 102 broadband alarm [Leventhall, 2007].

To address concerns about the suitability of the broadband signal as a warning alarm, Brigade, have released a “white paper” in March 2009 [Brigade, 2009] entitled “Broadband Sound – the safer back up alarm” which aims to set out:

“...both the safety and the environmental benefits of broadband sound as applied to back-up alarms. The rationale for its adoption as standard fit on trucks, fork-trucks and mobile plant is self-evident...”

A figure in this document, shown below as Figure 6.11, summarises the assessment by Brigade of the comparison for the elements of safety, environment and health.

	Factors	Tonal	bbs®
Safety	Recognition:		
	Loudness / Audibility	<i>An alarm with appropriate loudness should be installed</i>	
	Is sound an effective danger warning	Depends	Yes
	Is the danger relevant	Depends	Yes
	Response	Unreliable	Good
	Hard of hearing - audibility	Risky	Good
	Cause confusion	Likely	Unlikely
Environmental	Strident	Yes	No
	Noise complaints	Yes	No
Health	Risk of hearing damage & stress	Greater	Lower

Figure 6.11 Assessment of alarm features from Brigade promotional literature [Brigade, 2009]. Note 'bbs' is the Brigade broadband alarm.

6.5. Summary

The options for motion hazard warnings for plant on construction sites include spotters, visual, proximity and acoustic alarms.

Use of spotters may be required for specific types of construction work, but generally not preferred for other work in part due to the need for additional personnel and the degree of vigilance required.

Visual alarms may be suited to some work areas but are not widely accepted as sufficient and are normally used in conjunction with other warning signals.

Proximity sensors coupled with in-cabin alarms and often coupled also with in-cabin rear cameras, are primarily used to alert the driver of potential damage to objects. Proximity sensors can also be coupled with an external audible alarm to warn personnel in the area of the potential risk from moving plant. The importance of proper alignment of the sensors may limit their widespread use on construction sites.

Audible alarms are widely accepted as hazard alerts and especially the tonal or 'beeper' alarm. Recent advances in technology have resulted in a range of audible alarms including those which adjust the level to be above the background, alarms that focus the sound in the area where a person may potentially be at risk and alarms with a pulsed broadband rather than a pulsed tonal signal. The broadband alarm is promoted by the suppliers as having both safety and environmental advantages and these claims are assessed in the following sections of this report.

7. 'ON-SITE' FACTORS FOR AUDIBLE BROADBAND ALARMS

The aim of an acoustic motion alarm is to provide an audible warning to anyone in the area to take the necessary safety action. As a classical alarm signal it should provide three pieces of information about the hazard [Catchpole et al 2004]; namely:

- 'what' is the hazard;
- 'where' is the hazard; and
- 'when' is it a hazard.

The pulsed tonal alarm, or "beeper", has been the universally recognised warning signal till advances in electronics have made alternative signals more readily available. Various types of alternative signals that contain more audible information than simply a warning tone, referred to as auditory icons, have been proposed for specific purposes, for example a warning sound like a crackling fire to warn of an engine fire in an aircraft. These signals are unlikely to be applicable for use as reversing alarms on construction sites for some time.

For plant on construction sites the currently available acoustic option to a "beeper" alarm is the pulsed broadband alarm manufactured by Brigade. This section of the report reviews the characteristics of broadband alarms and attempts to assess the evidence for the claims by the manufacturers that such alarms provide a superior warning for moving plant on construction sites.

7.1. Loudness

The loudness provides the 'what' and 'when' for an acoustic warning signal. Regulations, codes etc do not clearly prescribe a required loudness for movement alarms but simply require the subjective assessment that the alarm is 'audible'. ISO 9533 [1989] for alarms on earth moving equipment indicates that the alarm passes if the noise level of the alarm is at least equal to the sound level for the engine at maximum governable speed but not under load.

The advice from Brigade relating to the broadband alarm is that "*an alarm with appropriate loudness should be installed*". The noise level varies with each model and ranges from 62 to 107 dB in steps of 5 dB ie 62 dB, 67 dB, 72 dB, 77 dB, 82 dB, 87 dB, 92 dB, 97 dB, 102 dB and 107 dB.

The verbal advice from the Australian supplier [private communication] is that the 102 and 107 dB alarms are suitable for mining equipment while the 92 and 97 dB alarms are usually suitable for construction equipment. One brochure for the US market (see Figure 5.10 above for extract from this brochure [Brigade bbs-tek,-] indicates suitable uses as:

- 102 and 107 dB units as “Ideal for dump trucks, bulldozers, loading shovels and all heavy earthmoving machinery”
- 92 and 97 dB units as “Ideal for trucks, buses and coaches, light mobile plant, forklift trucks and industrial vehicles”
- 77, 82 and 87 dB units as “Ideal for forklift trucks, light commercial vehicles, MPVs and cars”

In contrast, the Brigade website [Brigade Electronics, -] lists the specifications for each alarm on separate web pages and extracting the recommended application for each alarm leads to the following summary:

- 102, 107 Ideal for dump trucks, bulldozers, loading shovels and all heavy earthmoving machinery.
- 92, 97 Ideal for trucks, buses and coaches, light mobile plant, forklift trucks and industrial vehicles
- 87 Ideal for forklift trucks, light commercial vehicles, MPVs and cars.
- 62, 67, 72, 77, 82 Ideal for trucks, buses and coaches, light mobile plant, forklift trucks and industrial vehicles.

And for some special units

- 92HV, 97 HV Ideal for forklift trucks
- 92 ADR Specifically designed for petroleum tankers and vehicles requiring ADR specification alarms
- 82 HV, 87 HV Suitable for Electric Forklift Trucks

So from this data the suitable alarms for the range of equipment used on construction sites could be those with sound level output of 102 or 107 dB. However this differs from two other sources giving guidance on suitable levels:

- a) A paper by Leventhall [2007] which provides data on listening tests for the broadband alarm on a number of items of construction plant. These studies involved 30 subjects presented with the sound of a vehicle and a broadband alarm for which the level was gradually increased from 59.4 dB to 82.8 dB. Five vehicles that would typically be found on a construction site were used. The subjects noted when the alarm was audible and then when they considered it was a good warning signal. The outcome of the listening tests were that the noise level of the alarm only needed to be between 6 and 1 dB below the noise level of the machine to be considered as a good warning signal. It is important to note that these were active listening tests and the subjects were not in a normal working environment or focussed on a work task. Nor did the tests include a comparison on the perception of tonal alarms. More details on these tests are given in Annex A.
- b) As part of a study on reversing alarms for SA Department of Transport Energy and infrastructure on "Broadband auditory Warning Alarms" [Bassett Consulting Engineers, 2009] measurements were made for the broadband alarm with level 107dB on 5 items of construction equipment. Images of these items have been extracted from web listings for the type of plant listed in the Bassett report and are presented in Figure 7.1. The procedure followed for these measurements was in accord with the (now superseded) Australian Standard [AS 4742 2003] which is identical with ISO 9533 [1989]. The 107 dB alarm clearly passed the requirement for a pass according to this standard with the alarm excess in the central rear test position ranging from 9 to 26 dB. The recommendations in the Bassett report were that the BBS 97 would be suitable for Caterpillar 428D, 335E and 924 G and that the BBS 87 would be suitable for the Hino ranger and the BBS 102 suitable for the Caterpillar 248B.



Figure 7.1: Images from web listings in Machinery Trader and MPI Truck sales so may vary slightly from those tested in the Bassett report.

The Brigade 'white paper' [Brigade Electronics, 2009] claims that the broadband alarm is effective at a '*Lower dB(A) rating*' and that

Scientific analysis has revealed that a broadband back-up alarm is equally effective at 5dBA lower SPL than a conventional tonal alarm

One of the references for this statement is to a UK Health and Safety Executive (HSE) report *Improving the safety of workers in the vicinity of mobile plant* [IMC,2001]. Within this report the only mention of the loudness of the broadband alarm is on page 12:

The University of Leeds has undertaken extensive research in this field and has commercialised a generic technology through Sound Alert Technology Limited. In HSE trials of a prototype reversing alarm based on this technology fitted to a CAT966D earth-moving vehicle (conducted in August 2000), it was observed that the detectable threshold level was ~5 dB(A) lower than for a conventional single tone reversing alarm. It is thus speculated that reversing alarms based on broadband noise localisation will have a part to play in reducing mobile plant accidents, by increasing vehicle localisation capability, together with offering reduced audible nuisance.

However there appears to be no other papers or reports in the public domain to support this. The second reference is to "*Martin Lever, HS&E Manager RMC (Cemex); verified results of 150 subjects at South East Quarries Liaison Safety Day 2003*" but it appears this report is not available in the public domain.

So it is somewhat challenging for the purchaser of the broadband alarm for use on construction plant to select the alarm with optimal loudness without first undertaking an on-site trial.

7.2. Character of sound

The character, or the information content, of the sound contributes to the 'what' and 'when' for an acoustic warning signal. Regulations, codes etc do not clearly prescribe a required character but simply require the subjective assessment that the alarm is 'audible'. Studies have been carried out on the design of alarms to create a sense of urgency. One such study found that alarms of high frequency, rapid pulse rate and a high level of loudness produced the highest ratings of perceived urgency in the tested subjects [Hass et al, 1996].

The frequency of occurrence of an alarm signal also has a large effect on the response of people. It has been shown that alarm signals audible where there is no

hazard (for example at distance from the mobile plant) not only pollute the sound environment and distract people from their tasks but also generate a false alarm effect. People tend to match their reaction to an alarm to the perceived rate of false alarms for the system [Edworthy & Hellier, 2005]. This means that if a person perceives an alarm to be 90% reliable, they will respond 90% of the time whereas if an alarm is perceived to be 10% reliable, then people will only respond 10% of the time. The same paper noted that the design of an alarm signal is critical because if a less than ideal alarm signal is used too often, people's hearing as the primary warning sense becomes overused.

Due to its use for many decades, the "beeper" signal has become the universally recognised warning signal. For a different type of auditory alarm signal to be effective, the alarm meaning needs to be learnt. This is because people are not very good at recognising and remembering different alarm sounds and an association needs to be established between the alarm sound and the event [Edworthy & Hards, 1999].

A broadband noise is not a classic alarm signal. A paper on localisable alarms [Catchpole et al, 2004] states that

"A broadband noise will generally provide the best location cues but alone will not make a suitable alarm sound".

The authors further suggest that

..... a broad band noise to guide the listener to the location of the sound source, and tones and/or sweeps to provide the usual what and when alarm information.

However it would appear that as long as the signal stands out from the background noise and appropriate training is provided, people can associate an unfamiliar alarm noise with the hazard.

7.3. Directionality

The main aim of a movement alarm is to warn only those who are in the immediate vicinity of the danger of the need to take evasive action, that is identify where is the hazard. There are two aspects of directionality for a warning signal. One is the localisation of the approaching vehicle by the person who hears the alarm. The other

is the directionality of the alarm signal itself so that it is heard by those who are close to or within the danger zone and not by others on or outside the site.

7.3.1. Localisation of the hazard

Identification of location is promoted by the suppliers as an advantage of a broadband alarm over a tonal alarm thus better satisfying the 'where' for a hazard warning signal.

It is widely accepted that the mechanism for perception of the direction of sound varies across the frequency range. In the low frequencies, generally considered to be up to around 1,500 Hz, the perception of direction is based on the time difference between the arrival of the sound at one ear and then the other ear (referred to as the inter-aural time difference, ITD). The 'zone of confusion', as shown in Figure 7.2 [Brigade Electronics, 2009], arises as there are a number of locations for the sound source that would give the same time difference in arrival at the ear. The further the distance from the sound source the larger the area of the "zone of confusion". In the middle frequency range the perception of direction is based on the difference in sound level at each ear (referred to as the inter-aural intensity difference, IID). The frequency cross-over between the time-difference technique and the sound level technique begins at 700 Hz and is complete at 2800 Hz [Howard & Angus,2006]. In the high frequencies the perception is based on detection of the modification of the sound wave as it passes around the head, around the ear and down the ear canal; ie the head transfer function. The outer ear, or pinna, plays an important role in perception of direction in these higher frequencies. Localisation of acoustic signals with frequency range spanning the three methods is considered to be accurate to within 5 degrees [Withington, D. 2000].

As well as these mechanisms in the hearing process, simple head movement is often used sub-consciously to resolve an ambiguous direction cue. [Howard & Angus,2006].

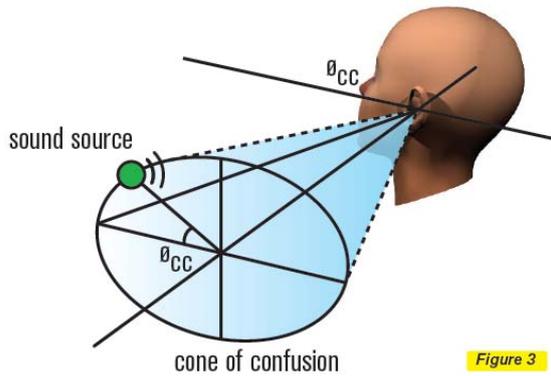


Figure 3

Figure 7.2: Graphic representation of the 'zone of confusion' for assessment of directionality of a sound in the low frequencies. All points of the circle would have the same difference in arrival time at the ear [Brigade Electronics, 2009]

The claim that detection of direction is better with the broadband alarm is based on the argument that because the signal covers a range of frequencies the different perception mechanisms are involved simultaneously. Hence the greater success in perception of direction is achieved for a sound that spans a range of frequencies than for a single tone.

However it is relevant to note the change point in frequency between one mechanism and another is not a precise value and may vary somewhat from person to person. While many tonal alarms do have their fundamental frequency below 1,500 Hz, (refer back to Table 5.1) there are harmonics at higher frequencies; as can be seen from the peaks in the example in Figure 5.8. While these harmonics may not be as loud as the fundamental, they are at higher frequencies and so multiple processes may well be available for the localisation for a tonal alarm.

Also from Figure 7.2 it can be seen that the area of the 'zone of confusion' becomes smaller the closer the source is to the ear. Thus as the moving plant with a tonal alarm comes closer the localisation would improve.

It is also relevant to note that much of the work supporting the benefit of a broadband alarm is based on studies on the perception by drivers of emergency signals. For example in a paper on evacuation signals, Withington [2001] states:

In laboratory tests using a driving simulator, involving 200 drivers, participants were unable to tell whether the sound of an approaching emergency vehicle was directly behind or in front of them 56% of the time. A potentially dangerous situation if they were at the wheel of a real car! The solution, a new siren incorporating broadband noise, is now in use by many of the UK emergency services.

There is one study on perception of broadband reversing alarms [Withington 2004], which involved 1477 vehicles of which 313 were fitted with broadband alarms. Figure 7.3 from this paper shows that 80% reported that they could “*always tell which vehicle is reversing*” for the broadband alarm, compared with only 10% for a tonal alarm.

National Institute for Occupational Health and Safety (NIOSH) has recently funded a study to investigate the difference in the localisation of broadband versus. tonal alarms under controlled conditions. The outcomes of this study are not yet available but it is understood [private communication NIOSH] that no clear outcomes were obtained. Similar Canadian studies on the effectiveness of broadband alarms are in planning.

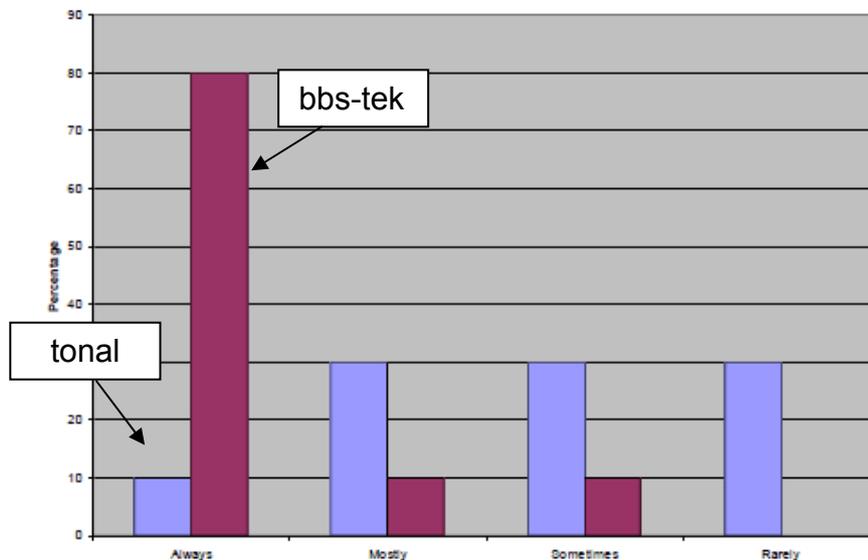


Figure 7.3:
Responses to the question on “which vehicle is reversing” [Withington 2004]

7.3.2. Directionality of the alarm

The aim for an alarm signal is that the sound is heard primarily by those who need to take evasive action and not by others in the area. The distribution of sound from any alarm depends on the design of the alarm and its enclosure, the placement of the alarm on a vehicle and the frequency spectrum of the alarm signal. For most loudspeakers (one of the main components of an acoustic alarm), the higher frequencies tend to beam forward while lower frequencies are more broadly distributed. The design of the loudspeaker enclosure, i.e. the alarm casing, can modify the actual distribution of the sound. The positioning of the alarm in a suitably

recessed location on the item of plant can also provide shielding and hence more directionality for an alarm.

Figure 7.4 is a graphic representation from Brigade promotional material [Brigade Electronics, 2009] comparing the distribution for a broadband and tonal alarm. The smaller circle for the broadband alarm is based on the assumption that it is 5 dB lower than the tonal alarm and that it has greater directivity.

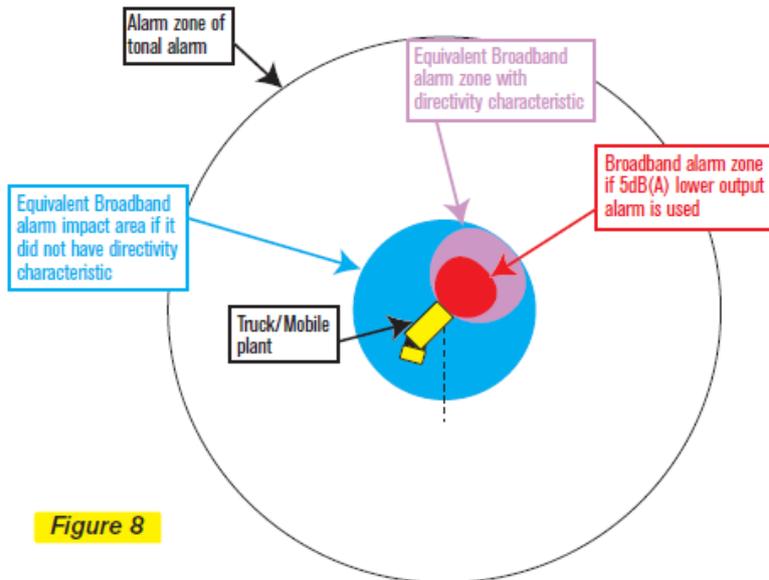
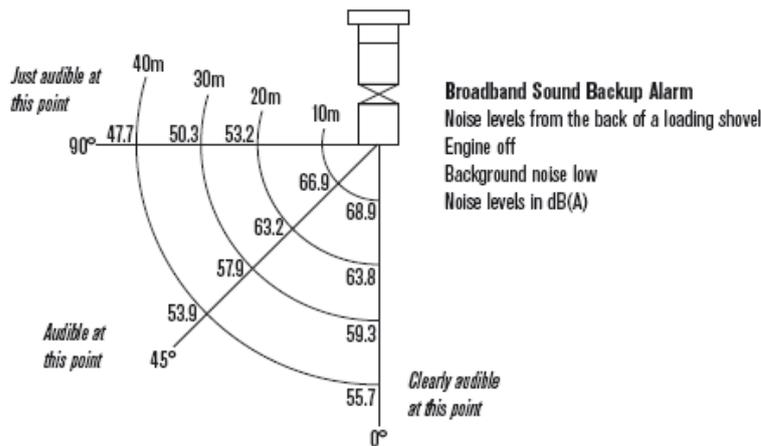


Figure 7.4:

Representation from the Brigade promotional material of distribution of the sound around an item of plant for a broadband alarm compared with a tonal alarm [Brigade Electronics, 2009]

Measurements made for Brigade on a construction site [Brigade Electronics, 2009]. show the spread of sound around a broadband alarm fitted '*to the back of a loading shovel*', as illustrated in Figure 7.5. This data shows a drop of up to 10 dB between positions directly in front and those at 90 degrees to the side. Note that a reduction in level of 10 dB is generally perceived to be a halving of the loudness of the sound. The data supports the claim that the sound from the Brigade broadband alarm is greater in the area of potential risk at the rear of the vehicle. It can be surmised that to the side the frequency spectrum would have less of the higher frequencies and, coupled with the design and placement of the alarm, the overall sound level of the remaining part of the broadband signal would be reduced.

**Figure 7.5:**

Distribution of sound around a broadband alarm fitted to the rear of a loading shovel [Brigade Electronics, 2009].

As part of the study on reversing alarms for SA Department of Transport Energy and infrastructure, measurements were made for 5 alarms on 5 items of construction equipment [Bassett Consulting Engineers, 2009 and hence referred to as the 'Bassett Report']. The measurement procedure was in accord with AS 4742 2003 (which is withdrawn but was identical with ISO 9533). Similar data was obtained for the distribution of the sound around the rear of each of the items. Further analysis of the data from the Bassett report for a broadband and two focused alarms for 2 of the 5 items of plant is presented graphically in Figure 7.6. These figures show that the sound distribution of the sound for a broadband alarm is similar to that for the focussed tonal alarms. The Bassett report does comment that the distribution of the sound can be affected by screening from protruding components of the item of plant, such as the folded arm of a backhoe.

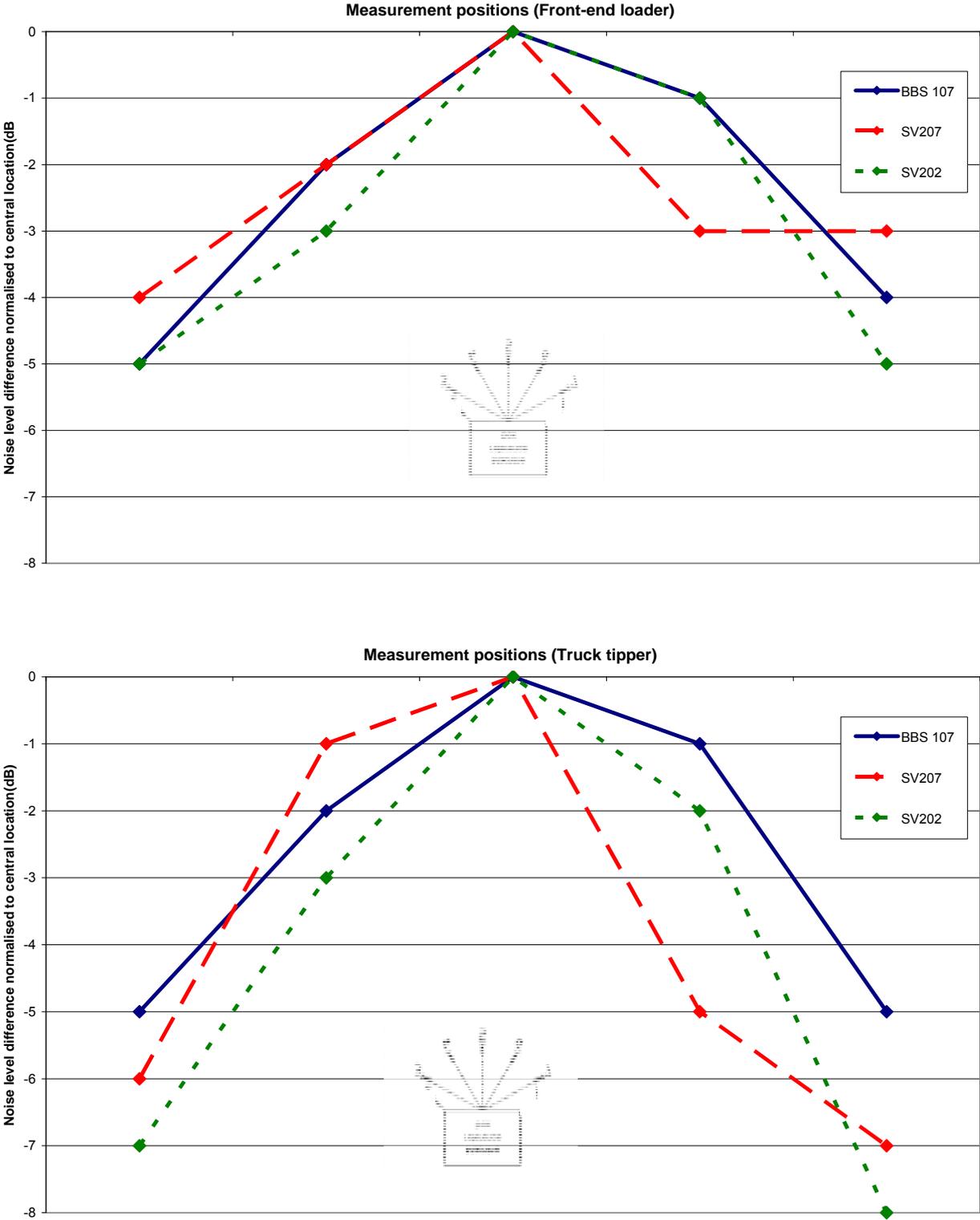


Figure 7.6: Comparison on the distribution of sound for a broadband alarm and two focussed alarms fitted to a front end loader and to a tipper truck [Bassett Consulting Engineers, 2009].

7.4. Conflicts with use of hearing protectors and hearing impairment

The use of hearing protectors, which are often required for workers on construction sites, limits the level of sound reaching the ear. Use of ear muffs further restricts the ability to localise a sound due to cover over the outer ear. Most hearing protectors are more effective at the higher frequencies. Hearing impairment from exposure to excessive noise levels in the workplace has a high incidence for those working in the construction industry. Such 'noise induced' hearing loss typically presents as a reduction in the ability to hear sounds in the higher frequencies. It commences with a dip in the hearing ability around 4,000 Hz and, with continued exposure, this dip deepens and widens across the frequency range. Noise induced hearing loss normally shows a notch in hearing ability around 4,000Hz and this notch deepens and widens with increased noise induced hearing loss. Few studies have investigated the effects of either of the use of hearing protectors or hearing impairment on the ability to perceive the types of warning signals that are used on construction sites.

One study that looked at the audibility of reverse alarms with the use of hearing protectors found that individuals with a substantial hearing loss are still capable of hearing a reversing alarm even when the signal to noise ratio is very low and while wearing hearing protectors [Robinson. & Casali, 1999]. However, at lower noise levels, (less than 85 dB(A)), people with significant hearing loss began to experience difficulty detecting the alarm signals. It is important to note that in this study, only one type of tonal alarm reversing alarm signal and one type of passive hearing protector were tested. It was found that the detectability of an alarm while wearing a hearing protector depended on both the signal to noise ratio and the hearing loss of the individual. It was also found that if the guidelines in ISO 7731 were followed and an alarm signal was 15 dB louder than the background noise levels, then individuals with both significant hearing loss and wearing hearing protectors would not have difficulty in detecting the alarm signal.

A report by Muchenje [2008] compared the ability of those with normal and 'non normal' hearing to perceive a warning signal in noise while wearing passive and 'active' protectors. These active protectors reproduce the ambient sound inside the

earmuff until the ambient level rises to a danger level and then the passive protection is utilised. The outcome of this study was that there was no advantage in the detection of the signal with the active hearing protectors for either group. In part this was because the ratio of the warning signal to the ambient noise remained essentially the same.

A study by Casali et al. [2004] also focussed on the effects of wearing passive and active hearing protection on the ability to detect warning signals in noise up to 85 dB(A). They found that well fitting hearing protectors, irrespective of their type, actually enhanced the ability to detect a tonal reversing signal (around 1250 Hz) when the ambient noise level was below 85 dB(A).

No studies have been found that investigate the perception of tonal versus broadband sounds by those with hearing impairment and/or those wearing hearing protectors. The majority of reversing tonal alarms have their frequency around 1,000Hz and the main energy in the broadband alarm is above 1,000 Hz, i.e. the range that would be most affected by both hearing loss and the wearing of hearing protectors. Based on available information it is difficult to make any judgement on the likelihood of greater perception of the warning signal for either a tonal or broad band signal for a movement alarm on construction sites.

7.5. Summary

While the promotional material states that the broadband sound can be 5 dB lower and provides for a better localisation than a tonal alarm, there is to date little supporting evidence from documented studies carried out by independent organisations. Independent studies however indicate that the broadband alarm has a similar horizontal sound distribution to a focussed tonal alarm. There are no comparative studies on the perception, by those wearing hearing protection and/or for those with a hearing impairment, of a broadband and a tonal signal for movement alarms on construction sites.

8. 'OFF-SITE' FACTORS FOR AUDIBLE BROADBAND ALARMS

8.1. Intrusion above background noise

As part of its very nature as a warning signal, the sound from a 'beeper' alarm stands out against the site noise. In the surrounding community the 'beeper' signal can often be perceived and leads to annoyance and complaints.

The broadband alarm signal covers a wider range of the frequency spectrum and the different frequency components will be attenuated over distance to a differing extent. As much construction noise is low frequency and so transmits well over distance, the noise from the site activities may not be reduced to the same extent. Consequently at a distance from the site the signal to noise ratio for the broadband alarm to the activity noise is likely to be lower than within the site.

In addition, the directional quality of the broadband alarm means that the noise to the side and front of the item of plant is considerably reduced. Consequently the broadband alarm signals would only be heard in the community when the plant was reversing in that direction. So, if the broadband alarm could be heard in the community, the length of time it could be heard would be less than for a non focussed "beeper" alarm.

The promotional material for the broadband alarm states that the level for the alarm can be 5 dB lower than for a tonal alarm while still being effective as an alarm. If this is the case, the intrusive level of the sound in the community will be even less.

It is reasonable to say therefore that the broadband alarm signal may well not produce the same intrusion both in terms of duration and level as a "beeper" motion alarm.

8.2. Attenuation over distance

The attenuation of sound over distance depends on many factors including characteristics of the source, surrounding surfaces, meteorological factors etc. If it is assumed that a tonal sound around 1200 Hz, which is typical for warning alarms, and a broadband sound both have the same level near to the source, then at a distance the higher frequencies within the broadband signal will be attenuated to a greater extent. Consequently, at a distance the overall sound level for the broadband alarm will be lower than for the tonal alarm.

8.3. Perception of the sound of alarm

There is evidence, as discussed in the next section of this report, that there are few (even no) complaints from the community about noise from motion alarms when the broadband alarms are used. This indicates that for those projects either the noise from the broadband alarm cannot be heard or if it is heard the characteristics of the sound are not as annoying as for a tonal alarm. In either case the goal of reducing the community reaction to the noise from the construction has been achieved.

8.4. Summary

For the same level at source it is likely that, at distance, the noise from a broadband reversing alarm will be less than for a tonal alarm. Furthermore if the broadband alarm is 5 dB lower at source, as promoted by the suppliers, the intrusion in the community will be further reduced. The directional nature of the broadband alarm also reduces the duration for any intrusion. The lack of complaints about noise from motion alarms when broadband alarms are used demonstrates the benefits of this type of motion alarm.

9. EXAMPLES OF USE OF BROADBAND ALARMS

9.1. Australia

9.1.1. Market for Broadband

The sale of broadband alarms in Australia over the few years is an indication of their popularity. The overall sales to date of all models from the BBS 82 through to BBS 107 from 2002 is over 10,600. The suppliers have advised that sales in 2008/09 are very strong and that the newly released self adjusting broadband alarm is proving popular. Advice from the supplier is that the BBS 92 and BBS 97 are typically used on construction sites while the BBS 102 and BBS 107 are typically used on extractive industry sites. The data on sales for the BBS 92 plus BBS 97 and on the sales for BBS 102 plus BBS 107 have been extracted from the data provided by the supplier [private communication, Feb 2009] and are shown in Figure 9.1.

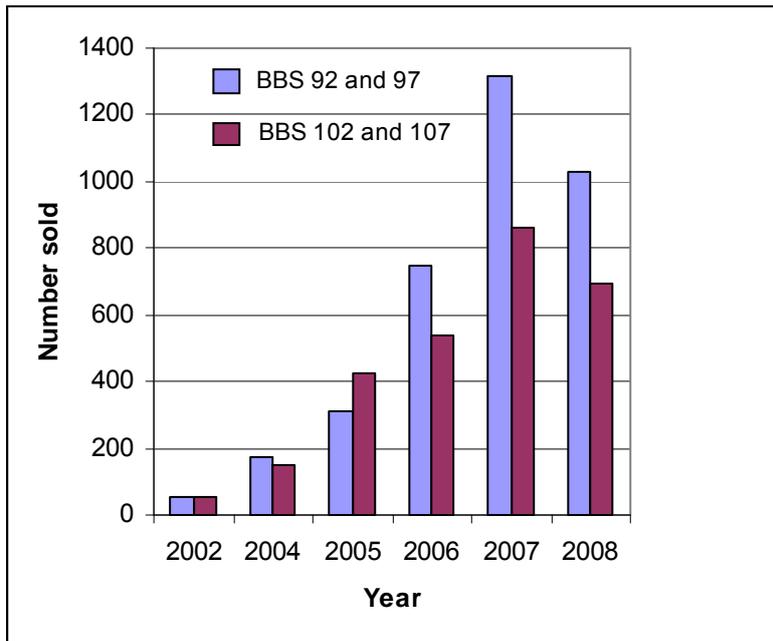


Figure 9.1: Sales for some of the broadband alarms in Australia [private communication]. Types BBS 92 and 97 are typically used on construction sites while BBS 102 and 107 are typically used on mining sites.

9.1.2. NSW – Transport Infrastructure Development Corporation (TIDC)

The TIDC *Construction Noise Strategy (Rail Projects)* [TIDC, 2007] lists in Table 1 under “Source Controls” that:

Non-tonal reversing beepers (or an equivalent mechanism) must be fitted and used on all construction vehicles and mobile plant regularly used on site and for any out of hours work.

The implementation of this control has led to an overall reduction in the number of community complaints about noise from alarms. It is understood that the risk assessment for the use of broadband alarms was undertaken by the contractor for a project at Macdonaldtown and this assessment has formed the basis for the use of the broadband alarms on all TIDC sites since that time. Advice from TIDC is that there have been no subsequent concerns about safety issues in the use of this type of alarm.

9.1.3. NSW – Road Traffic Authority (RTA)

The following excerpts and Table 3 are from the QA Specification G22 of *Occupational Health and Safety (Major Works)* [RTA, 1008], which require the use of self adjusting or ‘smart’ alarms:

“J1.2.4 Reverse Alarm

All trucks must be fitted with a reverse alarm that is automatically activated when reverse gear is selected. Alarms which vary the output in response to changes in the surrounding noise level, i.e. self-adjusting type alarms (e.g. "Smart Alarm"), are preferred. The alarm's noise level range shall be 87 to 112 dB(a) at 1 metre from the alarm. Self-adjusting type alarms must be mounted with an unobstructed 'vision' to the rear of the truck. All alarms must be clearly audible above the noise level of the truck. Fixed output reverse alarms originally fitted by the truck manufacturer are acceptable.
and

J2.1.7 Reverse or Travel Alarm

All plant must be fitted with a reverse alarm, which is clearly audible and automatically activated when reverse gear is selected.

Excavators and plant with output in response to changes in the surrounding noise level, (e.g. "Smart Alarm") are preferred. The alarm's base noise level must be not less than 87 dB(A) measured at a distance of 1 metre. Self-adjusting type alarms must be mounted with an unobstructed 'vision' to the rear of the Plant. Fixed output reverse alarms originally fitted by the equipment manufacture are acceptable.

For rollers with an operating mass less than 4,500 Kg, an alarm with a base noise level of 85 dB(A) is acceptable, provided the Plant:

- (a) has a noise level less than 80dB(A),*
- (b) does not have an enclosed cab."*

It is only recently that self adjusting broadband alarms have become available and a trial of the use of such alarms, has been sponsored by Sri Dharan, Manager of RTA Fleet Hire. Jim Smith [private communication March 2009] has trialled these alarms following noise complaints in relation to the work on the Oxley highway, Port Macquarie. From this trial of self adjusting broadband alarms were fitted to a grinder and roller and two models were compared: one with sound level in the range 77 to 97dB and the other in the range 92 to 107dB. The 77 to 97dB model was found to be audible and some key points from the assessment were that:

- The broadband alarm was direction
- The noise level from the alarm was less annoying at the site buildings
- No further complaints were received
- Site personnel needed to get used to the different type of alarm
- The same type of alarm should be used on all plant on the site,

The Hume Highway Duplication was a major project for which it was necessary to work out of normal hours. The alliance sponsored a desk top study of alternatives to tonal alarms [Renzo Tonin and Associates, 2008] which recommended, among other options, further trials of 'smart' broadband alarms along with rotating beacons. Following a trial, Ian Old who was responsible for site safety, assessed that the broadband alarms were suitable for use on batch plants and water carts but not suitable for use on the larger items of plant like dozers and scrapers [private communication, 2009]. His main concern was that these latter items have tight turning circles and there may be a number of such plant on site at any one time. He considered it essential that all those working in the area are aware of the vehicles in the vicinity. In the trials, the directionality of the broadband alarm meant that those to the side or front of a reversing vehicle did not have sufficient awareness of the movement. Unfortunately there is no record of the sound level of the broadband alarm that was used in this trial.

9.1.4. Victoria – Middleborough Road Rail Separation

A major infrastructure project, the Middleborough Road Rail Separation project in Victoria, won an award from the Civil Contractors Federation Earth Award for innovations, 2007. The citation for the award included [Infolink, 2007]

'Despite widespread industry and public scepticism that this ambitious project could be achieved, the Alliance completed it in record time. Among the innovations was the adoption of broadband reversing alarms.'

This project was near to residential areas and required 24 hours and 7 days operations to complete in the allocated time. A Vicroads "Worksite Safety Update" (No 59 April 2007) states that

"Various products were tested by Major Projects Division Eastern Projects Group including the traditional reversing beepers and the modern broadband reversing alarms. As the result of the trials and consultation with WorkSafe and other stakeholders Broadband Alarms were required to be fitted to all mobile plant based on site and this was also extended to delivery plant where practicable. Because the broadband sound is different to that which most workers had been previously exposed it was necessary to include a demonstration of the broadband alarm sound as part of the site induction process. The broad band reversing alarms were very effective and significantly improved safety associated with both the awareness and threat detection and avoidance of reversing plant. "

9.1.5. South Australia – Dept Transport, Energy and Infrastructure

In a report for SA Department for Transport, Energy and Infrastructure, on broadband audible warning alarms [Bassett Consulting Engineers, 2009] discussions with representatives from 8 companies/organisations involved with major constructions are summarised. The reduction in environmental noise and reduction in complaints about reversing beepers were common outcomes. In relation to broadband alarms the following comments have been extracted from Table 2 of the report.

Steve Fermio formerly from Transport Infrastructure Development Corporation (TIDC) NSW

Not aware of any safety incident attributable to broadband alarms over millions of work hours; Leighton contractors in the presence of TIDC trialed the broadband alarms on various types of machinery and worker age groups (i.e. young to old). No alarm signal detection difference was noted –happy to use; Theiss also conducted their own broadband alarm trial and are happy to us;. Demonstrating the sound of broadband alarms was incorporated into site inductions for new workers; Tonal alarms were noted to potentially lull workers into a false sense of security; Broadband alarms were noted to potentially reactivate workers thinking about safety; TIDC have been very satisfied with the transition to broadband alarms, particularly by significantly minimising the number of noise complaints.

Mike Boyle from Theiss in Qld

He was not aware of any safety issues associated with broadband alarms.

Randy Kiemm from Penrice Soda Products, SA

No safety issues associated with broadband alarms noted- Noted reduced fatigue for plant operators over a working shift.

Thalia Marshall from John Holland in Vic

Broadband alarms were preferred because it was easier for workers to identify machine locality, particularly within the danger zone. No safety issues associated with broadband alarms noted

Ray Rossi from Spray line, VicRoads

For these trucks, SprayLine has fitted broadband reversing alarms. The experience to date is that the broadband noise is easily discernable by the workers who have associated the noise with reversing crushed rock/asphalt trucks. A comment was also made that the standard tonal "beepers" are so common and non-directional that the workers become immune to the sounds of tonal reversing alarms.

Richard Strauch from Boral in Vic

Broadband alarms are recognised as being associated with reversing trucks and not other mobile plant. The broadband noise is directional and does not cause disturbance in the local communities. The range of the broadband noise appears to be longer (directionality) than the normal beepers.

These extracts from the Bassett report indicate that the use of the broadband warning alarm has been accepted for use on various sites. The Bassett report does not discuss the process of the site risk assessment.

9.2. International Examples of use of Broadband Alarms

The bbs-tek broadband alarms have good market penetration in both the UK and US. The 2007/8 edition of Noise News [from Brigade Electronics, -.] stated that over 8,000 bbs-tek alarms had been fitted in the US. It should be noted that a proportion of these would have been sold for use for non construction plant like forklifts in industry. That same edition of Noise News also stated that these alarms are “*strongly recommended*” by some of the larger suppliers like Cat dealer H O Penn.

There are a number of reports in trade literature of the use of bbs-tek broadband alarms. These articles are generally short, not peer reviewed and without any quantitative assessment (see Figure 9.1 below as a typical example). These items focus on the benefit in terms of reduced annoyance in the surrounding environment. While these articles are effectively ‘testimonials’ and a form of promotion of the use of the broadband alarm, it can be assumed that some form of assessment has been made by the person responsible for safety. Thus they do provide a measure of the acceptance of broadband reversing alarms over a range of industries. Following are just some examples.

- Port of Houston - The Applications section of the US publication Construction Equipment, Dec 2007, states:

“Port of Houston Authority is in the process of retrofitting equipment at work on the Bay Terminal construction project”

- Grace Pacific Corporation - In the section ‘S&V Observer’ from Sound and Vibration [February 2007] Henry Morgan from Brigade Electronics gives an overview of the features of the broadband alarm and states that Grace Pacific Corporation in Hawaii has

"installed bbs-tek alarms on most of its quarry machine operations. Since then the company has not had a single noise complaint related to back up alarms"

- Memphis Stone and Gravel - in the same article by Morgan, the Tennessee business:

"Has found that its voluntary installation of bbs-tek alarms has greatly reduced local concerns about noise pollution"

- Burlington Slate Ltd - In the news section of the UK trade journal Mining and Quarry World [Sept/Oct 2002] an item on the use by Burlington Slate Ltd of the broadband alarm states that:

"the majority of Burlington Slade's quarries are within the National Park in the Lake District...the company comes under intense environmental scrutiny from local residents particularly regarding noise nuisance.. subsequently trialled the 107 db(A) bbs-tek reversing alarm.. outcome of using the bbs-tek was successful with virtually no noise leaving the boundary of the quarry but sufficient warning being given to personnel within the working areas.. intend to fit further alarms to more of our vehicles"

- WBB Minerals - A similar successful implementation is in the news item of Mining and Quarry World [July/Aug 2002] on the use by WBB Minerals of bbs-tek 102 dB(A) alarms fitted to plant machinery at the South Devon quarry, see Figure 9.2. Following complaints about noise from the surrounding residents they:

"carried out noise trials from their gardens as well as well as in the quarry and processing areas.....bbs-tek.... won their vote as it simply eliminated the problem"

- Day Group – in the Safety and Health Practitioner (December 2002) states that Day Group, Brentford (UK):

"has added the bbs-tek 92 dB(A) reversing alarm to its entire fleet of 35 tipper trucks"

NOISE POLLUTION IS NO LONGER A PROBLEM AS WBB MINERALS USES BBS-TEK™

WBB Minerals, supplier of industrial minerals such as refined ball clays, silica sands and industrial resins, has recently purchased 50 bbs-tek™ reversing alarms from Brigade Electronics for use on vehicles at its Devon Quarry Operations.

WBB Minerals and its predecessors have been working the ball clays of southwest England for over 300 years. The company has also been working kaolins in the area since 1873 and the silica sand and industrial minerals division of the company has been in operation for approximately 100 years. The company now supplies more than 6,000 customers worldwide and operates in over 40 sites in nine countries throughout Europe. In the UK, its operations stretch from Devon to Norfolk and up to Cheshire and Scotland. Its key customers include small and large scale ceramic producers, glass manufacturers, the foundry industry and building and construction companies.

A number of WBB Minerals' quarries in Devon are located close to residential areas and the issue of noise from reversing beepers on plant machinery became apparent at one particular site following a number of complaints from local residents. This was a particular problem as the site worked 24 hour loading operations and 12 hour shifts on the tipping face.

South Devon Quarry Manager, Joff Pugh, started to trial alternative beepers available on the market including the new bbs-tek™ reversing alarm, in an attempt to solve the problem. "Noise problems caused by reversing beepers aren't easy to solve because of the obvious conflict with health and safety standards. The tipping operation is a busy area with large plant moving around so the alarms are essential. However, as the tip grew higher the noise from the beepers became more intrusive for our neighbours." He continued, "As a responsible company, we decided to work with the local residents from the village to see which of the alarms they thought would be most suitable. We carried out noise trials from their gardens as well as in the quarry and processing areas. The bbs-tek™ reversing alarm won their vote as it simply eliminated the problem. Importantly, we also carried out a risk assessment and were satisfied that the alarm met our safety criteria. In fact, our staff have really noticed the difference especially those who work with the alarms all day, who say it is far 'easier on the ear' than some of the other products previously used."

The bbs-tek™ reversing alarm, developed by Brigade uses a technology known as broadband sound or "white sound". The bbs-tek™ reversing alarm is both directional and localisable, concentrating the sound within the immediate danger zone. This increases people's response to the alarm, and diminishes the chance of its being ignored. More importantly, it also makes the bbs-tek™ reversing alarm safer than an equivalent pure tone alarm, because the latter can usually be heard well outside the danger zone, leading to the risk that people will disregard it - even when in real danger.

With its unique and distinctive "shh" sound, the bbs-tek™ reversing alarm dissipates sound more quickly (with increasing distance) than pure tone at a similar decibel rating, and is heard at lower source sound pressure levels than an equivalent pure tone.

The fifty 102dB(A) new bbs-tek™ reversing alarms are fitted to plant machinery such as dozers, loaders and dumpers at WBB Minerals' South Devon quarry. Due to the nature of the operations at the quarry, the alarms have a robust heavy casing to ensure that they do not get damaged whilst the vehicle is in operation.

Since the initial trial during Summer 2001, the ball clay operations of WBB Minerals are now in the process of completing a change to the bbs-tek™ reversing alarm on all their vehicles.



Noise Pollution is no longer problem as WBB uses bbs-tek™

Contact: Brigade Electronics plc
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Fax: +44 (0)20 8852 32 62
E-mail: sales@brigade-electronics.co.uk
Web: www.brigade-electronics.co.uk

Figure 9.2: Example of the typical style of trade industry case study of the use of broadband alarms [from Mining and Quarry World, July/August 2002, p158]

- SAE Award The broadband reversing alarms have won a number of awards including a Society of Automotive Engineers (SAE) Environmental Excellence in Transportation (E2T) Awards in 2004 [SAE, 2005]. The award was presented for:

"Broadband sound (bbs-tek) back-up alarms provide a massive reduction in the noise pollution caused by conventional narrow-band back-up alarms together with providing a safer working environment."

- New York In 2005 New York introduced a law to "To amend the administrative code of the city of New York, in relation to the noise control code" and with a specific section on Construction Noise Management stating that

"The commissioner shall adopt rules prescribing noise mitigation strategies, methods, procedures and technology that shall be used"

The New York Department of Environment Protection Notice of Adoption of Rules for Citywide Construction Noise Mitigation [City of New York, 2007] associated with this law sets out specific requirements for construction sites. Rule f states that

Quieter back-up alarms shall be used in pre-2008 model year vehicles when practicable for the job site. 2008 model year or newer vehicles shall be equipped with a quieter back-up warning device in accordance with OSHA standards.....

And in Section 4 on Back-up alarms it is stated that:

Quieter alarms or similar backup devices that meet OSHA requirements may be selected from the list below or from equivalent quieter alarms

a) Examples of manually-adjustable backup alarms include:

Preco Model 45AA

Ecco Model 820

b) Examples of automatically-adjustable backup alarms include:

Preco Model 1048

Ecco Model SA907

Grote Model 73100

c) Examples of community sensitive backup alarms include:

bbs-tek Brigade Model BBS-92

It is interesting to note that in this case the broadband alarm is only specified for use in “community sensitive” areas. It is not clear from the documentation what defines a “community sensitive” area.

Only the model name is given in the rules and the data on the models has been sourced from the supplier’s information available from the internet and listed in Table 9.1. The switchable or self adjusting alarms cover a wide range of noise levels but the broadband alarm is fixed to an upper limit of 92 dB output. It is interesting to note that this alarm is proposed for use irrespective of the noise level of the equipment it is being used on.

Table 9.1: Comparison of the specifications for those alarms listed in New York rules [City of New York, 2007]. Only the model name is given in the rules and the data on the models has been sourced from the supplier's information available from the internet .

Model	Tonal	Focussed	Noise level range
Preco Model 45AA	yes	no	87, 107 (switchable)
Ecco Model 820	yes	yes	87, 107 (switchable)
Preco Model 1048	yes	no	82-107, self adjusting
Ecco Model SA907	yes	yes	82-107, self adjusting
Grote Model 73100	yes	no	92-102, self adjusting
bbs-tek Brigade Model BBS-92	no	n/a	92

- UK HSE Case study - The Sims Group is the world's leading recycler of metals and waste electronic equipment and is proud that it has achieved a reduction of accidents on their sites by 50%. In a case study reported on the UK HSE website [HSE, 2008] the company has a very positive attitude to safety measures and the Paul Urbonas, Safety Manager for the Group states that:

Transport is one of our front line key risk areas and we aim to deliver continual improvements. For example, we have changed our dated pure tone reversing alarms on our mobile plant to broadband 'white noise' sirens.

- 2012 Olympics Code of Construction Practice, [Olympic Delivery Authority, 2007] has the following section specifically on reversing alarms and the use of a broadband alarm is one option:

5.5 Reversing alarms

5.5.1 As far as reasonably practicable, noise from reversing alarms will be controlled and limited, in accordance with the Section 61 consents. This will be managed through the following hierarchy of techniques:

The site layout will be designed to limit and where reasonably practicable, avoid the need for the reversing of vehicles. Measures will be undertaken to ensure that drivers are familiar with the worksite layout.

Banksman will be utilised to avoid the use of reversing alarms.

Reversing alarms incorporating one of more of the features listed below or any other comparable system will be used where reasonably practicable:

- highly directional sounders;*
- use of broad band signals;*
- self adjusting output sounders; and*

- flashing warning lights.

Reversing alarms will be set to the minimum output noise level required for health and safety compliance.

- The Noise Abatement Society – This is a UK registered charity which aims to eliminate excessive noise in all its forms by campaigning to raise awareness, by lobbying parliament and through education. One of its current initiatives is for 'Quietenning the streets with Broad Band sound' which is in response to calls to their help line from those annoyed by tonal reversing alarms. The Noise Abatement Society considered that broadband alarms could reduce the annoying sound and to encourage a faster adoption of these alarms on the vehicle fleet they implemented a scheme [Noise Abatement Society, 2007]

...whereby the Society would sponsor the free fitting and trial of new Broad Band reversing alarms to councils so that the benefits of this new technology might be witnessed first hand by the policy makers and swiftly embraced."

"Since this initiative was launched, many councils have responded from all over the United Kingdom and they will be given the opportunity to trial and assess the new broad band reversing alarms for their own municipal vehicles."

9.3. Summary

There is considerable evidence use of broadband alarms has been successful on construction and mining sites both within Australia and internationally. The broadband alarm has become very popular for use on mining sites but it should be noted that such work sites operate differently to construction sites. At a mining site the range of equipment and the workforce is relatively stable. In contrast, on most construction sites there can be a greater diversity of personnel and plant during the project. Hence understanding and acceptance of a different type of warning signal may be easier to achieve on a mining site than for a construction site.

Industry experience to date has shown that with the appropriate selection of the loudness of the alarm and with suitable training/induction on the nature of the alarm, the broadband alarm can be used safely on construction projects. In particular the case studies demonstrate that where there is a justified need to undertake construction work outside the standard (ie daytime) hours, alternatives to reversing 'beeper' alarms (such as broadband alarms) can lead to fewer (or no) community complaints about noise from alarms.

10. RECOMMENDATIONS

This review has identified that when there is a requirement for an audible movement alarm as a safety feature for construction equipment there is currently no requirement that specifically prescribes the use of a 'beeper' type alarm. If an item of plant has a 'beeper' alarm supplied as standard then this alarm can be replaced by an alternative audible signal as long as a risk assessment has been undertaken.

There is a range of alternatives to 'beeper' alarms that are feasible - ie are available and can be used with appropriate worker training. These alternatives are also reasonable – ie do not impose a significant cost per item of plant on industry and, subject to appropriate selection, do not reduce on-site worker safety.

The main alternatives for movement alarms on construction sites are;

- Spotters which may be appropriate on particular sites and for particular hazards
- Visual alarms which may be appropriate on particular sites but are rarely used as the sole warning of moving plant
- Audible alarms which are generally preferred as a warning of moving plant on construction sites

There are two main risks for moving plant: on construction sites which require different approaches to provision of warnings

- Risk of damage to objects that are in the pathway of the moving plant when the person in charge of the moving plant must take action
 - suitable warning comprises proximity alarm coupled with an in-cabin audible alarm and optional rear view camera
- Risk of injury to people who may be in the vicinity of the moving plant when those in the area of potential danger must take action as the person in charge of the plant may not be able to take action
 - Preferred warning is an external audible warning alarm

Once an external audible warning alarm is required there is the potential for noise impacts on the community. Work site layout and practices can minimise the need

for the movement that activates the alarm; most commonly this is reduction of reversing. This can assist to minimise the noise impact but is not usually sufficient alone to overcome the problem. Options for audible alarms to reduce the noise impact include:

- Broadband alarms which have been demonstrated cause less annoyance in the surrounding communities. Broadband alarms have lower sound levels away from the area of potential danger and hence the additional benefits of the focussed alarms.
- Self adjusting broadband alarms that vary in level depending on the surrounding noise further reduce any noise impact.
- Self adjusting 'beeper' alarms that vary in level depending on the surrounding noise thus reducing the loudness of noise impact.
- Proximity sensors coupled with audible alarms thus reducing the duration of the noise impact.
- Proximity sensors coupled with broadband alarms would further reduce the duration of any noise impact.
- 'Beeper' alarms that focus the sound mainly in the area of potential danger thus reducing the spread of sound around the site.

Implementation of alternatives to the conventionally accepted "beeper" type audible external alarm requires a risk assessment. Where a risk assessment identifies an alternative is suitable, some factors that may relate to applying the alternative are:

A. If one company is responsible for all work on site and there is little variation in workers and plant then:

1. Use of the same type of alarm sound on all plant used regularly on site to ensure association of the sound as the warning.
2. Conduct a trial to check appropriate placement on each item of plant and adequate sound level and for each item.
3. Provide training on the type of alarm during site induction.
4. Install appropriate site signage.

B. If there is one site manager but a number of subcontractors hence varying workforce and different items of plant on site then:

1. Consult with all plant operator/owner/renters on the options.
2. Require the same type of alarm sound on all plant used regularly on site to ensure association of the sound as the warning.
3. Require a demonstration of appropriate placement on each item of plant and of adequate sound level and for each item.
4. Ensure training provided on the type of alarm during site induction
5. Install appropriate site signage.

Note that the above are only some of the considerations necessary for a risk assessment and the person responsible may use a variety of means to support their decision making. Further work may be required to assist with guidance material for those undertaking such risk assessment.

11. CONCLUSION

A warning of a reversing vehicle is essential for those who need to take action to avoid an accident. The options for movement alarms include spotters, visual alarms, audible alarms and proximity sensors plus alarms. The most common form of alarm is an audible alarm.

Pulsed tonal alarms (normally referred to as 'beeper' alarms) are widely accepted as hazard alerts. Advances in audible alarms include those which adjust the level to be above the background, those which focus the sound in the area where persons may be potentially at risk and those with a pulsed broadband signal.

While there is no independent verification of all of the features of broadband alarms as promoted by the suppliers, the alarms have been used on many construction sites following assessment that they provide an effective warning. The alarm signal is more focussed on the area where a person is potentially at risk and there is less risk of confusion from multiple alarm signals on the site.

Note that the study highlights that where a risk assessment is required as part of the project approval, the person responsible for undertaking this assessment may use a variety of means to support their decision making. Further work may be required to assist with guidance material for those undertaking such risk assessment. However

some key features for effective implementation of the alternative alarms on a construction site include:

- Use of the same type of alarm sound for all vehicles on site - to ensure association of the sound with the warning and to avoid confusion caused by a mix of warning signals
- Selection of appropriate sound level – this is not necessarily obvious and trials of different models may be necessary
- Correct location of the alarm on the item of plant – so that the sound is heard clearly in the area where a person is potentially at risk
- Appropriate training for all site personnel and signage - to ensure association of the sound with a hazard.

'Beeper' alarms frequently cause annoyance for the community surrounding construction sites. Broadband alarms have been demonstrated to reduce noise complaints from the community due to the character and nature of the sound.

This review has shown that there is a range of alternatives to 'beeper' alarms that are feasible - ie are available and can be used with appropriate worker training. These alternatives are also reasonable – ie do not impose a significant cost per item of plant on industry and, subject to appropriate selection, do not reduce on-site worker safety. It is up to industry to consider these alternatives, along with any other relevant factors, when designing their system of work to minimise noise impact on the community surrounding the site – particularly when planning to work at night.

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ANNEX A

The following data has been extracted from Leventhall [2007] *The Loudness of Broadband Alarms and Audibility over Machine Noise* as it shows results from a trial installation of the broadband alarm on some items of plant.

The protocol was

2.2 Each machine's noise at a constant level about 90dB(A) was mixed sequentially, in a digital editing package, with nine different levels of broadband sound. The first (inaudible or just-audible) level was increased in eight steps of 3dB to a very clearly audible level about 24dB higher. The combined machine and alarm sounds were presented via a loudspeaker to ten subjects facing it over 5m of hard ground.

Figure 4 shows all the subjects indicated that the broadband sound at level 7, i.e. 77 dB was a good warning signal for the CAT 725. Table 4 shows the comparative data for a good warning signal for the different types of equipment. Note that there is considerable inconsistency in the data in this table.

Figure 11 shows the spectrum for the CAT 725 and for the broadband alarm at level 7. It should be noted that the CAT 725 spectrum has lower levels in the higher frequencies where there is the most energy from the broadband alarm. In contrast the spectrum for the CAT 962 has more energy in the higher frequencies and the listening test required the alarm to be at level 9, i.e. 82.8 dB to be considered to be a good warning signal.

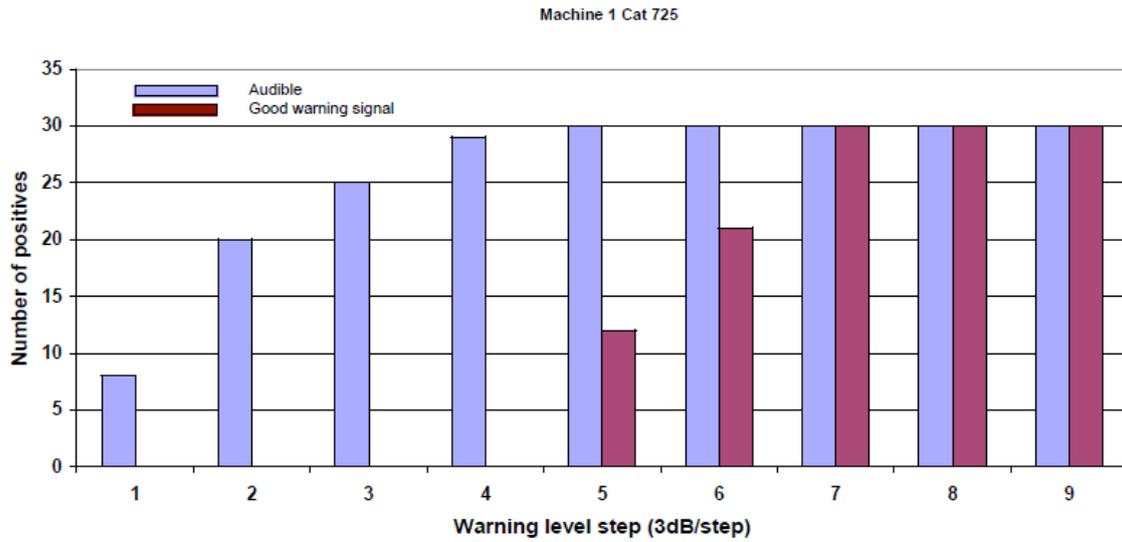


Fig 4 perception of broadband alarm in noise of CAT 725.
 The lowest alarm level was perceptible at Step1 The alarm scored 29/30 audibility at Step 4 and reached fully effective alarm level at Step 7. This was a 9dB difference

Machine	Machine level LAeq dB	Alarm level LAeq dB for effective action
Cat 725	78.0	77.0
JCB 380	82.9	80 - 83
Cat 962 G	86.7	83
Volvo L150E	85.5	77-80
Linde 2.5	86.3	80

Table 4 Comparison of Machine Levels and Alarm Levels

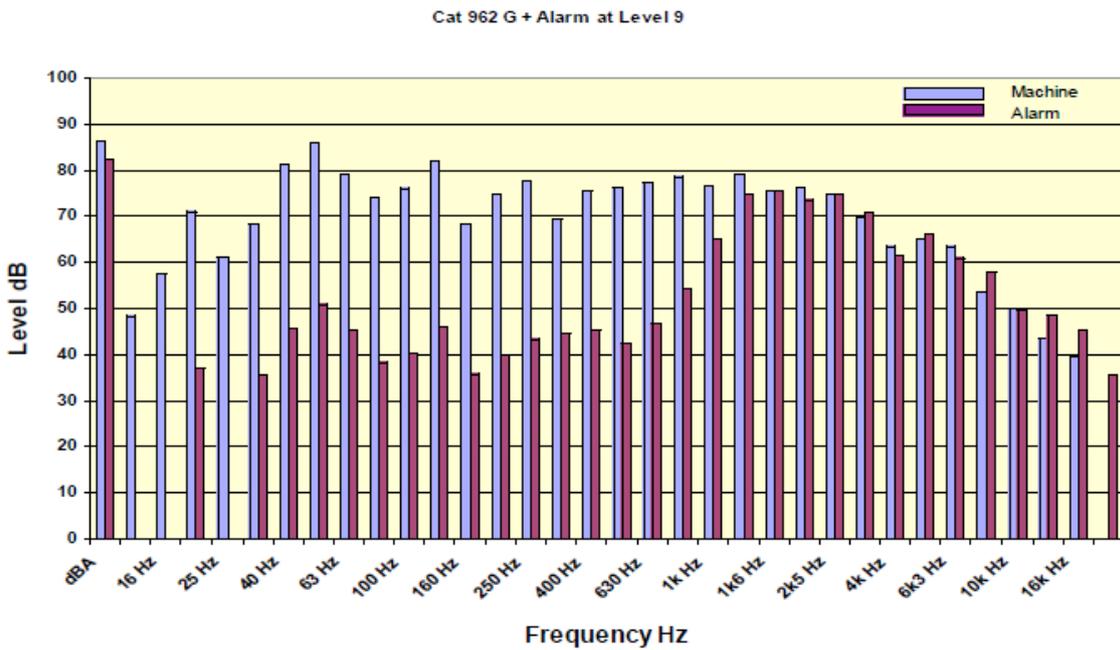
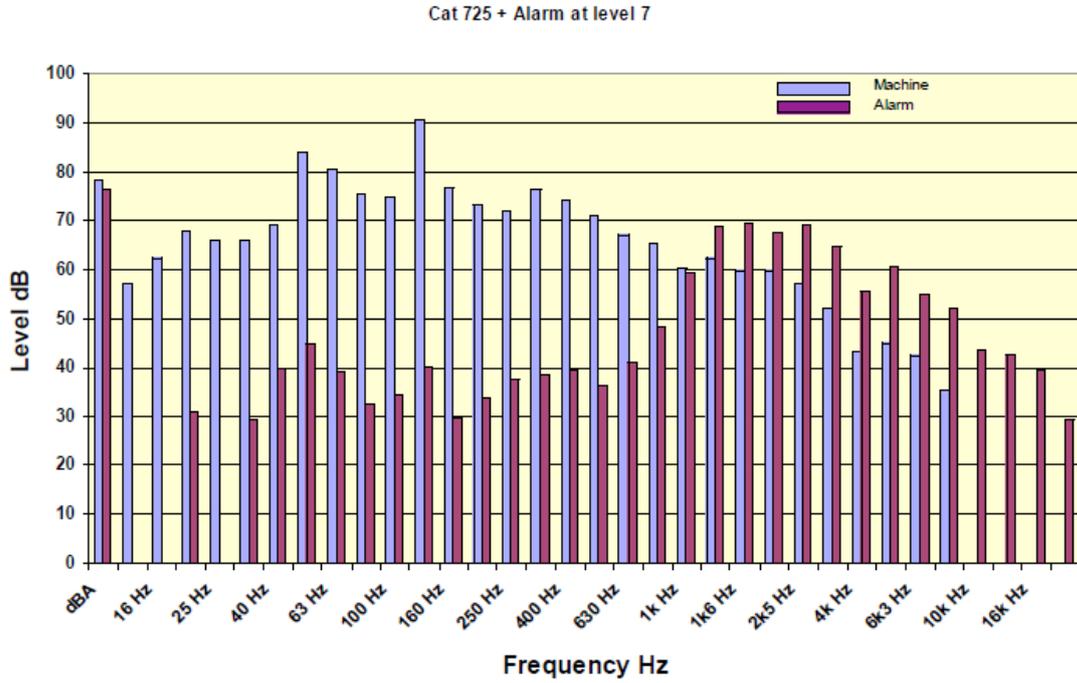


Fig 11 Spectra of Cat 962G and broadband alarm at Level 9 – see Fig 6
 The alarm components are similar to the machine components in the 1250Hz to 3150Hz region