

Assessing the use and effectiveness of acoustic warning signals

OG status: Fully open

Author unit / section: SD/Health Risks/FOD Noise & Vibration

Target audience: NVSI inspectors, HSE Inspectors & SD NV scientists

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Summary

Questions for Inspectors inspecting sites where acoustic warning signals are used

Inspectors may come across the use of acoustic warning signals (reversing alarms, fire alarms, trip alarms) during general inspections. The following questions are intended to raise awareness of the potential hazard and the steps that can be taken to prevent incidents occurring because of ineffective acoustic warnings. Where acoustic warning signals are used on site the inspector can ask:

1. Has a suitable risk assessment been undertaken that deals with the effectiveness of the acoustic warning signals in drawing attention to the identified hazard?
2. Have alternative methods of controlling workplace risks, other than by using acoustic signals, been considered? Alternative controls include:
 - Changing work processes to avoid the need for acoustic signals.
 - Using reversing alarms which automatically adjust for background levels.
 - Using visual warning signals on vehicles or machines.
 - Using presence-sensing signals that only sound when there is a person in a dangerous location.
 - Using hearing protection with communication systems linking driver to banksman/workers or linking machine operators to other workers.
 - Using trained banksmen when operating vehicles/plant within a construction site.
 - Ensuring appropriate separation between vehicles/plant and workforce.
3. Is there evidence that warning signals are clearly audible above typical ambient workplace noise for all employees (advice on assessment is contained in Appendix B)
 - All employees, and any third parties to whom there is a duty of care, should be able to hear the acoustic warning signals.
 - There should be evidence that the following have been considered when selecting and using acoustic warning signals:
 - The level and characteristics (high or low frequency/pitch) of all existing and expected noise levels (especially relevant in high noise environments).
 - Specific requirements for hearing protection.
 - Hearing impairments of employees.
 - The location and installation of the signal and its condition.
4. Can it be shown that employees, and affected third parties to whom there is a duty of care, understand the meaning of the acoustic warning signal?
 - Can individuals hear the signal, particularly when they are not expecting it?
 - Can they understand its meaning (e.g. fire alarm, reversing alarm)?

- Do they know what to do when they hear it?
5. Are there any conflicting statutory requirements that affect the selection of an appropriate acoustic warning signal (e.g. night time noise limits set by the local authority or boundary noise limits set by the relevant environment agency)?
- NOTE: Compliance with other legal requirements does not remove the legal duty to control risk under health and safety legislation. It may therefore be necessary to consider alternative warning systems, such as visual signals or alternative working methods.

Action by inspectors when investigating audibility issues

The significance of ineffective warning signals is often only identified during the latter stages of an incident investigation. It is therefore essential that suitable evidence and sufficient information be obtained at the time of the incident to enable a thorough investigation of the acoustic warning signal at a later stage. Appendix A provides a guide for investigations.

Introduction

Acoustic warning signals alert people to approaching vehicles or alert the operator to a safety issue (e.g. the reversing alarm on a lorry or fault alarm on a production line). The Supply of Machinery (Safety) Regulations 2008 require machinery to be fitted with warning devices (either acoustic or visual) where a person may be endangered by a fault in the operation of unsupervised machinery or where a person may be within a danger zone and it is not possible for the operator to ensure that the danger zone is clear – these devices must be unambiguous and easily perceived.

Acoustic warning signals are commonly found in the workplace. The audibility of warning signals, and therefore their success to warn of danger, is dependent on:

- Control of noise from other activities that could mask the warning signal.
- Correct selection and use of hearing protection.
- Due account being taken of employees or third parties with a hearing impairment.
- The correct installation and maintenance of the warning signal.

The effectiveness of an acoustic warning signal should be considered, taking into account high noise levels, the use of hearing protection and known hearing losses.

This OG provides guidance on:

- Consideration of acoustic warning signals during inspection visits.
- An assessment methodology for use in any investigation of acoustic warning signals, taking into account the requirements of existing health and safety legislation.
- Suitable enforcement action for inspectors to follow.

Purpose

The purpose of the OG is:

- To outline the hazards associated with ineffective acoustic warning signals and other sounds used to warn of danger in the workplace.
- To provide an aide-memoire for inspectors assessing acoustic warning signals.
- To set out the recommended approach for the assessment and evaluation of acoustic warning signals, where investigation is necessary.

Background

Failure to consider the audibility of acoustic warning signals in the workplace has contributed to injuries and fatalities. Between 1998 and 2015 the Health and Safety Executive investigated eleven incidents, some of which resulted in fatalities, to establish whether ineffective acoustic warning signals had contributed to the incident. These investigations focussed on whether the acoustic warning signal was likely to have been clearly heard or clearly understood at the time of the incident.

In most cases the question was whether an employee, other worker or member of the public could clearly hear an approaching vehicle (e.g. car, train or construction vehicle) over other background noises. The remaining incidents were related to acoustic warning signals attached to plant and machine items, that had not been heard by the person operating the plant or machine item.

The signals investigated were either acoustic warning alarms (e.g. reversing alarms, dash mounted alarms and horns) or simply the sound generated by a vehicle as it approached the site of the incident. These incidents commonly occurred in high levels of background noise, often generated by external sources, such as road/rail traffic and workplace machinery. The following areas are likely to have consistently high levels of ambient (background) noise and, where audible warning signal are used, may warrant an assessment of audibility:

- Railway lines.
- Dual carriage way roads or motorways.
- Construction or civil engineering works.
- Large scale fixed plant or machinery associated with an industrial process.

Lessons learnt

In the majority of the incidents the Health and Safety Executive reviewed, there was no evidence that the audibility of the acoustic warning signals had been considered, either in a general risk assessment or as part of a noise risk assessment. It was also found that the meaning of the acoustic warning signal was not always understood.

In addition to the general requirements on risk assessments under the Management of Health and Safety at Work Regulations 1999, there is a specific requirement under the Control of Noise at Work Regulations 2005 for employers to consider any *'indirect effects on the health and safety of employees resulting from the interaction between noise and audible warning signals or other sounds that need to be audible in order to reduce risk at work'*, Regulation 5(3)(d). Guidance on the Control of Noise at Work Regulations also states that the need to communicate and hear warning signals clearly and distinctly should be considered when selecting hearing protection.

In the incidents reviewed, the sound level and frequency characteristics of the noise generated by the warning signals generally failed to satisfy the objective criteria for audibility defined in BS EN ISO 7731 *Ergonomics – Danger signals for public and work areas – Auditory danger signals*. The warning signals were either not loud enough or not distinctive to be effective as audible warnings of danger. In one incident, although the warning signal was clearly audible, it was not clear whether those intended to hear it would have understood its meaning.

Acoustic warnings signals in the workplace

Acoustic warnings have an important role in attracting attention and conveying important safety information.

- For an acoustic warning signal to be effective it must be:
- Clearly audible above noise from other processes within the workplace.

- Clearly audible above noise from activities not associated with the workplace (e.g. nearby road or rail noise).
- Clearly audible even when hearing protection is worn.
- Immediately recognisable as a warning signal to any individuals to whom the employer has a duty of care.
- Associated with a specific behavioural response that is clearly understood.
- Located, installed and maintained correctly.
- In addition, it is likely that a specific assessment of risk is required to determine the effectiveness of acoustic warning signals for individuals with significant hearing impairments, even if background noise levels are not considered to be high.
- Systems of work that rely on speech communication between workers will be prone to the same aspects of audibility as apply to other acoustic warning signals. As such, their effectiveness should be considered as part of the workplace risk assessment.

Other sounds in the workplace may also be perceived, both by employers and workers, as warning or alerting signals even though not intended or designed as such. Examples include the sound of an approaching vehicle or the sound made during a particular phase of a machine cycle. The same criteria of effectiveness can be applied to these types of warning alerts as to those specifically designed as acoustic warning signals.

Enforcement Management Model

The 'benchmark risk' associated with ineffective acoustic warning signals is *negligible serious personal injury to single/low numbers of casualties* the risk of being hit by a vehicle is not entirely mitigated by the provision of acoustic signals, while the likelihood of large numbers of people being affected is low.

- The decision to take enforcement will be influenced by other failures in the system of work, such as poor management or inadequate training for the actions required when the alarm sounds (for example, exiting a building when the fire alarm sounds).
- Acoustic warning signals should be considered as a contributing factor in enforcement when:
- An actual injury has occurred because of inadequate provision of an acoustic warning signal: a Prohibition Notice and/or an Improvement Notice should be served and prosecution considered as the most relevant standards are likely to be either Established or Defined (see Table 1).
- An inspection identifies inadequate provision of an acoustic warning signal or an inadequate assessment of risk even though no injuries have occurred: an Improvement Notice and/or Prohibition Notice should be served as the most relevant standards are likely to be either Established or Defined (See Table 1).
- Risk assessments and operational procedures do not take into account alternative means of risk control, where restrictions have been placed on the

use of acoustic warning signals by other enforcement agencies to comply with environmental noise limits (e.g. planning conditions, pollution control or noise abatement notices): an Improvement Notice or a Letter should be considered.

Duties under health and safety regulations

Table 1 details the enforcement expectations, based on regulatory documentation, which are applicable when assessing the suitability of acoustic warning signals. Table 2 provides details on other sources of guidance that support enforcement actions.

Definitions of defined and established standards can be found in the Enforcement Management Model <http://www.hse.gov.uk/enforce/emm.pdf>.

Table 1 – Sources of relevant Regulations	
Document	Reference/Initial Enforcement Expectation (IEE)*
Control of Noise at Work Regulations 2005 - <i>Defined Standard</i>	<i>Regulation 5(3)(d). Indirect effects on the health and safety of employees resulting from the interaction between noise and audible warning signals or other sound that needs to be audible in order to reduce risk at work.</i> <u>IEE – Improvement Notice</u> - Where acoustic alarms are in use and they appear to be inaudible due to other noise sources and this has not been addressed in any risk assessment.
Construction (Design & Management) Regulations 2015 - <i>Defined Standard</i>	<i>Regulation 28(2). Where a person may be endangered by the movement of a vehicle, suitable and sufficient steps to give warning to any person who is liable to be at risk from the movement of the vehicle must be taken by either or both - the driver or operator of the vehicle; or where another person is directing the driver or operator because, due to the nature of the vehicle or task, the driver or operator does not have full visibility, the person provided directions.</i> <u>IEE – Improvement Notice</u> – Where the acoustic alarm or horn is insufficiently loud. <u>IEE – Prohibition Notice</u> - If the acoustic alarm or horn has been disabled consider a Prohibition Notice.
Workplace (Health, Safety and Welfare) Regulations 1992 - <i>Defined Standard</i>	<i>Regulation 17(1). Every workplace shall be organised in such a way that pedestrians and vehicles can circulate in a safe manner.</i> <u>IEE – Improvement Notice/Prohibition Notice</u> – Where acoustic alarms are used as a secondary means of controlling segregation between vehicles and pedestrians and it is found that they are inaudible, disabled or poorly maintained such that they are not effective.
Health & Safety at Work etc. Act 1974 - <i>Defined Standard</i>	<i>Section 8. Creating an offence under 33(1)(a): where it is believed that the signal has been interfered with.</i> <u>IEE – Improvement Notice/Prohibition Notice (Prosecution)</u> – Where a person can be shown to have tampered with an acoustic alarm so as to make it ineffective. PN to control the immediate risk and IN to secure sustainable compliance.

*Initial Enforcement Expectations are indicative only and need to be adjusted for compliance and administrative arrangements as well as duty holder factors.

Table 2 – Sources of relevant Guidance	
Document	Reference/Initial Enforcement Expectation (IEE)*
A Guide to Workplace Transport Safety (Ref HSG 136 (3 rd Ed) 2014 - <i>Established Standard</i>	Paragraph 228. <i>If reversing alarms are fitted they should be kept in good working order and be loud and distinct enough so they can be heard.</i>
Controlling Noise at Work. Guidance on Regulations (HSE Ref. L108 2006) - <i>Established Standard</i>	Paragraph 52. <i>Noise can mask important warning signals and messages, leading to potential safety issues. You will need to consider the characteristics of any audible warning and information signals in your workplace to take account of the possible masking effects of the general noise environment and of any hearing protection worn. You may want to consider visual warnings, or the use of hearing protection with communication facilities.</i> Paragraph 276. <i>When considering these devices (hearing protectors with communication facilities), check to ensure it is possible to hear necessary warning sounds (e.g. speech and safety alarms)* above the sounds reproduced at the ear. Safety alarms should not normally be relayed through the communication system because of the risk of system failure.</i>
BS EN ISO 7731: 2008 <i>Ergonomics – Danger signals for public and work areas – Auditory danger signals - Established Standard</i>	Document deals with the recognition of acoustic danger signals, especially in cases where there is a high level of background noise.

Further information

- Management of Health and Safety at Work Regulations 1999 As amended 2005, HMSO
- Control of Noise at Work Regulations 2005, HMSO.
- BS EN ISO 7731:2008 Ergonomics – Danger signals for public and work areas – Auditory danger signals. 2008, British Standards Institute.
- Health and Safety at Work etc. Act 1974, HMSO.
- Workplace (Health, Safety and Welfare) Regulations 1992, HMSO.
- Enforcement Management Model (EMM) Operational Version 3.2, October 2013, HSE.
- Guide to Workplace Transport Safety (HSG136), September 2014, HSE.
- Directive 2006/42/EC of the European Parliament and of the council on machinery, and amending Directive 95/16/EC (recast), 17 May 2006, Official Journal of the European Union.
- The Supply of Machinery (Safety) Regulations 2008, HMSO.
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Contact

Advice and support for Inspectors on acoustic warning signals is available from Noise and Vibration Specialist Inspectors. If in doubt, Inspectors should always ask for advice. Contact details for Noise and Vibration Specialists can be found by searching “Noise & Vibration” on the HSE Staff Directory (‘Organisations’ tab).

Noise and Vibration Specialist Inspectors can:

- advise you on reasonably practicable control measures for noise, hand-arm vibration and whole-body vibration, including complex or novel situations;
- help you with evidence of daily (or weekly) personal noise and vibration exposures, especially when circumstances are complex or unusual, including measurement; HSE SD scientists¹ can be used if specialist instrumentation is needed;
- advise you on compliance with the current noise and vibration legislation.

Occupational Health Inspectors can:

- advise on the quality and suitability of health surveillance services;
- provide clarification on the health surveillance requirements of current noise and vibration legislation; advise on the appropriate management of employees diagnosed with noise or vibration injury or who are otherwise at particular risk from noise or vibration.

Noise and Vibration Specialist Inspectors and Occupational Health Inspectors can also provide expert evidence for prosecution.

¹ Inspectors wishing to call on reactive support from HSE SD on matters relating to noise, hand-arm vibration or whole-body vibration, should in the first instance contact a Noise and Vibration Specialist Inspector, who will act as the Technical Customer for any such work. See FOD Info System Homepage (FISH) / Specialist Assistance and particularly <http://intranet/fish/specialist.htm>

Appendix A – A structured approach to investigations involving acoustic warning signals

This appendix suggests information that should be collected during the initial stages of an investigation where audibility issues have potentially contributed to the incident. Collecting suitable evidence and sufficient information during the initial investigation will allow a thorough investigation of the acoustic warning signal at a later stage.

Identify whether the use of acoustic warning signals is relevant to this investigation.

Secure any evidence, including equipment used for operations and warning signals (e.g. warning alarms, vehicles), or direct it to be left undisturbed.

Gather evidence on:

- *Incident details*
 - Obtain details of the precise location of the incident and the activities in progress at the time of the incident, possibly through the use of CCTV records.
 - Identify the location of the injured or deceased person in relation to the relevant sources of background noise and the warning signal.
 - Collect information on any weather conditions at the time of the incident that might have affected the audibility of the warning signal, e.g. wind speed, direction or rain.
- *Ambient noise*
 - Obtain details of all noise sources contributing to the level of ambient noise at the incident location at the time of the incident.
- *Warning signals or other important noise sources*
 - Identify all acoustic warning signals, or other important noises, at the incident site.
 - Identify any communication (e.g. two-way radio) or entertainment systems (e.g. personal music players) generating additional noise that might have a detrimental effect on the audibility of the warning signal or other important noises and, if possible, take these items into possession as evidence.
 - Identify the warning signal under investigation (it could be an acoustic alarm or noise generated by a vehicle) and obtain information on the type and model number, the condition at the time of the incident, location of the warning signal, and mounting method (if appropriate).
 - Investigate whether employees recognise that the warning signal is targeted at them and whether the meaning of the warning signal is clear (in terms of their actions in response to hearing the warning signal).

- Consider the following:
 - Is more than one type of acoustic signal used at the incident site?
 - Are the signals sounded frequently?
 - Is the noise generated by different signals distinct?
 - Is the meaning of the different signals consistent and clear?
 - Can the signal automatically adjust for background levels?
- *Hearing protection*
 - Obtain details of any hearing protection used by the injured or deceased person and, if possible, take their hearing protector into possession as evidence.
 - Investigate the following if appropriate:
 - Was the hearing protector worn or was it just issued?
 - Had the hearing protector been purchased by the employer or by the injured or deceased person (by personal choice or as recommended by a health professional)?
 - Establish what training and information the employer provides on the correct use of hearing protection.
- *Hearing impairment*
 - Obtain health records for details of any reported hearing impairment (e.g. hearing losses, tinnitus).
- *Subjective tests*
 - If possible, carry out a simple listening check on-site to see whether the warning signal is clearly audible above the current ambient noise and/or ask those who are expected to understand the signal if they can hear it clearly
- *Maintenance of signals*
 - Establish whether the warning signal has been correctly located and whether the maintenance technician responsible for fitting the warning signal has been provided with clear instructions.
 - Investigate the current state of maintenance of the warning signal, and establish whether it is being regularly maintained.
- *Risk assessments*
 - Obtain details of general risk assessments and noise specific risk assessments.
 - Identify whether the audibility of the warning signal was considered prior to the incident. Particularly if the incident occurred in a high noise area or if controls on acoustic warning signals had been introduced by a third party (e.g. local authority, environmental protection agency).

- Identify the criteria that were used to ensure that the warning signal selected was clearly audible above all relevant ambient workplace noises for all employees.
- Establish whether listening checks were carried out to ensure that all employees recognised the warning sounds they were listening out for, and that the warning signals were clearly audible above the ambient noises at all work locations.
- Identify the training and information provided to employees on the type and purpose of acoustic warning signals used in the workplace.

If necessary you can contact the local HSE Specialist Noise and Vibration Inspector who can arrange for objective tests for audibility to be undertaken, or give advice on gathering and interpreting information.

Appendix B – Recommended method for the objective assessment of acoustic warning signals to be adopted by Noise & Vibration Specialists

Assess the audibility of the acoustic warning signal using objective criteria set in BS EN ISO 7731:2008.

- Use the standard method defined in BS EN ISO 7731 as a starting point when assessing the audibility of acoustic warning signals. It may be necessary to measure noise parameters other than those specified in BS EN ISO 7731 (either in addition to or as a substitute for the specified parameters). In these circumstances, it must be made clear what measurements have been made and the reason for any deviations from the standard method defined in BS EN ISO 7731.
- Measure the L_{ASmax} (and other parameters as appropriate) for the ambient noise.
- Measure the L_{ASmax} (and other parameters as appropriate) for the warning signal noise.
- Measure unweighted octave or one-third octave band levels for the ambient noise (using the L_{Smax} parameter).
- Measure unweighted octave or one-third octave band levels for the warning signal noise (using the L_{Smax} parameter).
- Calculate the effective masked threshold from unweighted octave or one-third octave band levels (ambient noise).
- Identify the frequency and temporal characteristics of the warning signal noise.

Investigate the impact of using hearing protection on the audibility of the warning signal.

- Assess whether the hearing protection device would reduce the A-weighted sound pressure level of the warning signal as perceived by the wearer to less than L_{ASmax} 65 dB at the ear. Assume that the hearing protector is properly fitted for this assessment; this represents the worst-case situation in terms of the audibility of the warning signal.
- Investigate the impact of using hearing protection on the effective masked threshold, based on the assumed protection for the hearing protector (i.e. mean attenuation minus one standard deviation).

Investigate the impact of known hearing losses on the audibility of the warning signal

- Where possible investigate the impact of known hearing losses on the effective masked threshold, based on audiometric test for the injured/deceased person.

Determining variability in ambient noise levels

- Where the local noise environment has altered between the time of the incident and the time of the investigation it may be possible to establish likely ambient noise levels by consulting noise maps (e.g. Airport contour maps), prediction methods (e.g. Calculation of Road Traffic Noise) or noise modelling methods.

- Uncertainty is expected and these methods should only be applied to help verify that measurement data gathered at comparable periods and levels of operation, is indicative of noise levels at the time of the incident.