Annex 1: Overview of hearing conservation annexes

(For information only)

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1 Structure of hearing conservation programmes

1.1 Introduction

A successful hearing conservation programme (HCP) invariably consists of at least two and sometimes three distinct but complementary elements (Figure 1.1) intended to reduce the risk of noise-induced hearing loss (NIHL). The first of these is an engineering-based strategy to eliminate or reduce dangerous noise at its source, or at least to control its transmission through the workplace (Annex 4). Source and transmission control through noise control engineering (NCE) offers the greatest potential for reducing the risk of NIHL and accordingly, should be regarded as the preferred approach to hearing conservation. Although initially more costly and time-consuming to implement, it amounts to a systematic solution to the noise hazard, and reduces reliance on individual employees' compliance with what are often inconvenient, unpopular and ultimately more expensive strategies.

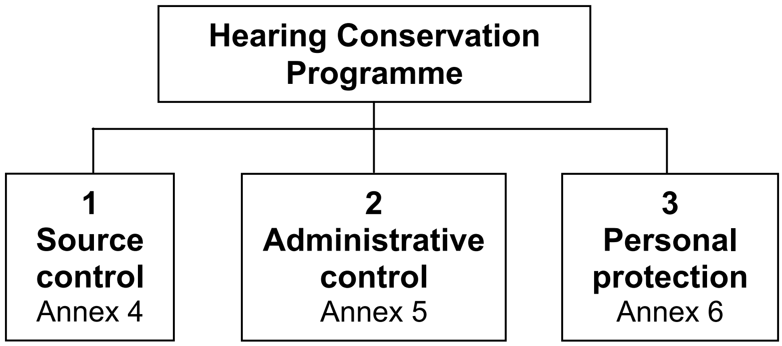


Figure 1.1 Elements of hearing conservation and their prioritisation

In some instances administrative controls (Annex 5) to limit employee exposure and the resultant risk of hearing loss can be incorporated into the HCP. Such measures include changes in the organisation of work, alternative scheduling of noisy tasks and, in some instances, the rotation of employees into and out of noisy areas to limit individual exposure. The latter requires that employees be trained to perform multiple tasks, and is also reliant on a sufficient availability of productive tasks in quieter areas to accommodate individuals who have reached a pre-determined level of exposure. As well as the additional training necessary to enable rotation of employees, further impact on productivity can be expected as result of time lost moving between tasks and workplaces. Furthermore, there may be safety implications where individuals are expected to perform multiple and divergent tasks as members of different teams. Where these limitations can be overcome, it must still be appreciated that the use of employee rotation would impose the administrative burden of monitoring and documenting each individual's overall exposure level, based on the duration of exposure in each of his or her various workplaces and the noise levels prevailing there. Given the limitations of employee rotation, it is likely that if at all feasible, administrative control measures would be restricted to changes in the organisation of work, e.g. the alternative scheduling of noisy tasks.

The extent to which NCE and administrative controls are successful in reducing risk will determine the level of reliance on the third element of an HCP, personal protection (Annex 6). Unfortunately, all too many hearing conservation programmes embrace this approach as the final solution to the noise hazard, despite the fact that it should be regarded as a temporary last resort. Personal protection is a form of receptor control, in that it seeks to limit noise immission (the level of unwanted sound energy incident on the ear), through the individual use of hearing protection devices (HPD). While personal protection can be more readily implemented than NCE or administrative controls and is initially less costly than either of these, there are a number of associated costs to be considered that go far beyond that of providing consumable HPDs on an ongoing basis.

Firstly, the success of a personal protection strategy is heavily reliant on employees' recognition of noise as a hazard, their appreciation of its potential impact on their work and personal lives, as well as their ability to make effective use of appropriate HPDs. This implies the need for cogent education and training programmes to inform and motivate employees, and to equip them with the requisite skills to protect themselves, often requiring time away from work to participate in training sessions. Evaluation of efforts aimed at motivating and training employees to make effective use of HPDs would require, among others, a programme of compliance monitoring (Annex 6) and appropriate interventions where indicated, also entailing some costs.

Reliance on personal protection in a noisy work environment (in contrast with reducing noise to safe levels) also creates the need for risk-based medical examinations (RBME, Annex 7) to ensure the efficacy of HPDs, as well as medical surveillance in the form of regular audiometric examinations for noise-exposed employees (Annex 8). The purpose of audiometry is to monitor employees' hearing levels and evaluate the HCP's overall effectiveness, including its personal protection strategy. As is true of education and training, RBMEs and audiometry require time away from the job, thus contributing to escalations in unproductive shifts. Although difficult to quantify, further impact on productivity and, more importantly, on safety can be expected as a result of the sense of isolation and interference with communication that can occur while wearing HPDs. Finally, where personal protection ultimately fails to prevent NIHL, thus leading to impairment, the cost of compensation is borne by the employer and his insurers, while reduced employment opportunities, lost earnings and diminished quality of life have severe impact on affected employees.

Each element of a hearing conservation programme comprises a considerable number of functions and activities, indicating the need for co-ordinated input from a multi-disciplinary team of specialists who communicate effectively and interact constructively under the leadership of a credible source of authority within the organisation. The present overview of the Hearing Conservation Annexes is intended to provide guidance in the overall management of an HCP, with particular emphasis on the need to coordinate and evaluate the execution of critical functions and activities, particularly where they influence other elements of the programme. Responsibility and accountability for critical functions must be assigned to specific individuals and/or departments, to ensure their competent execution and contribution to the overall effectiveness of the hearing conservation programme.

Of equal importance is the need for the HCP to be reviewed at regular intervals to identify areas for improvement, thus enabling enhancements to the programme's effectiveness. Here again, responsibility must be assigned for specific aspects of the review process, with the relevant individuals/departments held accountable for execution.

The present approach is to suggest possible functional and organisational structures for the HCP that ensure the linking of critical actions required in terms of the Mine Health and Safety Act. These actions are detailed in the annexes that follow, but the present overview provides brief notes regarding their purpose and intent, and how they relate to other aspects of the hearing conservation programme.

1.2 Functional structure

Figure 1.2 illustrates a functional structure for an HCP, based on the need to coordinate critical activities within the programme. Accordingly, the figure's point of departure is the fundamental process of risk assessment, the outcome of which will determine whether the need exists for a hearing conservation programme. In accordance with the preceding discussion, Figure 1.2 indicates the level of preference for implementing the various elements of the HCP, as previously illustrated in Figure 1.1.

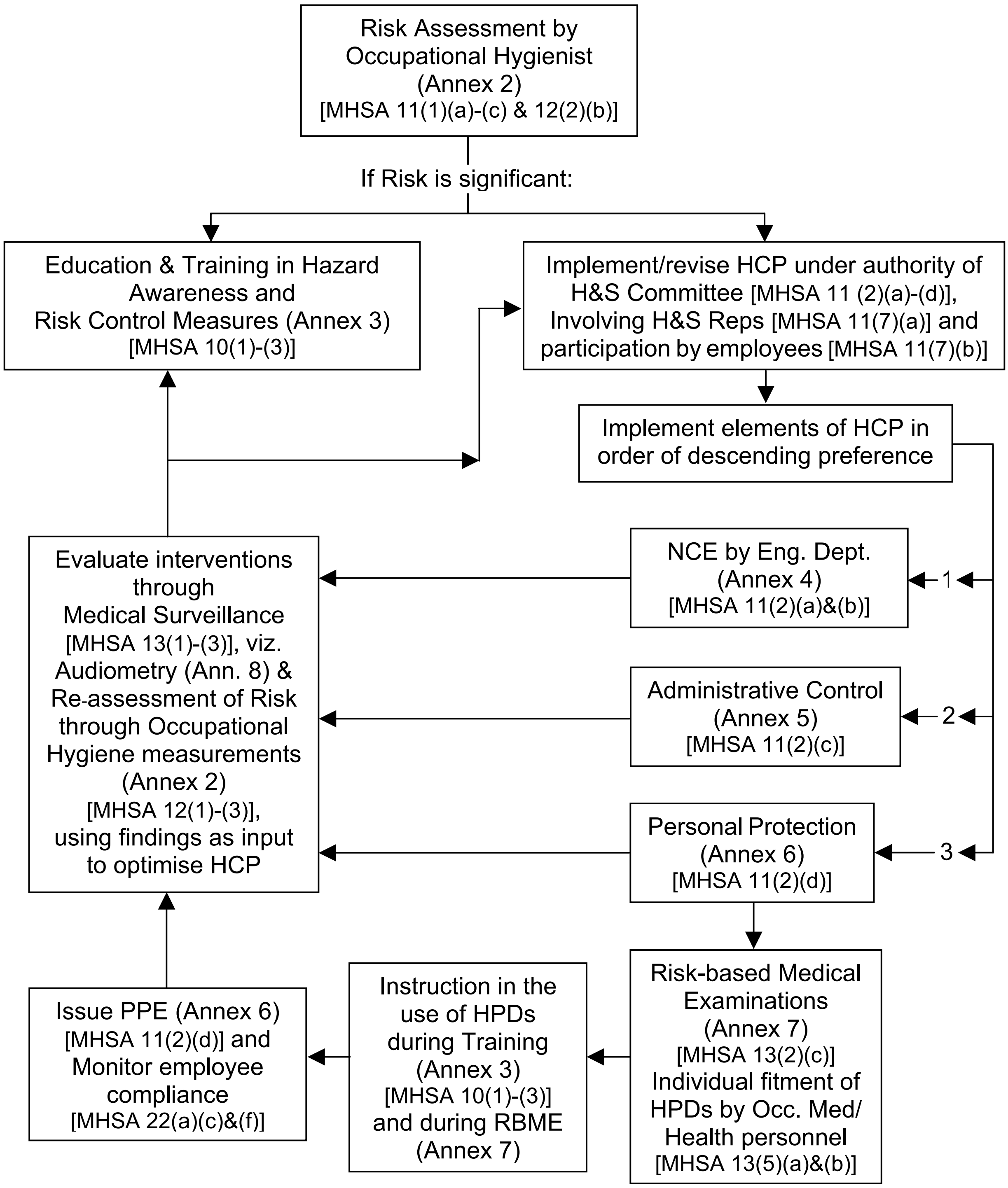
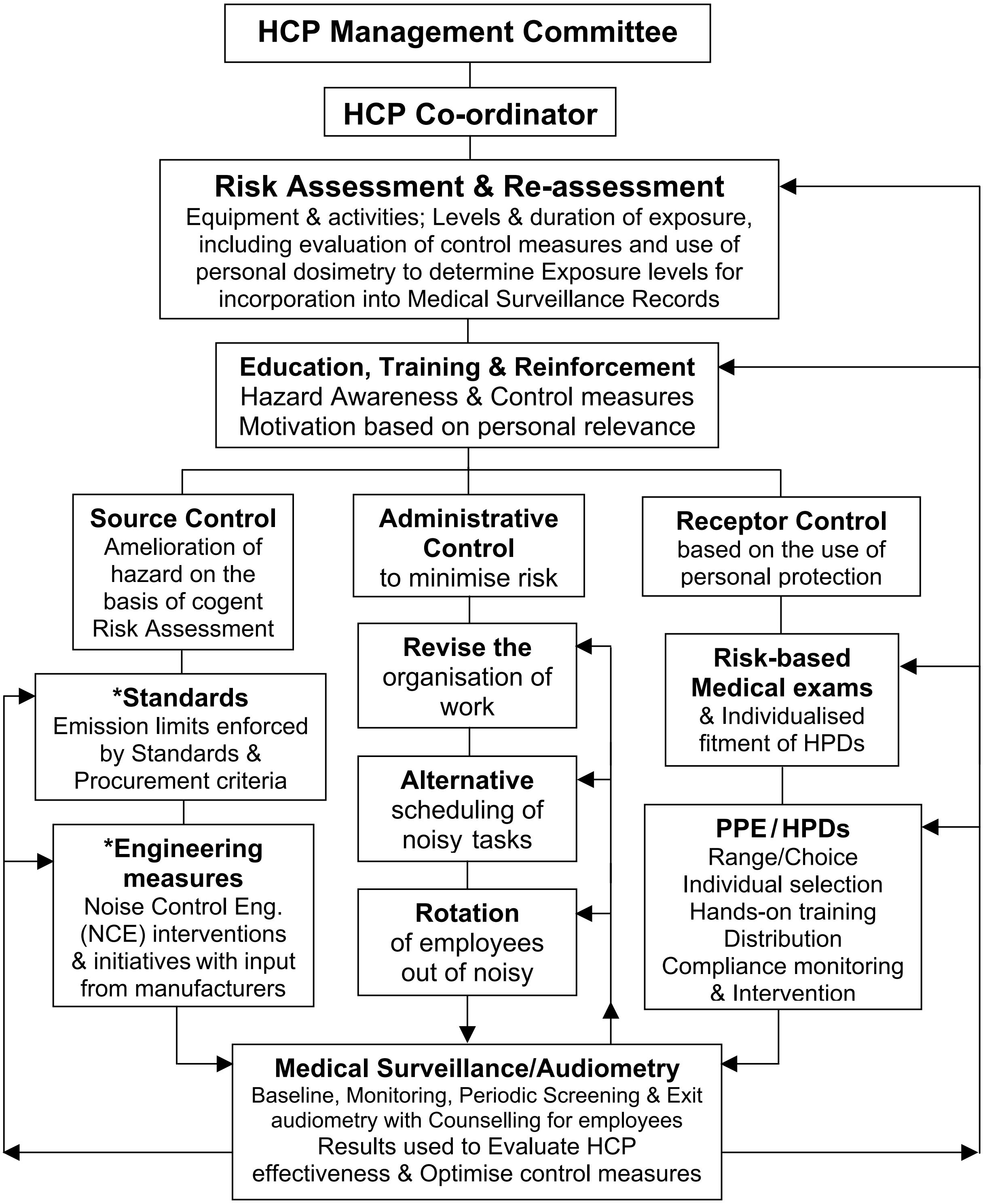


Figure 1.2 Functional structure of a hearing conservation programme

1.3 Organisational structure

While the previous section and its accompanying figure considered the structure of an HCP in terms of critical functions and activities, the present one is based more on an organisational approach, although critical functions are indicated. Figure 1.3 presents a structure for an HCP in organisational terms, and should be viewed in conjunction with Figure 1.2 and, for that matter, Figure 1.1.



*To be detailed in employers' codes of practice

Figure 1.3 Organisational structure of a hearing conservation programme

2 Critical functions and activities

Critical functions and activities required in terms of a hearing conservation programme are detailed in the various annexes that follow. Most individuals involved in the implementation and control of an HCP would perform or be responsible only for certain aspects and should consult the relevant annex(s). Nevertheless, all officials should be familiar with the purpose and intent of other aspects, particularly where they relate closely to their own area of involvement. Accordingly, a brief overview of critical functions and activities within the HCP is provided in the sub-sections that follow.

2.1 Noise measurement for risk assessment (Annex 2)

Risk assessment, within the context of accepted occupational hygiene practice, embraces the identification and assessment of hazards, viz. their “recognition [and] evaluation” (MHSA Section 102, Definitions: “occupational hygiene”). Accordingly, risk assessment represents the fundamental point of departure in dealing with any hazard, be it potential or actual. Within the present context, this process entails the quantification of noise and employee exposure levels to establish whether a hazard exists and, if so, to assess and prioritise sources of employee exposure and risk, thus enabling the implementation of appropriate control measures.

Risk assessment for the noise hazard and the application of measurement procedures detailed in Annex 2 are responsibilities of the occupational hygienist, but the results of these activities have bearing on all other aspects of the programme. It is important that all those involved in the HCP are aware of the risk assessment findings, at least to the extent that they relate to their own areas of responsibility. In addition, findings with regard to employee exposure level should be linked or incorporated into the records for medical surveillance, either on the basis of individual employee, occupation, workplace or work activity.

2.2 Education and training (Annex 3)

Education to ensure employees’ appreciation of the noise hazard and its potential impact is fundamental to the success of a hearing conservation programme. This is largely due to the fact that employees often fail to recognise noise as a hazard that can significantly affect their lives, both at work and in their personal relationships. Consequently, employees may regard hearing protection devices as unnecessary, as well as inconvenient and uncomfortable, potentially leading to non-compliance and, ultimately, to NIHL. Training initiatives must always specifically target the intended audience, but where the intention is to educate, motivate and change attitudes, this requirement becomes crucial.

Annex 3 provides objectives and core training elements for educating employees with regard to the noise hazard and for motivating them to protect themselves. It also suggests the use of learning activities and supervised, hands-on training aimed at imparting the knowledge and skills essential for making effective use of HPDs.

Although education and training are often seen as the realm of the training practitioner, supervisory personnel also have an important role to play, particularly with regard to reinforcement and retention training, and where a significant portion of employees’ training is provided in the workplace.

2.3 Noise control engineering (Annex 4)

Annex 4 considers, in general terms, possible means to reduce noise at source or to control its transmission through the workplace using engineering-based methods. This aspect is the responsibility of engineering personnel, but it should be appreciated that noise control engineering (NCE) is a specialised field and, accordingly, the input of suitably qualified and experienced individuals should be sought, including designers and manufacturers of equipment identified as significant contributors to employee exposure.

In order to derive maximum benefit from NCE, this preferred strategy for hearing conservation should fully incorporate the sub-elements of noise standards and limits for equipment, as well as their enforcement through the employer's procurement policy. In addition, it will be essential for engineering personnel to maintain an awareness of new developments in technology and machinery design, to enable ongoing reductions in noise either at or near the source.

2.4 Administrative measures (Annex 5)

Annex 5 considers possible means of minimising employees' exposure to the noise hazard through administrative measures that include revisions to the organisation of work, alternative scheduling of noisy tasks and the rotation of employees out of noisy areas, and discusses the limitations of such measures.

2.5 Personal protection (Annex 6)

Where the two preferred means of controlling employees' exposure to noise (NCE and administrative measures) have failed to sufficiently reduce the risk of NIHL, a personal protection strategy based on the use of HPDs is indicated. This approach should be regarded as a last resort and as a temporary supplement to other elements of the HCP (Figure 1.1).

Assuming that the prerequisites of effective education, motivation and training (Annex 3) and risk-based medical examinations (Annex 7) have been satisfactorily addressed, reasonable benefits can be expected from the use of personal protection. Annex 6 identifies the standards applicable to HPDs, considers the various types available and provides general criteria for their selection. It also points out the need to offer employees a reasonable range of suitable devices from which to choose. The annex states the requirement for individual fitment of HPDs to be performed by an occupational health practitioner or other appropriately competent person, as part of the risk-based medical examination.

Monitoring employees' use of HPDs should be recognised as an important source of information for managing the employer's personal protection strategy. The findings can offer insights into the appropriateness and acceptability of HPDs being issued, as well as the effectiveness of education, motivation and training initiatives, and of distribution methods. Accordingly, general guidelines for HPD compliance monitoring are presented, with a recommendation for monitoring to be performed at quarterly intervals.

In addition, Annex 6 also states employers' and employees' legislated responsibilities with regard to the use HPDs within the context of a hearing conservation programme.

2.6 Risk-based medical examinations (Annex 7)

The purpose of risk-based medical examinations (RBME), which should be incorporated into existing medical examination procedures, is firstly, to determine whether any contraindication exists for an employee or prospective employee to work in noisy areas. Such contraindications could be based on safety concerns (e.g. an inability to hear warning signals while wearing HPDs) or health concerns (e.g. an abnormal susceptibility to hearing loss).

The RBME also serves to identify any abnormality or temporary condition that could negatively influence the effectiveness of HPDs issued in terms of the hearing conservation programme, or the validity of an audiometric examination about to be administered as part of medical surveillance.

Annex 7 provides guidance in the application of RBME procedures, both routinely and where a change in circumstances indicates the need for a re-examination (e.g. a change in workplace noise levels), requirements for personnel conducting such examinations/re-examinations, as well as in classifying the outcome and determining relevant actions to be taken. Accordingly, Annex 7 should serve as a reference for Occupational Health and Occupational Medical Practitioners.

2.7 Medical surveillance and audiometry (Annex 8)

Medical surveillance to monitor employees' hearing and, thus, evaluate the effectiveness of measures to control the incidence of noise-induced hearing loss is the responsibility of occupational health and occupational medical practitioners. Audiometry constitutes the primary input to this essential process, and Annex 8 provides detailed guidance in the application of standardised audiometric testing procedures.

Aspects dealt with include equipment and calibration requirements, qualifications and registration of audiometrists, facilities, examination and testing procedures, the recording and evaluation of results, as well as indications for referral.

3 Review of hearing conservation programmes

Given the potential impact of NIHL on employers' operations and finances, as well as on employees' health, earning potential and quality of life, a hearing conservation programme should be controlled and reviewed in accordance with the same management principles that employers apply to their business activities. There are a number of reasons for the common failure of HCPs to prevent hearing loss and compensable impairment, including inordinate reliance on personal protection in the absence of source or transmission control and administrative measures, as well as the often-cited lack of management commitment. The latter shortcoming frequently manifests itself as a lack of co-ordination and control within the programme and its various elements.

Even a personal protection strategy, generally regarded as the simplest (but, in the absence of other measures, least effective) element of an HCP, entails a considerable number of sub-elements that must be adequately addressed for the strategy to be effective. Firstly, the risk assessment process must quantify the levels and nature (i.e. the spectral characteristics) of noise for all noisy work situations, to enable the determination of attenuation requirements and identification of an appropriate range of HPDs.

Risk-based medical examinations should then be applied, to establish whether any contraindications exist for individuals' use of HPDs, as well as to ensure their satisfactory fit. In cases of pre-existing hearing loss, it may also be necessary to expand the RBME to consider audiometric test results and the nature of the hearing loss, for the purpose of determining special requirements for HPD attenuation (e.g. “flat-and-low” attenuation HPDs to enhance the individual’s ability to communicate and perceive warning signals).

The next requirement would be to ensure adequate levels of hazard awareness and motivation among employees, and to provide hands-on training in the use of HPDs. Once all prerequisites have been met, an effective distribution system must be established, with adequate provision for replacing lost or damaged HPDs during the shift.

Despite efforts to ensure employee compliance with the required use of HPDs, an ongoing monitoring programme would be required, to determine levels of compliance and the reasons for any exceptions observed. This information should reveal any inadequacies in the range of devices made available to employees or their fitment during RBMEs, as well as in the education/motivation/training programme, and the HPD distribution system. Where inadequacies are identified, the information should be fed back to those responsible for the relevant sub-elements, to enable the formulation and implementation of appropriate corrective measures.

Finally, overall effectiveness of the personal protection strategy (and the HCP) must be evaluated by means of a medical surveillance programme involving regular audiometric examinations. The results can immediately identify individual hearing loss but, more importantly, application of audiometric database analysis (ADBA) techniques can reveal overall trends and problem areas, e.g. occupations, workplaces or work tasks where hearing losses occur more rapidly or to a greater extent. Again, where the results identify problems or inadequacies, the information should be used to formulate appropriate corrective measures.

It is quite clear that the success of even a single element of the HCP, personal protection in the present example, is reliant on the co-ordination, review and revision of a number of sub-elements, each with its own complexities. In the case of a comprehensive HCP that includes the elements of source/transmission control and administrative measures as well as personal protection, the need for effective management and regular review is crucial. Specific circumstances will determine the methods and frequency of the review process in accordance with the employer’s code of practice and, accordingly, the present purpose is to provide general guidance without being overly prescriptive.

3.1 Aspects to be reviewed

The various activities and elements of a hearing conservation programme will require review at different intervals, in accordance with their nature and the role that they play in the programme at large. These aspects are discussed in the sub-sections that follow, but it should be borne in mind that the evaluation and review of individual aspects should be reported as they are completed, with interim findings incorporated into the overall report on HCP effectiveness.

3.1.1 Noise measurement for risk assessment (Annex 2)

This aspect embraces the determination of noise emission and employee exposure levels, which are normally performed by the occupational hygienist. In terms of SABS 083: 2000, noise measurements and the confirmation of noise zoning should be performed at least every two years, but immediately where changes are made to equipment or the area where it is installed. Such instances would include the replacement, major overhaul or upgrading of noisy equipment, the implementation of noise reduction or control measures, as well as the addition or removal of walls, partitions, doors, windows, etc.

With regard to the measurement of exposure levels, which should be done by means of personal noise dosimetry where noise is variable/intermittent or employees do not have fixed workstations, monitoring should be done on an ongoing basis, with the results reviewed quarterly or at six-monthly intervals as appropriate.
Noise emission and exposure levels should be evaluated both in terms of previous results, and the noise reduction plans and targets adopted by the HCP Management Committee and/or the Health and Safety Committee. Where results indicate an unfavourable trend or failure to achieve an agreed target, engineering personnel should be informed and asked to provide an appropriate action plan.

3.1.2 Education, motivation and training (Annex 3)

This aspect should be monitored on an ongoing basis, with evaluation procedures incorporated into the education and training process. Although employee compliance with the requirement to use HPDs can provide some measure of effectiveness, an evaluation of the training itself, e.g. the use of pre- and post-testing, should be considered. In certain instances such measures could enable corrective interventions before the conclusion of training, but would also serve to indicate where there is a need to revise the methods used for subsequent groups.

In most cases, the review and evaluation of education and training provided in respect of the noise hazard should be conducted on a quarterly to six-monthly basis, with revisions applied as soon as the need becomes apparent.

3.1.3 Source and transmission control (Annex 4)

Measures to address noise at source and to control its transmission through the workplace would normally be evaluated as an adjunct to the risk assessment process but, in addition to the occupational hygienist, would also involve engineering personnel. The number of significant noise sources and their risk-based prioritisation for corrective measures should determine the measures planned for implementation.

A review of the NCE strategy should consider the measurement-based evaluation of actions already implemented, using pre-NCE levels and agreed targets as criteria. The review should also examine plans for future interventions to ensure their appropriateness, feasibility and compliance with priorities established during the risk assessment process. In the longer term, audiometric test results will provide a measure of NCE effectiveness, but this indicator would normally require a one-year period to identify any change in employees' hearing status, and the findings would be retrospective, i.e. recorded only after the damage is already done.

Intervals for NCE review will ultimately depend on the number of significant noise sources and the complexity of corrective measures, but in most instances should not be longer than one year or less than six months. Standards, limits and targets for noise emission and exposure levels should be reviewed and revised on an annual basis.

3.1.4 Administrative control (Annex 5)

Where administrative control measures are included in the HCP, an evaluation of their effectiveness will rely on the results of personal noise dosimetry (Annex 2) and/or audiometry (Annex 8). Given the need for a reasonable number of samples to establish trends in employees' exposure levels, a review interval of three to six months would be required in most instances, but a 12-month period would likely be required for audiometric trends to emerge.

3.1.5 Personal protection/Receptor control (Annex 6)

Despite the perceived simplicity of implementing a personal protection strategy, the number of sub-elements involved and their implications for other aspects of the programme make the review process for this element relatively complex.

Employees' compliance with the use of HPDs is an immediate and, to some extent, prospective indicator of the personal protection strategy's efficacy and, accordingly, should be monitored on an ongoing basis with the results reviewed at quarterly intervals, given the implications that findings could have for other aspects of the HCP. Compliance levels may indicate inadequacies in the range of HPDs available to employees (including appropriateness with regard to attenuation and individual ergonomics), the application of RBME procedures, as well as the effectiveness of education/motivation/ training initiatives and distribution of HPDs. Ongoing monitoring and a relatively short review interval would provide an early warning of any shortcomings in the prerequisites to an effective personal protection strategy, thus enabling appropriate action before appreciable hearing losses develop.

3.1.6 Risk-based medical examinations (Annex 7)

Risk-based medical examinations (RBME) are intended to ensure the appropriateness of receptor control measures for limiting the risk of NIHL. While the findings of a RBME are mainly applicable to the individual employee concerned, trends that might be identified could have implications for other aspects of the HCP, e.g. the occurrence of ear infections (education and training, Annex 3 and 6, the latter with regard to HPD instruction) or instances where the HPDs offered are inappropriate (HPD selection criteria, Annex 6).

Accordingly, relevant findings of RBMEs should be summarised in regular reports that identify any untoward trends, for quarterly or six-monthly review by the HCP Management Committee and/or the Health and Safety Committee.

3.1.7 Medical surveillance and audiometry (Annex 8)

Audiometry for noise-exposed employees provides the ultimate indication of an HCP's overall effectiveness, as it measures hearing losses that the programme is meant to prevent. An individual's hearing threshold levels can immediately indicate where a (further) loss of hearing has occurred, but far more significant are shifts and trends for the workforce at large. Identifying those occupations, workplaces and activities where hearing loss is progressing most rapidly, particularly in the case of large workforces, normally requires the application of ADBA techniques with adequate provision to eliminate the effects of workforce turnover. Various parameters can be used to measure the influence of noise on hearing, including audiogram categorisation (particularly with respect to the higher test frequencies of 3, 4 and 6 kHz), average or total threshold shift at 3, 4 and 6 kHz, threshold shift at 4 kHz only, standard threshold shift (STS) or percentage loss of hearing (PLH).

Most employees would undergo audiometric testing on an annual basis, but those performing high-risk work (8-h time-weighted average equivalent noise exposure >105 dBA) may be tested every six months, depending on the employer's code of practice. Accordingly, the review of audiometric test results should be conducted at similar intervals, with an annual assessment of findings for the entire workforce, and six-monthly assessments of trends for high-risk occupations, workplaces and activities where applicable.

Reports on the results of audiometric testing should present current findings in comparison with previous results, as well as with any targets that may have been set by the HCP Management and H&S Committees. Areas of greatest concern should be highlighted, and recommendations made for the formulation and implementation of appropriate corrective measures.

3.1.8 Overall review of the HCP

Reports on the overall review of the HCP should be compiled annually and incorporate, at least in summary form, the findings of interim reviews for various elements and sub-elements of the programme. Every review, be it an element-specific interim assessment or an evaluation of the entire programme, should identify areas for improvement and include an action plan with criteria for assessing progress over the next period of review.

4 Co-ordination and management of the HCP

Given the complexities involved in the implementation, monitoring and review of a hearing conservation programme, close co-ordination and effective management are essential and the role of the HCP co-ordinator is therefore crucial. This person must be suitably qualified, appropriately experienced and have the authority and leadership qualities necessary to effectively coordinate the activities of a multidisciplinary team of specialists.

Annex 2: Noise measurement for risk assessment

(For information only)

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1 Introduction and scope

This annex details uniform methods and procedures for measuring and assessing occupational noise based on established standards, most notably SABS 083: 2000, but other standards as well where applicable. Certain of the noise measurement procedures described are relevant to manufacturers/suppliers of noisy machinery and equipment, but most relate to employers' responsibility for assessing risks and for monitoring and controlling employees' exposure to noise. A third category of procedures provides for confirmation of emission and exposure levels in cases of dispute, applicable where a need exists to confirm/refute machinery compliance with an established noise emission specification, or to corroborate employees' exposure levels.

1.1 Applications for noise measurements

Principal emphasis is placed on measurement procedures to be applied by employers in assessing and monitoring the noise hazard, owing to the need for uniform monitoring and accurate exposure determinations. These are prerequisites for valid risk assessment, for the identification and prioritisation of critical noise sources for control treatments (and evaluating the benefits thereof), as well as for the benchmarking of employers' hearing conservation programmes. All these activities should be regarded as tools for effective management of the noise hazard and its associated risks. However, deriving demonstrable benefits from their application is contingent on valid noise measurements that enable pro-active and prospective risk management. Furthermore, the accurate quantification of noise and employee exposure levels can provide information essential for evaluating the adequacy of provision made for future compensation claims, while the results of standardised measurements could serve as an equitable basis for determining employers' contributions to compensation funds based on risk to employees. Accordingly, the measurement and assessment of occupational noise by employers is dealt with in considerably more detail than other applications for noise measurement.

The third category of measurement procedures, broadly termed "confirmation and disputes", includes methods for evaluating compliance of new or re-furbished machinery with a given noise emission limit (as stipulated by the employer's procurement criteria or claimed in suppliers' machinery specifications). The use of such procedures and inclusion of their results in the procurement process should be seen as a means of encouraging manufacturers to reduce noise emissions from their products.

The same procedures could also be applied, but perhaps less stringently, as a means of quality control subsequent to completion of maintenance and repairs, whether performed in-house or by outside suppliers. This third category of measurement procedures also provides for the resolution of disputes regarding exposure level for an individual or group of individuals. Such disputes could arise between employer and supplier, employer and employees/representative organisation, employer and regulatory authority, or between an employer and an insurer. It is also conceivable that such a dispute could form the basis of compensation claim litigation.

It should be borne in mind that many of the procedures described in the present annex are best applied by specialists having the requisite knowledge and experience and, in such cases, the employer should regard Annex I as a reference to assist with the interpretation of consultants' findings and recommendations.

2 Definitions and explanations

For the purposes of this annex on noise measurement, definitions in the sub-sections that follow (“Acoustic terms”, “Acoustic parameters” and “Instrument-related terminology”) will apply.

2.1 Acoustic terms

sound: the aural sensation (detectable by the ear) caused by rapid fluctuations in air pressure about the prevailing mean atmospheric pressure. (The unit of sound pressure is the pascal, abbreviated as Pa.) These pressure fluctuations can be generated by a vibrating solid surface in contact with the air, in which case the magnitude or amplitude of the air pressure fluctuations (and hence, the amplitude of sound pressure) is proportional to the velocity and displacement of the vibrating surface. Where fluctuations in air pressure are produced by the rapid expansion and contraction of surrounding air as a result of turbulent air, gas or fluid flow (as in hoses, pipes, ducts, exhausts, etc.), the amplitude of air pressure fluctuations, i.e. the sound pressure, is proportional to the level of turbulence. In addition to air, sound can be generated in any compressible and viscous medium, including gases, liquids and solids.

frequency of sound: the rate at which pressure fluctuations in the surrounding or transmitting medium are produced, measured in cycles per second or Hertz (Hz). Frequency is ultimately determined by the rate at which the source vibrates and induces pressure variations in the surrounding or transmitting medium. The frequency of a sound determines the pitch perceived by the listener, with higher frequency sounds perceived as having a higher pitch.

Although the frequency of sound can be accurately quantified in Hz, it is generally characterised in terms of octave-bands. Octave-bands are specified by their respective centre frequencies, and each octave-band’s centre frequency has a value double that for the preceding octave-band (viz. 31,5; 63; 125; 250; 500; 1 000; 2 000; 4 000; 8 000 and 16 000 Hz). It is common practice to note 500; 1 000; 2 000 and 4 000 Hz, etc. as 0,5; 1; 2 and 4 kHz (kilohertz), etc., respectively.

spectrum of sound: the range of frequencies, from the lowest to the highest, over which sound is produced. This term can also be defined more precisely as “the composition of sound as a function of frequency”.

Sound or noise can be narrow-band, i.e. occurring only within a limited range of frequencies, or broad-band, i.e. occurring across a wide range of frequencies. Knowledge of the spectral characteristics of sound provides an indication of the specific source within the machinery being considered, of possible means for reducing the level or controlling its transmission, as well as the type of personal protection that would be most appropriate for exposed persons.

sound power: the total amount of acoustic energy emitted by a sound source during a specified time interval, divided by the duration of that interval in seconds, i.e. the total amount of sound energy emitted per second. The unit of sound power is the watt, abbreviated as W, which by its definition (1 joule/s) incorporates the time factor. Total sound power is given by the following relation:

$$W = (p^2/\rho c)\,A \qquad (1)$$

where:

- W is total sound power emitted, in decibels,
- P is the average sound pressure over the surface of an imaginary enclosure surrounding the source, in pascals,
- ρ is the density of the surrounding air, in kg/m^2,
- c is the velocity of propagation of the sound, in m/s, and
- A is the total surface area of the imaginary enclosure, in m^2

Sound power is a more direct means of quantifying acoustic emissions than the commonly used measure of sound pressure level, as sound power has an absolute value for a given source, independent of environmental influences. However, practicality normally dictates that sound power be expressed as a *level* on a logarithmic decibel scale. Sound power level is abbreviated as L_W and given by the following relation:

$$L_W = 10 \log W/W_0 \qquad (2)$$

where:

- L_W is sound power level, in decibels,
- W is the total acoustic outputs, in watts, and
- W_0 is the reference power of 10^{-12} w, which corresponds with the threshold of normal hearing

It is common practice to characterise the noise emissions of equipment or machinery in terms of sound pressure level. This parameter is analogous to room temperature, in that its value is a function of the machinery's sound power and the properties of the environment where it is operating. As it is impossible for the manufacturer to anticipate the specific circumstances of installation and use, the practice of specifying sound pressure level can lead to higher-than-specified values once the equipment is installed and operating, particularly where the stated levels are based on free-field determinations as is normally the case. Therefore, comparisons of noise emission would be better served if manufacturers were to specify their products' noise emission in terms of sound power, in the same manner that heating and cooling appliance manufacturers characterise their products on the basis of thermal or cooling power, measured in watts or kilowatts.

intensity of sound: the average rate at which sound energy is radiated from a source. Measurements of sound intensity consider the flow of energy through the surface of an imaginary enclosure surrounding the source, where the imaginary enclosure approximates the shape of the source and the surfaces of the enclosure are perpendicular to the direction of energy flow. The unit of intensity is watts per square metre (relative to the surface area of the imaginary enclosure), which is abbreviated as W/m^2. Sound intensity is given by the following relation:

$$\mathrm{I} = p^2/\rho c \qquad (3)$$

where:

- I is the intensity of the sound, W/m^2,
- P is the average sound pressure, in pascals, over the surface of an imaginary enclosure surrounding the source,
- ρ is the density of the surrounding air, in kg/m^2, and
- c is the velocity of propagation of the sound, in m/s

Intensity is proportional to the square of the velocity amplitude for the vibrating source and, thus, is proportional to the square of the sound pressure. A sound's intensity is closely related to our perception of its loudness. For a source radiating sound power in all directions, the power flows outwards through an imaginary sphere, the surface area of which is $4 \pi r^2$ at distance r from the centre of the source. Because the surface area of the sphere increases proportionally with the square of r, the fixed amount of sound power being radiated by the source is distributed over a larger surface area at greater distances. This causes the intensity and perceived loudness of a sound to decrease in proportion to the square of the distance from the source, in a similar manner to which perceived warmth decreases at greater distances from a radiant heater.

decibel (dB): generally defined as 10 times the log of the square of a ratio (ratio of the quantity being considered to a prescribed reference level). For quantifying sound pressure level, the decibel is 10 times the log of the square of the ratio of the sound pressure being measured to the reference sound pressure (20 μPa or 2×10^{-5} Pa), as given by the following formula:

$$\mathrm{dB} = 10 \log (p/p_0)^2 \qquad (4)$$

where:

p is the pressure of the sound being considered, in pascals, and

p_0 is the reference sound pressure of 20 μPa or 2×10^{-5} Pa

The principal reason for using the logarithmic decibel scale is that the ear is sensitive to a huge range of sound pressures (20 μPa to 20 Pa), which is difficult to represent on a linear scale. In addition, the ear's response to sounds of different loudness is logarithmic rather than linear. Accordingly, the logarithmic decibel scale is generally used to quantify sound pressure as a *level*, relative to the threshold of normal hearing, which is 20 μPa at 1 kHz. This lower limit or threshold for normal hearing, as the reference level, is arbitrarily assigned a value of 0 on the decibel scale, resulting in the upper limit of the hearing range (20 Pa, generally regarded as the normal threshold of pain) being equivalent to a decibel value of 120.

A 3 db difference in sound level is the smallest change perceivable by the average listener. Although halving or doubling the sound power may be significant in terms of mechanical power and potential impact on the human hearing mechanism, this results in only a 3 db change in sound level and a nearly imperceptible change in apparent loudness.

noise: sound that is deemed undesirable, either because it annoys, distracts or interferes with those hearing it, or because it has the potential to damage the hearing mechanism and cause hearing loss for those exposed to it.

noise-induced hearing loss (NIHL) and **noise-induced permanent threshold shift (NIPTS)**: an increase in hearing threshold level, or alternatively, a reduction in the sensitivity of hearing, caused by prolonged exposure to dangerous noise, normally affecting both ears to a similar extent.

noise zone: an area within which persons could be exposed to noise equal to or in excess of the noise rating limit for hearing conservation (SABS 083: 2000).

hearing conservation: the prevention or minimisation of noise-induced hearing impairment by the control or reduction of noise through engineering methods, administrative measures and/or, as a last resort, the issuing of personal protection in the form of suitable hearing protection devices (HPD), as well as the implementation of hearing conservation or hearing loss prevention procedures (SABS 083: 2000).

2.2 Acoustic parameters

sound pressure (p): the root-mean-square sound pressure, in pascals (Pa), determined without use of frequency weighting.

A-weighted sound pressure (p_A): the root-mean-square sound pressure, in pascals (Pa), determined by use of frequency weighting network A (SABS IEC 60651).

sound pressure level (L_p): the level of the sound, in decibels (dB), determined without use of frequency weighting and given by the following equation [ISO 1999: 1990 (E)]:

$$L_p = 10 \log \left(\frac{p}{p_0} \right)^2 \tag{5}$$

where:

p is the sound pressure being considered (in Pa),

p_o is the reference level for sound pressure (20 μPa) and

L_p is expressed in decibels (dB)

A-weighted sound pressure level or sound level (L_{pA}): the sound pressure level, in decibels, of A-weighted sound pressure given by the following equation (SABS 083: 2000):

$$L_{pA} = 10 \log \left(\frac{p_A}{p_0} \right)^2 \tag{6}$$

where:

p_A is the A-weighted pressure in pascals,

p_o is the reference sound pressure (p_o = 20 μPa), and

L_{pA} is expressed in decibels (dB)

NOTES:

1. The internationally accepted unit for sound level, dB, is by definition an A-weighted value when used to quantify L_{pA}. In practice, dBA or dB(A) is commonly used to distinguish A-weighted values from other values.
2. A-weighting is the practice of weighting the value for sound pressure levels, in accordance with the human ear's varying sensitivity to sounds of different frequencies. The ear is able to detect sounds ranging in frequency from 20 Hz to 20 kHz, but is more sensitive to those near the centre (in octave-band terms) of this range. The threshold of hearing outside the range of greatest sensitivity (approximately 1 to 4 kHz) becomes progressively greater for higher and particularly for lower frequencies, making it necessary for the sound to be louder before the ear responds to it. This reduced sensitivity is also apparent at levels above the hearing threshold, in that higher- and lower-frequency sounds appear softer than mid-frequency sounds having the same sound pressure level. A-weighting de-values the contribution of sound components at the higher and lower frequencies, resulting in an overall or full-spectrum value for sound pressure level that more accurately

reflects the listener's perception of loudness. Other frequency weighting scales are briefly discussed in Section 2.3, under "Frequency weighting".

equivalent continuous A-weighted sound pressure level ($L_{\mathrm{Aeq},\,T}$): the value of the A-weighted sound pressure level, in decibels, of a continuous steady sound that, during a specified time interval T, has the same mean square sound pressure as a sound under consideration, the level of which varies with time. It is defined by the following equation (SABS 083: 2000):

$$L_{\mathrm{Aeq},\,T} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p^2{}_{\mathrm{A}}(t)}{p^2{}_{\mathrm{o}}} \, \mathrm{d}t \right] \qquad (7)$$

where:

$L_{\mathrm{Aeq},\,T}$ is the equivalent continuous A-weighted sound pressure level, in decibels, determined over a time interval T that starts at t_1 and ends at t_2,

p_{o} is the reference sound pressure level ($p_{\mathrm{o}} = 20\ \mu\mathrm{Pa}$), and

$p_{\mathrm{A}}(t)$ is the instantaneous A-weighted sound pressure of the sound signal, in pascals

NOTES: 1. The period ($t_2 - t_1$) chosen for measurement or calculation of $L_{\mathrm{Aeq},\,T}$ should be of sufficient duration to be representative of the entire period that is being considered.

2. For a continuous unvarying sound, the values for $L_{\mathrm{Aeq},\,T}$ and $L_{p\mathrm{A}}$ will be numerically equal.

rating level ($L_{\mathrm{Ar},\,T}$): the value of the impulse-corrected equivalent continuous A-weighted sound pressure level, in decibels, during a specified time interval T, that is representative of the noise in the working environment. (The representative value must have the same mean square sound pressure, i.e. contain the same quantity of sound energy, as the actual sound under consideration.)

For continuous measurements of steady noise that has uniform impulse characteristics, the rating level, in decibels, is given by the following equation (SABS 083: 2000):

$$L_{\mathrm{Ar},\,T} = L_{\mathrm{Aeq},T} + K \qquad (8)$$

where:

T is the duration of the specified time interval,

$L_{\mathrm{Aeq},\,T}$ is the equivalent continuous A-weighted sound pressure level, in decibels, determined over the specified time interval T, and

K is an impulse correction factor (in decibels) applicable to the specified time interval

For composite measurements of noise with impulse characteristics that are present for only part of the specified time interval, equation (9) is used to adjust the level of K in proportion to the duration of impulse noise and, thus, determine the rating level (SABS 083: 2000).

$$L_{Ar,T} = 10 \log \left[\frac{1}{T} \sum \mathrm{ni} - 1 \left(T_i \times 10^{\left(L_{Aeq.T_i} + K_i \right)/10} \right) \right] \qquad (9)$$

where:

$L_{\mathrm{Aeq},Ti}$ is the equivalent continuous A-weighted sound pressure level in decibels, determined over the time interval T_i ,

T equals $\sum$ni - 1 T_i ,

K_i is the impulse correction factor, for time interval T_i, in decibels,

n is the total number of time intervals, and

the result is rounded to the nearest decibel.

8 h rating level ($L_{\mathrm{Ar},\,8h}$): the rating level normalised to a nominal 8 h workday, obtained by determining the rating level over the reference time interval, i.e. by substituting the reference time interval T_o (8 h) for T in equations (8) and (9), as indicated in equations (10) and (11), respectively (SABS 083: 2000), both of which yield decibel values:

$$L_{\mathrm{Ar,\,8\,h}} = L_{\mathrm{Aeq,\,8\,h}} + K \qquad (10)$$

$$L_{Ar,8h} = 10\log\left[\frac{1}{8h}\sum ni - 1\left(T_i \times 10^{\left(L_{Aeq.T_i} + K_i\right)/10}\right)\right] \qquad (11)$$

noise rating limit for hearing conservation: the value of the rating level $L_{\mathrm{Ar,\,8\,h}}$ (viz. 85 dB), at and above which hearing impairment is likely to result (SABS 083: 2000).

A-weighted sound exposure, $E_{\mathrm{A},\,T}$: the time integral of the squared A-weighted sound pressure over a specified time period, T, or event, in pascal squared seconds ($\mathrm{Pa}^2\cdot\mathrm{s}$), as defined by the following relation (ISO 1999: 1990):

$$E_{\mathrm{A},\,T} = \int_{t_1}^{t_2} p_{\mathrm{A}}^2\,(t)\,\mathrm{d}t \qquad (12)$$

where:

$p_{\mathrm{A}}(t)$ is the instantaneous A-weighted sound pressure of the signal integrated over a time period T in seconds, starting at t_1 and ending at t_2. For a nominal 8-h working day T is equal to 28 800, in which case the value of $E_{\mathrm{A},\,T}$ will be numerically equal to that of $L_{\mathrm{EX,\,8h}}$.

NOTES: 1. The sound exposure level, $L_{\mathrm{EA},\,T}$, in decibels, is expressed as:

$$L_{\mathrm{EA},\,T} = 10\log\,(E_{\mathrm{A},\,T} / E_o) \qquad (12.1)$$

where: E_o is 4 x 10^{-10} $\mathrm{Pa}^2\cdot\mathrm{s}$, as given in ISO 1996: 1982 and in SABS IEC 60804: 1993.

2. Noise exposure normalised to a nominal 8-h working day, $L_{\mathrm{EX,\,8h}}$, is obtained from:

$$E_o = 1{,}15 \times 10^{-5}\ \mathrm{Pa}^2\cdot\mathrm{s}, \qquad (12.1.1)$$

where: E_o is 44,5 dB less than $L_{\mathrm{EA},\,T}$ (see next definition and explanation).

noise exposure normalised to a nominal 8-h working day, $L_{EX, 8h}$: the value of the equivalent continuous A-weighted sound pressure level in decibels incident on the ear for 8 h that is representative of the fluctuating sound to which the individual is actually exposed. The representative value must contain the same quantity of sound energy and, thus, have the same effect on the ear as the actual sound to which the individual is exposed. $L_{EX, 8h}$ has a meaning corresponding with that of equivalent noise exposure (N_{eq}), and that of 8-h equivalent time-weighted average noise exposure (TWA_{8h}). It is given either by equation (13) or (14) (SABS 083: 2000):

$$L_{EX, 8h} = L_{Aeq, T_e} + 10 \log \left(\frac{T_e}{T_o}\right); \quad (13)$$

or

$$L_{EX, 8h} = 10 \log \frac{E_{A, T_e}}{1{,}15 \times 10^{-5}} \quad (14)$$

where: $E_{A, Te}$ is the A-weighted sound exposure in Pascal squared seconds ($Pa^2 \cdot s$) over time interval T_e ;

T_e is the effective duration of the workday in hours, and

T_o is the reference duration (8 h).

NOTE: Where the effective duration of the workday, T_e, does not exceed 8 h, the values for $L_{EX, 8h}$ and $L_{Aeq, 8h}$ will be numerically equal.

2.3 Instrument-related terminology

sound level meter (SLM): an instrument used for the measurement of various frequency- and time-weighted sound pressure levels. It may, depending on its level of sophistication, provide only instantaneous indications of sound pressure level, or be capable of incorporating all sound pressure levels detected during the measurement interval into an integrated or average sound pressure level.

Type (of instrument): the degree or level of precision for SLMs, microphones filter sets and acoustic calibrators, specified as:

- Type 0: laboratory reference grade, with an accuracy of ± 0,4 dB
- Type 1: precision grade, with an accuracy of ± 0,7 dB
- Type 2: general-purpose grade, with an accuracy of ± 1,0 dB
- Type 3: field survey grade, with an accuracy of 1,5 dB

frequency weighting: the human ear can detect sounds ranging in frequency from 20 Hz to 20 000 Hz, but our hearing is most sensitive near the centre (in octave-band terms) of this range. This can result in a sound of high intensity that has a relatively low or relatively high frequency seeming softer than a less intense sound of medium frequency.

It is, therefore, useful to weight those frequencies that the ear is most sensitive to, or as is more often the case, to proportionally reduce the sound pressure value for sounds occurring at frequencies that the ear is less sensitive to. There are three frequency-weighting networks that normalise the intensity of a sound according to the human ear's sensitivity. These are the A-, B- and C- (frequency) weighting networks, which respectively correspond with the human ear's frequency-dependent sensitivity to sounds of relatively low, medium and high intensity (SABS IEC 60651: 1993). These weighting networks or normalising curves were developed in an attempt to quantify sound in accordance with the human ear's response to it. Although many modern sound level meters include a facility for C-weighting, it is only used for noise control engineering applications. Today the B frequency-weighting network is no longer in use, and for environmental and occupational noise measurements, A-weighting is used exclusively. Frequency weighting is also discussed, in terms of A-weighting, in paragraph 2 of "A-weighted sound pressure level", Section 2.2.

time-weighting or **detector response**: a function of a sound level meter that determines its responsiveness to the time-varying characteristics of the sound being measured (SABS IEC 60651: 1993). Depending on these characteristics, the SLM is appropriately set (provided its detector response is selectable). The applicable noise measurement standard normally prescribes the detector response setting for a particular situation or type of measurement. However, the norm is to use:

- "F" or fast characteristic for fluctuating noise where it is important to determine the highest level occurring during the measurement time interval;
- "S" or slow characteristic for continuous noise of constant amplitude, and
- "I" or impulse characteristic (I-time weighting) where impulse noise is present.

acoustic filter set: a device that allows the measurement of sound within a selected range of frequencies, while largely excluding the effects of sound outside that range. This enables a determination of the nature of a sound signal, e.g. predominantly low, medium or high frequency, or broad-spectrum (mixed frequencies) sound. Depending on the design of the SLM, some filters are incorporated into the instrument and can be switched "in" or "out", while others can be detached from the SLM when not required for easier handling. The two most common types of filters are octave-band and 1/3-octave-band filters, capable of broad-band and narrow-band frequency analysis, respectively.

personal sound exposure meter or **noise dosimeter**: an integrating or averaging sound measurement device worn by a person for a representative period of time to determine the level of noise exposure. These instruments are useful in assessing exposure for individuals not having fixed workstations (e.g. maintenance and supervisory personnel), those working where noise levels are variable, and for individuals identified as being susceptible to noise-induced hearing loss.

microphone: a transducer that converts variations in air pressure into electrical signals that can be analysed and measured as sound pressure levels by a SLM or by a SLM and acoustic filter set.

Microphones for SLMs are classified into three different types based on their general characteristics, which dictate the applications for which they can be used:

- Free-field microphones, designed to compensate for the geometrical effect that their presence has on the sound field, are used where the sound emanates from one direction only. A free field microphone should, ideally, be directed towards the source. It essential to avoid the effects of reflected sound when using this type of transducer, hence the general requirement to position the microphone not less than 1,5 m from any sound-reflecting surface such as walls, windows, etc. (SABS 083: 2000).

- Pressure microphones do not compensate for their presence in the sound field and their use is generally restricted to calibration applications, where sound pressure is measured inside an acoustic cavity, e.g. during the calibration of audiometers and their transducers, using an artificial ear. Pressure microphones can also be used where it is possible to ensure that the surface of the microphone's diaphragm is perpendicular to the direction of sound propagation.

- Random incidence microphones, which compensate to a limited extent for their presence in the sound field, are for use in a diffuse or reverberant field where sound emanates randomly from all directions. Such applications would include measurements inside a reverberant room having smooth, reflective surfaces and a regular shape, as well as measurements in a reverberation chamber, as found at acoustic laboratories.

A sound level meter or noise dosimeter is normally supplied with a microphone that is appropriate for general sound measurements, i.e. a free-field microphone suitable for normally encountered intensity and frequency ranges. The observer should ensure that the performance of such microphones and the accuracy of measurement results are not negatively influenced by his or her presence in the sound field, implying the need to stand well behind the microphone. It is also important to avoid the influence of reflective surfaces.
For specialised applications, including instances where unusually high or low frequency or unusually high intensity sounds must be measured, the SLM manufacturer should be consulted regarding the choice of microphone.

microphone windscreens and turbulence screens: these are accessories provided by microphone manufacturers for use where air movement is likely to generate flow noise at the microphone's diaphragm. This is most common outdoors, but can also occur in artificial ventilation streams. Windscreens also provide limited protection for the microphone against shocks and bumps, although this should never be relied upon. Where high air velocities exist, a turbulence screen or a purpose-designed nosecone should be fitted to the microphone, both of which should be supplied by the microphone manufacturer for the specific microphone being employed.

acoustic calibrator: a device that produces an acoustic signal of specified frequency and intensity, used to confirm the accuracy of a SLM or noise dosimeter before and after each series of sound measurements. Most sound measuring instruments have a trim adjustment to match the instrument's display to the known level of signal being emitted by the acoustic calibrator.

Two types of acoustic calibrators are available, viz. piston phones, which contain a mechanical signal source, and sound level calibrators, which incorporate an electrical signal source.

3 Measurement of noise and noise exposure

The purpose, instrument requirements and measurement procedures for various applications are considered in their respective sub-sections, which follow.

3.1 Purpose of measurements

Valid risk assessments and appropriate risk management interventions are dependent on accurate measurements. Risk assessments necessarily entail the determination of impairment risks to employees and financial risks to employers, the latter relating to compensation claims. Interventions to manage risk should be based on the identification of critical sources of exposure (including machinery and activities) and their prioritisation for corrective measures. Prioritisation should consider not only the level of noise emitted or the resulting exposure levels, but also the number of employees affected.

"Before and after" comparisons to evaluate the effectiveness of interventions to reduce noise and resultant exposure levels, as well as benchmarking comparisons among employers' noise reduction programmes, require accurate results derived from the uniform application of standardised measurement procedures.

A longer-term benefit to be derived from valid and comparable noise measurements would be the ability to refine established dose-response models in accordance with NIHL effects on local employees. This would allow more accurate predictions for the extent of hearing loss resulting from a given level and duration of exposure, enabling more accurate risk assessments and a better determination of likely requirements for meeting future compensation claims. It could also provide a basis for encouraging employers to control the risk of hearing impairment, by linking the level of compensation insurance premiums to the level of risk imposed on employees.

Accordingly, this section provides guidance in the measurement, recording and assessment of noise and exposure levels, to ensure the validity and comparativeness of results, the appropriateness of management interventions based on them, as well as the accurate determination of future compensation requirements.
Measurements should obviously be made for major sources of noise, but should also consider those activities and operations that contribute to employees' exposure. Where an offending machine may not be so amenable to noise reduction treatment, it may be possible to devise alternatives for the way in which work is performed or the sequencing and scheduling of operations to minimise employees' exposure to major sources. As is the case for major noise sources, activities and operations that contribute to exposure should also be prioritised for corrective measures, based on the level of emissions, the number of people affected and the duration of their exposure.

3.2 Instrument precision

The current (fourth) revision of SABS 083 (2000) stipulates a requirement for Type 1 precision (SABS IEC 60651 and 60804) for sound measuring instruments used to assess occupational exposure. The third revision of the same standard also specified Type-1 precision, but its second revision (1983, as amended in 1986 and 1989), which replaced the original SABS 083: 1970, stated that in cases of dispute, measurements taken with instruments that comply with the requirements for Type 1 precision are adequate. This was generally interpreted to mean that for occupational assessment purposes where there was no dispute, Type 2 instruments are adequate.

Accuracy requirements for the various Types or precision grades of sound measuring instruments are defined by SABS IEC 60651 for sound level meters, SABS IEC 60804 for integrating sound level meters, IEC 1252 for personal sound exposure meters and SABS IEC 60942 for acoustic calibrators. The levels of precision identically stipulated by all of these standards are indicated in Table 3.2.a.

Table 3.2a
Level of precision and description for various instrument Types

Type	Description	Precision (dB)
Type 0	Laboratory reference grade	± 0,4
Type 1	Precision grade	± 0,7
Type 2	General purpose grade	± 1,0
Type 3	Field survey grade	± 1,5

While instrument precision is indisputably important in accurately determining noise and exposure levels, the absolute precision of the measurements is not the only requirement for valid and accurate occupational exposure assessments. The sampling strategy applied in performing those measurements can have far greater impact, particularly in the case of parameters as intrinsically variable as workplace noise and worker exposure levels.

SABS 083: 2000 stipulates an energy-doubling rate of 3 dB, indicating that a 3-dB increase in sound level results in a 100 per cent increase in the energy being emitted (or immitted in the case of exposure). Accordingly, the 0,3-dB improvement in accuracy that results from using Type 1 instruments rather than Type 2 devices (1,0 dB minus 0,7 dB) represents an overall accuracy improvement of 10 per cent (0,3 / 3 × 100). It cannot be disputed that such an improvement is significant, but it is at considerable financial cost to employers, which is arguably less significant than other costs involved.

Use of Type 1 instruments effectively imposes constraints on the number of measurements that can be made owing to the fact that Type 1 SLMs typically cost 50 per cent more than otherwise similar Type 2 devices. Accordingly, a given budget allocation for sound measuring equipment will only provide two-thirds as many Type 1 instruments as Type 2 devices (1 / 1,5 = 0,67 or 2/3). Assuming that an employer uses his entire instrument budget to purchase instruments and that all instruments are fully utilised, Type 2 devices will provide 1½ times as many samples as Type 1. Workplace noise and noise exposure levels are parameters that vary according to a number of operational and performance factors, to the extent that experts regard results corresponding within 2 dB to be comparable and indicative of confirmation. In quantifying such intrinsically variable parameters, it is clearly more beneficial to increase the total number of samples by 50 per cent, than it is to improve the accuracy of individual samples by 10 per cent.

A further argument for allowing the use of Type 2 instruments is that the cost of microphone replacement is only one-fourth that for a Type 1 instrument, and the microphone is certainly the most vulnerable part of a SLM. In the event of a damaged transducer the SLM becomes unavailable for measurements, and is more likely to remain so for a longer period if the replacement cost is four times as great. While not as significant as microphone replacement costs, electro-acoustic calibration (required annually in terms of SABS 083: 2000) is slightly more expensive for Type 1 instruments, due to the increased time required for more stringent accuracy checks.

To further consider the issue of Type 1 vs. Type 2 precision, it is useful to examine the requirements for instrument accuracy in other countries, as summarised in Table 3.2b.

Table 3.2b
Instrument accuracy requirements in various countries

Country	Minimum level of accuracy required for occupational noise measurements	Source(s) and applicable standards
Australia and New Zealand	Type 2 for noise assessments and Type 3 for preliminary checks	**Standards Australia/Standards New Zealand:** AS/NZS 1269.1: 1998: SLM: AS/NZS 1259.1, and AS/NZS 1259.2; PEM: AS/NZS 2399
Canada	Type 2 for industrial field evaluations (Type 1 is characterised as for engineering, laboratory and research measurements)	**CCOHS, 1998**
Italy	Type 1	Personal communication from Paul James, Managing Director: Quest Technologies
Singapore	Type 1	Personal communication from Paul James, Managing Director: Quest Technologies

South Africa	Type 1	**SABS 083: 2000:** SLM: SABS IEC 60651 and SABS IEC 60804 Use of PEMs not permitted for rating level but is permitted for exposure level
United Kingdom	Type 2	**British Standards Institute: BS 5969: 1991:** SLM: IEC 60651 and IEC 60804 PEM: IEC 61252
United States	Type 2	**ACGIH:** MIL-STD-1474C:1991: SLM: ANSI S1.4-1983 & IEC 804 PEM: ANSI S1.25-1991 & IEC 804 **NIOSH:** DHHS 98-126 and ANSI S12.19-1996: SLM: ANSI S1.4-1983 & ANSI S1.4A-1985 PEM: ANSI S1.25-1991 **MSHA:** FR Vol. 61 No. 243 (1996): SLM: ANSI S1.4-1983 PEM: ANSI S1.25-1991
International	Type 2	**ISO 1999: 1990 & ISO 9612: 1997:** SLM: IEC 60651 and 60804; PEM: IEC 61252

ACGIH American Conference of Governmental Industrial Hygienists
ANSI American National Standards Institute
AS/NZS Australian/New Zealand Standard
BS British Standard
CCOHS Canadian Centre for Occupational health and Safety
ISO International Standards Organisation
NIOSH National Institute of Occupational Safety and Health
MSHA Mine Safety and Health Administration
PEM personal exposure meter
SLM sound level meter

An inspection of Table 3.2b clearly indicates that the requirement for Type 1 accuracy for occupational noise measurements is an exception rather than the norm. Whether the reasons for this relate to an appreciation of the need for large numbers of samples or to the acceptance of $\pm$1 dB accuracy is unclear. What is clear, however, is that Type 2 precision ($\pm$1 dB) is adequate for monitoring parameters that are likely to vary by $\pm$2 dB on a day-to-day basis, as is the case in many workplaces. This is particularly true when use of Type 2 instruments would allow a larger sample size, clearly the best strategy for addressing the intrinsic variability of the parameters being measured.

Bearing in mind that the preceding discussion applies to risk assessment and occupational hygiene monitoring applications, for engineering purposes and to resolve cases of dispute regarding noise or exposure levels, Type 1 instruments should be used.

3.3 Instrument calibration requirements

Irrespective of the Type or precision of instruments used, the accuracy of sound measuring devices and their associated calibrators should be regularly confirmed by means of electro-acoustic calibration checks. These should be performed by a suitably equipped and certified laboratory or institution that complies with the requirements of SABS 0259: 1990. Such calibrations must be traceable to the National acoustics standard, in accordance with the Measuring Units and National Measuring Standards Act, (Act 76 of 1973), as amended by the Measuring Units and National Measuring Standards Amendment Act (Act 24 of 1998) (SABS 083: 2000).

The purpose of calibration checks is to confirm that an instrument still retains its original level of precision (as specified by the manufacturer), be it Type 1, Type 2 or otherwise. SABS 083: 2000 stipulates that all items of equipment used for measuring occupational noise must be calibrated at intervals not exceeding one year.

It may be noted that ISO 9612: 1997 makes the recommendation that intervals between laboratory calibration checks not exceed three years. While it might be argued that annual checks impose a burden on employers in terms of cost and instrument availability, it should be recognised that the value of accurate measurements and the implications of basing management interventions and expensive noise control measures on invalid results are considerable. Where an instrument is fully utilised for its intended purpose, it will frequently be exposed to the risk of damage, either by mechanical shock, extremes of temperature, humidity and (in the case of mining) barometric pressure, or by chemical contaminants. Such hazards are particularly relevant to microphones, which may still give the appearance of normal function when their responsiveness to varying sound pressures and their linearity of output have changed. Such effects are most reliably detected by electro-acoustic calibration checks. Accordingly, the accuracy of all sound measuring and associated instruments (e.g. acoustic calibrators and sound recording devices) should be confirmed on an annual basis, as stipulated in SABS 083: 2000.

3.4 Noise measurements by manufacturers and suppliers

Local legislation for all spheres of industrial enterprise imposes “duty of care” responsibilities on manufacturers of machinery and equipment (Mines Health and Safety Act, 1996 and Occupational Health and Safety Act, 1993). Accordingly, it is incumbent upon manufacturers to assess the potential risks imposed on users of their products, in the present instance, to quantify the level of noise emissions and estimate likely levels of immission for exposed persons. Such assessments should also serve as the first step to identifying means of reducing noise emissions, either through the redesign of machinery or the addition of noise reduction modifications.

Given the potential for large numbers of employees deployed by many employers to be exposed to the risk of NIHL from a given type of machine, the quantification of noise levels by manufacturers effectively represents a global risk assessment. It then follows that such assessments should be conducted as precisely as possible. The other requirement, to assess the need and identify opportunities for noise reduction, also depends on a high level of precision, to ensure that expensive re-engineering and design initiatives for product refinement are based on precise and valid measurements. This indicates that Type 1 precision is essential for the noise measurements and assessments required of machinery and equipment manufacturers for their products.

3.4.1 Quantification of emission levels

The diversity of machinery and equipment deployed in the many and varied types of industrial operations, as well as the manner in which such products are used, results in a multitude of different application situations. Detailed descriptions of measurement and assessment procedures for such a range of product applications is clearly beyond the scope of the present annex. However, guidance is offered in the form of references to relevant standards for noise measurement (appended), and it would be for manufacturers to determine which of these provide the most appropriate basis for assessing noise emissions from their products. In addition to the appended list of standards, general criteria for such assessments would be that:

- The product being tested is representative of what is supplied to purchasers, in terms of its specifications and any ancillary equipment included with it
- The product is operated during the noise emission tests in a manner that is typical of its normal application or, where such a condition is difficult to define, that it is operated in accordance with its intended purpose and the manufacturer's instructions as provided to purchasers
- Where a product is commonly used for a number of applications, the manufacturer should endeavour to conduct tests under the various conditions appropriate for such applications, in order to provide potential users with representative assessments that indicate likely emission and exposure levels
- Where optional noise reduction modifications or enhancements are available, the product should be tested both with them and without them, to enable potential purchasers to assess the likely benefits of any noise reduction options offered
- Where the range of potential applications for a product is such that specific situations of use are likely to impose environmental effects on the accuracy or representativeness of measurements (e.g. a product that could be used either in a confined space or in a free-field situation), consideration should be given to the use of sound power determinations, in preference to traditional sound pressure level measurements

It should be recognised by manufacturers that the primary purpose for quantifying machinery emission levels is to evaluate the need for noise reduction measures and, where indicated, to determine suitable means of addressing such needs. If deemed necessary for the purpose of risk control, or useful to gain market advantage, such measures are best incorporated into standard machinery through design changes or standard add-ons or, alternatively, by offering them as additional-cost options.

3.4.2 Determination of spectral characteristics

Determining the spectral or frequency characteristics of machinery noise emissions is intended to:

- Determine the nature (frequency distribution) of noise emissions, thus enabling the systematic identification of specific sources of noise within the machinery,
- Enable the prioritisation of sources within the machinery for possible noise reduction measures,
- Provide information essential for devising appropriate means of noise reduction
- Analytically evaluate the effectiveness of noise reduction measures and enable appropriate refinements,
- Demonstrate the benefits derived from noise reduction measures, incorporated into the machinery or made available as added-cost options (In the latter case, such information should inform potential users, to better enable decisions regarding the purchase of noise control options), and
- Once all feasible possibilities for at-source noise reduction have been exhausted, to determine specific requirements for transmission control and/or personal protection, in order to fully inform (potential) users of risk control requirements.

For the same reasons cited with regard to determination of emission levels, frequency analysis measurements by manufacturers should employ Type 1 SLMs and microphones, in conjunction with Type 1 octave- or one-third-octave-band filter sets (as appropriate) that comply with the requirements of IEC 61260. The nominal frequencies for octave- and one-third-octave-bands should comply with those stated in ISO 266: 1997, *Acoustics-Preferred frequencies*.

While broad-band octave analysis may be adequate for relatively simple machinery, narrow-band one-third-octave analysis should be employed for machinery that is more complex in terms of having a greater number of noise-producing components. The more detailed information provided by such methods ensures a better basis for sub-source determination and prioritisation, as well as for devising appropriate noise reduction measures and later evaluating them. However, where frequency analysis results are intended to determine personal protection requirements for exposed persons, octave-band analysis should be used, since attenuation values for hearing protection devices are stated in terms of octave-band.

Specific procedures for frequency analysis will depend on the standard being applied, which will be dictated, in turn, by the specific purpose of the measurements. For defining the spectral characteristics of noise emissions in order to inform purchasers, the procedures applied in determining emission levels would generally dictate those for frequency analysis. For engineering applications, where the purpose is to investigate or evaluate noise reduction measures, more specialised procedures would apply. In this regard, manufacturers should consult the various standards referred to in Section 3.4.1, in order that the one(s) most appropriate for the intended purpose can be identified.

3.4.3 L_W determination as an alternative to conventional SPL measurements

It will be noted from their titles, that some of the standards listed in Section 3.4.1 relate to the quantification of sound power level (L_W). Such determinations involve specialised measurement procedures, sometimes at greater immediate cost than what would be incurred for traditional sound pressure level (SPL) measurements, a result of the requirement either for specialised sound intensity measurements performed *in situ*, or exhaustive SPL measurements performed in a reverberation room. However, the advantage of quantifying a source's sound power level is that it provides an absolute quantification of the sound energy emitted by that source, irrespective of the acoustic environment (e.g. reflective or absorbent surfaces, the presence of other sources, etc.). This is in contrast to traditional SPL measurements that quantify the *effect* of noise emissions in a given acoustic environment, which varies with the environment in much the same way that a heater or air conditioner will produce a different effect (i.e. air temperature) in a different situation.

It is normal practice to characterise heating or cooling appliances in terms of their capacity (in watts), rather than the temperature that they are capable of maintaining (which will vary according to the situation). The appliance's likely effect on air temperature in a given situation is then determined on the basis of standard calculations and experience. Where the power of sound being emitted has been quantified (in watts or sub-units thereof, but more often as a *level*, L_W, in decibels or sometimes in bels), its effect in terms of mean SPL can be accurately predicted for a given enclosed acoustic environment, according to the following relation (Hassall and Zaveri, 1979):

$$L_W = L_p + 10\log_{10}\left(\frac{Q}{4\pi r^2} + \frac{4}{R}\right) \qquad (15)$$

where: L_W is the sound power level, in decibels;

L_p is the mean surface sound pressure level, in decibels, over the test hemisphere (an imaginary hemispherical enclosure surrounding the source, used to establish microphone positions);

Q is the directivity factor (detailed in the various standards);

r is the radius of the test hemisphere in metres (i.e. the distance of the microphone from the source), and

R is a constant determined by the sound absorption of the room's surfaces.

In practice, a determination of R must be made for the room or area where the source will be located, which requires knowledge of the room's volume, V in m^3; its total surface area (walls/windows, floor and ceiling), A in m^2; and its reverberation time (measured), T in seconds. R is then calculated according to the following relation (Hassall and Zaveri, 1979):

$$R = \frac{V}{\frac{T}{0{,}16} - \frac{V}{A}} \tag{16}$$

While relationships (15) and (16) enable the use of a machine's sound power level to predict sound pressure level in a given enclosed area, predictions for a free-field environment can be based on a 6-dB reduction in sound pressure level for every doubling of distance. However, it should be recognised that this assumes there are no reflecting surfaces in the sound field, as these would result in actual sound pressure levels being somewhat higher than predicted, to an extent determined by the size of such surfaces and their proximity to the source and the microphone position. Such discrepancies are typically of the order of 1 to 2 dB.

Sound power level determinations offer other practical advantages when performed by means of *in situ* sound intensity measurements. First of all, accurate measurements for a given machine are possible while others are operating, even when extraneous sources are as much as 10 dB louder than the one being considered. Accordingly, there is normally no need to shut down other equipment, which could interfere with operations where the machinery being assessed has already been installed. Where the source in question can only operate in conjunction with other equipment, *in situ* sound intensity measurements would also be the best means of accurately determining a source's sound power level.

Similarly, sound intensity measurements can be made for specific sub-assemblies and components within the machinery being considered while excluding the effects of others. This is particularly advantageous where it is desirable to individually evaluate and prioritise parts of a machine for noise reduction treatment. The same advantage would apply to evaluating the effects of noise reduction measures: noise from other sources in the machinery normally has no effect on the accuracy of measurements for the specific component or sub-assembly being considered. Furthermore, octave- and one-third-octave-band analysis of sound power level provides frequency-specific information that is directly applicable to the determination of transmission control requirements, whether by absorption, isolation or enclosure.

Determining the sound power level for a particular noise source provides an absolute quantification of its noise emissions independent of the acoustic environment, enabling an accurate prediction of sound pressure levels at various distances from the source in a given environment. This enables considerable cost savings by eliminating the need for a specific assessment of the machinery in each different situation, clearly an advantage for equipment used for a range of different applications. In addition, quantification of sound power level greatly reduces the chance of discrepancies between specified and actual emission levels and, hence, the potential for disputes between manufacturers and purchasers.

3.5 Noise measurements by employers

The Mine Health and Safety Act (1996) and the Occupational Health and Safety Act (1993) both require employers to assess the health and safety risks that hazards pose to their employees, and to take all reasonably practicable steps towards eliminating or controlling those risks. Such assessments involve the measurement of hazard levels, in the present case, noise, for which two basic parameters must be quantified. Firstly, the level of noise that prevails in the workplace and, secondly, the level of exposure for employees, the latter being a function of noise level, proximity to the source and duration of exposure.

3.5.1 Purpose

Noise measurement should not be seen as an exercise culminating only in the submission of a routine report, but recognised as part of the risk assessment process and providing the primary basis for addressing the hazard through constructive risk management interventions. These can be summarised as:

- Identification of major noise sources (machinery) and activities (operations and tasks) that contribute significantly to worker exposure

- Prioritisation of noisy machinery (for possible reduction and/or transmission control measures) and activities that contribute significantly to worker exposure (for possible changes in task design or means of execution), both on the basis of noise level, number of employees exposed and the relative duration of their exposure
- Evaluation of requirements for and the feasibility of noise reduction and/or transmission control measures for all noise sources and activities identified as significant contributors to worker exposure
- Evaluation of the appropriateness of personal protection provided for exposed persons, and identification of more suitable protection where indicated
- Investigation of extreme or questionable personal exposure results and unfavourable audiometric results or trends, in order to identify and resolve the cause
- Confirmation of emission levels for new/refurbished machinery, and implementation of quality control noise measurements for significant sources of exposure to determine emission levels subsequent to routine maintenance and repair

3.5.2 Instrument accuracy and calibration requirements

For reasons discussed in Section 3.2, Type 2 precision is regarded as adequate for the routine assessment or monitoring of occupational noise and employees' exposure to it. Applications where Type 1 precision is preferred include engineering measurements to inform employers' noise control initiatives. Type 1 precision is essential for resolving disputes, either between an employer and an equipment manufacturer regarding machinery emission levels, or between the employer and a regulatory authority or employee regarding employee exposure levels.

As stated in Section 3.3, irrespective of the purpose of measurements or precision level of instruments used, all sound measuring equipment should be subjected to annual electro-acoustic calibration checks, performed by an approved laboratory in accordance with relevant standards and legislation.

3.5.3 Identifying causes of exposure to enable effective intervention

It is not sufficient to simply quantify noise and exposure levels associated with various machinery, workplaces and occupations, as this provides only limited insight into specific causes of employee exposure. Without a clear understanding of these specific causes, means of ameliorating their impact will remain elusive, exposure levels will remain high, and employees will continue to incur hearing loss.

3.5.3.1 Requirements for effective intervention

Interventions to reduce the risk and the occurrence of noise-induced hearing loss must be based on:

- Identification and prioritisation of specific activities and operations that significantly contribute to exposure and the quantification of noise levels, determining whether:
  - Machinery associated with the operation in question is amenable to noise reduction or transmission control measures
  - Alternative machinery or processes can do the job more quietly, or with fewer people being exposed
  - Adjacent machinery and activities extraneous to the operation in question contribute to noise exposure, and if so:
    - whether measures to reduce noise or control its transmission are feasible
    - whether such machinery/activities or the operation in question can be relocated
    - whether one of the coinciding operations can be alternatively scheduled
- Duration of activities and operations that contribute significantly to worker exposure, and then determining whether:
  - Alternative machinery or processes can do the job in less time or with fewer people being exposed
  - Individual employees' involvement in such operations can be limited to a shorter period through worker rotation
- Evaluation of personal protection provided for employees with regard to its:
  - Acceptability;
  - Adequacy, and
  - Appropriateness,

  particularly where reduction, relocation or replacement of noise sources; control of noise transmission; rotation of employees; and relocation or alternative scheduling of coinciding activities/operations (as contemplated above) are not feasible, or cannot achieve the required reductions in employees' exposure.

Determinations made during the assessment process summarised above should result, not only in the identification and prioritisation of significant contributors to employees' noise exposure, but also provide information to enable effective interventions aimed at reducing exposure and associated risks.

3.5.3.2 Employee input to identify causes of exposure

Identifying the sources and activities that contribute most significantly to employees' noise exposure is best accomplished by appropriate and accurate measurements, as well as by gathering information from employees, including work-study personnel, supervisors, and exposed employees themselves. Such inputs can be used to determine the amount of time employees spend in close proximity to major noise sources, and in performing various tasks and activities. When this information is combined with the results of noise measurements for those sources and activities, it becomes possible to identify significant contributors to employees' exposure. These can then be prioritised according to their relative impact on individual exposure levels (which would be a function of noise level, proximity to the source and duration of exposure) and the number of people affected, so that the most significant contributors can be targeted for amelioration.

Personal noise dosimetry is a valuable means of identifying activities and noise sources that constitute the most significant contributors to worker exposure, particularly if the instruments used perform real-time data logging. This issue is discussed in Section 3.5.8.3.

3.5.4 General guidelines and generic procedures for noise measurements

The subject of noise measurements, e.g. a source, area or operation/activity/task, as well as their purpose, e.g. assessing impact on employees' exposure or the feasibility/ effectiveness of noise control measures, will determine the actual measurement procedures to be used, but more particularly, the method of their application. Measurement procedures applicable to source, area, activity and personal exposure assessments are detailed in Sections 3.5.5, 3.5.6, 3.5.7 and 3.5.8, respectively, and their sub-sections. The present section (with its sub-sections) provides general guidelines for sampling, describes the preferred parameters for measurement and generic procedures relevant to most applications and measuring instruments.

3.5.4.1 Representativeness of measurements

An issue of critical importance to all noise assessments, regardless of their purpose and application, is the representativeness of results. The intrinsic variability of noise in many workplaces indicates that the duration of the measurement interval and its alignment with typical operations and work cycles are far more critical to the validity of assessments than is the absolute accuracy or precision of the measurements.

For continuous and steady noise, i.e. noise that is uninterrupted and unvarying/non-fluctuating (e.g. a fan that is always on and not subjected to varying loads), it is a simple matter to obtain representative results. For sources that are not always running but when doing so run steadily, it is also relatively easy to ensure that all measurements are performed only while the source is operating. Sources that operate intermittently and varyingly (e.g. machinery subjected to varying loads, such as diesel-powered mobile equipment) are the most difficult to assess. In such instances it is best to determine the periodicity of the operation by establishing its normal cycle, and then ensure that the measurement interval encompasses at least one and preferably several complete operating cycles. The observer's familiarity with the operation in question or prior consultation with supervisory/operating personnel should enable the determination of appropriate measurement intervals that coincide with typical workplace operations.

3.5.4.2 Preferred parameters for measurement

The basic acoustic parameters to be quantified during noise assessments will depend on the specific purpose of the measurements.

Emission and transmission of noise by sources and noise level for areas and activities

To determine emission levels and transmission of noise from sources, and prevailing noise levels for areas and activities, the preferred parameter is equivalent continuous A-weighted sound pressure level, $L_{Aeq,\ T}$, which for a nominal 8-h working day becomes $L_{Aeq,\ 8h}$.

Frequency-weighting

By definition, the measurement of $L_{Aeq,\ T}$ requires the use of A-weighting. Accordingly, the observer must ensure the A-weighting network is enabled when using a SLM that allows the frequency-weighting network (A, B or C) to be selected or switched off entirely. For instruments where frequency weighting cannot be selected or switched off, A-weighting is invariably applied to measurements as the factory default.

Time-weighting

Where $L_{Aeq,\ T}$ is measured with an integrating/averaging sound level meter, which is preferable since it removes the need for composite time/event measurements and subsequent calculations, the instrument's time-weighting should be set to "I" or "Impulsive" in all instances (SABS 083: 2000).

Conventional non-integrating or non-averaging sound level meters should normally be set to "F" or "Fast" (ISO 1999: 1990). Exceptions are when determining the appropriate correction factor for impulse noise, which requires the comparison of measurements made with "S" and "I" settings (SABS 083: 2000). The general principle to apply when measuring noise level is to match the instrument's time-weighting to the noise being measured, with "S" being adequate for continuous steady noise, "F" being preferable for fluctuating or variable noise, and "I" being essential for accurately measuring impulse noise. The response times for these three settings are defined as 1 s, 125 milliseconds (ms) and 35 ms, respectively (SABS IEC 60651).

Exposure level for employees

Quantification of employees' exposure, particularly to estimate the risk of hearing loss, is best done by determining the A-weighted sound exposure for a stated time interval T, ($E_{A,\ T}$). For a representative 8-h working day this parameter becomes $E_{A,\ 8h}$ and is numerically equivalent to the noise exposure level normalised to a nominal 8-h working day, $L_{EX,\ 8h}$. Parameters that are equivalent to the preceding two and have corresponding meanings include the 8-h time-weighted average (TWA_{8h}) and equivalent noise exposure (N_{eq}), with all four of these parameters having values that are numerically equal for a nominal 8-h working day.

For employees having fixed working locations near steady and continuously operating noise sources, determining exposure is a simple matter of measuring L_{Aeq}, as this parameter will be numerically equal to the various parameters for quantifying exposure relative to a nominal 8-h working day. Accordingly, in such cases a SLM measurement made for a representative period at the employee's position will indicate his or her exposure level. The measurement interval should be of sufficient duration to encompass a reasonable number of operating cycles for the task or machinery being considered.

Where work activities and resulting noise levels are variable, and particularly where individuals do not have fixed working locations, employees' exposure levels are most accurately determined by means of a personal sound exposure meter/noise dosimeter (ISO 1999: 1990 and ISO 9612: (1997). This indicates the merits of personal noise dosimetry, despite the restrictions placed on its use by SABS 083: 2000.

3.5.4.3 Generic procedures for the preparation of sound measuring instruments

In the case of integrating sound level meters and personal noise exposure meters, it is essential that the instrument's internal settings be in accordance with local criterion levels. These are stipulated in SABS 083: 2000 as:

- Exposure limit: 85 dB
- Low threshold limit: 80 dB
- Energy exchange or doubling rate: 3 dB

The instrument supplier should have made these settings prior to delivery, but the user is advised to confirm them, by first consulting the manufacturer's instructions and then examining the instrument.

Instruments should be in good operating condition and equipped with serviceable batteries. In this regard, it is good practice to carry a spare set of batteries for all instruments, including the acoustic calibrator. All instruments (particularly microphones and calibrators, which are susceptible to condensation) should be allowed to reach the ambient temperature of the measurement area before being switched on, and then allowed to "warm up" for a period sufficient to ensure stable readings.

Sound measuring instruments and their microphones should be field-calibrated by the user immediately prior to commencing measurements, and calibrated again immediately after completing them. Where the results of the pre- and post-measurement field calibrations differ by more than 1,0 dB, results from the intervening noise measurements should be discarded, and the cause of the apparent instrument instability investigated. General procedures for the field calibration of sound level meters are provided below. Corresponding procedures for personal noise exposure meters are provided in Section 3.5.8, which deals specifically with noise dosimetry.

Settings for field calibration of sound level meters

Where the instrument has selectable functions, they should be set as indicated:

- Display/parameter to be measured: "SPL" (sound pressure level)
- Detector response/sampling method: "RMS" (Root-mean-square) and not "Peak"
- Loudness or full-scale deflection (FSD): set to accommodate (i.e. not be exceeded by) the calibrator's output level, e.g. 100 dB for a 94-dB calibration signal or 120 dB for a 110- or 114-dB signal
- Filter "Out". (The filter can be switched "In" and set to the frequency that corresponds with the calibrator's output (e.g. 1 000 or 250 Hz), to exclude possible effects of extraneous noise, but performing the field calibration in a reasonably quiet environment, in accordance with good practice, should render the filter irrelevant in such an environment, as the level of the calibrator's signal would greatly exceed that of any background noise
- Frequency-weighting: normally irrelevant, but "Linear" (no weighting) should be used, unless the manufacturer's instructions indicate otherwise
- Time-weighting: "Fast", unless the manufacturer's instructions indicate otherwise
- Microphone response/incidence or directionality of sound being measured: "Frontal", irrespective of the incidence of the sound that will ultimately be measured

Calibration of sound level meters

Remove the microphone windscreen (if fitted), carefully and slowly fit the calibrator over the microphone and switch the calibrator on, allowing the meter's display to stabilise. The instrument's display must be adjusted to correspond with the known output of the acoustic calibrator, by using a small screwdriver to turn the sensitivity adjustment/ calibration trim pot. The calibrator's output (in terms of level and frequency) is normally indicated by a label affixed by the manufacturer, and confirmed during the device's annual electro-acoustic calibration check.

The calibrator should be fitted to the microphone and removed slowly, to avoid generating large pressure changes that could damage the microphone's diaphragm. For similar reasons, one should never blow onto or across a microphone.

3.5.5 Assessment of noise sources

Two types of assessments are considered in this section, viz. those for determining potential impact on employees (OH measurements), and those aimed at investigating requirements for or evaluating the effectiveness of noise reduction and transmission control measures (engineering measurements). Both applications require the use of a sound level meter (SLM), while the second also requires frequency analysis, to adequately describe the noise and determine requirements for controlling it (using either an octave- or one-third-octave-band filter). It should be noted that Type 1 precision is preferred for engineering measurements, to better enable appropriate control measures without expensive trial and error.

The general requirements and guidelines for noise measurement described in Sections 3.5.2 and 3.5.4 (including sub-sections 3.5.4.1 to 3.5.4.3, as relevant to the specific application for measurements) are applicable to the procedures described in the sub-sections that follow.

3.5.5.1 Determining potential impact on employees

Measurements for source assessment are most often intended to quantify the level (and where instrumentation allows, the spectral characteristics) of noise emissions, in order to determine potential impact on employees and prioritise sources for possible noise reduction or control measures. Different sources will require different measurement strategies, as discussed below.

"Large or major" sources

The assessment of sources to determine their potential impact on employees requires that microphone positions correspond with those likely to be occupied by employees, and that for "large" or major sources (those to which several individuals are exposed), a number of measurements be made at various locations as appropriate. The presence of employees will normally have no appreciable effect on the sound field of a "large" source, provided the transmission path (between the source and the microphone) is not obstructed during measurements.

Distant sources

Where noise attributable to a given source remains considerable at distant locations (either as a result of high emission levels or "efficient" sound transmission) it will be necessary for measurements be made at distant positions. These should be in accordance with positions normally occupied by employees, and without obstruction of the transmission path by employees unless dictated by their normal working positions. In any case, the observer should not obstruct the noise transmission path.

"Small or minor" sources

Measurements for "small" or minor noise sources (those to which a small number of people are exposed) are particularly sensitive to the presence of persons in the sound field and, accordingly, such presence should be avoided if possible. Where this requirement cannot be met or is inappropriate (due to workers' normal positions), it will still be essential for the observer to avoid obstructing the transmission path. To this end, use of a tripod to support the SLM in the appropriate position will enable the observer to remove himself/herself from the sound field.

Measurements for "small" sources are also very susceptible to the effects of reflecting surfaces. Accordingly, the microphone should be positioned at least 1,2 m from such surfaces (SABS 083: 2000), unless the source being assessed is normally operated or attended to by a employee, in which case the employee's normal position will dictate microphone placement, irrespective of reflective surfaces.

Where a source is operated or attended to by an individual specifically allocated for that purpose, the microphone should be situated at the position normally occupied by the person's head, preferably without the person being present. Where operational requirements dictate the person's presence, or where the source requires an operator to enable representative measurements, the microphone should be positioned approximately 0,10 m from the entrance of the more-exposed ear (the ear closer to or more-directed towards the source) (ISO 9612: 1997) and directed towards the source.

Measurement procedures

The general requirements and guidelines for noise measurement provided in Sections 3.5.2, 3.5.4 (including subsections 3.5.4.1 to 3.5.4.3) and 3.5.5, as well as those relevant to various types of sources as discussed in the present sub-section are applicable.
Select the appropriate instrument settings in accordance with specific requirements, which for assessing potential impact on employees indicates the need for A-weighting. Other settings, if available, should be as follows:

- Detector response: "RMS"
- Time-weighting: as appropriate: "I" for integrating/averaging SLMs (SABS 083: 2000) and "F" for conventional non-integrating SLMs (ISO 1999: 1990)
- Filter: "Out" or "Off"
- Sound incidence: as appropriate, i.e.:
  "Frontal" where noise exposure can be attributed to a single source and where there is little or no reflected sound reaching exposed employees; or
  "Random" in the case of multiple sources or significant reflection causing noise to reach the employee from a number of directions
- FSD: as appropriate for the prevailing noise level, ensuring that a higher range is selected where any overload is observed.
- Display: L_{Aeq} or L_{eq} (which becomes L_{Aeq} with A-weighting enabled) if available, otherwise SPL (again with A-weighting enabled)

The observer should make a sketch of the location where measurements are to be made, clearly indicating the positions of and distances between noise sources and all reflecting surfaces. Employees' normal positions should also be clearly indicated and annotated, as these will determine the microphone positions for noise measurements. Recordings for observed noise levels should be annotated in accordance with the sketch, to facilitate the subsequent compilation and analysis of results.

The general requirement for microphone position is 1,5 m above the floor or ground (as relevant) and not less than 1,2 m from any sound-reflecting surface (SABS 083: 2000), with the observer remaining as far as possible from the microphone and not obstructing the transmission path. This implies that the sound level meter should, at the very least, be held at arm's length or preferably, mounted on a tripod, with the observer standing back to avoid influencing the sound field.

Position the microphone as appropriate for the source being assessed and, in the case of an integrating/averaging SLM, allow the instrument to measure and integrate for a representative sampling interval. If the source's operation is cyclical or subject to the influence of associated operations/tasks, at least one and preferably several cycles should be included in the measurement. If the noise emitted by the source in question is both continuous and steady, a short measuring interval will suffice.

The requirement for a representative measuring interval also applies to the use of a conventional non-integrating SLM. Furthermore, for intermittent and/or fluctuating sources the observer should also separately record the displayed levels for each sub-interval of the measuring interval, these corresponding with identifiable phases or stages of the source's operation. In addition, the observer should record the duration of each sub-interval, in order that the average level can later be calculated in accordance with the level and duration for individual stages or sub-intervals. Continuous and unvarying (all levels within 5 dB) sources can be adequately assessed over a short period and without segmenting the measuring interval, but the observer should note the instrument readings as they are displayed, then calculate and record their arithmetic mean.

Procedures described in the two preceding paragraphs (as applicable to the SLM being used) should be repeated for each position normally or likely to be occupied by employees.

3.5.5.2 Investigating noise reduction or transmission control for noise sources

Where the purpose of measurements is to investigate the requirements/feasibility or evaluate the effectiveness of noise reduction/transmission control measures, frequency analysis techniques are indicated, these involving the use of an octave or one-third-octave filter. In addition, to better enable appropriate control measures without expensive trial and error, Type 1 precision is preferred.
Microphone positions should enclose or surround the source, firstly at positions in close proximity to it (normally at a distance of 1 m), in order to quantify the sound energy being emitted. This should be done for each frequency in the selected range, preferably 31,5 or 63 to 8 000 Hz, but at least from 125 to 4 000 Hz.

Subsequent measurements to determine the transmission of energy into and through the work environment should be made for each frequency, at a distance twice that of the previous measurements, repeated at such increasing distances until sufficient information has been recorded to:

- characterise and quantify the transmission of noise through all relevant areas of the work environment, and
- enable the determination of requirements for controlling such transmission,

or

until it becomes apparent that the levels observed will not significantly contribute to employee exposure.

It will normally be necessary to make such measurements along several lines of direction in accordance with employees' positions, unless the source is enclosed (on three sides, top and bottom), with the noise radiating in a single direction.

Source assessments, as such, are generally undertaken to investigate the feasibility of noise reduction or control measures, or to evaluate their results where they are already implemented or being developed. Irrespective of the specific purpose, the quantification of emitted and transmitted noise must ensure that the contribution of any significant background noise is taken into account, as discussed below.

Determining background noise effects

The quantification of background noise is essentially an extension of instrument calibration procedures, as it amounts to a calibration of the environment. Distinguishing background noise from source emissions is generally less critical when assessing impact on employees, as it normally constitutes part of their exposure. However, where background noise is significant and atypical of the normal situation (e.g. where machinery installation or building renovations are underway in or near a workplace), and more particularly where a source is being assessed to investigate or evaluate noise reduction or control measures, the effects of background noise must be quantified to enable their exclusion from measured results. Given the general requirement for engineering measurements to incorporate frequency analysis techniques, background noise determinations should also include frequency analysis.

The measurement of background noise requires that the source being considered is temporarily shut down, either before or after noise measurements (source plus background) are made. The two resulting sets of measurements (source-with-background noise and background noise only) should both include a reading for each centre frequency (octave- or one-third-octave-band as appropriate), at each selected microphone position.

The values for each pair of results should then be compared and the difference calculated, to determine the appropriate correction factor for removing the contribution of background noise, as indicated in Table 3.5.5.2 (adapted from SABS 083: 2000). It is assumed that values for source-with-background noise will be greater than corresponding values for background noise. If this is not the case, both values or sets of values should be discarded and the relevant measurements repeated.

Similarly, if the difference between two corresponding values is less than 4 dB, both measurements should both be discarded and repeated (SABS 083: 2000). If repeating the questionable measurements yields results similar to the discarded ones and the source(s) of background noise cannot be interrupted during measurements, the appropriate correction factor from Table 3.5.5.2 should be applied. In doing so, however, it must be recognised that accuracy of the noise level determined for the source may be negatively affected.

Table 3.5.5.2
Correction factors for measured signals to compensate for the effects of background noise

Difference between Source-with-background-noise and Background noise (dB)	**Correction factor to be subtracted from Source-with-background-noise value (dB)**
0	0*
1 to 3	3*
4 to 5	2
6 to 9	1
$\geq$10	0

*A difference of less than 4 dB between the values for Source-with-background noise and Background noise only is normally indicative of questionable results.

Measurement procedures
The general requirements and guidelines for noise measurement provided in Sections 3.5.2, 3.5.4 (including sub-sections 3.5.4.1 to 3.5.4.3) and Section 3.5.5, as well as those relevant to quantifying the effects of background noise as discussed in the present sub-section, are applicable.

The use of frequency analysis techniques is required when assessing sources for noise control purposes, with Type 1 precision preferred. It is assumed that an integrating/averaging SLM will be used for such measurements, as use of a conventional non-integrating instrument would be laborious, and be subject to errors originating from the need to calculate noise level from the results of numerous noise and time (sampling duration) measurements.

Select the appropriate instrument settings in accordance with specific requirements. As the underlying purpose of source assessments is normally to either evaluate or enable measures for controlling potential impact on employees, A-weighting should normally be selected. Where an absolute quantification of emission level or transmitted noise is required, as when the absolute (unweighted) effect of a specific reduction or control intervention is to be evaluated, no frequency-weighting should be applied, i.e. “Linear” should be selected. Other settings, if available, should be as follows:

- Detector response: “RMS”
- Time-weighting: “I” (SABS 083: 2000)
- Filter: “In” or “On”
- Sound incidence: as appropriate, i.e.,
  “Frontal” where noise originates from a single direction, i.e. with little or no reflected sound from other directions, or
  “Random” where significant reflection causes noise to reach the microphone from a number of directions
- FSD: as appropriate for the prevailing noise level, ensuring that a higher range is selected where any overload is observed.
- Display: L_{Aeq} if A-weighting is required or L_{eq} for linear/unweighted measurements, with the selection made for frequency-weighting (A-weighted or Linear) determining which parameter is measured and displayed

The observer should make a sketch of the location where measurements are to be made, clearly indicating the positions of and distances between noise sources and all reflecting surfaces. All measurement positions should also be clearly indicated and annotated, as should recordings for observed noise levels, the latter being in accordance with the sketch to facilitate the subsequent compilation and analysis of results.

The general requirement for microphone position is 1,5 m above the floor or ground (as relevant) and not less than 1,2 m from any sound-reflecting surface (SABS 083: 2000). This relates to the normal position of a person's head (when present) and the general purpose of measuring noise to assess potential impact on employees. Where the purpose is to consider noise reduction or transmission control measures, microphone position may differ from the preceding requirement. In any case, the observer should remain as far as possible from the microphone and not obstruct the noise transmission path. This implies that the sound level meter should, at the very least, be held at arm's length or preferably, mounted on a tripod, with the observer standing back to avoid influencing the sound field.

For each measurement made, allow the instrument to measure and integrate for a representative period. This will be dictated by the nature of the source, with fluctuating or cyclical sources requiring a longer measurement interval. The duration of each measurement interval should be recorded.

Noise emission measurements should be made at each selected microphone position, these having been chosen to closely surround the source (at a distance of 1,0 m or as practical considerations dictate). Determine a value for L_{Aeq} or L_{eq}, as appropriate, for each centre frequency in the selected range (e.g. 63 to 8 000 Hz).

Noise transmission measurements should be made in outward directions (relative to the source, and as appropriate for the directions of sound propagation) at increasing distances (each one at double the distance from the source as its corresponding predecessor), until all relevant affected areas in the workplace have been considered. Again, L_{Aeq} or L_{eq} measurements at each microphone position should include a determination for each centre frequency in the selected range.

Where background noise (from sources other than that being considered) exists, it will be necessary to repeat each measurement, at each microphone position, for a duration similar to that of the corresponding measurement made for the source. Then compare corresponding values (i.e. those for the same position and the same frequency) to determine any correction for background noise in accordance with Table 3.5.5.2, and record each result accordingly.

3.5.6 Assessment of noisy areas

The procedures for measurements considered in this section are similar to certain of those discussed previously, in terms of their purpose and the methods to be applied. The purpose would normally be to determine potential impact on employees and enable the prioritisation of noisy areas for possible control measures, as well as to enable compliance with requirements for noise zoning (SABS 083 2000).

An area is noisy as a result of either one large source being situated in or near the workplace; or the presence of a number of small sources, these normally being located within the area rather than nearby. For area assessments both situations should be treated the same, given that the purpose common to both is the assessment of potential impact on employees to enable prioritisation for possible control measures. Accordingly, the methods for areas with a single source and for areas with multiple sources will be similar and, for practical reasons, resemble those recommended for the assessment of "large" sources (Section 3.5.5.1).

3.5.6.1 Procedures

Preparation

The area should be examined to determine the normal activities and positions of employees present, with particular reference to their positions relative to the noise source(s). Note should be taken of any noise level fluctuations, which would normally be greater for a number of small sources, and less significant for a single large source.

Measurement positions should then be selected in accordance with employees' normal or likely locations, and microphone positions should correspond with those normally occupied by employees' heads. If possible, measurements should be made without employees present, particularly where noise is attributable to a number of small sources. Where operational requirements dictate the person's presence, or where the source requires an operator to enable representative measurements, the microphone should be positioned approximately 0,10 m from the entrance of the more-exposed ear (the ear closer to or more-directed towards the source) (ISO 9612: 1997) and directed towards the source. Irrespective of employee presence, the noise transmission path between the source(s) and the microphone should not be obstructed and or the sound field influenced by such presence, including that of the observer. In this regard, use of a tripod to support the SLM and microphone is preferred.

The appropriate measurement interval for each microphone position should be determined on the basis of fluctuations in noise level, with greater fluctuation or periodicity of noise level indicating a need for longer measurement intervals.

The acoustic parameter to be quantified is $L_{\mathrm{Aeq},\,T}$, with T being equal to the measurement interval. Where the measurement interval is representative of a nominal 8-h working day, $L_{\mathrm{Aeq},\,T}$ will be numerically equal to $L_{\mathrm{Aeq},\,8\mathrm{h}}$, the preferred parameter for assessing noise level (ISO 1999: 1990 and ISO 9612: 1997).

Measurements

The general requirements and guidelines for noise measurement provided in Sections 3.5.2, 3.5.4 (including sub-sections 3.5.4.1 to 3.5.4.3), Section 3.5.5 (including relevant aspects of sub-section 3.5.5.1), as well as those relevant to certain areas as discussed in the present sub-section are applicable.

Select the appropriate instrument settings in accordance with specific requirements, which for assessing potential impact on employees indicates the need for A-weighting. Other settings, if available, should be as follows:

- Detector response: "RMS"
- Time-weighting: as appropriate: "I" for integrating/averaging SLMs (SABS 083: 2000) and "F" for conventional non-integrating SLMs (ISO 1999: 1990)
- Filter: "Out" or "Off"
- Sound incidence: as appropriate, i.e.:
  "Frontal" where noise exposure can be attributed to a single source and where there is little or no reflected sound reaching exposed employees, or
  "Random" in the case of multiple sources or significant reflection causing noise to reach employees from a number of directions
- FSD: as appropriate for the prevailing noise level, ensuring that a higher range is selected where any overload is observed.
- Display: L_{Aeq} or L_{eq} (which becomes L_{Aeq} with A-weighting enabled) if available, otherwise SPL (again with A-weighting enabled)

The observer should make a sketch of the location where measurements are to be made, clearly indicating the positions of and distances between noise sources and all reflecting surfaces. Employees' normal positions should also be clearly indicated and annotated, as these will determine the microphone positions for noise measurements. Recordings for observed noise levels should be annotated in accordance with the sketch, to facilitate the subsequent compilation and analysis of results.

The general requirement for microphone position is 1,5 m above the floor or ground (as relevant) and not less than 1,2 m from any sound-reflecting surface (SABS 083: 2000), with the observer remaining as far as possible from the microphone and not obstructing the transmission path. This implies that the sound level meter should, at the very least, be held at arm's length or preferably, mounted on a tripod, with the observer standing back to avoid influencing the sound field.

Position the microphone as appropriate for the location being assessed in accordance with the normal position of a person's head and, in the case of an integrating/averaging SLM, allow the instrument to measure and integrate for a representative sampling interval. If the noise is cyclical or subject to the influence of specific operations/tasks, at least one and preferably several cycles should be included in the measurement. If the noise is both continuous and steady, a short measuring interval will suffice.

The requirement for a representative measuring interval also applies to the use of a conventional non-integrating SLM. Furthermore, for intermittent and/or fluctuating noise the observer should also separately record the displayed levels for each sub-interval of the measuring interval, these corresponding with identifiable phases or stages of operations or activities. In addition, the observer should record the duration of each sub-interval, in order that the average level can later be calculated in accordance with the level and duration for individual stages or sub-intervals. Continuous and unvarying (all levels within 5 dB) noise can be adequately assessed over a short period and without segmenting the measuring interval, but the observer should note the instrument readings as they are displayed, then calculate and record their arithmetic mean.

Procedures described in the two preceding paragraphs (as applicable to the SLM being used) should be repeated for each position normally or likely to be occupied by employees.

3.5.7 Assessment of noisy activities

Activities that contribute significantly to employees' noise exposure normally do so as a result of machinery and equipment employed during such activities/operations or, less frequently, by proximity to a significant noise source. In some instances proximity to a number of small sources can be responsible, but this is normally not the case and is more closely associated with noisy areas, as opposed to noisy activities. The purpose of noise measurements for activities/tasks/operations is to assess potential impact on employees and enable the prioritisation of exposure contributors for possible control measures. Since the source of exposure is normally machinery used during the activity in question, the methods applied are similar to those recommended for the assessment of noisy areas (section 3.5.6.1) and more particularly, for "small" noise sources (Section 3.5.5.1). "Small" noise sources are taken to mean those that affect a small number of employees, and should not be confused with sources that are physically small but significant in terms of the number of people exposed to them.

3.5.7.1 Procedures

Preparation
The activity should be observed to determine the constituent tasks performed and their normal sequence and duration, as well as any influence from adjacent or preceding/ subsequent activities (relative to the overall production process). Employees' positions should be noted, with particular reference to how they relate to those of noise source(s). Cognisance should also be taken of any fluctuations in noise level and how they relate to adjacent/preceding/ subsequent activities.

Measurement positions should then be selected in accordance with employees' normal or likely locations, with selected microphone positions corresponding with those normally occupied by employees' heads. It will not likely be possible for representative measurements to be made without employees present, as this would normally bring the activity to a halt. Accordingly, for each employee's position the microphone should be placed approximately 0,10 m from the entrance of the more-exposed ear (the ear closer to or more directed towards the source) (ISO 9612: 1997). In addition, the microphone should be directed towards the source. Despite employees' likely presence, the noise transmission path between the source(s) and the microphone should not be obstructed or the sound field influenced, including by the presence of the observer. Where possible, use of a tripod to support the SLM and microphone is preferred.

The appropriate measurement interval for each microphone position should be determined on the basis of fluctuations in noise level, with greater fluctuation or periodicity of noise level indicating a need for longer measurement intervals.

The acoustic parameter to be quantified is $L_{\mathrm{Aeq},\,T}$, with T being equal to the measurement interval. Where the measurement interval is representative of a nominal 8-h working day, $L_{\mathrm{Aeq},\,T}$ will be numerically equal to $L_{\mathrm{Aeq},\,8h}$, the preferred parameter for assessing noise level (ISO 1999: 1990 and ISO 9612: 1997).

Measurements
The general requirements and guidelines for noise measurement provided in Sections 3.5.2, 3.5.4 (including sub-sections 3.5.4.1 to 3.5.4.3), Section 3.5.5 (including relevant aspects of sub-section 3.5.5.1) and Section 3.5.6.1, as well as those relevant to activities as discussed in the present sub-section are applicable.
Select the appropriate instrument settings in accordance with specific requirements, which for assessing potential impact on employees indicates the need for A-weighting. Other settings, if available, should be as follows:

- Detector response: "RMS"
- Time-weighting: as appropriate: "I" for integrating/averaging SLMs (SABS 083: 1996) and "F" for conventional non-integrating SLMs (ISO 1999: 1990)
- Filter: "Out" or "Off"
- Sound incidence: as appropriate, i.e.:
  "Frontal" where noise exposure can be attributed to a single source and where there is little or no reflected sound reaching exposed employees, or
  "Random" in the case of multiple sources or significant reflection causing noise to reach employees from a number of directions
- FSD: as appropriate for the prevailing noise level, ensuring that a higher range is selected where any overload is observed.
- Display: L_{Aeq} or L_{eq} (which becomes L_{Aeq} with A-weighting enabled) if available, otherwise SPL (again with A-weighting enabled)

The observer should make a sketch of the location where measurements are to be made, clearly indicating the positions of and distances between noise sources and all reflecting surfaces. Employees' normal positions should also be clearly indicated and annotated, as these will determine the microphone positions for noise measurements. Recordings for observed noise levels should be annotated in accordance with the sketch, to facilitate the subsequent compilation and analysis of results.

The general requirement for microphone position is 1,5 m above the floor or ground (as relevant) and not less than 1,2 m from any sound-reflecting surface (SABS 083: 2000), but where the employee's head is normally positioned near a reflecting surface, that should dictate microphone position. The observer should remain as far as possible from the microphone and not obstruct the noise transmission path. This implies that the sound level meter should, at the very least, be held at arm's length or if possible, mounted on a tripod, with the observer standing back to avoid influencing the sound field.

Position the microphone as appropriate for the activity being assessed, again, in accordance with the normal position of a person's head and, in the case of an integrating/averaging SLM, allow the instrument to measure and integrate for a representative sampling interval. If the noise is cyclical or subject to the influence of specific sub-tasks or adjacent/preceding/subsequent activities, at least one and preferably several cycles should be included in the measurement. If the noise is both continuous and steady, a short measuring interval will suffice.

The requirement for a representative measuring interval also applies to the use of a conventional non-integrating SLM. Furthermore, for intermittent and/or fluctuating noise the observer should also separately record the displayed levels for each sub-interval of the measuring interval, these corresponding with identifiable phases or stages of the activity. In addition, the observer should record the duration of each sub-interval, in order that the average level can later be calculated in accordance with the level and duration for individual stages or sub-intervals. Continuous and unvarying (all levels within 5 dB) noise can be adequately assessed over a short period and without segmenting the measuring interval, but the observer should note the instrument readings as they are displayed, then calculate and record their arithmetic mean.

Procedures described in the two preceding paragraphs (as applicable to the SLM being used) should be repeated for each position normally or likely to be occupied by employees.

3.5.8 Assessment of noise exposure level

Issues relating to the assessment of noise exposure level are considered in the sub-sections that follow and include recommended methods, criteria for sampling strategies, advantages of personal dosimetry, detailed measurement procedures, as well as methods for analysing and interpreting results.

3.5.8.1 Recommended method for noise exposure determinations

SABS 083: 2000, acknowledges the value of personal noise dosimetry in quantifying exposure for individuals without fixed working positions (e.g. supervisory and maintenance personnel) and those identified as susceptible to hearing impairment. However, the said standard effectively excludes dosimetry for general use by stipulating rating level ($L_{\mathrm{Ar},\,T}$) as the preferred parameter. Other standards (ISO 9612: 1997 and ISO 1999: 1990) explicitly recommend dosimetry as the most accurate basis on which to assess all employees' noise exposure and their resultant risk of impairment, while in the US it is regarded as the "gold standard" for determining employee exposure levels.

While a conventional, non-integrating sound level meter can be effectively used to assess exposure for stationary employees who are primarily exposed to continuous and unvarying noise, even sophisticated integrating/averaging SLMs are inconvenient for use where noise levels fluctuate, particularly where employees are mobile. Given the practical difficulties and likely sampling errors where exposure assessments are based on SLM determinations, it would seem more appropriate to perform the required measurements by means of personal noise dosimetry, in accordance with a coherent sampling strategy based, among others, on level of noise, number of employees exposed and relative duration of exposure.

3.5.8.2 General criteria for sampling strategy

The traditional approach to segmenting the workforce for exposure monitoring and sampling is based on occupation. This is appropriate where employees' designated occupations unequivocally define the operations and tasks that they perform and are exposed to. However, the frequent practice of categorising employees on the basis of administrative criteria and nomenclature often renders the occupation less than descriptive of their actual duties and, hence, the level and extent of their exposure to various hazards. This is particularly true in the case of noise, which varies widely as result of numerous operational factors. Accordingly, the monitoring of employees' exposure by noise dosimetry should incorporate a sampling strategy that places greater emphasis on the activities that employees are involved in, rather than their designated occupation, as such, or the location where they perform their duties.

Ideally, each employee should be sampled on a regular basis, at least every two years, but where the size of the workforce prevents this, all noisy activities/occupations should be representatively monitored on an ongoing basis. Greater emphasis should be placed on activities and occupations where exposure levels are highest, through a higher frequency of monitoring to yield a greater number of samples. Effective monitoring requires continuous acquisition and analysis of information, indicating that noise dosimeters should be deployed on an ongoing basis, with the analysis of results proceeding similarly, and the findings reviewed regularly at the highest management levels.

3.5.8.3 Advantages of dosimetry-based exposure assessments

Personal noise dosimetry offers several advantages over conventional SLM-based methods, which are discussed below.

Identification and quantification of risk to enable appropriate control measures

The underlying purpose of noise dosimetry, as for all types of noise monitoring, is to quantify and prioritise the hazard and risks for possible control measures. Risk of hearing impairment is directly proportional to the level and duration of exposure, indicating that the quantification of exposure will provide the best indication of risk. The most coherent monitoring programmes that employers have in place are generally those for medical surveillance. However, audiometry as presently applied can only retrospectively identify noise-induced hearing loss, which is particularly unfortunate, given the irreversible nature of the condition. Noise dosimetry, in contrast, represents a prospective means of identifying high-risk occupations, activities and individuals, which can then serve as a basis for prioritising sources of exposure for amelioration in advance of NIHL and impairment.

Real-time data logging
The facility to record noise levels and duration along with the time of occurrence, as offered by current dosimeters, represents a powerful means of identifying specific contributors to exposure. This information, together with employee input (from work-study personnel, exposed persons and their supervisors), can be used by occupational hygienists to clearly demonstrate significant sources of employee exposure, and motivate control measures for major contributors.

Representativeness of results
Given the potential for noise exposure assessments to facilitate the identification of significant sources of risk (in terms of location and occupation/activity), it follows that such information should be acquired by the most accurate and cost-effective means available. Provided a coherent sampling strategy is adhered to, personal dosimetry allows greater numbers of more representative measurements than SLM-based methods, which are subject to practical constraints and entail subjectively determined measuring intervals, potentially with negative impact on representativeness. Despite restriction on the use of dosimetry in SABS 083: 2000, these points further support the argument for personal noise dosimetry to be regarded as the preferred method for assessing noise exposure.

3.5.8.4 Procedures
It is essential that the instrument's internal settings be in accordance with local criterion levels, stipulated in SABS 083: 2000 as:

- Exposure limit: 85 dB
- Low threshold limit: 80 dB
- Energy exchange or doubling rate: 3 dB

The instrument supplier should have made these settings prior to delivery, but the user is advised to confirm them, by first consulting the manufacturer's instructions and then examining the instrument.

Preparation of noise dosimeters
For each instrument to be issued, ensure that the microphone cable is not damaged in any way, i.e. broken, frayed or twisted. Also, confirm that the instrument's belt clip will securely fix the device as intended, either on the belt or in the pocket, to avoid damage to the instrument or interference with the employee. A sliding clip (as used for employee ID cards) should be permanently attached along the length of the microphone cable, to control cable slack and prevent fouling, particularly where the instrument will be worn in the chest pocket.

Instruments should be in good operating condition and equipped with serviceable batteries. In this regard, it is good practice to have a spare battery for each dosimeter, as well as for the acoustic calibrator. Ensure that the instrument's battery has sufficient capacity to operate for the intended sampling interval, normally 8 h. Most dosimeters provide an indication of a low battery, either by an indicator specifically for that purpose, or by some aberrant value indicated by the display.

All instruments (particularly microphones and calibrators, which are susceptible to condensation) should be allowed to reach ambient temperature before being switched on, and then allowed to "warm up" for a period sufficient to ensure stable readings.

Calibration of noise dosimeters

Noise dosimeters and their microphones should be field-calibrated by the user immediately prior to issuing the instruments, and calibrated again immediately after recovering them. Where the results of the pre- and post-sample field calibrations differ by more than 1,0 dB, the sampling results should be discarded, and the cause of the apparent instrument instability investigated.

If the instrument is provided with a selectable display set it to “Sound level”. Otherwise, proceed as indicated by the manufacturer’s instructions. Remove the microphone windscreen (if fitted), fit the calibrator over the microphone and switch the calibrator on, allowing the meter’s display to stabilise.

The instrument’s display must be adjusted to correspond with the known output of the acoustic calibrator, by using a small screwdriver to turn the sensitivity adjustment/ calibration trim pot. The calibrator’s output (in terms of level and frequency) is indicated by a label affixed by the manufacturer, and confirmed during the device’s annual electro-acoustic calibration check. Ensure that the meter display is stable and in accordance with the calibrator’s specified output before closing the dosimeter and replacing the microphone’s windscreen.

Briefing participants

Employees to be issued with noise dosimeters should be identified in advance, in accordance with the employers’ sampling strategy, and thoroughly briefed regarding their participation in the noise exposure-monitoring programme. Potential participants should be provided with an explanation of the measurements’ purpose and encouraged to raise any questions or concerns they may have. They should understand that the employer is concerned about noise in the workplace and the dosimetry results will serve to determine where the greatest problems exist.

The operation of a dosimeter should be demonstrated to potential participants, including its response to varying noise levels. However, they should be asked to refrain from intentionally exposing the instrument to unusual noise or otherwise interfering with the measurements, and from tampering with the instrument or its microphone.

The wearing of the instrument should be demonstrated, highlighting its small size and unobtrusiveness, i.e. it will not inconvenience the employee, interfere with normal movement or with the performance of his/her duties. In this regard, employees should be shown how the device can be satisfactorily worn in more than one manner, and told that they will be able to decide how they will wear their dosimeter.

It should be emphasised that a dosimeter only records the level and duration of noise, and not the sound itself, i.e. it is not a sound recording device intended to monitor employees’ activities.

It should be made clear that each sample will be one of several hundred, and that results from all employees involved in corresponding or similar activities will be compared and combined. The message here is that results for a given employee will not lead to any immediate action, but rather contribute to compiling an overall picture of noise exposure. To discourage employee tampering or attempts to influence results, it should also be mentioned that unusually low or high sampling results will be investigated and confirmed by repeat samples to ensure overall accuracy of exposure assessments.

Employees should be told that they will be informed of their sampling results at the end of the shift when they return the instrument. Interested individuals will be pleased to learn the outcome of their measurements, and all individuals will know in advance that their results (and their instruments) will be examined at the end of the sampling period in their presence.

Employees should understand that there is no linkage between their noise exposure result and the outcome of any compensation claim they may have lodged or be contemplating. In other words, overexposing the instrument will not result in a compensation payment or enhance the prospects for any claim, pending or otherwise.

Employees should be made aware of the importance of the measurements, of the cost of replacing a dosimeter or its microphone, and of the consequences that would result should it become necessary to do so.

The purpose of the measurements should be reiterated, all questions answered, employees' participation encouraged, but the option to decline made available. If employees are compelled to participate they are less likely to co-operate and comply with the requirements of the survey and, hence, the results are more likely to be unsatisfactory.

Issuing dosimeters
It is assumed that the instruments' criterion levels are correctly set and that all previously recorded results been cleared from the memory. It is also assumed that the instruments have been field-calibrated, and that battery capacity is adequate for the intended sampling interval (preferably a full shift).

For each dosimeter, record the instrument number or serial number, and the name, occupation and working area of the person to whom it is being issued. Start the instrument, i.e. switch it on and activate the recording/data-logging function, then note the time of activation. Before closing the instrument and fitting it to the participant, confirm that the instrument is recording or running.

Employees should **not** be permitted to fit dosimeters themselves.
Fit the instrument to the employee, either on the belt or in the chest pocket, in accordance with the individual's preference. Determine, from the employee or from knowledge of his/her appointed task, if one ear is more exposed to noise than the other during normal activities. If so, the microphone should be attached on the same-side shoulder as the more-exposed ear, midway between the neck and the outer edge of the shoulder, facing forward or sideways (as appropriate for the likely origin of noise), and not upwards.
The microphone cable should be routed so as to prevent it from fouling or catching. An extra cable clip (as described previously) should be used to secure any cable slack.

Instruct the participant to leave the dosimeter exactly as it has been fitted, until the responsible official (normally the same official fitting the instrument) removes it at the end of the shift or sampling period. Ensure the employee understands that no additional garments should be worn over the microphone, and emphasise that the dosimeter and microphone should not be tampered with.

Confirm that the participant is happy with the way the instrument is fitted and understands the arrangements for recovering it (i.e. time and place). Acknowledge the employees' assistance.

Recovering dosimeters and extracting results
For each dosimeter, remove the instrument from the employee and while he or she is still present, quickly examine the instrument for damage while accessing the controls and display. Pause the instrument to prevent further acquisition of data and note the time. Display the relevant parameter (variously indicated either as HTL-TWA, TWA_{8h}, N_{eq}, dB-TWA or %-Dose) and inform the employee of the result.

Determine from the employee whether workplace noise levels differed from the norm and, if so, to what extent. If possible, similar input should later be sought from the employee's supervisor. Any such information should be recorded along with other details of the sample.

Answer any questions the employee may have and thank him or her for participating.

For each dosimeter, manually display and record the values for all relevant parameters (these to at least include $L_{EX,\ 8h}$ or its equivalent, and Run time/measurement interval). Alternatively, print out the values or download the results to computer, as appropriate for the instruments being used. Where the results cannot be captured immediately, the instruments should retain the results for a reasonable period, but delaying the capture of data should be avoided.

When downloading computer, do not clear the instruments' memories until it has been confirmed that the results have been captured and are coherent.

Interpretation of results
Some dosimeters display the noise exposure result as a percentage of permissible noise dose. (For South African noise criteria, a dose of 100 % corresponds with the equivalent of an 8-h exposure to a continuous noise level of 85 dB.) Interpreting results from such instruments first requires reference to Table 3.5.8.4a (adapted from SABS 083: 2000 and ISO 9612: 1997), to convert noise dose to the preferred parameter, noise exposure level normalised to a nominal 8-h workday ($L_{EX,\ 8h}$, in decibels). This quantity has a corresponding meaning to the time-weighted average for 8 h (TWA_{8h}), dB-TWA and equivalent noise exposure (N_{eq}), all of which are also quantified in decibels, and is therefore numerically equal to them. All four of these parameters are, in turn, numerically equal to equivalent continuous A-weighted sound pressure level for an 8-h sampling interval ($L_{Aeq,\ 8h}$), as would be determined by representative measurements using a sound level meter.

Table 3.5.8.4a
Percentage daily dose (relative to 85 dB) and corresponding values for A-weighted sound exposure over 8 h and for Noise exposure level normalised to a nominal 8-h workday

Dose (%)	$L_{EX,\,8h}$ (dB)	$E_{A,\,8h}$ ($Pa^2 \cdot s \times 10^3$)
10,4	75	0,364
12,5	76	0,458
16,7	77	0,576
20,8	78	0,726
25,0	79	0,913
33,3	80	1,115
41,7	81	1,45
50,0	82	1,82
66,7	83	2,29
83,3	84	2,89
100	**85**	**3,64**
133	86	4,58
167	87	5,76
200	88	7,26
267	89	9,13
333	90	11,5
400	91	14,5
533	92	18,2
667	93	22,9
800	94	28,9
1 067	95	36,4
1 333	96	45,8
1 600	97	57,6
2 133	98	72,6
2 667	99	91,3
3 200	100	115,0

An inspection of Table 3.5.8.4a clearly illustrates the significance of exposure levels exceeding 85 dB by more than 5 dB; e.g. a level of 91 dB would amount to four times the permissible exposure. This indicates that, in the absence of effective control measures (engineering- or personal protection-based), an employee should only be exposed to such a noise environment for 2 h per day. The large reduction in permissible exposure time required where $L_{Aeq,\,8h}$ exceeds 85 dB by a seemingly small number of decibels results from the fact that the decibel is a logarithmic quantity. Accordingly, exposure levels exceeding the 85-dB limit by more than 5 dB should be regarded as indicative of extreme exposure requiring control measures. For certain activities or occupations it is possible that exposure levels may exceed the limit by even greater margins, in which case urgent attention should be directed at identifying and ameliorating the cause.

Analysis of results

Compiling the results of noise exposure measurements without deriving useful information and appropriately applying it constitutes a waste of valuable resources, and is likely to undermine the credibility of hearing conservation efforts. Furthermore, it must be appreciated that such efforts are more likely to be inappropriate and ineffective where there has been a failure to consider information derived from the exposure monitoring programme, thereby wasting more resources and further undermining programme (and management) credibility.

Assuming that the employer's sampling strategy is appropriate for the number of employees and their allocation to various areas/workplaces and occupations/activities, the analysis of results should readily lead to the identification of problem areas. When these are critically examined in the light of supplementary information provided by the occupational hygienist and various employee inputs, potential means of amelioration should be identifiable. The first problems to be addressed should be those noise sources and activities that contribute most to overall worker exposure, i.e. those associated with the greatest exposure levels and affecting the greatest number of employees.

Although use of an appropriately structured database would enhance the analysis of noise exposure measurements, lack of such a facility should not be accepted as an obstacle to analysis. As the sample base grows, sufficient data will become available for meaningful analysis. Calculate the mean exposure level and distribute individual results over the range of values observed for each sampling category (activity/occupation and/or area/ workplace). Increments used to segment the range will depend on its size, but should be small enough to allow meaningful distinctions to be made, generally indicating that increments should not be greater than 10 dB. Where larger increments appear necessary, it is likely that the category being considered is too broad and should be further segmented, preferably on a basis that will serve to distinguish between sources as well as levels of exposure.

Essential information to be derived from the analysis includes the identification of areas (relative to noise sources) and activities (relative to operations) where the greatest exposure levels occur, the number of employees affected and the time they spend near or involved in (as relevant) contributors to exposure. For reasons of practicability, mean time-weighted average exposure levels should be classified on the basis of Table 3.5.8.4b (adapted from Royster, Berger and Doswell-Royster 2000), in order to categorise exposure levels in accordance with the risk they impose (ISO 1999:1990).

<u>Table 3.5.8.4b</u>

Classification of observed noise exposure levels

Mean TWA (dB)	**Exposure rating factor and characterisation of risk**
≤82	**0**: Insignificant risk
83-85	**1**: Potential risk
86-90	**2**: Moderate risk
91-95	**3**: Significant risk
96-105	**4**: Unacceptable risk
≥106	**5**: Extreme risk

Multiplying the exposure rating factor for each category (area/workplace or activity/ occupation) by the number of employees affected and then multiplying the product by an appropriate time factor (relative or absolute) will yield a noise exposure risk rating. This rating should be used to prioritise contributors to exposure (be they noise sources as such, or noisy activities and operations) for analytical assessments (described in the following paragraph) and possible risk management interventions.

Application of findings

Areas and activities having the highest noise exposure risk ratings should receive immediate attention in the form of an analytical assessment by a team of specialists that includes occupational hygiene, engineering and production personnel. Such assessments should also consider input from other employees, including work-study and supervisory personnel, as well as from exposed employees themselves. The purpose would be to determine what actions could be taken to control significant sources of exposure, e.g.:

- Use of alternative production methods or processes
- Modifications to machinery
- Enclosure, isolation or relocation of noise sources
- Installation of sound-absorbing barriers
- Administrative controls such as limiting individual employees' exposure by rotation
- Appropriate combinations of the above measures

Personal protection should always be regarded as the last and *not* the first line of defence, since its effectiveness depends on employees' recognition and appreciation of the hazard, their ability to correctly use PPE and their motivation for doing so. Experience has shown that for a number of reasons these prerequisites are rarely met, with the end result that employees continue to incur hearing loss despite large expenditures for PPE/HPDs and training initiatives.

3.5.9 Re-assessment of noise levels for sources, areas and activities

The re-assessment of employees' exposure to noise should continue on an ongoing basis, while noise level re-assessments for machinery, areas and activities would likely be conducted only periodically. However, such re-assessments of contributors to exposure should be conducted as a matter of routine, at least once every two years. Furthermore, an immediate re-assessment would be indicated where changes are made in the workplace, or when a need for re-assessment becomes apparent. Such instances would include:

- Installation or commissioning of new or refurbished plant/machinery
- Major overhaul/repairs
- Addition or removal of walls, partitions, barriers or any other reflective surfaces
- Provision of any noise reduction/transmission control measures
- Unexpected or otherwise questionable results from noise measurements
- Unfavourable trend in employees' noise exposure results
- Unfavourable trend in employees' audiometric test results
- Occurrence of an accident or "near-miss" where noise is suspected as a contributing factor
- Employee complaints of excessive noise

3.5.10 Noise measurement as a means of quality control

Employers can effectively utilise noise measurements as a means of quality control after the refurbishing or overhaul of plant or machinery, particularly where such equipment is known to constitute a significant source of noise exposure. The principle is that efficient operation necessarily includes lower levels of machinery vibration and, hence, less energy being wasted and emitted in the form of noise. Accordingly, many manufacturers use vibration and noise measurements to monitor the overall quality of their products, e.g. household appliances, office equipment and large industrial plant.

The employer may compel machinery refurbishers to provide information on noise emissions, but it would still be advantageous to confirm those levels once such equipment has been returned or re-commissioned. The applicable procedures would be similar to those described for noise sources in Sections 3.5.5.1 and 3.5.5.2, although the latter section would generally be more relevant. Quality control noise measurements would normally not require Type 1 instrument precision but, given the possibility of discrepancies between the refurbisher's and employer's results leading to disputes, Type 1 instruments would be preferable for confirmation or quality control purposes.

The same principle could be applied, perhaps less stringently, after in-house maintenance and repairs to significant noise sources, with noise levels recorded in the job report. There would be no need for Type 1 precision, frequency analysis or multiple measurement positions, but rather a simple sound level determination at a specified reference point (e.g. at the operator's or attendant's position), preferably compared with a similar reading made prior to the maintenance or repairs.

3.6 Confirmation and disputes

Despite the application of standardised measurement procedures in assessing noise sources and levels of employee exposure, there may be instances where discrepancies or disputes arise. In some instances these may be partially attributable to differences in the criteria, motivation or agendas of the parties concerned, but accurate information derived from appropriate measurement procedures should provide a valid basis for resolving the issue.

3.6.1 Machinery noise emissions

The most likely scenario for a dispute would be where a particular item of machinery is determined by the employer to emit noise at a greater level than stipulated in his procurement criteria, or indicated by the supplier's product specifications. Similar disputes could also arise between an employer and a service provider in the case of refurbished equipment. In either instance the equipment in question should be assessed in a manner that will enable confirmation of emission levels in terms of the relevant criterion, either the supplier's specification or the employer's requirement. This will determine which measurement procedures should be applied, either those for manufacturers (Section 3.4) or those for employers (Section 3.5.5, viz. sub-section 3.5.5.2).

Type 1 instrument precision would be required, as would correction for any background noise that may exist. If the relevant criterion does not include the specification of emission levels for individual centre frequencies, octave- or one-third-octave-band frequency analysis would not be necessary, although such measurements would assist in identifying the specific cause(s) of the discrepancy being investigated.

Where the employer and equipment supplier/service provider cannot agree on the measurement procedures to be applied or the results thereof, or one or both parties do not have access to the necessary instrumentation, an impartial acoustics consultant or inspection authority should be engaged to conduct the assessment. Irrespective of who performs the assessment, all instruments should have valid calibration certificates and copies of these should be appended to the report.

3.6.2 Employee noise exposure levels

Disputes regarding employees' noise exposure levels are most likely to occur between the employer and a regulatory authority or employee (the latter possibly involving an employees' representative organisation). Two methods of assessing exposure level are described, with the one to be applied depending on circumstances of the individual's or group's exposure to noise.

3.6.2.1 SLM-based assessments

Where the disputed noise exposure is wholly attributable to a continuous and non-fluctuating source, Type 1 SLM measurements conducted in accordance with Section 3.5.5.1, 3.5.6.1 or 3.5.7.1, as appropriate, would be suitable to confirm employee exposure. The resulting $L_{\text{Aeq},\,T}$ value should be used to determine $L_{\text{EX, 8h}}$ in accordance with equation (9) in Section 2.2.

3.6.2.2 Dosimeter-based assessments

Given that most noise exposure involves multiple and varying noise sources, and sometimes multiple workplaces, personal noise dosimetry would most often be the appropriate means of confirmation. This recommendation is despite the fact that virtually all noise dosimeters provide only Type 2 precision, but it can be motivated by the argument that a 0,3-dB decrement in precision is preferable to the more significant sampling errors that are likely when using a sound level meter. All dosimeters used during the confirmation of noise exposure levels should have a valid calibration certificate from an approved laboratory, and be used in accordance with the procedures detailed in Section 3.5.8.4.

Sampling strategy and analysis of results

In order to ensure that the exposure levels determined during confirmation measurements are representative, the employee or group of employees in question should be sampled for at least five consecutive shifts during a typical (in terms of production or operational activities) working week. An average level should then be determined for each individual. Where an individual's daily results are all within a range of 10 dB, the arithmetic mean will provide an accurate average. Where this is not the case, the individual's mean exposure level over the 5-day sampling period, which would generally relate to a nominal 40-h working week, should be determined according to the following relation (ISO 9612: 1997):

$$L_{\text{EX, W}} = 10 \log \left(\frac{1}{5} \sum_{i=1}^{n} 10^{0,1\, L_{\text{EX, 8h}}} \right) \qquad (17)$$

where: $L_{\text{EX, W}}$ is the weekly average of daily values for $L_{\text{EX, 8h}}$ in decibels;
n is the number of days in the working week (normally 5), and
i is the number of sampling intervals per day (defined as 1).

In the case of a group of employees, not less than five per cent of the total number of individuals so employed but no fewer than three such persons should be included in the weeklong sample. Mean exposure level over the 5-day sampling period should be determined for each member of the group, in accordance with equation (14), above. Mean exposure level for the period should then be calculated for the group, as an arithmetic mean where individuals' 5-day averages are all within 10 dB, or as a logarithmic mean where the range of values is greater than 10 dB.

In addition to reporting the group's 5-day mean exposure level, individual means should be distributed across their range to indicate the number of employees in each exposure level category, which should not be greater than 5 dB.

Exclusion of potential confounding factors

In order to prevent the introduction of confounding factors to the sampling process, the supervisors of all participants should be informed of the assessment and of its purpose. The intention would be to ensure that the relevant employees' activities and, hence, their noise exposure results during the sampling period are both typical and representative of their normal involvement in operations. In addition, supervisors should be asked to remain vigilant for possible malpractice on the part of participants, i.e. that they wear their dosimeters for the entire shift and that they do not deliberately expose their instruments to unusual noise. The official responsible for the sampling process should meet with relevant supervisors at the end of each shift, to ascertain whether any such malpractice may have occurred and to determine if operations and activities during that shift were typical. Any indications of malpractice or atypical operations should be noted and, where they occur, the affected samples should be discarded and repeated.

Ensuring credibility and acceptance of findings

To avoid possible contentions regarding the validity or credibility of the noise exposure assessment, employee or union representatives, or officials of the relevant regulatory authority (as applicable) should be informed of the intended sampling procedures in advance, and given the opportunity to make any relevant comments. In addition, such representatives should be invited to observe the sampling process and be present when the results are extracted from participants' dosimeters. They should also be provided with an explanation of the analysis and of the overall findings, preferably in the form of a report, which they should be asked to acknowledge receipt of.

3.7 Information management and utilisation

An essential requirement for the results of machinery-associated and activity-based noise and employee exposure assessments to enable effective intervention is that they be accessible through an appropriately designed and coherent database. Pertinent information to be made available would include noise and exposure levels, task or exposure duration, the findings of team-based assessments for identifying contributors to exposure and means of controlling them, as well as the effects of implementing any control measures. Recording such information in database format would facilitate the identification of critical problem areas, as well as the further development of that information through the recognition and analysis of trends. Specifying the structure and functional operation of such a database requires specialised expertise and is clearly beyond the scope of this annex for noise measurement. However, the database should address all contributors to worker exposure, i.e. noise sources, noisy areas and activities, and include:

- Definable categories for segmenting samples in accordance with the deployment of workers (in terms of area/workplace and activity/occupation)
- Total number of employees in each defined category and number/percentage of those already sampled
- Mean exposure level and distribution of exposure levels within each defined category
- Employees' daily (or weekly) duration of exposure to identified contributors (in relative or absolute terms)
- Noise and exposure levels observed before and after the implementation of noise reduction treatments or control measures of any sort (including engineering, administrative, personal protection), as well as pertinent details of such measures to enable assessments of their overall effectiveness
- Findings from team-based assessments of noise sources and noisy areas/ activities aimed at identifying specific contributors to exposure and opportunities for their control
- The correlation of noise and exposure levels for various workplaces and activities with the results of audiometric monitoring, also with provision to examine the effect of all noise reduction/transmission and exposure control measures

The advantages of personal dosimetry as a means of reliably assessing employees' exposure to noise indicates that dosimetry should be the primary means of determining exposure levels and resultant risk. Implementing an appropriate sampling strategy (in terms of the number of employees exposed to various noise sources or involved in noisy activities), particularly when combined with real-time data logging and various employee inputs, represents the most powerful means of identifying and prioritising specific contributors to exposure. Accordingly, the envisaged database should be structured to incorporate actual results and supplementary information derived from the personal exposure-monitoring programme, as indicated above.

Access to an appropriately structured database for all relevant departments and functions, subject to its effective utilisation, would provide a powerful tool to enable appropriate decisions towards managing risks associated with the noise hazard. In addition, where the database structure and content format is uniform across various employers and industries, appropriate analysis of information on an industry- or nation-wide basis would enable:

- Benchmarking of employers' hearing conservation/hearing loss prevention and noise reduction programmes
- Employers' evaluation of any noise reduction and/or control measures being considered, based on the benefits that others have realised from such measures
- Recognition of noise exposure and hearing loss trends
- Evaluation of progress in reducing noise and exposure levels
- Identification of research needs
- Determination of likely costs for future compensation claims
- Refinement of dose-response models for local populations, to enable more accurate risk assessments and appropriate compensation provision

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Attachment:
Standards relevant to the quantification of machinery noise

- ISO 9612:1997, Acoustics- Guidelines for the measurement and assessment of exposure to noise in a working environment
- ISO 1683:1983, Acoustics- Preferred reference quantities for acoustic levels
- ISO 3740:1980, Acoustics- Determination of sound power levels of noise sources: Guidelines for the use of basic standards and for the preparation of noise test codes
- ISO 3741:1988, Acoustics- Determination of sound power levels of noise sources: Precision methods for broad-band sources in reverberation rooms
- ISO/DIS 3741, Acoustics- Determination of sound power levels of noise sources using sound pressure: Precision methods for reverberation rooms
- ISO 3742:1988, Acoustics- Determination of sound power levels of noise sources: Precision methods for discrete-frequency and narrow-band sources in reverberation rooms
- ISO 3743-1:1994, Acoustics- Determination of sound power levels of noise sources: Engineering methods for small, movable sources in reverberant fields, Part 1: Comparison method for hard-walled test rooms
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- ISO 7574-2: 1985, Acoustics- Statistical methods for determining and verifying stated noise emission values of machinery and equipment, Part 2: Methods for stated values for individual machines
- ISO 7574-3: 1985, Acoustics- Statistical methods for determining and verifying stated noise emission values of machinery and equipment, Part 3: Simple (transmission) method for stated values for batches of machines
- ISO 7574-4: 1985, Acoustics- Statistical methods for determining and verifying stated noise emission values of machinery and equipment, Part 4: Methods for stated values for batches of machines
- ISO 9614-1:1993, Acoustics- Determination of sound power levels of noise sources using sound intensity, Part 1: Measurement at discrete points
- ISO 9614-2:1996, Acoustics- Determination of sound power levels of noise sources using sound intensity, Part 2: Measurement by scanning

Annex 3: Education, motivation and training

(For information only)

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1 Introduction
Education is a fundamental prerequisite to the success of any hearing conservation programme, and one that must be addressed at all levels in the organisation. The essential purpose is to improve employees' awareness of the noise hazard and its consequences, and to motivate them towards active participation in controlling the risks according to their position and function within the organisation. This represents a considerable challenge, particularly among those most at risk, given that noise is an unseen hazard with irreversible effects that are not painful or otherwise immediately apparent. Consequences for employees include a permanently diminished capacity to fulfil their duties, to earn an income, and to interact with family and friends. The impact of noise on the organisation is also considerable, impeding communication, productivity and safety, and exposing the employer to the financial burden of compensation costs.

2 Induction of employees exposed to noise

2.1 Objectives
One of the most effective strategies for conserving employees' hearing in a noisy environment, aside from reducing noise at the source, is to ensure that individuals employed in such areas are aware of the hazard and the impact it can have on their hearing as well as their jobs and employment prospects, (as well as) and their social and family relationships. An appreciation of the negative effects that noise can have on their own lives should encourage employees to participate in the identification and control of significant sources of risk, and motivate them to actively protect themselves from noise-induced hearing loss.

The objectives of employee induction and education with regard to the noise hazard are to:

- Promote a comprehensive understanding of the nature, the cause and the consequences of noise-induced deafness, and motivate employees to take steps towards preventing loss of their own hearing
- Ensure that employees are capable of recognising dangerous noise and encouraged to contribute to risk assessments and the implementation of appropriate control measures
- Promote positive employee attitudes towards hearing protection devices (HPD) and encourage effective utilisation, by explaining how HPDs function and by demonstrating their enhancement of communication in noise
- Ensure employees' ability to effectively utilise HPDs, by demonstrating their proper use and care and developing employees' competence through supervised, hands-on training in the fitting of individually selected HPDs

2.2 Notes for trainers
To ensure that the requisite knowledge is transferred to learners, trainers should make use of appropriate visual aids and learning activities, employing a language medium that is appropriate for the group. To ensure that learners acquire the skills and competence necessary for effective use of HPDs, trainers should arrange for an assortment of devices representative what employees will be able to select from, i.e. earplugs, earmuffs, semi-insertable plugs or caps, as appropriate.

The trainer's introduction should briefly summarise the nature of sound with regard to its frequency or pitch and its intensity or loudness. Emphasis should be placed on noise, which is defined as unwanted or dangerous sound, in particular sound that is capable of damaging the ears and causing hearing loss.

The objectives identified above should then be adequately addressed through group discussions, appropriate demonstrations and learning activities, with ample opportunity for employees to ask questions, raise concerns and obtain clarity.

3 Core training elements for noise

3.1 Scope

The core training elements for noise support the development of courses and learning activities to assist in the implementation of measures aimed at reducing the risks associated with occupational noise exposure. These elements do not address job-specific training, safe work procedures or work instructions; but do provide for training to support appropriate changes in work practices and the induction/re-induction of noise-exposed employees.

The core training elements provide guidance regarding general training requirements for various target groups through the provision of criteria and performance indicators, rather than through content details for a particular course. It should also be noted that core training elements do not provide for specialised training, e.g. that required for occupational hygienists who will conduct detailed assessments of employees' noise exposure. (Noise measurement procedures within the context of risk assessment are addressed in Annex I, but not to such an extent that the previously uninitiated could be regarded as competent to perform such measurements.)

3.2 Target groups

Two main groupings of target populations are identified for training with regard to occupational noise:

- **Everyone in the workplace**, i.e. employers and senior managers, line managers and supervisors, health and safety representatives/committee members and all noise-exposed employees, should have an overview of the legislation relating to occupational noise, the processes of hazard identification and risk assessment, as well as how risk management systems and procedures will be implemented in the workplace.
- **Those who will be responsible** for formulating and implementing risk management systems and procedures relating to noise (i.e. managers, supervisors and health and safety representatives/committee members) will be required to develop their competence in the design of hazard identification, risk assessment and risk management systems.

3.3 Training aims

Training with regard to occupational noise is intended to provide learners with the competencies necessary for implementing processes and activities required by the legislation to eliminate or reduce risks associated with exposure to occupational noise in accordance with their role in the organisation. A given training course must address the specific needs of its target group. For example, employees at various levels would require the basic knowledge and skills to participate in the identification of noise hazards, the assessment of risks and their control through the application of appropriate risk management procedures. Individuals responsible for the formulation of risk management systems, strategies and procedures require skills and knowledge applicable to the design and implementation of systems to identify, assess and manage risks associated with exposure to occupational noise.

3.4 Training objectives

The training objectives below were developed from the learning outcomes analysis sheets (appended), and are broad enough to cover the knowledge and skills generally required by management and employees. The difference is in the level of application of knowledge and skills. For example, a shop floor employee, as a result of training, should be able to adhere to safe work procedures aimed controlling occupational noise exposure that would otherwise result in the development of noise-induced hearing loss. Employee representatives would use knowledge gained during training to represent employees in the process of implementing strategies and procedures aimed at controlling the risks associated with occupational noise exposure.

Employers, managers and supervisors have varying levels of responsibility and input to the design and implementation of risk management systems, codes of practice and work procedures that enable compliance with the legislation and reductions in risk to employees and, accordingly, these functions should be the focus of training for managerial/supervisory personnel.

Although legislation requires manufacturers, importers and suppliers of plant and equipment to minimise the risks their products impose on employees, and inform users and employers with regard to such risks and possible control measures, training in these aspects is beyond the scope of the present annex.

The Attachment of this annex provides guidance in formulating training objectives for various target groups, and developers/providers of training courses should apply this information and other relevant criteria (e.g. those prescribed by the Mine Qualifications Authority) to ensure that on completion of their training, learners are able to demonstrate the required competencies.

3.5 Performance indicators

Performance indicators are appended as a guide to assist in the design and evaluation of training courses for various target groups. The respective roles and responsibilities of management representatives and employee representatives should be noted.

3.6 Main topics and content areas

Specific details of how each topic area is to be addressed will be decided largely by the training provider, but should be in accordance with learners' needs and, hence, course objectives. Courses should employ established adult learning methods that are appropriate for the specific target group, and facilitate the transfer of learning into the workplace. Training objectives may be addressed through more than one session and extend into several topic areas.

Main topic areas for an overview or general training course should include:

- Legislation relating to occupational noise and means of compliance, including employers' codes of practice and risk management systems
- Risk of hearing loss resulting from exposure to occupational noise, including possible impact on work, family and social life
- Hazard identification, risk assessment (including noise measurement) and risk management procedures within the context of occupational noise
- The need for communication and consultation with all concerned in formulating and implementing measures aimed at managing risk and complying with legislation
- Workplace strategies for the management of risks associated with occupational noise
- Occupational hygiene monitoring and medical surveillance

Main topic areas for those responsible for implementing measures to comply with the requirements of legislation should include:

- Legislated requirements for employers' codes of practice and risk management systems
- Hazard identification, risk assessment (including noise measurement) and risk management procedures within the context of occupational noise
- Communication and consultation with employees regarding the implementation of systems and procedures to comply with legislated requirements
- Workplace strategies and procedures for the management of risks associated with occupational exposure to noise
- Provision of information and training for employees exposed or likely to be exposed to the noise hazard
- Legislated requirements for occupational hygiene monitoring and medical surveillance programmes
- Record-keeping and administrative requirements
- Duty of care responsibilities for manufacturers, importers and suppliers of noisy equipment

3.7 Notional times

The duration of training courses will depend on the specific needs of various target groups. A broadly aimed course for general employees would likely require a 3-h session, while more intensive training in hazard identification, risk assessment and risk management procedures could require up to three days. Training in the latter should include learners' application of action plan development techniques for hazard identification, risk assessment and risk management, and examine criteria for occupational hygiene monitoring, medical surveillance, HPD selection and informing noise-exposed employees.

Note: More detailed training, with provision for the supervised practical application of relevant procedures, is required for learners to achieve competence in risk assessment/ noise measurement, noise control engineering or audiometric testing. These aspects are considered in Annexes 1, 3 and 7, respectively, but the descriptions of procedures therein are not sufficient to achieve competence among individuals lacking the relevant qualifications and experience.

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Note: Relevant publications, legislation, guidelines and employers' codes of practice should be consulted when applying core training elements for noise in the design and provision of training courses.

This attachment details the roles, responsibilities, and requisite learning outcomes and knowledge/skills for various target groups, also providing suggested competency-based performance indicators (some of which reflect the transfer/application of learning to the workplace) for assessing learning outcomes. Course developers and training providers should use such information as the basis for determining competency-based learning outcomes or training objectives.

Analysis of learning outcomes in this manner reveals certain similarities in the skills and knowledge required for various target groups, indicating some potential for different target groups to be trained together. In this regard, it should be noted that some learning outcomes are presented as relevant for all target groups, while others are intended for specialised groups involved in the formulation and implementation of systems and procedures to enable compliance with legislation.

Learning outcome 1: Legislated requirements relating to occupational noise

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Systems and programmes to enable compliance with legislation; Effective implementation strategies	Design and implementation of revised work procedures to reduce risk in own area	Criteria for systems, programmes and procedures to comply with legislation	Hazard identification, risk assessment and risk management as relevant to own workplace

Relevant skills and knowledge for all target groups:

- Knowledge of occupational noise legislation, the employer's code of practice and standards, as well as inter-relationships among these
- Knowledge of employers', employees' and manufacturers' responsibilities with regard to occupational noise
- Knowledge of the consultation process used in developing and implementing risk management systems and safe work procedures for occupational noise
- Knowledge of procedures for hazard identification, risk assessment and risk management, and of appropriate follow-up actions
- Knowledge of employer's strategies for implementing systems and procedures to comply with legislation and reduce risks to employees

Key performance indicators for given target group		
Employers and Senior managers	**Line Managers and Supervisors**	**Employees**
Compliance with legislated requirements by: Formulation of appropriate code of practice and standards; Implementation of effective risk management systems; Allocation of sufficient resources	Understanding of legislation, code of practice and standards; Implementation of risk control procedures in own area; Assessment of plant/equipment design and work processes in own area of responsibility	Assistance with implementation of measures for compliance; Adherence to safe work practices

Learning outcome 2: Health and safety effects of exposure to noise

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Awareness training for noise risks; Skills training for control measures; Exposure monitoring and Medical surveillance Communication and implementation strategies	Reinforcement of employee training and adherence to safe work practices; Encouragement of employee cooperation during exposure monitoring and medical surveillance	Criteria for evaluating training, exposure monitoring and medical surveillance programmes	Noise hazards, risks and personal relevance; Requirements for safe work practices; Exposure monitoring and medical surveillance procedures

Relevant skills and knowledge for all target groups:

- Provisions for hazard education/training in employer's code of practice;
- Basic understanding of how noise is generated and transmitted in the workplace
- Knowledge of noise's impact on the structure and function of the ear, and its psycho-social effects (impairment, disability, handicap and social dysfunction)
- Ability to apply practical tests for identifying dangerous noise
- Understanding of the basis for demarcation of noise zones
- Understanding of employer's standards for controlling risks from occupational noise and own responsibilities in this regard
- Skills necessary for application of/adherence to safe work practices
- Ability to correctly fit HPDs and knowledge of their limitations in reducing risk
- Appreciation of the value of safe work procedures, exposure monitoring and medical surveillance in managing the risk of NIHL

Key performance indicators for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
Training, exposure monitoring and medical surveillance programmes implemented, continuously monitored and regularly evaluated	Active participation in training programmes; Correct application of HPDs in noise zones; Adherence to safe work practices; Cooperation and assistance during exposure monitoring; Cooperation with medical surveillance procedures

Learning outcome 3: Hazard identification to enable risk assessment

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Hazard identification procedures and implementation strategies, including consultation/communication; Coordination of hazard identification process	Hazard identification procedures for own area and facilitating implementation	Evaluation criteria for hazard identification procedures and implementation strategies	Identification of hazards in own workplace; Communication of concerns to supervisors and Health & Safety representatives

Relevant skills and knowledge for all target groups:

- Provisions for hazard identification in employer's code of practice;
- Knowledge of criteria for identifying noise hazards
- Knowledge of strategy and procedures for identification process
- Knowledge of correct reporting procedures, including the use of forms provided
- Correct application of criteria and procedures for identifying noise hazards, with consideration of relevant factors

Key performance indicators for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
Adequate resources allocated for hazard identification process; Consultative mechanisms in place and utilised to involve H&S representatives and employees; Suitable forms designed and circulated to document the identification of hazardous equipment and tasks; Hazard identification process coordinated and monitored; All possible hazards considered, with consultation involving supervisors, employees and H&S representatives; All noise hazards identified and recommendations formulated to inform the risk assessment process	All potential sources of risk in own workplace observed, inspected and documented using the forms provided; Supervisors and H&S reps informed of all hazards and related concerns

Learning outcome 4: Risk assessment for occupational noise

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Risk assessment procedures, criteria and implementation strategies; Consultation and communication of adopted strategy; Prioritisation of risks and formulation of action plans	Facilitating assessment process in own area of responsibility	Criteria for evaluating risk assessment procedures and implementation strategy; Communicating requirements for risk assessment and facilitating implementation; Criteria for evaluating results and prioritising risks	Purpose and benefits of risk assessment; Assessment criteria and procedures relevant to own workplace and function

Relevant skills and knowledge for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
Provisions for risk assessment in employer's code of practice; Development of criteria, procedures and implementation strategies for risk assessment; Consultative and communication techniques; Design of documentation and evaluation forms; Scheduling, coordination and monitoring; Interpretation of risk assessment findings; Formulation of action plans based on results	Provisions for risk assessment in employer's code of practice; Methods and procedures for risk assessment in own area; Criteria for assessing risks; Observational skills applicable to assessing risks in own workplace; Inspection and recording; Understanding of basis on which risks are assessed and classified

Key performance indicators for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
Risk assessments performed by competent persons for all identified hazards, in accordance with code of practice and relevant standards; Application of adopted criteria in evaluating risk assessment findings; Risk assessments properly documented and findings communicated to employees; Recommendations emanating from risk assessments evaluated for possible implementation	Assistance with risk assessment for identified hazards, in accordance with own function; Understanding of risk assessment findings and resultant action plans

Learning outcome 5: Risk management for occupational noise

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Risk management systems, procedures and implementation strategies; Consultation and communication techniques; Negotiation and motivation techniques; Training and instruction requirements; Coordinating the implementation of risk management measures; Evaluating results	Contributing to development and implementation of risk control measures in own area; Informing and motivating employees regarding use of control measures	Evaluation criteria for risk management systems, procedures and implementation strategies; Requirements for training content, informational, motivational and instructional materials; Promoting communication between management and employees	Evaluating potential risk management measures for own workplace; Implementation requirements for measures adopted; Consulting with co-workers, supervisors and H&S reps regarding control measures and remaining concerns

Relevant skills and knowledge for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
Provisions for risk management and control measures in employer's code of practice; Comprehensive knowledge of equipment and processes requiring noise control treatment and their prioritisation from the risk assessment process; Sources of appropriate expertise; Awareness of technological developments and new research findings; Criteria for risk management systems, procedures and implementation strategies; Development of appropriate risk management systems, procedures and administrative mechanisms, e.g. flowcharts, proformas and record-keeping systems; Consultation during development of systems and procedures that are based on engineering, administrative and personal protection strategies; Formulation of evaluation criteria; Knowledge of training, instruction and supervision requirements and of special needs; Informational and motivational techniques for communicating procedures and strategies	Provisions for risk management and control measures in employer's code of practice; Prevailing risks and requirements for control measures in own workplace; Advantages & disadvantages of possible control methods; Criteria for selection of noise and exposure control measures; Criteria for evaluation of adopted control measures; Awareness of mechanisms and procedures for participating in development/ selection of control measures for own workplace

Learning outcome 5 (cont'd)

Key performance indicators for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
Control measures implemented to reduce noise emission and employee exposure; Noise control addressed in equipment operating and maintenance procedures; Noise reduction criteria incorporated into equipment maintenance procedures and procurement criteria; Ongoing consultation practiced with employees, H&S reps and supervisors; Enabling information, motivation and support provided, including training, instruction and supervision; Procedures in place for ongoing monitoring and assessment of risk management measures; Appropriate action taken in the event of unfavourable findings from occupational hygiene monitoring or medical surveillance, including reprioritisation of risks; Adequate resources allocated; Appropriate hearing protection devices identified for all required applications, with consideration given to special needs	Active participation during consultation process; Contribution to the development and implementation of risk management procedures in own workplace; Feedback provided to supervisors and H&S reps regarding the effectiveness of risk management procedures, including special needs Adherence to procedures for reducing noise emission during equipment operation; Application of noise reduction criteria during maintenance procedures; Adherence to risk management procedures, including the proper use of HPDs in designated areas; Willing participation in educational, training and motivational programmes

Learning outcome 6: Implementation of occupational hygiene monitoring

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Requirements for OH monitoring programme, considering identified noise hazards and risks; Administrative measures to link results of OH monitoring with medical surveillance records; Sources of risk to be considered during OH monitoring; Evaluating findings and prioritising remaining risks; Using findings to evaluate and revise risk control measures	Facilitating OH monitoring in own area and ensuring all sources of risk are monitored; Encouraging cooperation of employees; Communicating findings to employees; Formulating measures to address risks identified by monitoring	Criteria for OH monitoring; Communicating reasons for OH monitoring to gain employee cooperation; Evaluating findings of OH monitoring; Evaluating action plans formulated in response to findings	Value of OH monitoring; Identifying sources of risk to be monitored and informing supervisors and H&S reps; Facilitating monitoring procedures; Meaning of findings; Contributing to formulation of corrective measures

Relevant skills and knowledge for all target groups:

- Findings and recommendations of risk assessment process
- Effect of risk management measures
- Remaining sources of risk
- Provisions for OH monitoring in employer's code of practice
- Implementation strategy for monitoring occupational noise and exposure levels
- General knowledge of noise measurement techniques and methods
- Schedule for noise level and exposure measurements, in relation to production schedules and work tasks
- Constraints to OH monitoring imposed by production schedules and processes
- Identification, observation and examination techniques to monitor sources of risk
- Mechanisms and procedures for reporting concerns related to noise and risks
- Sources of OH monitoring assistance, expertise and instrumentation

Key performance indicators for all target groups:

- Employee cooperation and assistance with OH monitoring procedures
- Results of OH monitoring communicated to exposed employees and to officials responsible for relevant risk control measures
- Factors contributing to exposure (e.g. extended working hours, atypical equipment or operating methods) evaluated and findings communicated to relevant officials
- Affected employees and responsible officials consulted regarding additional control measures
- Appropriate control measures implemented/revised where noise and exposure levels are unacceptable in terms of risk to employees
- Results of OH measurement linked to/incorporated in medical surveillance records

Learning outcome 7: Implementation of medical surveillance/audiometry

Target group and expected learning outcomes/competencies			
Employers and Senior managers	**Line managers and Supervisors**	**HCP Management and H&S Committees**	**Employees**
Requirements for medical surveillance/ audiometric testing programmes; Linkage of OH monitoring results and medical surveillance records; Use of findings to evaluate and revise risk management strategies and control measures	Facilitating medical surveillance and encouraging employee cooperation; Communicating audiometric trends to own employees; Formulating revisions to risk control measures in own area of responsibility	Promoting the implementation of audiometry and employee cooperation; Evaluating audiometric trends; Criteria for evaluating risk management strategies and control measures on basis of audiometric trends	Value of medical surveillance/ audiometry; Meaning and implications of own test results; Potential control measures for any risks that are demonstrated by audiometry

Relevant skills and knowledge for all target groups:

- Purpose and benefits of audiometric testing
- Provisions for medical surveillance/audiometry in employer's code of practice
- General knowledge of audiometric test methods
- Relevance of audiometric testing in evaluating risk control measures
- Time requirements of audiometric testing and production schedules
- Implications of individual test results and audiometric trends
- Criteria for assessing risks demonstrated by audiometry results and formulating revisions to control measures
- Criteria for hearing loss and hearing impairment, including compensation for NIHL

Key performance indicators for given target group	
Employers, Senior managers, Line managers and Supervisors	**Employees**
All noise-exposed employees subjected to audiometric testing at regular intervals, in accordance with employer's code of practice; Employees informed of findings; Counselling and re-training provided for individuals with significant hearing loss; Appropriate action taken in cases of significant hearing loss, e.g. medical referral or specialist evaluation; Audiometric trends communicated to officials responsible for relevant control measures; Control measures in individual workplaces re-assessed and revised on basis of own employees' test results	Cooperate with audiometry; Understand own test results and implications of any hearing loss identified; Act to prevent further hearing loss, if identified; Contribute to formulating revisions to risk control measures in own workplace

Annex 4: Noise control engineering
(For information only)

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1 Introduction

A hearing conservation programme, to address the true source of risk, must include noise control engineering (NCE) initiatives as a fundamental strategy to control the occurrence of NIHL. Modern machinery is far more efficient than that previously available, wasting only minimal amounts of energy in the production of mechanical vibration and noise. Indeed, the levels of acoustic energy emitted by modern machinery are minuscule in comparison with what is applied to the intended purpose and the total amount of energy consumed.

This is not to say that there is no scope for reducing machinery noise, although it does highlight the fact that successful NCE measures must be based on an analytical assessment of the source in question. It must be appreciated that, until quite recently, efforts to develop new machinery designs were generally focussed on achieving the required level of performance, with only secondary consideration given to limiting the amount of noise produced. Growing public concern over noise pollution and pressure on employers to limit employees' exposure to noise have led to a new generation of machinery, although it must be acknowledged that such progress is most apparent in domestic appliances, office equipment and motor vehicles.

Accordingly, where an employer engaged in engineering, manufacturing or mining wishes to address the issue of noise at its source, his options may be limited to measures that, individually, cannot provide the required reduction in emission and exposure levels. Among the options to be considered are:

- Adoption of alternative methods or processes, provided such technologies are available and viable
- Modification of existing machinery, possibly incorporating noise control features of current models
- Isolation of major noise sources from employees, where practicable

Where no single noise reduction strategy can provide the desired result, a combination of such measures is necessary. For a comprehensive presentation of the principles and applications of noise and vibration control, refer to Beranek and Ver (1992).

The application of NCE principles to the design of industrial plant and machinery is a specialised field of mechanical engineering that should be better understood by equipment manufacturers than by occupational hygienists. In a similar vein, an employer's implementation of alternative production methods requires a strategic business decision based on technical, operational, and economic considerations, all within the context of his area of enterprise and the market in which he competes. The present document is not intended to offer machinery manufacturers or employers of noise-exposed employees guidance in their respective areas of expertise, but is rather intended to examine the principles of NCE, various strategies for applying them, and means of evaluating the results.

Given the requirement for most noise reduction measures to be tailored to a specific application, a detailed and comprehensive treatment of this topic is beyond the scope of this annex. However, the basic principles and various approaches for reducing noise at the source, controlling its transmission and limiting its immission on the ears of employees are considered, with illustrative examples provided.

It must be appreciated that the application of NCE principles and strategies depends on the noise source in question, as well as on the specific circumstances of its installation and use. This is particularly true in the case of equipment that is already in operation. Accordingly, the present annex is necessarily limited to a general treatment of noise control, and the reader is encouraged to consult other sources of information, some of which are cited, as well as the manufacturers of specific noise sources where greater detail or more specific guidance is required.

2 Basic approaches to noise control engineering

Engineering measures aimed at reducing noise and employees' exposure to it can be categorised into two basic approaches, viz.:

- At-source reduction of noise, and
- Control of noise propagation/transmission into and through the workplace

Noise is the result of:

- Vibration within machinery
- Impact between parts of machinery and material which, in turn, cause vibration
- Turbulence in the flow of certain materials

Accordingly, reducing noise at the source requires engineering measures based on an understanding of the fundamental causes of the noise in question.

Controlling the transmission of noise involves interruption of the propagation path, either by enclosing the source or the exposed employees, or by installing sound reflecting or absorbing barriers between the source and receiver. Designing an effective enclosure requires an understanding of the nature of the noise being emitted, while the successful use of barriers requires knowledge of the noise being emitted, as well as an understanding of the manner in which it is transmitted, i.e. direct or reflected and whether it is airborne, structurally borne or both.

A fundamental requirement for enabling effective noise control measures is the use of frequency analysis techniques to quantify levels of emitted and transmitted noise. Without an understanding of the specific nature of the noise, selecting an appropriate strategy and means for controlling it is impossible. Accordingly, and given the costs associated with devising and implementing NCE measures, it would be preferable for measurements associated with such initiatives to be performed with Type 1, precision-grade instruments.

2.1 At-source reduction

Means of achieving at-source reductions for various types and sources of noise are considered in the sub-sections that follow.

2.1.1 Vibration

Machine vibration is best addressed within the machinery itself, firstly, by eliminating as far as possible the rattling of loosely fitted or worn components, which may involve little more than simple maintenance. Minor modifications such as the isolation of vibrating panels and component enclosures with an elastic interface or insertion layer (e.g. a rubber gasket) can further reduce vibration and resultant noise. Additional reductions to the vibration of panels and covers can be achieved by coating or cladding them with a damping material or by affixing pieces of high-density and resilient material to their centre, either on the inside or outside, as the situation permits. Where vibration is unavoidable, the provision of damping between the relevant component and others can eliminate or reduce secondary/sympathetic vibrations, which often generate more noise than the actual source of the disturbance. Such measures rarely result in negative impact on machine performance and, on the contrary, generally enhance it and reduce maintenance requirements.

2.1.2 Impact noise

Noise that is initially attributed to vibration often originates from material or machinery striking a panel or some other object. Stiffening such panels or objects and providing damping can greatly reduce the vibration and resultant noise. Where unavoidable impact occurs between machinery components or between machinery and material, the use of plastic, nylon or compound components in place of metal ones can, where practicable, greatly reduce impact noise. Such modifications can sometimes cause a loss in performance and invariably increase maintenance requirements, due to the need for more frequent replacement of worn components. However, this can be at least partially offset by reductions in those maintenance requirements attributable to the internal shock and resultant vibrations caused by impact. Reducing the height that tipped or dumped material falls from, as well as stiffening, covering and damping receptacles or containers that material falls into can reduce impact and noise, as well as requirements for maintenance and repairs.

2.1.3 Fluid turbulence

Noise from fluid turbulence can be reduced by eliminating sharp bends in pipes, ensuring that pipe dimensions permit lower flow velocities, installing better-designed valves and pressure regulators, and by damping the mountings of pipes and hydraulic lines. Preventing or periodically removing the build-up of scale inside pipes and valves can also control such noise. In addition to reducing noise, measures to control fluid turbulence normally contribute to enhanced flow and reduced maintenance requirements for pumps, pipes, valves and regulators.

2.1.4 Fan noise

The provision of cooling fins for heat producing machinery, or larger fins where they already exist, may allow the elimination of ancillary fans and the noise that they produce. Provided such measures do not significantly increase operating temperatures, performance would be unaffected and in addition, elimination of such fans would reduce maintenance requirements.

Ventilation and extraction fans often contribute significantly to employee exposure and can induce the generation of additional noise in their ducting. Fan noise can be addressed by a number of means and sometimes by their combination, depending on requirements. Possible measures include the use of a different type of fan or profile of fan blade, replacing guide vanes with more efficient types or altering their position, reducing turbulence at the fan's intake with airflow guides, or altering the number of fan blades and/ or the fan's rotational speed. Provided such measures are compatible with requirements for fan duty and the appliance's basic design, losses in performance should be minimal and could possibly be offset by increasing passive ventilation.

Where ducting is included in the fan installation, efforts should be made to control vibration in ducting induced by the fan. This can be achieved by de-coupling or isolating the fan from the ducting with an elastic or flexible duct section, installing elastic insertion or gasket material between the fan and its mountings and between sections of ducting, as well as between the ducting and its supporting brackets.

2.1.5 Exhaust noise

Where exhaust noise constitutes a major contributor to noise emissions, as is the case with pneumatic- and diesel-powered equipment, the installation of a silencer can greatly reduce noise levels. Similarly, extractor fans can be fitted with attenuators to control exhaust noise, although such a device would require careful matching with the extraction system to maintain acceptable performance, as well as regular cleaning and maintenance. Specially designed compressed air nozzles can eliminate much of the noise attributable to this type of source, normally with minimal losses in performance.

2.2 Controlling the propagation of airborne noise

Control measures for the transmission of noise, particularly where it is airborne, are generally easier to implement than at-source reduction, as they involve interrupting the propagation path. For airborne noise, the enclosure of noise sources and provision of partitions, barriers or attenuators to limit the transmission and reflection of noise are measures that can be applied with good results. However, the effect of such measures are generally less dramatic than those realised from at-source reduction, and are more susceptible to circumvention and the effects of inappropriate or inadequate maintenance.

2.2.1 Enclosures

Where direct access to a major noise source is not required for normal operation, enclosing it may be a viable option. The enclosure should be of a sufficiently dense and stiff material, and be clad with an appropriate absorbent lining so as to prevent the enclosure itself from becoming a noise source. Where vibration of the enclosure still occurs, damping its inner and/or outer surfaces with cladding or a suitable coating can limit the extent of vibrations being radiated into the surrounding air as noise.

The necessary access for maintenance operations should be provided, with tightly fitting hatches or inspection covers to avoid compromising the enclosure's acoustic integrity. In this regard, a seemingly insignificant gap or opening, whether inadvertent or deliberate (e.g. to provide ventilation, in the case of the latter), can drastically reduce the enclosure's effectiveness.

Where noise sources generate significant amounts of heat, provision must be made for ventilation and/or cooling without rendering the enclosure ineffective, e.g. through a closed ventilation system that extracts warm air and conveys it to a remote location, without the introducing additional noise to the workplace from a cooling fan or refrigeration plant.

Where it is impossible to enclose a major noise source but automated processes and plant are employed, it may be possible to provide an acoustic enclosure for employees, particularly where their function is mainly one of monitoring plant operation. Even where employees are periodically required to physically intervene, the provision of a quiet "refuge" in the form of an acoustic enclosure can serve to reduce employees' exposure time and hence, their exposure level. The benefits derived from such a provision would depend on the relative times spent at or near noisy machinery and in the enclosure, and the enclosure's effectiveness in excluding plant noise.

2.2.2 Barriers

Where total enclosure of a noise source or exposed employees is not possible, partitions and barriers can often be used effectively. Clearly, the potential for such measures to reduce noise is less than for enclosures, indicating that such an approach would be suitable only where enclosures are not possible and only moderate reductions in noise level are required. The choice of material to be used (including its density and absorbency), as well as the size of barrier, will be dictated by the level and frequency of the noise to be controlled. Barrier position, relative to the source and the area where noise is to be reduced, will also be determined by the nature of the noise and by its line of propagation or directivity.

High frequency and highly directional noise at relatively low levels can be effectively controlled with smaller and less dense barriers, while low frequency and multi-directional noise at high levels requires large and dense barriers, strategically positioned to prevent the flanking of noise around the barrier. Where noise appears to be multi-directional, this may be a result of the noise being partially structure-borne, being airborne and reflected by ceilings and/or walls, or some combination of the two. Again, effective control measures would depend on careful analysis to determine the propagation mechanisms involved and devising an appropriate solution.

Barrier placement must also be in accordance with the operational requirements of the workplace, and not introduce ergonomic constraints that could impact on productivity or safety. Depending on the nature and position of the source, hanging panels or curtains (the latter for less extreme sources) suspended by cables or chains can often contribute towards adequate control of airborne noise transmission, generally with less interference to operations than introduced by floor-mounted barriers.

2.2.3 Reflected noise

A general treatment for controlling the propagation of noise from a number of sources within a large area is to affix sound absorbent material (e.g. mineral wool or glass fibre) to the ceiling. Such treatment will have no effect on the noise level near a given source (which should be otherwise addressed). However, it will control reflection and reverberation, reducing noise levels at distant locations by 3 to 5 dB and possibly by as much as 8 dB, thus limiting overall noise in the area. A similar treatment involving the walls as well as the ceiling, and employing highly absorbent, 100-mm (thick) perforated panels can reduce reverberant sound by as much as 10 dB. Such measures, whether they involve the ceiling only or the ceiling and walls together, in combination with local absorption (around individual sources and including operators' positions), can provide even greater reductions in reverberant noise.

2.2.4 Pipe- and duct-borne noise

Airborne noise can be transmitted to distant areas or to other rooms through ducting, in which case a ventilation attenuator may be required. Such devices generally have some negative impact on airflow and accordingly, an attenuator should be carefully matched to or designed for the specific type of fan and ducting system to which it is fitted. Attenuators are also susceptible to contamination by humidity and particulates (e.g. dust), indicating the need for regular maintenance. Continued effectiveness is contingent upon maintenance operations that do not disable, disturb or otherwise compromise the attenuator's function, implying the need for maintenance personnel to be given appropriate training and/or access to relevant technical information from the attenuator supplier.

Where pipes and ducting pass through walls, airborne noise can be transmitted through the openings, apertures or gaps into quieter areas. Accordingly, care must be taken to ensure that all gaps and openings around pipes and ducting are sealed to gain the full noise-excluding effect of walls or partitions. Pipes and particularly ducts may themselves require treatment, as discussed in Section 2.3, “Controlling the propagation of structure-borne noise”.

2.2.5 Attenuation with distance

Another strategy for controlling the propagation of airborne noise, or at least its impact on employees, is to take advantage of the attenuation effect of air, by remotely siting noise sources in areas not frequented by employees. This approach is not viable for machinery or plant directly associated with operations, but infrastructural sources such as compressors, generators or ventilation fans can often be dealt with in this manner. In a free-field situation (i.e. an open area with no reflecting surfaces) noise levels diminish by 6 dB for every doubling of distance from the source. In a typical large factory building the attenuation effect of increased distance is normally a 4- to 5-dB reduction for each doubling of distance. In an enclosed and highly reverberant environment (e.g. in underground excavations or in a room with highly reflective walls, there may be no such reduction apparent even for a number of distance doublings. In such situations the noise will appear to be equally loud in all positions, with no apparent direction of origin as a result of the strong reflection and reverberation effect. Clearly, the treatment of such areas with sound absorbents should be a priority, particularly where large numbers of employees are affected.

2.2.6 Active noise control

Active noise control or noise cancellation techniques involve the use a sound signal generated at equal but opposite pressures to the source being controlled, resulting in destructive interference waves that cancel emissions from the source. This is not a new concept, but the relatively recent availability of suitably responsive electronic signal processors and computer-derived algorithms to match the “anti-noise” to the source and maintain its continued alignment with the source have made active noise control a viable option for certain applications.

In its simplest configuration, an active noise control system comprises:

- A microphone appropriately positioned to provide representative and continuous measurements of the noise to be controlled
- A signal processor with frequency analysis capability and appropriate mathematical algorithms to analyse noise emissions from the source and devise a mirror-image or 180° opposite-phase signal
- An amplifier that adjusts its output in accordance with instructions from the signal processor
- A loudspeaker or other type of transducer that emits an anti-noise signal to cancel out noise from the source

In addition, an adaptive feedback circuit normally provides the signal processor with information regarding the effect produced by the anti-noise signal, in order that ongoing adjustments can be made to its frequency and intensity. In practice, a number of microphones, a multi-channel signal processor, powerful amplifiers and numerous loudspeakers or actuators are required. In addition, transducer locations must be determined through a careful analysis of the specific noise source in question, as well as the manner in which noise is propagated in the area (Eriksson, 1992).

Practical and computational constraints on the complexity and responsiveness of algorithms to analyse noise emissions and formulate the anti-noise signal, as well as limitations in actuators' ability to withstand harsh environments, impose limitations on the types of applications where active noise control is effective. These are invariably confined to sources that produce relatively steady noise at low frequencies, typically below 500 Hz, and where temperature, humidity and dust are not excessive. Most of the successes in active noise control have involved the control of noise from ventilation fans, particularly in "clean" air-conditioning systems. These have often utilised hybrid designs, employing active control for the low-frequency components of noise and passive attenuators for high-frequency emissions. However, it must be recognised that the use of an attenuator, either at the fan or in the ducting, can have negative impact on ventilation performance.

Development of an active noise control system requires specialised acoustics, computer programming and electronics expertise beyond the resources available to most employers. Where required, the out-sourcing of such expertise may be a viable option, provided that suitably qualified and experienced consultants are available. However, active noise control systems are generally designed for a specific application, involving the allocation of specialised skills and other resources for considerable periods of time. This would indicate that equipment and machinery manufacturers are normally in a better position to embark on the development of such systems, as part of their product improvement programme.

The application of active noise control has progressed considerably in recent years, largely as a result of improvements in the signal processing response time and on-chip memory capacity of modern hardware. One aspect of this technology that has not benefited from corresponding advances is the development of low-cost actuators that are resistant to harsh conditions, including temperature, humidity/water and corrosive environments. Where detailed information is required the reader is advised to consult the references cited by Guicking (1988 and 1991) in his extensive bibliography on the topic. For information on the present state-of-the-art for active noise control, current literature should be consulted (e.g. Eriksson, 1999).

2.3 Controlling the propagation of structure-borne noise

Where machinery vibrations are transmitted to an underlying load-bearing structure, these can travel throughout the building, causing other structures to vibrate, (e.g. walls, windows, pipes or ducting) and generate noise in areas far removed from the actual source, with no identifiable direction of the noise or its ultimate source. A number of such noise sources operating simultaneously can create an all-pervasive din that defies any attempts to identify its origins. Familiarity with machinery operating schedules and a process of elimination can establish which machines contribute most to structurally borne noise, and these can be assessed individually, with a view to implementing suitable control measures.

Lighter sources can be isolated from their supporting structures by the provision of an elastic interface, e.g. rubber mounting blocks or sprung mountings, to reduce the level of vibration transmitted to the building's structure. Heavier sources that generate high levels of vibration (and hence, noise) require specially designed machine foundations that are isolated or de-coupled from the structure of the building.

In a certain sense, noise transmitted by pipes and ducting can be regarded as structure-borne, and its control can be achieved by similar means. In the first instance, pipes should be isolated from pumps by a section of flexible pipe or hose, and ducts isolated from fans with a section of flexible ducting. The installation of battens and brackets to support pipes and ducts along walls or ceilings should include an intervening layer of elastic interface or gasket material. To further control the transmission of vibration from pipes and ducts into the building's structure, they should be isolated from supporting brackets and clamps with a similar damping material. All clamps and brackets should be tightly fitting and closely spaced to further control pipe and duct vibration, indicating the possible need to install additional support brackets. Where duct vibration is still excessive, cladding to damp the outer surfaces will normally reduce it, along with the noise it generates.

3 Implementation strategies for NCE

3.1 Existing machinery

Before implementing noise reduction and control measures for existing plant and machinery, an assessment must be made of the total costs for the measures being considered, including possible impact on plant performance, maintenance and employee efficiency. These should be evaluated against the extent of exposure reduction likely to result, valued in terms of reduced risk of hearing impairment for all affected employees and the eventual compensation payments that would otherwise be required. The results of such cost/benefit analyses should provide sufficient information to enable decisions concerning the implementation of noise reduction and control measures.

Where a particular source will require a number of modifications or treatments to achieve the desired result, these should be planned so as to ensure that the initial measures are not undone when implementing the final ones.

Prerequisites for the coherent implementation of NCE measures can be summarised as:

- Assessment and prioritisation of all noise sources in accordance with their respective contributions to employee exposure
- Evaluation of all possible measures to reduce noise or control its propagation (including a cost/benefit analysis that considers the value of possible efficiency losses, as well as that of likely risk reductions)
- Selection of the most suitable measures for implementation, based on the findings of their respective evaluations
- Where a phased approach will be used to implement reduction and control measures, ensure that their sequence of implementation allows earlier measures to be retained and added to, rather than being removed and then replaced with subsequent measures

Noise reduction targets or noise limits must then be set for all relevant noise sources, activities and workplaces, in accordance with the likely noise reductions determined by evaluations. The next step would be to devise a schedule for implementing selected measures, avoiding periods of peak production demand, and preferably coinciding with planned maintenance operations. Where outside contractors will perform any of the intended work, their schedules should also be closely co-ordinated with those of production and maintenance operations.

3.2 New machinery

When it becomes necessary to purchase new machinery, noise emission levels should be considered along with other relevant performance specifications, and suppliers should be required to provide such information. In some instances a quieter machine may be available at greater cost, or noise reduction options may be available, also at greater cost. In such cases the higher price should be evaluated against reductions in employee exposure and risk of hearing impairment, for the number of persons to be affected over the life of the equipment, the latter quantified in financial terms on the basis of likely reductions in compensation payments.

Where quiet alternatives are unavailable, employers should encourage manufacturers to begin developing them, by making noise emission level an important criterion for the selection of new machinery. Limits should be set in accordance with what is realistically achievable, and these should be incrementally reduced over time, again with cognisance of what can realistically be achieved. This process should continue until machinery noise emissions are at safe levels, with limits and time schedules for compliance negotiated with manufacturers and suppliers.

Before new machinery is installed an evaluation should be made of possible measures to limit the propagation of noise in the workplace, including the control of airborne noise (Section 2.2 and its constituent sub-sections), and structure-borne noise (Section 2.3). Such measures can be implemented far more cost-effectively at the time of major installations than afterwards. The same principle applies to new factories and plant facilities: designing and planning for noise control is far more effective and less costly than retrofitting noise reduction measures.

4 Examples of NCE treatment

Examples of NCE treatments, some of which have been referred to in the text, are summarised in Table 4.

Table 4
Examples of NCE treatment for various noise sources

Source	Problem	Treatment	Effect
Boiler exhaust	High pressure-steam is vented through a large-diameter pipe several time a day, producing low-frequency noise at high noise levels.	Fit a perforated-cone exhaust diffuser to existing vent pipe, which splits the single exhaust jet into many smaller ones, lowering velocity and reducing noise, as well as transforming the frequency of the noise from low to high. This higher frequency noise is more easily attenuated than the original low frequencies, allowing the addition of a perforated and absorbent attenuator to further reduce noise emissions.	An overall noise reduction of up to 40 dB without any loss in performance. However, the attenuator will require periodic maintenance, possibly including occasional replacement of the absorbent fill material.
Compressed air scaling and cleaning gun	A simple, single-jet nozzle generates violent air turbulence at the outlet and unacceptable noise levels.	Replace single-orifice nozzle with a compound nozzle to produce a lower-speed annular air stream around main high-speed stream and smooth transition of latter	Noise reduction of 20 dB

Source	Problem	Treatment	Effect
		into the surrounding still air.	
Hand-held pneumatic grinder	High-velocity exhaust air is vented through the handle of the grinder, causing turbulence and noise in the surrounding air.	Fill the handle with steel wool packing to diffuse the exhaust air and reduce exhaust velocity.	Noise reduction of 15 to 20 dB
Noise transmission into adjacent enclosures	The existing single-layer partition previously installed to control noise transmission into an adjacent office was found to be ineffective.	Replace the single layer partition with a partition comprising two layers and an intervening air gap.	Noise in the adjacent office is reduced by 10 dB, without increasing the overall thickness of the partition.
Large fans	Low-frequency noise is produced at high intensity levels, creating a noise problem at distant locations.	Increase the number of fan blades and reduce the fan's rotational speed using an electronic speed controller, in such a way to maintain the required fan performance or output.	The frequency of fan noise is increased in proportion to the increase in the number of blades. High frequency noise is attenuated more with increasing distance than low frequencies, and lower fan speed reduces motor noise.
Turbulence noise from ventilation fan	Fan is too close to an obstacle, either a change in the ducting's cross-section or a bend or a regulating valve, causing turbulence and vibration at the fan's intake, and increasing the level of noise produced by the fan.	Re-position fan or obstacle. Decrease sharpness of bends in duct, allowing greater opportunity for turbulence to dissipate before air reaches intake. Install flow guides ahead of fan intake.	The reduced turbulence lowers vibration at the fan and in the ducting. Noise levels are reduced. Less mechanical stress is imposed on the fan and ducting.
Ducting that transmits fan noise	Ducting transmits noise from a ventilation or extraction fan.	Introduce changes in the ducting's cross-sectional size and add side branches to the network, to reflect some transmitted noise back towards the source by reactive attenuation. In practice, changes in duct size should be to a larger duct to allow expansion of air into what now acts as a reactive silencer. This also prevents the introduction of turbulence into the air stream. Use of absorbent panels inside ducts can also reduce transmitted noise.	Varying reductions in transmitted noise, depending on specific details of the original ventilation network and the modifications introduced. Reactive attenuation can supplement or even serve as a substitute for a fan attenuator.
Pipes and ducts	Sharp bends, closely spaced control valves and the internal accumulations of scale create turbulence in the flow of material being conveyed.	Install gentler bends to reduce turbulence. Increase the distance between control valves to allow settling of turbulence before reaching next valve. Control or periodically remove accumulations of scale.	Reductions in turbulence and resultant noise levels. Reduced loading of pump and improved performance. Reduced maintenance for control valves. Enhanced material flow.
In-line fluid regulating valve	Small-surface valve seat causing high flow velocity and turbulence around seat. Indirect fluid path and sharp edges in valve body further	Install valve with a larger seat and more direct fluid flow through the valve body. Additionally, use of a pressure-reducing insert	Reduced turbulence, Less vibration and noise, Better valve performance, and Reduced demand on

Source	Problem	Treatment	Effect
	contributing to turbulence. Vibrations transferred along pipe as structure-borne noise.	ahead of the valve will prevent cavitation downstream of valve	pump
Radiated noise	Large, unbroken vibrating surfaces efficiently radiate vibrations into the surrounding air as noise.	Replace flat, unbroken panels with perforated or expanded metal panels to reduce surface area and increase the number of edges around radiating surfaces for pressure equalisation.	Energy radiated into the surrounding air is reduced, and pressure equalisation around perforations allows some cancellation of the noise before it is propagated into the surrounding air.
Wide drive belt	A single wide drive belt produces high levels of low-frequency noise.	Replace the single, wide belt with a suitable number of narrow belts.	Although the total area of noise-radiating surface is only slightly reduced, the gaps and edges between individual belts allow some cancellation of noise and reductions of up to 10 dB.
Material hoppers	Bins or hoppers with welded side panels and bottoms radiate noise when they are filled, particularly when material falls into them. Noise is also produced when bins or hoppers are rolled across uneven floor surfaces.	Rather than welding side and bottom panels together, connecting them by means of tubular frame provides more edges for the cancellation of radiated noise. Damp hoppers and bins with internal lining. Reduce fall height and fit rubber wheels or casters in place of metal on mobile bins.	Cancellation of noise around the increased number of edges provides reductions in radiated impact noise of as much as 15 dB. Use of expanded metal sides can decrease noise levels even further, as can the damping of hoppers with an elastic lining, the control of fall height and use of rubber casters.
Sandblasting bay	Noise from this unenclosed source is transmitted throughout the workshop.	An insulated machine room is built to enclose the sandblasting bay, with heavy lead and rubber laminated curtains to contain noise and still provide good access.	Noise in the immediate vicinity of the source is reduced by up to 20 dB. Similar treatment can be applied to most principal sources of noise.
Small machines producing high-frequency noise	High frequency noise from a small bench-mounted machine is reflected by the walls and ceiling into adjacent areas.	Install a lightweight absorbent screen near the source at a relatively high position, and cover the ceiling with absorbent panels to prevent reflection into adjacent areas. Alternatively, enclose the source with an absorbent cabinet to contain noise and reduce levels at the operator's position.	Reduces high frequency noise at the operator's position and controls propagation into adjacent areas. Surrounding cabinets must permit necessary operator access. Similar treatment for all "small" noise sources will reduce overall noise levels in the entire area.
Structure-borne noise plant noise	Noise from a refrigeration plant or a compressor is transmitted into the structure of the building and through pipes.	Install spring-damped machine mountings or pre-ferably, provide an isolated machinery foundation. Damp all pipe supports and brackets. Use flexible pipe sections between the plant and its reticulation system and flexible electrical cabling rather than steel conduit for electrical cables.	Noise previously transmitted throughout the facility is contained within the immediate area of the source.

Source	Problem	Treatment	Effect
Vibrating sources	A small vibrating noise source is in contact with a large panel, causing high levels of noise to be radiated into the surrounding area or alternatively, a panel is in contact with a large vibrating source.	Isolate or separate the source from the radiating panel or alternatively, damp and/or perforate the panel to reduce noise transmission.	Noise levels are noticeably reduced, with the level depending on the intensity of the source, and the size/density of the vibrating panel.
Workshop with high levels of low- and high-frequency noise	A number of machines, large and small, produce high levels of noise at a number of frequencies, which affect the entire area.	Suspend vertically oriented, high-density baffles from the ceiling, using taller/higher/ denser baffles for lower frequency noise. Where vertically oriented panels will obstruct equipment such as an overhead crane, horizontal panels should be suspended as far from the ceiling as possible.	Vertically oriented panels absorb sound on two sides. Horizontally suspended panels more effective if positioned away from ceiling. Noise levels near individual sources are unchanged, but overall noise in area is reduced by up to 10 dB through control of reflected noise.

5 Evaluating NCE measures

5.1 After implementation

The provision of NCE treatments should, as a matter of course, be immediately followed by an evaluation to determine their effectiveness. This is intended not only to serve as a means of quality control, i.e. the comparison of expected or anticipated noise reductions with those actually achieved, but also to provide feedback on the return from investment in NCE initiatives and to ensure continued support for such measures.

The measurement procedures to be applied are essentially the same as recommended in Annex 2 (Risk Assessment), Section 3.4 (Noise measurements by manufacturers and suppliers) and Section 3.5 (Noise measurements by employers), and their respective sub-sections. In order to ensure the validity of NCE evaluations and the comparativeness of pre- and post-NCE results, all measurements should be performed in the same manner as those conducted during initial noise assessments.

All measurements should be documented and comprehensive records maintained. These will serve as a basis for an ongoing evaluation of the NCE programme, indicating the need to quantify the value of noise control benefits in financial terms, based on reductions in the risk of hearing impairment and the employer's potential exposure to compensation claims.

5.2 Re-evaluation and maintenance

Where the routine re-assessment of noisy machinery, areas and activities is to be done biennially (SABS 083: 2000), many NCE measures should be re-evaluated more frequently, given their susceptibility to deterioration and circumvention. In this regard, effective maintenance is essential to the continued control of noise emission and employee exposure levels, indicating the need for proactive, planned and preventative maintenance strategies. These should incorporate quality control noise measurements of the sort recommended in Section 3.5.10 of Annex 2, in order to ensure ongoing benefits from NCE initiatives, as well as to confirm that maintenance procedures contribute to controlling risks associated with the noise hazard.

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Annex 5:
(For information only)
Administrative measures to limit noise exposure

Administrative measures constitute the second of three possible approaches to reduce employees' exposure to hazardous noise, after noise control engineering and, where practicable, in preference to personal protection. The Mine Health and Safety Act (MHSA) includes in its Objects of Act, provision "to require employers and employees to…eliminate, control or minimise the risks relating to health and safety at mines." [MHSA 1(b)]. This implies that eliminating or controlling risks would be preferable to minimising them, but that the latter would be an acceptable course of action where elimination and control are not practicable.

Personal protection and administrative measures can both be regarded as means to minimise risk. However, and despite the universal view among hearing conservationists that personal protection should be treated as a last resort to be considered only after all other means have proven unfeasible or inadequate, PPE is all too often embraced as the first line of defence, and frequently implemented in the absence of any other risk control measures. This is understandable, insofar as at-source noise reduction normally requires either the replacement of expensive and otherwise serviceable plant (assuming that quiet alternatives are available) or its modification, with the latter often having negative impact on the efficiency of production and maintenance operations, both of which ultimately impose constraints on profitability. However, experience has proven that personal protection strategies, for various reasons, generally fail to realise their full potential, and that hearing conservation programmes too reliant on PPE invariably fail. This would indicate that some consideration should be given to administrative measures to supplement other exposure reduction strategies.

Despite limitations on the practicability of administrative measures, which aim to reduce risk through changes in the organisation of work, this approach does offer some potential to contribute to reducing exposure to dangerous noise. Examples include the alternative scheduling of noisy operations, e.g. staggering production schedules to avoid the simultaneous execution of noisy tasks in the same or adjacent areas, and the rotation of employees out of noisy areas. However, the latter requires that employees be trained for multiple tasks, as well as sufficient availability of useful work in quieter areas to accommodate individuals approaching their exposure limit. Prospects for the successful implementation of employee rotation are further limited by its likely impact on productivity as employees move between tasks and workplaces, and potential safety implications resulting from employees' reduced familiarity with certain of their duties.

Where these limitations can be overcome, the use of employee rotation would still impose the administrative burden of determining and documenting individual exposure levels, based on the duration of exposure in each of the various workplaces and the noise levels prevailing there. Given the inherent limitations of employee rotation, it is likely that administrative measures in most work situations would be restricted to changes in the organisation of work, e.g. the alternative scheduling of noisy tasks.

Despite being a preferable alternative to personal protection, administrative measures offer only limited potential for contributing to the success of a hearing conservation programme. This potential should be evaluated with due consideration to specific circumstances in each work situation and concomitant limitations on the practicability of administrative measures, before a decision is taken regarding their implementation.

Annex 6: Personal protection
(For information only)

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1 Introduction and scope

Hearing protection devices (HPD) are items of personal protection equipment (PPE) that, as a result of the attenuation they provide, reduce the immission of noise on the human hearing mechanism in order to limit the risk of noise-induced hearing loss.

The present annex provides recommendations for the selection, use, care and maintenance of HPDs, as well as guidance in adopting appropriate criteria for these essential aspects. Special types of HPDs, e.g. those applying the principles of noise cancellation or electronic transmission of communication sounds to the user's ears, are beyond the scope of this annex.

In order to ensure that HPDs provide the requisite level of protection, these devices should be appropriate for the intended application, be compatible with the user's individual needs and work situation, and be used at all times when in a noisy environment. The latter requirement underscores the importance of fit, comfort and employee acceptance.

2 Standards and requirements

In any area of work where it has not been possible to reduce noise levels to below 85 dBA, either through reasonably practicable noise control engineering measures or administrative control practices, HPDs that conform with the requirements specified in SABS 1451 Parts 1 or 2, as relevant, and including ISO 4869 must be supplied free of charge by the employer and be properly used by employees.

Note: HPDs should not be regarded as a substitute for engineering-based noise reduction or control measures (Annex 4), or minimising exposure through administrative measures (Annex 5) where such measures can be demonstrated to be reasonably practicable.

3 Types of HPDs

HPDs differ from one another in terms of their positioning or manner of application, viz.:

- Circum-aural devices enclose or surround the ears, i.e. earmuffs,
- Supra-aural devices seal off the entrance to the ear canal, i.e. ear caps,
- Intra-aural devices are inserted into the ear canal, i.e. earplugs, and

earplugs vary with regard to whether they are:

- Disposable, i.e. unmoulded or formable earplugs, or
- Reusable, i.e. pre-moulded and, in the case of the latter, whether they are custom-moulded for a specific individual.

Working in conditions of extreme noise may require more protection than what is provided by earmuffs or earplugs alone, but it should be appreciated that the attenuation provided by combinations of HPDs (e.g. the simultaneous use of earplugs and earmuffs) will be somewhat less the sum of the attenuation from each of the individual devices being considered. In fact, certain unfavourable combinations of HPDs can yield less protection in practice than what is provided by individual devices used alone. Where a need for additional protection exists, competent advice should be sought regarding the ability of various HPD combinations to provide the required attenuation. Where documented attenuation data are available for specific combinations of HPDs, these should be regarded as preferable.

Re-usable HPDs must be supplied by the employer as new and unused, and be maintained by the employee in a clean and functional condition, stored in a suitable container or case when not in use. In the case of disposable HPDs, an adequate supply of new, unused devices in unopened factory packaging must be readily available at all times.

4 Range of choice and selection criteria

Provided that only devices capable of delivering an appropriate level of protection for the intended application are offered, it is advantageous for employees (users) to be allowed to choose from a reasonable range or selection of HPDs. In addition to the level and spectral characteristics of noise in the workplace, the selection process must consider individual needs (e.g. existing hearing loss) and the nature of work tasks. These requirements indicate that HPD selection, fitment and instruction are best addressed during or immediately following risk-based medical examinations (RBME, Annex 7), under the supervision of an Occupational Health Practitioner (OHP).

Individualised selection and consultation with the OHP towards that end must:

a) Consider the level and nature (relative to frequency) of protection provided by a given HPD in conjunction with that required for a given work situation/noise environment and any pre-existing hearing loss, with cognisance of the fact that unnecessarily high attenuation levels would cause sensory deprivation and interference with communication, especially for individuals with appreciable hearing loss,
b) Consider that environmental conditions and physical work rate may render some HPDs unsuitable for certain work situations (e.g. where hot, humid conditions and/ or physical exertion would lead to discomfort and heavy perspiration), despite the devices' other attributes,
c) Provide for an acceptable level of user comfort with regard to fitment, weight, thermal conditions in the workplace and, where applicable, clamping force,
d) Ensure HPD compatibility with other forms of PPE, e.g. hardhat, safety glasses/ goggles or respiratory equipment where the use of such equipment is required, and
e) Consider possible safety implications of the attenuation provided by HPDs, not only for the user, but for co-employees as well.

Note: With regard to the level of protection provided by HPDs, the Noise Reduction Rating (NRR) commonly cited by manufacturers and suppliers should only be used in a comparative or qualitative sense. NRR is based on attenuation values determined under controlled laboratory conditions, which cannot be regarded as representative of workplace conditions of use, where the actual level of protection will invariably be less than indicated by the NRR. More appropriate bases for quantifying HPD attenuation levels are the octave-band (long-method computation), REAT (real-ear attenuation at threshold) and HML (high, medium, low) methods variously used by HPD manufacturers.

5 Fitment

Individualised selection and fitment of HPDs must be conducted by a competent person, i.e. an OHP or other suitably competent person, preferably in conjunction with the RBME. This examination incorporates an HPD compatibility assessment, the findings of which must be considered during selection and fitment, as should the selection criteria outlined

in Section 4 of the present annex. Accordingly and as stated previously, selection, fitment and instruction with regard to HPDs should be addressed at the time of the RBME.
The competent person conducting HPD fittings must be satisfied that the employee is well capable of inserting or otherwise applying the devices selected, so as to obtain a level of protection that is adequate for the noise environment where he or she will work.

Note: Employees' proficiency in fitting the selected HPDs be evaluated by means of occlusion tests or the application of simulated noise, these techniques in addition to observing the employee during the fitting of HPDs.

6 Compliance monitoring

The level of employee compliance with mine standards for the use of HPDs may be formally evaluated in each workplace or area of work by means of random sampling techniques. Such monitoring should be conducted on an ongoing basis, but compliance in each workplace or work area should be evaluated at least quarterly. Only suitably trained staff should perform random sampling evaluations.

The primary purpose of compliance monitoring is to provide input to the ongoing review of the HCP, its elements and constituent procedures. Reasons that may be cited by employees for non-compliance are listed in Table 6, with corresponding HCP elements, possible factors contributing to non-compliance and/or required actions.

<u>Table 6</u>

Possible reasons for non-compliance with relevant HCP elements, possible contributing factors and required actions

Employee's reason for non-compliance	Relevant HCP element, possible contributing factor and/or required action
HPDs not issued	Distribution/Availability/Control
HPDs lost; replacements not available	Distribution/Availability/Control
Noise not regarded as health hazard	Education
Area/workplace not regarded as noisy	Education or Re-assess individual's hearing status
Area/workplace not noisy	Risk assessment, possibly followed by Re-zoning
HPDs perceived to be ineffective	HPD training, Individual's choice of HPD, RBME or Procurement criteria
HPDs impair communication	Individual's choice of HPD, RBME, Re-assess individual's hearing status or Procurement criteria
HPDs uncomfortable or cause pain	Individual's choice of HPD, RBME, Procurement criteria or Examine individual for pathology
Ear infection, irritation, etc.	Medical treatment, Education, HPD training

Where employees commonly cite any of the tabulated reasons or others as grounds for non-compliance, and where any element or aspect of the HCP appears to be a factor in the non-compliance, appropriate revisions to such elements or aspects would be indicated.

The results of compliance monitoring must be analysed and the findings documented in a quarterly report produced for consideration by the Health and Safety Committee, with feedback provided to officials responsible for elements or aspects of the HCP identified as requiring revision.

7 Employer's responsibilities

The employer, i.e. the owner/operator/manager, is responsible for ensuring that:

- A reasonable range of HPDs is available, with due consideration of the criteria listed in Section 4 of the present annex, and that employees select HPDs with the assistance of an OHP to ensure provision for any individual requirements determined during the RBME/HPD compatibility assessment,
- HPDs issued in terms of the HCP are provided free of charge,
- Advantages and limitations of the various HPDs available are explained to employees,
- Employees receive instruction in the use and care of HPDs as part of their education with respect to noise (Annex 3) and their HPD training during or immediately following the RBME (Annex 7), and
- Standards, procedures and disciplinary measures relevant to HPDs are explained to employees.

8 Employees' responsibilities

Employees are responsible for:

- Complying with mine standards that relate to the use of HPDs,
- Caring for HPDs in the prescribed manner,
- Reporting any problems that may preclude use of the HPDs issued, and
- Reporting any concerns that relate to noise sources, communication problems or perceived levels of protection.

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Annex 7: Risk-based medical examinations
(For information only)

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1 Purpose

The general purpose of a risk-based medical examination (RBME) is to determine whether any medical or physical contraindications exist that would preclude a prospective or existing employee from working in an environment with an established and well-defined health and/or safety hazard. The RBME should not be viewed as a separate entity but should rather be integrated with other medical protocols where applicable. As such, the RBME becomes part and parcel of the employee's medical history and medical surveillance record.

The RBME for noise is mandatory for all employees who, as part of their normal work routines, are exposed to sound pressure levels equalling or exceeding 85 dBA, irrespective of the exposure time. Medical examination protocols must therefore be devised in such a way that job category and workplace allocation, with particular reference to prevailing health and safety hazards, are clearly indicated. Relevant mine and medical examination protocols must also be sufficiently sensitive to respond to any instance where, as a result of any changes in the work situation, exposure to a hazard reaches critical levels, thereby warranting an out-of-routine RBME. Examples include changes in:

- Job category or nature of duties,
- Workplace,
- Operations, and/or
- Workplace conditions, environmental or otherwise

In cases of existing hearing loss, it may also be necessary to expand the RBME to consider the nature and extent of such loss, for the purpose of determining special needs with regard to Hearing Protection Devices (HPDs) attenuation. An example of such an instance would be an individual who would be unable to hear warning signals while using standard-issue HPDs, indicating the need for "flat- and low-attenuation" devices.

Similarly, the RBME should consider whether an individual is unusually susceptible to the detrimental effects of noise exposure, by examining the results of previous audiograms where these are available. In some instances the outcome of such an assessment could be the exclusion of the individual from work in excessively noisy areas, due to an unacceptable risk of impairment.

The RBME for noise exposure, therefore, consists of four elements, namely:

(a) an assessment of the external ear canal (and, where possible, the middle ear) to establish eligibility for audiometry, i.e. a pre-audiometric medical examination;
(b) an assessment of the external ear canal to establish compatibility with respect to HPDs, particularly insertable types;
(c) in cases of significant hearing loss as demonstrated by records of previous audiometry, an assessment of any special needs with regard to HPD attenuation. Where low-attenuation devices are indicated, their use would enhance the ability to communicate and hear warning signals while wearing HPDs in noise, and
(d) where the results of previous audiometry indicate extreme susceptibility to NIHL, a decision regarding the individual's further exposure to dangerous noise.

The assessments referred to above and described in the sub-sections that follow should be done by a qualified person (e.g. an Occupational Health Practitioner), who should refer any concerns to the Occupational Medical Practitioner prior to audiometry or the issuing of HPDs.

2 Pre-audiometric medical examination

The purpose of the pre-audiometric examination is to identify any factor likely to influence the audiogram (particularly where base-line audiometry is to be performed), to such an extent that the results obtained would not be a true reflection of the individual's actual hearing levels. For example, an individual with excessive cerumen (wax) obstructing the ear canal would be unable to record an accurate audiogram and, furthermore, removal of the cerumen by syringing or irrigation would have temporary impact on his hearing acuity, indicating that audiometry should not be conducted before two to three days have elapsed.

Pre-audiometric medical examinations of the ear canal place emphasis on otoscopy but should be extended, where warranted, to include tympanometry and oto-acoustic emission screening.

In the case of existing employees, the findings of pre-audiometric medical examinations must be compared with those of previous examinations. Where such comparisons reveal changes that may have an influence on hearing levels, e.g. scarring, disease or medication effects, the Occupational Medical Practitioner should be advised prior to conducting an audiogram, since it may be necessary to establish a new datum by means of a new base-line audiogram. Its purpose would be to document any changes in hearing acuity that are unrelated to noise exposure.

3 HPD compatibility assessment

HPD compatibility assessments must be designed to ensure that the HPDs issued provide sufficient protection against noise, ideally, for the full period of exposure. Accordingly, such assessments should be conducted:

- On recruitment,
- During periodical medical examinations,
- As part of the HPD compliance monitoring programme, i.e. where non-compliance is detected, and
- Whenever critical changes occur with respect to job category (noise levels), environmental conditions (e.g. heat and humidity) or mining operations, to such an extent that a review of the HPD being used is indicated.

To enable appropriate interventions based on all pertinent information, clear and well-defined communication lines should be established to ensure that the findings of HPD compatibility assessments are routinely applied during selection and fitment procedures.

Within the context of a RBME, the focus of HPD compatibility assessments is mainly on the integrity of the external ear canal, inclusive of the concha. Related issues, such as HPD selection and fitment, are dealt with in Section 4 of the present annex and in Annex 5 (Personal protection). The purpose of the HPD compatibility assessment is simply to establish whether conventional insertable HPDs can be used successfully to limit exposure.

HPD compatibility assessments must be performed by a qualified person, e.g. an Occupational Health Practitioner, or a person with proven experience and competence. From the introductory paragraph, it will be evident that two basic distinctions exist with regard to these assessments, namely:

- Initial assessments, which apply to all new or prospective employees (i.e. individuals who have had no previous exposure to occupational noise or experience in the use of HPDs), or where such individuals cannot provide a clear work history, and
- Review assessments, which apply to existing employees, specifically in cases of a change in job/workplace/conditions, persistent non-compliance with regard to the use of HPDs where such use is required, etc.

Initial HPD compatibility assessments should be aimed at identifying any medical or anatomical conditions that could interfere with or be aggravated by the use of insertable devices. Where such conditions exist, HPDs should not be issued unless medical consultation and/or corrective treatment can be provided, or the condition identified as a possible contraindication has been refuted as a potential source of problems. Areas of concern would include, among others, extreme tenderness, inflammation (either in or around the ears), sores, discharge, congenital or surgical malformations and excessive cerumen.

The procedures for reviewing HPD compatibility are identical to those for initial assessments, but should consider the possibility that the aetiology of any problems identified could relate to inappropriate HPDs, worn-out HPDs, poor HPD hygiene or even environmental- or work-related factors.

In addition, all incidents of external ear canal problems or complaints should be analysed to examine the possibility of any common origin, e.g. place of work/accommodation, job category or type of HPD.

The outcome of the HPD compatibility assessment must be classified as either:

- “No restriction”, i.e. no medical or anatomical constraints to the use of any HPDs,
- “Restricted use of HPDs”, either “Temporary restriction” or “Permanent restriction”,
- “Change of HPD recommended”, with an indication of criteria for alternative devices,
- “Insertable HPDs not recommended”,
- “Special/Custom-moulded HPDs to be considered”, or
- Any other classification deemed appropriate by the examiner.

The findings and recommendations of the HPD compatibility assessment must be made available to the HPD fitter and, conversely, no HPDs should be issued without considering the findings of the HPD compatibility assessment.

4 Assessment of special needs and unusual risks

This aspect of the RBME is intended to establish whether an individual has any special needs with regard to HPD attenuation, or whether he is unusually susceptible to the development of NIHL. Such assessments require the evaluation of previous audiometric test results and, accordingly, may only be possible for existing employees.

Where previous audiograms indicate significant hearing loss as a result of noise exposure, it may be necessary to issue HPDs that provide less attenuation than standard-issue devices, to reduce the interference with speech communication and perception of warning signals that impaired individuals experience when using standard-issue HPDs in noise. The non-standard devices referred to, commonly characterised as “flat- and low-attenuation” HPDs, provide less attenuation, particularly at the higher frequencies where normal HPDs are most effective. The use of “flat- and low-attenuation” devices would allow individuals with moderate impairment to more accurately perceive important sounds, while still protecting them against further hearing loss.

Where previous audiometric results indicate abnormal susceptibility to the development of NIHL, generally revealed by the comparison of results from a number of monitoring intervals, the risk of impairment may be too great to allow further exposure above certain levels. Such individuals should be counselled with regard to their hearing status and the risk of further exposure, with a view to a participative decision on their re-allocation to a quieter occupation or workplace. In cases of extreme susceptibility or advanced hearing loss, it may be necessary to exclude the individual from any further exposure to dangerous noise, preferably with his informed consent.

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(For information only)

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1 Medical surveillance

In terms of the Mine Health and Safety Act (MHSA), viz. Sections 13(1) and (2), employers must establish a system of medical surveillance, as defined in Section 102 of the Act, for persons who are or may be exposed to an occupational health hazard. The medical surveillance programme must be appropriate for the hazard [MHSA 13(2)(a)] and be designed to provide the employer with information that enables the elimination, control or minimisation of the hazard and its associated risks [MHSA 13(2)(b)].

With regard to the noise hazard, audiometry (Section 2 of the present annex) is the most appropriate form of medical surveillance, since it quantifies hearing loss that can then be considered in terms of the individual's exposure to noise (Annex 2, Noise measurement for risk assessment). This implies the need to link or incorporate the results of noise exposure determinations, i.e. occupational hygiene (OH) measurements (Annex 2), with employees' records of medical surveillance [MHSA 12(3)]. Where such linkage is not possible on an individual basis, it should be made on the basis of occupation, activity and/or workplace.

1.1 Introduction

Noise is recognised as a "significant' hazard" where employees' equivalent exposure levels equal or exceed 50 per cent of the occupational exposure limit (OEL) of 85 dB, i.e. where the 8-h time-weighted average equivalent noise exposure level equals or exceeds 82 dB. In terms of the Occupational Hygiene Regulations 9.2(2) and the MHSA [9(1)-(6)], where a significant hazard is identified the employer is obliged to implement a mandatory code of practice, which would involve monitoring the hazard where the 8-h time-weighted average noise exposure level equals or exceeds 82 dB, and implementing medical surveillance where it equals or exceeds 85 dB.

1.2 Purpose of medical surveillance

The preceding indicates that medical surveillance for noise-exposed employees should commence where time-weighted average exposure levels relative to an 8-h working day or a 40-h working week equal or exceed 85 dB, and that below this limit the hearing conservation programme would, in essence, consist only of monitoring employees' noise exposure levels.

There are, among others, three fundamentally important stipulations in the MHSA that define the general context within which medical surveillance should be conducted:

- "…after assessing risks in terms of section 11(1) [(a) and (b) of the Act] it is necessary to do so." [13(1)(b)],
- "…that [occupational hygiene measurements] can be linked…to each employee's records of medical surveillance." [12(3)], and
- "Every system of medical surveillance must be designed so that it provides information…to eliminate, control and minimise the health risk and hazards…" [13(2)(b)(i)].

With respect to noise exposure and its impact on hearing, audiometry is the means to comply with requirements for medical surveillance. However, it should be evident from the preceding points that medical surveillance cannot be restricted to audiometry *per se*, but that its primary objective should be to enhance the effectiveness of the hearing conservation programme (HCP). Accordingly, for audiometry to fulfil the purpose of medical surveillance, it must contribute to meeting that same objective.

1.3 Role of audiometric database analysis in medical surveillance

Implementation of a medical surveillance programme will not contribute to reducing the risk of noise-induced hearing loss unless it incorporates some form of audiometric database analysis (ADBA) to identify and prioritise areas where interventions are required. Specific methodologies and techniques to be employed in analysing audiometric test results are not prescribed in this annex, but the potential benefits of ADBA are summarised below:

1. In a general sense, ADBA promotes accountability on the part of management, supervisors and even employees, since it provides for focussed evaluations of various elements of the HCP.

2. ADBA offers the means to identify inherent weaknesses in the HCP that can ultimately have a profound bearing on the programme's overall efficacy, including application of the very audiometric test procedures that are intended to assess programme effectiveness. For example, certain analyses of audiometric data can be used to identify anomalies caused by changes in audiometer calibration, earphone or cable faults, excessive background noise in the test environment, as well as deviations from standardised test procedures or incompetence on the part of the audiometrist. Once the results of audiometric testing are confirmed to be valid, their analysis can reveal inadequate/inappropriate hearing protection devices (HPD) or their incorrect application, deficiencies in education/motivation/training, as well as in engineering or administrative measures intended to reduce noise or employees' exposure to it.

3. ADBA facilitates comparisons between different hearing conservation programmes (for benchmarking purposes) and specific features/aspects of different workforce populations, e.g. comparisons in terms of occupation/workplace, types of HPDs used, as well as HPD distribution, monitoring and enforcement procedures.

4. ADBA can provide input to educational and motivational programmes through positive reinforcement, e.g. by using grouped audiometric data in relation to typical hearing loss within an unprotected or under-protected group of employees, to highlight the importance of personal protective equipment (PPE).

5. ADBA is a source of objective data for reviewing specific aspects of hearing conservation policy, e.g. in-house standards, procurement practice, monitoring procedures, HPD efficacy and the competence of staff responsible for critical tasks within the HCP.

6. ADBA can promote the cost-effective application of hearing conservation measures, by identifying areas of weakness that require further expenditure or, alternatively, by identifying areas of strength where expenditure could possibly be contained or even reduced. Of fundamental importance is that the employer's potential liability for future compensation claims can be weighed against the cost of improving HCP effectiveness. Where short-term benefits can be demonstrated in terms of reductions in temporary threshold shift (TTS), long-term benefits will eventually manifest themselves as a plateau or stabilisation in the incidence of permanent threshold shift, i.e. noise-induced hearing loss (NIHL).

7. Inasmuch as ADBA offers a quantitative basis for comprehensive and objective assessments of HCP effectiveness, appropriate actions based on the findings of such assessments can lead to enhanced effectiveness and credibility of the programme and, in turn, to greater levels of participation and support among employees, ultimately contributing to improved relations between labour and management.

Employers' codes of practice must stipulate specific means of applying ADBA techniques, and the extent to which they will be used within the context of medical surveillance. For example, ADBA could compare occupations/activities and/or workplaces on the basis of significant shifts in hearing level for the various noise-sensitive test frequencies (4 kHz only, or a combination of 3, 4 and 6 kHz), the prevalence of standard threshold shifts (STS), collective increases in percentage loss of hearing (PLH), or changes in the relative number of employees categorised as 1, 2 or 3 (normal, warning level or referral level, respectively).

Specific ADBA procedures to be employed will be governed by:

- Size and composition of the workforce,
- Diversity of workplace operations,
- Variations in employees' exposure levels,
- The extent to which ADBA procedures are supported by the audiometric test system, and
- The competence of occupational health personnel in applying ADBA techniques.

With regard to the last two points, where the required comparisons or analyses are not supported by the existing audiometric test system, the supplier should be approached with a view to expanding its capabilities. Where lack of familiarity with ADBA techniques among occupational health personnel is a constraint, the relevant staff members should be given appropriate training, which in the first instance, should be provided by the supplier of the audiometric test system.

2 Audiometry

This section details requirements for audiometric testing procedures to be applied where a hearing conservation programme is required, i.e. where noise control engineering has not been possible or has failed to eliminate the noise hazard. Audiometric testing in the absence of appropriate control measures cannot reduce the risk of NIHL, and should not be regarded as a solution to the noise hazard, but as a means of identifying and prioritising problem areas to enable the formulation of appropriate interventions.

Test procedures detailed below make allowance for a variety of audiometers and testing environments and cater for older and newer technologies, without compromising the validity of test results.

2.1 Definitions

The following definitions apply:

Audiogram: a record of an individual's audiometric test results, i.e. hearing threshold levels, in either graphic, tabular or computer-based format (see **Audiometry** for definitions relating to different types of audiograms)

Audiologist: a graduate in speech therapy and audiology registered as such with the Health Professions Council

Audiometer: an instrument for the measurement of hearing (in particular, of the threshold of hearing) that complies with the relevant requirements specified in IEC 60645-1.

automatic audiometer: a pure-tone audiometer that adjusts the level of the test signal and other aspects of the test procedure in accordance with the subject's responses. The instrument automatically generates an audiogram to record the subject's hearing threshold levels.

computer-controlled audiometer: a pure-tone audiometer operated by means of computer software that provides for the control of testing procedures in a manner similar to that of an automatic audiometer, but with computer-based storage of results to enable their analysis

manual audiometer: a pure-tone audiometer requiring manual control (by the audiometrist) of the test signal's presentation, frequency and level, and the manual recording of hearing threshold levels

diagnostic audiometer: an audiometer intended for use during specialist diagnostic hearing assessments, with features that provide for air conduction and bone conduction methods, as well as for masking and speech discrimination techniques

screening audiometer: an audiometer intended for screening purposes, including baseline and exit audiometry, employing basic air-conduction techniques

Audiometrist: a person registered with the Health Professions Council of South Africa as an audiometrist or as a hearing aid acoustician, or one of the following persons:

a medical specialist in otorhinolaryngology (an ear, nose and throat specialist),

a graduate in speech therapy and audiology,

a person who holds a certificate in audiometry issued by an institution recognised and approved by the Department of Labour or the Department of Minerals and Energy, as relevant, or

an occupational medical practitioner.

Audiometry: the process by which an individual's hearing threshold levels are determined over a specified range of audio frequencies comprising, as a minimum requirement, 500; 1 000; 2 000; 3 000; 4 000 and 6 000 Hz, but often including lower and higher frequencies as well, e.g. 250 and 8 000 Hz. Routine audiometry employs basic air-conduction techniques, and includes the types of audiometry defined below:

baseline audiometry: audiometric testing of an individual before, or within 30 days of commencement of, work in a noise zone. The record of such audiometry, i.e. the baseline audiogram, will serve as a reference for all future decisions regarding the hearing acuity of that individual and will form part of his/her service and medical surveillance records.

Baseline audiometry shall be preceded by a period of at least 16 hours during which there has been no exposure to noise levels in excess of 85 dB. The use of hearing protection devices during this period that comply with the attenuation requirements of SABS 1451 will **not** satisfy this requirement.

The baseline audiogram recorded will be the better of the individual's two audiograms (i.e. the audiogram indicating lower hearing threshold levels) performed on the same day and that do not differ from each other by more than 10 dB at any of the following frequencies: 0,5, 1, 2, 3 and 4 kHz.

Where it is not possible to obtain two audiograms that comply with these requirements or there is suspicion of ear pathology (e.g. perforated tympanum or conductive deafness), the employee shall be referred for medical opinion. Medical opinion may be that referral to an audiologist is required for the purpose of establishing baseline-hearing levels.

Where it is not possible for an audiologist to obtain the required baseline audiogram, other techniques such as speech perception threshold will be acceptable for baseline purposes.

diagnostic audiometry: audiometric testing performed for the specific purpose of a specialist evaluation of an individual's hearing status, employing air conduction, bone conduction, masking and/or speech discrimination techniques, as appropriate

periodic screening audiometry: mandatory audiometric testing performed on an annual basis to ascertain an individual's hearing threshold levels, i.e. to determine the occurrence and extent of any permanent threshold shifts. These tests are to be performed for all persons having noise exposure levels that equal or exceed 85 dB.

Periodic screening audiometry shall be preceded by a period of at least 16 hours during which there has been no exposure to noise levels in excess of 85 dB. The use of hearing protection devices during this period that comply with the attenuation requirements of SABS 1451 is deemed to satisfy this requirement.

monitoring audiometry: subject to the employer's code of practice, audiometric testing that may be performed at six-monthly intervals for individuals having noise exposure levels in excess of 105 dB. These tests should be conducted immediately after exposure to noise, given their intended purpose of enabling the early identification of hearing loss among individuals in high-risk occupations or workplaces, by testing for temporary threshold shifts (TTS).

In instances where TTS is identified, periodic screening audiometry may be applied, depending on the employer's code of practice, to determine whether the shift is in fact temporary and, where it is not, the occurrence and extent of permanent shifts in hearing threshold level.

exit audiometry: audiometric testing performed at the conclusion of employment in a noise zone. The record of such audiometry, i.e. the exit audiogram, shall form part of the individual's medical surveillance records, and be retained in accordance with legal requirements [MHSA 15(1) & (2)].

Exit audiometry shall be preceded by a period of at least 16 hours during which there has been no exposure to noise levels in excess of 85 dB. The use of hearing protection devices during this period that comply with the attenuation requirements of SABS 1451 (Parts 1, 2 or 3) will **not** satisfy this requirement.

Controlling authority: a regulatory agency, i.e. a government department, responsible for the enforcement of occupational noise regulations and for administering compensation claims resulting from noise-induced hearing loss

Decibel (dB): a logarithmic value used to quantify sound pressure as a *level*, relative to the threshold of normal hearing, i.e. 20 μPa at 1 kHz. The decibel is defined by the following relation:

$$L_p = 10 \times \log (p_1/p_0)^2,$$

where: L_p is the *level* of the sound pressure in decibels

p_1 is the pressure, in Pascals, of the sound being considered, and

p_0 is the reference level of 20×10^{-6} Pa, corresponding with the threshold of normal hearing for a sound that has an audio frequency of 1 kHz

Hearing protection device (HPD): a hearing protector that circumaurally, supra-aurally or intra-aurally occludes the ear or the opening to the external ear canal, and that complies with the attenuation requirements stipulated in SABS 1451 Parts 1, 2 or 3, as applicable

Hearing threshold level (HTL): the lowest level of sound pressure, expressed in decibels, that an individual is generally able to detect (i.e. the majority of the time) for a given audio frequency

Threshold shift: a change for the worse (i.e. an increase) in an individual's HTL at a given audio frequency

permanent threshold shift (PTS): an irreversible change for the worse (i.e. an increase) in HTL that may be attributed to noise exposure

temporary threshold shift (TTS): a reversible change for the worse (i.e. an increase) in HTL that can be attributed to noise exposure, and from which the individual recovers after a period of isolation from noise, normally after 16 h

Medical opinion: the opinion of a medical specialist or an occupational medical practitioner

Medical specialist: a medical practitioner specialising in otorhinolaryngology (i.e. an ear, nose and throat specialist) who holds a qualification recognised by the Health Professions Council

Occupational medical practitioner: a medical practitioner who holds a qualification in occupational medicine, or an equivalent qualification, recognised by the Health Professions Council

Percentage Loss of Hearing (PLH): the sum of the values determined for hearing losses at 0,5; 1; 2; 3 and 4 kHz that are derived from the approved frequency-specific tables (Attachment 1 of the present annex)

2.2 Audiometric equipment

Further to definitions provided in the preceding section, requirements for audiometers used in various applications and for associated equipment are discussed in the sub-sections that follow.

2.2.1 Screening audiometers

Audiometers used for baseline, periodic screening, monitoring and exit audiometry must comply with the requirements for Type 4 accuracy specified in IEC 60645-1, and provide for testing at the audio frequencies of 500; 1 000; 2 000; 3 000; 4 000; 6 000 and 8 000 Hz.

2.2.2 Diagnostic audiometers

Audiometers used for diagnostic purposes must comply with the requirements for Type 3 accuracy specified in IEC 60645-1, and provide for testing at the audio frequencies of 250; 500; 1 000; 2 000; 3 000; 4 000; 6 000 and 8 000 Hz.

2.2.3 Audiometric test booths

Acoustic enclosures or “soundproof” rooms used for screening or diagnostic audiometry must comply with the relevant requirements stipulated in SABS 0182: 1998 “The measurement and assessment of acoustic environments for audiometric tests”.

2.2.4 Mobile audiometric testing facilities

Specially designed mobile facilities for on-site screening audiometry, i.e. at an employer’s premises, must comply with the relevant requirements stipulated in SABS 0182: 1998. In addition, mobile audiometric testing facilities must satisfy the following requirements:

- Audiometers must be mounted on suitable anti-vibration platforms
- The mobile facility must be designed, constructed and maintained in such a way that at no time will audiometers be exposed to environmental conditions that exceed the manufacturer’s design specifications
- The audiometric test booths/soundproof rooms shall have adequate lighting and ventilation to ensure that test subjects will not suffer any discomfort or experience any distractions that could have negative impact on the accuracy of results
- With the facility’s lighting and ventilation systems operating, sound pressure levels inside the test booths/soundproof rooms must comply with the limits for ambient noise stipulated in SABS 0182: 1998 for screening audiometry

The entire structure, i.e. the “booth and caravan” or “booth and autovilla”, as applicable, must have a combined sound insulation index of at least 35 dB, determined in accordance with the methods stipulated in ISO 140/1-1978 (E).

2.3 Audiometer calibration and verification checks

Various procedures to ensure the validity of audiometric test results are detailed in the sub-sections that follow.

2.3.1 Annual objective or electro-acoustic calibration

Screening and diagnostic audiometers shall have a valid calibration certificate when newly commissioned. Thereafter, audiometers must be electro-acoustically calibrated on an annual basis, in accordance with the procedures stipulated in SABS 0154-1: 1996. Electro-acoustic calibration procedures must be performed by a service provider who has the necessary training and equipment, and can demonstrate traceability to the National acoustics standard, in accordance with the Measuring Units and National Measuring Standards Act (Act 76 of 1973), as amended by the Measuring Units and National

Measuring Standards Amendment Act (Act 24 of 1998). All calibration certificates must be retained for record-keeping and inspection purposes, as well as for the validation of audiometric test results in cases of dispute.

2.3.2 Weekly subjective or biological calibration

Screening and diagnostic audiometers must undergo subjective or biological calibration checks on a weekly basis, conducted by personnel performing audiometry (Section 2.4). This procedure involves the recording of an audiogram for a person with known and stable hearing threshold levels, implying that such a person must not be routinely exposed to excessive noise of an occupational or recreational nature. In addition, the calibration or reference subject must have hearing threshold levels that do not exceed 25 dB at any test frequency.

The results of the subject's weekly audiograms must be compared with his/her calibration reference audiogram. If the weekly test results reveal a hearing threshold level that differs by 10 dB or more at any frequency from the corresponding value recorded during the calibration reference audiogram, the audiometer must be withdrawn from service and electro-acoustically re-calibrated, as described in Section 2.3.1, after which a new calibration reference audiogram must be recorded.

The records of all subjective or biological calibrations, including calibration reference audiograms, must be retained for record-keeping and inspection purposes, as well as for the validation of audiometric test results in cases of dispute.

2.3.3 Daily listening checks

Each day, prior to audiometric testing, an audiometrist with normal hearing must confirm that the audiometer is functioning correctly. After an inspection of all cables and connections, and confirming proper function of the subject response button, listening checks must be performed to ensure the absence of unwanted or extraneous sounds, e.g. hums, clicks or distortion. These listening checks must be made at a minimum of three hearing level (HL) or loudness settings for all test frequencies. Should any unwanted or extraneous sounds be evident, the audiometer must be withdrawn from service for inspection and repair, after which an electro-acoustic calibration must be performed (Section 2.3.1), and a new calibration reference audiogram recorded (Section 2.3.2).

2.3.4 Mobile audiometric testing facilities and suitability of test sites

In addition to the preceding requirements, the following provisions shall apply to mobile audiometric testing facilities:

- **Site calibration** Where a service provider conducts audiometric tests for an employer on a regular basis, it would be expedient to select a specific location on the employer's premises to perform testing. Noise measurements inside the test booth/soundproof room, conducted in accordance with SABS 0182: 1998, and a report documenting compliance with this standard would indicate that the mobile testing facility, when sited at the selected location, would be equivalent to a fixed or permanent testing facility.
- **External noise levels** Any location having an average ambient (external to the facility) A-weighted sound pressure level in excess of 75 dB should be regarded as unsuitable for screening audiometry.

- **Selection of test sites** Mobile audiometric testing facilities should, where practicable, only be sited at locations having the lowest and most uniform ambient noise levels. In general, this would require that the testing facility be situated away from plant, machinery, busy roads, maintenance areas and electrical substations. To confirm that a given location is suitable for the purpose of screening audiometry, one or both of the following tests should be conducted at the intended location, and the findings documented:
    - Measure the average A-weighted sound pressure level in the booth of the mobile facility at the approximate position of a test subject's head. If the average level observed is below 45 dB, the site can be regarded as suitable for screening audiometry. **Or**,
    - Record an audiogram for a person having known and stable hearing threshold levels that do not exceed 25 dB at any test frequency. Compare the audiogram recorded at the intended test site with the person's reference audiogram. Where the comparison reveals no differences in hearing threshold level greater than 10 dB for any test frequency, the site can be regarded as suitable for screening audiometry.

For each location where screening audiometry is performed, records documenting the results of the site calibration, external noise measurement and site selection/evaluation procedures described above should be retained for record-keeping, confirmation and inspection purposes, as well as for the validation of audiometric test results in cases of dispute. Such records should include A-weighted sound pressure levels observed inside and outside the mobile testing facility, as well as all reference audiograms and site evaluation audiograms.

2.4 Personnel performing audiometry/providing medical opinions

The qualifications required for personnel performing various types of audiometry and providing medical opinions are stated in the sub-sections that follow.

2.4.1 Baseline, periodic screening, monitoring and exit audiometry

Audiometry for the abovementioned purposes may be conducted by any of the following individuals (defined in Section 2.1):

- An audiologist
- A medical specialist
- An occupational medical practitioner
- An audiometrist

2.4.2 Diagnostic audiometry

Diagnostic audiometry may only be performed by:

- An audiologist, or
- A medical specialist (in otorhinolaryngology)

2.4.3 Medical opinion

In complex cases or when a patient's permanent disability is expected to be more than 10 per cent, the medical opinion of a medical specialist must be obtained.

In all other instances where the hearing loss is adjudged to be noise-related, the medical opinion, in the first instance, shall be that of an occupational medical practitioner.

2.5 Registration

Registration requirements for audiometrists, as well as for audiometric testing and audiometer calibration service providers are discussed in the two sub-sections that follow.

2.5.1 Audiometrists

Individuals performing baseline, periodic screening, monitoring and exit audiometry must be registered as audiometrists with the Department of Labour or the Department of Minerals and Energy, as applicable.

2.5.2 Audiometric testing service providers

All audiometric testing service providers who perform periodic screening audiometry for noise-exposed employees must be registered with the relevant Controlling Authority.

All registered audiometric testing service providers shall be required to submit returns to the relevant Controlling Authority on a regular basis, to ensure that current standards are adhered to, that the required procedures are applied, and that the calibration status of their audiometric instruments is maintained.

Registered testing facilities may, at the discretion of the relevant Controlling Authority, be audited on a random basis, to ensure that the provisions of these regulations are complied with.

2.5.3 Audiometer calibration service providers

Individuals or organizations providing calibration services for audiometric testing equipment must register with the relevant Controlling Authority.

All registered audiometer calibration service providers shall be required to submit returns to the relevant Controlling Authority on a regular basis, to ensure that current standards are adhered to and that the calibration status of their equipment is maintained.

Registered audiometer calibration service providers may, at the discretion of the relevant Controlling Authority, be audited on a random basis to ensure that the provisions of these regulations are complied with.

2.6 Quality control checks for audiometric testing facilities

It is essential for personnel performing audiometry to ensure that no deficiencies exist in the test facility's equipment or environment that could have negative impact on the accuracy of audiometric evaluations. Relevant aspects are considered in the sub-sections that follow.

2.6.1 Acoustic enclosures, cabling, connections and earphones

Personnel performing audiometry shall check the following aspects for proper function on a daily basis, and take immediate corrective action where necessary:

- Acoustic seals on doors

- Ventilation and lighting systems in the test booth/soundproof room
- Electrical mains cables and connections
- Acoustic cables and connections
- Earphone headbands (for proper tension)
- Earphone cushions (for damage, resilience/acoustic seal, cleanliness and hygiene)
- Subject response button

2.6.2 Background noise

Personnel performing audiometry shall conduct subjective checks on a daily basis to confirm that noise levels inside the test booth/soundproof room are sufficiently low to prevent masking or other interference with audiometric testing, and take immediate corrective action where necessary.

2.6.3 Distractions

Personnel performing audiometry shall ensure that the test subject is comfortable and, if possible, that visual contact is maintained between the audiometrist and test subject. No undue stress should be placed on the subject by environmental distractions, e.g. visible/ audible distractions or thermal discomfort.

2.7 Otoscopic examinations

Prior to audiometric testing the test subject must undergo an otoscopic examination to ascertain the presence of any excess earwax (cerumen) or pathology involving the ear canal, tympanic membrane or middle ear that could adversely influence the accuracy of test results.

Where excess wax is found in the ear canal, it should be removed by appropriate means. In the case of baseline or diagnostic audiometry, the patient should be allowed to recover for three days prior to testing, in order to ensure the accuracy of test results.

Subjects found to be suffering from infection, discharge or similar problems must be referred for medical opinion and appropriate treatment, prior to audiometric testing.

An otoscopic examination alone may not be adequate for the diagnosis of some ear infections and diseases, indicating the importance of questioning the patient about any recent ear ailments or complaints.

2.8 Conditioning test subjects

Depending on the purpose and type of audiometric testing, certain measures are required to condition the subject, as detailed in the sub-sections that follow. Such measures should be documented in the audiometric record.

2.8.1 Baseline, periodic screening and exit audiometry

Baseline, periodic screening and exit audiometry should be preceded by a period of at least 16 hours during which the test subject has had no exposure to noise levels in excess of 85 dBA, to ensure that the hearing threshold levels (HTL) recorded are not influenced by temporary shifts in threshold. In the case of periodic screening audiometry, but **not** in the case of baseline or exit audiometry, the use of hearing protectors during the 16-h pre-audiometry period is deemed to satisfy this requirement, provided that such hearing protectors comply with the minimum attenuation requirements of SABS 1451 (Part I, II or III, as appropriate). Measures applied to limit pre-audiometry exposure to noise should be documented in the individual's test record.

2.8.2 Monitoring audiometry

No pre-test conditioning of subjects is necessary for monitoring audiometry, as these tests should be conducted immediately after exposure to noise, given that the purpose of this form of increased surveillance is the early identification of any temporary threshold shifts (TTS), and that where results indicate the possible occurrence of TTS, a re-evaluation of the appropriateness of the individual's HPDs and his/her application thereof (including training and motivation) would be applicable.

2.8.3 Diagnostic audiometry

Diagnostic audiometry must be preceded by a period of at least 16 hours during which the patient is not exposed to noise levels that exceed 85 dBA. The wearing of hearing protection devices during this period **does not** satisfy this requirement. Measures applied to satisfy this requirement should be documented in the individual's test record.

2.9 Acquisition and recording of subject-related information

The individual's service and medical records should be at hand, including the findings of pre-audiometric otoscopy, the risk-based medical examination (Annex 7) and measures taken to ensure that the subject is appropriately conditioned for audiometric testing. The following steps should then be taken:

- Complete a new record sheet or data capture field for the test subject
  NB: Computer-based record-keeping systems must make adequate provision to ensure that data are not lost as a result of computer failure, or any changes in hardware or software.
- Record all pertinent information, including the results of noise exposure determinations (Annex 2) for the individual or his/her occupation/workplace
- Question the test subject regarding general health, use of medication, ear infections or complaints, colds etc. and record all relevant information
- Ascertain whether either ear is better than the other, e.g. by reference to previous test results or the individual's stated preference for one ear when using a telephone, etc. and, where one ear is better, test that ear first
- At this point, any pertinent information regarding abnormalities or deviations found during the otoscopic examination or the risk-based medical examination should be noted

2.10 Instruction of test subjects

Adequate instruction of the test subject is a critical prerequisite to the accurate assessment of hearing threshold levels. Where possible, the subject should be instructed in his/her own language with regard to:

- How to respond when a sound is heard, i.e. by pressing a button or raising a hand/finger, as appropriate

- What to do when the sound is no longer heard if such a response is required, i.e. release the button, lower the hand/finger, as appropriate
- The importance of responding as soon as a sound is heard, or where required, when it is no longer heard
- The requirement to respond to any signal heard, regardless of how faint it may sound
- The importance of not adjusting or tampering with the earphones
- The need to refrain from causing any noise by moving about, fidgeting or talking
- How to interrupt the test in the event of any disturbance or discomfort

Ensure that the test subject has understood the instructions and where there is any uncertainty in this regard, repeat the instructions.

2.11 Final preparation of test subjects

Before proceeding with audiometric testing the following steps must be taken:

- Ask the subject to remove any earrings, hearing aids, spectacles, headwear, etc.
- Ensure that long hair is moved away from the ears, to prevent any interference with the acoustic seal between the earphone cushions and ears
- Earphones should be fitted by the audiometrist
- Ensure that the test subject is comfortable and has no unanswered questions or concerns regarding the test procedure
- Ensure that there is adequate lighting and ventilation in the test booth/soundproof room
- Close the door to the test booth/soundproof room and confirm that it seals properly

2.12 Familiarisation phase

Before commencing with hearing threshold level determinations, the audiometrist should ensure that the test subject is familiar with the procedure and understands how to respond appropriately. The two sub-sections that follow detail familiarisation procedures for automatic/computerised and for manual audiometry, respectively.

2.12.1 Automatic and computerised audiometry

Set the audiometer to the first test frequency and observe the subject's response for 20 to 30 seconds to determine whether the subject has understood the instructions. If this is not the case, the instructions should be repeated and be followed by a second practice run. If the subject shows consistent responses, begin the test phase.

2.12.2 Manual audiometry

Present a signal at a frequency of 1 000 Hz and a level of 40 dB. If the subject fails to respond, increase the level in 10-dB steps until a response is obtained. Where no response occurs at a level of 70 dB, the audiometrist should confirm that the earphones are emitting a signal before increasing the level further.

Once a response is obtained, present the first test signal at the lowest HL or loudness level. Increase the level in 10-dB steps until a second response is obtained. Interrupt the tone for 1 to 2 seconds and present it again at the same level. If responses are consistent, begin the test phase.

2.13 Test phase

During the test phase, the subject's hearing threshold levels are determined for each test frequency. The two sub-sections that follow consider test phase procedures for automatic/computerised and for manual audiometry, respectively.

2.13.1 Automatic and computerised audiometry

Begin testing and continue until hearing threshold levels have been determined at each test frequency for both ears. The results of the audiogram should then be saved.

2.13.2 Manual audiometry

Where a manual audiometer is used, the preferred sequence of test frequencies is:

1) 1 kHz
2) 2 kHz
3) 3 kHz
4) 4 kHz
5) 6 kHz
6) 8 kHz
7) 500 Hz
8) 250 Hz (optional)
9) 125 Hz (optional)
10) Repeat 1 kHz for the first ear tested

According to ISO 6189, one of two methods, viz. the ascending or the bracketing method, may be used to determine hearing threshold level. Given its simplicity, the ascending method is recommended and its procedures are as follows:

a) Start the test with the better ear (Section 2.9) at a frequency of 1 kHz and a level that is 10 dB below the response level observed during the familiarization phase.
b) After each failure to respond to a test signal, increase the level or loudness of the signal by 5 dB until a response is obtained.
c) After each response, decrease the level by 10 dB and present a signal. If no response is obtained, increase the level in 5-dB increments and re-present the signal until a response is obtained. Repeat the procedures in Step c) until three responses are obtained from five presentations at the same level, and record the hearing threshold level for 1 kHz on the audiogram.
d) Repeat Steps a)-c) at each test frequency, until a hearing threshold level has been recorded for each.
e) Repeat Steps a) to c) at 1 kHz. If this second result for 1 kHz is within 5 dB of the corresponding initial result, proceed to the other ear, repeating Steps a) to d), and following the same sequence for test frequencies [1) to 7), 1) to 8) or 1) to 9), as applicable] but omitting the repetition of 1 kHz [10)].
f) If a variation of 10 dB or greater is observed between the two thresholds for 1 kHz, re-test the first ear at all frequencies and in the same order [1) to 7), 1) to 8) or 1) to 9), as applicable], until the two results for 1 kHz are within 5 dB. If inconsistencies persist after three attempts, refer the subject for medical opinion or to an audiologist for further evaluation.

The symbols illustrated in Table 2.13.2 should be used to graphically represent hearing threshold levels and non-responses for manual audiometry.

Table 2.13.2
Symbols for hearing threshold levels and non-response

Method of presenting test signal	Symbol	
	Right ear	Left ear
Response to:		
Air conduction signal	O	X
Bone conduction signal, with masking, on mastoid	[	]
Bone conduction signal, with masking, on forehead	¬	⌐
No response to:		
Air conduction signal	↙O	X↘
↙Bone conduction, with masking, on mastoid	[	]↘
↙Bone conduction, with masking, on forehead	¬	⌐↘

Note: To make valid comparisons between two audiograms for a given test subject where one audiogram was determined using a manual audiometer and the other using an automatic or computerised instrument, 3 dB should be added to the hearing threshold levels determined with the automatic or computerised audiometer.

2.14 Actions to be taken on the basis of audiometric test results

Actions to be taken on the basis of test results for each type of audiogram are detailed in the sub-sections that follow.

2.14.1 Baseline audiograms

The following actions are applicable for baseline audiograms:

- The better of the two audiograms recorded (i.e. that indicating lower hearing threshold levels) shall be regarded as the individual's baseline audiogram, provided that the two audiograms do not differ by more than 10 dB at the test frequencies, 0,5 1, 2, 3 or 4 kHz. Where this provision is not met, additional audiograms shall be recorded until two audiograms with corresponding results that are within 10 dB have been obtained.
- The individual's percentage loss of hearing (PLH) shall be derived from the baseline audiogram, using the approved frequency-specific tables (Attachment 1).
- The baseline audiogram and the PLH derived from it shall be entered in employees' records of medical surveillance and maintained in accordance with legal requirements [MHSA 15(1) & (2)].

2.14.2 Periodic screening audiograms

The following actions are applicable for periodic screening audiograms:

- The employee's PLH shall be derived from the periodic screening audiogram using the approved frequency-specific tables (Attachment 1) and compared with the PLH derived from the baseline audiogram. Where the periodic screening audiogram indicates an increase in PLH of nn per cent or greater relative to the baseline audiogram and this confirmed by repeat audiometry, the employee shall be referred for diagnostic audiometry. If no baseline audiogram is available it will be assumed that the employee's hearing was normal before exposure to noise, i.e. that the PLH was 0 per cent at the time of commencing employment in a noise zone.
- Where the periodic screening audiogram indicates an increase in hearing threshold level (HTL) of 15 dB or greater at any of the audio frequencies of 3, 4 or 6 kHz relative to the baseline audiogram and this confirmed by repeat audiometry (performed only after re-instruction of the employee in the audiometric procedure and refitting of earphones by the audiometrist), the following procedures shall be applied:
  - i) The findings shall be explained to the employee,
  - ii) The employee shall be referred for retraining and re-instruction, as outlined in Annex 3, and
  - iii) The suitability of the hearing protection provided shall be re-assessed, as detailed in Annex 7.
- The periodic screening audiogram, the PLH derived from it, and any increase in PLH and/ or HTL at 3, 4 or 6 kHz relative to the baseline audiogram shall be entered in the employee's record of medical surveillance, and maintained in accordance with legal requirements [MHSA 15(1) & (2)].

2.14.3 Monitoring audiograms

The following actions are applicable for monitoring audiograms:

- Where the monitoring audiogram indicates an increase in hearing threshold level in either ear that equals or exceeds 15 dB at any of the audio frequencies of 0,5; 1; 2; 3; 4; 6 or 8 kHz relative to the baseline audiogram, a repeat audiogram shall be performed immediately, but only after re-instruction of the employee in the audiometric procedure and refitting of earphones by the audiometrist.
- Where the repeat audiogram confirms any increase in hearing threshold level of 15 dB or more at the same frequency and in the same ear that was indicated by the initial monitoring audiogram, the following procedures shall be applied:
  - i) The employee shall be informed of the findings,
  - ii) The employee shall be referred for retraining and re-instruction, as outlined in Annex 3, and
  - iii) The suitability of the hearing protection provided shall be re-assessed, as detailed in Annex 7.
- The monitoring audiogram and any increase in HTL indicated by it may be entered in the employee's record of medical surveillance, and periodic screening audiometry may be applied to determine the extent of permanent threshold shifts, depending on the employer's code of practice.

2.14.4 Exit audiograms

The following actions are applicable for exit audiograms:

- The individual's PLH shall be derived from the exit audiogram using the approved frequency-specific tables (Attachment 1 of this annex) and compared with the PLH derived from the baseline audiogram.
- Where the exit audiogram indicates an increase in PLH of nn per cent or greater relative to the baseline audiogram and this confirmed by repeat audiometry, the individual shall be referred for diagnostic audiometry. If no baseline audiogram is available it will be assumed that the individual's hearing was normal before exposure to noise, i.e. that the percentage loss of hearing was 0 per cent at the time of commencing employment in a noise zone.
- Where an individual is referred for diagnostic audiometry as contemplated in the preceding point, the diagnostic audiogram, the PLH derived from it, and any increase in PLH relative to the baseline audiogram shall be entered in the individual's record of medical surveillance [MHSA 17(4)(b)].
- The exit audiogram and the PLH derived from it shall be recorded on the individual's exit certificate [MHSA 17(1)-(4)], and a copy of the exit certificate shall be entered in the individual's record of medical surveillance [MHSA 17(4)(b)].

2.15 Diagnostic audiometry

The medical opinion of the occupational medical practitioner should be sought before referral for diagnostic audiometry.

Diagnostic audiometry must be performed by either an audiologist or a medical specialist. The subject must not have been exposed to noise levels in excess of 85 dBA during the 16 hours immediately preceding diagnostic evaluation, a requirement that **cannot** be met through the use of hearing protection devices.

Diagnostic evaluations must include pure-tone air conduction, as well as bone conduction audiometry. Additional techniques such as narrow-band or speech discrimination audiometry may also be used where indicated.

Two diagnostic audiograms must be recorded during two different sittings, which may take place on the same day. If the two audiograms differ by more than 10 dB for either ear at any of the mandatory test frequencies, a third audiogram must be conducted during a third sitting to obtain consistent results. Should the third audiogram also indicate inconsistencies greater than 10 dB, the subject should be re-evaluated in six-months. Where consistent audiograms are not obtained, even after six months' time, the subject may be referred for specialist evaluation to assess hearing loss.

The audiologist or medical specialist performing diagnostic audiometry should refer to provisions in the Compensation Commissioner's Internal Instruction, "The Determination of Disability in Cases of Noise-induced Hearing Loss" (Attachment 2 of this annex).

2.16 Information to be recorded

Information to be recorded for various types of audiometry is detailed in the two sub-sections that follow.

2.16.1 Periodic screening audiometry

The following information shall be recorded or be apparent in the records of periodic screening audiometry:

- The individual's name, identity number, company or work identification number and age
- Nature of the individual's work and date of employment
- Details of observed noise levels and noise exposure levels relevant to the individual or to his/her occupation or workplace, including such levels relevant to previous allocations, and the period worked in each occupation or workplace
- Name, address, qualifications and registration number of the person conducting audiometry
- Relevant medical details, e.g. the individual's use of medicines, occurrence of colds, allergies, wax in the ear canal, etc.
- The individual's baseline audiometric data and PLH derived from them
- The individual's current hearing threshold levels and PLH derived from them
- Relevant comments regarding the individual's response to testing
- Details of any differences found between the baseline and current audiograms
- Details of any actions taken
- Copies of any medical opinions obtained, and the names and addresses of individuals providing such medical opinions

All records must be maintained in accordance with legal requirements [MHSA 15(1) & (2)], and computer-based systems must make adequate provision to ensure that data are not lost as a result of computer failure or changes in hardware or software.

2.16.2 Diagnostic audiometry

The following information shall be recorded or be apparent in the records of diagnostic audiometry:

- The individual's name, identity number, company or work identification number and age
- An indication of the positive identification of the individual by means of an identification document, ID card or similar document bearing a photograph
- Name, address, qualifications and registration number of the audiologist or medical specialist conducting the audiometry
- Observed hearing threshold levels for pure-tone air and bone conduction audiometry at all frequencies required for diagnostic audiometry, and the values for PLH respectively derived from these HTLs
- Observed hearing threshold levels for speech discrimination and/or any other audiometric techniques, as applicable
- Relevant comments regarding the individual's response to testing
- Comments regarding the current test results' consistency with previous results
- A report on the evaluation's findings, i.e. a specific assessment regarding the possibility of a causal relationship between any abnormalities identified and occupational (or other) noise exposure, or of a link with any other causes
- Signature of the audiologist or medical specialist conducting the evaluation

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Attachment 1

No. 22296 GOVERNMENT GAZETTE, 16 MAY 2001

A6/3/1
A 10/4/3/4
Circular Instruction No. 171

THE DETERMINATION OF PERMANENT DISABLEMENT RESULTING FROM HEARING LOSS CAUSED BY EXPOSURE TO EXCESSIVE NOISE AND TRAUMA

COMPENSATION FOR OCCUPATIONAL INJURIES AND DISEASES ACT, No. 130 of 1993

The following instructions are issued to clarify the position in regard to claims for impairment of hearing:

1.1 An occupational disease due to excessive noise in industry, and

1.2 An occupational injury due to factors other than excessive industrial noise [head trauma (resulting from e.g. blows to the head), or acoustic trauma causing the immediate loss of hearing produced by one or more exposures to sudden intense forms of acoustic energy such as explosions, gunfire or blasts].

Such "accidents" may cause binaural (both ears) or monaural (one ear) impairment of hearing.

1.3 In loss of hearing "by accident" in either one or in both ears the impairment may be caused by either conductive loss when the middle ear is injured or by perceptive loss when the inner ear is injured or by a combination of both conductive and perceptive loss when both the middle and the inner ear are injured the so-called "mixed deafness".

1.4 Impairment of hearing claimed to result from exposure to excessive noise in industry (occupational noise of an excessive nature) usually manifests itself over a number of years and results in binaural impairment of hearing.

1.5 The provisions of Section 65(4) of the Act referring to prescription shall be strictly applied with due regard to the provisions of Section 38 of the Act.

1.6 The date of the commencement of the disease shall be the date of the first audiogram showing an increase from the baseline in the percentage loss of hearing (PLH) by 10% or more. The PLH values are calculated using the results of the baseline audiogram and the diagnostic audiogram using the attached tables.

Annexure A

1.7 Persons to be submitted for compensation consideration would be:

- Employees whose PLH has deteriorated by more than 10% PLH from the baseline audiogram; or

- Employees who have more than 10% PLH and for whom no baseline is available (see section 5).

1.8 A medical opinion must be provided by either:

1.8.1 An ENT-specialist if the case is complicated or the degree of disablement is expected to exceed 15% (PLH > 30 % from baseline); or

1.8.2 An Occupational Medical Practitioner if the case is uncomplicated and the degree of disablement is expected to be 15% or less (PLH 30% from baseline).

2 BINAURAL HEARING IMPAIRMENT

2.1 In cases where binaural hearing impairment is claimed as a result of mechanical or acoustic trauma, the principles as laid down under paragraph 1.4, 1.5 and 1.6 for occupational hearing loss due to excessive noise in industry apply, with the exception that the ENT-Surgeon /Occupational Medical practitioner should certify that the impairment found on examination is compatible with the nature of the injury sustained or is due to acoustic trauma of the nature and intensity experienced by the employee and that no other cause(s) for the impairment of hearing were found on examination.

3 MONAURAL HEARING IMPAIRMENT

3.1 Noise-induced hearing loss affects both ears to more or less an equal degree and the impairment is due to a perceptive loss. If, therefore, the loss of hearing is monaural, it must be assessed whether the loss is commensurate with noise exposure to one ear more than the other such as gun shots in security workers. The assessment of permanent disablement for the loss of hearing in one or both ears as detailed takes cognisance of such additional factors as tinnitus, unhealed perforations of the tympanic membranes with possible recrudescence of infections following thereon and/or mastoidectomies. In the event of recurring infections in the two latter instances, medical treatment should be provided and the employee should receive periodical payments.

4 DOCUMENTATION TO ACCOMPANY A CLAIM FOR COMPENSATION

Claims will be submitted either to the Compensation Commissioner or to the Mutual Association as applicable. Over and above the standard documentation required i.e. Employer’s Report of an Occupational Disease/Injury (W C1.1/2) and Notice of an Occupational Disease/Injury and Claim for Compensation (WC1.14/3), the following documents are required:

4.1 **Claimant's service record** - this should confirm in writing exposure to excessive occupational noise. The intensity and duration of exposure should be commensurate with the hearing impairment.

4.2 It should be proved that the noise was of such a nature and intensity and exposure to it of such duration, as to be likely to have caused permanent noise-induced hearing impairment. The compensability of a claim can only be considered where noise level readings exceed the maximum laid down by the South African Bureau of Standards (S.A.B.S. 083-1983) and which is known as the N85 Noise Rating Curve Level.

4.3 **Medical opinion** - this should state that the hearing loss is compatible with noise induced hearing impairment. In atypical cases an appropriate explanation should be provided.

4.4 **Audiograms** - two audiograms conducted by the diagnostic audiologist should be submitted. The audiograms should be performed after at least 24 hours have elapsed from the last exposure to excessive noise. The audiograms may be done on the same day but at different sittings. The audiograms must not differ by more than 10 dB at any frequency. The better diagnostic audiogram will be used to calculate PLH for compensation purposes.

If required, a third audiogram shall be performed. If this is still not within the 10 dB limit then the assessment shall be delayed for a period of 6 months. If audiograms of the required quality are still not obtained after 6 months 'then referral to an ENT-specialist will be made in order to determine hearing loss.

4.5 **A copy of the baseline audiogram** (and calculated PLH)-This is important as the baseline PLH will be subtracted from the better diagnostic audiogram PLH to determine the hearing loss for which the Commissioner, Mutual Association or Employer Individually Liable, is responsible.

4.6 **Proof of employee's identity** - the audiologist performing the audiogram should attest in writing to the employee's identity.

5 CALCULATION OF PERMAMENT DISABLEMENT

5.1 The better of the two diagnostic audiograms will be used: Ensure that all documentation (4) is present and correct.

5.2 Calculate (from PLH tables - Annexure A) a PLH for each of the following frequencies: 500, 1000, 2000, 3000 and 4000 Hz (Air conduction results to be taken except if specified otherwise by the medical officer).

5.3 Sum the values for each frequency to obtain the PLH.

5.4 If a baseline PLH is available this value is subtracted from the PLH obtained from 5.3.

5.5 If a baseline PLH is unavailable the PLH in 5.3 is taken as the value from which permanent disability will be calculated.

5.6 Permanent Disablement is calculated by halving the value of the PLH obtained in either: 5.4 (if a baseline PLH is available) or 5.5 (if a baseline PLH is unavailable).

Annexure A

Determination of percentage loss of hearing

Using the hearing threshold levels (HTL) determined by baseline, periodic screening, exit or diagnostic audiometry (as applicable), determine the contribution to percentage loss of hearing (PLH) from hearing losses at the frequencies of 0.5; 1; 2; 3 and 4 kHz, using Tables A1-1 to A1-5, respectively. Then sum the contributions from the stated frequencies to determine PLH.

Table AI-I
Contribution to PLH by hearing losses at 0,5 kHz

HTL in worse ear (dB)	**4 Contribution to PLH by hearing loss at 0,5 kHz in better ear and given hearing loss at 0,5 kHz in worse ear**																
	Hearing threshold level in better ear (dB)																
	≤15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**≥95**
≤15	0,2																
20	0,4	0,6															
25	0,6	1,0	1,4														
30	1,0	1,4	2,0	2,8													
35	1,3	1,8	2,5	3,4	4,5												
40	1,7	2,2	3,0	3,9	5,1	6,4											
45	2,0	2,6	3,4	4,3	5,5	6,8	8,1										
50	2,3	2,9	3,7	4,7	5,8	7,1	8,4	9,7									
55	2,5	3,2	4,0	5,0	6,1	7,3	8,6	9,9	112)								
60	2,7	3,4	4,2	5,2	6,3	7,5	8,8	10,0	11,3	12,6							
65	2,8	3,5	4,4	5,4	6,5	7,7	8,9	10,2	11,5	12,7	14,0						
70	2,9	3,7	4,5	5,5	6,6	7,8	9,1	10,3	11,6	12,9	14,2	15,5					
75	3,0	3,8	4,7	5,7	6,8	8,0	9,2	10,5	11,8	13,1	14,5	15,7	16,9				
80	3,1	3,9	4,8	5,8	6,9	8,1	9,3	10,6	12,0	13,3	14,7	16,0	17,2	18,2			
85	3,2	4,0	4,9	5,9	7,0	8,2	9,4	10,7	12,1	13,5	14,9	162	17,4	18,4	19,1		
90	3,4	4,1	5,0	6,0	7,1	8,3	9,5	10,8	12,2	13,6	15,0	16,3	17,6	18,5	19,2	19,7	
≥95	3,4	4,2	5,1	6,1	7,1	8,3	9,5	10,8	122	13,6	15,0	16,4	17,6	18,6	19,3	19,7	20,0

Table A1-2
Contribution to PLH by hearing losses at I kHz

HTL in worse ear (dB)	**5 Contribution to PLH by bearing loss at 1 kHz in better ear and given hearing loss at 1 kHz in worse ear**																
	Hearing threshold level in better car (dB)																
	≤15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**≥95**
≤15	0.5																
20	0,8	1,2															
25	12	1,8	2,7														
30	1,8	2,6	3,8	5,3													
35	2,6	3,5	4,7	6,3	8,5												
40	3,2	4,2	5,6	7,4	9,5	12,0											
45	3,8	4,8	6,3	8,1	10,4	12,8	15,3										
50	4,2	5,4	6,9	8,9	11,0	13,2	15,8	182									
55	4,7	5,9	7,5	9,3	11,4	13,7	16,1	18,6	21,0								
60	5,0	6,3	8,0	9,8	11,9	14,1	16,5	18,9	21,3	23,6							
65	5,3	6,6	8,3	10,1	12,2	14,4	16,8	19,2	21,6	24,0	26,3						
70	5,6	6,9	8,6	10,4	12,5	14,7	17,0	19,4	21,9	24,3	26,7	29,1					
75	5,7	7,1	8,7	10,7	12,8	15,0	17,3	19,7	22,2	24,6	27,2	29,6	31,8				
80	5,9	7,4	910	11,0	12,9	15,2	17,6	20,0	22,5	25,1	27,6	30,0	32,3	34,1			
85	6,2	7,5	9P3	11,1	13,2	15,5	17,7	20,3	22,7	25,4	27,9	30,5	32,7	34,5	35,9		
90	6,3	7,8	9,5	11,3	13,4	15,5	17,9	20,3	22,8	25,5	28.2	30.6	33,0	34,8	36,2	36,9	
≥95	6,5	8,0	916	11,4	13,4	15,6	17,9	20,3	22,8	25,5	28,2	30,8	33,2	35,0	36,3	37,1	37,5

Table A1-3

Contribution to PLH by hearing losses at 2 kHz

HTL in worse ear (d B)	6 Contribution to PLH by bearing loss at 2 kHz in better ear and given bearing loss at 2 kHz in worse car																
	Hearing threshold level in better ear (dB)																
	≤15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**≥95**
≤15	0,3																
20	0,5	0,8															
25	0,8	1,1	1,7														
30	1,1	1,5	2,3	3,2													
35	1,5	2,1	2,9	3,8	5,1												
40	2,0	2,6	3,3	4,4	5,7	7,2											
45	2,3	2,9	3,8	5,0	6,2	7,7	9,2										
so	2,6	3,3 3,91	4,2	5,3	6,6	8,0	9,5	11,0									
55	2,9	3,6	4,5	5,6	6,9	8,3	9,6	11,1	12,6								
60	3,0	3,8	4,7	5,9	7,1	8,4	9,9	11,3	12,8	14,1							
65	3,2		5,0	6,0	7,4	8,6	10,1	11,4	12,9	14,4	15,8						
70	3,3	4,1	5,1	6,2	7,5	8,9	10,2	11,7	13,1	14,6	16,1	17,4					
75	3,5	4,2	5,3	6,5	7,7	9,0	10,4	11,9	13,4	14,9	16,2	17,7	19,1				
so	3,6	4,4	5,4	6,6	7,8	9,2	10,5	12,0	13,5	15,0	16,5	18,0	19,4	20,4			
85	3,6	4,5	5,6	6,6	8,0	9,2	10,7	12,2	13,7	15,2	16,7	18,2	19,5	20,7	21,5		
90	3,8	4,7	5,7	8	8,0	9,3	10,7	122	13,7	15,3	1618	18,5	19,8	20,9	21,6	22,2	
≥95	3,9	4,8	5,7	6,9	8,1	9,3	10,7	12 -2	13,7	15,3	17,0	18,5	19,8	21,0	21,8	22.2	22.5

Table A1 – 4
Contribution to PLH by hearing losses at 3 kHz

HTL in worse ear (dB)	7 Contribution to PLH by bearing loss at 3 kHz in better ear and given loss at 3 kHz in worse ear																
	Hearing threshold level in better ear (d B)																
	≤15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**≥95**
≤15	0,1																
20	02	0,3															
25	0,3	0,5	0,7														
30	0,5	0,7	1,0	1,4													
35	0,7	0,9	1,2	1,7	2,3												
40	0,8	1,1	1,5	2,0	2,5	3,2											
45	1,0	1,3	1,7	2,2	2,7	3,4	4,1										
so	1,1	1,4	1,9	2,3	2,9	3,5	4,2	4,8									
55	1,2	1,6	2,0	2,5	3,0	3,6	4,3	4,9	5,6								
60	1,3	1,7	2,1	2,6	3,1	3,7	4,4	5,0	5,6	6,3							
65	1,4	1,8	2,2	2,7	3,2	3,8	4,4	5,1	5,7	6,4	7,0						
70	1,5	1,8	2,3	2,8	3,3	3,9	4,5	5,2	5,8	6,5	7,1	7,7					
75	1,5	1,9	2,3	2,8	3,4	4,0	4,6	5,2	5,9	6,6	7,2	7,8	8,4				
80	1,6	2,0	2,4	2,9	3,4	4,0	4,7	5,3	6,0	6,6	7,3	8,0	8,6	9,1			
85	1,6	2,0	2,5	3,0	3,5	4,1	4,7	5,4	6,0	6,7	7,4	8,1	8,7	9,2	9,5		
90	1,7	2,1	2,5	3,0	3,5	4,1	4,7	5,4	6,1	6,8	7,5	8,2	8,8	9,2	9,6	9,8	
≥95	1,7	2,1	2,6	3,0	3,6	4,1	4,7	5,4	6,1	6,8	7,5	8,2	8,8	9,3	9,6	9,8	10,0

Table AI-5
Contribution to PLH by hearing losses at 4 kHz

HTL in worse ear (dB)	8 Contribution to PLH by hearing loss at 4 kHz in better ear and given loss at 4 kHz In worse car																
	Hearing threshold level in better ear (dB)																
	≤15	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**≥95**
≤15	0,0																
20	0,1	0,1															
25	0,1	0,2	0,3														
30	0,2	0,3	0,5	0,8													
35	0,3	0,5	0,7	1,0	1,5												
40	0,4	0,6	0,9	1,3	1,8	2,5											
45	0,5	0,8	1,1	1,5	2,1	2,7	3,5										
SO	0,7	0,9	1,3	1,7	2,3	2,9	3,6	4,4									
55	0,8	1,0	1,4	1,9	2,4	3,1	3,8	4,5	5,2								
60	0,9	12	1,5	2,0	2,6	3,2	3,9	4,6	5,3	6,0							
65	0,9	1,2	1,6	2,1	2,7	3,3	3,9	4,6	5,3	6,0	6,7						
70	1,0	1,3	1,7	2,2	2, 7	3,4	4,0	4,7	5,4	6,1	6,9	7,5					
75	1,1	1,4	1,8	2,3	2,8	3,4	4,1	4,8	5,5	6,2	6,9	7,6	8,2				
SO	1,1	1,4	1,9	2,3	2,9	3,5	4,2	4,9	5,6	6,3	7,0	7,7	8,4	8,9			
85	1,2	1,5	1,9	2,4	3,0	3,6	4-1	4,9	5,7	6,4	7,1	7,8	8,5	9,0	9,5		
90	1,2	1,6	2,0	2,5	3,0	3,6	4,3	5,0	5,7	6,5	7,2	7,9	8,6	9,1	9,5	9,8	
≥95	1,3		2,0	2,5	3,1	3,7	4,3	5,0	5,7	6,5	7,2	8,0	8,7	9,2	9,6	918	10.0

No. 1194 **16 November 2001**

Instruction No. 171 SUPPLEMENT

Transitional arrangements between Instruction No. 168 and No. 171

Introduction:

This instruction sets out the procedures to be followed to ensure proper management and implementation of Instruction No. 171 as well as a smooth transition from the repealed Instruction No. 168 to the new Instruction No. 171.

Conducting and Recording of a Baseline Audiogram:

1 A baseline audiogram must be conducted on all employees in any working place where the equivalent continuous A - weighted sound pressure level, normalised to an eight hour working day or a forty hour working week, is equal to or exceeds 85 decibels A (dBA).

2 A baseline audiogram must be conducted on every current employee exposed to noise as contemplated in (1) within two years of the date of this Instruction.

3 From the date on which Circular Instruction 171 was published, every new employee exposed to noise as specified in (1) must have a baseline audiogram done within 30 days of commencement of employment.

4 The baseline of an employee conducted in terms of this Instruction applies as that employee's baseline for his total working career.

5 An employee's baseline must be recorded and such record must be kept for 40 years.

Transfer between workplaces or changing employer

1 The baseline audiogram results, as well as the most recent subsequent audiogram conducted whilst in employment, should be given to an employee when he is no longer exposed to noise or leaves employment at that workplace.

2 The baseline audiogram as well as the most recent audiogram with the PLH as calculated, must be presented at employment to the new employer.

3 At recruitment, the new employer must record the baseline as well as the subsequent PLH sustained with the previous employer and the latter may be verified with an initial audiogram at recruitment.

Use of the Baseline Audiogram:

1 The baseline audiogram must be used to calculate any current hearing loss sustained in terms of Instruction No. 168. Where an employee has occupational hearing loss compensatable in terms of Instruction No. 168, referral must be made to the Compensation Commissioner or to the Mutual Association as applicable, for consideration of compensation.

2 The baseline must be recorded for the purpose of using these values for all future reference to the baseline of an employee.

3 The baseline audiogram should then be used in determining any future compensatable hearing loss in terms of Instruction No. 171.

4 Following two years from the date of this Instruction, where there was failure to conduct a baseline of an employee's hearing during these two years, it would be assumed that it was normal for the purposes of the baseline as set out in Instruction No. 171.

Standards for the Baseline Audiogram:

1 Testing for the baseline audiogram must be done 16 hours after an employee has been removed from an environment in which the noise level was equal to or exceeded 85 dBA. The use of hearing protection devices to effect this attenuation will not be acceptable.

2 The baseline audiogram is the better of the employee's two audiograms performed on the same day and that do not differ from each other by more than 10 dB for any of the following measured test frequencies, i.e. 0.5, 1, 2, 3, and 4 kilohertz (kHz).

3 If it is impossible to obtain two audiograms that comply with the requirements of (2), the employee must be referred to a competent person to establish baseline-hearing levels.

4 If it is impossible for the competent person to establish baseline-hearing levels as contemplated in (2), the competent person may establish baseline-hearing levels by using other techniques, such as speech reception thresholds.

This Instruction supplements Instruction No. 171.