OCCUPATIONAL NOISE EXPOSURE

—

SELECTION AND USE OF HEARING PROTECTORS

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PERSONAL HEARING PROTECTORS

The *Health and Safety in Employment Act, 1992* requires employers and employees to take a number of steps to ensure a safe and healthy place of work. The *Health and Safety in Employment Regulations, 1995* states the maximum levels of noise to which employees may be exposed. They also specify the duties of designers, manufacturers and suppliers of hearing protectors.

The information contained in this publication is intended to assist employers and employees to choose hearing protectors that will give suitable protection against excessive noise levels and exposures. It is based on the Approved Code of Practice "*Management of Noise in the Workplace*" (August 2002)[(1)] and the Joint Australian/New Zealand Standard AS/NZS1269: 1998 "*Occupational Noise Management*"[(2)].

NOISE EXPOSURE LIMITS

The maximum level of noise to which a worker may be exposed, whether or not they are wearing an hearing protector, is specified in the Health and Safety in Employment Regulations 1995, and is:

A Noise Exposure Level, ($L_{Aeq,8h}$)[(3)] of 85dBA, or

A Peak Level (L_{peak})[(4)] of 140 dB (Peak, unweighted)

It is important to appreciate that the use of a personal hearing protector does not reduce the noise exposure; it simply gives the person protection from the noise exposure.

STANDARDS

The measurement of the real-ear sound attenuation of hearing protectors in New Zealand and Australia is now conducted using the joint Australian/New Zealand Standard AS/NZS1270, 2002: *Acoustics – Hearing Protectors*.

The major changes from the 1988 edition (AS1270) which were incorporated into a 1999 version of 1270 concerned principally the procedures involved in the method for the measurement of the real-ear attenuation of hearing protectors. These include:

(a) A subjective method, using test subjects who are inexperienced in the fitting and use of hearing protectors is specifically adopted.

(b) The specification of noise bands instead of pure tones as test signals.

(c) A reduction in the number of test signals from 21 to 7.

(d) The adoption of a different method of assessing test signal distortion.

(e) The introduction of a more direct procedure for evaluating background noise in the test room.

These changes brought the Standard into close alignment with the corresponding technical provisions of ISO 4869-1—1990, *Acoustics—Hearing protectors—Part 1: Subjective method for the measurement of sound attenuation.* Requirements regarding directionality of the test signal sound field were also added. In this case the provisions of ANSI S12.6—1997, *Methods for Measuring the Real-Ear Attenuation of Hearing Protectors* were followed as the corresponding requirements of ISO 4869-1 are regarded as unsatisfactory.

A further revision of the 1999 standard made some changes to the physical tests requirements and guidance for testing specialist devices. The method for the measurement of real ear attenuation of hearing protectors in the 2002 version (section 4) is unchanged from the 1999 version.-This latest version of the Standard was published on 18 January 2002.

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(1) Available from OSH

(2) Available from Standards New Zealand.

(3) The level of noise that, if it were present for 8 hours, would contain the same amount of sound energy as the actual varying noise.

(4) The peak unweighted level of sound pressure when using a meter with "P" response. It is not the same as the L_{max} or the maximum level available on some sound level meters.

HEARING PROTECTOR TESTING

The requirements and wording of the section in the AS/NZS1270; 2002 Standard dealing with the methods for the measurement of the real-ear attenuation of a hearing protector is modelled on the corresponding sections of ANSI S12.6—1997:Method B: Subject Fit together with the extensive research on which the ANSI Standard is based.

The results obtained using the new 2002 edition of the AS/NZS1270 Standard are not expected to differ significantly from the results obtained using previous editions of the Australian Standard. This is because that while the subject management procedures have been specified in greater detail in the new Standard, the principles underlying them remain the same. In effect, the procedures specified simply make explicit the long-standing practices of Australian and New Zealand laboratories when testing hearing protectors.

COMPARISON OF AS/NZS 1270-2002 AND ANSI 12.6-1997

With respect to the measurement techniques used, the two Standards are essentially the same as far as Method B in the ANSI Standard is concerned. The two most important areas involved are in the selection of suitable subjects for the testing and the manner in which testing is conducted, particularly with respect to the management of the subjects during the testing.

The basic philosophy behind the procedures is aimed at determining the level of protection that the device is likely to achieve in a workplace in practice when used by workers in real situations. Other standards have tended to result in the determination of the level of protection that can be achieved with protectors on people in the laboratory and in ideal or near ideal situations.

The Method A in ANSI uses the experimenter-supervised fit protocol of test subject management and is more aligned therefore to the method used in ISO4869-1: 1990.

NEW INTERNATIONAL STANDARD

A new ISO Standard is currently under development, Draft ISO 4869.7 "*Acoustics - Hearing protectors - Part 7: "Method for measurement of sound attenuation by the subject-fit method*". This draft standard is at the final stages of Committee Drafting and is based on both the ANSI S12.6 Standard (Method B) and the Joint AS/NZS 1270: 2002 Standard.

ACCEPTED STANDARDS

In order to achieve a value for the acoustic performance of hearing protectors that is as close as is practicable to the performance of a protector that is used by a well informed user in workplaces with well supervised and managed hearing protector programs in place, OSH considers that the only suitable Standards to use for that purpose are:

- AS/NZS1270: 1999 *Acoustics – Hearing Protectors*
- AS/NZS1270: 2002 *Acoustics – Hearing Protectors*
- ANSI 12.6: 1997 *Methods for Measuring the Real-Ear Attenuation of Hearing Protectors.*

These Standards are therefore referred to in this document as the "Accepted Standards".

HEARING PROTECTOR RATINGS

Until the publication of AS/NZS1270 in 1999, hearing protectors were "graded" based upon the results of sound attenuation[1] testing according to standards such as the Australian Standard, AS1270: 1988 "*Hearing Protectors*" and the International Standards Organisation Standard ISO 4869.1: 1990 "*Acoustics—Hearing protectors—Part 1: Subjective method for the measurement of sound attenuation*". Both these documents used a subjective method (using people to measure the difference in hearing levels when wearing and not wearing a hearing protector) to determine how well a hearing protector reduced the level of different frequencies of sound. It was an attempt, in the laboratory, to assess how well they would perform when used in a work situation. Their effectiveness at reducing (attenuating) noise determined the *"Grade"* into which they were placed. There could have been significant differences in the results obtained by using the different Standards and this could have resulted in a different Grade for a particular protector.

The Joint AS/NZS1270 Standard was developed, in part, to overcome these sorts of problems but most importantly to give results that mimic as close as is practicable, the performance of a protector used by a well informed user in workplaces with well supervised and managed hearing protector programs in place. Protectors tested to this Standard are now *"classified"* in a similar way to the older "Grading" method. There are, however, significant differences

(1) Reduction in the level of sound

between the two and so **A PROTECTOR GIVEN A "GRADE" CANNOT BE SIMPLY CHANGED INTO A "CLASS" WITHOUT THE APPROPRIATE TESTING TAKING PLACE.**

HEARING PROTECTOR CLASSES USING ACCEPTED STANDARDS

Hearing protectors are now assigned to one of five hearing protector **classes** according to their acoustic performance. They should be selected on the basis of the Noise Exposure Level ($L_{Aeq,8h}$) to which an employee is exposed, see Table 1 below:

TABLE 1: NOISE EXPOSURE CLASSES

Hearing Protection Class	$L_{Aeq,8h}$ (dBA)	Types of Suitable Hearing Protectors
1	Less than 90	Earplugs or Earmuffs
2	90 to less than 95	Earplugs or Earmuffs
3	95 to less than 100	Earplugs or Earmuffs
4	100 to less than 105	Earplugs or Earmuffs
5	105 to less than 110	Earplugs or Earmuffs

Earplugs are not limited in Class as was the case with the previous Grading method. The Class into which an earplug is placed is determined by the results of the testing.

OSH POLICY

Hearing protectors that have previously been Graded and recognised by OSH were considered as suitable for use in a workplace until an appropriate period of time had elapsed for protectors to be re-tested to one of the current Accepted Standards. Testing to one of the Accepted Standards must be carried out by a laboratory accredited (by a recognised accreditation body) to carry out such acoustic testing according to this Standard before the measurement data will be accepted by OSH. This means that any laboratory worldwide so accredited can carry out this testing.

HEARING PROTECTORS LISTED BY OSH

OSH requires the following information to be submitted before adding any device to the OSH web-site list of Classified Hearing Protectors:

- A copy of the accreditation certificate for the testing laboratory to conduct tests to an Accepted Standard
- A copy of the testing report produced in accordance with an Accepted Standard
- A copy of the promotional material for the hearing protector

Note: testing to the earlier 1988 version, of AS 1270 or to ISO4869-1 1990 is no longer acceptable for the assessment of the performance of hearing protectors in New Zealand.

The list of all protectors that have been tested to one of the Accepted Standards–and that have been "Classified" according to that Standard has been developed and is on the OSH website. www.osh.dol.govt.nz. This list contains those products that have supplied information to OSH with the test data.

-The list of previously tested protectors that had been tested to either AS 1270: 1988 "Hearing protectors" or ISO 4869.1: 1990 "*Acoustics—Hearing protectors—Part 1: Subjective method for the measurement of sound attenuation*" and that had been "Graded" according to the method used by ESR[1] has now been deleted from the website and is no longer considered relevant. (ESR was engaged by OSH to provide technical assistance in the testing of hearing protectors at that time).

It is important to realise that because of the differences in the methods of testing in the two sets of standards, Grades and Classes are quite separate and are not interchangeable. Protectors tested to the old AS Standard or the ISO Standard cannot be given a "Class", they can be only given a "Grade".

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[1] Environmental and Science and Research Ltd, Auckland (previously known as the DSIR)

The list of classified hearing protectors that is on the OSH Website includes only hearing protectors evaluated by the Occupational Safety and Health Service of the Department of Labour, and currently recognised for the purposes of Section 10(2)(b) of the Health and Safety in Employment Act 1992 as suitable for protecting against noise up to the Class stated.

LIST OF CLASSIFIED HEARING PROTECTORS

1. Hearing protectors are listed according to hearing protection class. Within each class, devices are listed in order according to brand name within the following classifications:
   - Earplugs
   - Earmuffs
   - Communications Earmuffs
   - Earmuff/Helmet Combinations

2. All new earmuffs and earplug packaging must be clearly marked (with the appropriate numbers inserted) as follows:

> HEARING PROTECTOR CLASS **X**
> Tested to AS/NZS1270, when selected, used and maintained as specified in AS/NZS 1269 this protector may be used in noise up to **Y**dBA assuming an 85dBA criterion. A lower criterion may require a higher protector class

Note: If tested to ANSI S12.6: 1997 - Method B rather than AS/NZS1270, this Standard should replace AS/NZS1270 in the label above.

3. X is the class of the protector calculated according to paragraph A4 of Appendix A of AS/NZS1270: 2002. Y is the corresponding dBA value shown for that class in Table 2 below.

TABLE 2: NOISE EXPOSURE CLASSES

Hearing Protector Class, X	Highest level of noise, Y (dBA)
1	90
2	95
3	100
4	105
5	110

4. The attenuation of hearing protectors is measured in accordance with the procedures described in standards such as the AS/NZS1270: 1999 or 2002 or ANSI S12.6: 1997 using “Method B”. The mean attenuation **(Mean)** and standard deviation **(SD)** data for each hearing protector are determined from attenuation results obtained using the required number of subjects. The Assumed Protective Value **(APV)** of the device is calculated at each frequency by subtracting one standard deviation from the mean attenuation. This results in a value of attenuation that will be achieved for approximately 84% of users. These data may be used in the octave band method of hearing protector selection. The data can also be of assistance in selecting appropriate devices within a Class for a particular application since the performance of devices within a class can vary substantially.

RESPONSIBILITIES:

1. If a hearing protector is not worn for the entire period of exposure to excessive noise the wearer will be under protected, no matter how good it is. The use of a much higher Class hearing protector than necessary does not compensate for the time that the protectors are NOT worn.
2. Damaged or poorly maintained hearing protectors will not provide the stated protection. Earmuff cushions should be replaced as soon as they begin to deteriorate and should normally be replaced at least once a year. Any modification to hearing protectors may also reduce the attenuation provided, and will therefore no longer be recognised by the Occupational Safety and Health Service of the Department of Labour as suitable protection.
3. If the seal of earmuff cushions against the head is interfered with, for example by wearing spectacles, the attenuation of the device may be reduced by several decibels.
4. It is most important that earplugs be fitted properly in order to achieve the attenuation stated. The performance of poorly fitted earplugs may be reduced by more than 1 class.
5. Hearing protectors should be selected from the appropriate hearing protector class. Over protection should be avoided as this may result in impaired communication and acoustic isolation.
6. Homemade hearing protectors such as cotton wool provide negligible hearing protection and may break up when removed from the ear canal causing problems for the wearer. They are not recognised as suitable protection in any situation.
7. Stereo headphones (for example, those used with personal stereos and radios) are particularly hazardous when substituted for recognised hearing protectors because they normally do not provide any protection from the noise. In addition the wearer is likely to turn up the volume until the music/program can be clearly heard above the ambient noise. Not only does this significantly increase the noise exposure, but also the wearer is further acoustically isolated from the work environment and may not hear warning signals or instructions.
8. The responsibilities of employers and workers with regard to noise under the Health and Safety in Employment Act (1992) [the Act] are:

   Section 6: Employers are to ensure the safety of employees while at work.

   Section 7: Employers must systematically identify hazards and determine whether they are a significant hazard.(1)

   Section 8: Employers must take all practical steps to eliminate excessive noise.

   Section 9: Where excessive noise cannot be eliminated, employers must take all practicable steps to isolate employees from it.
   Note: This does not mean by using hearing protectors.

   Section 10: Employers must minimise the exposure to excessive noise by engineering/administrative means and ensure that employees are protected from this exposure by the use of suitable hearing protectors. Employers must also monitor the employees' noise exposure, and with their informed consent, monitor the employees' hearing.

   Section 11: Employees must be given the results of these tests.

   Section 13: Employers must ensure that employees are properly trained in the use of noise reducing provisions on equipment and the correct use of hearing protectors.

   Section 19: Employees must ensure their own safety at work. This includes the correct use of any noise controls on equipment and the proper use of hearing protectors.

9. The responsibilities of employers and also designers, manufacturers & suppliers of plant and hearing protectors, with regard to noise under the Health and Safety in Employment Regulations (1995) are:

   Regulation 10: The definitions of “employer” and “employee” with respect to Regulation 11 are extended beyond those in the Act.

   Regulation 11: The noise exposure limits are prescribed as an $L_{Aeq,8h}$ of 85dBA and an L_{peak} of 140 dB. This means that noise exposure above these limits is deemed to be a significant hazard.

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(1) Excessive noise is a significant hazard since it causes Noise Induced Hearing Loss, which is listed in the First Schedule as Serious Harm.

The levels are required to be measured in accordance with AS 1269, 1989 (the predecessor to AS/NZS 1269: 1998).

Where noise levels exceed or are likely to exceed the stated levels, the areas/machinery are required to be appropriately labelled, with instructions on the use of appropriate hearing protectors.

Regulation 65: Provides for the recognition of Standards and other documents by a notice in the *Gazette*.

Regulation 66: Designers of plant are required to ensure that plant noise emission is minimised as far as practicable. They are also required to provide to manufacturers and suppliers, comprehensive and comprehensible information about the proper operation of the plant.

Regulation 67: Manufacturers and suppliers of plant are required to ensure that plant noise emission is minimised as far as practicable. They are also required to provide to purchasers and hirers, comprehensive and comprehensible information about the proper operation of the plant.

Regulation 68: Designers of hearing protectors are required to ensure that the protector will give adequate protection from the noise against which it is intended to protect. They are also required to provide to manufacturers and suppliers, comprehensive and comprehensible information about the proper use of the protector.

Regulation 69: Manufacturers and suppliers of hearing protectors are required to ensure that the protector will give adequate protection from the noise against which it is intended to protect. They are also required to provide to purchasers and hirers, comprehensive and comprehensible information about the proper use of the protector.

SELECTION AND USE OF HEARING PROTECTORS

New Zealand occupational noise regulations and codes of practice specify that hearing protector selection is to be based on attenuation data obtained in accordance with the Standard. This being the case, it is vital that such data reflects the attenuation obtainable by informed users in workplaces with well managed and well supervised hearing protector programs, rather than the maximum attenuation that the hearing protector can provide under ideal conditions. An example of such a program is described in AS/NZS 1269.3—1998, *Occupational Noise Management, Part 3: Hearing protector program*. (Currently under review by Standards Australia/Standards New Zealand)

The selection, wearing and management of the use of hearing protectors in the workplace is dealt with using this Standard. It is the current version which resulted from the review of it's predecessor AS1269: 1989, and has therefore now superseded the 1989 version. It is published in 5 parts dealing separately with an Overview, Measurement and Assessment of Noise Immission and Exposure, Noise Control Management, Hearing Protector Program and Auditory Assessment. This Standard is the most up to date consensus view of what constitutes the best practicable means of managing noise in the workplace held by the Australia and New Zealand Standards committee.

In order to ensure that an employer fulfils their obligations under the Act, it is recommended that the procedures and requirements of AS/NZS1269: 1998 be adopted.

SELECTING HEARING PROTECTORS WITH ADEQUATE NOISE REDUCTION

There are two possible methods used for determining the hearing protector required for given exposure conditions:

- The **CLASSIFICATION SYSTEM** (which uses a method similar to the Australian SLC_{80} method) requires only a measurement of the Equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$) of the noise(s) to determine the Noise Exposure Level, $L_{Aeq,8h}$ together with the 'Peak' sound pressure level in the case of impactive or impulsive noise. This is now the preferred method to be used for hearing protector selection in industry in NZ.
- The **OCTAVE BAND METHOD** is more accurate but requires that the frequency content of the noise to be measured in at least seven octave bands (125Hz to 8kHz). In practice, the octave band method is restricted to unusual situations, for example, those involving a very high level noise or noise with intense tonal, infrasonic or ultrasonic components. These situations are relatively rare in industry.

WARNING: An alternate single number rating commonly seen on hearing protector packaging - the NRR - is used to rate hearing protectors in the USA. The NRR rating number often appears on the packaging of earplugs (and sometimes on earmuffs). The value is usually much higher than both the Australian SLC_{80} value and the reduction indicated by the classification of the device in New Zealand. NRR has not been standardised in either New Zealand or Australia and should not be used. There is no simple way of converting the NRR number to a Class.

ADDITIONAL NOTE:

During the development of the AS/NZS 1270: 2002, the Standards committee considered the different assessment systems available and the class system was chosen to replace the Australian SLC_{80} system in Australia and the Grading system in New Zealand, since it simplifies the process of the selection of appropriate hearing protectors for people at work. However, AS/NZS1269.3: 1998 – *Hearing Protector Program* does allow for the use of selection procedures other than Classification and Octave Band. As a consequence, the SLC80 method is still used by some people in Australia.

The suitable type of hearing protector for a given exposure condition therefore normally requires only the determination of the Noise Exposure Level ($L_{Aeq,8h}$) and the Peak Level (L_{peak}).

Details of how to determine the $L_{Aeq,8h}$ and L_{peak} are contained in the Australian/New Zealand Standard AS1269.1: 1998: "*Occupational Noise management – Part 1: Measurement and assessment of noise immission and exposure*".

INSPECTION AND MAINTENANCE OF HEARING PROTECTORS

It is recommended that the recommendations and procedures stated in AS/NZS1269.3: 1998 "*Hearing Protector Program*" are followed carefully.

It is most important that hearing protectors are regularly inspected and maintained. Hearing protectors need to be regularly inspected for damage or deterioration.

Hearing protectors selected from the list of recognised protectors that have been modified in any way can no longer be considered as tested and graded or classified, unless the testing laboratory has tested those modifications.

Adequate provision should be made for clean storage of protectors when not in use. Facilities should be readily available for the cleaning of reusable protectors. Hearing protectors should be cleaned and disinfected according to the manufacturer's instructions.

For devices in daily use it is recommended that earmuff cushions and foam inserts be replaced after 6 months and that the earmuffs be replaced after 1 year. Reusable earplugs should be replaced at least every 3 months.

It should be appreciated that these times are very approximate and highly dependent upon the care in use of the protector. Replacement may be necessary much earlier than indicated above.

Manufacturers and suppliers of hearing protectors must ensure that all purchasers are provided with information that will enable the protectors to be used in a safe and proper manner.

The following information must be provided in or on the package in which the protector is supplied:

- The method of adjusting and fitting the protector
- Instructions for cleaning and disinfecting the protector, if appropriate
- Maintenance requirements, if appropriate
- List of spare parts available for replacing worn or damaged components
- Mass of the protector (Earmuffs)
- Clamping force (Earmuffs & Ear Canal Caps)
- Notes warning about the effects of wear and tear and the effects of other items impairing seals
- Details of the mean, standard deviation and mean-minus-standard deviation attenuations.(these must be displayed so that they can be viewed without opening the package)
- A label showing the *Class* of the hearing protector

Information provided by a manufacturer or supplier of hearing protectors must be consistent with the hierarchy of the control of noise as required by the Act.

REDUCTION IN EFFECTIVENESS OF HEARING PROTECTORS

The removal of hearing protectors for even short periods of time can dramatically reduce their effectiveness and lead to under-protection for the wearer (see figure 1 below).

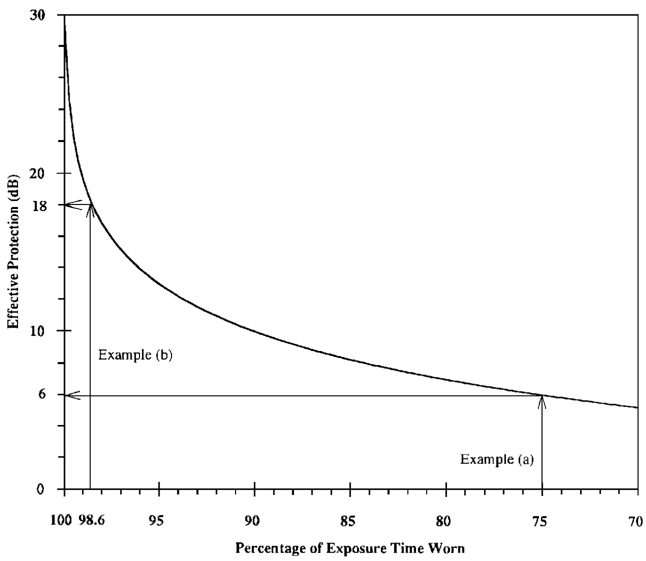

Figure 1: Reduction in the effective protection provided by a high-grade hearing protector with decreased wearing time in a given noise environment

Due to the difficulties of wearing hearing protectors for long periods of time in some environments, it is important that regular brief rest periods in quiet areas be provided, to maximise the proper use of protection when actually needed.

Over a working day, periods of a few minutes unprotected exposure are easy to accumulate, for example by placement and removal of the protectors while in the noisy area rather than before entering and after leaving it; or by removing hearing protectors briefly for purposes of comfort, communication or any other reason.

Examples:

(a) If not worn for 15 minutes during a total exposure time of 1 hour (worn 75% of the time), the effective protection provided by a high performance (30dB) hearing protector is only 6dB. This means that worn in this way, the high performance protector effectively gives the same protection as a low performance (6d~~b~~B) protector worn <u>all the time</u> (for the full hour of exposure).

(b) If not worn for 5 minutes during a total exposure time of 6 hours (worn 98.6% of the time), the effective protection provided by a 30dB hearing protector is only 18dB; making the effective protective value 12dB less than expected.

DETERMINATION OF THE NOISE EXPOSURE LEVEL, $L_{Aeq,8h}$

The correct way to select an appropriate hearing protector is to determine the overall $L_{Aeq,8h}$ for the partial exposures that a person is exposed to over a typical working day and then determine the appropriate class using Table 1 on page 3.

The $L_{Aeq,8h}$ may be determined in the following way:

1) Table 3 (below) can be used to determine the $L_{Aeq,8h}$ using the following method:

- Convert each noise level to a pascal-squared (Pa^2) value
- Multiply each Pa^2 value by the respective exposure duration in hours, giving a partial exposure
- Add these resulting partial exposures together, to obtain the total exposure in Pa^2h
- Divide this total exposure by 8, to obtain the 8 hour average Pa^2
- Convert this value of Pa^2 using Table 2 again to obtain the $L_{Aeq,8h}$

This is the employee's **Daily Noise Exposure Level** ($L_{Aeq,8h}$**)**

TABLE 3: DECIBEL TO PASCAL-SQUARED CONVERSION

dB	**Pa^2**	**dB**	**Pa^2**	**dB**	**Pa^2**	**dB**	**Pa^2**	**dB**	**Pa^2**
75	**0.013**	**85**	**0.13**	**95**	**1.3**	**105**	**13**	**115**	**130**
75.5	0.014	85.5	0.14	95.5	1.4	105.5	14	115.5	140
76	**0.016**	**86**	**0.16**	**96**	**1.6**	**106**	**16**	**116**	**160**
76.5	0.018	86.5	0.18	96.5	1.8	106.5	18	116.5	180
77	**0.020**	**87**	**0.20**	**97**	**2.0**	**107**	**20**	**117**	**200**
77.5	0.022	87.5	0.22	97.5	2.2	107.5	22	117.5	220
78	**0.025**	**88**	**0.25**	**98**	**2.5**	**108**	**25**	**118**	**250**
78.5	0.028	88.5	0.28	98.5	2.8	108.5	28	118.5	280
79	**0.032**	**89**	**0.32**	**99**	**3.2**	**109**	**32**	**119**	**320**
79.5	0.036	89.5	0.36	99.5	3.6	109.5	36	119.5	360
80	**0.040**	**90**	**0.40**	**100**	**4.0**	**110**	**40**	**120**	**400**
80.5	0.045	90.5	0.45	100.5	4.5	110.5	45	120.5	450
81	**0.050**	**91**	**0.50**	**101**	**5.0**	**111**	**50**	**121**	**500**
81.5	0.057	91.5	0.57	101.5	5.7	111.5	57	121.5	570
82	**0.063**	**92**	**0.63**	**102**	**6.3**	**112**	**63**	**122**	**630**
82.5	0.071	92.5	0.71	102.5	7.1	112.5	70	122.5	710
83	**0.080**	**93**	**0.80**	**103**	**8.0**	**113**	**80**	**123**	**800**
83.5	0.090	93.5	0.90	103.5	9.0	113.5	90	123.5	900
84	**0.10**	**94**	**1.0**	**104**	**10**	**114**	**100**	**124**	**1000**
84.5	0.11	94.5	1.1	104.5	11	114.5	110	124.5	1100

The pascal-squared values in the Table above have been rounded to 2 significant figures. This will result in an accuracy of at least ±5% or ±0.2 dB.

2) Alternatively, the noise exposure level may be calculated directly using the following equation:

$$L_{Aeq,8h} = 10 \mathrm{Log}\left[\frac{1}{8}\sum_{i=1}^{n}\left(T_i \times 10^{\left(0.1 \times L_{Aeq,T_i}\right)}\right)\right] \ \mathrm{dB(A)}$$

where, L_{Aeq,T_i} is the equivalent continuous A-weighted sound pressure level occurring over the time interval T_i (in hours).

n is the total number of part time intervals
(Note: the intervals do not necessarily add up to 8 hours)

EXAMPLE 1

Suppose hearing protectors are to be selected for an employee whose typical daily noise exposure pattern is as shown in the Table 4 below.

TABLE 4: TYPICAL DAILY NOISE EXPOSURE PATTERN FOR THE EMPLOYEE

Machine/Process	Measured Noise Level $L_{Aeq,T}$ (dBA)	Exposure Duration T (Hours)
Furnace	105	0.5
Chipping hammer	95	4.0
Power hacksaw	87	1.0
Welding	90	1.5

In this example, the conversion process described above is illustrated below by putting the data into a table:

TABLE 5: EXPOSURE DETAILS OF THE EMPLOYEE

Machine/Process	Measured Noise Level $L_{Aeq,T}$ (dBA)	Pa^2 value (from Table 5)	Exposure Duration T (Hours)	Partial Noise Exposure (Pa^2h)
Furnace	105	13	0.5	6.5
Chipping hammer	95	1.3	4.0	5.2
Power hacksaw	87	0.2	1.0	0.2
Welding	90	0.4	1.5	0.6
Daily Noise Exposure (DNE)				**12.5**

The Total Daily Noise Exposure (DNE) is thus 12.5 Pa^2h.

The $L_{Aeq,8h}$ is determined by dividing this DNE by the 8 hours in a nominal working day.

Note: It does not matter whether the duration of the actual noise exposure is 8 hours or not, this process automatically works out the 8 hour equivalent level of exposure.

The Pa^2 value averaged over a normalised period of 8 hours is therefore 12.5/8 = 1.56 Pa^2

The $L_{Aeq,8h}$ is obtained by converting 1.56 Pa^2 back to decibels (dB) using Table 3.

The $L_{Aeq,8h}$ is therefore between 95.5 and 96dBA, which is normally rounded to the nearest whole number.

So **$L_{Aeq,8h}$ = 96dBA**

The protector to be selected in this example is therefore Class 3 (from Table 1).

Alternatively, the calculation can be performed using the formula above. The process is illustrated below:

$$L_{Aeq,8h} = 10Log\left\{\frac{1}{8}\left[\left(0.5\times10^{(0.1\times105)}\right)+\left(4\times10^{(0.1\times95)}\right)+\left(1\times10^{(0.1\times87)}\right)+\left(1.5\times10^{(0.1\times90)}\right)\right]\right\}$$

$$= 10Log\left\{\frac{1}{8}\left[\left(0.5\times10^{10.5}\right)+\left(4\times10^{9.5}\right)+\left(1\times10^{8.7}\right)+\left(1.5\times10^{9.0}\right)\right]\right\}$$

$$= 10Log\left\{\frac{1}{8}\left[\left(0.5\times3.16\times10^{10}\right)+\left(4\times3.16\times10^{9}\right)+\left(1\times5.01\times10^{8}\right)+\left(1.5\times1\times10^{9}\right)\right]\right\}$$

$$= 10Log\left\{\frac{1}{8}\left[\left(1.58\times10^{10}\right)+\left(1.26\times10^{10}\right)+\left(0.05\times10^{10}\right)+\left(0.15\times10^{10}\right)\right]\right\}$$

$$= 10Log\left\{\frac{1}{8}\left(3.04\times10^{10}\right)\right\}$$

$$= 10Log\left\{0.38\times10^{10}\right\}$$

$$= 10\times9.58$$

= 95.8 dB(A)

So $L_{Aeq,8h}$ = 96dBA (rounded to the nearest whole number)

RELATIONSHIP BETWEEN NOISE EXPOSURE LEVEL AND NOISE EXPOSURE

Table 6 below illustrates the relationship between Noise Exposure Level and Noise Exposure. It shows, for example, that a 3dB increase in noise exposure level results in a doubling of the noise exposure. A 10dB increase results in a ten times increase.

TABLE 6: NOISE EXPOSURE LEVEL CONVERTED TO NOISE EXPOSURE

Noise Exposure Level $L_{Aeq,8h}$(dBA)	Daily Noise Exposure (Pa^2h)	Noise Exposure Level $L_{Aeq,8h}$(dBA)	Daily Noise Exposure (Pa^2h)
80	0.32	98	20
81	0.40	99	25
82	**0.51**	**100**	**32**
83	0.64	101	40
84	0.80	102	51
85	**1.0**	**103**	**64**
86	1.3	104	80
87	1.6	105	100
88	**2.0**	**106**	**130**
89	2.5	107	160
90	3.2	108	200
91	**4.0**	**109**	**250**
92	5.1	110	320
93	6.4	111	400
94	**8.0**	**112**	**500**
95	10	113	640
96	13	114	800
97	**16**	**115**	**1000**

The exposure values in the Table above have been rounded to 2 significant figures. This will result in an accuracy of at least ±5% or ±0.2 dB.

When the total daily noise exposure in Pa^2h is known, the noise exposure level may be determined directly from Table 6.

GLOSSARY

Asymmetrical earmuff:
The shape of the front and back and/or the top and bottom of the earcup is different. If the earcups are not positioned correctly the attenuation of the earmuff may be significantly reduced.

*Disposable earplug *:*
The earplug is designed to be worn once.

*Ear canal cap *:*
A hearing protector that covers the ear canal entrance and is held in place by a headband.

Earmuff:*
A hearing protector that covers the entire ear and is held in place by a suspension system.

*Earplug *:*
A hearing protector that inserted into the ear canal.

*Hearing protector *:*
A device worn by a person to reduce the unwanted effects of sound.

Nape earmuff:
The earmuff is worn with the headband behind the head. A head-strap is normally provided that is to be worn over the head.

Overhead earmuff:
The earmuff is worn with the headband over the head.

Pre-moulded earplug:
These are inserted into the ear canal without the need for prior shaping. They are made from a number of materials and are often available in a range of sizes.

Universal earmuff:
The earmuff can be worn with the headband over the head, behind the head or under the chin.

*User formable earplug *:*
The earplug is shaped by the user before insertion into the ear canal

Octave Band Attenuation Data:

Mean
The average attenuation at a particular frequency when measured on a number of people.

SD
The standard deviation of the data obtained from measurements on a number of people. Standard deviation is a statistical value that is a measure of the variation in the results of the measurements.

APV
The assumed protective value of a particular protector at a particular frequency. The value is obtained by subtracting one standard deviation from the mean value.

* Taken from the *Section 1.4 Definitions* in *AS/NZS 1270: 2002.*

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