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HEARING PROTECTION PERFORMANCE

FOR THE AUSTRALIAN COAL INDUSTRY

Report No. 96303

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Prepared for

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SUMMARY

Tests have been carried out to establish the 'spot check' performance of hearing protection with the Australian Coal Industry. A sample was taken of twenty six subjects and with a wide range of *'in use'* hearing protection.

It was found that the average performance of hearing protectors (commonly assessed in Australia in terms of a single number known as sound level conversion SLC_{80}) was 3 to 4 B less than the laboratory statistical data would indicate.

The use of safety spectacles with ear muffs and the lack of regular fitting instructions for ear plugs further reduce performance. In addition, it was found that inadequate training regarding the importance of hearing protection wear rate (ie time spent actually wearing hearing protection when in noise areas) reduces the performance of all hearing protectors (SLC_{80}) on average by 6 dB to 16 dB (down to only SLC_{80} 14) regardless of the theoretical performance.

This information can be used by those responsible for implementing the noise management plan at coal mine sites. In particular this can be used to answer the questions given in the current coal mine noise management document such as: *"have calculations been made by a competent person to demonstrate that hearing protection in use will theoretically provide the desired attenuation?"* and *"is the hearing protection likely to provide the same degree of performance in practice?"*

1. PREAMBLE

Exposure to excessive noise can result in noise induced hearing loss which is also known as industrial deafness. This can have a dramatic effect on the lives of the many people who have been exposed. It affects not only the individual exposed but also their family, friends, work colleagues and the community as a whole. In addition to the social consequence of noise induced damage, it also has an immense effect on the economy. The annual workers compensation payments now (1995/6) exceeds $100 000 000 in NSW alone (ref 1) and is, by far, the single largest incidence of occupational disease. The incidents of industrial deafness in the mining industry in NSW represents 5.9% (ie $ 5 900 000) of the total distribution of deafness by industry (ref 1).

It is therefore essential in the mining industry that a strict noise management at coal sites is implemented. A noise management at coal sites document has been prepared for the Joint Coal Board Health & Safety Trust by the Joint Coal Board Safety Committee on Noise Induced Hearing Loss authored by Thomas Mitchell (Ref 2). The stated objectives of this document are to:

1. Minimise occupational noise induced hearing loss and tinnitus by an approach that emphasises the reduction of noise levels at work considering the hierarchy of noise control measures. These are:

   a. *Elimination and substitution of equipment and processors,*
   b. *Engineering control measures,*
   c *Administrative control measures; and*
   d. *Personal hearing protective equipment.*

2. Promote and adopt a systematic approach to the management of exposure to excessive noise.

3. Promote the recognition and understanding of the effects of exposure to noise.

4. Promote implementation through established consultative processes.

5. Utilise existing resource documents to formulate a national approach to the management of occupations noise problems.

Although, quite rightly, personal hearing protection is the last on the list (1d), it is the noise control measure most widely used in the mining industry.

2. INTRODUCTION

The Noise Management at Coal Mine Sites document (ref 2) (page 32 Appendix F - Personal Program Checklist) asks the question *"Have calculations been made by a competent person to demonstrate that hearing protection in use will theoretically provide the desired attenuation?"* This will require a knowledge of not only the noise levels which mine employees are exposed to, but also the duration spent in noise and the octave band frequency of the noise. Although the latter may be difficult to obtain in some circumstances, this information is attainable.

The next question is *"Is the hearing protection likely to provide the same degree of performance in practice?"* If a "No" is obtained to either question, then the hearing protection program should be reviewed.

It is highly unlikely that the person responsible for implementing the noise management program will be able to provide a quantifiable answer to the second question let alone an affirmative answer. Hence the program is in a permanent state of review!

This report presents the results of research aimed at providing data to enable the person responsible for implementing the noise management program to make a reasoned judgement of hearing protection ***in practice***. It does this by reporting the results of a series of 'spot checks' on the field performance of mineworker's actual hearing protectors. These are then compared with the results of the theoretical performance given by the manufacturers or acoustical test laboratories.

3. NOISE LEVELS IN THE NEW SOUTH WALES COAL MINING INDUSTRY.

Although an equipment noise survey was not carried out as part of this project an overview of typical noise levels and exposures obtained from discussions with various mine operators are given below.

3.1 Continuous Miner

The principal underground coal winning unit is the continuous miner. Typical noise exposures for continuous miner drivers are between 90 and 103 dBA with 8 hour equivalent exposures ($L_{Aeq,8hrs}$) in the order of 96 dBA to 97 dBA.

3.2 Shuttle Cars

The shuttle car drivers and roof bolters experience similar noise exposures to the continuous miner drivers. The range of noise levels at the driver ear position of shuttle cars ranges from 86 dBA to 94 dBA. A considerable portion of this is being attributed to the continuous miner operation when the car is being filled under the continuous miner.

3.3 Roof Bolting

The roof bolting is required for roof support and this involves drilling holes by means of pneumatic or hydraulic equipment. The hydraulically operated machines normally operate within the range 84-90 dBA. When the motor is running without load the level is approximately 84 dBA, when the machine is drilling and bolting the level rises to 88-90 dBA and the highest level occurring when the bolts are being tightened. The machines operate intermittently throughout the shift. The time taken to drill each hole depends mainly on the hardness of the strata. Lower levels are experienced while changing drills, when changing from one hole to another, and when the employees are relocating from one place to another. The compressed air operated machines are much noisier than the hydraulically operated type. They are usually used in the harder types of roof strata and noise levels can exceed 100 dBA.

3.4 Long Wall Equipment

Long wall face equipment tends to be operated more continuously than some other type of face equipment. Normally noise exposures are in the range of 94-96 dBA. Noise levels of over 100 dBA can occur for short periods.

3.5 Auxiliary Equipment

In addition, auxiliary equipment such as pumps, fans and conveyors emit noise levels exceeding 95 dBA.

4. RISK ASSESSMENT AND NOISE LEVELS

The legal limits for noise exposures to people at work are given in the Occupational Health & Safety (Noise) Regulation 1996 (ref 3) under the Occupational Health & Safety Act 1983 (ref 4). For the purpose of Part 3 of the Act (the provision of which are adapted accordingly), a place of work is unsafe and a risk to health if any person is exposed there to noise levels:

- **a. that exceed an 8 hour noise level equivalent of 85 dBA; or**

- **b. that peak at more than 140 dB(Lin).**

This regulation applies to all places of work other than mines within the meaning of the Coal Mines Regulation Act 1982 (ref 5) or the Mines Inspection Act 1901 (ref 6). However, the Coal Mines Regulation Act (section 63A) places an obligation on the engineering inspector to preserve health and safety of mine employees. The engineering inspector can impose on the owner or manager such prohibitions and restrictions, and require that the owner or manager to carry out such works or do such things to be necessary for the purpose of safeguarding the safety and health of the person employed at the time.

The Coal Mines Regulation Act does not specify any noise criteria but it would seem unreasonable not to apply the same criteria for mine workers as is given in the Occupational Health & Safety (Noise) Regulation for the rest of the working community. There must be a moral duty for those responsible for workers in mines to abide by this regulation.

The Table 4.1 provides maximum durations (exposure times) as a function of noise level to equal the legal limit of 85 dBA 8 hour equivalent.

TABLE 1.1 NOISE LEVEL AND EXPOSURE 'TRADE-OFF'

Noise Level (dBA) L_{pA}	Maximum Exposure Time*
85	8 hr
88	4 hr
91	2 hr
94	1 hr
97	30 min
100	15 min
102	10 min
105	5 min
109	2 min
112	1 min
115	28 secs
120	9 secs
123	5 secs
< 130	Less than 1 second

*Calculated from $8 / 10^{((L_{pA}-85)/10)}$ (in hours)

The estimated prevalence of noise induced hearing impairment in noise exposure populations is given in Appendix D Table D1 of the Australian Standard Acoustics-Hearing Conservation AS1269/1989 (ref 7). This is based on equations given in International Standard ISO 1999 which shows the median together with the fifth and ninety fifth percentile values of noise induced permanent threshold shifts in decibels to be expected at 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz and 6 kHz for various combinations of noise exposure and noise duration.

The table shows that, if noise induced hearing impairment is not to exceed 10 dBA over a working lifetime for 95% of the noise exposed population at any of the frequencies, then exposure levels must be kept to an equivalent continuous level over an 8 hour day of not more than 85 dBA. Alternatively, if noise induced hearing impairment is to be kept to not greater than 2 dBA for 95% of the population at any of the frequencies, then exposure levels must be kept to not greater than 80 dBA.

This table only gives the noise induced permanent threshold shift not the total permanent threshold shift to be expected in noise exposed populations. The permanent threshold shift will be greater than the values given in the table and is determined by a combination of noise induced threshold shift, threshold shift associated with aging and threshold shift due to other conditions (such as otological substances) which have an adverse effect on hearing.

The predicted prevalence of noise induced hearing impairment in noise exposed populations of 5%, 50% and 95% and for the most sensitive frequency, 4 kHz, is shown in Figures 4.1 to 4.3 below.

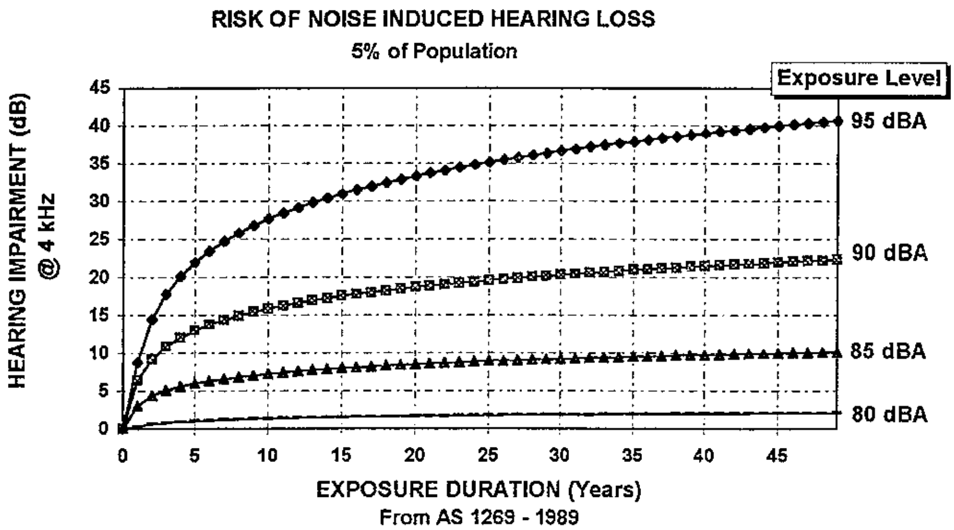

Figure 4.1 The Risk of Noise Induced Hearing Loss at 4 kHz for 5% of the Exposed Population

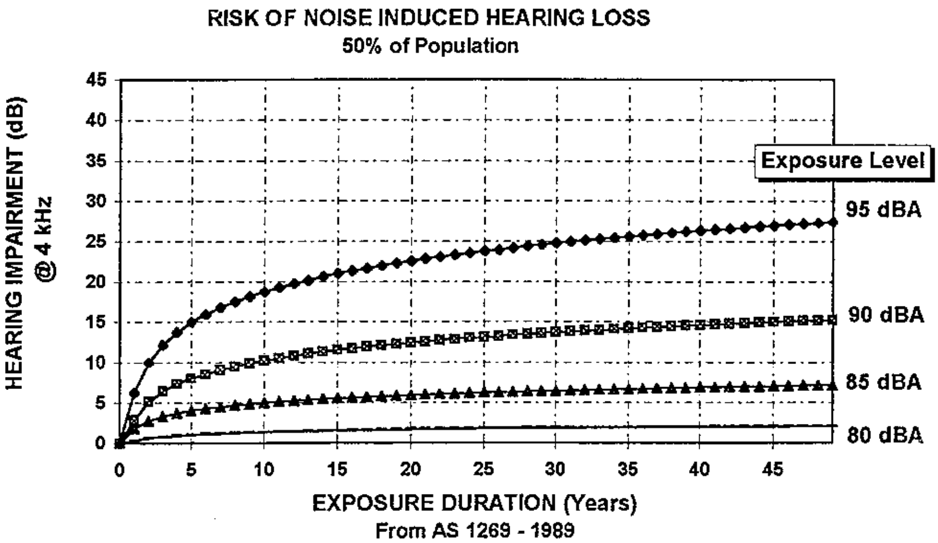

Figure 4.2 The Risk of Noise Induced Hearing Loss at 4 kHz for 50% of the Exposed Population

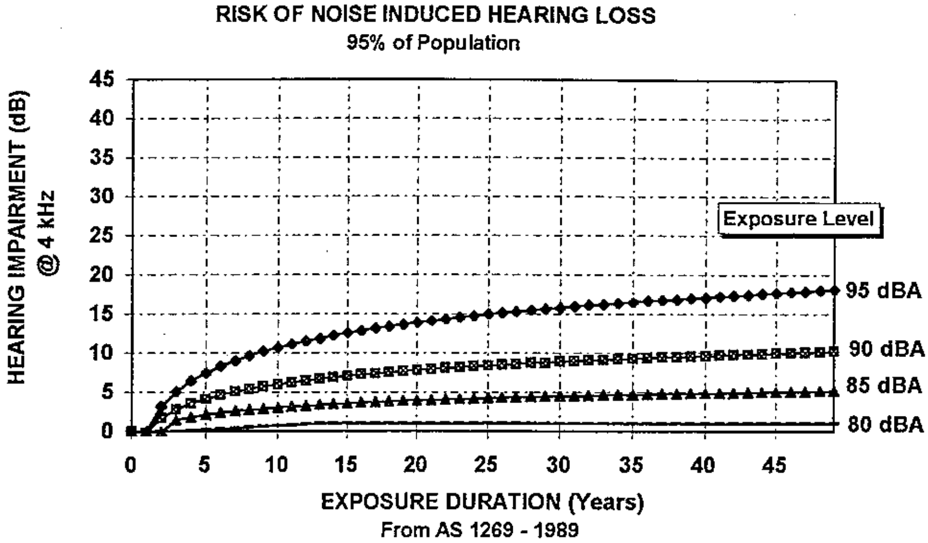

Figure 4.3 The Risk of Noise Induced Hearing Loss at 4 kHz for 95% of the Exposed Population

The risks where recently re-examined in a paper by Prince et al (ref 7). This provides further evidence of excessive risks of noise induced hearing damage at noise levels in the ranges of 85 dBA to 89 dBA and 90 dBA to 102 dBA. The results showed that excess risk estimated for time–weighted average sound levels below 85 dBA were sensitive to statistical model form and assumptions regarding the sound level to which the 'control' group were exposed. However, the analysis shows that exposures over 85 dBA presents a slightly higher risk of noise induced deafness that indicated by the Australian Standard AS 1269 (ref 8).

5. EXPERIMENTAL PROCEDURE

The original concept was to test mine workers' hearing protector performance in an established acoustical laboratory. Unfortunately, this was not considered possible by most of the mine managers contacted, due to the travelling time involved. The alternative was to construct a transportable laboratory and take this to the mines. This alternative was, therefore implemented.

There is an Australian Standard, AS 1270 - 1988 Acoustics – Hearing Protectors (ref 9) which gives a method for testing hearing protector performance. This requires at least 15 subjects per hearing protector type and includes instructions to adjust the hearing protector in broad band noise until the noise appears to be minimal. Spectacles and others factors that may reduce the performance are excluded. Statistical data can then be obtained from the results.

The tests described in this report were NOT designed to comply with this Standard and were not designed to exactly repeat already established theoretical statistical data. Rather the tests were designed to give a 'spot check' on individual mine workers' hearing protector performance at a given time.

This data should not be used in place of manufacturers' data but used by the person responsible for implementing the mining noise management program as an indicator of the likely degree of performance achieved **in practice.**

5.1 Subjects

The twenty six subjects for this study were all male volunteers from three mines. All of those tested were regular users of hearing protection for at least part of their working time. The age range of the subjects is shown in Figure 5.1. As the results are found from the difference with and without the use of hearing protection, it was not considered necessary to make adjustments to allow for any hearing loss the subjects may have.

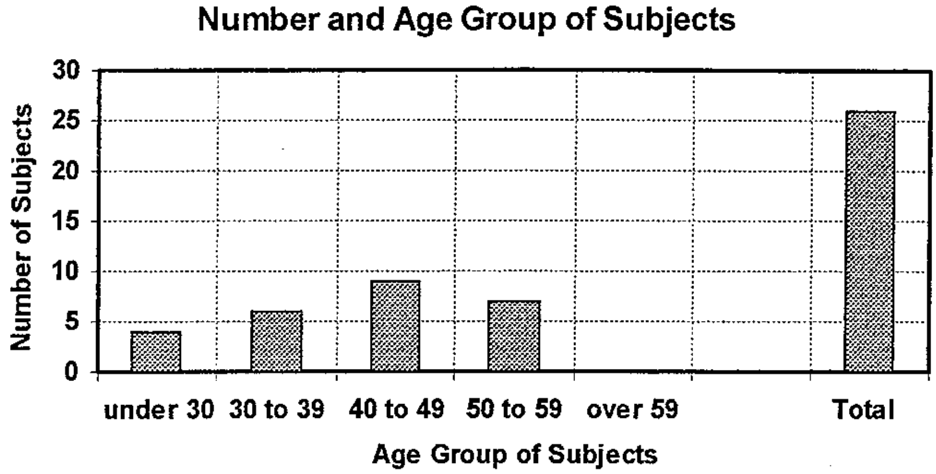

Figure 5.1 The Number of Subjects with Respect to Age.

5.2 Equipment and Instrumentation

The building, used in the tests was a transportable, custom made laboratory with an anechoic chamber approximately 2.4 m square as shown in Figure 5.2 below. The clinical audiometer was manufactured by Madsen, the amplifier was a Technics, the loudspeaker was a Genaxxa and the analysers used were a Bruel and Kjaer sound level meter model 2231 with an octave band analyser type 1624 and a CEL Instruments Limited real time frequency analyser model 593.

The sound level meters used during the research conform to Australian Standard 1259 "Acoustics – Sound Level Meters", as Type 1 precision sound level meters which has an accuracy suitable for both field and laboratory use. The calibration of the meters was checked before and after the measurement period with a Bruel and Kjaer acoustical calibrator type 4230. No significant system drift occurred over the measurement periods.

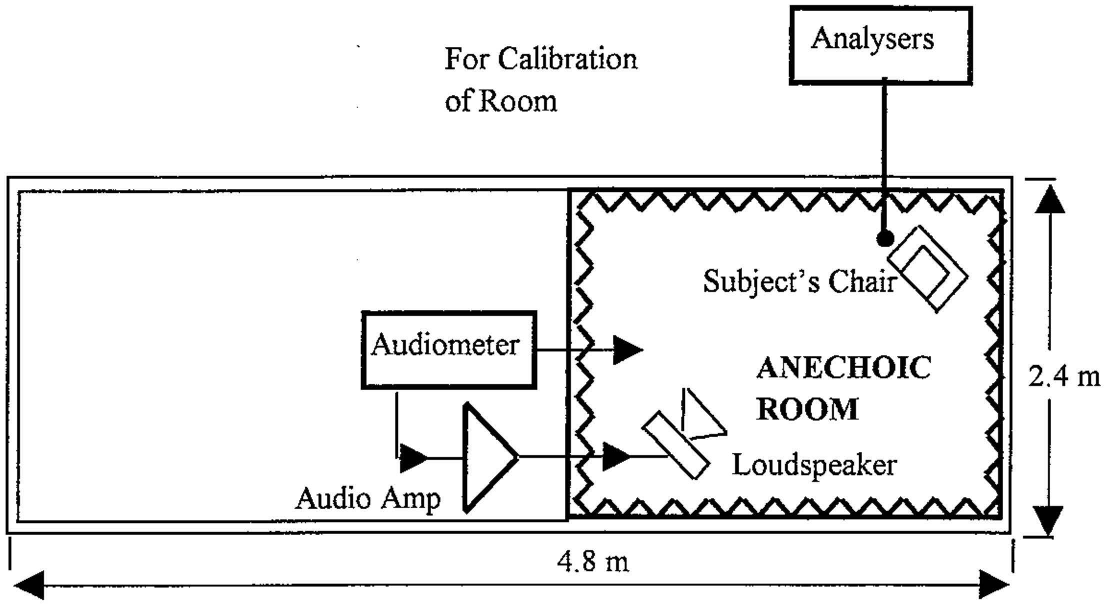

Figure 5.2 The Transportable Test Chamber Specially Commissioned to Carry out the Hearing Protector Testing. (Not to Scale).

The building was sited in the quietest practicable position within the limits of the electrical supply requirements. A typical example is shown in the Figure 5.3.

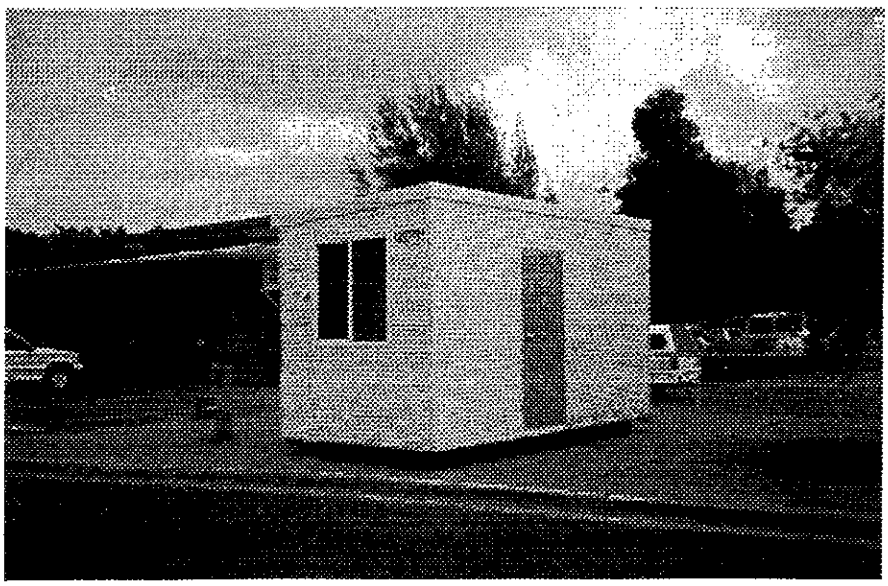

Figure 5.3. A photograph of the transportable Test Chamber on one of the sites.

Typical background levels are shown in Figure 5.4

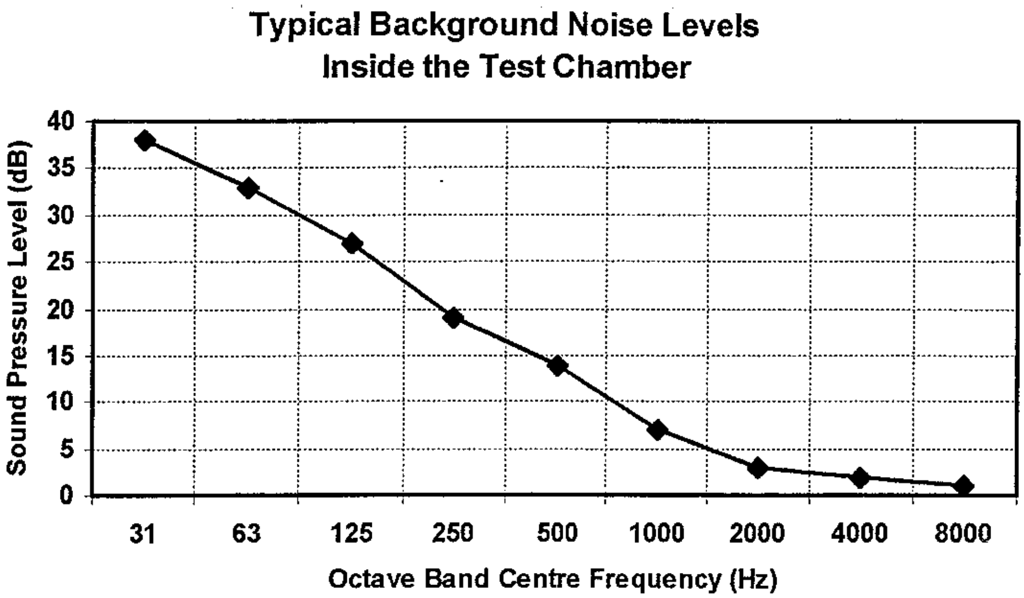

Figure 5.4. Typical background (L_{A90}) Noise Levels in the Anechoic Room on Site at the Mine Locations.

Where intermittent noise was audible the tests where stopped until the noise subsided.

5.3 Measurement Procedure

The subjects were tested before the start of their shift. Each subject was asked to bring his own hearing protector normally used, for the test. Often the subjects reported the occasional use of an alternative protector, in which case these were tested too.

The subjects were informed this was independent research into the effect of hearing protectors rather than a test of their hearing. They were then asked a series of short questions ie:

"How long have you worked here?
How long have you worked in mining?
How long are your shifts?
What type of hearing protector do you normally use?
Any other type of hearing protectors used?
How long do you wear per day?

How long are hearing protectors taken off in noise risk and hazard?
Have you had any training in the fitting of hearing protectors?
Have you ever experience temporary ringing in the ears?
Do sounds sometimes sound muffled?
Do you need to turn the TV or radio up after a working day?
Your name?
Your age?
Additional information"

The subjects were then introduced to the audiologist and individually seated in the sound attenuating, anechoic chamber. From the outset they sat facing the loudspeaker. Their hearing threshold in each ear was first measured with headphones on, and then their free field binaural threshold was measured.

The subjects were initially given no instructions other than to put on their hearing protection (which they normally used) in the normal way. Subjects with spectacles, facial hair, old protectors, etc were not excluded. The free field, binaural threshold was again measured, this time taking into account the hearing protector.

In certain cases additional measurements were carried out. These were:-

a) where subjects showed signs of incorrect fitting of plugs (subjects were given detailed instructions and the protector performance was re-tested).

b) where safety spectacles were being used with muffs (tests were carried out both with and without spectacles); and

c) where plugs and muffs were used together (tests were carried out with muffs, plugs and the combination of the two).

5.4 Protectors

Table 5.1 shows the list of the protectors that were tested at the three sites. The number of subjects is also included. Where the subject reported that they used two types of protector, both types were tested. The types of hearing protectors common found in use during this survey were the Peltor muffs (both individually mounted or helmet mounted) and EAR plugs.

TABLE 5.1 PROTECTORS TESTED

Hearing Protector				No. of Protectors Tested
Manufacturer	Model	Type	Site	
EAR	E-A-R	Plug	A, B	6
Peltor	H7	Muffs	A, B	4
Peltor	H7P3E	Muffs Helmet Mounted	A, B	5
Peltor	H9	Muffs	A, B	3
Peltor	H9P3E	Muffs Helmet Mounted	A, B	1
Protector Safety	EP35	Plugs	A	1
Protector Safety	Orange	Muffs Helmet Mounted	A	1
Hellberg	26006	Muffs Helmet Mounted	B, C	3
Howard Light	Airsoft SNR 30	Plugs	B	1
Bilsom	Down	Plugs	C	2
Bilsom	728	Muffs Helmet Mounted	C	1

6. RESULTS

The results of the research are divided into two sections. The first section covers the objective measurements of the protectors. Detailed results for each test, with frequency analysis, are shown in Appendix A. The Appendix is again divided into the results for plugs and the results for muffs.

The second section presents the results of the verbal survey and covers the reported essentials for a practical assessment of hearing protectors such as wear rate and exposure time. This section also covers the reported training received and the 'warning signs' for noise induced deafness.

6.1 Hearing Protector Performance

As mentioned in section 5 of this report, these tests were intended to provide 'spot checks' of the effectiveness of hearing protectors for mine workers and not statistical data as required by AS 1279 (ref 9). The sound level conversion (SLC_{80}) is a statistical value intended to provide the theoretical performance of hearing protectors for 80% of the population (in fact, a 3 dB lower performance can be obtained for low frequency noise exposures). This is not a meaningful value for the 'spot check' results given in this report. However, the calculations have been carried out, and the SLC_{80} values are reported, simply to provide a single number for easy comparison with manufacture's data. This is shown in Table 6.1 below:-

TABLE 6.1 HEARING PROTECTOR PERFORMANCE

Subject Ref.	Hearing Protector Type	SLC_{80}		
		Results	Manufacturer's Data	Difference*
HM	Protector Safety EP35 Plugs	14	16	-2
GY	EAR Plugs	18	22	-4
SD	-"-	18	22	-4
DM	-"-	19	22	-3
PR	-"-	21	22	-1
RJ	-"-	19	22	-3
JH	Bilsom Down 202	14	24	-10
JH	Bilsom Down 202	20 with fitting instructions	24	-4
GC	-"-	19	24	-5
GC	-"-	24 with fitting instructions	24	0

**A minus figure indicates that the spot checks gave a practical attenuation which was lower than the theoretical.*

TABLE 6.1 (continued) HEARING PROTECTOR PERFORMANCE

Subject Ref.	Hearing Protector Type	SLC$_{80}$		
		Results	Manufacturer's Data	Difference*
PD	Howard Leighton Plugs	23	32	-9
PD	-"-	26	32	-6
WL	Peltor H7 Muffs	23	30	-7
RP	-"-	24	30	-6
KM	-"-	24	30	-6
KM	-"-	23 with safety specs	30	-7
GL	Peltor H7P3E Muffs	22	24	-2
GC	-"-	20	24	-4
MS	-"-	22	24	-2
DD	-"-	25	24	-1
GJ	-"-	23	24	+1
RS	Peltor H9 Muffs	21	24	-3
JM	-"-	22	24	-2
BF	-"-	17	24	-7
TR	Peltor H9P3E Muffs	17	20	-3
TR	Peltor H9P3E Muffs	15 with safety specs	20	-5
JA	Hellberg 2606	22 with safety specs	25	-3
RJ	-"-	17	25	-8
RJ	-"-	14 with safety specs	25	-11
PY	-"-	23	25	-2

**A minus figure indicates that the spot checks gave a practical attenuation which was lower than the theoretical.*

TABLE 6.1 (continued) HEARING PROTECTOR PERFORMANCE

Subject Ref.	Hearing Protector Type	SLC_{80} Results	Manufacturer's Data	Difference*
PY	-"-	20 with safety specs	25	-5
JH	Bilsom 728 Muffs	26	30	-4
JH	Bilsom 728 Muffs	25 with safety specs	30	-5
GC	Helberg 26006	23	25	-2
GC	Hellberg 26006	33	Combined with Bilsom Plugs	
PR	Peltor H7	25	30	-5
PR	Peltor H7	36	Combined with EAR Plugs	

**A minus figure indicates that the spot checks gave a practical attenuation which was lower than the theoretical.*

6.2 Response to Questionnaire

During the measurements, the subjects were asked a series of questions as outlined in section 5.3 of this report.

6.2.1 Hearing Loss Warning Signals

Of the 26 subjects, 23 (88.5%) reported affirmatively to at least one of the three questions relating to hearing loss warning signals. Of particularly concern were the three youngest subjects (under 25 years of age with only 2 to 3 years' work experience) who all reported that they used a higher volume for television reception that other members of their family. This is a possible indication that hearing protection is not totally effective.

6.2.2 Training in Noise Hazards

Of the 26 subjects 12 (46.2%) reported that they have received no training in noise hazards, 11 (42.3%) reported that they have received some training and only 3 (11.5%) reported that they have received adequate training in noise hazard. This is shown in a pie chart format in Figure 6.1 below:

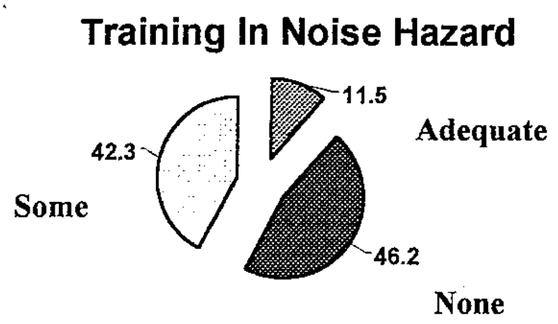

Figure 6.1 A Breakdown of the Percentage of the Reported Training Received in Noise Hazard.

6.2.3 Training in Hearing Protection Fitting

Of the 26 subjects 14 (53.8%) reported that they have received no training in hearing protection fitting, 5 (19.2%) reported that they have received some training and 7 (26.9%) reported that they have received adequate training in hearing protection fitting. This is shown in a pie chart format in Figure 6.2 below:

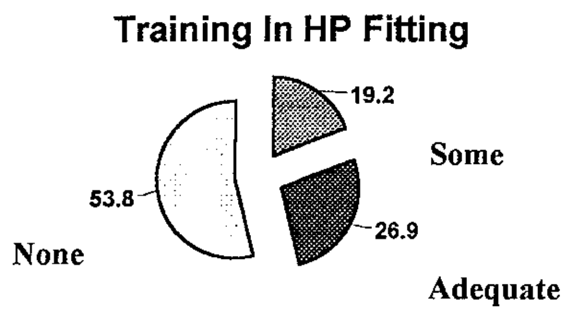

Figure 6.2 A Breakdown of the Percentage of the Reported Training Received in Hearing Protection Fitting.

6.2.4 *Time Spent in Noise with Hearing Protectors Removed*

It is not realistic to expect that hearing protectors be worn for 100% of the time spent in noise. For example muffs are removed to wipe sweat from around the pinna, hearing protectors are removed to improve on perceived verbal communications or hearing protectors are removed to hear machine functions. It was difficult for the subjects to accurately report how long hearing protectors were removed when in noise and some prompting was required to induce a reply to this question that may have introduced some bias. However, only 3 subjects (11.4%) reported that they did not remove hearing protectors in noise at all and 3 subjects reported that they could spend up to one hour in the noise without hearing protection. The average reported time spent unprotected in noise was 22.9 minutes. For noise levels of 100 dBA an unprotected duration 22.9 minutes will result in an 8 hour equivalent exposure of 87 dBA regardless of the theoretical hearing protector performance. Here, hearing damage of between 7 dB and 15 dB @ 4 kHz would be expected over a working lifetime.

7 DISCUSSION

7.1 Hearing Protector Performance

The difference between the SLC_{80} found in these tests and those given by the manufacturers or laboratory SLC_{80}'s are shown in Figure 7.1 below. On average from the 27 test samples we found that the SLC_{80} was 4.2 less than manufacturer's or laboratory data. This had a standard deviation of approximately 2.8. Hence we would expect that 50% (ie the mean) of the miners would have between 4 dB and 5 dB less SLC_{80} than would be predicted by manufacturers or laboratory data and 84% (ie mean minus one standard deviation) of miners would have between 1 dB and 2 dB less SLC_{80} than would be predicted by manufacturers or laboratory data. Figure 7.1 also show a normal distribution curve described by the Gauss function.

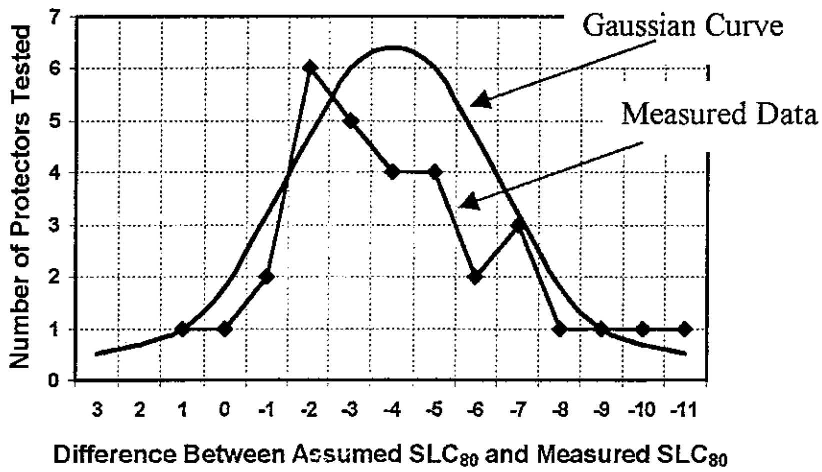

Figure 7.1 An analysis of hearing protector performance results and a predicted gaussian curve.

7.1.1 The Effect of Spectacles

In addition the use of safety spectacles with ear muffs reduces the effect on average by 2 dB with a standard deviation of 1.3 dB. Although this figure may seem marginal it can be seen from Figures A 23 to A 25 that the effect of spectacles with earmuffs can have a much more dramatic effect at the high frequencies. This can reduce the performance for example by 8 dB to 10 dB in the critical 2 kHz to 8 kHz frequency range.

7.1.2 The Effect of Fitting Instructions for Plugs

In three cases ear plugs were fitted by the subjects themselves and those three cases we had an average of 6 dB less SLC_{80} than manufacturer's or laboratory data. However, with a short but detailed description of how to fit ear plugs we increased the difference between our results and manufacturer's data from 6 to only 1.3 dB.

7.2 Response to Questionnaire

We found that on average 50% of the surveyed population reported no training in noise hazards or how to fit hearing protection (see sections 6.2.2 and 6.2.3). This is particularly important for ear plugs as we have seen from our test results with an increase of 4 dB to 5 dB which can be obtained with proper fitting instructions. This is effectively equivalent of more than halving the risk of noise induced damage and training in the noise hazard can also increase wear rates which should substantially reduce the reported 88.5% of the population who gave an affirmative answer to the questions relating to hearing loss warning signals.

Training is also very important for people who wear ear muffs. This is to ensure that they realise the effect of taking off hearing protectors in the noise even for very short time periods. As reported earlier just over 20 minutes was the average time reported that people took off hearing protection and for levels of 100 dBA this will result in exposures exceeding the legal limit given in the Occupational Health and Safety (Noise) Regulation 1996 for New South Wales (ref 4).

8. CONCLUSIONS AND FURTHER ACTION

8.1 Conclusions

The average performance of a hearing muff in these tests was an SLC_{80} of 22 and the average performance of an ear plug was an SLC_{80} of 18. However, when the effect of wear rate is taken into account, both protectors will give a performance of 14. This is based on the ear muffs being removed for approximately 20 minutes in an 8 hour working shift and the ear plug being removed for approximately 12 minutes. This is a conservative estimation of the details given in the verbal survey for miners. This is shown on Figure 8.1 below.

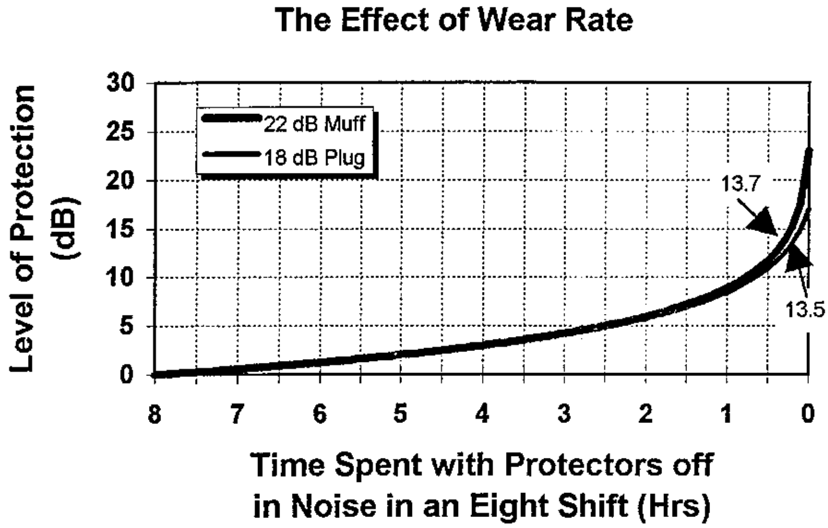

Figure 8.1 The effect of wear rate (ie time spent wearing hearing protection). This shows that a protector rated at 22 dB is reduced to only 13.7 dB if the protector is removed for 20 minutes in an 8 hour shift. The plug will give a similar performance reducing from 18 dB to only 13.5 dB if removed for only 12 minutes in an 8 hour shift.

It is therefore concluded that regardless of manufacturers or laboratory data on hearing protection performance the realistic protection is approximately 14 dB. Hence anyone exposed to over 99 dBA $L_{Aeq,8hr}$ average will be likely to be exposed to over 85 dBA even where hearing protection is supplied. Any employee exposed to average noise levels over 94 dBA $L_{Aeq, 8hr}$ (see section 3) is likely to be exposed to *'in-ear'* noise levels of over 80 dBA, even where hearing protection is supplied and worn for typical, realistic time periods.

To comply with the noise management plan for mines (ref 4) it must be assumed that manufacturers or laboratory data on hearing protection performance are not applicable and the maximum SLC_{80} that can be realised in practice for miners is 14. Hence personal choice and comfort far outweighs manufacturers theoretical performance data. Fortunately this is also recognised by the more astute and responsible manufacturers (see for example ref 11).

It is clear from the response to the questionnaire that training in noise hazard and the fitting of hearing protectors is either non-existence (or forgotten) or inadequate. It has been shown that detailed fitting instructions substantially (ie by 60% to 80 %) increases performance (sees section 7.1.2).

8.2 Recommended Further Action

- Reduce noise exposure from all sources to meet goals of 99 dB ($L_{Aeq,8hr}$) or less within two years and 94 dB within five years.

- Carry out detailed noise hazard training for all exposed employees within one year and update every three years. Detailed training will involve at least a four hour session by a noise accredited trainer as recommended by WorkCover, NSW (ref 12). This must include the importance of hearing protection wear rate, and the fitting of plugs as it is not intuitive.

- Offer a wider range of hearing protectors to all miners (a choice of three types of muffs and three types of plugs is recommended).

- Investigate the current technology available for combined muffs and safety spectacles suitable for miners.

- Repeat hearing protector tests for miners every three to four years to audit progress.

9. REFERENCES

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4. *Occupational Health and Safety Act* 1983, No 20 NSW Government Information Service.

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6. Mines Inspection Act (1901).

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9. *Acoustics - Hearing Protectors* - Australian Standard AS 1270: 1988.

10. *Attenuation of Hearing Protectors*, Seventh Edition - National Acoustic Laboratories, (1994).

11. *Attenuation and Protection,* - Berg G., - Proceedings of the 16th Annual Conference of the Australian Institute of Occupational Hygienists, December 1997.

12. Occupational Health and Safety Noise in the Workplace Trainer's Manual WorkCover, NSW (1997).

10. ACKNOWLEDGMENTS

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4) The Industrial Audiology Centre (Ross Woolven) who supplied the test chamber and carried out the audiological tests;

5) Last but not least the Joint Coal Board Health and Safety Trust for providing the funds to carry out this research.

Without all of the above people's interest and dedication to the improvement of health and safety in mines, this research could not have been carried out.

Quality Assurance

Wilkinson Murray Pty Limited is committed to and has implemented AS/NZS ISO 9001 : 1994 "Quality Systems - Model for quality assurance in design, development, production, installation and servicing". This management system has been externally certified and Certificate of Approval No 543 has been issued.

AAAC

This firm is a member firm of the Association of Australian Acoustical Consultants and the work here reported has been carried out in accordance with the terms of that membership.

Revision	Date	Status	Prepared by:	Checked by:
A	5 February 1998	Draft	Ken Scannell	Matt Harrison
B	22 July 1999	Final	Ken Scannell	David Luck

APPENDIX A – DETAILED RESULTS

This appendix provides the detailed results of the tests. This is divided into two sections, the first section covers plugs and the second section covers muffs.

A.1 Hearing Protector Performance

These tests are designed to provide 'spot checks' of the effectiveness of hearing protectors for mine workers and NOT statistical data as required by the Australian Standard AS 1270 (ref 9). The sound level conversion (SLC_{80}) is a statistical value intended to provide a theoretical performance of hearing protectors for 80% of the user population (in fact, a 3 dB lower performance can be obtained for typical low frequency noise exposures). This is not a meaningful value for 'spot check' results given in this report. However, the calculations have been carried out, and the SLC_{80} values are reported, simply to provide a single number for easy comparison with manufacturer's and laboratory data.

A.1.1 Plugs

A.1.1.1 *Protector Safety Model EP35*

Only one subject reported the use of Protector Safety Model EP35 plugs. Our tests showed a general agreement with the statistical results (from NAL ref 10) in all frequencies apart from 4 kHz and 6 kHz. At these frequencies our subject reported 10 dB to 15 dB less performance. Overall our subject rated the protector at 14 SLC_{80} compared to the 16 SLC_{80} given by NAL. The full results are shown in Figure A.1. below:-

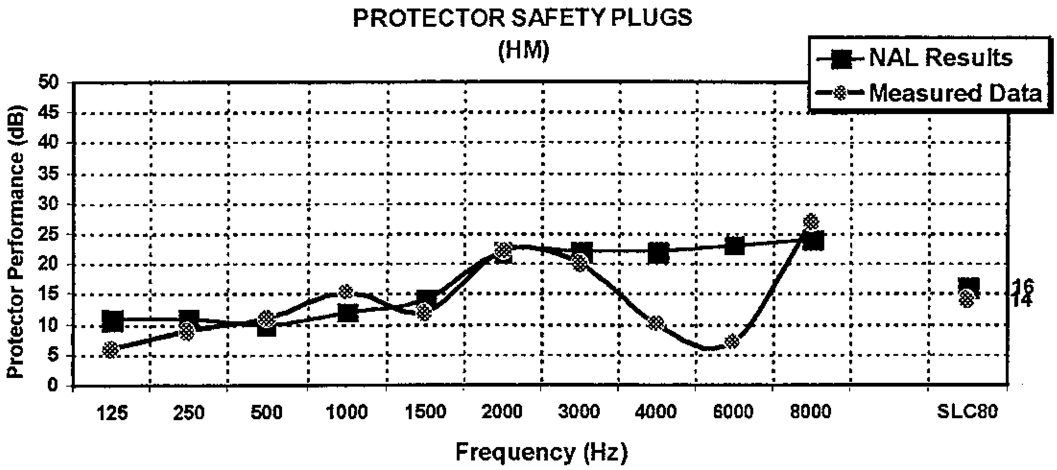

Figure A.1. Results for the one test using the Protector Safety EP35 Plugs.

A.1.1.2 *E.A.R Plugs*

Five subjects reported the use of EAR Model E-A-R plugs. The statistical results (from NAL ref 10) give a SLC_{80} of 22. Overall our subjects rated the protectors at 16, 18,19,19 and 21 SLC_{80}. This gives an average SLC_{80} of 18.4 compared to the 22 SLC_{80} given by NAL. However, in one case where brief fitting instructions were given this was increased to the NAL value of 22 (see Figure A.6). The full results are shown in Figures A.2 to A.6. below.

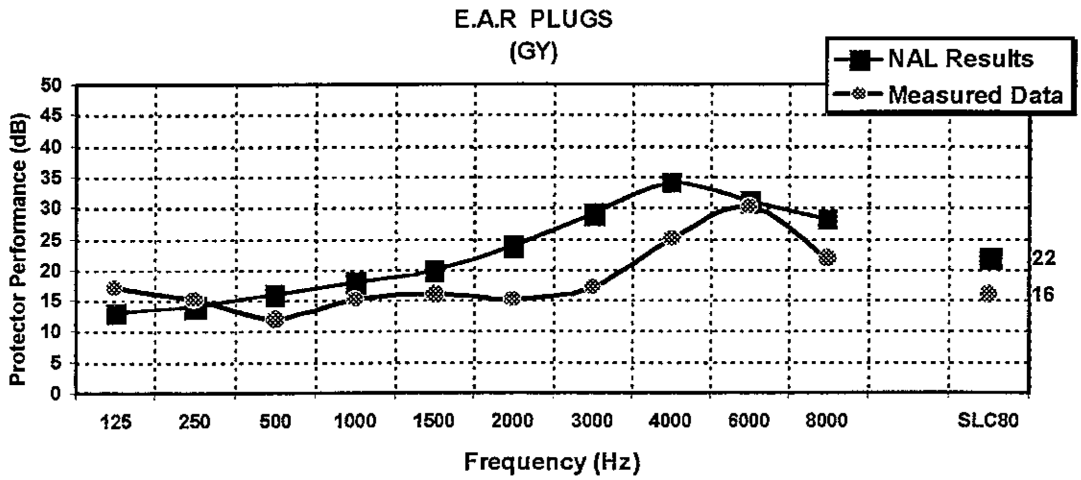

Figure A.2. Results for the one test using the E.A.R. Plugs.

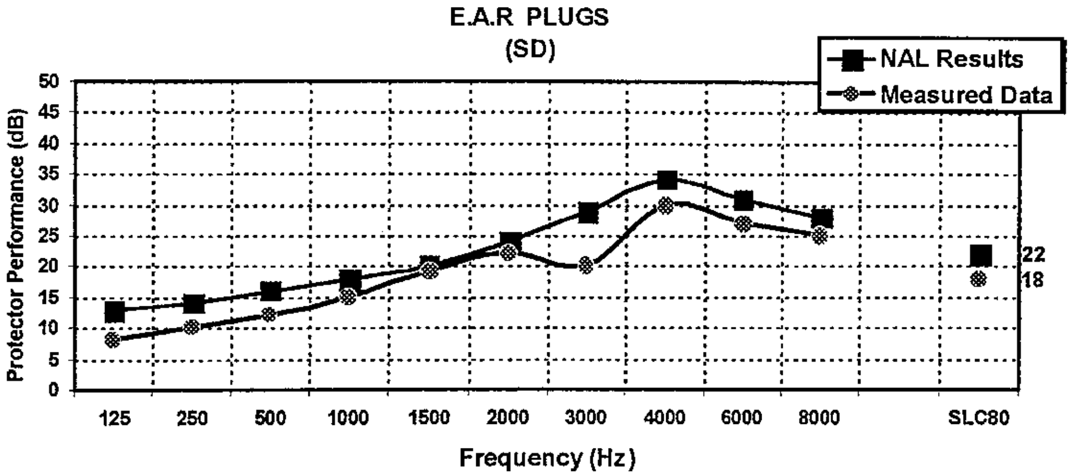

Figure A.3. Results for the one test using the E.A.R. Plugs.

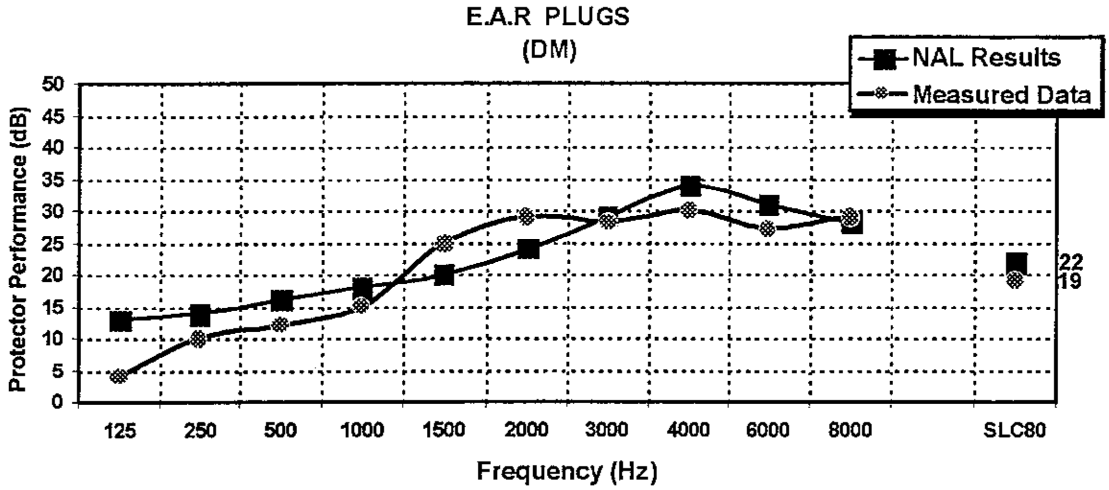

Figure A.4. Results for the one test using the E.A.R. Plugs.

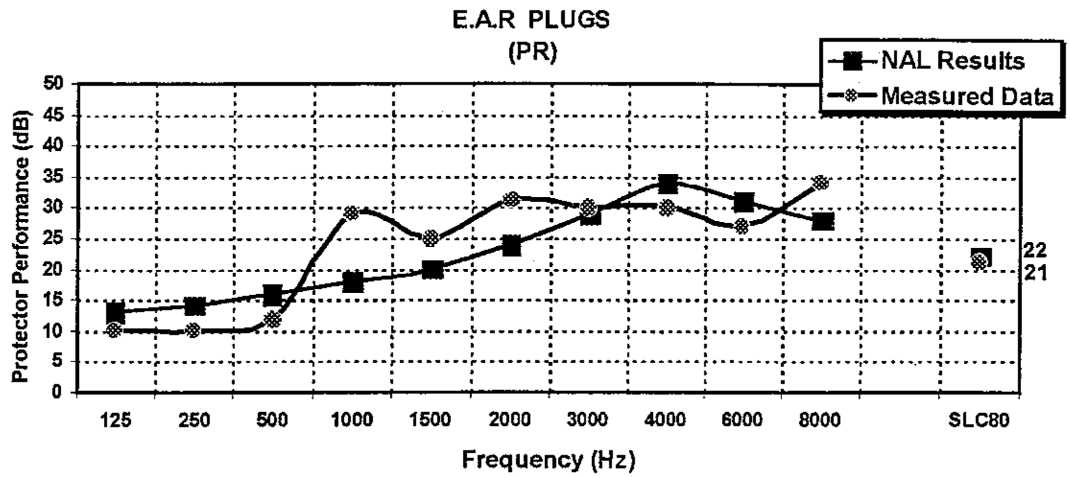

Figure A.5. Results for the one test using the E.A.R. Plugs.

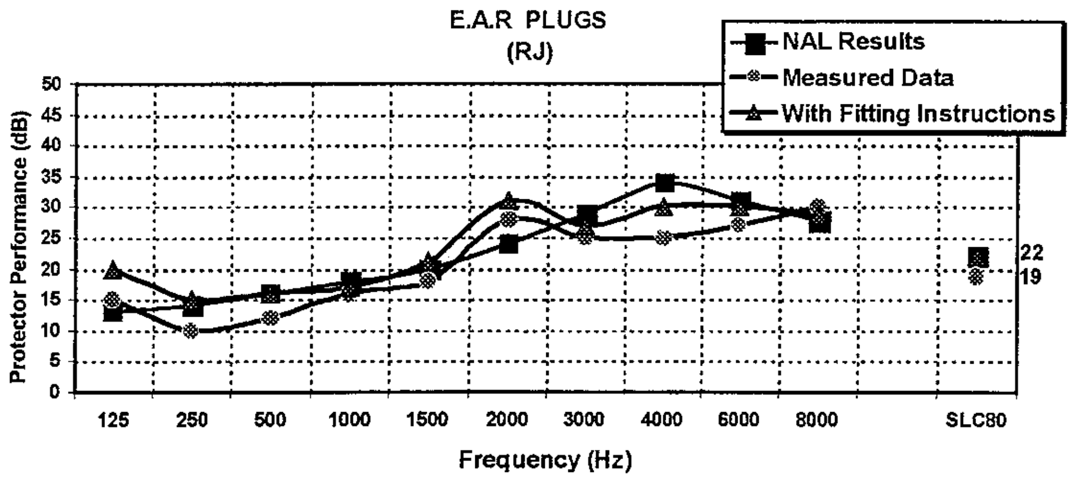

Figure A.6. Results for the one test using the E.A.R. Plugs. This also shows the effect of brief fitting instructions – raising the SLC_{80} from 19 to 22.

A.1.1.3 Bilsom Down 202 and Bilsom Soft Plugs

Two subjects reported the use of *Bilsom* model *'Down 202'* or *'Soft'* plugs. The statistical results (from Bilsom) give an SLC_{80} of 24. Overall our subjects rated the protectors at 14 and 19. This gives an average SLC_{80} of 16.5 compared to the 24 SLC_{80} given by Bilsom. However with brief fitting instructions the rated values were increased to 22 and 24 giving an average of 23 only 1 dB less that the Bilsom data. The full results are shown in Figures A.7 and A.8 below:-

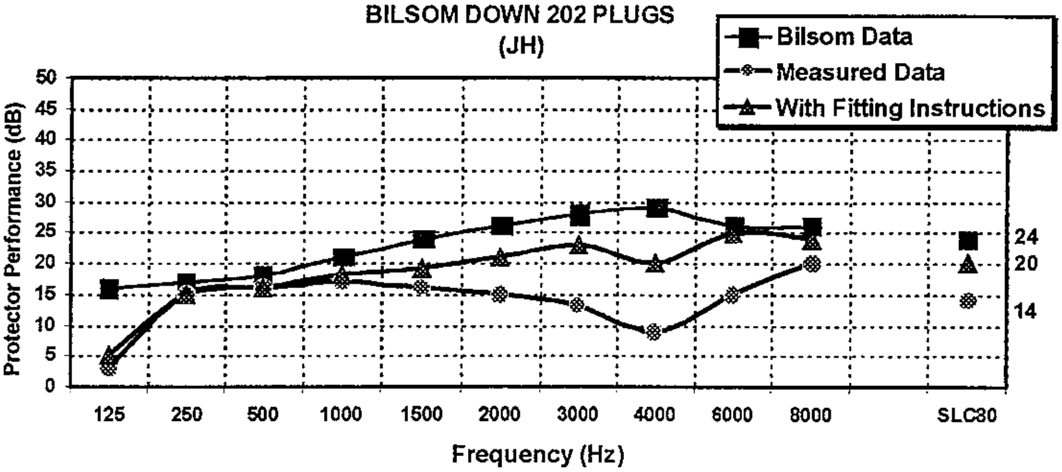

Figure A.7. Results for the one test using the E.A.R. Plugs. This also shows the effect of brief fitting instructions – raising the SLC_{80} from 14 to 20.

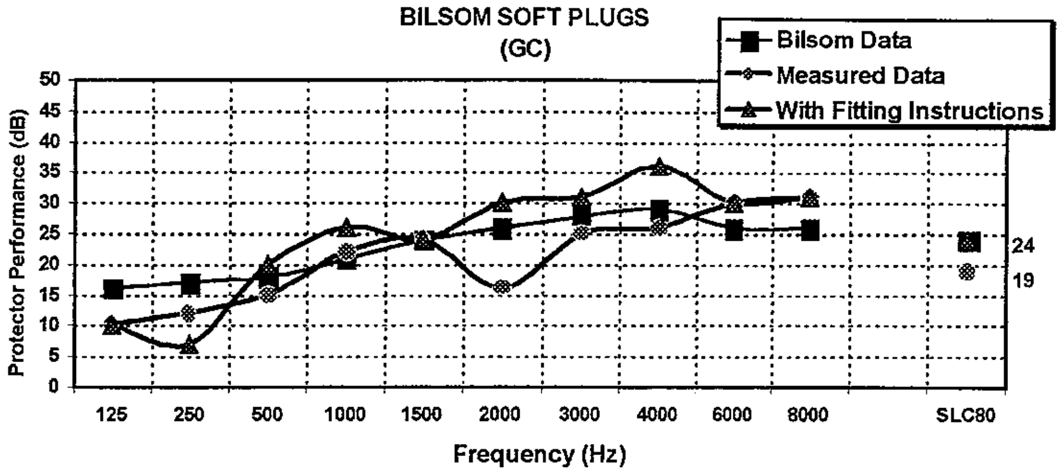

Figure A.8. Results for the one test using the E.A.R. Plugs. This also shows the effect of brief fitting instructions – raising the SLC_{80} from 19 to 24.

A.1.1.4 Howard Leight Airsoft SNR 30 Plugs

Only one subject reported the use of Howard Leight Airsoft SNR 30 Plugs. Overall our subject rated the protector at 19 SLC_{80} compared to the 25 SLC_{80} given by the manufacturers. However with brief fitting instructions this was increased to 25. The full results are shown in Figure A.9 below:-

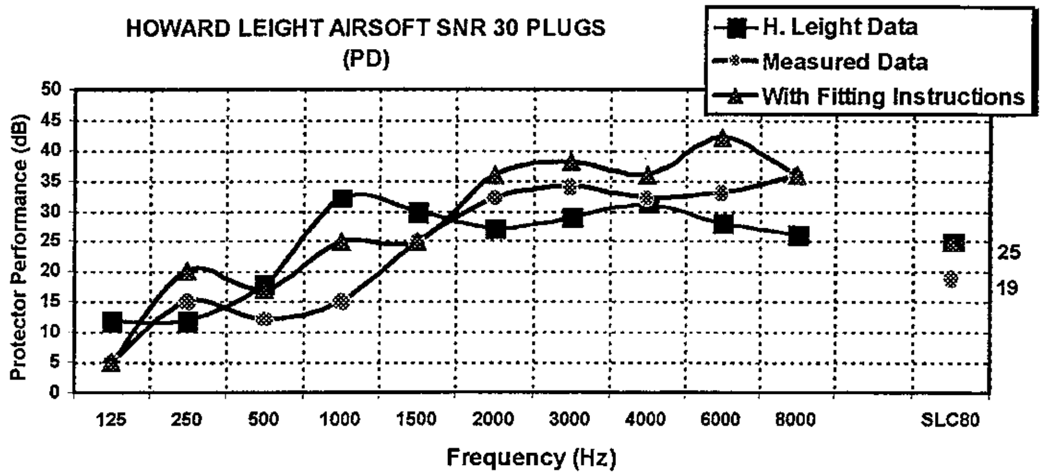

Figure A.9. Results for the one test using the Howard Leight. Plugs. This also shows the effect of brief fitting instructions – raising the SLC_{80} from 19 to 25.

A.2.1 Muffs

A.2.1.1 Peltor H7 Muffs

Three subjects reported the use of Peltor H7 Muffs. These muffs provide a very high theoretical performance with a 30 SLC_{80} given by the manufacturers. However, our subjects rated the protectors at 23 or 24 SLC_{80} with an average of just under 24. The SLC_{80} was only slightly less when safety spectacles are used (see Figure A.12) but the level of protection was reduced by approximately 5 dB in the important frequency range 1.5 kHz to 4 kHz. The full results are shown in Figures A.10 to A.12 below:-

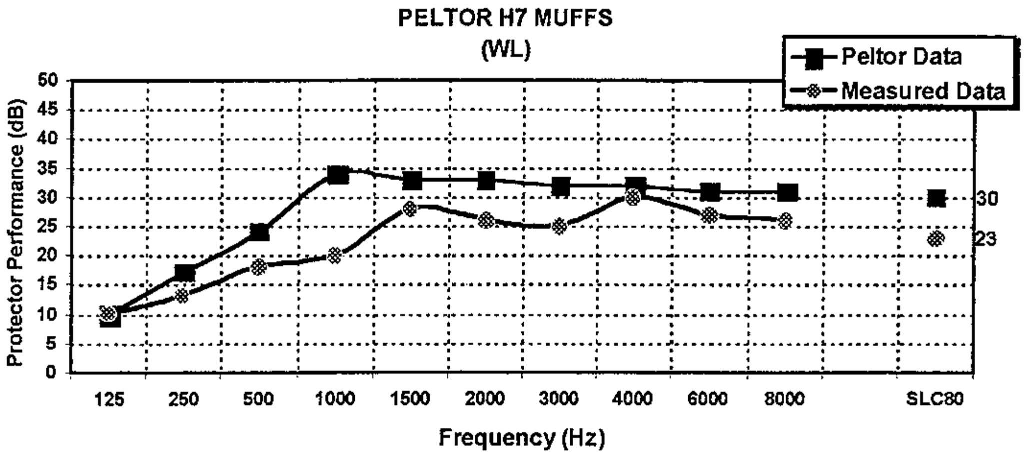

Figure A.10. Results for the one test using the Peltor H7 Muffs.

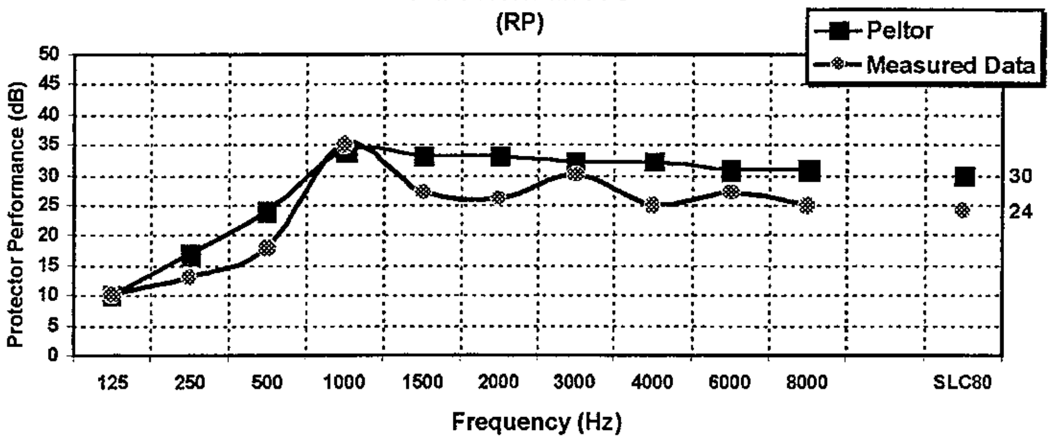

Figure A.11. Results for the one test using the Peltor H7 Muffs.

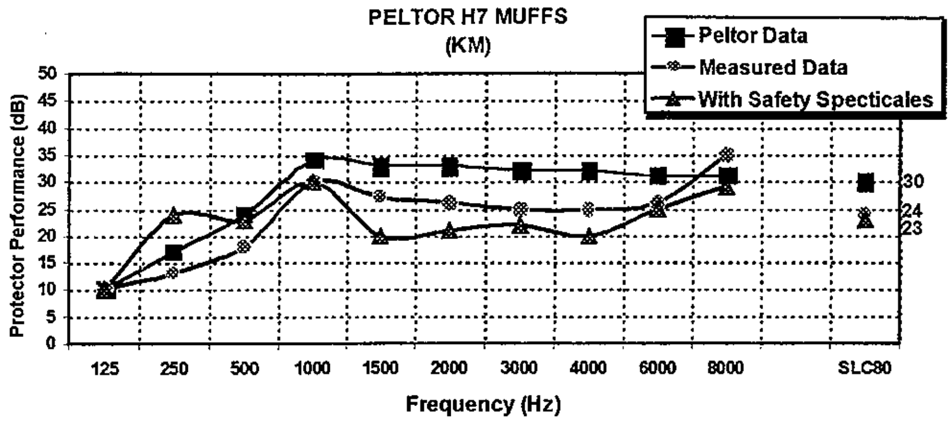

Figure A.12. Results for the one test using the Peltor H7 Muffs. This shows the effects of safety spectacles reducing the SLC80 by only 1 dB but giving approximately 5 dB less protection in the important frequency range of 1.5 kHz to 4 kHz.

A.2.1.2 Peltor H7P3E Helmet Mounted Muffs

Five subjects reported the use of Peltor H7P3E helmet mounted muffs. Our subjects rated the protectors at 20, 22, 22, 23 and 25 giving an average of 22.4 SLC_{80} compared to the 24 SLC_{80} given by the manufacturers. In these tests, a reduction in performance of 2 dB was found compared with non-helmet mounted. The full results are shown in Figures A.13 to A.17 below. It is interesting to note that this section contains the one and only subject to report a performance better that the manufacturers data (see Figure A.16).

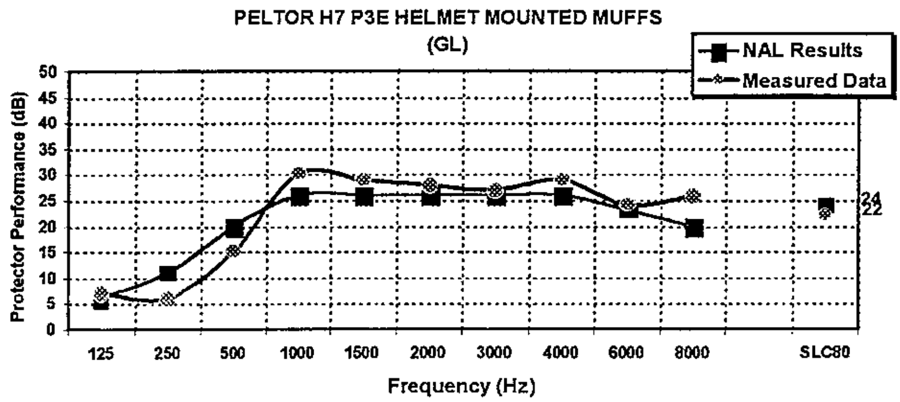

Figure A.13. Results for the one test using the Peltor H7P3E Helmet Mounted Muffs.

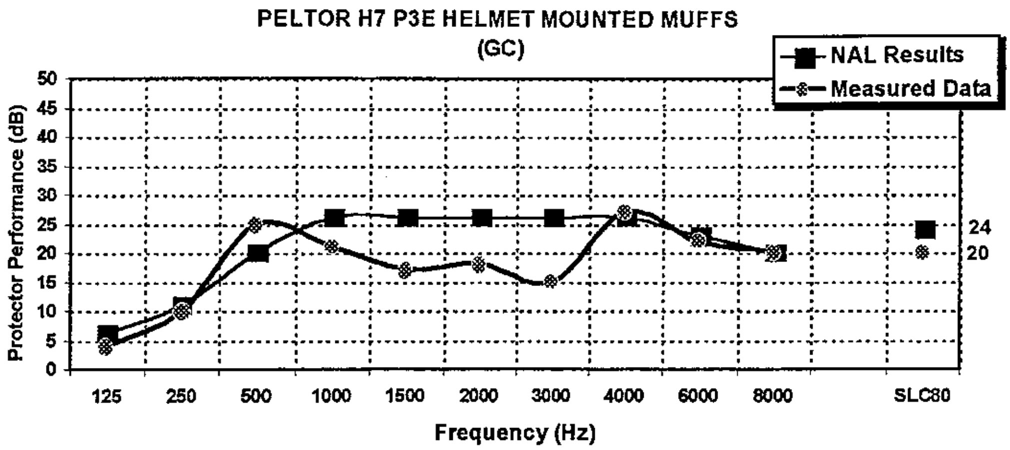

Figure A.14. Results for the one test using the Peltor H7P3E Helmet Mounted Muffs.

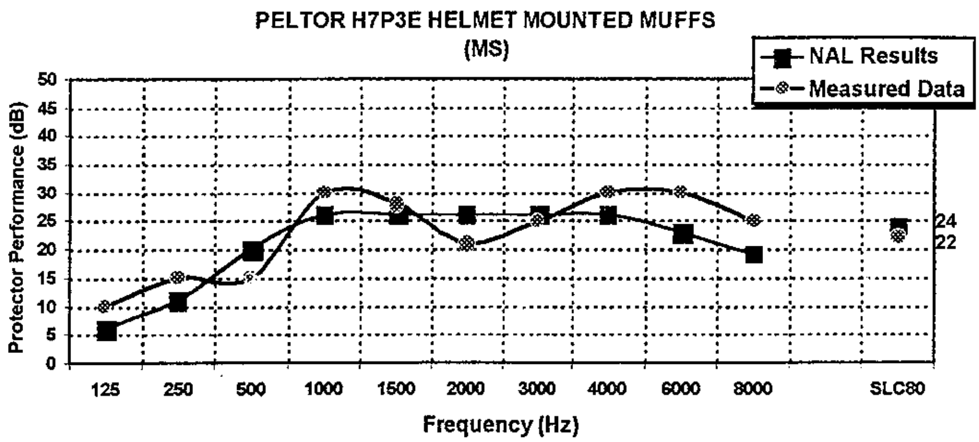

Figure A.15. Results for the one test using the Peltor H7P3E Helmet Mounted Muffs.

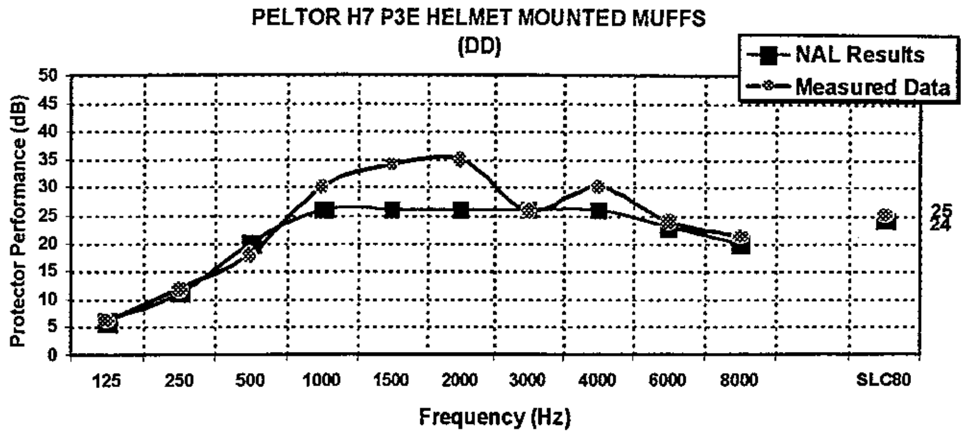

Figure A.16. Results for the one test using the Peltor H7P3E Helmet Mounted Muffs. This is the only result in these tests where a subject reported a better performance than the manufacturers' data.

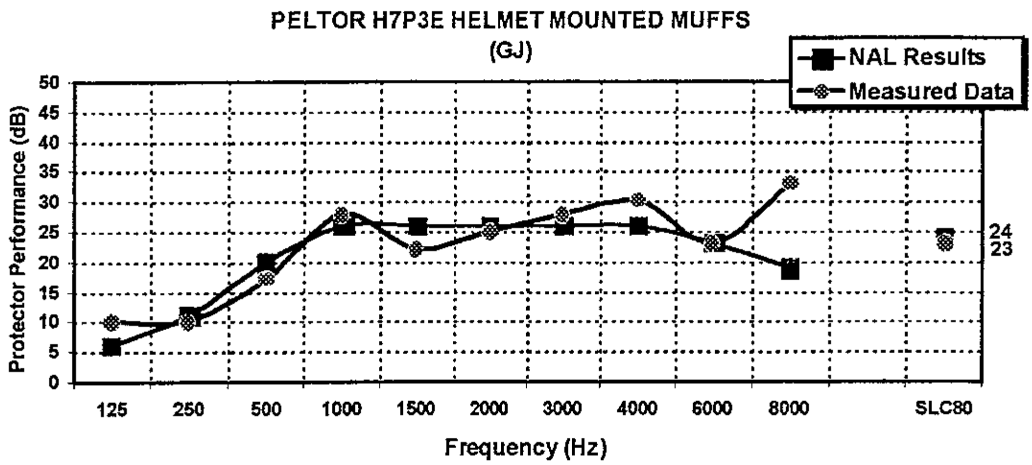

Figure A.17. Results for the one test using the Peltor H7P3E Helmet Mounted Muffs.

A.2.1.3 Peltor H9 Muffs

Three subjects reported the use of Peltor H9 muffs. (These are lighter weight muffs than the H7's). Our subjects rated the protectors at 17, 21 and 22 giving an average of 20 SLC_{80} compared to the 24 SLC_{80} given by the manufacturers. The full results are shown in Figures A.18 to A.20 below.

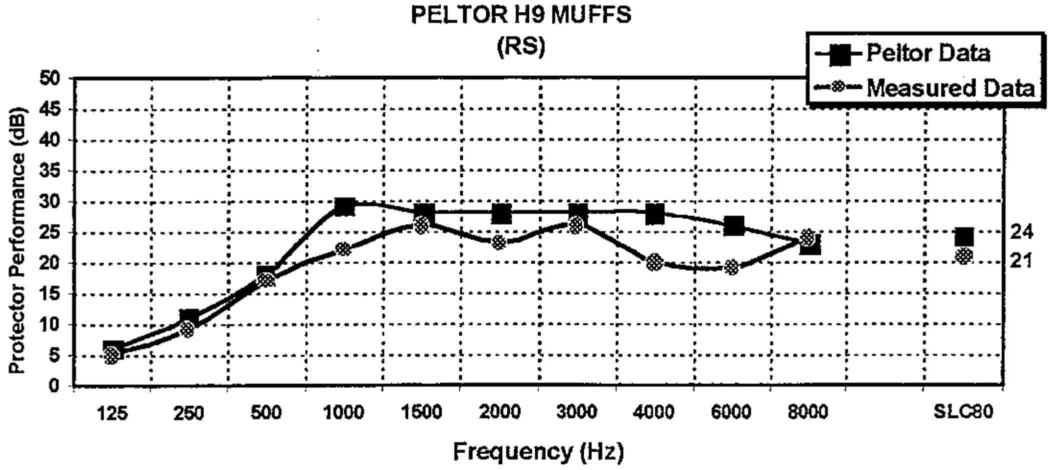

Figure A.18. Results for one test using the Peltor H9 Muffs.

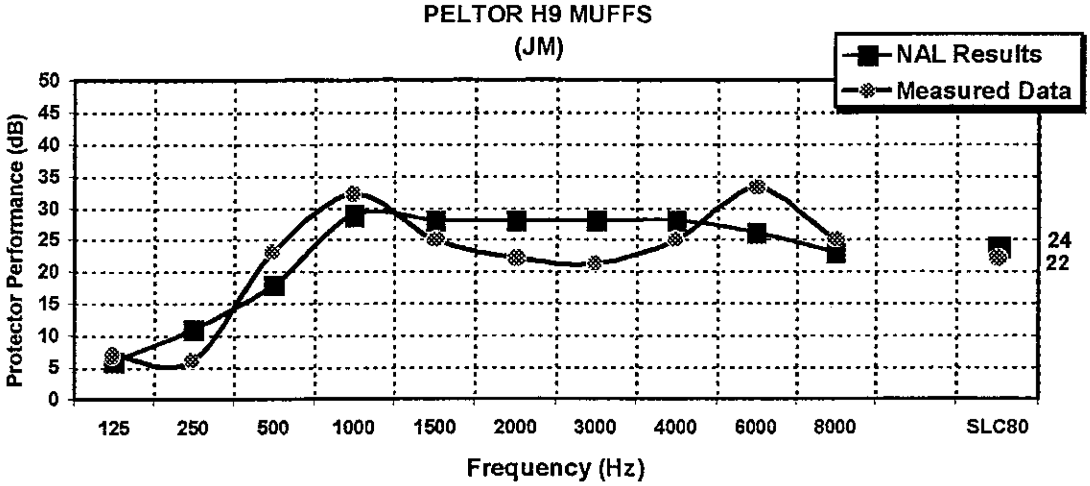

Figure A.19. Results for one test using the Peltor H9 Muffs.

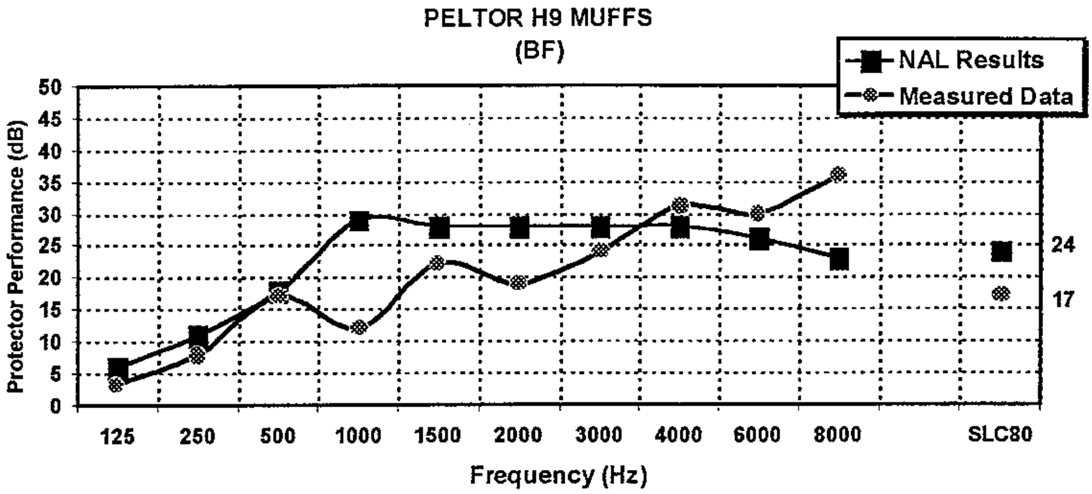

Figure A.20. Results for one test using the Peltor H9 Muffs.

A.2.1.4 Peltor H9P3 Helmet Mounted Muffs

Only one subject reported the use of Peltor H9P3 helmet mounted muffs. These muffs were old with cracked seals; this resulted in a poor performance in the important frequency range of 3 kHz to 8 kHz. At these frequencies our subject rated the protectors at 5 dB to 10 dB lower that the manufacturers data. Overall our subject rated the protector at 17 SLC_{80} compared to the 20 SLC_{80} given by the manufacturers. When the subject wore safety spectacles in addition to the helmet mounted muffs (as he normally does) the performance dropped to 15 SLC_{80} as shown in Figure A.21 below.

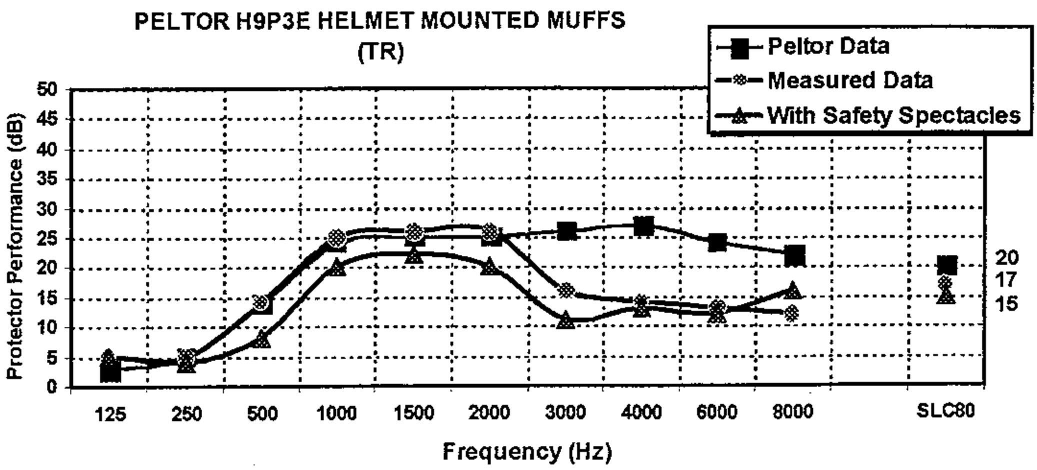

Figure A.21. Results for the one test using the Peltor H9PE3 Muffs.

A.2.1.5 Hellberg 26006 Helmet Mounted Muffs

Three subjects reported the use of Hellberg 26006 helmet mounted muffs. The SLC_{80} results were 17, 22 and 23 giving an average of 21.7 compared to the 25 SLC_{80} given by the manufacturers. In two cases (see Figures A.23 and A.24) the effect of combined muffs and safety spectacles were assessed. In each case the showed a further reduction in SLC_{80} by a value of 3. The full results are shown in Figures A.22 to A.24 below.

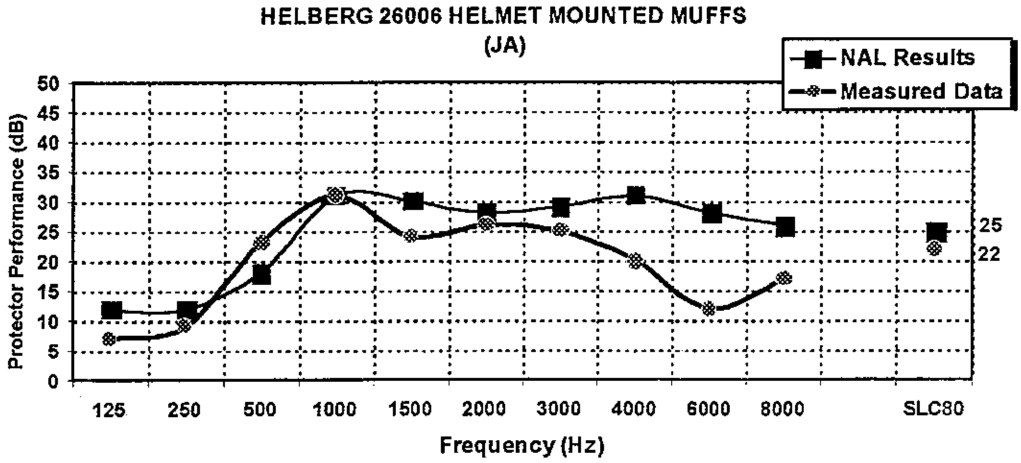

Figure A.22. Results for one test using the Hellberg 26006 Muffs.

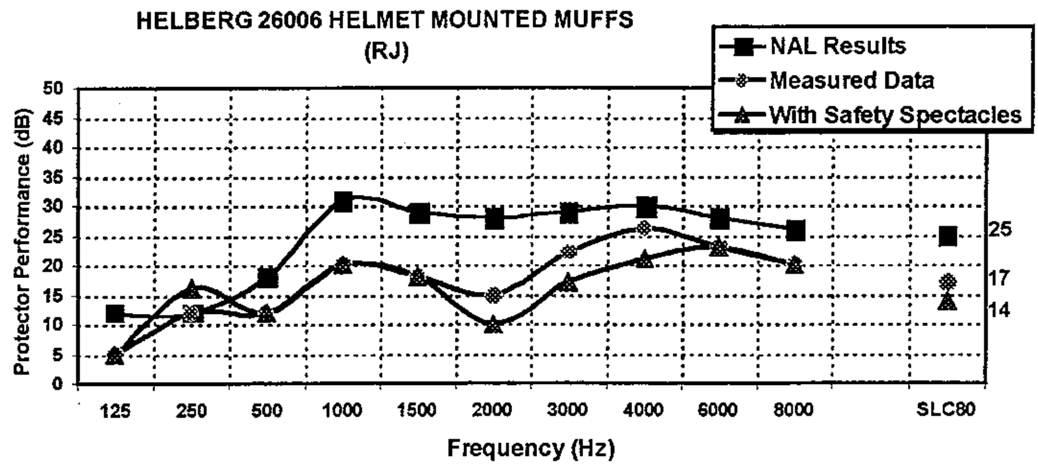

Figure A.23. Results for one test using the Hellberg 26006 Muffs with and without the addition of safety spectacles.

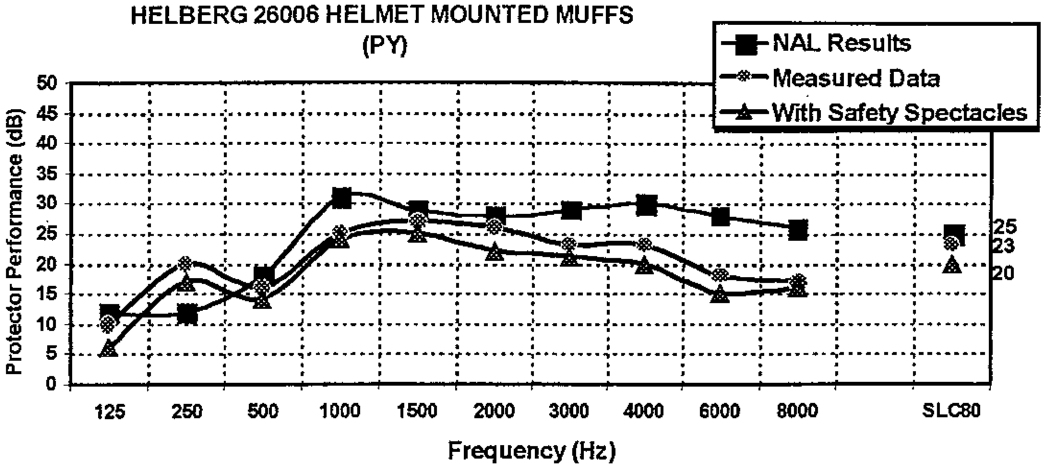

Figure A.24. Results for one test using the Hellberg 26006 Muffs with and without the addition of safety spectacles.

A.2.1.6 Bilsom 728 Helmet Mounted Muffs

Only one subject reported the use of Bilsom 728 helmet mounted muffs. The SLC_{80} result was 26 compared to the 30 SLC_{80} given by the manufacturers. In addition the effect of combined muffs and safety spectacles were assessed. This showed a further reduction in SLC_{80} by a value of 1, however the reduction was 5 dBA in the 2 kHz, 3 kHz and 6 kHz frequencies. The full results are shown in Figure A.25 below.

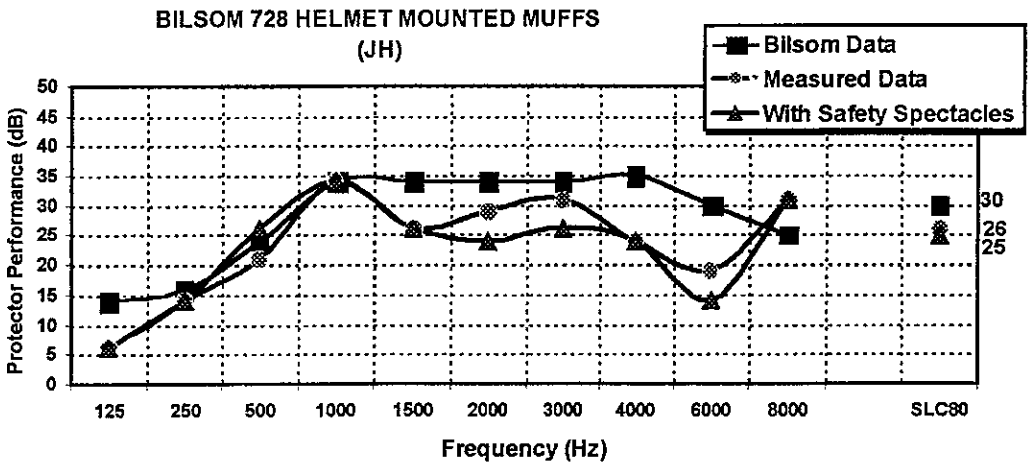

Figure A.25. Results for one test using the Bilsom 728 Muffs with and without the addition of safety spectacles.

A.2.1.7 Combined Muffs and Plugs

Two subjects who reported the use of both muffs and plugs were tested with muffs alone, plugs alone and the combination of muffs and plugs together. It is well known that the individual performance of the muffs and plugs cannot be added either arithmetically (overestimates) or logarithmically (underestimates). In these test SLC_{80} of 33 and 36 were found for a combination of Hellberg 26006 helmet mounted muffs with Bilsom down lugs and Peltor H7 muffs with E.A.R. plugs respectively. It is unknown if these combinations have been tested statistically, however seven combinations have been tested at NAL (ref 10) where typical SLC_{80}'s of 34 were found. The full results are shown in Figures A.26 to A.27 below.

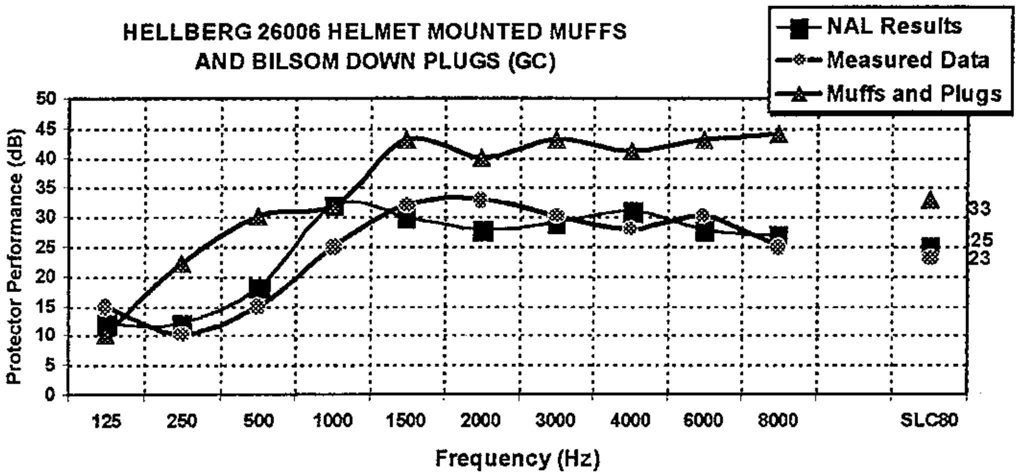

Figure A.26. Results for one test a combination of Hellberg 266006 Muffs and Bilsom Down Plugs.

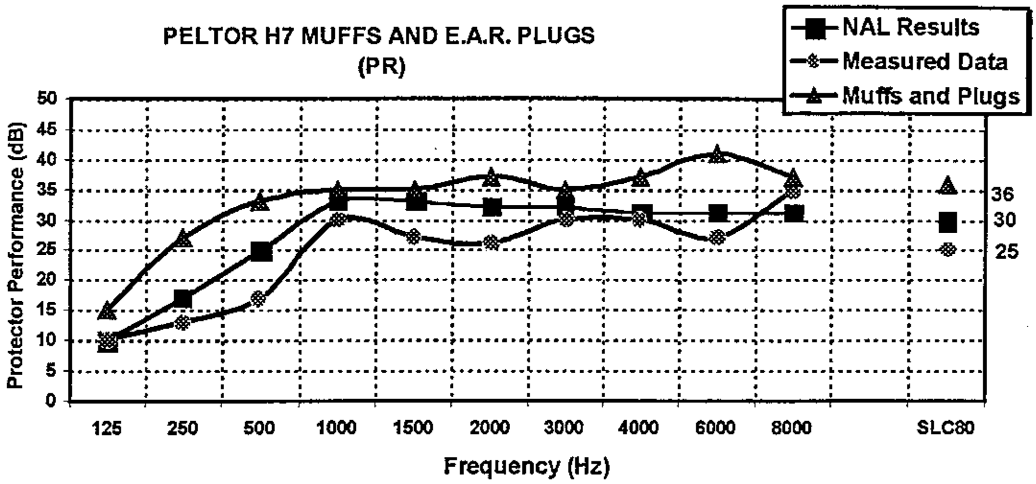

Figure A.27. Results for one test a combination of Peltor H7 Muffs and E.A.R. Plugs.