Occuptional Noise-Induced Hearing Loss

- A Survey

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ABSTRACT

A survey of twelve Christchurch entreprises known to have noisy working conditions involved interviews with health nurses or management responsible for occupational safety, as well as a sample of employees in each enterprise. The survey assessed the level of knowledge in both groups of various aspects of noise-induced hearing loss ("industrial deafness"), and looked at how well preventative measures taken in each enterprise met the known requirements of a hearing conservation programme. The presence of an occupational health nurse, the level of employee knowledge and the reported usage of hearing protectors were all statistically related to a range of variables considered a priori to have explanatory significance. Reasons for the current level of awareness and practical preventative interest were discussed, and suggestions for more effective prevention made.

INTRODUCTION

Industrial deafness, that is, permanent hearing loss caused by excessive noise exposure during the course of ones employment, constitutes a serious occupational hazard. Indeed, the condition is a highly prevalent, though little recognised "industrial disease".

By taking a sample of Christchurch industries, this thesis attempts to:

1) assess the degree of knowledge amongst workers at the various levels of industry, of the effects of noise on hearing,

2) to assess the extent to which hearing conservation programs have been implemented, and

3) to extract conclusions of practical significance from the data obtained.

This introductory chapter is divided into three parts. Firstly, scientific knowledge, and terminology relevant to industrial deafness is examined, with a view to specifying significant risk factors. Secondly, the law as it relates to maximum levels of occupational noise exposure is described, and its provisions contrasted with evidence derived from scientific research, and finally, the current position as regards compensation of sufferers is described.

This thesis adopts an ergonomic perspective in examining noise in occupational settings. According to McCormick (1976), the central approach in ergonomics is "... the systematic application of relevant information about human characteristics and behaviour to the design of man-made objects, facilities and environments that people use". In this context, the inability of the human hearing mechanism to withstand high levels of noise, without permanent damage, places constraints on the working environment.

1. Scientific Knowledge Concerning the Effects of Noise on Hearing

a) Quantifying Auditory Acuity

Before considering the effects of noise on hearing, it is necessary to describe how hearing loss is assessed. The range of frequencies (the physical correlate of pitch) to which the normal ear is sensitive is approximately 20 - 20,000 Hertz. The level of audiability depends heavily upon frequency and has received international standardization (I.S.O., 1964). For the purposes of this thesis, preserving the ability to understand speech is considered of primary importance; namely being able to detect and discriminate those sounds with frequencies between 300 and 4000 Hz. This is not however to deny the importance of being able to sense sounds of frequencies greater than 4 kHz, or for that matter, less than 300 Hz. Any music or "hi-fi" enthusiast will readily verify this.

For most purposes, hearing acuity is measured by pure-tone air-conduction audiometry. By presenting a discrete range of tones, of known frequency and intensity through headphones, it is possible to obtain an accurate assessment of hearing sensitivity for both ears. The frequencies usually selected for testing are 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz, although certain frequencies at either extreme may be omitted, depending on the purposes of the test. The "hearing level" or, more correctly, "hearing loss", for a given frequency, is defined as the difference in decibels between the maximum intensity necessary for detection (usually 50% detection), minus the minimum intensity detected by otologically - normal young (20 year reference group) persons.

i.e. Hearing Level = Subject's Threshold - Reference Threshold.

Thus pure-tone audiometry involves examining, for each ear in turn, sensitivity for sample frequencies within the range most closely involved in speech.

b) Defining the Onset of Impairment

The relationship between pure-tone audiograms and ability to understand speech communications is not as simple as might first be though - gross sensation does not necessarily equate with perception, particularly in noisy listening conditions.

A common practice in assessing hearing is to average hearing loss over a specified set of speech-related frequencies. Most frequently used is the average hearing level at 500, 1000 and 2000 Hz, although an alternate set of frequencies sometimes adopted is 1000, 2000 and 3000 Hz. There is some evidence that this latter set is a more valid index of impairment (Kryter 1973,

p. 1211) especially in relation to noise-induced losses, e.g. Harris 1965 p. 826.

Considerable debate has taken place over the last 20 years as to what average hearing level or "fence", constitutes the onset of impairment (e.g. see Kryter 1973, p. 1211) with medico-legal compromises often over-riding objective evidence.

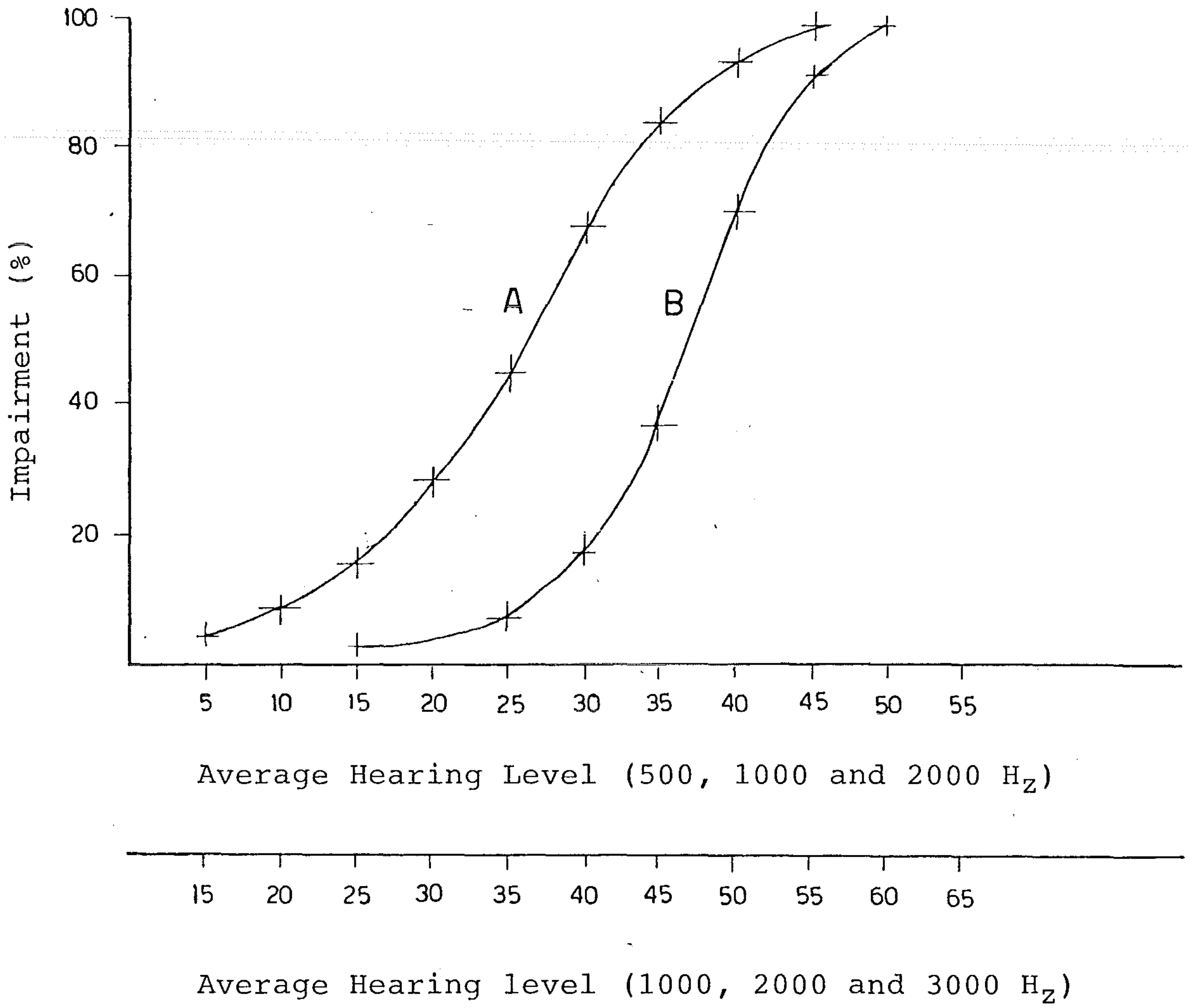
Kryter (1973), an acknowledged expert in the field, suggests that "... a practical criterion for application to workers in industry is that the start to impairment of hearing speech in the work-a-day world is said to occur when the listener would be just able to understand all simple, unrehearsed sentences when presented to him in the quiet at an average intensity level at the listener's position of about 65 dB(SPL), i.e., speech at an "everyday level" (Kryter 1973, p. 1214). This level is 10 dB greater (approximately twice as "loud") than the level used by the average person when conversing in the quiet at a distance of one metre.

This criterion, according to Kryter, corresponds to an average hearing level of 15 dB at 500, 1000 and 2000 Hz, or equivalently, 25 dB at 1000, 2000 and 3000 Hz (see Figure 1).

Figure 1

Relationship Between Hearing Level and

Impairment of Speech Reception in Quiet



A. Phonetically-balanced words at a weak conversational level (50 dB).

B. Sentences at normal conversational level (55 dB)

- speech level measured in free field 1 meter from speaker
- adapted from Kryter (1973)

Even at this level, a person would have far from normal hearing. They would miss 2% of sentences in a quiet conversation and 15% of monosyllabic phonetically-balanced words at a weak level of production effort. Perhaps more importantly, Kryter fails to mention that their understanding of speech in the presence of any competing background noise would be severely affected (see Hodge and Price, 1978, p. 183).

This suggested criterion (average) hearing level is considerably more conservative than many officially-recognised "fences", e.g. the New Zealand noise exposure legislation attempts to prevent persons suffering a hearing loss of greater than 25 dB averaged over 500, 1000 and 2000 Hz (c/f Kryter's 15 dB). However, an equivalent fence to Kryter's suggested cutoff-level (15 dB @ 500, 1000 and 2000 Hz) has recently been adopted by the American National Institute of Occupational Safety and Health (N.I.O.S.H), i.e. 25 dB @ 1000, 2000 and 3000 Hz.

c) Noise Induced Hearing Loss - The Condition

The actual mechanism of impairment of hearing by noise is not yet well understood, although the condition has been recognised for centuries, and in recent times has often been described as "Boilermaker's Disease". It should be noted there are wide individual differences in the effects of given noise exposures, both in the short and long term.

Temporary hearing loss from noise, or more correctly, "noise-induced temporary threshold shift" (TTS), lasting from seconds to several weeks, may be induced by brief exposure to high levels of noise, or from sustained exposure to more moderate levels.

Continued exposure to such levels (often found in certain occupational settings) will, after sufficient time, result in a permanent sensorineural hearing loss, i.e. "<u>noise-induced permanent threshold shift</u>" (N.I.P.T.S). N.I.P.T.S. is defined as "... that part of hearing level ascribable to noise exposure, as opposed to other factors, such as ageing, which also cause an elevation of threshold" (EPA, 1979, p 2). Separating noise damage from other potential aetiological factors is not as simple as this statement might appear to imply. For example, age-related hearing loss, or "presbycusis", cannot be considered as basically additive to noise-induced damage (e.g. EPA, 1979, p 43).

Noise-induced hearing damage, has been shown, from studies on man and other animals (e.g. Bohne, 1976), to be localized primarily in the Organ of Corti, part of the "inner ear". Noise of sufficient intensity and duration irreparably damages the sensory hair cells of that organ and their associated supporting structures.

There is some speculation that there are differences in the damage mechanism for different types of noise. Brüel (1977), for example, suggests, from available evidence, that damage from continuous noise can be characterised as a "... fatigue phenomenon, whereas damage from high energy impulse sound is effected by instantaneous rupture of the fine hair cells in the Organ of Corti" (1977, p 6).

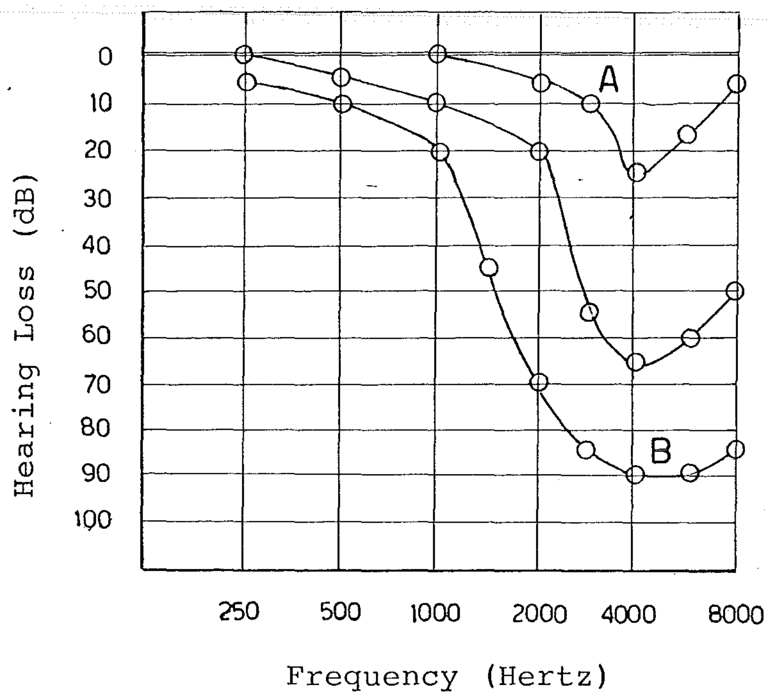
Persons experiencing temporary threshold shifts often fail to realize that permanent damage is occurring, as the onset of notable damage may require years of exposure, and in many cases is falsely attributed to normal drop-off in hearing with age.

There is good evidence, on a <u>population</u> basis, that TTS at 2 minutes after the onset of a noise (TTS_2) will translate to a permanent threshold shift of about the same magnitude after 10 years of working exposure to that same level of noise (Kryter, 1966). TTS_2 might appear to have potential value as a predictive tool in determining individual susceptibility to N.I.P.T.S. However, it turns out not to be predictive on an individual basis (Ward et al, 1958) for a variety of reasons including in particular the degree of existing damage (Miller et al, 1972).

A characteristic audiogram is associated with N.I.P.T.S. Typically a "notch" appears in the audiogram centred between 3000 and 6000 Hz, with the lower frequencies being unaffected. As additional damage occurs, the notch widens and deepens, progressively reducing acuity at lower/mid-range frequencies and thus causing severe impairment (see figure 2).

Figure 2

Classical Audiometric Pattern of Progressive Noise-Induced Hearing Loss



A. Loss in early stages, e.g. after 5 years exposure

B. Severe degree of loss, e.g. after 30 years exposure

Unlike certain conductive disorders of the hearing mechanism, N.I.P.T.S. is irreversible and not amendable to any presently-known treatment. Noise-induced hearing loss is the physiological analogue of low pass filtering in electronics, and, because of the nature of speech coding, results in much vital information being lost.

d) <u>Problems Specific to Noise-Induced Hearing Loss</u>

Noise-induced deafness is far more debilitating than might be inferred from the audiogram. One apparently mystifying aspect of noise-induced hearing loss, from the point of view of its sufferers, is their inability to understand speech in <u>any</u> competing background noise, despite the fact they may function reasonably well in quiet conditions (see Dickman 1974). Speech is "loud enough", but not at all intelligible.

This phenomenon is relatively easily explained. Background noise, almost invariably, has most of its spectral energy in the low frequencies. Hearing in background noise relies to a large extent on higher frequency information, and this helps explain why normal-hearing persons are able to understand speech when its level may be up to 10 dB less than the overall ambient noise. Thus if a person's high-frequency hearing is impaired, they will have considerable problems functioning in background noise.

Significant problems of this nature are often seen in clinical practice even when thresholds up to 2000 Hz are well within normal limits. This is further justification for the apparently conservative "low fence" adopted for defining the onset of significant loss (see section I, b).

Secondly, a condition often found in conjunction with noise-induced hearing loss is tinnitus, an auditory sensation without a corresponding external stimulus and frequently described as "ringing in the ears". Tinnitus varies widely between individuals on all four parameters - pitch, type of noise, loudness and frequency of occurrence. At best, it may be a very soft tone that is noticeable only in quiet conditions, while at the other extreme, the tinnitus may be present continuously and of such loudness as to interfere with speech reception. Severe tinnitus not only affects speech perception and sleep, but may even produce suicidal attempts (Macfarlan, 1947). Management of tinnitus whether medical, audiological and psychological, is very often quite unsuccessful.

The third and perhaps most important aspect of noise-induced hearing loss is that, while a significant cause of hearing loss, it is often the one with the least favourable prognosis as far as successfully fitting a hearing aid is concerned (Webster 1978 p 217). Despite significant recent advances in the electro-acoustic performance of hearing aids, it is still not possible to accurately tailor the performance characteristics of an aid to most noise-induced losses. The basis of this problem is the extremely sudden and severe drop in sensitivity at one point in the audiogram. It is not uncommon to have thresholds of 20 dB at 1000 H_Z, and 70 dB Hearing Loss at 2000 H_Z, i.e. a drop from relatively normal hearing, to a severe loss. This amounts to a difference of 10^5 in terms of intensity (see EPA 1973, App 5.5). While it is possible to get aids whose required filtering approximates the slope of this dropoff, providing amplified sound at frequencies which are severely impaired may produce loudness tolerance problems, or have limited benefit due to distortion from the extent of sensory cell destruction.

While it is possible to circumvent some problems if the loss is mild, any loss with thresholds worse than 50 dBHL in the 2000 - 4000 H_z region will, for a variety of reasons, cause real problems.

Another problem with the application of hearing aids to advanced noise-induced losses is that hearing aids are not capable of distinquishing between (wanted) speech and (unwanted) background noise. This results in reduced discrimination and wearer comfort in noisy situations - exactly those where improvements are most needed. Thus for a variety of reasons, noise-induced hearing loss presents considerable and often insurmountably problems to its sufferers, and to clinicians attempting to alleviate problems arising from it.

e) Determination of Risk to Hearing

Having earlier defined a "low fence" for the onset of impairment, it now remains to specify a level of noise exposure that will limit damage to hearing from noise, to this level, after a lifetime's exposure in a work situation.

Extensive research in the last fifteen years has been aimed at the prediction of hearing damage from given noise exposures. This is no simple task; age, noise, ototoxic drugs and various disease processes all exert their influence on hearing, and this, combined with problems in accurate noise measurement and the determination of exposure histories, makes the task of prediction extremely complex.

A convention widely adopted in quantifying noise exposures is to assign to them a single "equivalent continuous level" (L_{eq}) - an A-weighted (see appendix 1) sound level (8 hours/day, 5 days/week exposure) assumed to be equivalent in risk to the noise exposure in question. Thus, for continuous noise, or intermittent noise of a relatively stable nature while present, it is possible to derive an L_{eq} (EPA Document, 1973, Appendix 8).

This is made possible by adopting the "equal-energy hypothesis" which argues, with good empirical support, that the hazard to hearing is determined by the total sound energy (intensity X exposure duration) to which the ear is exposed. This hypothesis specifies an "integration rule" which allows a 3 dB increase (decrease) for every halving (doubling) of the exposure time, either side of the daily eight hour (standard) exposure time. It must be noted at this point that the "equal energy" rule can be applied safely only to relatively continuous noise (see section I[f]).

There are several advantages in using an A-weighted sound level. It is generally a reliable predictor of noise hazard in most practical situations (low frequency noise is an exception); it is convenient in as far as all basic sound level meters include an A-weighting network and finally, A-weighted measurements are readily converted to certain other noise rating system, e.g. I.S.O. Noise Rating (NR) Contours.

Having provided a useful quantitative index of noise exposure and a cutoff level for hearing impairment, only two more variables need be specified before a "safe" level of noise exposure can be chosen.

Firstly, because of wide individual differences in susceptibility to N.I.P.T.S., it is impossible in practice to protect every person from significant noise-induced hearing loss. A reasonable compromise is to attempt to protect 90% of the (occupationally) noise-exposed population. To protect those remaining 10%

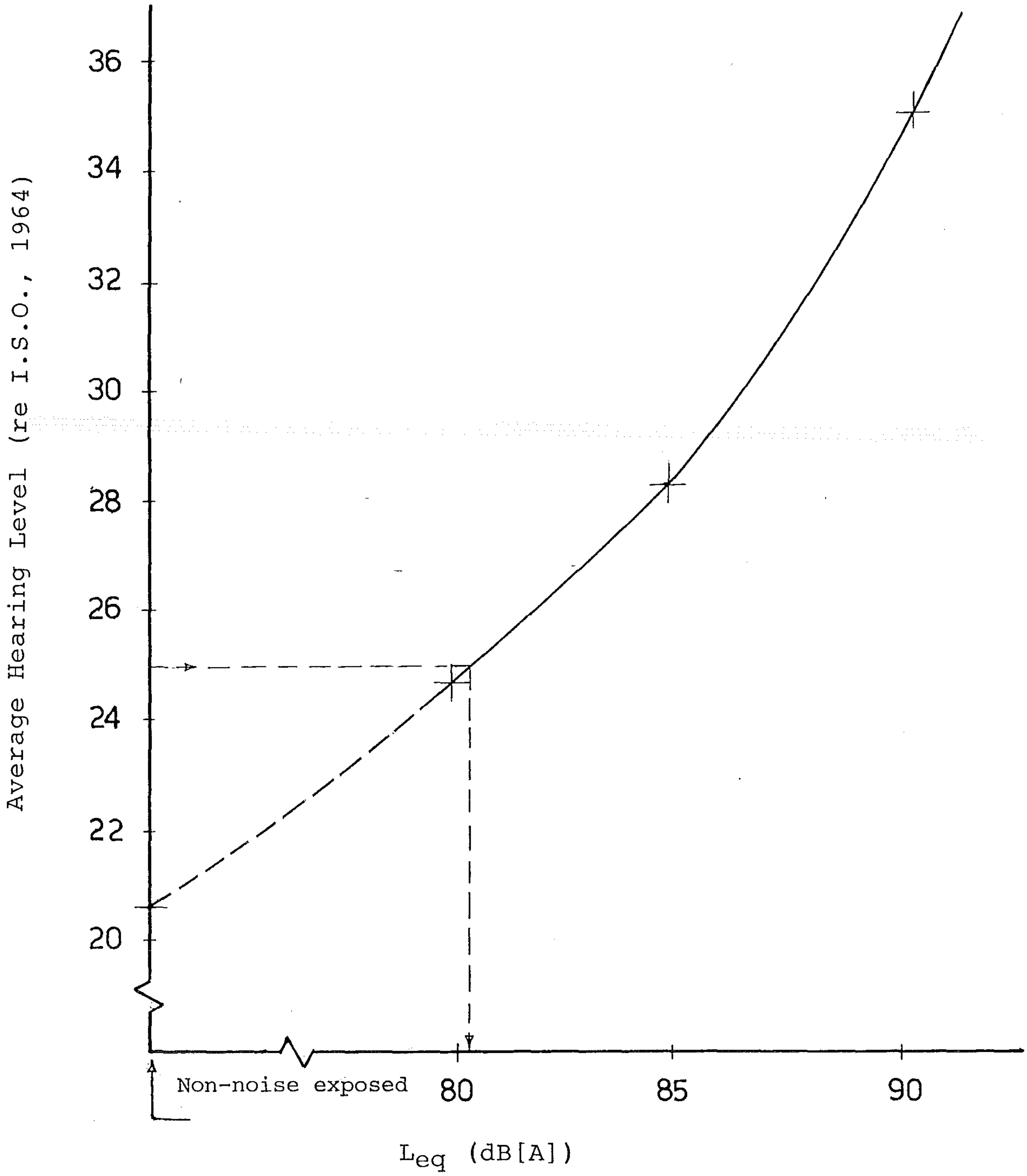
who are exceptionally susceptible, regular audiometric monitoring of all at-risk employees is needed coupled with the use of individual hearing protection, or removal to a quieter work station, for those showing evidence of progressive impairment.

The final variable to be specified is that of age at retirement, and by implication, the number of years of exposure. Previous legislation in many countries was based on a maximum damage period of ten years, but there is considerable evidence to show that damage after this time is far from asymptotic, especially in the case of more moderate exposure levels (Kryter 1973, p 1219). In addition; presbycusis has not yet exerted any influence, at least in those commencing work in a noisy environment at a young age. If, sixty years can be regarded as a reasonable retirement age, an average of forty, not ten years occupational exposure is a reasonable estimate.

Having specified all relevant variables, it now remains to determine, from relevant research, the maximum L_{eq} that can meet the damage-risk criteria. The two most important and extensive studies in this area are those by Robinson (1968) and Passchier-Vermeer (1968). Based on these studies, Figure 3 gives the predicted (90th percentile) hearing threshold level (averaged at 1000, 2000 and 3000 Hz) as a function of noise exposure and presbycusis. It can be seen by interpolation on Figure 3 that the L_{eq} required to limit damage to 25 dB (averaged) at 1000, 2000 and 3000 Hz is approximately 80.5 dB (A).

Figure 3

Hearing Threshold Level As A Function Of Noise Exposure and Presbycucis



1. "Hearing Threshold Level" is presented as the average loss at 1000 2000 and 3000 Hz, at age 60 years for the 90th population percentile.

Derived from the averaged data of Passchier-Vermeer (1968) and Robinson (1968) - see E.P.A. 1975b.

f) Impulsive Noise - A Special Problem

Specifying safe limits of exposure to impulsive noise is more difficult than for continuous noise. Although considerable research effort has, and is still being expended, the large number of parameters involved has, so far, prevented the complete development of "safe" guidelines for the range of impulsive noises commonly found in industry.

Impulsive or impactive noise means intense noise of short duration (less than 0.5 sec), with rapid growth (more than 40 dB/second) and often rapidly changing spectral composition (EPA Document 1973 p 5). Typical sources of impulsive noise are firearms (most widely studied), impacts in industrial processes (e.g. boilermaking and sheet-metal punching) and shot-firing in mining or quarrying.

Either basic parameters are needed to adequately characterize impulsive noise. These are:

(1) Peak sound pressure level.

(2) Duration of the event (from onset, till return to ambient level)

(3) Rise and decay time.

(4) Type of waveform.

(5) Spectrum.

(6) Total energy of the event.

(7) Number of impulses in the cumulative exposure.

(8) Average interval between impulses.

Impulsive noise often levies its toll far faster than would be predicted by measurements taken on a normal sound level meter, even when this is set on fast response. The acoustic reflex, which can limit the intensity of noise reaching the inner ear, cannot exert its protective influence in most cases of exposure to impulsive noise, due to its inherent onset delay. In addition, as Brüel (1977) has pointed out, many potentially hazardous impulsive noises are not perceived as hazardous, even though their frequency spectrum may be centred on frequencies to which the ear is maximally sensitive. This is because the "averaging time" of the ear is in the region of 35 milliseconds, far longer than the duration of damaging high-energy peaks in most impulsive noise. From analyses of various types of impulsive noise found in industry, Brüel has shown that, contrary to widely held opinion, impulsive noise has high spectral energy in the region of 3000 - 6000 Hz. In addition, the ear has a natural resonance amplification in the area of 3000 - 4000 Hz, that in certain cases may be as high as 12 dB.

Taking all four factors in combination (i.e. prevalence of impulsive noise, measurement inaccuracy, resonance amplification, spectral energy), these provide the basis for a reasonable explanation, as to why hearing damage for impactive/impulsive noise is centred in the higher frequencies (3000 - 6000 Hz).

Various guidelines have been proposed for limiting exposure to hazardous impulsive noise, although the vast majority have received no official acceptance. For example, Coles and Rice (1971) have specified a trading relationship between impulse duration and maximum safe sound pressure level for 90% of ears. A correction factor is also given, depending on the number of impulses, as related to the nominal exposure of 100 impulses (see EPA 1973 p 19).

However, as McRobert and Ward (1973) have pointed out, the value of these specified limits is low in practice, as other relevant parameters are ignored, thus reducing the validity of predictions. Their practical significance is even less when one realizes that measurements in a "real life" situation require extensive use of expensive equipment by relatively expert personnel.

2. Legal Aspects of Noise in New Zealand

a) Legislation on Noise Exposure

In 1971, an amendment to the Factories Act (1946) introduced a new provision covering noise in occupational settings, Section 67A reads.

"(1) If, in the opinion of the Medical Officer of Health, any noise arising from any process or activity carried out in any factory is likely to cause impairment to the hearing of persons employed therein, the occupier shall take all such steps as may be practicable to prevent those persons from being exposed to that noise.

(2) If, in the opinion of the inspector, it is not practicable to prevent exposure to the noise by reducing the noise level of the process or

activity, or by isolating or insulating the process or activity, the occupier shall cause all persons exposed to the noise to be provided with a personal ear-protection device of a type approved by the Medical Officer of Health."

This legislation clearly, places responsibility on the employer to reduce noise levels, so employees are not likely to incur serious damage to hearing. In addition, the latter part of section 74(1) requires noise-exposed workers to use individual hearing protection, which has been provided for them.

The Factories Act amendment was followed by similar legislation in the "Construction Amendment Act" and the "Mining (Safety) Regulations (1973)".

The "...opinion of the Medical Officer is defined in practice by the "Occupational Health Handbook", and at present is based on a standard L_{eq} of 85 dB(A), with an upper limit of 115 dB(A) regardless of exposure duration. The "equal energy" hypothesis is adopted - thus a 3 dB "integration rule" is specified.

More recently, the "Factories and Commercial Premises Act, 1981" has effectively replaced the Factories Act Amendment. Section 47 of this new

Act states:

"The occupier of an undertaking shall take all practical steps, by either -

(a) Controlling at source the noise arising from the processes and activities carried on in or about that undertaking; or

(b) Isolating or insulating those processes and activities, -

to ensure that no worker employed in or about that undertaking is exposed to any noise so arising that would be likely to impair his hearing if he were not using a hearing protection device.

(2) Where a worker employed in or about any undertaking is exposed to any noise that would be likely to impair his hearing ... the occupier of that undertaking shall provide the worker with an individual hearing protection device of a type approved by the Director-General of Health."

The standard L_{eq} remains the same as previously, yielding the following maximum (intensity by time) exposures.

Continuous Level dB(A)	Maximum Exposure Time/Day
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 minutes
100	15 minutes
103	8 minutes
106	4 minutes
109	2 minutes
112	1 minute
115	30 seconds

As before, no worker is allowed any exposure to levels exceeding 115 dB(A) continuous noise without hearing protection.

What is readily apparent, when comparing the legal limits with the "safe" L_{eq} derived previously, is that even if the legislation were fully implemented, a reasonable proportion of workers would still have impaired hearing at the end of a working lifetime. In any case, it is highly improbable that anything like perfect implementation could be achieved, as the nature of certain industrial processes (e.g. boilermaking) makes substantial reductions in noise immision practically impossible. Noise surveying, to assess risks to hearing, is carried out by both the Department of Health and the Department of Labour - the former on a (supposedly) regular monitoring basis.

b) Accident Compensation for "Industrial Deafness"

Noise-induced hearing loss may be one of the most prevalent industrial "diseases", but it is eminently preventable. In the past, hearing conservation programmes were virtually non-existent. Consequently, many of our older workers have varying degrees of noise-induced hearing loss, and some have severe loss.

On the 1st April 1974, "industrial deafness" (the usual medico-legal description of notable N.I.P.T.S) became a compensable industrial "accident". The main sections of the Accident Compensation Act covering Industrial Deafness are Sections 68, 119 and 120. If a loss of earning capacity is involved, section 113 would apply, but as far as can be ascertained, there has never been a claim for industrial deafness where a loss of earing capacity has arisen.

Section 68 lays down the criteria for the acceptance of a claim for Industrial Deafness. Section 119 deals with lump sum compensation for the loss or impairment of bodily function created by the degree of Industrial Deafness. Section 120 relates to awards for the loss of capacity to enjoy life, stemming from the disability.

Section 119 allows for a maximum lump sum payment of $7,000 at present, but in the case of industrial deafness, once the percentage loss of hearing is established, that percentage is applied to 75% of the "total loss of bodily function", i.e. $5,250 maximum. This is in accordance with the second schedule of the Act. Section 120 of the Act also allows for a lump sum of $10,000 (maximum) for specific loss of capacity to enjoy life, stemming from the disability.

The normal procedure for a noise-deafened person filing a claim, is firstly to fill out a form (ACC form C25) indicating the history and nature of the "injury". The Corporation then usually refers the claimant to an Otologist who determines, according to the "appropriate" formula, the degree of disability, usually expressed on a percentage basis. The Corporation, after taking other relevant information into account, decides whether compensation is payable, and if so, the amount. Successful claimants are also entitled to a hearing aid, if they so desire one. Subsequent claims may be made, if further hearing deterioration from noise becomes evident.

The Corporation, from the compensation as opposed to the prevention side, uses the Australian National Acoustic Laboratories formula, which specifies cutoff points of 15 dB loss at 500 - 3000 Hz, and 20 dB at 4000 Hz. While some handicap may exist at this level, the Corporation does not actually pay compensation to anyone with less than a calculated 5% disability.

The procedure for determining the overall "percentage loss of hearing" involves firstly binaural assessment of the hearing level (re I.S.O. 1964) for the frequencies 500, 1000, 1500, 2000, 3000 and 4000 Hz. A chart is provided for each frequency with "better ear" and "worse ear" hearing levels on separate axes. The percentage contribution of the given losses for each ear, at that frequency, are read directly, and the total impairment determined by summing the component percentages.

Impairment is assumed to be linear between the high and low "fences" of 95 and 15 dB loss respectively, with the exception of a 20 dB low fence at 4000 Hz, as noted previously.

the maximum contributions of the different audiometric frequencies to the overall percentage impairment are 20 (500 Hz), 25 (1000 Hz), 20 (1500 Hz), 15 (2000 Hz), 10 (3000 Hz) and 10% (4000 Hz), with a linear 6:1 weighting in favour of the better ear. One implication of this particular weighting is that a person with "perfect" hearing in one ear and total loss in the other is deemed to have lost only 16.5% of his hearing, although his localisation of sound source is effectively lost, and his functioning in background noise, or indeed any "difficult" hearing situation, is significantly impaired.

Of perhaps greater importance, the nature of the weighting formula and the actual condition mean it is virtually impossible to have a loss of more than a determined 50%, through noise exposure alone. Thus, the rather small <u>maximum</u> lump sum for "loss of bodily function" becomes even more insignificant when this fact is taken into account. What is readily apparent to anyone working in the field of hearing impairment is that small lump-sum payments do not in any way compensate for the <u>true permanent</u> loss of enjoyment of life.

METHOD

Management and workers were interviewed in a sample of noisy Christchurch enterprises to assess awareness of various aspects of industrial deafness, and the types of measures being taken to prevent its occurrence.

Given that legislation requires workers be protected from significant noise induced hearing loss, what options are available to an employer to reduce exposure levels? The only sure solution is to eliminate the problem at its source, that is, through emission control. However, factors such as technical infeasibility, combined with the costs of modifying or replacing existing equipment, often preclude this option. There are also limits to administrative noise controls, such as job rotation to reduce the overall L_{eq} per worker. An example would be where the job task may be incompatible with such time-juggling, because of skill or sequencing requirements.

The third most frequently adopted option is the provision of hearing protection devices. The issuing of such devices alone in no way guarantees that workers' hearing will be protected from damage by noise at work. A carefully planned and executed hearing conservation programme (HCP) is needed, as any fragmented approach is usually doomed to failure (Mellard, 1976). Such a programme should comprise:

1) Assessment of hazard through noise surveys.

2) Pre-employment and regular monitoring audiometry, and appropriate follow-up where indicated.

3) Controlled issue and maintenance of personal hearing protection devices.

4) A continuing program of education for all at-risk employees.

5) Full and obvious backing of the program at the highest levels of management.

In addition to evaluating any existing H.C.P's on the basis of these required components, it was considered worthwhile to examine factors which possibly influence the presence and/or effectiveness of a H.C.P. Such factors might include

- knowledge, beliefs and attitudes of management and workers.

- existing legal requirements and degree of enforcement.

- noise emission levels existing in the company/ enterprise.

- characteristics of the company/enterprise, e.g. size, existence of specialist health/ safety staff.

a) Selection Criteria

Given sufficient time and personnel resources, it may be possible to examine a random, representative sample of enterprises with potentially dangerous noise levels, in a city the size of Christchurch. For obvious reasons, this was not a viable proposition for one person with limited time and resources. Thus the obtained sample of enterprises taken in Christchurch during 1980 is in no way claimed to be random or truely representative in its coverage.

The manner in which individual enterprises were selected varied. They were in the main selected by scanning through "Yellow Pages" listings of industries likely to have high emission levels e.g. heavy engineering. Others were selected as a result of information received from other students of their experience of a particular company, e.g. vacation employment which indicated potentially-damaging noise levels.

Three Government Department workshops were included in the sample, as these were expected to have conditions optimally favourable to the development of effective H.C.P's.

Upon tentative selection, an enterprise was approached for permission to conduct structured interviews, firstly with relevant management, and secondly with a random sample of employees. A personal assurance of anonymity was given, with a view to maximising the changès of co-operation, and the accuracy of any data obtained.

Of the fourteen enterprises approached for such permission, only two refused to co-operate. The factory manager of one of these enterprises (a food packaging company) refused permission of entry, because of a pending prosecution by the Labour Department. The company had apparently failed to comply with section 67A(1) of the Factories Act, by not attempting to adopt measures which would reduce noise exposure levels. The personnel manager of the second company (a large clothing manufacturer) refused access because he did not "want staff to worry about any danger" and claimed to be "unsure if the noise levels are excessive", although he refused to be more explicit when questioned on this latter point.

The final sample consisted of the following:

1) Three Government Department workshops, two with an attached occupational health nurse.

2) Three large private companies (>250 employees) with an occupational health nurse and safety officer.

3) Three medium-sized companies (>50 but <250 employees) without a health nurse.

4) Three small companies (<30 employees) obviously without an occupational health nurse.

An attempt was made to interview at least ten employees, from each enterprise which agreed to participate in the survey. This was achieved with two of the three large companies, the third being able to schedule nine interviews because of time restrictions. However, the problems of scheduling interviews turned out to be far greater than anticipated, and many of the smaller companies were finally willing and/or able to provide five employees for interviews.

Overall, the survey yielded a sample of twelve enterprises, and structured interviews with 90 employees and 12 "relevant management".

b) Nature of Structured Interviews

Interviews consisted of a fixed set of questions, one version for "relevant management" (i.e. in order of preference, an occupational health nurse, safety officer or shop-level manager) and a second version for employees (see Appendix 2). Within each version, "Knowledge" items were examined with forced multichoice questions, with answer options displayed on printed cards, and secondly open-ended questions were employed to investigate more general areas, for which multichoice questions would be inappropriate.

1) "Relevant Management"

The following area were investigated:

a) Knowledge of the effects of noise on hearing including

- noise terminology, specifically noise levels

- awareness of noise-induced hearing loss as an occupational hazard

- the danger of continuous noise as opposed to single exposures

- the severity and significance of warning symptoms

- individual differences in susceptibility

- the importance of continuing protection over the years

- relevant legislation on maximum permissible exposure levels, and their perception of its adequacy

- the efficacy of a hearing aid in cases of advanced noise-induced hearing loss

b) Assessment of the extent to which a hearing conservation program has been instituted, including

- company policy on hearing protectors and their supply

- attempts at education of workers of the risks

- extent of any audiometric monitoring programme (if present) and measures taken if damage is detected

- attempts at emission control, i.e. reducing noise to its source

c) An estimate of the proportion of their workers at risk from hearing loss, due to noise exposure at work.

d) Completion of a noise survey and knowledge of the results and implications.

e) Whether any employees had ever lodged an Accident Compensation claim for "industrial deafness".

2. "Employees"

Questions were directed at the following areas:

a) Estimates of

- personal hearing acuity relative to their age group

- likely future effects on their hearing of continued exposure to current noise levels

- whether their personal noise exposure exceeded the legal limits

b) Frequency of use and type of personal hearing protector employed.

c) Knowledge of the effects of noise exposure on hearing including

- awareness of noise-induced hearing loss as an occupational risk

- the danger of continuous noise as opposed to single noise exposures

- the significance of warning symptoms of varying severity

- individual differences in susceptibility

- the importance of continuing protection over the years

- the efficacy of a hearing aid in cases of advanced noise-induced hearing loss

d) Verification of claimed company policy and procedure in the following areas

- advice on use, and supply of individual hearing protection devices

- education efforts re noise-induced hearing loss

- audiometric monitoring

- claims for "industrial deafness" under Accident Compensation

All interviews were conducted in private, on an individual basis.

For each of the participating companies, an attempt was made to obtain a copy of the most recent noise survey conducted on the premises, should one exist. These were supplied for five of the six largest concerns, but surveys had either never been carried out, or their results were unobtainable for the rest of the participating enterprises. It was hoped to use survey results as at least a relative measure of risk for each particular concern, but this would not have been possible even if all companies had been able to supply such information. The problem resulted for the survey technique employed in most surveys - specific noise levels were measured for certain workareas/machines, but these measurements are meaningless in isolation, and in no way indicate the particular exposure L_{eq} of their operator.

RESULTS AND DISCUSSION

Section A

Summarised Raw Data

Information obtained through application of the two interview schedules may be conveniently divided into two areas

- knowledge questions relevant to industrial deafness

- factual data of a non-knowledge nature.

(1) Knowledge Questions

Six questions were common to both management and employees. Results from these are presented for each question in turn, and their significance discussed. Three other knowledge questions, unique to management, are presented later.

(a) Awareness of Industrial Deafness (Management Q4, Employee Q10).

Respondents were asked what effects prolonged exposure to high levels of noise would have on hearing. All management and 82% of employees correctly indicated that it would result in permanent damage to hearing. While 82% is a high percentage, every at-risk worker should know this fact. This suggests that basic education is lacking.

(b) Individual Differences In Susceptibility to N.I.P.T.S. (Management Q7, Employee Q11).

The question asked if hearing loss caused by high levels of noise was more pronounced in men, the same for all persons or varied widely regardless of sex. Only 33% of management and 23% of employees correctly indicated that susceptibility varied widely irrespective of sex of the person exposed. Most respondents who were wrong thought susceptibility to be the same for all persons.

Thus, the vast majority of respondents, both management and employees, failed to realise there are large individual differences in susceptibility to N.I.P.T.S. They, therefore, could not adequately appreciate the rationale behind monitoring audiometry, and other aspects of a H.C.P. aimed at protecting susceptible employees. There is at present no accurate method of predicting who is more susceptible, without resorting to audiometry after a period of noise exposure.

(c) Recognition of Signs of Industrial Deafness (Management Q6, Employee Q12).

The four situations mentioned in this question are all potentially risky, and are presented in order of increasing subtlety, i.e.

a) "when you feel pain in your ears from the noise level".

b) "when you have trouble understanding speech after a day's work, but are recovered next day".

c) "when you notice no effect on your hearing soon after the noise stops".

d) "when you notice no effect on your hearing after five years of working on the job".

The percentage of respondents correctly identifying each situation as potentially dangerous is presented in Table 1.

TABLE 1

Percertage of Respondents Correctly Identifying At-Risk Situations (Management Q6 = Employee Q12)

Situation	Management	Employees
a)	100	89
b)	75	79
c)	58	46
d)	33	27

All management respondents and 89% of employees correctly identified situation a) as potentially dangerous. The same comment applies to this employee proportion as it did to the first question concerning awareness of industrial deafness - while 89% is a high percentage, all workers should readily recognise such a blatantly at-risk situation.

It can be seen that there is a progressive drop-off, for both management and employees, in the proportion able to identify the subsequent (more subtle) situations, where a person's hearing could still be at risk. The phenonemon of temporary threshold shift (T.T.S.), a classical warning sign, is described in practical terms in option b) - "when you have trouble understanding speech after a day's work but are recovered next day". Any attempts at education of workers in this area should result in their being aware that T.T.S. precedes N.I.P.T.S.

The last two situations are far more subtle, and are based on the fact that industrial noise exposure usually takes years before serious permanent damage becomes apparent. In fact, even at this late stage, such losses are often attributed to a natural dropoff in hearing with age (presbycusis), or to "mumbling" (never on your part!).

The low proportions of respondents being able to identify these more subtle situations as potentially dangerous to their hearing would point to the need for education. Workers must be made aware of the subtle manner in which occupational noise exposure levies its toll - nowhere near as dramatic as having your foot crushed by a forklift, but rather, presenting a serious yet invisible social disability.

(d) Rate of Progression of N.I.P.T.S. (Management Q8, Employee Q13)

This question concerned the progressive nature of N.I.P.T.S. The options were a) most notice slight damage, b) damage adds up slowly [correct], c) most damage occurs in the early stages of exposure. The correct option was chosen by 63% of workers, and only 50% of relevant management.

Surprisingly, only one health nurse was able to choose the correct option, while only one non-nurse respondent was wrong! Four of the five nurses who were wrong chose option c) - "most of the damage is done very early on", which is clearly not the case with severe noise - induced hearing loss. This finding suggests that health nurses have been misinformed at some stage, of the rate at which industrial deafness progresses.

(e) Danger of Continuous Noise Exposure (Management Q5, Employee Q14)

This question dealt with the degree of hearing loss induced by a single loud noise which resulted in tinnitus, and that of prolonged exposure to loud noise of lesser intensity. The latter is in fact more damaging to hearing, yet only 67% of management and 62% of employees realised this.

It may be noted that 38% of workers is still a high proportion for believing that one loud noise producing temporary tinnitus is usually more damaging than continuous exposure to steady-state noise. Awareness of the danger to continuous noise must surely be a pre-requisite to convincing workers of the need to wear protection in any continuously noisy conditions.

(f) Efficacy of a Hearing Aid for Severe Industrial Deafness (Management Q9, Employee Q15)

When a person suffers severe N.I.P.T.S., can a hearing aid restore hearing fully, make speech louder and clearer, or make speech louder but not solve the clarity problem. The correct option in this case is "speech sounds louder but distorted". Here only 39% of workers and 17% of management chose this option. Exactly 50% of workers and 83% of management thought, that in severe cases, "speech sounds louder and clearer" with an aid. At least no management respondent thought an aid could restore hearing fully.

What is apparent from the small proportion of both workers and management choosing the correct option, is that they underestimate the seriousness of the condition as far as remedial meausres go. A hearing aid in such cases is of limited help, especially in background noise where the sufferer has his greatest problems.

Knowledge Questions Specific to Relevant Management

The first three questions in the management interview schedule were related to noise measurement terminology, specifically familiarity with common noise levels. 91.6% of management respondents were able to identify "decibels" as the unit of sound intensity, a fairly easy task. However, only 25% were able to identify 60 dB as an average conversational level, and, again, only 58% knew that 140 dB was the level at which noise becomes painfully loud.

As expected, most respondents were able to choose the correct unit of sound intensity but the low proportion able to relate levels in dB to specific situations indicates poor familiarity with sound measurement generally.

(g) Total Knowledge Scores

For each respondent, an overall knowledge score was derived by simple arithmetic addition of number of correct answers. (4 were possible for Management question 7, Employee question 11). This gave a possible maximum score of 9 for employees, and 12 for relevant management respondents.

Tables 2 and 3 give the distribution of scores, for management and workers respectively.

Table 2

Distribution of Knowledge Scores for Relevant Management

Knowledge Score	Number of Respondents
12	-
11	-
10	1
9	4
8	2
7	1
6	2
5	1
4	-
3	1
2	-
1	-

TABLE 3

Distribution of Knowledge Scores for Workers

Knowledge Score	Percentage
9	1.11
8	8.88
7	16.67
6	18.89
5	15.55
4	20.0
3	11.1
2	3.3
1	2.2
0	2.2

n = 90, mean = 4.76

While the range of questions involved is reasonably extensive, there is little that can legitimately be said about the absolute level of summed knowledge scores. Such scores have more value in a relative sense, e.g. comparing the knowledge of different health nurses and other management. However, it should be noted that a person merely guessing would be expected to get a total of three correct.

Management questions 1, 4 and 6(a) should be answerable by most laymen. There is little chance that management incapable of answering these correctly could take informed action in any attempts to protect their workers' hearing.

(2) Non-Knowledge Questions

(a) Relevant Management

(i) Proportion of Employees Considered at Risk (Q. 10)

Table 4 presents estimates by management of the proportions of their workers at risk for industrial deafness.

Table 4

Management Estimates of Workers "At Risk"

Proportion at Risk	Number of Respondents
None or a negligible proportion	4
5-10%	5
10-20%	0
over 20%	3

It can be seen that 75% of management respondents estimated that less than 10% of their workers were at risk for noise induced hearing loss, on the basis of existing exposure levels. There is no way a corresponding real figure can be derived for the enterprises surveyed - this would require complete noise surveys based on worker L_{eq}, and a determination of actual protector use for all employees.

However, of the copies of noise surveys provided by certain enterprises, it was not unusual to find noise emission levels in excess of 100 dB(A), and regular exposure to such levels definitely constitutes a risk to hearing.

The author feels that the level of risk estimated by management is definitely an underestimate, based on the noise levels observed during data collection, and more importantly the number of clear-cut cases of significant industrial deafness seen during data collection.

Either management's interpretation of "adversely affected" was unnecessarily lax, they over-estimated protector use, or they were deliberately attempting to downplay the risk. In one enterprise, the author's examination of a random sample of monitoring audiograms showed significant and progressive dropoffs in hearing, yet the nurse estimated "none or a negligible proportion" were at risk.

(ii) Attempts At Education of Workers (Q. 11)

Only three respondents were unable to describe any efforts directed at educating their workers of the dangers of industrial noise exposure. Of the remaining nine enterprises, Table 5 gives the types of methods employed.

Table 5

Educational Efforts Cited by Management

Method	Number of Respondents
Ongoing informal talks during audiometry and/or induction	5
Safety Films	3
Posters	7
Supply of Pamphlets	1

It must be stated that attempts at education of at-risk workers could not be described as extensive or intensive. The best medium, cited by five management respondents, was ongoing informal talks during and after monitoring audiometry. This technique provides feedback on shifts in hearing (if present) as well as informational counselling, and has proven value in motivating employees to wear individual protection devices. Zohar et al (1980) found that informational feedback after audiometry, of the measured effectiveness of wearing protectors, produced dramatic long-term increases in the wearing behaviour of all employees involved. This well-designed study used a classical educational approach as a control, i.e., safety films, lectures and, later, even threats of dismissal. The control group showed no long-term increases in wearing frequency.

To account for the wide variation in attempts at education of workers, it was felt a criterion could be adopted, to indicate whether significant efforts at education of workers had been made. Accordingly, a data category labelled "significant educational efforts" was established, which is defined by the presence of at least <u>two</u> of the following :

- continuing educational counselling during audiometry and/or induction

- ongoing educational films

- supply of educational pamphlets and/or posters.

Using this definition, nearly half (44%) of all workers interviewed were considered to have never received significant education by their present employers, on the risks of industrial noise exposure.

(iii) Claimed Company Policy on Protectors (Q. 12)

The stated policy of management on the issue and use of individual hearing protection devices is presented in Table 6.

Table 6

Stated Policy on Protectors

Policy	Number of Respondents
No policy	-
Only recommend their use	1
Only supply them free	1
Recommend their use *and* supply free	8
Supply free and insist they be worn	2

Discussion of these results can be found in Section C (3).

(iv) Audiometric Monitoring Programmes and Followup Procedures (Q. 13, 14)

Details of audiometric testing, aimed specifically at identifying significant N.I.P.T.S., are summarised in Table 7.

Table 7

Frequency of Audiometric Monitoring

Frequency Tests Carried Out	Number of Enterprises
Never	4
Occasionally or very irregularly	3
Regular and compulsory	5

Question 14 was inapplicable in four cases, as an obvious prerequisite was the existence of an audiometric monitoring programme. Of the enterprises with such a programme, only one took no specific action following identification of an employee with a significant hearing loss, or shift in hearing. One other enterprise took the step of informing the individual, and further encouraging their use of protectors.

The remaining five enterprises informed the individual of a shift in hearing, and sought medical referral as a matter of course. In one of these five, the possibility of removing the individual to a quieter job/workstation was considered.

For industrial audiometry to be effective in identifying at-risk and impaired employees, the testing must be regular (generally annual) and attendance compulsory. Less than half (41%) of the enterprises surveyed met this requirement. Thus, the other 59% had no means of accurately, identifying workers whose hearing is dropping as a result of noise exposure.

In addition to testing, a well-defined set of followup procedures should be operating, whereby significant shifts in hearing are dealt with by medical referral, careful individual counselling, to inform the individual and strengthen motivation for wearing protectors, and where applicable, consideration of shifting the worker to a quieter job. Only one enterprise was able to report that this level of followup was in current use.

Thus, of the eight enterprises where audiometry was employed to detect noise-induced hearing loss, only one met the requirements of regular compulsory testing, and adequate followup procedures.

(v) Attempts at Engineering Noise Controls (Q. 15)

Only four enterprises were unable to cite even a single attempt at reducing a noise source by engineering techniques. It must, however, be emphasised that efforts in this area could not be described as extensive, or significant in terms of effectiveness in the overall hearing conservation programme. With the exception of one enterprise, they were invariably minor isolated instances, motivated for example by employee complaints about the extreme noise level of a particular machine, caused by a faulty muffler. No respondent was able to cite specific figures on the degree of noise reduction achieved by such attempts.

Engineering noise control, i.e., eliminating the problem at source, is the only sure method of guaranteeing that workers will not be exposed to harmful levels of noise. However, many companies feel it is economically impractical to spend large sums of money to reduce noise to safe levels, especially when management (falsely) assumes personal protection devices will achieve the same end result with less cost. In addition, many industrial processes, e.g. hammering in boilermaking or rivetting in ship-building, make substantial reductions in noise emissions virtually impossible.

These two reasons (economic considerations and technical infeasibility) may help explain why no enterprise in this survey was able to cite significant attempts at engineering noise controls, as well as being able to quantify the degree of success.

(vi) Knowledge of Legal Limits on Noise Exposure (Q. 16)

Responses to this question are summarised in Table 8, on the basis of being able to name specific legislation and/or noise limits in current use.

Table 8

Management Awareness of Legal Limits

Level of Knowledge	Number of Respondents
No knowledge	7
Could only name legisation	1
Could only cite isolated figures, e.g. decibels	3
Knew legislation and levels	1

Legally-prescribed maximum noise-exposure levels form the basis of any hearing conservation programme, as they determine the minimum level of protection which must be aimed for. It is, therefore, of particular concern that only one management respondent was able to correctly identify the current legisation and its stated maximum levels of noise exposure. Fifty eight percent of respondents had no idea whatsoever of the legislation or levels in current use. Besides pointing out the need for education, this would also suggest that the level of enforcement of the legislation is so minimal, as to allow relevant management to ignore it.

(vii) Availability of Noise Surveys (Q. 17)

Respondents were questioned as to the existence of a noise survey, and asked where possible to provide a copy of the survey. Survey availability is summarised in Table 9.

Table 9

Availability of Results of Noise Survey

Position	Number of Enterprises
No survey ever carried out	3
Survey carried out, but results lost or unobtainable	3
Copy of survey provided	6

Awareness of specified legal limits on noise exposure must be related to results of an actual noise survey for relevant management to be able to appreciate the objective risk to their workers. Noise surveying is however no minor task. It requires considerable time, manpower and equipment to be carried out to an acceptable level. To be meaningful, results must ultimately be presented in terms of L_{eq} for specified workers. It is really a waste of time to cite noise emission levels of specific machines, or ambient noise levels in a given room. In the vast majority of cases, workers are not tied to specific machines or rooms for their entire working day. Thus even though a particular machine may have a high emission level at the operator's ear, e.g. 100 dB(A), the operator may only use it for several minutes a day and, therefore, not be at risk from this machine alone.

In all five noise surveys sighted by the author, results were presented in terms of emission levels, not L_{eq}. Three of the smaller enterprises had never had a noise survey carried out, although from a technical point of view they had missed out on little, assuming results would have been presented as emission levels.

Although all noise surveys seen were technically inadequate, they may have had a side benefit in a motivational sense. It was readily apparent talking to (relatively) informed health nurses, that they were unaware of the distinction between emission level and L_{eq}. Therefore, any high figures seen listed on a noise survey might be taken as indicating high risk, and hopefully would be reflected in increased efforts on the prevention side.

(viii) Accident Compensation Claims (Q. 20)

Only one enterprise reported that none of its employees had ever lodged a claim for industrial deafness. In one of the larger companies, sixty employees had actually applied, with the help of the company, for compensation.

At present, the procedure for a noise-deafened worker to claim Accident Compensation does not result in his current employer being attributed any blame for this "accident". There are three probable reasons for this, from a medicolegal as opposed to political standpoint. Firstly, many workers change jobs frequently and it is therefore impossible to document exact noise-exposure histories. Secondly legislation specifying maximum permissable exposure levels has not been in force long, so the legal obligations of employers were extremely limited in the past, as far as preventing industrial deafness was concerned. Thirdly, many workers have significant non-occuptional sources of noise exposure, e.g. shooting, which complicate the determination of work related N.I.P.T.S.

While not having actual figures, if would appear from the data obtained, most claimants are at least forty years of age, and thus have had many years of noise exposure. In some of the older claimants, significant military noise exposure has also been experienced further complicating assessment. The fact that employers are not held responsible in any legal sense for noise-induced hearing loss may help explain why the management respondents in this survey were so open about the matter. It is good that the Accident Compensation Act recognises "Industrial Deafness" as a specific "accident" but, as was pointed out in the Introduction, small monetary handouts in no way compensate the individual for the severe social handicap an advanced noise-induced loss causes.

(ix) Perception of Adequacy of Legal Limits (Q. 21)

It is clear from management respones to question 16 that they were unaware of the actual technical details, or arguments pertaining to, current legislation intended to limit occupational noise exposure. Their perception of its adequacy is summarised in Table 10.

Table 10

Management's Perceived Adequacy of Noise Legislation

Response Option	Number of Respondents
Inadequate in Many Cases	5
Adequate in All Cases	7
Overprotective	-

Given that management are unaware of any technical aspects of the legislation, it is likely that responses to this question are determined largely by their perception of the level of enforcement of such legislation. If this assumption is correct, management in noisy industry infer, on the basis of level of inforcement, that legal limits on noise exposure are not conservative, in as far as attempting to protect worker's hearing is concerned.

(b) Employees Non-Knowledge Questions

(i) Perceived Own Hearing (Question 1)

Table 11 summarises how employees perceived the state of their hearing, relative to their own age group.

Table 11

Workers Perception of their Hearing

Response	Percentage of Employees
"Poor"	33.3
"Average"	63.4
"Well Above Average"	3.3

An age breakdown of those responding "poor" is given in Table 12.

Table 12

Proportion of Workers with "Poor" Hearing, By Age

Age of Respondent	Percentage Choosing "Poor"
Less than 30 years	4%
30-39 years	17%
40-49 years	45%
50 years or older	65%

The most valuable comparison, available from information obtained by this question, is by looking at the data on the basis of age (Table 12). Essentially all younger workers, i.e., less than 30 years, considered their hearing was at least average for age. However, a significant trend is apparent - the older the age group, the greater the proportion considering their own hearing to be poor, relative to their peers. It is of course possible that older people have an intrinsic bias towards perceiving their hearing as poorer than that of their peers regardless of their hearing level, but it is also likely that their response is a realistic appraisal, reflecting the cumulative effects of prolonged exposure to excessive noise.

(ii) Perceived Future Effect of Noise on Hearing (Q. 4)

Table 13 presents the options workers chose as being best representative of the likely future effects of noise on their hearing.

Table 13

Workers Perceived Future Effect of Noise on Hearing

Response	Percentage
"Unaffected"	35.6
"Noticeably Affected"	61.1
"Deteriorate Rapidly"	3.3

There is little that can be said about responses to this question, for two reasons. Firstly, there is a problem with the wording in that the respondent's use of hearing protectors could strongly influence his choice of perceived future effect. As an example, we will take two younger employees, who both work in a high level of noise, but who vary significantly in their use of protectors. If one used protectors all the time, he could truthfully choose the response "unaffected", dispite the fact he worked in a high level of noise. The other worker who might not wear any protection would (on the basis of probability) at least need to answer ".... noticeably affected". This problem became apparent only when analysing results, and could have been overcome with a qualifier in the question, specifying that the worker assume no protectors are used.

Secondly, the initial inclusion of this question was motivated by the hope of eventually being able to compare this perceived risk to the objective risk, as measured by noise survey results. In retrospect, better wording of the question would not have allowed such a comparison, as adequate noise survey results proved non-existent.

(iii) Perceived Personal Noise Exposure Relative to "Legal Limit" (Q. 5)

Table 14 summarises how workers perceived their overall noise exposure, relative to an undefined "legal limit".

Table 14

Perceived Noise Expsoure Re "Legal Limit"

Response	Percentage
"above"	66.67
"below"	33.33

Again, nonavailability of accurate noise survey results prevented a comparison of employee estimates with actual exposures. However, the majority (67%) considered their overall noise exposure was above the "legal limit".

Whatever factors influence an employee's perception of this "legal limit" are unknown, but it is certainly not information given by their management - this is clear from answers to management question 16. It could well be that the incidence of hearing problems seen in older workmates may contribute to this perceived "limit".

(iv) Reported Frequency of Hearing Protectors Usage (Q. 7)

Table 15 summarises reported use of individual protection devices.

Table 15

Reported Usage of Protectors

Response	Percentage
(Never)	28.89
"Sometimes"	13.33
"Only in Noisy Jobs"	35.55
"Always"	22.22

The reported level of protector wearing would almost certainly never exceed the actual level, assuming the respondents' interpretation of the usage categories was the same as the author's. On the information available, it is impossible to determine whether reported usage significantly exceeded actual usage. It is however fair to say that conditions during the interview were reasonably conducive to accurate reporting, as an informal atmosphere was encouraged by the interviewer, and an assurance of complete anonymity given at the start.

The fact that 43% of employees reported they either never, or only "sometimes" wore protectors suggests that a significant number of employees are highly at-risk for industrial deafness. Failure to wear protection did not appear to be less prevalent in the noisier enterprises surveyed.

Section B

General Comments by Workers

Tables of figures often fail to capture the personal element. The comments summarised below come almost entirely from older workers who have had years of noise exposure, and who obviously have "paid the price".

It can readily be seen that the classical description of N.I.P.T.S. as "Boilermaker's Disease" still has high validity.

(1) Comments By Hearing Aid Users

- A 54 year old crane operator was unaware that his hearing problems were due to noise until an audiogram was carried out. He now wears a hearing aid but finds it is no great help in background noise.

- A 54 year old boilermaker finds his hearing aid is "some help", but is "certainly not the answer".

- A 48 year old boilermaker has an aid, but finds he still has great trouble trying to converse in a group. He also mentioned management deception during noise surveys by shifting men off noisy jobs.

- A 54 year old welder/labourer successfully claimed ACC for industrial deafness and now wears an aid. He has been told he has a severe problem, on the basis of the test results. He wears his aid socially where it is of moderate help, except in high background noise.

- A 61 year old loom technician successfully claimed ACC and wears a hearing aid. His only comment on the aid was that he can "hear the birds now".

- Two other workers, aged 40 and 51, had successfully claimed ACC for Industrial Deafness, and wore aids with unknown success.

(2) Other Comments

- A 36 year old boilermaker knew he had notable noise-induced damage already and was told he would be "stone deaf" at 55. He said the tight employment situation kept him in the same job.

- A 33 year old fitter/turner said he knew of three workers whose hearing had been severely damaged by noise, and who got no real benefit from an aid.

- A 47 year old worker, who was the union representative, said he was "not interested in the money" (they got 6c/hour for wearing protectors) nor did he want to wear muffs as the working conditions were very hot. He just wanted to see the noise level reduced.

- A 42 year old boilermaker, who had successfully claimed ACC, said management were "very apathetic" about noise. He said that on the Employer's Claim Form for ACC, management had stated that there were no other employees with industrial deafness, when in fact simply asking their workers would have revealed this was not the case.

- A 54 year old boilermaker who had successfully claimed ACC, no longer went to a pub because he found it impossible to hear.

- A 41 year old boilermaker felt he had a real social disability in that he could not hear in any background noise. He found this "very embarassing as people think you are a bit stupid".

- Another 58 year old boilermaker had successfully claimed ACC for Industrial Deafness but did not wear an aid.

What is readily apparent from reading these comments is that noise-induced hearing loss causes its greatest problems in background noise ("crowds") and that a hearing aid will not solve this problem to any great degree.

Section C

Health Nurse As An Explanatory Variable

While the questionaire design does not allow causality to be determined for response variables such as protector use, it is certainly of interest to examine the data for statistical relationships.

Because any H.C.P. must be well co-ordinated to be successful, it was considered worthwhile to look for differences in various factors examined in the survey, by breaking the data down on the basis of presence or absense of a full-time occuptional health nurse.

In presenting data broken down on this basis, any category labelled "HN" indicates data from employees working in an enterprise with an industrial health nurse. Conversely, "non-HN" indicates absence of such a nurse.

(1) Summary of Statistical Comparisons

Table 16 gives the reported protector use of workers, broken down on the basis of presence of a health nurse.

Table 16

Reported Protector Use *vs* Health Nurse

Response Category	HN	Non-HN
"Never"	6	20
"Sometimes"	8	4
"Only in Noisy Jobs"	24	8
"Always"	17	3

An appropriate statistical technique for evaluating whether use of protectors differs for each group is the Rank Sum Test with extensive ties (see Leach, 1979, Chapter 2).

In this instance, the explanatory variable is presence of a health nurse, and the response or dependent variable is reported usage of protectors. It is assumed that the response variable is ordinal, i.e. that

"Always" reflects greater usage than

"Only in Noise Jobs", which in turn reflects greater usage than

"Sometimes", which in turn reflects greater usage than

"Never"

Applying the test, $Z = 4.35$, $p < .0002$ (2-tailed)

This is a highly significant result and indicates higher reported usage of protectors in enterprises where there is a health nurse.

Having shown that the groups differ, it is interesting to determine how strong the relationship is between group and reported usage. This "strength of association" can be assessed by a statistic known as Somer's delta (δ) (see Leach, 1979 pp 80-85). Delta ranges from -1.0 to +1.0.

In this instance, $\delta = .535$

This indicates how much more probable it is in a randomly selected pair of workers, one from a HN enterprise and one from a non-HN enterprise, to obtain a pair in which the HN worker reports greater usage, than it is to obtain a pair in which the non HN worker reports the greater usage. If the two groups reported equal usage, we would be just as likely to obtain a pair in which the HN worker reported greater usage as we would to select a pair in which the non HN worker reported greater usage, and would be zero. In the present case, we are 53.5% more likely to obtain a pair in which the HN worker's reported usage exceeds that of the non HN worker. This represents a moderate degree of association between the presence of a HN and reported usage.

(b) Knowledge of Management

The possible maximum knowledge score for relevant management was 12. The mean number correct for HN management was 8.67 and for non-HN management, 6.17. The means were reliably different.

$t\ (10) = 2.58, \quad p < 0.05$ (2-tail)

Thus HN management scored higher on knowledge questions than did non-HN relevant management.

(c) Knowledge of Employees

The maximum possible score for employees was nine. The mean score of the 55 employees working in enterprises with a HN was 5.38 (SD = 1.91), while that of the 35 employees from non-HN enterprises was 4.68 (SD = 1.85). The difference between means approached significance,

$t\ (88) = 1.687,\ .05 < p < .10$

Thus, on average, presence of a health nurse is not associated with a higher knowledge score among workers.

(d) Perceived Own Hearing of Workers

Table 17 presents responses to employee question one (i.e. how they perceive their hearing relative to their age group), broken down on the basis of HN *v* non-HN.

Table 17

Presence of HN *vs* Workers Perceived Hearing

Response	HN	non-HN
"Poor"	17	13
"Average"	18	39
"Well Above Average"	0	3

Again, a Rank Sum Test with extensive ties was employed, where the explanatory variable was presence of a health nurse, and the response variable (perceived hearing relative to own age group) can be considered ordinal.

In this case, $Z = 2.44$, $p < 0.02$

and $\delta = .278$

Thus, workers in a HN enterprise (on average) perceived their hearing to be better than workers in a non-HN enterprise. However, in an ordinal sense, the relationship as measured by Somer's delta is not particularly strong.

(e) Perceived Noise Exposure Relative to "Legal Limit"

Responses to employee question 5, broken down on the basis of a health nurse, are presented in Table 18.

Table 18

Presence of Health Nurse *vs* Perceived Noise Exposure

	Response	
	"Above" legal limit	"Below" legal limit
HN	39	16
Non-HN	21	14

An appropriate significance statistic here is a Fisher Exact Probability Test with a large sample approximation (see Leach, 1979, pp 85-96). The presence of a HN had no effect on employees' perception of noise levels,

$Z = 0.84, \quad p > .20$

Thus, the two groups of workers (HN v non-HN) did not differ in their perceived noise exposure. As mentioned previously, there is no way of comparing actual noise exposure levels, due to lack of adequate noise survey results.

(f) Perceived Future Effect of Noise on Hearing

Employee's responses to Question 4 (the perceived future effect of noise exposure on their hearing) are presented in Table 19, broken down according to presence of a health nurse.

Table 19

Employees Perceived Future Effect *vs* HN

	Response Categories	
	"Unaffected"	"Noticeably Affected" *or* "Deteriorate Rapidly"
HN	16	39
Non-HN	16	19

The effect of HN can again be assessed using a Fisher Exact Test. The difference was non-significant,

$Z = 1.37$.

(2) Discussion of HN *v* Non-HN Comparisons

It must be made clear that the label "health nurse", in relation to any enterprise or group of workers, does not imply that the presence or absence of such a person accounts for any differences found. Indeed, it could well be that factors other than the presence of a health nurse are influencing the level or nature of various hearing conservation measures examined. Larger companies are obviously able to allocate greater resources (in absolute terms) toward employee safety and welfare.

Of greatest practical significance, HN workers reported a far higher frequency of protector usage. Only 25% of HN workers never or only sometimes wore protectors as compared with 69% of non-HN employees.

Was this difference the result of greater perceived risk on the part of non-HN workers? A comparison of responses on employee question five would suggest this is not the case. There was no significant difference between the proportion of workers in either group choosing the option "above" (the legal limit).

Another question related to greater protector usage by HN employees is: "Was the difference in wearing due to greater knowledge of HN workers?"

No significant difference was found between the mean knowledge scores of HN and Non-HN employees.

Thus, although the presence of a health nurse may not be associated with greater worker knowledge, employees who work in an enterprise with a nurse have greater reported usage of protectors. This suggests there may be certain practical advantages in simply having a nurse, e.g. issue of protectors and enforcing/encouraging their use. Comparison of knowledge scores for relevant management respondents shows that nurses know more than non-nurse management, of the dangers of noise exposure. Knowing more, and having the time and (presumably) motivation to institute protective measures might be expected to produce practical benefits. As Zohar et al (1980) suggest, sustained efforts are required on the part of the programme co-ordinator before new norms or behaviour standards are created which favour protector use. These norms, once established, tend to be self-sustaining and this finding may help explain why protector use in any enterprise tends to be polarized to either extreme, i.e. either very few workers using protectors, or else the majority do. It is breaking through a threshold of resistance that appears to be the problem with introducing protectors as the main preventative approach.

There is no obvious explanation for the fact that significantly more HN workers considered their hearing to be at least average for their age. It would not be reasonable to assume that greater use of protectors in HN enterprises was responsible. Hearing conservation programmes in such places have probably not been present for a long enough period to have resulted in a drastic effect on the proportion of workers with noticeably-impaired hearing. There is also nothing to suggest that the age structure is responsible for the difference.

The lack of difference in responses to employee question four (perceived future effect of noise exposure on their hearing) is probably a result of the wording, as mentioned previously.

Section C

Variables Related to Worker Knowledge

(1) Statistical Comparisons

Various questions related to knowledge of employees are raised, and statistical comparisons made.

(a) Is Worker Knowledge related to the knowledge of their management?

Using knowledge questions common to both management and employees, a correlation was derived comparing knowledge scores of management with the mean knowledge score of their employees.

The correlation between (mean) worker knowledge and management knowledge was

$r\ (10) = .68,\ \ p < 0.05$

Thus where management knows more, so it appears do their workers.

(b) Using the same questions, do management know more than worker?

The mean knowledge score for management was 5.33 (SD = 1.55) while that for employees was 4.76 (SD = 1.01). The difference between means approached significance by a related-measures t - test,

$t\ (11) = 1.75,\ \ .05 < p < .10$

Using questions common to both, management do not know significantly more than their workers.

(c) Is worker knowledge related to educational efforts by the company?

Using the definition of "significant educational efforts" described in Results Section A 2. (a) subsection (ii), the mean knowledge score of employees in enterprises who had carried out significant educational efforts was 5.5, while the mean for enterprises with no significant educational programme was 4.9. An unrelatedmeasures t - test showed the difference between the means was not significant.

$T\ (88) = 1.40, \quad p > .20$

Thus, the presence of a significant educational programme, aimed at alerting workers to the dangers of noise exposure, did not appear to produce a measurable increase in worker knowledge.

(2) Discussion of Comparisons

It has been shown that worker knowledge was in fact highly correlated with knowledge of their own relevant management, using the same knowledge questions for comparison. Secondly, significant attempts at education of at-risk workers did not result in a measureable increase in knowledge, relative to "uneducated" workers.

These findings further suggest that the higher usage rate of protectors amongst employees who work in a HN enterprise is mostly the result of direct, practical intervention by a health nurse, possibly by enforcing protector use rather than relying on enformed action by employees.

Section E

Variables Related to Protector Usage

(1) Statistical Comparisons

(a) Is Protector Use Predicted by Individual Knowledge?

Relevant data is presented in Table 20.

Table 20

Reported Protector Usage vs Worker Knowledge

Knowledge Score	Protector Use N	S	O	A
0	1	1	0	0
1	0	0	2	0
2	2	1	0	0
3	6	2	2	0
4	4	2	6	6
5	5	3	4	2
6	5	1	6	5
7	4	1	7	3
8	0	1	5	3
9	0	0	0	1

Note N = Never

S = "Sometimes"

0 = "Only in noisy jobs"

A = "Always"

In this case, we have an ordinal explanatory variable i.e. "knowledge score", and an ordered response variable, in terms of usage reported.

An appropriate test here is the Jouckheere test (see Leach, 1979, pp 178-183).

For the data in table 20

$Z = 2.54, \quad p < 0.01$ (1 - tailed)

This indicates a significant relationship between reported usage and individual knowledge. The strength of this association is indicated by Somer's delta as

$\delta = .202$

Thus, while there is a statistically reliable trend in table 20 for the better informed to report greater usage of protectors, the low value for Somer's delta indicates the relationship is weak.

(b) Is protector usage predicted by the presence of a health nurse?

Evidence exists that there is in fact a relationship in the data - [see results of a Rank Sum test in Section D 1. subsection (c)].

(c) Is protector use predicted by enterprise policy on protectors, as perceived by the worker?

Four separate categories are needed to summarize the company policy on hearing protectors as perceived by the worker. These were namely;

N = no identifiable policy

R <u>or</u> S = Recommend their use <u>or</u> supply them free

R <u>and</u> S = Recommend their use <u>and</u> supply them free

S & I = Supply them free and insist they be used

Table 21 indicates reported usage as a function of perceived management policy.

Table 21

Perceived Enterprise Policy on Protectors *vs* Protector Usage

Policy	Protector Use N	S	O	A
N	4	0	1	0
R or S	17	5	6	3
R and S	2	5	6	9
S & I	2	1	18	11

Note N = Never

S = "Sometimes"

O = "Only in noisy jobs"

A = "Always"

Application of a Jouckheere Test with ties (see Leach, 1979, pp 180-182),

$S = 4.80$, $p < .0002$, 2 - tailed,

indicated greater reported usage of protectors, with greater effort on the part of the company (enterprise) to encourage their use. The degree of association was also moderately strong.

$\delta = .446$

(d) Is protector use predicted by the amount of educational effort directed at workers?

Significant educational efforts are again defined as in Section D 1. (c), namely; at least two of the following:

- continuing informational counselling during audiometry and/or induction
- ongoing educational films
- supply of educational pamphlets and/or posters

Reported protector usage as a function of educational effort is portrayed in Table 22.

Table 22

Educational Efforts v Protector Use

Educational Efforts Reported by Workers	Protector Use N	S	O	A
No significant efforts	22	5	9	5
Significant efforts	4	6	23	14

Note N = Never

S = "Sometimes"

O = "Only in noisy jobs"

A = "Always"

A Rank Sum Test with extensive ties

$Z = 4.20, \quad p < .0002$ (2 - tailed)

indicated significantly greater reported protector use in enterprises making greater effort to educate employees. The relationship was moderately strong,

$\delta = .51$

(e) How close is the relationship between stated company policy on protectors, and company policy as perceived by the worker?

Data derived from employee question 8 was matched to responses on management question 12.

Table 23

Stated *v* Perceived Policy on Protectors

	Perceived Policy				
Stated Policy	N	R	S	S+R	S&I
N	-	-	-	-	-
R	5	-	-	-	-
S	-	-	10	-	-
S+R	-	-	14	40	1
S&I	-	-	-	7	13

Note N = No policy

R = their use recommended

S = supplied free

S+R = supplied free plus their use recommended

S&I = supplied free and their use insisted upon

An appropriate measure of association is Kendall's Tau b (τ_b) (see Leach, 1979, pp 202-205). This statistic, when applied to a table such as the one above, reaches a maximum of 1.0 only when all entries not on the leading diagonal are zero.

In this case,

$\tau_b = .759$

indicating a high degree of association. The null hypothesis of no association was tested using Jouckheere's Test,

$Z = 8.022$, $p < .0001$ (1 - tailed).

(f) Is protector use predicted by how workers perceived the future effects of noise on their hearing?

Responses on employee question four (perceived future effect of noise on their hearing) were collapsed into two categories

- unaffected

- affected, i.e. options "noticeably affected" and "deteriorate rapidly"

Data was also divided on the basis of presence of a health nurse.

(i) Health Nurse Enterprises

The relation of reported protector usage to perceived future effects on hearing is presented in Table 24.

Table 24

Perceived Future Effect vs Protector Use (HN)

	Protector Use			
Perceived Future Effect	N	S	O	A
Unaffected	2	0	9	5
Affected	5	8	15	11

Note N = Never

S = "Sometimes"

O = "Only in noisy jobs"

A = "Always"

A Rank Sum Test indicated that there was no significant association between the perceived future effect of noise on hearing, and reported protector use for HN employees,

$Z = -0.63, \quad p > .40$

(ii) Non Health Nurse Enterprises

Again, reported protector use versus perceived future effects on hearing is presented in

Table 25 for non-HN employees.

Table 25

Perceived Future Effect *vs* Protector Use (Non-HN)

Perceived Future Effect	Protector Use N	S	O	A
Unaffected	11	1	2	1
Affected	10	3	5	2

Note N = Never

S = "Sometimes"

O = "Only in noisy jobs"

A = "Always"

Again there was no significant effect,

$Z = 1.127, \quad p > .20$

Thus, responses on employee question four, i.e., the perceived future effect of noise on their hearing, were found not to be significantly related to reported protector use.

(g) Is protector use predicted by how workers perceive their noise exposure relative to the "legal limit"?

Data is again divided on the basis of presence of a health nurse. Response coding is as previously.

(i) Health Nurse Enterprises

For this group of employees, Table 26 presents perceived noise exposure relative to the legal limit versus reported protector usage.

Table 26

Perceived Exposure *re* Legal Limit *vs* Protector Use (HN)

Perceived Exposure re Legal Limit	Protector Use N	S	O	A
Below	2	0	9	3
Above	4	10	15	12

Note
N = Never
S = "Sometimes"
O = "Only in noisy jobs"
A = "Always"

Application of a Rank Sum Test indicated there was no significant association,

$Z = -0.16, \quad p > .40$

(ii) Non Health Nurse Enterprises

Table 29

Perceived Exposure re Legal Limit v Protector Use (Non-HN)

Perceived Exposure re "Legal Limit"	Protector Usage N	S	O	A
Above	8	4	6	3
Below	12	0	2	0

Note N = Never
S = "Sometimes"
O = "Only in noisy jobs"
A = "Always"

This time, a Rank Sum Test revealed a highly significant effect,

$Z = 2.54, \quad p < 0.02$ (2 - tailed)

and the degree of association, as measured by Somers delta, was moderately strong,

$\delta = .469$

Thus, only in enterprises without a health nurse, are employees who perceive their noise exposure to exceed the "legal limit", more likely to report a greater frequency of protector usage.

(h) Allied to questions six and seven in this Section, we may ask is there a relationship between employees perceived future effects of noise, and their perceived noise exposure relative to the legal limit?

Data is again presented on the basis of presence of a health nurse, and responses on employee question four are collapsed into "affected" versus "nonaffected" (see question six in this section).

(i) Health Nurse Enterprises

Table 27 relates HN employees perception of their noise exposure relative to the "legal limit", to their perception of the future effects of noise on their hearing.

Table 27

Perceived Exposure re Legal Limit vs Perceived Future Effect (HN)

Perceived Exposure re "Legal Limit"	Perceived Future Effect: Unaffected	Perceived Future Effect: Affected
Above	10	30
Below	7	8

(ii) Non Health Nurse Enterprises

Employee perceptions of their noise exposure relative to the legal limit, compared with future effect of noise on their hearing are presented for non-HN workers in Table 28.

Table 28

Perceived Exposure re Legal Limit vs Perceived Future Effect (Non-HN)

Perceived Exposure re "Legal Limit"	Perceived Future Effect: Unaffected	Perceived Future Effect: Affected
Above	7	14
Below	9	5

An appropriate test for a significance effect is a Fisher Exact Test,

For HN enterprises,

$Z = 1.261, \quad p > .20$

For Non-HN enterprises,

$Z = 1.43, \quad p > .20$

Thus, there is no statistical evidence for a relationship between perceived future effect of noise on hearing, and perceived noise exposure relative to the legal limit.

(2) Discussion of Comparisons

A highly important finding is that positive educational efforts by management are associated with greater reported usage of protectors. This finding, in combination with the absence of a relationship between educational efforts and individual knowledge, suggests that higher protector usage may be more the result of an affective response rather than any conscious rational decision by the worker. Apparently, "educated" workers do not retain actual details presented in the educational material but rather may develop a more positive attitude towards wearing protectors.

Enterprise policy on the issue and use of protectors also has a bearing on their actual use. Stated company policy on protectors was significantly and positively related to the level of reported use. This finding further reinforces the suggestion that health nurses play an important practical role in directly influencing the use of protectors.

Another finding which may seem contrary to previously established relationships is that individual knowledge is highly correlated with protector use. The fact that HN workers did not (on average) know more than non-HN workers, yet reported significantly higher protector use, did not provide any evidence for a relationship between knowledge and protector use. These findings suggest that employees in the gross grouping of "Health Nurse" were not particularly homogeneous, with respect to knowledge, and point out the value of examining intra-individual rather than inter-group differences in small samples.

Finally, it is interesting to note, that only in non-HN enterprises, was there a significant relationship between an individual's perception of his noise exposure relative to the "legal limit", and his frequency of protector use. The lack of such a relationship in HN enterpirses may be the result of a higher overall usage of protectors and/ or factors such as group norms influencing wearing. With a low overall usage of protectors in non-HN enterprises, it would be logical to assume that those workers with particularly high exposure levels may be more likely to wear protectors. There is also the possibility of an ambiguity in the wording of employee question five masking an actual relationship for HN employees. For example, those employees who wear protection could truthfully answer "below" (the legal limit), yet still be wearing protection because they perceive a risk.

In summary, the fact that three variables - individual knowledge, stated management policy and educational efforts - are all related to reported protector use, does not make for easy interpretation. What is clear though is that supplying protectors, in isolation, does not necessarily result in their being used.

CONCLUSION

It would appear, from the enterprises examined in this survey, that measures taken in New Zealand to prevent occupational noise-induced hearing loss are not sufficient to match the level of risk. The area is characterised by a low level of awareness by management and workers of important facts concerning industrial deafness, and by a paucity of comprehensive hearing conservation programmes. At least part of the responsibility for this situation must lie with government agencies responsible for enforcing relevant legisation. There is obviously no significant motivation for many employers to institute preventative measures, especially in enterprises where noise levels just exceed legislated levels.

Increased official interest is seen as worthwhile in the following four areas.

(1) Information to Employers

Management in noisy enterprises must be supplied with sufficient information to be able to take appropriate preventative action. One worthwhile approach might be the development of a comprehensive document on noise, which would be distributed to all enterprises known to have excessive noise levels. There are various areas of knowledge that would need to be covered in such a document.

Firstly, employers must be made aware that a well planned and executed programme is needed to prevent industrial deafness. It is not sufficient to provide protectors and hope workers will use them. A practically-orientated summary of current noise legislation should be included to make employers aware of their legal obligations. This important prerequisite to informed action was an area of knowledge shown to be particularly lacking in the enterprises surveyed. The merits of various approaches to preventing industrial deafness should be discussed, and emphasis placed on noise reduction at source whenever possible.

Secondly, the reader should be informed of the practical implications of having a noise-induced hearing loss, especially that of being unable to function in the presence of competing background noise. It is important that at-risk workers understand that loudness loss is not the main problem with industrial deafness - it is a perceived reduction in clarity that is the problem. Having "contracted" noise-induced hearing loss, a persons social life will suffer as their confidence in facing any situation involving group conversation will be severely affected. People with hearing losses tend to withdraw, rather than risk mishearing and appearing stupid. The limitations of hearing aids as treatment tools should be strongly emphasized, especially in noisy listening conditions where the sufferer has his greatest problems. Tinnitus should also be cited as a possible serious side-effect for which there is often no cure.

Thirdly, management should be made aware that monitoring audiometry is the only sure way to identify susceptible workers, and to judge how successfully a conservation programme is operating. It needs to be emphasized that audiometry is not an end in itself - there is no value in simply documenting progressive dropoffs in hearing. Appropriate followup procedures should be specified, so that effective followup action is taken in cases of identified loss. Audiometrists should be made aware that detailed feedback on test results is a valuable opportunity to educate workers, and to motivate their use of protectors.

There will always be a problem with instituting monitoring audiometry in smaller concerns, as the provision of equipment and trained personnel cannot be justified by management in such workplaces. In accepting this limitation, official consideration could be given, to providing whatever resources are needed to allow regular visits by an audiometrist to smaller concerns, especially those with high noise levels. The author is aware this already occurs with medium sized companies in some areas, but the extent of coverage appears to be far from extensive or sufficient. Management in smaller enterprises with a visiting audiometrist must be seen by their employees to strongly support such a service, by being as flexible as possible in scheduling tests, and by making attendance mandatory.

Fourthly, an ongoing education programme for at-risk workers should give high priority, especially for those newly inducted. The development of informed positive attitudes in younger workers towards the wearing of protectors is vital, if a norm is to be established favouring protector use. Once established, this type of behaviour tends to be self-sustaining and problems with enforcing protector use become lessened.

The final area that should be covered in such a document is the inclusion of noise emission standards, when choosing new or replacement plant and equipment. The initial outlay for quieter machines may not be significantly greater in many cases, but any such additional capital costs are more than offset by the problems involved with later attempting noise reduction, which may be doomed to failure. Government departments should set the example by including maximum noise emission levels in all tendering specifications.

In addition to providing valuable information on how to prevent industrial deafness, such a document would preclude the possibility of an employer using ignorance of the legislation as an excuse for inaction.

(2) Quality and Coverage of Noise Surveying

It is important that Government agencies involved with enforcing noise legislation are able to identify which workplaces have hazardous noise levels, as defined by existing legal limits. There appear to be a need for improvement both in the quality and coverage of noise surveying.

Many smaller concerns have never been subjected to a noise survey, if the limited sample of enterprises in this paper is any indication. There is no evidence to suggest that noise levels in smaller concerns are less hazardous than those in larger concerns. Thus, there can be little justification for not including smaller concerns in noise surveys.

It must be stressed that presenting noise survey results in terms of emission level is virtually meaningless in many cases. The only valid index of risk for continuous noise, and that on which the legislation is based, is L_{eq}. It is technically invalid telling an employer that on the basis of survey results presented in emission level, his workplace has been shown to be excessively noisy. The only obvious exception is where noise ever exceeds 115 dB(A) continuous, or because of a recent ruling by the Health Department, where impact noises have peak readings in excess of 140 dB(A).

Thus, there needs to be a significant improvement in both the coverage and mode of presentation of noise surveys if employers are to be coerced into taking preventative measures, on the basis of a validly-demonstrated risk.

(3) Noise Reduction at Source

It is worthwhile reiterating, that the only sure way to prevent noise-induced hearing loss is by limiting noise emissions to a safe level at the operators ear, that is, to eliminate the problem at source. While conceding that certain processes or operations make substantial noise reductions virtually impossible, there are many sources of occupational noise that would respond well to attempts at engineering noise control. This area of engineering is rather specialized, and at present there appears to be an insufficient number of suitably skilled people in this country to make widespread emission controls possible. Unless government departments are able to provide more noise engineers to act in a consultative role with companies, there is little chance that noise emission levels will be significantly reduced in private industry.

(4) Enforcement of "Legal Limits"

It would appear that at present, many employers in noisy industry are effectively able to ignore legislation aimed at limiting occupational noise exposure. This is especially true for smaller concerns which seem to escape the official attention of noise inspectors.

While realizing that the existing legal limits on noise have not been in force long, it is important that official policy dictates that eventually these limits will be fully enforced. Current laws aimed at preventing this significant and serious occupational "injury" are definitely worthy of full enforcement, especially as evidence presented in this paper shows that the legislated limits are not conservative.

Perhaps the Accident Compensation Corporation could become far more actively involved, at least in the area of education. The occasional poster or television advertisement is not sufficient to create a great enough awareness of the scope and significance of the problem. Any spending the Corporation makes in the interests of prevention would eventually be recouped in a reduced number of compensation claims for "industrial deafness". This sensible investment of Corporation funds would also be in line with its recently claimed focus on prevention rather than compensation.

As an area of worker safety and welfare, trade unions in noisy industry should be more actively involved with, and concerned about industrial deafness. They are neglecting an important area of member well-being, if they ignore noise exposure as an occupational risk. Union support to any hearing conservation programme is vital to its success, especially if the wearing of ear protectors is an important part of the programme. There is however little merit in union involvement, if interest is limited to securing a bonus payment for having to wear protectors. A co-ordinated approach by management and unions aimed at preventing industrial deafness in any noisy enterprise would certainly be to the benefit of all parties.

In conclusion, industrial deafness may not be a particularly topical problem, but its prevalence and seriousness warrant far greater efforts at prevention.

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Appendix 1

A-weighted Sound Level Measurements

Because the ear is less sensitive to frequencies at either extreme of the frequency range, especially those below 200 H_Z, a sound level measurement which gives equal emphasis to all frequencies does not relate well to perceived loudness. To allow for the frequency selectiveness of the human ear, various frequency - weighting networks have been devised. The most common is the A-scale, which has received international standardization with respect to the electroacoustic specifications of sound-level meters which incorporate this network (IEC, 1965).

This curve is derived from psychoacoustic experiments on "equal-loudness conducted by Fletcher-Munson (1933) and is specifically an "inverted 40-phon" curve. This gives the following approximate attenuation relative to (unweighted) sound pressure level.

Frequency (H_Z)	Attenuation *
100	-20
250	-8.6
500	-3.2
1000	0
2000	+1.2
4000	+1.0
8000	-1.1

* i.e. add to dB SPL to obtain dB(A)

Appendix 2

STRUCTURED INTERVIEW SCHEDULE - RELEVANT MANAGEMENT

(1) Which of the following is the unit commonly used in the measurement of sound intensity.

- Lux ------ (go to 4)
- watt ------ (go to 4)
- decibel
- rad ------ (go to 4)

(2) A normal conversation level corresponds roughly to

- 10 dB
- 20 dB
- 30 dB
- 60 dB
- 90 dB

(3) The intensity at which pain would first be experienced corresponds roughly to

- 60 dB
- 90 dB
- 140 dB
- 170 dB
- 200 dB

(4) Persons experiencing high levels of noise for prolonged periods

- are not really affected by it
- will become immune to noise
- will suffer permanent damage to hearing

(5) Which is more likely to permanently damage a person's hearing

- <u>one</u> very loud noise that causes temporary ringing in the ears
- a lower level of noise that continues over a period of years which may not cause ringing in the ears.

(6) Loud noise in a work situation can permanently damage a person's hearing under which of the following circumstances.

(true or false)

- when they feel pain in their ears
- when they have trouble understanding speech after a day's work but are recovered next day
- when they notice no effect on their hearing soon after the noise stops
- when they notice no effect on their hearing after five years of working on the job.

(7) Hearing loss caused by high levels of noise is... (choose one)

- much more pronounced in men
- the same for all persons
- of widely varying degrees, regardless of sex

(8) Damage to hearing can be of varying degrees. Which of the following statements is true, regarding the progression of damage to hearing, from normal hearing through to severe deafness caused by high levels of noise.

- most people notice when slight damage has been done
- damage adds up slowly and consistently
- most of the damage is done very early on

(9) How useful is a hearing aid when a person's hearing has been severely damaged by noise.

- it can restore hearing fully
- it makes speech louder and clearer
- speech sounds louder but distorted

(10) Estimate the proportion of workers in this (factory/ section/department) whose hearing is likely to be adversely affected if they continue to experience the same level of noise over an extended period

- none or a negligible proportion
- 5-10%
- 10-20%
- over 20%

(11) Has (the company/you/the company health nurse) ever provided, of (their) own volition, educational material to workers on the dangers of exposure to excessive amounts of noise, e.g. through pamphlets, films, lectures etc.

- No
- Yes (specify) (<u>N.B</u>. exclude ACC or Health Department material)

(12) What is the company's policy on individual hearing protectors?

- no policy and/or subject never discussed with workers
- recommends the use of protectors (specify)
- supplies protectors free (specify)
- supplies protectors and insists upon their use for specified employees and/or work areas.

(13) Hearing tests in this (company/department/section) are

- Never carried out (go to 15)
- carried out as normal hiring procedure
- carried out at regular intervals <u>and compulsory</u> (1 year spacing)
- sometimes carried out (specify)

(14) What happens when a worker is identified as having notable hearing loss, either at the start of employment or after a regular test?

Probes
- insistence on hearing protector use
- remove to quieter job
- inform the individual

(15) Have any attempts been made in this (factory/section) at controlling noise at its source, or reducing exposure levels by other methods.

- No
- Yes (specify type and motiviation)

(16) Is there a legally prescribed maximum noise level for <u>your</u> factory/workshop?

- No
- Yes (specify)

(17) Could you provide actual figures on the noise level at any or all work stations in your (factory/workshop)?

- No
- Yes (examples or evidence)

(18) Have you ever been officially warned by the local Medical Officer of Health, or a Health Inspector, that noise in your (factory/workshop) may cause permanent damage to the hearing of people working there?

(19) In dealing with claims for compensation, what basic criterion does the ACC apply to cases of occupational hearing loss, for compensation to be considered?

(20) Has any employee of yours ever lodged an Accident Compensation Claim for deafness caused by noise at work?

(21) I consider the present legal limits on noise at work to be -

- inadequate in many cases
- adequate in all cases
- overprotective

(22) COMMENTS:

STRUCTURED INTERVIEW SCHEDULE - EMPLOYEES

(1) For my age group, I consider my hearing to be -

- poor
- average
- well above average

(2) Have you ever had a hearing test while working in this (branch/company)?

- never
- only when I started
- regularly

(3) (Contingent on presence of audiometric monitoring programme)

(a) Was the examination compulsory?

- yes
- no

(b) Have you ever been given the results of hearing tests, or had the results explained to you?

- no
- yes (specify)

(4) If you work, for the rest of your working life, in the same job or in one that is at least as noisy, is your hearing likely to be

- unaffected
- to be noticeably affected
- deteriorate rapidly

(5) Do you think the noise level you normally experience at work is above or below the legal maximum?

- above
- below

(6) Have you ever, while working here, been provided with information on the dangers of noise, for example, through pamphlets, films, lectures.

- no
- yes (specify)

(7) Do you ever use hearing protectors?

- no
- yes

What type and how often do you use them

- plugs	- sometimes
- muffs	- only in noisy jobs (probe)
- both	- only when you think the nurse/ boss will notice
	- always

(8) What is the (boss's/nurse's/company's) attitude to hearing protectors?

- nothing has ever been said
- they recommend wearing protectors
- they supply the protectors free
- they supply protectors and insist they be worn

(9) Please indicate those of the following things that apply to you

- involved in noisy sports or pastimes e.g. shooting, motor racing, band
- military service
- wear, or diagnosed as needing a hearing aid

(10) Persons experiencing high levels of noise for long periods of time

- are not really affected by it (go to 14)
- will become used to it
- will suffer permanent damage to their hearing

(11) Hearing damage, caused by high levels of noise, is

- much more pronounced in men
- the same for all persons
- of widely varying degrees, regardless of sex

(12) In which of the following four situations could loud noise at work possibly be damaging your hearing permanently.

(yes/no)

- when you feel pain in your ears from the noise level
- when you have trouble understanding speech after a day's work but are recovered next day
- when you notice no effect on your hearing soon after the noise stops
- when you notice no effect on your hearing after five years of working on the job

(13) Damage to hearing can be of varying amounts. Which of the following statements is true, regarding the progression of damage to hearing, from normal hearing through to severe deafness caused by high levels of noise.

- most people notice when slight damage has been done
- damage adds up slowly and consistently
- most of the damage is done very early on

(14) Which is more likely to damage your hearing permanently?

- one very loud noise that causes temporary ringing in your ears
- a lower level of noise that continues over an extended period, but which may not cause ringing in your ears.

(15) How useful is a hearing aid when a person's hearing has been severely damaged by noise.

- it can restore hearing fully
- it makes speech louder and clearer
- speech sounds louder but distorted

(16) Do you know of any worker here who has claimed Accident Compensation for deafness caused at work?

(17) COMMENTS: