Commentary

To celebrate the BOHS’s 50th anniversary this year, we are reproducing in our on-line edition ‘classic papers’ from past issues of the Annals, with accompanying commentaries in the print and on-line edition. For this issue, the classic paper we reproduce is BOHS Committee of Hygiene Standards (1971) Hygiene Standard for Wide-band Noise. Ann Occup Hyg: 14: 57–64.

The 1971 BOHS Hygiene Standard for Wide-band Noise

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INTRODUCTION

For some considerable time, it has been recognized that noise can damage hearing. One manifestation of such damage is loss of hearing sensitivity, termed noise-induced hearing loss. This form of hearing loss is caused by dysfunction of the hair cells in the cochlea or inner ear; the loss affects the hearing for high frequencies; and the loss is usually about equal in degree for the two ears. The damage to hearing grows quickly over the first years of noise exposure, and thereafter slowly approaches a maximum loss associated with noise level. Once the noise exposure stops, the progression of the hearing loss stops. Occupational hearing loss due to noise exposure is, however, a preventable injury; reduction of noise level or noise duration can lessen or eliminate the risk of hearing damage. With an eye to preventing this occupational disease, present hearing conservation noise assessments are based upon a simple statement: 90 dB(A) averaged over 8 h is a potentially harmful daily noise dose for unprotected ears. This exposure limit first appeared in UK practice in the Hygiene Standard for Wide-Band Noise (British Occupational Hygiene Society Committee on Hygiene Standards, 1971).

During the 1950s and 1960s, there was considerable effort both in the UK and the USA to formulate ‘damage risk criteria’ for hearing loss due to noise exposure. A certain degree of hearing damage would be deemed acceptable or tolerable in a proportion of the exposed population; the risk was quantified by the stated proportion, such as 50%, 10% or 1%. The noise criteria were given typically as octave-band sound pressure levels (in decibels or dB relative to 20 micropascals) expected to produce the specified hearing deficit in the stated proportion of those exposed.

These damage risk criteria were quite limited in their application to real situations. Noises were assumed to be of constant character and at a constant level for long periods during the working day. Measurement of noise level required subjective estimates of average octave-band levels over relatively long periods. For low-frequency bands, violent and wide-ranging fluctuations of the sound level meter indicating needle had to be observed for many seconds. Bands were measured sequentially, not simultaneously. Considering the limitations of sound-measuring instruments, good estimates of noise band levels over the working day required a degree of patience and experience.

Damage risk criteria had another serious limitation. They were applicable only to persons who worked in the same unchanging noise each day for decades, or indeed an entire working lifetime. Changing noise levels associated with changing work practice would invalidate the presumed damage risk. There was no way to account for potentially harmful noise exposure acquired over a series of different noise epochs, as might occur if a worker changed jobs over his or her working lifetime.
The 1971 BOHS standard overcame these limitations: an easy-to-measure sound level was specified, to be used with an accumulating lifetime noise–exposure metric, expressing a combination of level and duration.

To show the ground-breaking nature of the BOHS standard, it will be helpful to examine several of the old-style damage risk criteria put forward before 1971. In addition, attention will be directed to an important study conducted jointly by the Medical Research Council (MRC) and the National Physical Laboratory (NPL). It can be argued that this MRC–NPL study changed the course of hearing conservation worldwide. The BOHS took advantage of the conclusions of the MRC–NPL study, to produce what might be thought to be the first modern noise standard.

### A BRITISH DAMAGE RISK CRITERION

In 1960, Burns and Littler published a chapter on noise in a textbook *Modern Trends in Occupational Health*. In respect of criteria for maximum permissible exposure to steady broad-band noise, these two British authorities wrote: ‘The uncertainties in present knowledge, allied to individual variation in susceptibility to occupational hearing loss, make it impractical to lay down maxima of exposure which may be expected to protect all ears throughout the working lifetime. Instead it is usual to make generalizations which in practice result in specifications of noise exposure which is believed to just reach the hazardous level for most people’ (Burns and Littler, 1960).

A noise exposure criterion was set out, ‘designed to preserve hearing at the frequencies important for good speech recognition’. Maximum values of sound pressure level (SPL) were recommended in specified frequency bands; the values reproduced in Table 1 applied to broad-band noise lasting 8 h/day, 5 days/week for a working lifetime. It was further recommended that ‘if these figures are reached in any of the bands, hearing conservation should be instituted’.

Table 1. SPL values, in specific frequency bands, at which hearing conservation should be instituted

<table>
<thead>
<tr>
<th>Frequency band (Hz)</th>
<th>Band level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5–150</td>
<td>100</td>
</tr>
<tr>
<td>150–300</td>
<td>90</td>
</tr>
<tr>
<td>300–600</td>
<td>85</td>
</tr>
<tr>
<td>600–1200</td>
<td>85</td>
</tr>
<tr>
<td>1200–2400</td>
<td>80</td>
</tr>
<tr>
<td>2400–4800</td>
<td>80</td>
</tr>
</tbody>
</table>

If all bands were present simultaneously at the individually stated hearing conservation limits, then in modern terms the overall level would be 89 dB(A).

These same band limits were also given in a report by the Committee on the Problem of Noise (1963) widely known as the ‘Wilson Report’. Concerning noise at work, the Report recommended that the Ministry of Labour should disseminate existing knowledge of the hazard of noise to hearing, impress upon industry the need to reduce noise, and advise on practical measures to that end. Just such information was circulated in a booklet *Noise and the Worker*, published jointly in 1963 by the Ministry of Labour and the Central Office of Information, with the object of encouraging industrial management to look clearly at the problem of noisy processes (Ministry of Labour/Central Office of Information, 1963).

### AN AMERICAN DAMAGE RISK CRITERION

CHABA, the Committee on Hearing, Bioacoustics and Biomechanics (a joint committee of the US National Academy of Science and the National Research Council) was asked to specify damage risk criteria for exposure to noise. The recommendations of the Working Group were published in a CHABA report in 1965, but made more widely available by Kryter et al. (1966). The basic criterion adopted by the Working Group was that a noise exposure would be ‘deemed acceptable’ if, after 10 yr of near-daily exposure, the resulting median hearing loss did not exceed 10 dB at frequencies $\leq 1$ kHz, 15 dB at 2 kHz and/or 20 dB at frequencies $\geq 3$ kHz. Hearing losses due to age or pathological influences were not considered.

The recommended damage-risk criteria were presented in the form of contours of maximum permitted levels for noise bands of different centre frequencies. These band level contours were ‘considered safe’ for one exposure per day, with the exposure duration lasting from 2 to 480 min (8 h). The maximum specified band levels for a single exposure lasting 8 h are given in Table 2. Each band was considered acceptable; it follows that a sound of all bands at the individual limits would also be deemed acceptable.

For a wide-band noise with octave components at each maximum level, the overall level would be 93.5 dB(A). Such a continuous daily noise exposure,

Table 2. SPL values, in specific frequency bands, deemed acceptable for an 8 h exposure each working day

<table>
<thead>
<tr>
<th>Octave band centre frequency (kHz)</th>
<th>Band level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.125</td>
<td>97</td>
</tr>
<tr>
<td>0.25</td>
<td>92</td>
</tr>
<tr>
<td>0.5</td>
<td>88</td>
</tr>
<tr>
<td>1</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>85</td>
</tr>
<tr>
<td>4</td>
<td>85</td>
</tr>
<tr>
<td>8</td>
<td>86</td>
</tr>
</tbody>
</table>
The reader should be aware that, in the 1950s and 1960s, a certain degree of hearing damage was considered to be an inescapable consequence of occupational or military noise exposure. The CHABA damage risk was stated to be a high-frequency noise-induced hearing loss <20 dB for 50% of exposed workers; the other 50% would suffer a loss >20 dB. This is not an inconsequential hearing loss. Nowadays, tolerance of such injury is much reduced; courts, industry, the medical profession, and health and safety organizations judge any consistently measurable shift of hearing thresholds to be a preventable injury.

NEW CONCEPTS FROM THE NATIONAL PHYSICAL LABORATORY

In 1962, the UK Ministry of Pensions and National Insurance commissioned a study of occupational noise and its effects upon the hearing of exposed workers. The investigation, undertaken jointly by the MRC and the NPL, was designed as a parametric study of the relations between the physical variables of occupational noise exposure and the statistics of hearing thresholds in a screened population. The intent was to explore the effect of noise *per se*, excluding other sources of hearing deficit (except that due to ageing). To arrive at relations of general validity, the study was planned to cover a wide range of the variables (noise level, noise spectrum and exposure duration) rather than focusing on a limited number of homogeneous situations as had more frequently been done by other researchers.

Robinson and Cook (1968) documented the noise aspects of the MRC–NPL study. They applied statistical tests to the measured hearing threshold levels and known noise exposure histories of >500 noise-exposed subjects. The experimental data were confined to cases of 8 h daily exposure to steady noise, with levels ranging from 75 to 115 dB(A), for employment periods ranging from 1 month to 50 yr. They concluded that noise-induced hearing loss was expressible in terms of a composite measure, sound immission, which is proportional to the total A-weighted sound energy received by the ear over the exposure duration.

In considering hearing damage by noise, use of sound immission leads to the ‘equal energy rule’: noise exposures containing equal amounts of acoustic energy cause equal amounts of hearing damage. The authors illustrated their point with a numerical example, indicating that the equal noise exposures will produce the same hearing deficit in the average person:

- Daily exposure to 100 dB(A) for 2 yr.
- Daily exposure to 90 dB(A) for 20 yr.
- Daily exposure to 100 dB(A) for 1 yr followed by daily exposure to 90 dB(A) for 10 yr.

The third exposure illustrates a new thought: varied levels over different times (years over a working lifetime or hours over a working day) may be aggregated into a single measure of acoustic energy.

The development of sound immission was described fully in Burns and Robinson (1970). For the MRC–NPL study, occupational noise level was determined for each individual worker-subject, with noise measured both as time-averaged octave-band sound pressure levels and as ‘noise climate’ in dB(A), yielding cumulative distributions of level on time (of the order seconds to minutes). The results are finally expressed in terms of A-weighted equivalent continuous sound level $L_{Aeq}$ using an average correction derived from the level distributions. (Equipment for the direct measurement of $L_{Aeq}$ was not available in the 1960s when the study was conceived and performed.)

It was found that noise level $L_{Aeq}$ and exposure duration $T$ could be collapsed into a single measure, the noise immission level (NIL), by the formula:

$$NIL = L_{Aeq} + k \cdot \log_{10}(T/T_0)$$

where $T_0$ is the reference duration (1 yr). The constant $k$ was determined by statistical analysis to be ~10; it was assigned this exact value. NIL is thus identified as a direct logarithmic measure of the total acoustic energy received over the occupational lifetime, expressed in dB(A). The equation also applies to daily noise exposure if $T_0$ equals 8 h.

The results of the MRC–NPL study were employed by the BOHS Sub-Committee on Wide-band Noise in the production of its 1971 noise standard for application by occupational hygiene specialists.

THE HYGIENE STANDARD FOR WIDE-BAND NOISE

‘Excessive exposure to noise is known to lead to injury to hearing. The purpose of this Standard is to specify exposures from which groups of people at work would not suffer from an unacceptable incidence and degree of such injury.’

The BOHS standard has features of a traditional damage risk criterion, combined with a recognizably modern exposure limit. The Sub-Committee on Wide-band Noise had evidence that a presumed noise-induced hearing loss of 40 dB averaged over the range of audiometric frequencies 0.5–6.0 kHz would produce a degradation in the auditory activities of everyday living, leading to a social handicap. The Sub-Committee also had evidence that workers with
a NIL of 105 dB(A) or less would have a very low incidence (1%) of average hearing loss reaching the 40 dB social handicap threshold.

An NIL of 105 dB(A) was deemed an acceptable exposure as no more than 1% of exposed individuals would experience hearing handicap after a lifetime exposure; the NIL limit would result from an 8 h daily exposure to 90 dB(A) for 30 working years. Non-steady exposures were also considered: ‘Any combination of level, pattern and duration of exposure which exceeds this immission is considered unacceptable, and steps should be taken to reduce exposure.’ Equations and tables were given to aid the hygienist in determining exposure for individuals with non-standard working days, working years or indeed working lifetimes.

The BOHS Standard stands at the threshold between old and new. Links to the old include the idea of a stated hearing loss deemed acceptable in a stated proportion of exposed persons. The standard also looks forward to workers’ daily noise exposures judged against a given action level.

**LATER DEVELOPMENTS**

In 1972, the Industrial Health Advisory Committee of the Department of Employment brought out its Code of Practice for reducing the exposure of employed persons to Noise (Department of Employment, 1972). Members of the IHAC Sub-Committee on Noise included representatives from the British Occupational Hygiene Society and from the NPL; the 1971 BOHS standard, and its supporting material, were considered and used by the Sub-Committee (Hickish, 1979), as were the results of the MRC–NPL study. The resultant Department of Employment Code was an advisory document, aimed at UK industry as a blueprint for action; it was not statutory or regulatory in nature, but simply advised of what was thought by the Department of Employment (and later, the Health & Safety Executive) to be good practice. However, disregard of the recommended procedures and limits of the Code was viewed as evidence of failure to take reasonably practicable steps to ensure worker safety.

Some time after the Code came out, the EEC proposed a Directive for the protection of workers from the risks of noise exposure. This proposal suggested a daily personal noise exposure limit of 85 dB(A), with a higher limit of 90 dB(A) for a 5 yr transition period. The European Parliament debated the proposed Directive in 1984, and resolved to relax the exposure limit to 90 dB(A). The Directive was finally adopted in 1986, to take effect for industry throughout the European Community from 1990.

In response to the European Directive, the UK Health and Safety Commission issued in 1987 a consultation document proposing regulations and guidance on the prevention of hearing damage from noise at work. After the consultative process, regulations were formulated and eventually issued (in the form of a Statutory Instrument) as The Noise at Work Regulations 1989. These Regulations came into force on 1 January 1990 and are still current today (HMSO, 1989).


The new Directive applies to risks from noise as a result of activities at work, with the intention of decreasing hearing risk in relation to the measures now in force in the member states. A daily noise exposure limit value of 87 dB(A) $L_{EX,8h}$ is specified; this is the time-weighted average of the noise exposure level over a nominal 8 h working day, accounting for all noises at work including impulsive noise. This limit value applies to sounds at the ear, ‘inside’ any hearing protection worn by the noise-exposed worker. There are additional provisions concerning peak acoustic pressures, action levels and weekly averages, which need not be considered here.

Member states of the EU are required to bring into force suitable laws or regulations to comply with this Directive within 3 yr of its adoption. The UK Health & Safety Executive is already considering new noise-at-work regulations, to meet the duties set out in the Physical Agents Directive (Noise).

**A FINAL COMMENT**

This reviewer found the 1971 BOHS noise standard both antique and modern at the same time. The idea of quantifying damage risk has fallen into disuse. Noise regulations no longer specify a degree of hearing loss acceptable in a fraction of the noise-exposed population, after a lifetime of noise. Present
thinking is now based upon warning and action levels which guide the safety practitioner (and the employer) from virtually no risk to hearing, up to a small but residual risk, on the basis of daily average noise exposure. These present-day ideas may be seen in the 1971 noise standard.

A fortunate and early exchange of ideas between the NPL and the BOHS brought into practice new concepts of noise specification for hearing conservation purposes. These concepts now dominate European and most international practice.

REFERENCES


