NOISE HAZARD IN THE DIVING ENVIRONMENT

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INTRODUCTION

Excessive noise in the workplace is a well known cause of deafness, and many thousands of claims for industrially-caused deafness have been successfully fought through the courts. Noise induced hearing loss is the single biggest source of claims for industrial injury in the United Kingdom. The exposure of workers to noise in the workplace is legally controlled in the UK by the Health and Safety at Work Act 1974, and specifically under the Noise At Work Regulations 1989 [1], hereinafter abbreviated to NAWR. The latter have been amended by the issue of a European Community Directive [2].

Noise Dose as a limit. The NAWR are based on the concept of a "noise dose". Briefly, this is based on the idea of equal sound energy; that a sound of a given level for a given time is equally hazardous in respect of hearing damage as one of say half of the noise power for twice the time, Two noise dose limits are adopted in the NAWR, of 85 and 90 dB at which different actions are required, but this has now been transcended by European legislation [2] which specifies a single sound dose limit equivalent to 85 dB(A) re 20 μPa for a "working day" which is defined as being over eight hours (all levels in this report are referenced to 20 μPa). Noise doses at a level greater than this have been shown to cause irreversible hearing loss. Where the exposure is for a shorter time than eight hours, the equal energy concept allows an increase of level of 3 dB for every halving of time of exposure, for instance, to 88 dB(A) for four hours or 91 dB(A) for two hours, Conversely, where the exposure is over a longer period of the day, as in saturation diving, the noise level must be lower, and over a twenty four hour period a level of about 80 dB(A) is the maximum permissible. In practice, the noise levels encountered in the workplace vary during the day, but the equal energy concept is still applied and in practice the dB LAeq - the "averaged" level, or level of a constant noise of equal energy - is calculated, and used in the same way. Reference [1] lists the rather involved method by which noise dose may be estimated, and there are now a wide range of sound level meters that provide this function for measurements taken in air.

While there is no physical reason for this scale being adopted, it has been found to relate well to the degree of hearing damage caused in many thousands of cases of industrial deafness and hence it has been universally adopted in legislation at European level.

CATEGORIES OF NOISE EXPOSURE

There are three main categories of occupational noise exposure to divers.

I. They may be exposed to noise while in transit to the place of work, for example while in flight in a helicopter to a diving platform.

2. They may be exposed to noise on the platform while at atmospheric pressure, say while in the Saturation or Dive Control rooms, or while working near to the atmosphere control plant.

These first two categories of exposure are well understood, and the means exists to evaluate the hazard.

3. They may be exposed to noise under hyperbaric conditions, while diving, during periods in saturation in living chambers, or while compressing or decompressing

This third category may be further divided into three sub-categories. These are:

3.1 Exposure to noise during non-diving periods in hyperbaric facilities, typically during rest periods, compression and decompression, bell duty etc..

32 Exposure to noise in diving dress with the ear "dry", that is, in a demand or free-flow helmet.

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3.3 Exposure to noise in diving dress with the ear "wet", for instance with SCUBA equipment or with a bandmask.

This third category is more poorly understood as a result oF

1. The incomplete knowledge of the behaviour of hearing at pressure.

2. The difference in sensitivity of the ear when "wet".

3. The relative lack of information concerning the self-noise of diving helmets (that is, the noise that they generate internally).

4. The relative lack of information concerning the noise generated by tools that the diver operates, and how this noise couples into the diving headwear and ear.

Saturation divers at pressure are at additional risk from noise because, unlike the industrial worker, they are exposed to the noise at their workplace for 24 hours a day. If the criterion of 85 dB(A) as a limit for eight hours exposure a day is modified by the equal energy rule, it suggests that any level of exposure over 80 dB(A) may be hazardous.

The noise exposure of personnel during diving has not in general received much attention, despite strong indications that divers become deaf as a result of their occupation. There are probably three main reasons for this.

First, it has not been possible until recently to accurately measure hyperbaric sound, and hence no evaluation of this component of noise exposure has been possible. Second, it has been considered to be a minor hazard in respect of the other hazards intrinsic in diving. However, the safety of diving has been greatly increased in recent years and consequently the relative importance of noise has increased. Third, there has been little information available as to the sensitivity of hearing in the hyperbaric environment, and hence as to the significance of noise. While this is now an active topic of research, information that is currently available indicates that the ear in hyperbaric air is probably slightly less sensitive to sound. While some authors claim that a small degree of extra immunity to noise is conferred by this effect, this is yet to be demonstrated, and until better evidence is available it is prudent to apply the existing criterion without alteration. The Noise At Work Regulations in addition do not recognise diving as a special case, and compliance with the legislation requires this.

A NOISE AUDIT: IS THERE A PROBLEM?

In order to understand whether noise is a problem in the diving environment a Noise Audit may be performed, which estimates or measures the noise to which a diver is exposed, and compares it to the criteria of the NAWR to determine if the level is hazardous. An audit may be performed by taking a set of measurements of hyperbaric and atmospheric noise in an operation in the field. The measurements may then be analysed and interpreted to present a balanced picture of the significance of noise to the divers involved in the operation. In air, audits of noise are sometimes performed by attaching a small noise dose meter to an employee, and logging the noise dose received as he performs his work over the course of a day. This is usually not feasible in the case of a diving operation, and hence the total noise dose to the divers must be estimated by measuring the noise during representative periods of the diver's activities, and calculating from the known pattern and duration of activities the estimated daily noise dose.

Is there a problem? In order to indicate the typical exposure of divers to noise during a diving operation, this paper presents an audit that indicates the typical exposure of a North Sea saturation diver. It is based on levels of exposure to noise which are typical of those measured by the authors. These have been split into the categories of

1. Noise external to hyperbaric facilities, including noise during transit to the facility, and

2. Hyperbaric noise, in particular during rest periods and work in the bell.

NOISE IN THE FACILITY EXTERNAL TO THE HYPERBARIC ENVIRONMENT.

The most straightforward way by which divers can be exposed to noise is atmospherically, while waiting to compress, after decompression, while working in areas adjacent to the diving installation or while in transit to and from the vessel.

TRANSIT

The diver is exposed to noise while travelling to the rig, typically while boarding the helicopter for transit. In the author's experience, the wearing of hearing protectors is indiscriminate, although in flight the communication headphones provide protection from noise. The levels of noise from helicopters during boarding may exceed 110 dB(A), and hence noise during transit cannot be excluded at the moment as a contributor to divers' noise doses, although it should be commented that since a typical tour of duty for a diver would be of the order of a fortnight or more this exposure is not a regular feature of their employment.

NON-HYPERBARIC NOISE

Typical levels of noise in the areas surrounding the hyperbaric facilities range from 70 dB in dive and saturation control rooms up to 90 dB or more in plant, gas storage and environmental control rooms.

For the case of members of the Life Support Staff, who might be exposed to these levels for substantial periods of time, there is a considerable risk of excessive exposure to noise and hence it is important that at a minimum hearing protectors are provided in such areas. It is less likely that off-duty divers would spend a significant period of time in these areas. Nevertheless, the noise doses accumulated during periods spent in these areas by divers will "top up" the exposure to other sources of noise.

HYPERBARIC NOISE EXPOSURE

Divers are exposed to noise in living chambers, in the diving bells, and as a result of the self-noise of diving equipment.

NOISE DURING REST HOURS

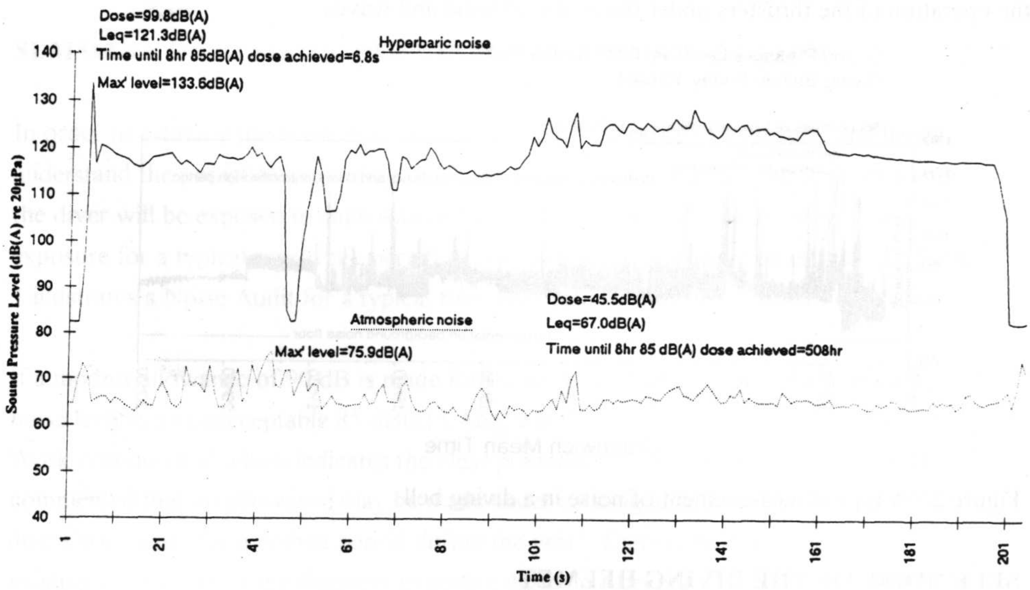
In living chambers, in addition to a background of noise caused by the atmospheric control, principally the carbon dioxide scrubbers, other periodic events such as inflow of gas for topping up cause higher levels of noise. Levels may be recorded for individual events and then a typical pattern of exposure developed by reference to diving record sheets. The total noise dose may thus be estimated. Similarly, while it may not be possible to record during actual compression and decompression of divers, it is often possible to measure the noise levels during a test compression and hence evaluate the total noise dose caused by it.

Typical levels of noise of 105 dB or more may be recorded while pressing divers down to their working depth. In the context of noise dose, an acceptable daily noise dose would be reached in about 5 minutes or so at this level of noise. Noise levels created by compression tend to depend on the differential pressure between the reservoir and the chamber, and are significantly higher (typically by 10-20 dB) at the start of compression, on leaving the surface, than at the end of compression at working depth where this measurement was made. At normal rates of descent, a working depth of say 250 feet of seawater (76 metres) would take 25 minutes to reach, so that the diver would receive at least five daily noise doses during compression. Noise exposure during compression may therefore represent a significant hazard to hearing.

Figure 1 illustrates a typical noise time history illustrating the sound pressure level inside and outside a compression chamber versus time in seconds during a compression from surface to 50 metres. It may be seen that although the external 9atmospheric) noise level is low, the internal (hyperbaric) noise level is high, at 120-125 dB, and a full daily dose of noise is achieved in 7 seconds or so at this level of noise

Decompression is generally much quieter, since the noise from the flow of gas is carried out with the exhausting gas.

Figure 1: Noise during a typical compression



HYPERBARIC NOISE IN DIVING BELLS.

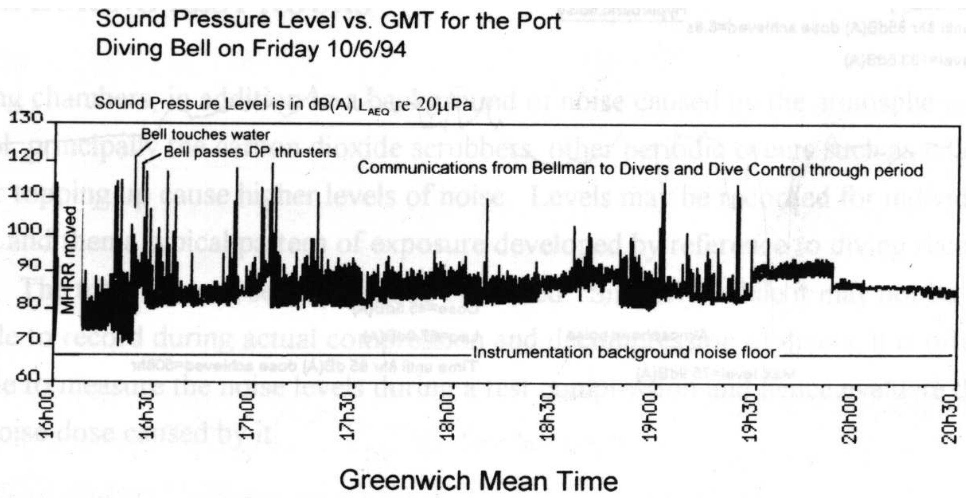
Measurements of noise in diving bells have indicated that significant levels of noise occur as bells become immersed in the water, possibly due to the transmission of external noise into the bell. Conversations with diving support staff indicate that during periods of poor weather, it is commonly difficult to hear the bellman above the noise created in bells by the ship's DP system.

The author has measured levels of 90 dB and above in submerged bells. This is substantially above the provisions of the Noise at Work Regulations and indicates a significant potential for long-term hearing damage, especially in view of the prolonged periods the bellman may spend in the bell.

Figure 2 illustrates the noise in a diving bell during a typical period of deployment.

It may be seen that the level of noise in the bell rises substantially as the bell touches the water. A second rise in level occurs when the bell passes the dynamic positioning thrusters. Changes in noise level during the work period may be attributed to changes in the operation of the thrusters under the action of wind and waves.

Figure 2: A typical measurement of noise in a diving bell.



SELF NOISE OF THE DIVING HELMET

Noise is created within the diving helmet of the diver due to the flow of gas into the helmet, flow of gas out of the helmet, by the communication system, and by any tools the diver operates. The author has measured levels of between 90 dB and 115 dB in a typical North Sea helmet. While some manufacturers are now spending strenuous efforts reducing the noise from their diving equipment, prompted to some degree by the European Personal Protective Equipment Directive, much of the existing equipment is extremely noisy. This situation will no doubt continue for some time.

It should be commented in this audit no allowance has been made for noise penetration into the diver's helmet from power tools or equipment used by the diver, or on the diving vessel. Measurement made by the author have indicated that in the case of the onshore air diver use of noisy hydraulic or pneumatic tools may constitute a considerable proportion of his time underwater. Conversations with North Sea divers indicate that the deep sea use of power tools is generally rather limited. However, where these are used it is strongly suggested that they should be evaluated as a source of potential hearing hazard.

SUMMARY OF RESULTS, DISCUSSION AND INTERPRETATION

In order to estimate the noise dose delivered by each category of exposure, and hence understand the potential for hearing damage, it is necessary to know the time for which the diver will be exposed to each source. The total time spent in each category of exposure for a typical two-week period of duty for a diver may then be estimated. Table I illustrates a Noise Audit for a typical two week tour of duty for a North Sea diver.

If a modest allowance of 90 dB is made for the level within the helmet, the averaged noise level is an unacceptable 85 dB(A) LAeq, which considerably exceeds the noise at Work criterion and which indicates the clear potential for hearing damage. It should be commented that no allowance may be made under existing legislation for the case of divers who work for a limited period during the year. There is no conclusion from existing information that infrequent exposure during a working year reduces the severity of the effects of noise and hence calculations of noise dose are made for the purposes of a noise audit as though the diver would be continuously exposed through his working year.

Table 1: a Noise Audit for a typical North Sea diver's tour of duty.

	Level dB(A)	No. of hours	Percentage of hours	Percentage of total dose
Compressing	95	1	0.3	3.0
Living Ch., active	80	112	33.3	1.0
Living Ch., asleep	70	112	33.3	10.5
Bell Duty	90	30	8.9	28.3
Diving	90	60	17.9	56.5
Bell checks etc.	75	21	6.2	0.6
TOTALS		336	100	100

Total equivalent level 88.4 dB(A) $L_{EP\,dn}$ re 20 μPa

It is interesting to note the relative contributions from the classes of exposure. While the diving occupies less than 20% of the diver's time, the noise audit indicates that nevertheless it contributes some 56% of the diver's total noise dose, due to the relatively high levels measured, and despite the fact that no allowance has been made for noise within the helmet caused by the operation of tools. However, even if the helmet noise is completely removed from the audit, the noise level is still unacceptable due to the contributions from other sources. The next most significant noise source is the diving bell, contributing 29% of the total noise dose. These two results indicate that, prima facie, it is noise during active work which is the most significant contributor to diver's noise doses. However, none of the sources of noise discussed herein may be regarded as of insignificant level.

CONCLUSIONS

In summary:

1. The Noise Audit herein presents typical noise levels, durations and corresponding estimated noise doses received by a diver during a typical two week tour of duty. The estimated averaged noise level is 85 dB(A) LAeq

2. On the basis of this, divers engaged in tiffs kind of diving operation may be exposed to noise levels well in excess of the limits defined as acceptable in the Noise at Work Regulations 1989.

3. The estimated time integrated noise dose caused simply by compression to depth of divers may in itself exceed the NAWR limits depending upon the working depth and hence the compression time. Divers compressing to 125 metres of seawater may exceed their maximum allowable daily noise dose by a factor of five times.

4. The overall picture presented by the Noise Audit does not indicate traumatic noise exposure caused by noise insults, but does indicate a high background of noise that the divers are exposed to over 24 hours a day which is at levels that are known to cause deafness in the long term.