NOISE ASSESSMENT AND HEARING CONSERVATION OF MILITARY MUSICIANS

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1 INTRODUCTION

Assessments of musicians employed in orchestras show that some musicians, in particular the brass and woodwind, are exposed to noise that could damage their hearing. Studies made of the noise exposure of military musicians, (predominantly brass, woodwind and percussion) show that their exposure can exceed the limits set in the Noise at Work Regulations. The issue was highlighted in 1999 by an audit covering the implementation of the Noise at Work Regulations within the MoD. This paper considers and summarises some of the actions taken by the MoD to address the problem, with particular emphasis on the exposure of members of a Royal Air Force Band and the issues surrounding the provision of personal hearing protection.

2 BACKGROUND

2.1 Exposure of Musicians

Measurements show that military musicians are exposed to high noise levels when rehearsing and performing. In some cases, high levels were measured when musicians practised alone in a good practice room. Service personnel are employed 24 hours per day, 365 days per year and therefore military musicians are “at work” whenever they practice, rehearse, or perform on behalf of the MoD. This means that their “exposure times”, as defined by the Noise at Work Regulations, are usually greater than those of their civilian counterparts.

2.2 Measures to Address High Exposure

The Army has the most bands and employs the majority of the 2,500 Service musicians. Within the Army, the high noise exposure of musicians was identified some years ago and work has been carried out by, and on behalf of the Army, to try to address the problem. For example, improving band practice rooms, as a significant proportion of a musician’s exposure is due to rehearsing. Following the noise audit, the Army took the lead by setting in motion three principal measures:

- Surveys of all band practice rooms
- A trial of personal hearing protection
- The introduction of annual audiometry for musicians

2.2.1 Band Practice Rooms

Many of the Services’ band practice rooms are not purpose built and the acoustic properties of some of them exacerbate the noise hazard. Surveys of these rooms have identified where remedial work is required and where such work will be effective, and a prioritised improvement programme has been instigated. However, exposure surveys made in good practice rooms show that improvements to the practice rooms alone are not enough to reduce exposure sufficiently.

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3 ASSESSMENT OF EXPOSURE

3.1 Royal Air Force Trial Band

A noise assessment was carried out for one of the Royal Air Force's concert bands. There are 35 members of the band playing brass, woodwind and percussion instruments. The band does not rehearse in a purpose built room, however, the structure of the room is such that it is suitable in terms of size and layout (Figure 1). The varying heights of the ceiling and heavy drapes placed across all the windows ensure much of sound energy created is prevented from reflecting back towards the band members and the room has a short reverberation time. In an attempt to manage the risk, the band had already procured a number of barriers that are used during rehearsals, but not performances.

Figure 1 – Layout of Band Room

Much of the workload of musicians is unpredictable but typical exposure is made up of 20 routine rehearsals, 2-3 seated concerts and 2 marching concerts per month. Additionally, small groups of musicians may form ensembles such as quartets, jazz bands, etc and perform at functions.

A routine rehearsal will last for 2½ hours excluding breaks. For the remainder of their working day, the musicians may spend some time on individual practice in addition to other non-music related duties.

3.2 Assessment Methodology

Seven Bruel & Kjaer (B&K) Type 4190 microphones were located amongst the 35 musicians during a standard rehearsal. Six were at fixed sites monitoring the bandmaster (conductor) and the following sections; percussion, bass saxophone, flute, trumpet and trombone. The seventh was used as a roving microphone to cover the remaining sections, e.g. French horns. Audio signals from all channels were recorded simultaneously to a GENEX magneto-optical disk recorder.

Samples were taken with the band in their usual rehearsal seating arrangement, with the barriers in place. Measurements were also carried out without the barriers to determine the effectiveness of the current controls. Finally, an assessment was made with the band in a close-up formation to simulate a typical performance formation. This was necessary as they are more likely to perform in church halls and school gymnasiums, than spacious concert halls.

Due to concert schedules it was not possible for the band to repeat the same piece of music a number of times in each of the three situations (with barriers, without barriers and close-up formation). Therefore, a subjective assessment was made of the greatest influences on a musician's exposure based on the volume of their own instrument, that of surrounding instruments and the volume of the overall band. A number of samples ranging from "very quiet" (*pp*) to "very loud" (*ff*) sections were averaged to obtain an estimate of the equivalent level ($L_{Aeq,t}$) for each scenario. These were combined with average rehearsal and concert times to obtain an estimate of daily personal exposure levels ($L_{EP,d}$).

3.3 Results

It was found that the $L_{EP,d}$ levels consistently exceeded the first action level and in many cases the second action level as well. It should be noted that these are an over-estimate of the actual exposure as they assume that the individuals and their neighbours were playing their instruments for the whole rehearsal time. In reality, time is spent listening to the conductor, or with small sections of the band rehearsing parts of the repertoire. Additionally, in most pieces of music there are likely to be 'rest' periods for sections of the band. Actual "playtime" of each instrument was not determined as part of this assessment. However, even if musicians are only playing for half of the total rehearsal time, exposure levels are not reduced sufficiently.

Removal of the barriers reduced the daily dose by up to 3dB for most sections, indicating that the current measures were at best ineffective and in some cases exacerbated the situation. In concert formation, as expected, the dose increased due to the reduced distance between sources and receivers.

4 REDUCTION OF NOISE EXPOSURE

4.1 Control at Source

Clearly, a band cannot make music without their instruments and so removing the sources is not an option. Muting the instruments will affect tone (although this process is used to obtain a desired effect for certain pieces of music). Requesting the band to rehearse more quietly is met with derision and it has been shown that there is little difference in L_{Aeq} levels between pieces considered to be "quiet" and "loud". It is also a fact that they need to rehearse at the volume to which they are expected to perform, in order to maintain and ensure the correct balance between the musicians. Obviously, during concerts and public performances the pieces must be played to the levels anticipated by the composer and expected by the audience.

4.2 Control in the Transmission Path

The short reverberation time and design of the rehearsal room make this a good rehearsal environment. The majority of exposure is caused by direct, rather than reverberant, sound. The main sources for an individual are their own instrument and those of their immediate neighbours.

The survey showed that the existing barriers used by the band are inefficient. This is not surprising given the design shown at Figure 2. The baffles make exceedingly good music holders and the trumpet and, in particular, trombone sections merely point the bells of their instruments through the gap underneath!

Figure 2 – Existing Barrier for Brass Section

It may be that correctly designed and installed barriers would have a positive effect in reducing exposure for an individual. However, such a system may have adverse effects, such as blocking the line of sight to the conductor, affecting the overall sound of the band and leading to an increase in exposure from an individual's own instrument. Additionally, the location of the barriers is critical for maximum effect and if removed during, or between, rehearsals, they are unlikely to be repositioned in the exact same location. When playing, musicians may position themselves so that they negate any positive effects.

4.3 Reducing Exposure Time

The fluctuation of workload means that daily exposure levels vary widely. However, adopting weekly averaging of exposure does not give a reduction of exposure sufficient to meet the requirements of the Regulations. Limiting formal rehearsal time would be likely to increase the time spent by a musician on individual practice and as this still 'counts' as Noise at Work exposure,

would have little effect on reducing overall exposure. For many musicians, noise levels are such that, meeting exposure limits by reducing exposure time would limit total allowed playing time to an unacceptable duration.

The only reasonable option appears to be the use of hearing protection. The DLO, on behalf of the Army, undertook to trial personal hearing protection to assess its effectiveness and acceptability for musicians.

5 PROVISION OF HEARING PROTECTION

5.1 Requirements of Hearing Protection for Musicians

Musicians require hearing protection that provides sufficient attenuation to protect against harmful noise, whilst allowing them to hear the sound produced by all of the instruments within the band sufficiently accurately, to enable them to blend in their own performance. To meet this requirement, the attenuation provided should be the minimum necessary to protect hearing and uniform across all frequencies. Measurements suggest that the hearing protection should provide around 15dB attenuation. Ideally, in addition, the hearing protection should be unobtrusive for use on ceremonial occasions. For this reason earmuff type protectors were not considered to be suitable.

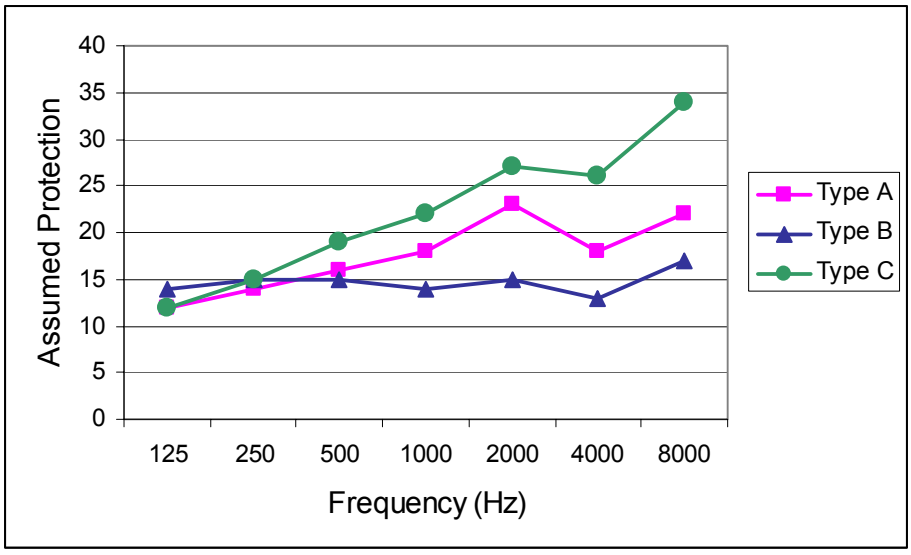
5.2 Hearing Protection for the User Trial

Three models of reusable earplugs, all meeting the requirements of European Standard EN352-2, were selected for the user trial. These were:

- Type A Universal fit earplug. Flanged, silicone earpiece "Flat" attenuation filter
- Type B Custom moulded insert. Soft silicone earpiece. "Flat" attenuation filter
- Type C Custom moulded insert. Hard acrylic earpiece. Pre-set attenuation filter

The assumed protection of each of the devices is shown in Figure 3. It can be seen that device B most closely matches the suggested requirements.

Figure 3 – Attenuation Characteristics of Trial Earplugs



5.3 User Trial

5.3.1 Hearing Protection Trial Band

A 32-member Army band was nominated to trial the earplugs. A study of the exposure of these musicians showed that the provision of good rehearsal and practice facilities was not enough to reduce noise exposure during rehearsals to safe levels and that hearing protection was required. The mean age of the group was 31 years. Results from the 32 musicians' most recent audiograms showed that none of the musicians had a hearing level anywhere near that indicating a social problem. (Individuals were not identified.)

5.3.2 Pre-Trial Briefing

At the start of the trial, the trials team and the participants met to exchange information, views and ideas to ensure that the trial could run effectively and produce meaningful results. The topics covered included:

- Effects of noise exposure on hearing
- Noise exposure of the band
- Requirements of the Noise at Work Regulations
- Hearing levels of musicians, including hearing levels within the band
- Personal hearing protection, in particular the items chosen for the trial
- The trial directive
- The participants' part in the trial
- How to complete the trial diary & questionnaire

Manufacturers provided the triallists with information on the use and maintenance of the earplugs.

5.3.3 Trial Procedure

Each member of the band was provided with the three trial devices and asked to wear each type for one third of the three-month trial period. However, if difficulties arose with a particular item, subjects were instructed that they could extend the use of a preferred item to cover that portion of the trial period. Subjects were asked to wear the hearing protectors in all noise situations. Each triallist was asked to keep a diary of his or her use of the devices throughout the trial and use the information to complete a questionnaire at the end of the trial.

5.4 Outcome of User Trial

5.4.1 Impairment of Musical Performance

With few exceptions, the triallists considered that the devices impaired their musical performance to an unacceptable degree. (Table 1) The musicians were unable to hear the true sound of their own instrument and found that they were unable to judge tuning, or intonation. The musicians had difficulty when trying to blend their performance with the whole, because they could not hear other sections of the band.

Table 1 – Q. Did any of the devices impair musical performance?

Ear Plug	Wholly Acceptable	Largely Acceptable	Borderline	Largely Unacceptable	Wholly Unacceptable
% of responses					
A	0	7	24	31	38
B	0	0	3	45	52
C	0	0	0	34	66

5.4.2 Other Reported Problems

Apart from the impairment of musical performance, other problems encountered included:

- Inability to hear instructions
- Pain when blowing instruments
- Headaches and nausea
- The sound of footfall through the body when marching

The inability to hear instructions was considered to be unacceptable for performances, especially when the musicians were required to march, or in sensitive situations such as funerals, or memorial services.

5.4.3 Overall Acceptability

When considering the overall acceptability of the devices, the majority of the triallists judged the devices to be wholly, or largely unacceptable. (Table 2) Device B, with the minimum and most uniform attenuation, should, in theory, have been found to be more acceptable than the other items trialled. However, this was not found to be the case. Physiological issues, such as the transmission of sound through the bone structure, appear to outweigh those of the attenuation. Marching bands have a particular problem of sound transmitted through the body from footfall.

Table 2 – Q. How would you mark the trial devices for overall acceptability?

Ear Plug	Wholly Acceptable	Largely Acceptable	Borderline	Largely Unacceptable	Wholly Unacceptable
			% of responses		
A	0	7	14	21	59
B	0	0	10	21	69
C	3	0	14	17	66

The loss of enjoyment of playing music when wearing earplugs was recorded in diaries and some musicians said that they were prepared to resign, if the use of hearing protection became compulsory.

5.5 Conclusion

The answers on the questionnaires and entries in the diaries revealed significant problems with the use of earplugs and none of the items trialled were found to be acceptable. Meeting the attenuation requirements is not sufficient for the hearing protection to be found acceptable. Other factors, such as occlusion of the ear canal, have a significant influence on acceptability.

These results are in agreement with findings from studies carried out on the use of hearing protection in civilian orchestras. The authors have been unable to find any orchestra where all, or most, of the musicians use plugs all the time. In most cases usage is limited to certain sections of the orchestra, usually the strings, and the protection is only worn when the musician perceives the music to be “loud”. Brass and woodwind players generally find earplugs unacceptable.

6 FUTURE WORK

It has been demonstrated above that, so far, the MoD has been unable to provide a suitable ‘one size fits all’ solution to the problem of exposure to noise at work for military musicians. A number of projects are still either underway, or planned to be undertaken, to enable the MoD to reduce the exposure of military musicians.

Work on improvements to rehearsal and practice rooms is continuing. The aim is to minimise reverberant sound to the lowest acceptable level.

The outcome of the hearing protection trial shows that there are many factors to be addressed in order to develop an acceptable solution. One area of work is an investigation into the effectiveness of modified filters (in earplugs) to prevent the pain experienced due to pressures involved in blowing instruments.

The views expressed in this paper are based on the professional views of the authors and may neither reflect the MoD's view, nor be binding upon the Ministry.