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THE USE OF QUESTIONNAIRES IN INDUSTRY TO DERIVE L_{Aeq}

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INTRODUCTION

The acceptance of the hypothesis that the hazard to the hearing represented by industrial noise can be related directly to the L_{Aeq} of the sound exposure has led to attention being directed away from the level of noise emitted by the machine, and towards the acoustic energy received by the employee over a working day. Considerable pressure is now on the Occupational Hygienist to produce L_{Aeq} ratings for each employee working in noise. This pressure has been exacerbated by the requirement given within the noise regulations proposed by the Health and Safety Commission that an employer should monitor the personal sound exposure of employees with L_{Aeq} ratings of 105 dB(A) and above, (Health and Safety Commission 1981).

This task may be possible if all employees work in the same, unchanging noise environment. However, if each individual is subjected to noise differing from that affecting his colleagues, and changing irregularly according to the work being processed, the job of measuring the sound exposure level of each employee in any sensible manner becomes difficult, very time consuming, and expensive. The Occupational Hygienist must be willing either to follow each individual for a representative portion of the working shift measuring sound exposure with a sound level meter and stop-watch, or purchase a large number of personal sound exposure meters.

The objective of the work described within this paper was to circumvent this problem by developing a questionnaire technique capable of providing an estimate of employee sound exposure. The location chosen was a manufacturing workshop which possessed a difficult noise environment in which to measure employee L_{Aeq} ratings, involving as it did noise emitted from hand held tools used intermittently. It was also required that a full noise survey be completed in the workshop, and an examination be made of the viability of performing half-shift instead of full shift sound exposure measurements as a method of reducing the time taken to complete a sound exposure survey.

METHOD

The workshop selected for the study embraced a variety of trades and included an Electrical Department, a Fitting Shop, a Machine Shop and Heavy Fitting Shop, a Smithy, a Plate and Girder Shop, and a Wagon Shop. Approximately half of the 200 employees within the Workshop were included in the study.

Noise measurements were undertaken in the Workshop using three types of instrument. Firstly, personal sound exposure meters were issued to various individuals to measure their noise exposure. Secondly, the noise emitted by various tools during various operations were measured with sound level meters at a position close to the ear of the employee. Finally, stationary noise level analysers were positioned in strategic positions to measure the general level of background noise. Five personal sound exposure meters were used. One of these was a Computer Engineering Ltd. (CEL) type 139, whilst the remainder were CEL type 122. The sound level meters employed were Brüel and Kjaer (B & K) types 2203 and 2218. The noise level analyser was a B & K type 4426. All instruments were of precision grade, except the CEL 122 personal sound exposure meters, which were industrial grade. However, the frequency response of these meters was checked, and found to be correct to within ± 1.75 dB over the frequency range 100 Hz to 6 kHz. The calibration of all instruments was checked regularly throughout the measurement periods.

The workforce was divided into seven activity groups, and a short questionnaire was devised for each. Designed to be completed by the employee, the responses indicated which tools had been used over a particular period, and the length of time for which these were operated. Data from the questionnaires were fed into a computer program which was written to combine the typical noise levels generated by the tools, obtained earlier in the study, with the time for which these were used to yield a calculated L_{Aeq}.

During the survey of the Workshop, 94 questionnaires were completed, and 58 usable measurements of L_{Aeq} were obtained from personal sound exposure meters, 16 of which were full shift measurements. On these 16 occasions the two activities were overlapped in that employees both carried a personal sound exposure meter for a whole shift, and completed a questionnaire, thus permitting comparison of calculated and measured L_{Aeq}. Additionally, the sound exposure meters used to obtain the full shift measurements were also read at the half-shift point, on as many occasions as possible, to provide data by which the extensive use of half-shift sound exposure measurements made earlier in the study could be investigated.

RESULTS AND DISCUSSION

Measurements from the stationary noise level analysers indicated that it was unlikely that the measured personal sound exposure levels would have been affected by the general background noise by as much as 1 dB, even under the least optimum conditions. However, locally occurring high levels of noise could obviously affect the noise dose of employees working in the vicinity.

A scattergram was constructed and is given in figure 1, showing the half-shift L_{Aeq} levels plotted against the full day L_{Aeq} values. A linear regression was calculated from the 14 available paired values which resulted in the equation:

$$y = 0.82x + 17.2 \qquad (1)$$

Although this equation indicates that the (x) and (y) parameters do not have a theoretically perfect 1:1 relationship, it can be seen that within the L_{Aeq} range 90-100 dB(A) the actual relationship is within ± 1 dB of the 1:1 ideal. Thus it can be assumed that in this working environment, half-shift noise dose measurements provide an adequate description of the full-day exposure.

Figure 2 shows the scattergram constructed from the 15 available pairs of data points representing the calculated and measured L_{Aeq} levels obtained from different employees. A linear regression resulted in the equation

$$y = 1.09x - 10.94. \qquad (2)$$

The ideal relationship between the two variables is also shown on figure 2, and indicates that on average the L_{Aeq} values calculated from the questionnaire responses underestimate the measured L_{Aeq} by between 2.75 dB(A) and 1.75 dB(A) over the range 90 dB(A) to 100 dB(A), respectively.

This process of underestimate by questionnaire can also be seen in the two histograms plotted in figure 3 which include the data from the 94 question-naires and 58 usable L_{Aeq} measurements. Displacing the histogram derived from the questionnaires several decibels to the right would cause the histograms to coincide more accurately.

It might be argued that a second order polynomial, or 's' shaped curve might provide a better fit to the data shown in figure 2 than was provided by the linear regression. However, it was thought that the number of data points was insufficiently large to warrant this procedure, and that the conclusions would remain the same over the noise range of greatest interest, 90 dB(A)-100 dB(A). The only significant changes caused by fitting the alternative curve would occur at low and high intensity exposure levels. The agreement between the calculated and measured values would be made worse at low exposure levels, and better at the high levels.

The underestimate of L_{Aeq} by the questionnaires could be a result of one, or a combination of several, factors. It is possible that the sound energy reach-ing the lapel worn microphone of a personal sound exposure meter is greater than that arriving at the microphone of a sound level meter held close to the ear of an exposed employee. Employees could have underestimated the length of time for which they were using the particular tool, although it is interesting that the ideal and regression lines shown in figure 2 do not lie parallel, but appear to converge at the higher L_{Aeq} levels. If underestimate of the time of exposure was the whole answer to the discrepancy between the measured and calculated levels, then the ideal and regression lines would remain parallel. The conver-gence of the two lines at the high sound exposure levels could be explained, in part at least, if the noise made by a colleague in the immediate vicinity was contributing significantly to the sound exposure of employees wearing a meter. This effect would probably decrease in significance as employee L_{Aeq} rose, for it is likely that the higher L_{Aeq} values would be dominated by the noise generated by the employee himself, hence causing the ideal and regression lines of figure 2 to converge at the higher levels. It was noted on 42 of the 94 questionnaires completed that these particular employees had been close to noise sources not generated by themselves during the period covered by the question-naires.

CONCLUSIONS

It is felt that this study has shown that questionnaires do have a place in the estimation of employee L_{Aeq}, providing that an allowance for underestimation of approximately 3 dB is made when considering the results of such an exercise.

It is not being suggested in this paper that questionnaires should replace personal sound exposure meters, but rather that the questionnaire approach represents an economical method of working on a large scale to find employees in a workforce who may be at risk. Large scale questionnaire surveys can be completed easily and swiftly on as many occasions throughout the yearly work cycle as is necessary to obtain a sensible measurement of employee L_{Aeq}. They may present the only economical method by which the employer can contain within manageable limits the necessary surveys of employee sound exposure.

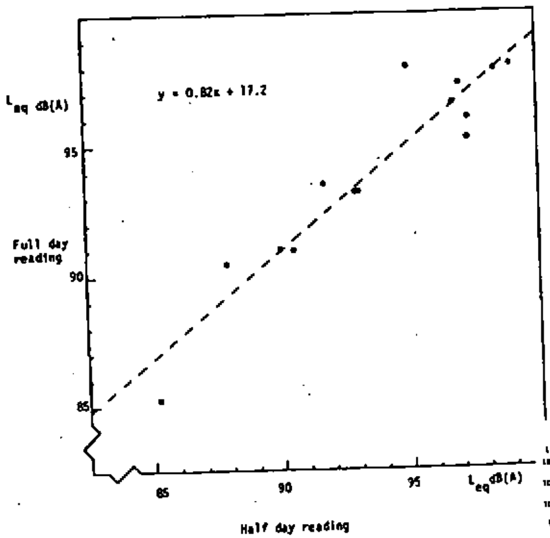

Figure 1. The correlation of full and half day dosemeter readings

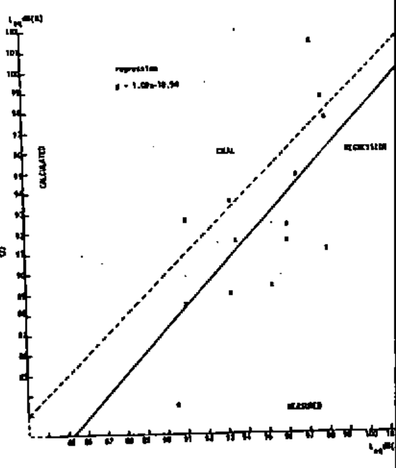

Figure 2. Correlation between measured and calculated L_{Aeq} values

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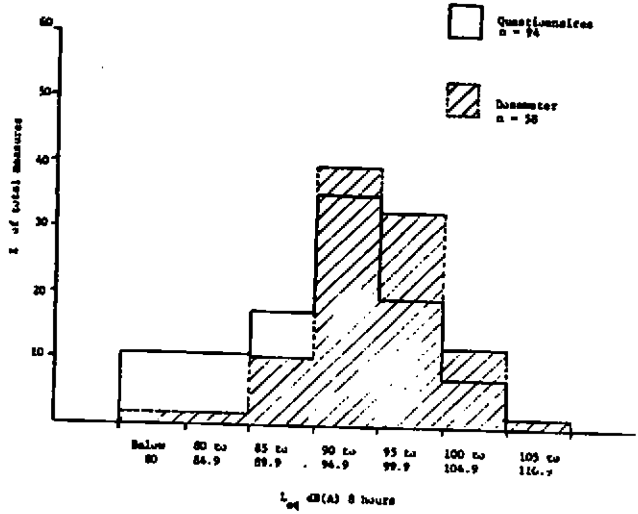

Figure 3 Showing the distribution of noise dose across workshop activities, as measured using two different methods.

REFERENCE

Health and Safety Commission "Protection of the hearing at work" 1981 Proposed noise regulations. HMSO, London.

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