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MEASUREMENT OF HAND-TRANSMITTED VIBRATION FROM A BEEF-SPLITTING SAW

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INTRODUCTION

The occurrence of hand-arm injuries due to the use of certain vibrating powered hand-tools is well documented [1], [2]. The most reported cases have involved the use of a) chain saws, b) grinders and other rotary tools, c) percussive metal working tools and d) pneumatic hammers and drills used in the mining industry. Several types of injury are associated with long-term exposures to hand-arm vibration, viz,

a) Circulatory disorders - e.g. vibration white finger (VWF)
b) Bone and joint disorders - e.g. bone cysts
c) Neurological disorders - e.g. nerve conduction velocity
d) Muscle disorder - e.g. atrophy
e) Other general (whole body) symptoms

The best observed and most widely investigated of these is white finger (or Raynaud's Phenomenon); there are many causes of this complaint, one of which is due to occupational vibration exposure i.e. vibration white finger. Symptoms initially include tingling and numbness of the finger tips, followed by blanching. Attacks typically last for half an hour and are followed by hyperaemia and associated pain. The attacks seem to be precipitated during cold, damp conditions, such as would be encountered in a slaughterhouse.

From enquiries made, it would appear that there were no reported investigations into the degree of vibration transmitted from a beef-splitting saw to the hand-arm system of the operative. Furthermore, incidences of vibration white finger due to this activity are not covered by the industrial injuries provisions of the Social Security Act 1975 and, therefore, benefit is not payable.

DESCRIPTION OF THE OPERATION

The subject of the test was a Kentmaster Model 203 Beef-Splitter which is typical of the type of instrument used in a slaughterhouse. The saw is used to split the carcasse longitudinally through the vertebral column whilst the body is suspended from the ceiling. The angle of attack of the saw varies considerably during the sawing process which results in the operative moving his hands frequently over the handle in order to maintain grip and exert the necessary force. The blade of the saw describes an elliptical pattern, although most of the movement is along the longitudinal axis.

STANDARDS FOR THE EVALUATION OF HAND-ARM VIBRATION

There are no regulations or codes of practice governing vibration exposure limits to the hand-arm system in this country. However both the British Standards Institution and the International Standards Organisation have produced guideline standards [3], [4], although the former remains in draft form. The investigation was undertaken according to ISO 5349:1986 owing to the more discrete analysis available due to the use of $\frac{1}{3}$ octave bands as against octave bands and following the guidance of Griffiths [5] whose work suggested it adopted a more stringent standard than that proposed by the British Standards Institution when the work was undertaken.

Unlike the documents immediately proceeding it, ISO 5349 derives a dose-response relationship for likely occurrence of vibration white finger as against guideline exposure levels. Because a dose-response relationship is derived, a daily exposure level needs to be calculated, based on a 4-hour period, and this is expressed in terms of a frequency-weighted acceleration magnitude, $a_{h,w}$. This is calculated from the equation

$$a_{h,w} = \sqrt{\sum_{j=1}^{n} (K_j a_{h,j})^2} \qquad (1)$$

where,

K_j = weighting factor for the jth $\frac{1}{3}$ octave band

$a_{h,j}$ = acceleration measured in the jth $\frac{1}{3}$ octave band

n = number of $\frac{1}{3}$ octave bands used

For a total daily dose other than 4 hours, the energy-equivalent acceleration is determined using equation (2)

$$(a_{h,w})_{eq(4)} = \left(\frac{T}{T_4}\right)^{\frac{1}{2}} (a_{h,w})_{eq(T)}$$

where,

$(a_{h,w})_{eq(4)}$ = energy equivalent acceleration for a 4-hour period

$(a_{h,w})_{eq(T)}$ = frequency-weighted energy equivalent acceleration for a period of T hours

T_4 = 4 hours

As can be seen, the preferred unit of vibration is acceleration, with this being expressed as an r.m.s. value rather than peak.

EXPERIMENTAL WORK

The choice of equipment is vital to ensure any signal being recorded is due to the vibration received by the transducer rather than arising from noise in the monitoring system. The methodology described in ISO 5349 was, therefore, closely followed with special attention being paid to the design parameters of the hand-arm adaptor (see Figure 1). The triaxial accelerometer mounting block on top of the adaptor enabled the vibration received to be measured in three planes, in accordance with the co-ordinate system described in the standard (Figure 2), in order to establish in which axis the main amplitude of the vibration was being transmitted.

The equipment set-up was as shown in Figure 3, with the tape subsequently being analysed using a B & K Type 2131 real time analyser and Hewlett Packard HP85 hard copier. It became clear that the greatest amplitude of vibration was being transmitted in the Z-direction and all measurements were therefore taken in this plane.

Several problems were encountered during the monitoring:

a) the accelerometer became loose on the hand-arm adaptor - this was overcome using bees wax.
b) the accelerometer cable became loose, requiring tightening after each splitting operation.
c) the hostile slaughterhouse environment - water, blood, fat and bone particles.

RESULTS

The splitting time for each carcasse of the average daily total of approximately 70 lasted for typically 80-90 seconds but, because of hand movements to adjust the grip on the saw, a 32 second Leq was all that could be obtained from the 30 samples recorded in order to avoid periods of system overload. This meant, however, that the analysis was carried out on different parts of the splitting operation.

The greatest magnitude of acceleration was found in the 25Hz ⅓ octave band, the derived mean and maximum energy-equivalent accelerations normalised for a 4-hour period being shown in Table 1.

Table 1. Calculated energy-equivalent accelerations, normalised to 4 hours, for the mean and maximum acceleration levels in the 25Hz ⅓ octave band

	Acceleration (ms^{-2}) @ 25 Hz	$a_{h,w}$	$(a_{h,w})_{eq(4)}$
Amax	8.94	5.63	2.82
$\bar{A}$	5.40	3.40	1.70

Using the graph reproduced in Figure 4, the exposure times for certain percentages of the population to exhibit blanching were calculated; these are shown in Table 2.

Table 2. Calculation of dose-response relationship

$(a_{h,w})_{eq(4)}$	Exposure time (years for % of exposed population to exhibit white finger)				
	10%	20%	30%	40%	50%
2.82	10.6	15	18.5	21.3	23.8
1.70	17.7	25	25	25	25

Similar calculations using centre frequencies other than 25Hz failed to show any likelihood of symptoms developing within 25 years using the method described.

CONCLUSIONS

Although serious difficulties were experienced in measuring the total dose received, there is a clear indication that vibration white finger can be experienced within the normal working life span of a slaughterman using this type of saw and that as much of a problem may exist with this type of operation as with those classically associated with the injury. More work needs to be carried out in an attempt to properly quantify the problem by minimising the sampling errors encountered.

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5 Griffiths, J.E.T. (1983): 'Measurement and evaluation of vibration transmitted to the human hand/arm system', Report No. DG/SSB/ESD/R152, Greater London Council, London.

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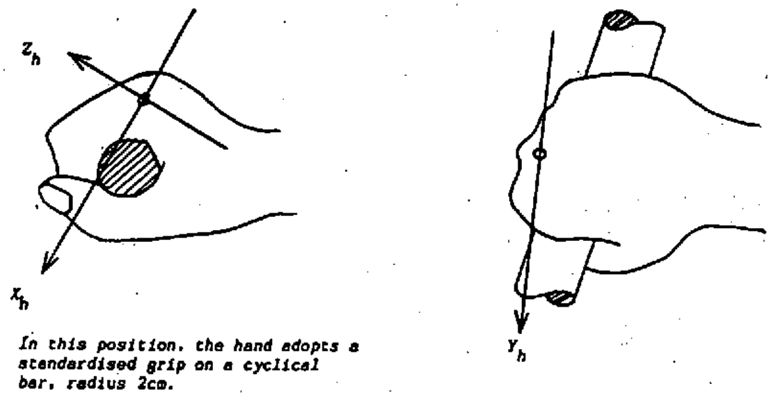

Figure 2. The co-ordinate system according to ISO5349

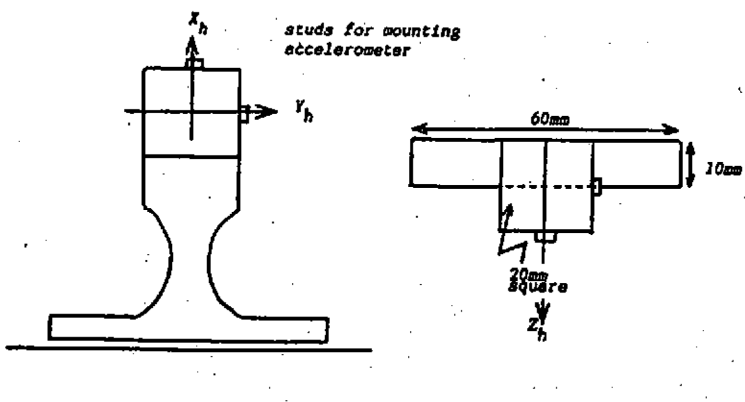

Figure 1. Hand-arm adaptor

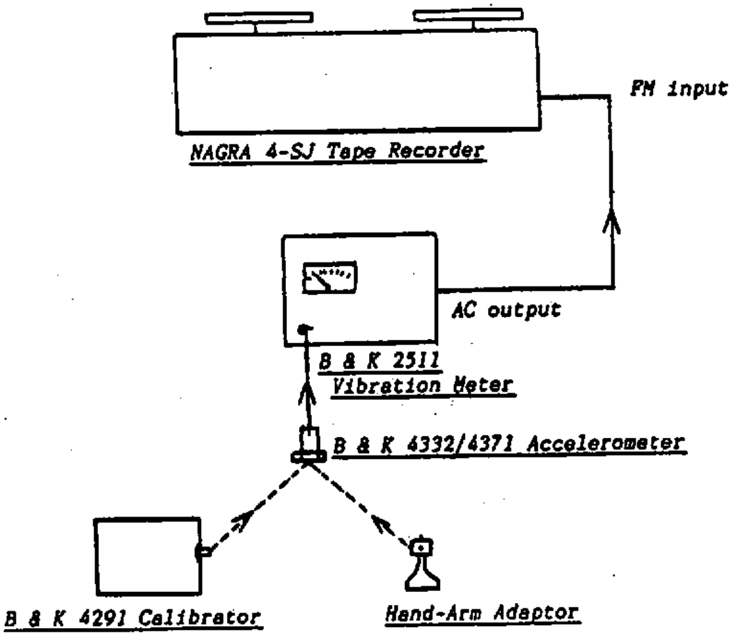

Figure 3. Equipment set-up

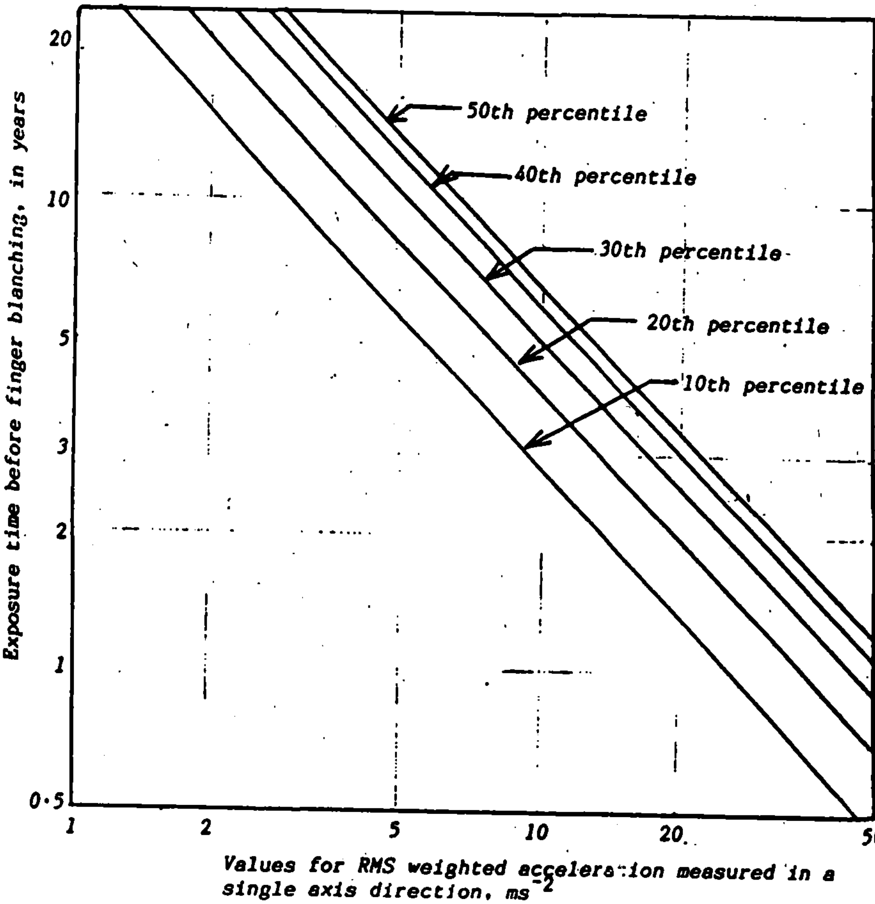

Figure 4. Exposure time for different percentiles of a population group exposed to vibrations in three co-ordinate axes