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PRACTICAL VIBRATION ASSESSMENTS ACCURACY & REPEATABILITY

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1. INTRODUCTION

Glasgow City Council (GCC) employs approximately 35,000 persons in all areas of Local Government, including Construction, Engineering, Manufacturing and Horticulture. Of these employees it is estimated that approximately 4,000 are exposed to occupational vibration at varying levels as part of their normal work activities. The policy and procedures referred to in this document were developed solely as an **operational guide** to managers, supervisors and safety professionals on Hand Arm Vibration (HAV).
It is designed to assist them in the development of safe systems of work throughout the organisation and is therefore not meant as a legally or mathematically definitive document. It does not cover all the procedures adopted by GCC but summarises some of the key elements. The implementation of this policy is an ongoing process that is constantly being reviewed and modified, therefore some of the procedures detailed may change over time.

2. LEGAL DUTIES

Employers Responsibility

If employees are at risk, employers and equipment manufacturers must consider what action is necessary to reduce the risk; so far as is reasonably practicable. This is to meet the requirements of current legislation, including the Health and Safety at Work etc. Act 1974 (HSW Act Sec 2.1) and the Management of Health and Safety at Work Regulations 1992 (MHSWR) as amended.
Employers are required under Regulation 3 of the MHSWR to conduct suitable and sufficient risk assessments on all work activities that could pose a risk to persons at work. This would include any employee exposed to significant levels of vibration from any tools or equipment. Employers are further required under Regulation 4 to establish appropriate arrangements and control measures to minimise the risk identified in the assessment process so far as is reasonably practicable. Employers are also required to conduct Health Surveillance under regulation 5 where it is considered appropriate having regard to the risks identified in the assessments. Hand Arm Vibration Syndrome (HAVS) is also a reportable industrial injury under the Reporting of Injures, Diseases and Dangerous Occurrences Regulations 1995 (RIDDOR)

Manufacturers and Suppliers responsibilities

Section 6 the HSW Act requires designers, manufacturers, importers and suppliers to supply machines and equipment which, are safe and without risks to health and safety, so far as reasonably practical, as well as to supply information about safe use.
The **Supply of Machinery (Safety) Regulations 1992 (SMSR)** further require that machines must be designed and constructed in such a way that the risks resulting from vibration and other sources are reduced to the lowest level taking account of technical progress and the availability of means to reduce them. They also require machine suppliers to provide safety instructions and **must provide information on vibration levels of hand-held or hand-guided machinery which is likely to subject employees to vibration levels exceeding a Root Mean Squared (RMS) of 2.5m/s² (a_h)**

Civil Action Claims

Over the last few years GCC has been exposed to an increasing number of claims for damages as a result of exposure to HAV. Other organisations have also starting to experience large numbers of successful claims, such as a damp proofing operative who received £76,000. Also the recent test case against British Coal Board that secured damages for 7 miners totalling £124,735 with many further claims expected, with total damages that could exceed £500 million.

3. OVERALL OBJECTIVES

The overall objective of the GCC Policy on HAV is to ensure safety of employees, minimise the costs (both direct and indirect), maximise the benefit and ensure accuracy and thoroughness of the measures adopted to meet the requirements of legislation and standards. This can only be achieved by **implementing a package of measures** that is effective throughout the entirety of the organisation.

4. POLICY IMPLEMENTATION

The process of implementing the policy took some time and is still ongoing. It largely followed the same procedures that would be expected when addressing any Health and Safety issue. The process included;

1. Identifying the scale of problem.
2. Developing a policy and setting standards .
3. Setting up a review and survey of existing equipment/processes to identify potentially hazardous jobs and machinery.
4. Establishing purchasing controls.
5. Conducting assessments of equipment.
6. Conducting a review and consolidation of all existing equipment.
7. Establishing vibration control measures for all remaining equipment.
8. Identifying time scales whereby an employee can "safely" use a specific piece of equipment or tool.
9. Providing information and training for employees.
10. Establishing a routine health surveillance programme for exposed employees.
11. Auditing and review of systems.

5. DEVELOPMENT OF HAV POLICY AND STANDARDS

The HSE have published **Hand Arm Vibration, (HS(G) 88)**, which is a good clear and concise general guide to the risk associated with HAV, however it provides limited guidance on the appropriate levels of vibration that an individual can be exposed to. It only sets one "action" level of an A(8) of 2.8 m/s^{-2} after which health surveillance is advised. It also gives little advice on the ways of, and the possible pitfalls in conducting vibration assessments in the field. Although this document gives a good introduction to combating the problems associated with HAV, further procedures had to be developed which included the setting of standards, targets and goals to minimise exposure. Part of the procedures was to develop and implement an assessment programme for all equipment.

Risk Assessments

Where an employee is exposed to a vibration risk, details of that risk are included within the normal risk assessment process. This may incorporate (if indicated by the appropriate action levels) a full assessment of the vibration levels associated with certain types of machinery **while the machine is in normal use**.

6. THE ASSESSMENT PROCESS

Identification of Sources of Vibration

The first step was to identify where hazardous equipment was used within GCC and thus the main areas of concern or processes likely to be hazardous. In consequence, a survey of all areas was completed to identify where problems existed.

Completion of Vibration Survey

A complete review of **all** equipment (likely to cause vibration) was conducted. This was mainly achieved by identifying each piece of machinery, listing the machinery by manufacturer or supplier and then contacting that company to ascertain their declared vibration levels. This was completed with varying degrees of success with many manufacturers unaware of the levels omitted by their machines as well as the requirements to supply the information.
A complete list was established although some equipment levels had to be estimated along the lines of similar machines as many manufacturers were no longer trading or the equipment was no longer produced. This survey gave the ability to initially prioritise the full detailed vibration assessments required and thus facilitate the introduction of control measures. The survey also had the beneficial effect of increasing the overall awareness and knowledge of HAV throughout GCC.

Prioritisation of Assessments

The vibration survey indicated that there were approximately 400 items of machinery that required assessment and as this can take 3-4 hours per machine, a system of prioritisation had to be developed. This was done using a combination of methods including the **vibration magnitude indicated by the manufacturer** and the **maximum time** the equipment is used in **any day** thus reaching an initial A(8) vibration level. The following table was used as a rough guide.

Priority	HAV Levels in (A8) m/s^2
Low	Less than 1.0
Medium	Between 1.0 and 2.5
High	Between 2.5 and 5.0
Very High	Greater than 5.0

Consideration was also given to the average usage time per week. i.e. if equipment was used continually every day it would take priority over equipment used infrequently.
Another criteria used was to simply look at the equipment that was most widely used by the largest number of employees. This ensured that assessments, and the subsequent controls, covered the greatest majority of employees in the shortest period of time. With a combination of all the methods above GCC was able to establish and prioritise a list for assessment and actions developed in order to minimise the vibration levels to all employees.

Manufacturers Information / Actual Measurements

Once the assessment programme started many of the declared levels provided by the manufacturer in accordance with SMSR proved to be inaccurate when assessing the equipment in operational circumstances. This underlined the importance of conducting vibration assessments when the machine was in actual use, and not solely relying on the manufacturers data. This misrepresentation was sometimes due to a lack of knowledge of the manufacturer, but was more often due to the fact that most of their tests were conducted in a standardised setting i.e. not necessarily representative of **operational use**. This may be due to the limited guidance on **how** assessments should be conducted to provide the information that is required by SMSR or the CE marking requirements.

Hand Arm Vibration "Action Levels"

There are no specific action levels stated within current legislation. However Managers and Health and Safety Officers needed guidance on the appropriate action to be taken at various levels of vibration. To do this GCC used the draft EC Physical Agents Directive as a model, instead of HS(G) 88. This was because HS(G) 88 only specifies the one level and does not provide further guidance at other levels. The higher standard as indicated by the draft EC Directive was therefore adopted to be the Council Standard. This will also prevent the need for a further change of procedure should the directive become "live". GCC will further always attempt to minimise exposure however, it has also set a target of keeping all individual daily exposures below a vibration "dose" of an A(8) 2.5 m/s^2 , so far as is reasonably practicable

The action levels adopted by GCC are as follows;

A(8) RMS Value	**Action Required**
Less than A(8) 1.0 m/s^2	Monitor, review if it is believed that this level could be increased
Above A(8) 1.0 m/s^2	***First Action Level*** Vibration assessment required Review safe systems of work to minimise exposure so far as is reasonably practicable. Information, instruction and training to employee/representatives
Above A(8) 2.5 m/s^2	***Second Action Level*** Employees must undergo health surveillance programme Records of assessments and control measures to be maintained Time scales for reduction of vibration levels to be documented
A(8) 5.0 m/s^2	***Exposure Limit*** No equipment is to be used above this level
MAXIMUM * VIBRATION MAGNITUDE	
Peak level of 10 m/s^2	Employee to undergo Health Surveillance Time scales for reduction of peak vibration levels to be documented
Peak level at or above 20 m/s^2	***Peak Action Level*** All equipment must be marked Increased medical surveillance Immediate control measures instigated Any exposures above this level must be reported to the Council H&S Group.

* This should be considered in addition to the action levels

Assessment of Equipment

The accurate measurement and assessment of industrial vibration exposure is a complex process requiring specialist skills and equipment. Whilst in principle it is no more difficult than measuring noise, in practice it requires different and specialised training over and above the incumbent generalist skills of most Health and Safety Professionals. The person that conducts the tests must have the appropriate skill and experience as well as the ability to advise management on how to manage the problem as well as the appropriate control measures that could be instigated. It is vital that the assessment includes **details on how to manage the problem and does not only give a one number answer.**

Measuring Hand-Arm Vibration

GCC conducts all its measurement of hand-transmitted vibration exposure, in accordance with British Standard BS 6842:1987, using the frequency weightings within that standard. The measurement process used is similar to that within HS(G) 88. The exposure to hand-transmitted vibration is quantified in terms of the acceleration of the surface in contact with the hand. The acceleration of the surface is expressed in metres per second squared (m/s^2).

Type of Measurements

When assessing equipment in the field it is important to get as accurate a result as possible. To achieve this assessments can be conducted in two main ways;

1. assessing each individual operator and the machines they use, and thus get the operators daily "dose" or
2. assessing the machine to get an average for the machine irrespective of operator.

In some circumstances where limited operators are completing a task that does not change and involves using specific tools for exact times, then assessing the persons "dose" may be useful. If however there are multiple operators that use a large number of different tools for differing periods it may be more appropriate to measure the equipment.
If this method is used it is important to note that variations can be seen between different work conditions, machines that are new or old, at different points within their maintenance schedules or when they are used by different operators. Assessments must therefore reflect this and be conducted on machines of different, ages, maintenance levels, work conditions and using different operators before an average for that machine can be estimated. This method was used in the majority of situations within GCC to allow for the flexibility of the workforce and multiple machine use.

Accuracy of Measurements

In order to ensure the precision of analysis enough measurements must be conducted to ensure that an accurate average can be calculated. Work is generally not truly repetitive e.g. the vibration "dose" received from digging up $1m^2$ of tar with a jackhammer will almost certainly not be the same as digging up the next $1m^2$. This is because of the many factors that interact when the job is being done e.g. age of the surface, grading, sub-base, encountering stones etc. In order to get a reasonable level of repeatability, GCC found that conducting 6 measurement runs at 1 min per axes achieved good results however, in some circumstances, particularly when using percussive tools, this number of measurements was sometimes inappropriate.

The measurement process takes some time and in some circumstances there may not be sufficient work to allow the time of use necessary to get accurate results. In this situation it may be necessary to manufacture a continuous work cycle for sufficient time to allow the work to be assessed accurately.

Equipment

The delicate nature of the instrumentation is also a problem when doing field assessments. Small microdot cables or delicate electronics do not bear up well with the often hostile work environments where vibrating equipment is used. Great care must therefore be taken of the equipment, and regular checks to ensure that all parts of the measurement chain are operating must be completed. Some work activities make it very difficult to protect the intricate equipment, therefore spare cables must always be accessible to prevent the assessment being abandoned. Similarly moisture can also have a detrimental effect whether it comes from rain or from the work process. It is therefore difficult to conduct assessments in these conditions.

The measurement equipment itself can also effect the operator. In order to minimise the disruption to employees and ensure that they were not hampered in doing their job, a harness device was developed to allow the individual to carry the meter themselves. If the meter has an automatic reading setting it allows the operator to continue their job until the designated time has elapsed and the reading has been completed.

The location of accelerometers can have a significant effect on the measured vibration level as well as the operation of the machine. A balance must therefore be struck between the operating of the machine and the accuracy of measurement. Ideally the measurement should be taken as close to where the hand is placed as possible. The attachment method of the accelerometers can also effect results such as the use of clamps, screws or blocks etc; again a balance has to be struck between the ideal and the practical.

Analysing the Work

The work activity should be broken down into discrete operations and each operation timed and measured. Probably one of the most difficult to estimate is the actual exposure time of the employee. When considering **actual use** against working hours, breaks, travel time, conducting activities not directly using the machine must be taken into consideration. In a standard 8-hour working day it was found that actual use would rarely be over 5 ½ hours per day. If possible accurate measurement of working time must be made, however the sight of a stopwatch may effect the way that an operator goes about their job as they will often be suspicious of what this information will be used for. Managers and operators often have different opinions as to the amount of tool use and to some extent bonus schemes or productivity may be linked to their use, this can skew the estimates.

Uncertainties in Measurement

There is a considerable amount of uncertainty within the measurement process and thus operational assessments are largely about balancing priorities and inaccuracies. Even taking a simple example of the measurement of a hand held drill used for securing bolts to walls some of the factors that could effect the repeatability and reliability of the vibration levels measured are;

- accelerometer attachment and how they effect the holding of equipment
- different operators
- measurement location
- type of work e.g. brickwork, (house brick, firebrick) concrete (strength, age), wood (wet, hard, soft), metal (type),
- push forces,
- speed of drill
- angle of use
- age of machine
- drill bit, size, sharpness
- heat
- operators gloves
- exposure time estimates
- incorrect work method
- technical problems such as accelerometers, electromagnetic interference, DC shift

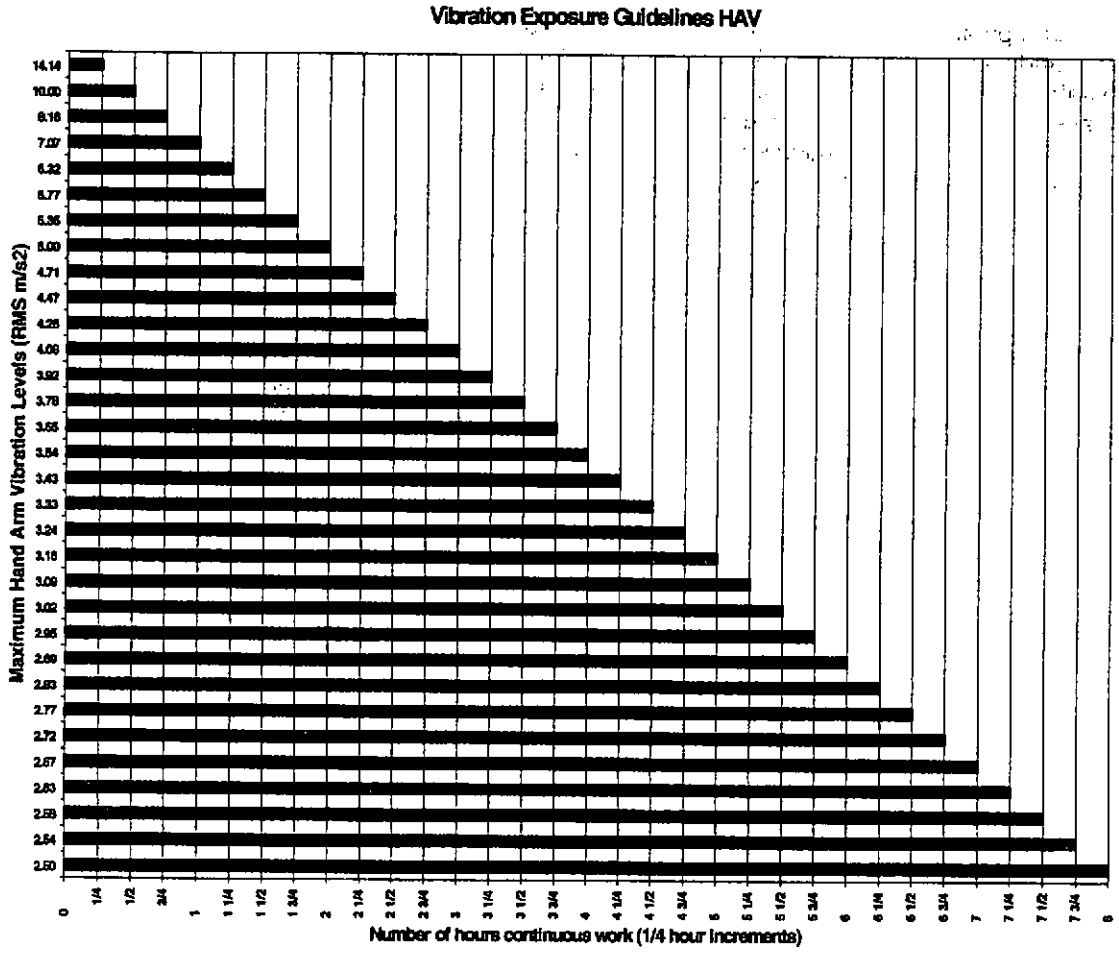
All of these factors interact and can effect the levels of vibration that the employee is exposed to. It can therefore be concluded that multiple tests must be conducted so that any inaccuracies from these factors in individual readings are averaged out to ensure that the results have a good degree of accuracy.

7. GUIDANCE TO MANAGERS

Practical guidance had to be developed to allow managers to maintain ownership of the problem and thus manage it. This included how to identify and initially quantify the vibration "dose" of the employee. This was linked with a purchasing policy that ensured that only the highest standard of equipment was brought into service. The following system was developed to quickly identify equipment that could have a problem if purchased.

Single Exposure

To allow managers to estimate whether a machine would be able to be used for sufficient time to do a required job, **prior to purchase OR use,** a graphical 'ready reckoner' was created to allow easy calculate of vibration "dose" (given RMS vibration magnitude from the manufacturer or an assessment). Or to estimate the vibration magnitude that a piece of equipment could work at to ensure that an A(8) of 2.5m/s^2 is not exceeded (given a certain time to do the job).



Average HAV levels over the working day which cause an A(8) of 2.5m/s²

Multiple levels and times of exposure

It was quickly realised that in the majority of work situations individuals were using more than one machine for differing time periods per day. In order to calculate their daily dose their total exposure had to be continually calculated using the equation contained in BS 6842. This was not popular with the operational management team or the operators themselves. It was considered almost impossible to continually re-calculate the numerous vibration levels and differing times each day that operators use equipment. This would make it effectively necessary for all operators to understand and use the formula continually throughout the day to calculate their "dose". It also made it extremely time consuming to continually re-calculate the different combinations of machines that could be used. A system was therefore developed to make the calculation simpler and allow the operators themselves to ensure that they do not exceed an A (8) of 2.5 m/s².

To do this equipment is marked with the percentage "dose" given a set time period of use (this is calculated by the Health and Safety Group after an assessment has been completed). This simply allows supervisors or operators to add these percentages and the number of set time periods to ensure that they do not exceed 100 and thus an A(8) of 2.5 m/s².

This system also allows a direct comparison of equipment i.e. the operator could select a machine with a lower "dose" instead of another if the machines were doing the same job. **This allows the individual themselves to minimise their exposure.**

Machinery Assessment Groups

These groups are run by the departmental operational management team with assistance from GCC Health and Safety Group and look at all aspects of the equipment such as price, productivity, reliability and safety implications. This ensures that the best equipment is procured for the job. As part of this process it is normal to trial the equipment in operational circumstances prior to purchase. This gives the opportunity to do a vibration survey on the equipment to ensure that the manufacturers information on vibration level is representative of actual use.

Strategies to Reduce Exposure

Probably the best control has proven to be an effective purchasing policy that prevents excessive exposure prior to persons coming into contact with the machine. GCC exercises considerable buying power and is able to put pressure on the manufacturers to produce low vibration equipment. From our experience it would appear that some manufactures have not fully addressed the problem yet, but with the continuing pressure on the sales department and a more informed purchaser this should be resolved.

8. HEALTH SURVEILLANCE

The Management of Health and Safety at Work Regulations 1992 requires employers to provide appropriate health surveillance for employees where the risk assessment shows it to be necessary. Where the calculated vibration levels indicate it appropriate (as per the GCC action levels) operators are sent for medical surveillance. Occupational Health professionals have a vital role in educating employees, supplementing the training and information provided by GCC. Whilst undergoing health surveillance employees are advised individually about HAV, the means of minimising exposure, symptoms and the likely effects of their continuing to work with HAV if symptoms have begun.

9. SUMMARY

With increased litigation and the possibility of further new legislation on the horizon, all employers will have to develop an integrated health and safety management system and policy on HAV. This must include the vibration assessment process as one of its core elements.
With the large amount of uncertainties associated with the accuracy and repeatability of field measurements, the sum that is produced at the end of the **analysis must not be used in isolation.** More emphasis must be placed on the practical measures to reduce and manage exposure (particularly with the uncertainties of the dose effect relationship).
Vibration analysis does provide management with an extremely valuable tool, as a general guide for the use of equipment and for the implementation of control measures in order to assist in ensuring the safety of their workers. One the biggest benefits in conducting an assessment programme over and above quantifying the vibration problem is to increase the management and employee awareness of the problem, making them examine their work activities and allow them to "self regulate" and thus minimise exposure for themselves. It also allows management to examine work routines in detail and perhaps introduce more efficient and cost effective activities.

REFERENCES

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4. The Supply of Machinery (Safety) Regulations (1992) SI No 3073