HAND-ARM VIBRATION ASSESSMENT
NORBAR PNEUTORQUE
NORBAR TORQUE TOOLS

CONTENTS

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1 INTRODUCTION

The **Industrial Noise & Vibration Centre (INVC)** was requested by Philip Brodey of Norbar Torque Tools to carry out a hand-arm vibration assessment of the Norbar Pneutorque compared to a standard pneumatic impact wrench.

Whilst the assessment provides measured field vibration values for the plant listed, it is the responsibility of the end-user to ensure that it is representative and that:

(i) the data covers the tools used by operators and the tasks carried out;

(ii) the assessment is kept up-to-date as new tools are purchased;

(iii) operators are trained in risk management procedures.

This vibration assessment can be provided in electronic form on disk, which can also be supplemented by the Hand-Arm Vibration manual on CD plus training material for use in-house to create a comprehensive HAV KnowledgeBase that is both accessible and easily updated.

2 VIBRATION MEASUREMENT CONDITIONS AND EQUIPMENT

All vibration measurements were made in three orthogonal directions using an accelerometer attached with a lightweight fixture rigidly clamped directly to the handle of the tool as close as possible to the position of the operator's hand. All measurements were made under real operating conditions on Thursday 8 September 2005.

Vibration acceleration measurements were made with the instrumentation described in Appendix A. Initial checks confirmed satisfactory operation of the equipment. Careful checks were made whilst measuring to monitor the vibration signals and check for overload of the instrumentation.

All measurements were made in accordance with British Standard BS EN ISO 5349 "Mechanical Vibration - Measurement and Assessment of Human Exposure to Hand-Transmitted Vibration" Part 1 "General Guidelines" 2001. The accelerometer was carefully placed on the handle of the tool, rigidly clamped with an adjustable band clamp, and aligned with the axes specified by the Standard.

The instantaneous vibration value was monitored during each test to ensure the level remained relatively steady. For each test, the measurement was carried out for sufficient time to obtain an accurate representation of the vibration value.

3 LEGISLATION FROM AN EMPLOYER/USER VIEWPOINT

Dedicated legislation limiting vibration exposure has been introduced this year as the Control of Vibration at Work Regulations 2005, which came into force on 6 July. Furthermore, Vibration White Finger (VWF) is reportable under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995.

The regulations are the UK implementation of the Physical Agents (Vibration) Directive 2002/44/EC. This defines two exposure values - an action value and a limit value - based on the "vibration total value" which is equivalent to the **vector sum**. If employees are exposed above the daily exposure action value (EAV) of 2.5 m/s^2 the employer must introduce a programme of controls to eliminate risk or reduce exposure to as low a level as is reasonably practicable. Health surveillance must also be provided to those employees who continue to be regularly exposed above the action value or otherwise continue to be at risk.

If employees are exposed above the daily exposure limit value (ELV) of 5.0 m/s^2 the employer must take immediate action to reduce their exposure below the limit value.

In addition, information and training must be provided to employees on health risks (and the action the employer is taking to control those risks). Records of the risk assessments and control actions must be kept, health records for employees under health surveillance should be kept and risk assessments should be reviewed and updated regularly.

Formal HSE guidance on hand-arm vibration will be issued on 27 September 2005 (Hand-Arm Vibration: Control of Vibration at Work Regulations 2005 - Guidance on the Regulations L140). However, in June, employer advice was issued in leaflet reference INDG 175 (Rev 2) and employee advice in leaflet INDG 296 (Rev 1). Both are available in priced packs from HSE books or may be viewed as pdf documents on the internet:

www.hse.gov.uk/vibration/information.htm

The assessment in this report is therefore based on the new regulations, ie. vector sum values:

Exposure Action Value (EAV) : A(8) = 2.5 m/s^2

Exposure Limit Value (ELV) : A(8) = 5 m/s^2

Note: Expert guidance should be sought for the applicability of any legislative instruments as the above notes are only intended to link generally relevant areas of the topic.

4 MANUFACTURERS' AND SUPPLIERS' DUTIES

Designers, manufacturers, importers and suppliers have had responsibilities since 1974 under Section 6 of the Health and Safety at Work etc Act 1974 to supply machines and equipment which, so far as reasonably practicable, are safe and without risks to health, and to supply information about safe use.

The Supply of Machinery (Safety) Regulations 1999 establishes the essential health and safety requirements relating to the design and construction of machinery. Machines must be so designed and constructed that the risks resulting from vibration (and noise) are reduced to the lowest level taking account of technical progress and the availability of means to reduce vibration (and noise), particularly at source.

Suppliers must not only give specific information regarding airborne noise emission but also, in the case of hand held or hand guided machines, information regarding vibration. Technical documentation must provide the weighted rms acceleration to which the hand-arms are subjected if this is likely to exceed 2.5 m/s^2. (Note: this is the vibration amplitude whilst the tool is operating in normal use, not the vibration dose averaged over an 8 hour day).

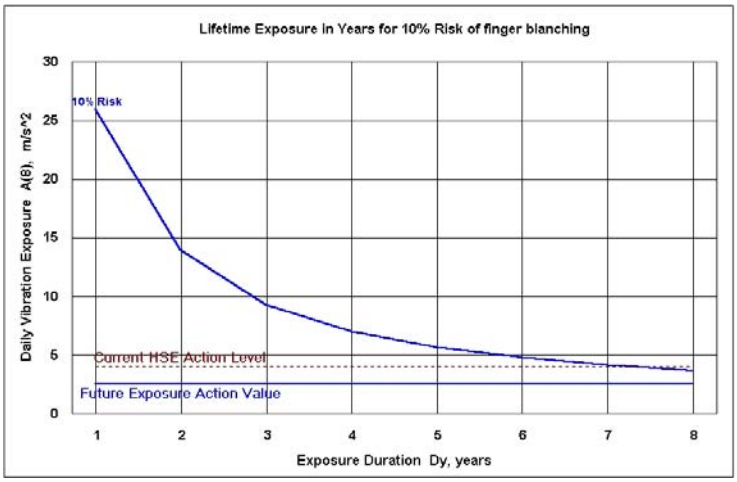
From the 1st January 1995, no machinery may be sold in the EC that does not legitimately bear the CE Mark. In order to claim conformance with the European Machinery Directive and display the CE Mark, a Technical Construction File which includes vibration (and noise) information must be maintained and made available to HSE Inspectors or Trading Standards Officers at 48 hours notice. Failure to comply with this EC law is a criminal offence on the part of the manufacturer or his representative in Europe and may also result in the prevention of machinery sales in the market.

General advice on the supply of new equipment is provided in HSE INDG270 04/98 "Supplying New Machinery".

Note: Expert guidance should be sought for the applicability of any legislative instruments as the above notes are only intended to link generally relevant areas of the topic.

5 VIBRATION EXPOSURE AND DAMAGE

Current advice on Hand-Arm Vibration (HAV) and what can be done to control it is presented in HSE guidance (reference 1), which contains information from BS 6842 (reference 8), now withdrawn. The aforementioned employer and employee guidance leaflets provide more specific advice (reference 8, 9 and 10 to be published September 2005). Annex C of the new replacement standard, BS EN ISO 5349-1 2001 (reference 7) is informative only, but provides tentative information on the relationship between vibration exposure and effects on health. Table C.1 relates the daily weighted vibration exposure level A(8) to the number of years' exposure that may cause finger blanching in about 10% of the vibration exposed population.



Exposure in years	1	2	4	8
Daily Vibration Exposure A(8) m/s^2	26	14	7	3.7

Note: *There is considerable uncertainty in these results. The state of knowledge of the dose effect relationship is limited. The probability of a vibration exposed individual developing finger blanching depends on several factors, including individual susceptibility.*

This relationship is only tentative, so it should be treated only as a rough guide for an "average" person.

The Exposure Action Value is based on an rms average vibration level over an 8 hour working day which would cause a vector sum daily weighted vibration exposure A(8) of 2.5 m/s^2 and similarly the Exposure Limit Value is based on an A(8) of 5 m/s^2.

Length of working day (hours)	16	8	4	2	1	½
rms average vibration level (m/s^2) to give A(8) of 2.5 m/s^2	1.8	2.5	3.5	5	7.1	10
rms average vibration level (m/s^2) to give A(8) of 5.0 m/s^2	3.6	**5**	7	10	14	20

However, a vibration dose A(8) of 2.5 m/s^2 should not be considered a safe level. Annex C of BS EN ISO 5349 suggests that *"symptoms of the hand-arm vibration syndrome are rare in persons exposed with an 8 hour energy-equivalent vibration total value A(8) at a surface in contact with the hand of less than 2 m/s^2 and unreported for A(8) values of less than 1 m/s^2"*.

6 RESULTS OF VIBRATION MEASUREMENTS

The tests were carried out at a Mercedes truck service centre at Brackley, Northamptonshire on Thursday 8 September 2005. Brief details of the equipment measured, tool or accessory used, operation, material, operating conditions and task performed are presented in Table 1. All tables are attached to the report after the main text.

The measured vibration for each tool in all three directions is presented in Table 2. The frequency weighted RMS vibration a_{hw} is representative of continuous ("finger-on-trigger") tool operation. No allowance is made for time spent loading, unloading, workpiece preparation or other periods of time/work pattern which will reduce operator exposure.

These are the vibration levels measured on the tool with a low frequency weighting filter applied (as specified in the International Standard) which quantifies the relative importance of different frequencies and corresponds to the way vibration is imparted into the hands and causes damage. A glossary of vibration terms and details of the vibration assessment are presented in Appendix B. Note that the measured values presented in Table 2 are vibration amplitude $a_{h,w}$ whilst the tool is operating in normal use, not the vibration dose averaged over an 8 hour day A(8).

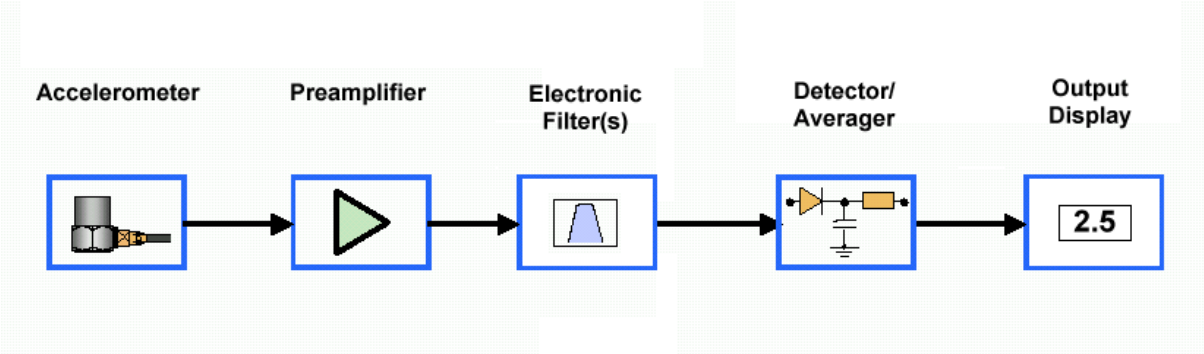
Notes:

1. The field values are typical for the conditions under which the plant was operating during these tests. Different values may be obtained under other operating conditions.
2. For hand-held percussive or impact equipment high peak accelerations can occur which overload some instruments.

When the measurement instrument indicates that meter overloads have occurred, this is noted for the plant concerned on each of the results tables, in the full results appendix and on the graphical summary. No overloads occurred during the assessment.

7 INSTRUMENTATION OVERLOAD

Instrumentation overload can occur when measuring hand-arm vibration of percussive or roto-percussive power tools such as breakers, impact wrenches, needle guns, hammer drills, etc. Overload of the instrument chain (accelerometer or meter input amplifier) causes distortion of the vibration acceleration signal.



When the results show that meter overload has occurred, the measured vibration values may be inaccurate and should only be used as a rough guide - in the absence of accurate vibration data.

8 IMPACT TOOLS

The vibration of impact tools varies dramatically depending on ground state and material, tooling fitted, condition of machine, air line pressure and other factors. In addition the accurate measurement of vibration on heavy duty impact tools is very difficult due to the inherent impulsive nature of the vibration produced and high peak accelerations (which can overload some instruments and even break accelerometers).

The HSE daily limit for operator exposure is based on limited historical vibration data that may not have truly reflected the impulsive nature of vibration from impact tools - which can now be measured more accurately with modern instrumentation. It is suspected that the daily dose relationship may be non-linear at the high vibration levels produced by impact tooling.

9 VIBRATION EXPOSURE ASSESSMENT

A graphical summary of the measured vector sum vibration levels is presented in Figure 1 for all items of equipment measured.

In order to provide an assessment of the vibration of the tool, it is necessary to know not only the vibration values but also the duration of typical daily usage where the tool is likely to be used. In the absence of detailed work study information (exact "finger-on-trigger" time) and daily usage patterns, 1 hour has been used as the trigger time in this assessment to produce the daily operator exposure A(8) for single tool use. If the actual trigger time is higher than this, then the daily operator exposure A(8) will also be higher.

The Daily Exposure A(8) presented in Table 3 is for single tool use and is calculated from the vector sum of the measured frequency weighted RMS vibration accelerations for each tool and the estimated tool usage time for each operation. Any other additional exposure to high vibration tools will increase the operator's vibration dose and exceed the estimates of Daily Exposure A(8) presented in this table.

Notes:	1.	When there are two handles, the Vector Sum of the frequency weighted vibration values is presented for the handle with highest vibration.
	2.	The single tool running time (or time to reach action level) is based on the vector sum and total continuous ("finger-on-trigger") tool operation time if the current HSE action level A(8) of 4 m/s^2 is not to be exceeded.

In addition to A(8), Table 3 also provides the single tool exposure points, running time and the number of years for a 10% risk of finger blanching - for this usage (ie. the stated "finger on trigger" time and measured vector sum values).

Additional information is presented in Table 4. The daily usage limit is presented for single tool operation based on not exceeding ACTION LEVELS A(8) of 2.5m/s^2 (EAV) and 4 m/s^2 (the former HSE action level) and a LIMIT VALUE of 5 m/s^2 (ELV) in an 8 hour day, with no other exposure to vibration. Note that the single tool running time is the time that the hand can be in contact with vibration (ie. "finger on trigger" time) without exceeding the stated daily exposure values.

A comprehensive data sheet including a full set of measured vibration results, analysis, equipment descriptions, tasks and operations is presented in Appendix C for each item of equipment tested. Where there is likely to be a risk from exposure to vibration, the Control of Vibration at Work Regulations 2005 requires employers to:

- reduce exposure to a minimum;
- provide information and training;
- carry out a programme of measures to reduce exposure and provide appropriate health surveillance when exposure reaches the exposure action value;
- keep exposure below the exposure limit value.

10 EXPOSURE POINTS

The conventional way to calculate the operator's daily vibration exposure A(8) uses the total vibration produced by the tool ("vector sum value") and the contact time ("finger on trigger") in a typical working day. Because the exposure time is not directly proportional to A(8), it is difficult to evaluate the operator exposures for different periods of use or where operators use more than one tool in a day.

An exposure points system simplifies the risk assessment procedure. The exposure points values equivalent to the action (and limit) values in the Control of Vibration at Work Regulations 2005 are as follows:

Exposure Action Value of 2.5 m/s^2 A(8)	=	100 points
Exposure Limit Value of 5 m/s^2 A(8)	=	400 points

One method for managing HAV is to calculate an exposure points value per hour of use, which is proportional to the measured vibration magnitude. The **1 hour exposure points** for each item of equipment measured are shown in Tables 3, 4 and 5.

For any particular tool the 1 hour exposure points score may be calculated as:

$$n_{1\ hr} = 2 \times (\text{Vector Sum})^2$$

so, for a vector sum value of 5 m/s^2, the 1 hour points score is:

$$n_{1\ hr} = 2 \times (5)^2 = 50 \text{ exposure points}$$

Example 1: If it is decided to limit operator exposure to below, say, the current Exposure Action Value, an A(8) of 2.5 m/s^2 or 100 points, then the above tool may be used for 100 / 50 = 2 hours.

Example 2: If two tools with 1 hour exposure points of 20 and 80 are in use for 2 and 2.5 hours respectively, then it is simple to calculate the combined exposure for multiple tool use using the 1 hour points system described above. The points score for each tool is 2 x 20 = 40 points and 2.5 x 80 = 200 points, so the combined exposure gives a total points score of 40 + 200 = 240 points. Hence this operator's daily exposure is 240 points, which is below the Exposure Limit Value of 400 points, but above the Exposure Action Value of 100 points.

11 ACTION PROGRAMME TO MANAGE POTENTIAL HAND-ARM VIBRATION PROBLEMS

The key elements of a general action programme to manage potential vibration problems are presented below. Note that "anti-vibration" gloves do not work for low frequency vibration other than for keeping the hands warm, as neither do many anti-vibration materials sold as vibration reduction methods. If anti-vibration gloves are to be issued, the frequency content of the tools with which they are used must be confirmed to ensure the gloves will provide protection. Fundamental engineering design does work, as evidenced by the relative effectiveness of anti-vibration measures now fitted to chain saws.

The key elements of a programme for the Management of Hand-Arm Vibration are listed below:

- Training
  - Management Briefings
  - Toolbox Talks
- Risk Reduction
  - General
  - Reduce Vibration
    - automate/change the way job is done
    - source modifications (manufacturer)
    - operational factors (air pressure, flow rate, etc.)
    - retrofit modifications (isolation, damping, etc.)
- "Buy Smooth" Purchasing Policy
- Health Surveillance
- Audit Programme
- Exposure Times/Job Rotation
- General Technical/Management Support Items

Further information or technical support on any of these elements can be provided by the **Industrial Noise & Vibration Centre (INVC)** to whatever level is required.

12 CONCLUSIONS

Hand-arm vibration syndrome is a widespread industrial disease affecting tens of thousands of workers. Its best known effect is vibration white finger (VWF). Any vibrating tool or process which causes tingling or numbness after 5 to 10 minutes of continuous use is suspect. The maximum daily exposure A(8) or Exposure Limit Value cited by the Control of Vibration at Work Regulations 2005 is a vector sum value of 5 m/s^2.

Manufacturers and suppliers of high vibration tools (greater than 2.5 m/s^2) have a legal duty to provide information. End-users should ensure that a purchasing policy is in place and request information on vibration levels and control measures designed into equipment. The most effective long term measure to reduce vibration is to buy low vibration tools as existing equipment wears out and is replaced.

Author 

STEVE WRAY

13 REFERENCES

Hand-Arm Vibration

1 *"Hand-Arm Vibration"*, HSG88, ISBN 0-7176-0743-7, 1994. (No longer current but contains useful guidance until new guidance is issued in September 2005).

2 *"Vibration Solutions : Practical ways to reduce the risk of hand-arm vibration injury"*, HSG170, 1997.

3 *"Power Tools: How to Reduce Vibration Health Risks. Guide for Employers"*, HSE INDG338, 03/01.

4 *"Survey of Exposure to Hand-Arm Vibration in Great Britain"*, HSE Research Paper No 26, K Kyriakides, ISBN 0-7176-0315-6, 1988.

5 *"Report on Elimination and Reduction of the Risks of Hand-Arm Vibration in the Foundry Industry"*, Ref: 3641/R53.165, November 1998.

6 *"British Standard Guide to Measurement and Evaluation of Human Exposure to Vibration Transmitted to the Hand",* BS 6842, 1987 (**now withdrawn**).

7 *"Mechanical vibration - Measurement and evaluation of human exposure to hand-arm vibration - Part 1 : General requirements",* BS EN ISO 5349-1 : 2001.

8 *"Control the Risks from Hand-Arm Vibration"*. Advice for employers on the Control of Vibration at Work Regulations 2005. HSE reference INDG175 (Rev 2).

9 *"Hand-Arm Vibration"*. Advice for employees under the new Regulations. HSE reference INDG296 (Rev 1).

10 *"Hand-Arm Vibration : Control of Vibration at Work Regulations 2005"*. Guidance on the regulations. HSE reference L140. (To be published on 27 September 2005).

Whole-Body Vibration

11 *"In the driving seat",* HSE INDG 242L, 11/96.

12 *"British Standard Guide to Measurement and Evaluation of Human Exposure to whole-body mechanical vibration and repeated shock",* BS 6841, 1987.

13 *"Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1 : General requirements",* ISO 2631-1 : 1997.

14 *"Exposure action and limit values for whole-body vibration : Implementing the new directive"*, C M Nelson and P F Brereton. Paper presented at the 37th UK Conference on Human Responses to Vibration, held at Loughborough University, 18 - 20 September 2002.

Legislation and General

15 *"Management of Health & Safety at Work Regulations 1999. Approved Code of Practice",* L21, HSE Books, ISBN 0-7176-0412-8.

16 *"Articles and Substances used at Work : the Legal Duties of Designers, Manufacturers, Importers and Suppliers and Erectors and Installers",* HSE INDG1(L) rev.

17 *"The Supply of Machinery (Safety) Regulations 1992",* SI No 3073, 1992.

18 Physical Agents (Vibration Directive 2002/44/EC published on 6 July 2002 in the Official Journal L177 Vol 45, p12.

19 *"Supplying New Machinery",* HSE INDG270, 04/98.

20 *"Buying New Machinery",* HSE INDG271, 04/98

HAV-Base: Hand-Arm Vibration Plant Risk for Single Tool Use

User Info Measurements carried out by INVC for Norbar Torque Tools

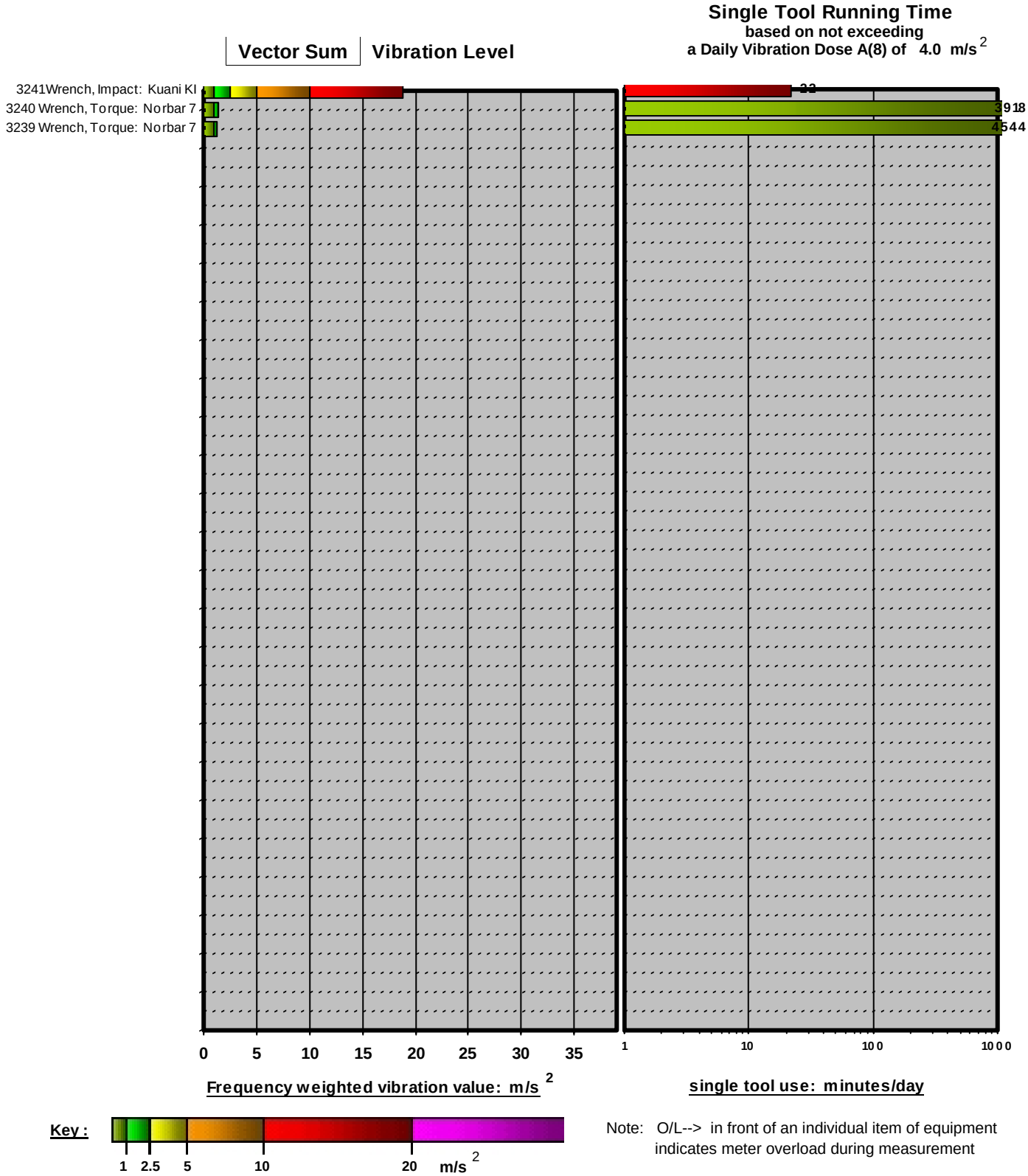


Figure 1: HAV Assessment - Graphical Results Summary

User Note Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements

R4686.sw

Table 1: Equipment, Operation, Material, Tooling, Task and Operating Conditions.

User Info : **Measurements carried out by INVC for Norbar Torque Tools**

Test	Description	aka	Overload	Manufacturer/Model	Plant No	Operation	Material	Tooling	Task	Operating Conditions
3241	Wrench, Impact - Pneumatic		☐	Kuani KI-36	0003006	Tightening	Nuts	32mm socket	Tightening wheel nuts	
3240	Wrench, Torque - Pneumatic	Pneutorque	☐	Norbar 77112	2005/3343	Tightening	Nuts	32mm socket	Tightening wheel nuts	
3239	Wrench, Torque - Pneumatic	Pneutorque	☐	Norbar 77112	2005/3343	Tightening	Nuts	32mm socket	Tightening wheel nuts	

User Note : **Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements**

Table 2: Measured frequency weighted RMS vibration acceleration of each tool in continuous use.

User Info : **Measurements carried out by INVC for Norbar Torque Tools**

Test	Description	Meter Overload	Manufacturer and Model	Handle 1	X1	Y1	Z1	Handle 2	X2	Y2	Z2
					weighted m/s ^{2}				weighted m/s ^{2}		
3241	Wrench, Impact - Pneumatic	☐	Kuani KI-36	Trigger	11.2	12.5	8.5	Support	9.2	9.1	3.7
3240	Wrench, Torque - Pneumatic	☐	Norbar 77112	Trigger				Support	1.3	0.5	0.3
3239	Wrench, Torque - Pneumatic	☐	Norbar 77112	Trigger	0.5	0.4	0.4	Support	1.2	0.4	0.4

User Note : **Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements**

Table 3: Daily Exposure A(8) for the stated "Finger-on-trigger" time and measured Vector Sum vibration values with the single tool running time which does not exceed a Daily Vibration Exposure A(8) of 4.0 m/s^2

User Info : Measurements carried out by INVC for Norbar Torque Tools

Test	Description	aka	Vibration Meter Overload	Manufacturer Model	"Finger-on-trigger" Time decimal hours	Highest Axis m/s^2	Vector Sum m/s^2	Daily Exposure A(8) m/s^2	TASK Exposure Points	10% Risk of finger blanching years	Single Tool Running Time minutes
3241	Wrench, Impact - Pneumatic		☐	Kuani KI-36		12.5	18.8	#Error		#Error	**22**
3240	Wrench, Torque - Pneumatic	Pneutorque	☐	Norbar 77112		1.3	1.4	#Error		#Error	**> 24 hr**
3239	Wrench, Torque - Pneumatic	Pneutorque	☐	Norbar 77112		1.2	1.3	#Error		#Error	**> 24 hr**

User Note : Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements

Notes:
1. Measured vibration values are for typical operations on the day of measurement with the individual tools measured.
2. Daily Exposure and Exposure Points - (displayed only for vector sum assessment) are highly dependent on accurate "Finger-on-trigger" time.
3. Years for 10% Risk of finger blanching is a rough guide for an "average" person based on a tentative relationship. Calculated value is only applicable between 1 and 8 years.
4. The single tool running time is the time that the hand can be in contact with vibration without exceeding the daily vibration exposure value stated in the title of this table.

Table 4. Measured Vector Sum vibration values and 1 Hour Exposure Points with single tool running time which does not exceed stated A(8) exposure values.

Action Value: 4 m/s^2 - HSE guidance 2002 — 2.5 m/s^2 - Physical Agents (Vibration) Directive.
Limit Value: - — 5 m/s^2 - Physical Agents (Vibration) Directive.

User Info : Measurements carried out by INVC for Norbar Torque Tools

Test	Equipment	Manufacturer and Model	Operation	Material	Measured Vector Sum m/s^2	HAV 1 HOUR Exposure Points	Running time - single tool use: for not exceeding Action Values A(8) : 2.5 m/s^2 minutes	4 m/s^2 minutes	Limit Value A(8) : 5 m/s^2 minutes
3241	Wrench, Impact	Kuani KI-36	Tightening	Nuts	**18.8**	**707**	**8**	**22**	**34**
3240	Wrench, Torque	Norbar 77112	Tightening	Nuts	**1.4**	**4**	**> 24 hr**	**> 24 hr**	**> 24 hr**
3239	Wrench, Torque	Norbar 77112	Tightening	Nuts	**1.3**	**3**	**> 24 hr**	**> 24 hr**	**> 24 hr**

User Note : Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements

Notes: 1. The Vector Sum value is for typical operations on day of measurement with the individual tools measured.
2. The single tool running time is the time that the hand can be in contact with vibration (ie "Finger-on-trigger" time) without exceeding the stated daily exposure value.

APPENDIX A
INSTRUMENTATION USED

Larson Davis Type HVM100 Hand Arm Vibration Meter	S/N 00610
Larson Davis Type SEN020 Tri-Axial Accelerometer	S/N P31617
Bruel & Kjaer Type UA0559 Mechanical Filter	

APPENDIX B
Glossary of Vibration Terms and Details of Vibration Assessment

1 VIBRATION TERMS

Hand-Arm Vibration (HAV) Assessment - The primary purpose of a vibration assessment is to identify those people exposed to high vibration equipment, so that action can be taken to manage the HAV problem and minimise the risk of vibration white finger (or hand-arm vibration syndrome).

Vibration-Induced White Finger (VWF) - Intermittent blanching affecting the fingers arising from a disorder caused by exposure to hand transmitted vibration. Often triggered by cold and may be accompanied by numbness.

Raynaud's Phenomenon - A condition where there is insufficient circulation of blood, usually with intermittent spasms and involving the fingers. Symptoms include blanching. Primary Raynaud's phenomenon includes VWF but symptoms are identical. Named after Maurice Raynaud (1834 to 1881).

Blanching - A withdrawal of normal colour or a white appearance usually of the fingers.

Hand-Arm Vibration or HAV - Mechanical vibration transmitted directly to the hands in contact with the vibrating surface.

Whole-Body Vibration or WBV - Mechanical vibration transmitted through the seat, feet or other body part in contact with the vibration source.

Band-Pass Filter - A filter which transmits energy at all frequencies between two given frequencies and attenuates at all other frequencies.

Mechanical Filter - Mechanical filters are designed to reduce the high-frequency vibration reaching the accelerometer, while allowing the vibration at hand-arm frequencies to pass unaffected. For impact/percussive tools, the use of mechanical filters helps to avoid errors due to distortion of the acceleration signal ("dc-shift" and overloads). See Annex C (informative) of BS EN ISO 5349-1:2002 or HSE guidance for more details.

2 HAND-ARM VIBRATION ASSESSMENT

Vibration levels are measured on each handle of the tool in mutually perpendicular axes, which gives three vibration acceleration values $\boldsymbol{a}_{hwx}$, $\boldsymbol{a}_{hwy}$ and $\boldsymbol{a}_{hwz}$ in m/s^2. These are the root-mean-square (RMS) acceleration values at the vibrating surface in contact with the hand and frequency-weighted using the weighting function W_h. This is a low frequency band pass filter defined in British Standard BS EN ISO 5349-1 : 2001. Vibration at frequencies below 2Hz and above 1500Hz is not thought to cause damage.

We recommend that vibration measurements should be taken in all three axes in line with forthcoming legislation "The Control of Vibration at Work Regulations 2005" - the UK implementation of the Physical Agents (Vibration) Directive which comes into force in July 2005. These regulations require the **"vector sum"** vibration acceleration value to be used for calculation of daily personal vibration exposure.

2.1 Measured Vibration

Vector Sum

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad \text{. . . . . Equation 1}$$

When two handles are fitted and held, the vector sum number to use is the higher value.

The "vector sum" or "vibration total value" are the same common terms for what is more accurately called the "root-sum-of-squares". You may see any of these terms in relevant Standards, Legislation or guidance.

Previous guidance (now superceded) permitted the use of a vibration assessment using the dominant axis alone. However it is impossible to predict consistently which axis is dominant, particularly on low vibration tooling. Any details of this old assessment method provided here are for INFORMATION ONLY. The "dominant" or "highest" axis vibration value is the maximum of a_{hwx} or a_{hwy} or a_{hwz} for both handles when fitted. THIS DOMINANT AXIS METHOD IS NO LONGER RECOMMENDED FOR USE.

2.2 Daily Personal Vibration Exposure

Single operation or tool use

Daily Personal Vibration Exposure

$$A(8) = a_{hv} \times \sqrt{\frac{T}{T_0}} = a_{hv} \times \sqrt{\frac{T}{8}} \quad \text{. . . . . Equation 2}$$

where T is the number of hours for usage per day. This is the total time for contact with the vibrating surface or handle (ie. "finger-on-trigger" time).

and T_0 is the reference duration of 8 hours.

Note:	The number of hours usage T and the reference duration T_0 must be in the same units (ie T in hours then T_0 = 8, T in minutes then T_0 = 480, T in seconds then T_0 = 28,800).

Multiple operation or tool use

Where there are multiple exposures (ie using different tools or carrying out different operations) then the daily personal vibration exposure is derived by adding the individual exposures as follows.

Multiple Tool Usage

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + \ldots A_n(8)^2} \quad \text{. Equation 3}$$

The individual $A_n(8)$ values are the partial vibration exposure values for each source for the individual user of a range of equipment.

2.3 Weekly Average of Daily Personal Vibration Exposure

When the daily exposure is usually below the exposure action value (2.5 m/s^2), but varies markedly and may occasionally exceed the exposure limit value (5 m/s^2) then the forthcoming Vibration Regulations allow the exposure to be averaged over a week **for the purposes of applying the exposure limit value**.

Weekly

$$A(8)_{week} = \sqrt{\frac{1}{5}\left(A_{MON}(8)^2 + A_{TUES}(8)^2 + A_{WED}(8)^2 + A_{THUR}(8)^2 + A_{FRI}(8)^2 + A_{SAT}(8)^2 + A_{SUN}(8)^2\right)}$$

Equation 4

$A_{MON}(8)$ to $A_{SUN}(8)$ are the daily exposures for all seven consecutive days. The value $A(8)_{week}$ (normalised to a 5 day working week) may then be compared with the exposure limit value in the usual way.

2.4 Exposure Action and Limit Values

The vector sum action value in current HSE guidance is as follows.

Action Level 4 m/s^2 - equivalent to "dominant" or "highest" axis value of 2.8 m/s^2 (no longer used)

When the forthcoming "Control of Vibration at Work Regulations 2005" come into force in July 2005, then the revised action value and a new limit value for daily personal vibration exposure A(8) are as follows.

Exposure Action Value	2.5 m/s^2
Exposure Limit Value	5 m/s^2

Note:	These values are based on "vector sum" measurements and are normalised to an 8 hour reference period.

A vector sum vibration dose of 4 m/s^2 A(8) should not be considered a safe level. "Studies suggest that symptoms of the hand-arm vibration syndrome are rare in persons exposed with an 8 hour energy-equivalent vibration total value A(8) at a surface in contact with the hand of less than 2 m/s^2 and unreported for A(8) values of less than 1 m/s^2". [Extract from Annex C (Informative) of BS EN ISO 5349-1 : 2001].

2.5 Single Tool Running Time or Time to Reach Exposure Value

Some employers find it useful to monitor and control vibration exposure by specifying a running time limit on individual tools. When only one vibrating tool is used in a single day, the single tool running time (M) which does not exceed an (action or limit) value can be calculated from the measured vector sum vibration value, a_{hv} provided there is no other exposure to high vibration tools during the working day.

$$M = \left(\frac{\text{action value}}{a_{hv}}\right)^2 \times M_o = \left(\frac{4}{a_{hv}}\right)^2 \times 480 \quad \text{. . . . . Equation 5}$$

where M is the single tool running time in minutes
M_0 is the reference duration of 480 minutes
and the chosen action value is 4 m/s^2

Alternative action or limit values of 2.5 or 5 m/s^2 may be used as necessary for the required evaluation.

Note:	The running time M and the reference duration M_0 must be in the same units (ie M in minutes then M_0 = 480, M in hours then M_0 = 8).

Do not use this equation for very large accelerations (and extrapolate M for short durations) as such exposures can be associated with other acute injuries to the hand-arm system.

"Daily usage limit" and "safe" working times are similar terms which you may encounter in relevant literature.

2.6 Exposure Points System

Where there are multiple exposures due to the use of different tools, a more sophisticated system is required to manage daily exposure - hence the following points system.

Exposure Points

$$n = \left[\frac{a_{hv}}{2.5}\right]^2 \times \frac{t}{8} \times 100 \quad \text{. . . . . Equation 6}$$

where t is the exposure time in hours.

The above equation can be used to calculate exposure points for each individual tool/operation. The total exposure is then obtain from a simple addition of the points for each tool/operation and can be compared with the relevant action/limit value to determine the management actions required.

Exposure Action Value	2.5 m/s^2	=	100 exposure points
	4 m/s^2	=	256 exposure points
Exposure Limit Value	5 m/s^2	=	400 exposure points

For any particular tool the number of exposure points accumulated in an hour is as follows.

One Hour Exposure Points

$$n_{1\ hour} = 2 \times a_{hv}^2 \quad \text{. . . . . Equation 7}$$

One hour exposure points is a very powerful and useful method which can easily be factored for the actual running time of each tool and processed as above for multiple tool use.

2.7 Prevalence of Finger Blanching

A tentative relationship between vibration exposures and finger blanching is presented in Annex C (referred to as informative as it provides guidance alone) of BS EN ISO 5349 : 2001.

Years for 10% Risk of Finger Blanching

$$D_y = \frac{31.8}{A(8)^{1.06}} = \left(\text{approximately } \frac{32}{A(8)}\right) \quad \text{. . . . Equation 8}$$

where A(8) is the daily personal vibration exposure
and D_y is the group mean total (lifetime) exposure duration, in years.
The calculated value is only applicable between 1 and 8 years.

The years for 10% risk of finger blanching is a rough statistical guide for a group of exposed persons and cannot predict the risk of finger blanching for an individual within a group (ie it provides a rough guide for an "average" person) based on the tentative relationship.

Note:	The state of knowledge of the dose effect relationship is very limited. The probability of a vibration exposed individual developing finger blanching depends not only on the risk factors, but also on individual susceptibility and behaviour.

3 ADDITIONAL TERMS IN HAV-BASE

HAV-Base
The **INVC** hand-arm vibration database contains the largest set of accurate field vibration data available in Europe. It enables HAV data to be stored and managed effectively and provides all the tools required to automate hand-arm vibration risk assessment and management. **HAV-Base Pro** (the professional version) provides additional features including advanced equipment selection, photographs (where available) of equipment and statistical information on groups of equipment in each category.

Graphical Summary
The measured field vibration data for any selected equipment (or equipment categories) is presented graphically as a bar graph showing the measured vibration value and the single tool running time (for not exceeding the chosen action level/limit value). This allows you instantly to choose and review test data for low vibration equipment. With **HAV-Base Pro** a graphical summary is also presented of the statistical data for a group of equipment in the same category showing the vibration value and running time (min/average/max and mean ± 1 standard deviation). This provides information to see how your equipment compares with other tooling (above or below average etc).

Virtual Assessment
Field vibration measurement at the operator's place of work is difficult to do properly, time consuming and expensive. The HSE encourages the use of published field vibration data for HAV assessments where it provides values (or range of values) which represent the equipment or tool and operating condition of your equipment (ie vibration information which represents workplace use of equipment broadly similar to the way you use it). **HAV-Base** allows you to generate a Virtual Assessment by selecting field vibration data based on equipment category (eg breaker) make and model, power source (pneumatic, electric etc), operation and material. A **Basic Virtual Assessment** is generated providing measured vector sum vibration values, 1 hour exposure points and single tool running time (not to exceed the chosen action/limit value) for all items of selected equipment. Alternatively, the user can enter their own "finger-on-trigger" equipment usage times to obtain a **Full Virtual Assessment** which includes single tool daily exposure A(8), exposure points, number of years for 10% risk of finger blanching and the same single tool running time.

Dual Assessment
A dual assessment presents not only the vector sum values, daily exposure A(8) and exposure point values, but also the running times for single tool use for not exceeding the action and limit values in current HSE guidance and the forthcoming "Control of Vibration at Work" regulations.

HAV Statistics
The HAV statistics allow you to generate detailed vibration statistics for a group of a equipment within the same category, providing average, range (min/max) of vector sum values, the standard deviation and the percentage and number of items in each group which exceed the action value based on a user entered "finger-on-trigger" time.

"Finger-on-Trigger" Time
The "finger-on-trigger" time is the total time that the hand is in contact with the vibrating surface or handle whilst the equipment is running. It is often over-estimated by operators and quoted as the total time to do a particular job, including preparation work and other tasks carried out whilst not actually using the hand tool. For assessment of Hand-Arm Vibration, an accurate "finger-on-trigger" equipment usage time (whilst running) is essential. The daily exposure A(8) is calculated from measured vibration values and is highly dependent on accurate daily contact or trigger time.

Overload
For highly percussive or impact tooling (eg breakers and other hammer action tools) some meters display vibration values in m/s^2 even when an overload has occurred. We recommend these values are not used but if you wish to enter them into **HAV-Base** please ensure you tick the overload flag box. These measurements will be invalid and more sophisticated instrumentation will be required such as appropriate accelerometer/charge amplifier systems and/or mechanical filters to measure this impulsive equipment.

Appendix C.

Hand-Arm Vibration Assessment:

User Info : **Measurements carried out by INVC for Norbar Torque Tools**

Equipment Details:

Equipment :	**Wrench, Impact**	Client :	**Norbar Torque Tools**
aka :		Dept :	
		TestID :	**3241**
Power :	**Pneumatic**	Date :	**08/09/2005**
Manufacturer :	**Kuani**	Ref :	**R4686.sw**
Model :	**KI-36**	Age :	months (since last refurbishment)
Plant or Serial No :	**0003006**	Tool /accessory :	**32mm socket**
Operation :	**Tightening**	Task :	**Tightening wheel nuts**
Material :	**Nuts**		
Type :	**Hand-Held**	Op Conditions :	

Hand-Arm Vibration Assessment:

Measured HAV Data

		Frequency weighted vibration values m/s^2 x	y	z	"Finger-on-trigger" time
Handle1:	**Trigger**	**11.2**	**12.5**	**8.5**	
Handle2:	**Support**	**9.2**	**9.1**	**3.7**	**decimal hours**

Daily HAV exposure

Highest Axis	Vector Sum	A(8) m/s^2	10% Risk years	Single Tool Running Time minutes
12.5				
	18.8			**22**

Meter Overload: ☐

Notes

The Single Tool Running Time is based on not exceeding a **Vector Sum** **Daily Dose A(8) of 4.0 m/s^2**

Years for 10% Risk of finger blanching is a rough guide for an "average" person, based on a tentative relationship.

Additional Information:

Data Source : **INVC Report**

Data Type : **FIELD**

Notes : Tightening 10 wheel nuts on Mercedes 2540 truck in 45 secs.

User Note : **Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements**

Appendix C.

Hand-Arm Vibration Assessment:

User Info : **Measurements carried out by INVC for Norbar Torque Tools**

Equipment Details:

Equipment :	**Wrench, Torque**	Client :	**Norbar Torque Tools**
aka :	**Pneutorque**	Dept :	
		TestID :	**3240**
Power :	**Pneumatic**	Date :	**08/09/2005**
Manufacturer :	**Norbar**	Ref :	**R4686.sw**
Model :	**77112**	Age :	**0** months (since last refurbishment)
Plant or Serial No :	**2005/33438**	Tool /accessory :	**32mm socket**
Operation :	**Tightening**	Task :	**Tightening wheel nuts**
Material :	**Nuts**		
Type :	**Hand-Held**	Op Conditions :	

Hand-Arm Vibration Assessment:

Measured HAV Data

		Frequency weighted vibration values m/s^2 x	y	z	"Finger-on-trigger" time
Handle1:	**Trigger**				
Handle2:	**Support**	**1.3**	**0.5**	**0.3**	**decimal hours**

Daily HAV exposure

Highest Axis	Vector Sum	A(8) m/s^2	10% Risk years	Single Tool Running Time minutes
1.3				
	1.4			**> 24 hr**

Meter Overload: ☐

Notes

The Single Tool Running Time is based on not exceeding a **Vector Sum** **Daily Dose A(8) of 4.0 m/s^2**

Years for 10% Risk of finger blanching is a rough guide for an "average" person, based on a tentative relationship.

Additional Information:

Data Source : **INVC Report**

Data Type : **FIELD**

Notes : Tightening 10 wheel nuts to 600 Nm on Mercedes 2540 truck in 1 min 16 secs. REPEAT on support handle only.

User Note : **Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements**

Appendix C.

Hand-Arm Vibration Assessment:

User Info : **Measurements carried out by INVC for Norbar Torque Tools**

Equipment Details:

Equipment :	**Wrench, Torque**	Client :	**Norbar Torque Tools**
aka :	**Pneutorque**	Dept :	
		TestID :	**3239**
Power :	**Pneumatic**	Date :	**08/09/2005**
Manufacturer :	**Norbar**	Ref :	**R4686.sw**
Model :	**77112**	Age :	**0** months (since last refurbishment)
Plant or Serial No :	**2005/33438**	Tool /accessory :	**32mm socket**
Operation :	**Tightening**	Task :	**Tightening wheel nuts**
Material :	**Nuts**		
Type :	**Hand-Held**	Op Conditions :	

Hand-Arm Vibration Assessment:

Measured HAV Data

		Frequency weighted vibration values m/s^2 x	y	z	"Finger-on-trigger" time
Handle1:	**Trigger**	**0.5**	**0.4**	**0.4**	
Handle2:	**Support**	**1.2**	**0.4**	**0.4**	**decimal hours**

Daily HAV exposure

Highest Axis	Vector Sum	A(8) m/s^2	10% Risk years	Single Tool Running Time minutes
1.2				
	1.3			**> 24 hr**

Meter Overload: ☐

Notes

The Single Tool Running Time is based on not exceeding a **Vector Sum** **Daily Dose A(8) of 4.0 m/s^2**

Years for 10% Risk of finger blanching is a rough guide for an "average" person, based on a tentative relationship.

Additional Information:

Data Source : **INVC Report**

Data Type : **FIELD**

Notes : Tightening 10 wheel nuts to 600 Nm on Mercedes 2540 truck in 1 min 25 secs.

User Note : **Data extracted from and processed by HAV-Base + NOISE-Base - the INVC database of field hand-arm vibration and operator noise measurements**