Maritime and Coastguard Agency

CO80 : CODE OF PRACTICE ON NOISE AND VIBRATION IN SHIPS

***CONSULTATION DRAFT ***

CO80 P1 2/09 : CODE OF PRACTICE FOR CONTROLLING RISKS DUE TO **WHOLE-BODY** VIBRATION ON SHIPS

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Preface

The EC Physical Agents (Vibration) Directive (2002/44/EC) is implemented for land based workers in Great Britain by the Control of Vibration at Work Regulations 2005 (SI 2005/1093) and for land based workers in Northern Ireland by the Control of Vibration at Work (Northern Ireland) Regulations 2005 (SR(NI) 2005 No.397)

For workers on ships Directive 2002/44/EC is implemented by the Merchant Shipping and Fishing Vessels (Control of Vibration at Work) Regulations 2007 (SI 2007/3077).

This Code of Practice is intended to assist those concerned with the design, building, owning or managing of ships to comply with the Merchant Shipping and Fishing Vessels (Control of Vibration at Work) Regulations 2007. This Code is based upon existing guidance on the EU Directives (European Commission, 2008) and the Control of Vibration at Work Regulations 2005 (Health and Safety Executive, 2005a), but with the information edited and packaged in the context of the provisions of the Merchant Shipping and Fishing Vessels (Control of Vibration at Work) Regulations 2007 (herein referred to as the “2007 Vibration Regulations”) as they apply to whole-body vibration.

Contents

1 Introduction

The Merchant Shipping and Fishing Vessel (Control of Vibration at Work) Regulations 2007 (SI 2007/3077) (the “2007 Vibration Regulations”) implement a 2002 European Union Directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from occupational vibration. To implement the EU Directive for land-based workers, UK regulations have already been introduced by the Health and Safety Executive, but these land-based regulations do not apply to the master and crew of a UK ship in respect of normal shipboard activities.

The 2007 Vibration Regulations extend the provisions of Directive 2002/44/EC to workers, irrespective of nationality, who are employed on UK registered vessels irrespective of whether they are operating on inland waters or at sea and also irrespective of where in the world they are operating. The 2007 Vibration Regulations include provisions for:

- action values and limit values for exposure to vibration,
- risk assessment,
- elimination of or, where this is not reasonably practicable, reduction of exposure to vibration;
- actions to be taken at action values and limit values,
- prohibition on exceeding limit values,
- information, instruction and training for vibration-exposed workers,
- health surveillance, and
- consultation with workers.

Those primarily affected by the vibration regulations will be operators and managers of ships, fishing vessels, and other marine craft, including yachts, work boats etc. registered in the UK on which paid workers are employed. The 2007 Vibration Regulations will apply also to charities and similar organisations that operate vessels, but only when there are paid workers on such vessels.

The main provisions of the vibration regulations may be seen in the overview of Appendix A. Employers are required to identify which of their employees may be at risk from vibration, to assess the degree of risk and to introduce measures to eliminate or minimise that risk. The provisions of the regulations will be enforced by means of inspections carried out by surveyors or inspectors from the Maritime and Coastguard Agency. As the regulations are intended to improve the health and safety of workers on board UK ships and fishing vessels, the regulations contain sanctions for non-compliance.

This Code of Practice is intended to help those concerned with designing, building, operating or managing vessels to understand their responsibilities under the Merchant Shipping and Fishing Vessels (Control of Vibration at Work) Regulations 2007 as they apply to whole-body vibration.

2 Scope of the Code

This Code of Practice deals with:

- the assessment of risk from whole-body vibration onboard ships,
- the measurement and evaluation of whole-body vibration;
- the assessment of the severity of exposures to whole-body vibration;
- the identification of controls to eliminate or reduce exposures to whole-body vibration;
- the involvement of crew members in the control of whole-body vibration risks, including the provision of information and training;
- the provision of health monitoring and surveillance for whole-body vibration.

The provisions of this Code are not intended to apply to passenger spaces, but if crew are required to work in such spaces they will be regarded as crew work areas.

3 Purpose of the Code

The objectives of this Code of Practice are to:

- explain the duties of employers regarding the assessment and control of health risks associated with exposure to whole-body vibration in the maritime environment;

- provide sufficient information to enable employers to assess the risks of injury to seafarers from whole-body vibration;

- set out measures to be taken to control that risk, either by appropriate design and use of equipment or by the use of methods to limit exposures to whole-body vibration;

- set out the requirements to monitor the health of seafarers;

- discuss the employer's duties to inform seafarers of the risks and consequences of exposure to whole-body vibration, and to provide adequate training for the safe use of vessels and machinery.

It is assumed that the readers of this code will be ship owners and managers, and other interested parties such as ship designers and builders. A degree of technical knowledge is assumed, but it is recognised that any single individual is unlikely to have the necessary knowledge and skills to deal effectively with all of the objectives of this code. To fulfil all the requirements of the vibration regulations, an employer may need to use the services of a technical specialist, who may be found either in-house or contracted-in.

4 Application of the Code

The 2007 Vibration Regulations apply to all vessels registered in the United Kingdom on which workers are employed, whether in UK inland waters or the territorial sea or anywhere else in the world. The guidance in this Code applies to all such vessels.

This Code is also relevant to United Kingdom vessels involved in civil protection services or public service activities, and to non-UK-registered ships and vessels when they are in UK waters.

Privately-owned pleasure craft fall within the scope of this Code if there are paid crew on such craft.

The Code covers the safety of crew, regardless of nationality. It applies to crew when they are on-board for the purpose of work, whether the vessel is in port, or at sea, including time when they are off duty.

4.1 Exemptions from the vibration regulations

In exceptional circumstances, the Secretary of State may grant exemptions for specific ships from the need to comply with the whole-body vibration daily exposure limit value for limited periods of up to four years, provided that vibration exposure is less than the exposure limit value when averaged over 40 hours (rather than the usual 8 hours).

The above exemption will only be granted where it can be demonstrated that it is not possible for the ship to comply with the daily exposure limit value, consultations have been held with workers and employers, the risks have been reduced to the minimum possible, and appropriate health monitoring is being provided.

Applications for an exemption from the daily exposure limit value under regulation 12 should be addressed to the nearest MCA Marine Office. The employer should include a detailed case, including all the measures that have been taken to comply with the regulations, and why it is not possible to comply with the daily exposure limit value.

5 Effects of whole-body vibration on crew

Whole-body vibration is caused by vibration transmitted through a surface supporting the whole body, such as a seat for a seated person, or the feet for a standing person. The transmission of vibration to the body is dependent on the frequency and direction of the vibration and the body posture. The prediction of the effects of a vibration from the characteristics of the vibration is therefore complex. Exposure to whole-body vibration causes motions and forces within the human body that may:

- cause discomfort;
- adversely affect performance;
- present a health and safety risk;
- aggravate pre-existing injuries;
- cause motion sickness (from low-frequency motions).

The effects of vibration on comfort and performance are not within the scope of this Code of Practice. Vessels that receive a habitability notation from a classification society are expected to meet certain standards for shipboard vibration with respect to effects on comfort and, in some cases, performance. Classification societies produce their own guides with different criteria, which often vary with the location in a ship. Currently, the procedures used by many classification societies are based on ISO 6954:1984 (e.g., Det Norske Veritas 2005; Lloyds Register, 1999; Registro Italiano Navale, 2002). The American Bureau of Shipping bases its procedures and criteria for evaluating and assessing shipboard vibration with respect to habitability on BS 6841:1987, which are broadly similar to the procedures for the evaluation of effects of vibration on comfort in ISO 2631-1:1997 (American Bureau of Shipping, 2001). In most cases, the vibration magnitudes required to meet the criteria for habitability will be lower than the magnitudes required to meet the 'exposure action value' for health risks in the 2007 Vibration Regulations, but this may not always be the case, especially when workers are exposed to shipboard vibration for periods approaching 24 hours a day.

This Code of Practice is principally concerned with the identification and control of risks to health and safety due to whole-body vibration, as required by the 2007 Vibration Regulations. This does not include motion sickness. The signs and symptoms of disorders that may be associated with exposure to whole-body vibration are discussed in Appendix E.

The risks to health and safety from whole-body vibration are greatest when the vibration magnitudes are high, the exposure durations long, frequent, and regular, and the vibration includes severe shocks or jolts. The most significant sources of whole-body vibration in the marine environment include the motions of small, high powered craft, when operated at speed in less than perfect conditions. The severity of the vibration, and the associated risk, will depend on the craft, the task, the vessel speed, sea conditions, crew skill and the duration of exposure. The operation of such vessels in smooth water, and the normal operation of other types of vessel, are less likely to produce very high magnitudes of whole-body vibration. However, it should not be assumed that this will always be the case because out-of-alignment or inappropriately selected or poorly maintained machinery on any size of vessel, in combination with the natural modes of the vessel structure, can induce high magnitudes of whole-body vibration.

The risks arising from exposure to whole-body vibration include back injury or the aggravation of pre-existing back injuries. However, back injury can be caused by ergonomic factors such as manual handling of loads and restricted or awkward postures, and these factors may be as important as, or more important than, exposure to whole-body vibration. Back injury can also be caused by activities in or out of work unrelated to the maritime environment. To tackle successfully the problem of back injury in crews of ships and small craft, all possible contributory factors should be identified and controlled.

The risk of back pain and other disorders will be increased where a seaman is exposed to one or more contributory factors while being exposed to whole-body vibration. For example:

- being exposed to whole-body vibration for long periods without being able to change position;
- being exposed to whole-body vibration while sitting in a stretched or twisted posture due to poor design of controls, incorrectly adjusted seats or restricted visibility;
- being exposed to whole-body vibration and then doing work involving manual lifting or carrying heavy loads.

Older people, those with previous back or neck problems, young people and pregnant women are also more likely to be at risk of back pain and other problems described in Appendix E.

5.1 Exposure action and limit values

The 2007 Vibration Regulations establish minimum standards for controlling the risks to seafarers from whole-body vibration. The vibration regulations set:

i. a daily exposure action value of 0.5 m/s^2, above which employers are required to implement measures to control the whole-body vibration risks of workers.

ii. a daily exposure limit value of 1.15 m/s^2, above which workers must not be exposed.

The exposure action value and exposure limit value are each standardised to an eight hour reference period.

6 Assessment of risks

6.1 Survey method

The Merchant Shipping and Fishing Vessels (Health and Safety at Work) Regulations 1997 (SI 1997/2962) require a suitable and sufficient risk assessment to be made of the risks of the health and safety of workers arising in the normal course of their activities or duties, for the purpose of identifying:

i. groups of workers at particular risk in the performance of their duties;

ii. the measures to be taken to comply with the employer's duties under the Regulations.

As part of this risk assessment, to comply with the 2007 Vibration Regulations, employers need to determine whether workers on their vessel are at risk from whole-body vibration.

The assessment of risks due to whole-body vibration should involve the following steps:

i. identify all workers who may be at risk from whole-body vibration;

ii. decide if workers are likely to be exposed above the daily exposure action value or the daily exposure limit value;

iii. identify any additional risks such as ergonomic factors, pre-existing injuries or individual susceptibility;

iv. identify the available methods for controlling the identified risks;

v. identify the steps that will be taken to control and monitor the risks;

vi. record the assessment, the steps that have been taken, and their effectiveness.

How this is done is for the employer to decide but one way might be to collect the basic information needed for this risk assessment by observing work tasks and by talking to managers, workers and others on the ship. This approach may produce enough information to permit the making of a broad assessment of the risk and, if necessary, to permit control measures to be introduced to reduce the risk to a reasonable level.

6.2 Identification of workers at risk

Exposures could exceed the daily exposure action value where one or more of the following situations are observed:

- uncomfortable magnitudes of vibration can be felt on the deck, seats or bunks near to engines, propulsion equipment or other machinery;
- workers frequently operate mobile machinery, such as fork-lift trucks;
- there are warnings in the vessel or engine handbooks of risks from whole-body vibration;

- the vessel, engine or other equipment is not designed for the tasks or conditions in which they are being used (handbooks and suppliers should be consulted to ensure equipment is suitable for the task and is being used correctly);
- small craft are being operated at high speeds in open sea conditions, exposing crews to shocks and jolts during wave encounters;
- workers report back problems.

The daily exposure limit value is most likely to be exceeded by workers on high-powered small craft operating at speed in rough water, particularly when crew are exposed to uncomfortable shocks or jolts, or need to take action to avoid becoming unseated during wave encounters. The factors that govern a worker's daily vibration exposure are the magnitude of the vibration and the length of time the worker is exposed to it. The longer the duration of exposure, the greater will be the risk (see Section 6.3).

Both ergonomic risks and vibration exposures need to be managed, especially if there is evidence of back problems. The following ergonomic factors may contribute to back discomfort and back pain:

- poor posture while driving or operating vessels or equipment;
- sitting for long periods without being able to change position;
- incorrect adjustment of seats or poorly placed controls, which require the helmsman or operator to stretch or twist;
- poor visibility of the operation being carried out, which requires twisting and stretching to get an adequate view;
- manual lifting and carrying of heavy or awkward loads;
- repeatedly climbing into or out of small craft.

All of the above factors can separately cause back discomfort or back pain. However, the risk will be increased where a person is exposed to one or more of these factors while being exposed to whole-body vibration.

All potential contributory risk factors must be considered together in the employer's plans to minimise the risk of back injury. Where the work of crew members includes the manual handling of materials employers should control risks according to the principles described in Chapter 19 of the MCA Code of Safe Working Practices for Merchant Seamen (Maritime and Coastguard Agency, 2007b).

6.3 Measurement and evaluation of exposures to whole-body vibration

The quantity that is evaluated, for comparison with the exposure action value and the exposure limit value is the daily vibration exposure, $A(8)$. This is expressed in units of metres per second squared (m/s^2) and represents the 8-hour energy-equivalent magnitude of whole-body vibration for a worker during a day.

The factors that govern a person's daily vibration exposure are the frequency-weighted magnitude of vibration and the duration the person is exposed. The greater the magnitude or the longer the duration of exposure, the greater will be the person's vibration exposure.

An exposure assessment will help an employer to be confident whether exposures exceed the exposure action value or the exposure limit value and to identify the control actions that will be most effective and practicable in reducing vibration exposures. It is important that employers are aware of activities where the risk to workers is high (e.g., where the daily exposure action value may be exceeded).

If a risk assessment has been carried out and appropriate actions have been taken to control the risks, it may not be necessary to make vibration measurements, particularly where exposures are likely to be below the exposure action value (Health and Safety Executive, 2005a).

6.3.1 Competent persons

The evaluation and assessment of vibration exposures should be performed by a 'competent person'. This person may be an employee of the ship owner or operator, or an external consultant contracted to the ship owner or operator.

The assessor should have a technical background sufficient to understand the necessary calculations as explained in this section of the Code of Practice. He or she should also have adequate general knowledge of vessel structure and layout, and be acquainted with the work schedules and practices used onboard the vessel being surveyed.

The measurement of vibration can be a complex task, so it is particularly important that, where vibration measurements are performed, whoever makes the measurements has sufficient competence and experience. Persons performing measurements of whole-body vibration must have a thorough understanding of the method of measuring and evaluating exposures defined in ISO 2631-1:1997, as well as training and practical experience in performing vibration testing.

Specialist consultants or engineers who are employed to assess vibration exposures should be able to demonstrate that:

i. they have practical experience in the measurement, evaluation and assessment of whole-body vibration;

ii. their equipment complies with the requirements of BS EN ISO 8041:2005 and is in current calibration: measuring instrument and calibrators should be returned to the manufacturer or other competent organisation capable of providing a calibration check traceable to a national standard laboratory at intervals not exceeding two years.

It is recommended that such consultants and engineers have a quality system in place that covers these activities and is compliant with the current version of BS EN ISO 9001.

6.3.2 Determining the duration of vibration

The vibration exposure of an individual during a working day may involve a series of different operations, some of which may be repeated. The vibration exposure may vary greatly from one operation to another. For example:

- operating a small craft at different combinations of speeds and sea conditions;
- performing tasks in various locations on a large vessel where there may be high vibration magnitudes in proximity to different machinery (e.g., engines, generators, thrusters and other propulsion machinery, winches).

All individual operations likely to contribute substantially to the overall vibration exposure should be identified, and the total duration of each of these should be determined for an individual worker during a single day. It is better to determine exposure durations by observation (e.g., using a stopwatch), than by asking workers, since operators asked for information on their typical daily vibration exposure duration often give an estimate that includes periods of time when there is no vibration. It is recommended that persons determining the duration of exposures consult BS EN 14253:2003+A1:2007. This standard provides practical guidance for the measurement and evaluation of occupational exposure to whole-body vibration with reference to health. It is aimed at land-based workers and is in accord with The Control of Vibration at Work Regulations 2005 (SI 1093/2005), but the same methods are used to measure and evaluate whole-body vibration exposures of workers on ships.

If workers are involved in many different operations in which they are exposed to whole-body vibration, BS EN 14253:2003+A1:2007 recommends that a survey should be undertaken to establish an ‘exposure profile’. This will help to determine the likely relative importance of each type of operation in the overall value of $A(8)$, to identify those for which measurements are required, and to assist in the planning of any necessary exposure controls.

6.3.3 Determining the magnitude of vibration

6.3.3.1 Definition of vibration magnitude

The vibration magnitude is expressed in terms of the frequency-weighted acceleration at the seat of a seated person or the feet of a standing person, as defined in ISO 2631-1:1997.

The vibration at the seat or deck is defined by the amplitude and frequency of the oscillations in three orthogonal axes, as illustrated in Figure 1. The vibration amplitude is usually expressed in acceleration units (metres per second squared, or m/s^2) because most vibration transducers produce an output that is related to acceleration. The vibration frequency is expressed in cycles per second, which is more usually stated as hertz (abbreviated to Hz).

The frequencies that are thought to be important for whole-body vibration range from 0.5 Hz to 80 Hz. Because the risk of damage is not equal at all frequencies a frequency-weighting is used to represent the likelihood of damage from the different frequencies. For whole-body vibration, two different frequency weightings are used. One weighting (the W_d weighting) applies to the two horizontal axes, the *x*-axis and the *y*-axis, and another (the W_k weighting) applies to the vertical, *z*-axis. The W_d and W_k frequency weightings, are shown in Figure 2. The frequency weightings incorporate high-pass and low-pass band-limiting filters that pass vibration at frequencies between 0.5 Hz and 80 Hz, and progressively attenuate vibration outside the range. However, the vibration regulations allow the evaluation of whole-body vibration to be restricted to frequencies greater than 1 Hz (see Section 6.3.3.3.2).

The acceleration magnitude (a_{wj}) for axis j (where j = x, y or z) is the root-mean-square average of the frequency-weighted acceleration time history, calculated according to:

$$a_{wj} = \left(\frac{1}{T} \int_0^T a_{wj}^2(t) dt \right)^{\frac{1}{2}}$$

where $a_{wj}(t)$ is the frequency-weighted acceleration in axis j as a function of time *t*, and *T* is the duration of the measurement.

When considering the risks to health from whole-body vibration, ISO 2631-1:1997 applies an additional multiplying factor to the frequency-weighted vibration values. For the two horizontal axes (*x*- and *y*-axes) the acceleration values are multiplied by 1.4. For the vertical axis (*z*-axis), the multiplying factor is 1.0. The magnitude of whole-body vibration, a_w, to be used for the assessment of risk is the greatest of the frequency-

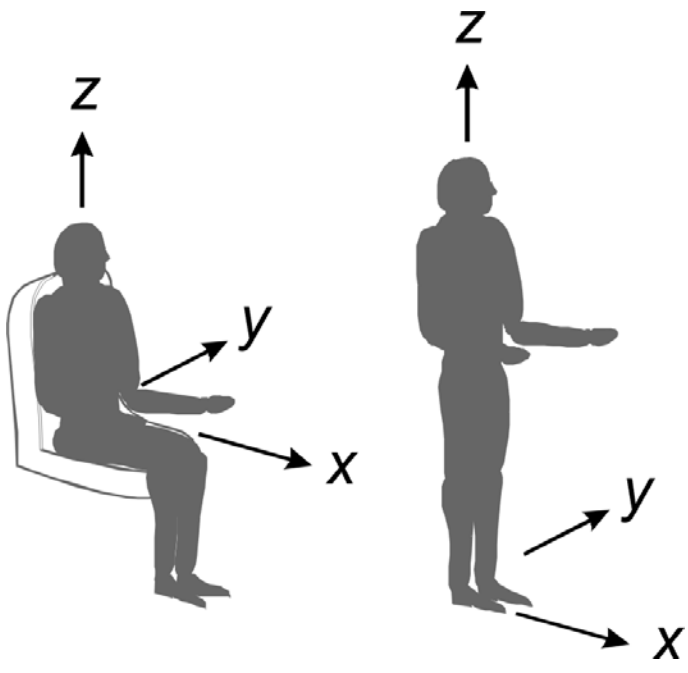

Figure 1 Whole-body vibration measurement axes for seated and standing workers

weighted accelerations in either of the three orthogonal axes after multiplication by the appropriate multiplying factor:

$$a_w = \max\lfloor 1.4a_{wx}, 1.4a_{wy}, a_{wz} \rfloor$$

6.3.3.2 Use of manufacturer's and other data sources

Unlike manufacturers of work vehicles and machines for use on land, there is currently no legal requirement for marine craft builders to declare vibration emissions (i.e., the magnitudes likely to occur) on marine craft, but handbooks, or the builders, should always be consulted to find out if they are able to provide such data.

Vibration measurements may have been made for various reasons, such as to determine equipment survivability, to evaluate habitability, or to obtain a notation from a classification society. Such measurements cannot be directly compared with the exposure action and exposure limit values if they were not measured and analysed by an appropriate method. Vibration magnitudes evaluated according to ISO 6954:1984 or BS EN ISO 6954:2000 will often under-estimate values obtained according to ISO 2631-1:1997 (as required by the vibration regulations), due to differences between the frequency weightings used by the different standards, but this may not always be the case if the vibration contains low frequency (e.g. wave-induced) components.

Ideally you should use vibration information for the craft (make and model) you plan to use. However, if this is not available you may need to use information relating to similar craft as a starting point, replacing the data with more accurate values when these become available.

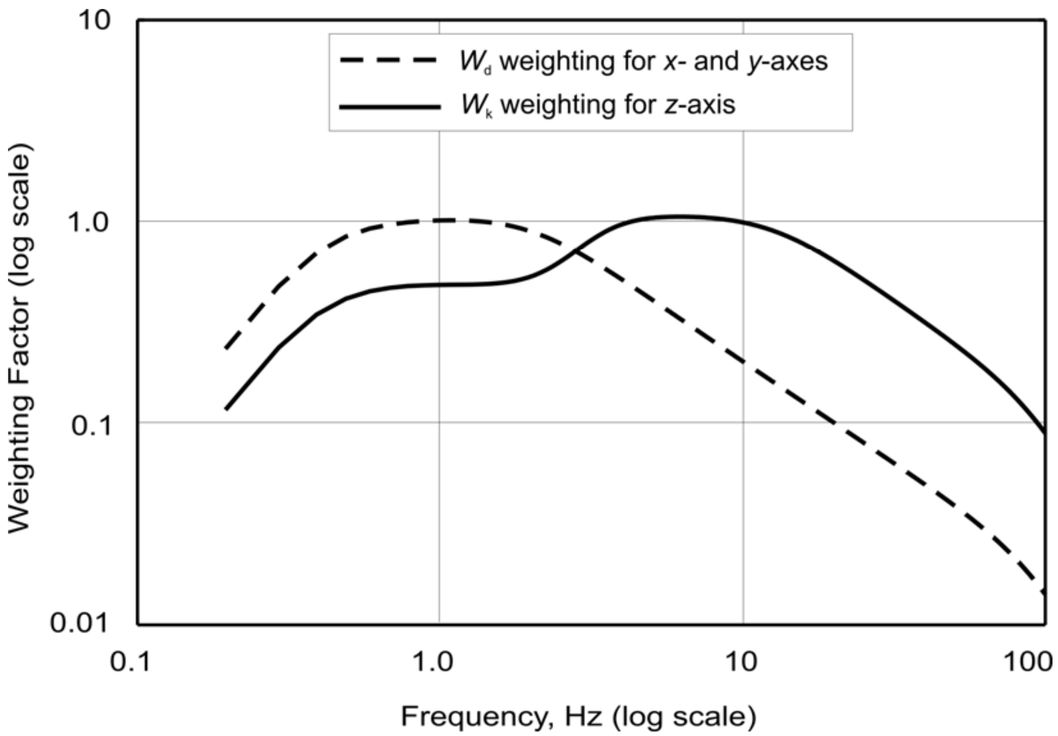

Figure 2 Frequency weightings for the evaluation of whole-body vibration

When choosing from published vibration information, the following factors need to be taken into account:

i. the type, size and power of the vessel;

ii. any features that may modify the vibration transmitted to crew (e.g., seats);

iii. the loading of the vessel;

iv. the speed, sea state and heading relative to the wave direction.

When using published vibration data it is good practice to try to compare data from more than one source if it is available.

6.3.3.3 Making measurements

Human exposures to whole-body vibration should be measured using the method defined in International Standard ISO 2631-1:1997. Practical guidance on using the method for measuring vibration at a workplace is given in BS EN 14253:2003+A1:2007. Although BS EN 14253:2003 is written around the regulations for land-based workers, the same methods are used in the 2007 Vibration Regulations to measure and evaluate exposures of workers on ships to whole-body vibration.

Measurements should produce vibration values that are representative of the vibration throughout the working period of a crew member. The operating conditions during the measurements should be selected to be representative of the worst conditions (e.g., loading, speed, heading, sea state) that occur during exposure to a particular source of whole-body vibration.

Measurement durations should be representative of a cycle of operation over which workers are exposed to a particular source of vibration. This may require measuring the vibration at several different crew stations over the whole period from when the vessel departs from the quay to when it returns.

Measurements can be made over short periods if the magnitude and frequency of the vibration remain constant for long periods, as in a large vessel on which the principal sources of whole-body vibration are engines, propulsion equipment and other rotating machinery operating at constant speed. In such cases, sample measurements should be made covering the whole range of operating conditions that can occur during a whole day's exposure to a source of vibration.

6.3.3.3.1 Measurement Instrumentation

The measurement of whole-body vibration requires suitable accelerometers (vibration transducers) and an instrument that either provides signal conditioning and analysis or the capability to record the acceleration time histories for later analysis. Whole-body vibration measuring equipment should comply with BS EN ISO 8041:2005 (Human response to vibration - measuring instrumentation) and be in current calibration, traceable to national standards.

The instrumentation can comprise a self-contained meter, or a sub-system that connects to a computer with suitable analysis software. It is desirable to use an instrument that records and displays acceleration time histories, since this makes it possible for the operator to directly observe problems due to overloading, mounting or connecting to the transducers.

The accelerometers should have a flat frequency response between 0.5 Hz and 80 Hz, and the accelerometers and measuring instrument should have a large enough dynamic range to encompass the range of accelerations that could occur at the measurement location. High peak accelerations can occur on some small high-speed craft and could overload unsuitable transducers or an instrument with an inappropriate range setting, whereas a smaller dynamic range may be more appropriate for some measurements on a large ship. Vibration must be measured in three axes using either a tri-axial accelerometer, or three single-axis accelerometers orientated in orthogonal directions (see Figure 1).

Calibration checks should be performed before and after measurements. If the accelerometers respond to DC acceleration, the calibration can be checked by rotating each accelerometer by 180 degrees relative to the gravitational vertical and observing a change of 19.6 m/s^2 (2 g) in the measured acceleration. Other accelerometers can be checked by mounting them on portable or laboratory calibrators that excite the transducers with sinusoidal vibration at a known magnitude and appropriate frequency.

For standing persons, the vibration should be measured on the supporting surface closely adjacent to the area of contact between the feet and that surface. Where the supporting surface is rigid the accelerometers may be rigidly fixed to that surface (advice on alternative methods for mounting of accelerometers is given in BS ISO 5348:1998). Alternatively, the accelerometers may be mounted in the middle of a rigid plate (with approximate dimensions 300 mm x 400 mm), with a person standing on the plate (see BS EN 14253:2003+A1:2007). The latter method should always be used if the supporting surface is covered by a resilient material.

For the measurement of vibration on seats, the accelerometers should be moulded into a flexible disc that complies with BS EN 30326-1:1994, and the centre of this disc should be positioned under the ischial tuberosities (sitting bones) of the seated person. Care must be taken to avoid artefacts due to intentional movements of the seated person (e.g., when entering, leaving or moving in the seat), which can result in over-estimates of vibration magnitudes. Inspection of acceleration time histories can be helpful to identify these events (see BS EN 14253:2003+A1:2007).

The daily exposure to vibration of workers on ships with crew accommodation includes any vibration to which they are exposed in recreation or sleeping areas. Where it is necessary to assess the vibration in sleeping areas (i.e., on bunks) the vibration may be measured on the deck at the base of the bunk. In most cases this should produce an over-estimate of the actual exposure of person reclined in the bunk.

6.3.3.3.2 Effects of frequencies below 1 Hz

The vibration regulations require that whole-body vibration is evaluated according to ISO 2631-1:1997. This standard requires vibration to be evaluated over frequencies between 0.5 Hz and 80 Hz. The W_d and W_k frequency weightings incorporate high-pass and low-pass band-limiting filters that accept vibration in this frequency range, and progressively attenuate vibration outside this range. Commercially available equipment for measurement and evaluation of whole-body vibration should comply with these requirements.

The vibration regulations allow the evaluation of whole-body vibration to be restricted to frequencies greater than 1 Hz. Since the restriction of the frequency range requires non-standard equipment it is recommended that evaluations of whole-body vibration are normally carried out according to the standard frequency range, unless they are performed by an experienced specialist.

The attenuation of vibration at all frequencies less than 1 Hz will reduce measured vibration magnitudes, particularly where the vibration includes a significant amount of wave-induced motions.

6.3.3.4 Alternative methods for assessing the risks of shock vibration

It is pointed out in BS EN 14253:2003+A1:2007 that the use of r.m.s. acceleration to evaluate daily vibration exposures may underestimate the severity of the exposure where the vibration contains shocks or impacts. International Standard ISO 2631-1:1997 defines alternative methods, including the vibration dose value (VDV), for evaluating the severity of vibrations containing occasional shocks, and particularly recommends that these are used when the crest factor (i.e., the ratio of the peak acceleration to the r.m.s. acceleration) is greater than nine. The VDV is expressed in units of $m/s^{1.75}$ and is defined for a particular direction of vibration as:

$$VDV = \left(\int_0^T a_w^4(t) dt \right)^{\frac{1}{4}}$$

were $a_w(t)$ is the frequency-weighted acceleration in m/s^2 in the appropriate measurement axis and T is the duration of the measurement.

The use of fourth power acceleration makes the VDV more sensitive to peaks in the acceleration. Unlike the r.m.s. acceleration, the VDV is not averaged over time, but accumulates with continued exposure.

The European Vibration Directive (European Commission, 2002) allows whole-body vibration exposures to be evaluated by either the r.m.s. or the VDV methods. The VDV measured over a working day is assessed against a daily exposure action value of 9.1 $m/s^{1.75}$ and a daily exposure limit value of 21 $m/s^{1.75}$.

It is recommended that measurements that contain shocks should be evaluated according to both the r.m.s. method, as required by the U.K. vibration regulations, and the VDV method. The risk may be identified from the method that gives the most severe assessment. A description of the VDV method, with examples of the evaluation and assessment of worker’s daily exposures, is provided in Appendix A1 of BS EN 14253:2003+A1:2007.

6.3.4 Calculating daily exposure durations

6.3.4.1 Daily vibration exposure

The daily vibration exposure, *A*(8), in any axis, depends on the frequency-weighted magnitude and the square root of the exposure duration:

$$A(8) = a_w \sqrt{\frac{T}{T_0}}$$

where a_w is the vibration magnitude (in m/s² r.m.s.), *T* is the daily duration of exposure to the vibration magnitude a_w, and T_0 is the reference duration of eight hours. On a ship, the daily duration of exposure could extend to 24 hours.

Examples of the calculation of daily vibration exposures are given in Appendix C.1.

6.3.4.2 Partial vibration exposures

Where the vibration exposure of an individual during a working day involves a series of different operations, a partial vibration exposure should be calculated from the magnitude and duration for each axis and for each operation.

Each partial vibration exposure represents the contribution of a particular vibration to the worker's total daily exposure. Knowledge of the partial exposure values will assist in establishing priorities: the periods with the highest partial vibration exposure values are those that should be given priority for control measures.

The partial vibration values are combined to give the overall daily exposure value, *A*(8), for that axis. The daily vibration exposure is then the highest of the three single-axis overall daily values.

Examples of the calculation of vibration exposures involving a number of operations with different vibration magnitudes are given in Appendix B.2.

6.3.4.3 Uncertainty of daily exposure evaluations

There are many factors that introduce uncertainty into the evaluation of vibration exposure. Uncertainty in vibration measurements can occur due to the following factors:

- Instrument calibration uncertainty;
- Mounting of accelerometers;
- Location and orientation of accelerometers;
- Accuracy of source data (e.g., builder's or other published data),
- Variations between helmsmen (e.g., experience, driving speeds or styles),
- Environmental factors (e.g., sea state, wind, temperature),
- Variations in the vessel or machinery (e.g., is there a need for maintenance, is the seat correctly adjusted?).

The uncertainty associated with instrumentation and calibration, and mounting of accelerometers will usually be small compared to the uncertainties due to selection of measurement location and variability in the work operation. When making vibration measurements, the assessor should determine the main sources of uncertainty (e.g. speed; heading; sea state) and the resulting variation in measured vibration magnitudes. Multiple measurements should be made of each operation, and the standard deviation of the measured magnitudes should be calculated and reported in addition to the arithmetic mean of the measurements (BS EN 14253:2003+A1:2007).

Where either the exposure duration or the vibration magnitude is estimated (e.g., based on information from the worker (exposure duration) or manufacturer (vibration magnitude)), the uncertainty in the predicted evaluation of a daily exposure can be large. The employer should take the possible sources of uncertainty into account in the risk assessment. A larger uncertainty increases the risk since workers may be exposed to higher than expected magnitudes of vibration.

6.4 Survey reporting

The vibration regulations require employers to keep a record of risk assessments and control actions. They are also required to keep health records for workers undergoing health surveillance and to review and update the health surveillance regularly.

Reports should be made of any vibration measurements that have been carried out, including:

- date of evaluation;
- person and institution carrying out the measurements and evaluation;
- the details and settings of the instrumentation and accelerometers, including calibration traceability;
- the mounting and orientation of the accelerometers;
- the location of each of the measurements on the vessel;
- type and adjustment of seats and subject weight;
- details of the vessel and auxiliary machinery;
- daily work patterns for each operation being evaluated;
- the operating conditions of the vessel and machinery during each measurement (e.g., task being performed, loading conditions, speed, sea state, wind speed, heading relative to wind and waves);
- acceleration measurement results including the measurement duration and frequency-weighted vibration magnitudes for each axis, and unweighted frequency spectra if frequency analysis is available;
- daily vibration exposure evaluation results including the vibration magnitudes for each operation or work cycle, the duration of vibration exposure for each operation or work cycle, the daily vibration exposure and an assessment of the accuracy of the measured daily exposure magnitudes (see Section 6.3.4.3).

Appendix D provides a suggested format for reporting whole-body vibration measurements according to the 2007 Vibration Regulations. Such a report might usefully be carried onboard the vessel to which it applies.

7 Avoiding or reducing exposure to whole-body vibration

The European Framework Directive 89/391/EEC on the introduction of measures to encourage improvements in the safety and health of workers at work (European Commission, 1990) suggests that the following hierarchy should be adopted for establishing priorities in a programme of preventative measures:

i. avoid risks;

ii. evaluate risks that cannot be avoided;

iii. reduce the risks at source;

iv. adapt the work to the individual (especially with respect to the design of work places, the choice of work equipment and the choice of working and production methods) so as to reduce effects on health;

v. adapt to technical progress;

vi. replace the dangerous by the non-dangerous or the less dangerous;

vii. develop a coherent overall prevention policy that covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;

viii. give collective protective measures priority over individual protective measures;

ix. give appropriate instructions to the workers.

7.1 Developing a control strategy

The risk assessment should enable methods for controlling exposure to be identified. While assessing vibration exposures it is important be thinking about the work processes that cause them. Understanding why workers are exposed to high magnitudes of vibration and ergonomic risks will help identify methods for reducing or eliminating the risks.

The important stages in this management process are:

- identify the main sources of vibration and shock vibration;
- rank them in terms of their contribution to the exposure;
- identify ergonomic risk factors;
- identify and evaluate potential solutions in terms of practicability and cost;
- establish targets that can be realistically achieved;
- allocate priorities and establish an ‘action programme’;
- define management responsibilities and allocate adequate resources;

- implement the risk control programme;
- monitor progress;
- review the risk control programme.

The approach that is taken to reduce risks from whole-body vibration will depend on the vessel, the practical aspects of the work being carried out, and on the current levels of exposure.

The controls may need to be adapted for workers who are at particular risk of injury (e.g., those who are more susceptible to vibration injury or show signs of developing injury at exposures below the exposure action value).

7.2 Involvement of workers

The successful management of risks requires the support and involvement of workers and their representatives. Representatives can provide a channel of communication with the workforce and assist workers in understanding and using health and safety information. MCA Marine Guidance Note 353 (M+F) advises that "ship safety representatives and workers should be consulted about proposals to manage risks from vibration exposure as well as back pain and other health problems arising from such exposure. There should be consultation on the results of the risk assessment, proposals for risk control, for providing information and training for employees, and for any health monitoring system".

Effective consultation involves:

- the sharing of information with workers about actions to improve health and safety;
- workers being given the opportunity to express their views and to contribute in a timely fashion to the resolution of health and safety issues;
- the views of workers being valued and taken in to account.

Effective consultation should result in the identification of control solutions that are well understood by the workers. Employers rely on workers to make control measures effective. Subject to adequate training and supervision, workers have a duty to make correct use of vessels and machinery and to cooperate with the employer to enable them to ensure that their environment and working conditions are safe by minimising and, where possible, eliminating risks to safety and health. The process of consultation encourages worker involvement and co-operation with control measures and so helps to ensure that controls are likely to be implemented.

7.3 Risk controls

7.3.1 Seating

The vibration exposure of a seated person, particularly in the vertical direction (*z*-axis), can be greatly influenced by the dynamic characteristics of a seat cushion. All seat cushions amplify vertical vibration to some extent, usually at frequencies in the region of 4 to 5 Hz, and attenuate vertical vibration at higher frequencies. They usually have little effect on the transmission of vertical vibration at frequencies lower than about 2 Hz. Soft seat cushions tend to produce greater amplification at frequencies around 4 Hz and greater attenuation at higher frequencies than firm seat cushions. Workers sitting on a soft seat may be exposed to lower magnitudes of high frequency vertical vibration (e.g., due to out-of-balance machinery rotating at more than 600 r.p.m.) than a worker standing on the floor at the same location, but the seated worker will tend to be exposed to greater magnitudes of some lower frequencies of vertical vibration due to amplification of vibration by the seat.

So as to minimize ergonomic risks, the seats of helmsmen and other machine operators may need to be provided with appropriate adjustments for height and fore-and-aft position, so as to accommodate different sizes of operator without stretching and twisting to operate controls and to allow variations in comfortable sitting positions.

7.3.1.1 Suspension seats

Suspension seats have a suspension system below the seat cushion, consisting of a spring and damper, so as to provide a lower resonance frequency than a conventional seat.

Where suspension seats are provided, it is important that the seat suspension is appropriate for the application. A poor choice of seat suspension system can result in a greater vibration exposure than would occur without the suspension.

There are currently no standardised methods for testing seats designed for marine environments and reporting the dynamic performance of the seat suspension. It is important that the manufacturer or supplier of a seat provides documented evidence or test results to show that a seat has been designed or adapted for, and tested in, the type of craft and operating conditions in which it is to be used. The probability of the suspension hitting the suspension end-stops, and the severity of any such impacts, should be considered because striking end-stops can create shocks that may increase the risk of injury.

A seat suspension must be easy to adjust for the weight of the operator since seats not adjusted for the weight do not perform optimally and are more likely to hit the end-stops.

7.3.2 Equipment selection, purchasing and maintenance

7.3.2.1 Equipment selection

MCA Marine Guidance Note 353 (M+F) advises that “employers should seek advice from suppliers on the type of craft, engines and other equipment that are most suitable, and with the lowest vibration, for the work proposed by the employer. Employers should avoid any craft or engines reported to have unusually high vibration. Choosing unsuitable vessels or equipment could increase vibration exposure as well as being less efficient”. Employers should therefore:

- select vessels, engines and other equipment so as to be appropriate for the work to be undertaken and the sea conditions;
- consult suppliers and manufacturers for advice on the risks from whole-body

vibration, how to reduce them, and how to train workers to operate equipment safely and efficiently. This information may be available in handbooks prepared by the manufacturers (see next section).

7.3.2.2 Purchasing policy

Employers should make sure that their purchasing department has a policy on purchasing suitable equipment that takes into account health and safety issues including vibration emission, ergonomic factors, and their particular operating requirements.

MCA Marine Guidance Note 353 (M+F) suggests that builders of vessels (especially small craft) and manufacturers of engines, and other equipment can assist in the following ways:

- designing and constructing vessels, engines and equipment that reduce whole-body vibration to the minimum that can be achieved;
- providing a technical handbook giving information on:
  - safe use of the vessel, engine or equipment in its intended application;
  - vibration emissions;
  - any maintenance procedures to maintain the performance of vibration reduction features;
  - whether there is likely to be any remaining risk from vibration;
  - instructions on how to use the vessel, engine or equipment to avoid risk from vibration.

Where possible, employers should purchase from builders and manufacturers who comply with the above requirements.

Although it is principally aimed at land-based machines, PD CEN/TR 15172-1:2005 provides some useful information on engineering methods for reduction of vibration hazards by design of machinery.

7.3.2.3 Maintenance

Regular servicing of vessels, engines, and equipment will help to minimise the vibration and shocks transmitted to crew members, so it is important to:

- make sure that engines and other machinery are properly maintained and tuned according to manufacturer's instructions;
- check and replace defective bearings and gears;
- lubricate and replace worn parts in seat and other vibration isolation systems (seek appropriate advice from seat manufacturers or vibration specialists when replacing a seat designed to reduce exposure to whole-body vibration);

7.3.2.4 Task and process design

PD CEN/TR 15172-2:2005 provides advice on management measures at the workplace that can assist the reduction of vibration hazards. One way in which reductions in exposure may be achieved is by redesigning tasks or processes that have been identified as sources of risks due to whole-body vibration. It is suggested that the first step in redesigning a task or process is to define the expected achievements in broad terms. This should enable the key elements to be listed, and the parts that contribute most to the vibration exposure to be identified. Actions to limit the vibration exposure may then be concentrated on these items.

Work tasks should be designed so that:

- whole-body vibration exposures are as low as practicable;
- the daily period of exposure to high magnitudes of vibration is as short as possible;
- exposure to severe shocks is avoided;
- the working posture does not increase the risks of back injury.

In many cases, operating at speed in open water is the main contributor to the vibration exposure. In this case, the vibration exposure and ergonomic risks may be reduced and controlled by:

- limiting the speed according to the sea conditions;
- providing seats that provide adequate postural support in all operating conditions, fit all the crewmen that use the vessel, and where appropriate, incorporate a suspension system that is properly adjusted for each crewman's weight;
- relocating controls to minimise repeated stretching and twisting.

7.3.3 Work schedules

To control the risks from whole-body vibration it may be necessary to limit the duration workers are exposed to vibration in some operations or in some areas of a ship. This might be achieved by the development of work schedules to avoid long periods of exposure in a single day and allow sufficient breaks for workers. Where workers are continually exposed to vibration on a ship at sea, breaks need to be taken in areas where the magnitudes of vibration are low.

7.3.4 Training and Information to workers

MCA Marine Guidance Note 353 (M+F) suggests that employers should provide workers with information on the following matters:

- the possible link to back pain from exposure to whole-body vibration, shocks and jolts;
- the likely sources of hazardous vibration;
- the risk factors (e.g. severity of vibration and length of exposure, poor posture, or manual handling of heavy objects);

- the findings of the risk assessment including the employer's decisions on any vibration exposures that need to be managed;
- the measures being used to control the risks;
- the role for health monitoring and the system of health monitoring;
- how to report back problems, or any other problems which might be linked to exposure to vibration;
- the ways workers and supervisors can help to minimise risk.

MCA Marine Guidance Note 353 (M+F) also suggests that workers should be trained and instructed in the correct use of vessels or equipment that can cause whole-body vibration, to ensure that they can:

- adjust the seat position and controls, where adjustable, to provide good lines of sight, adequate support, and ease of reach for any foot or hand controls;
- where fitted, adjust the weight setting of a suspension seat to avoid the seat suspension 'bottoming out';
- adjust the vessel speed to suit the sea conditions to avoid excessive bumping and jolting;
- steer, accelerate, or reduce speed smoothly;

Workers should also be trained to recognise when machine components that affect vibration exposure need maintenance or replacing.

To reduce the risks of developing lower-back pain workers should be encouraged to maintain their general fitness, and to consider the risks to their backs from non-work activities, for example using poor lifting techniques or adopting poor postures for long periods.

7.4 Vibration monitoring and reassessment

Management of vibration exposure is an ongoing process. Employers need to ensure that systems that are put in place to control risks are being used and that they are giving the expected results.

7.4.1 How to find out if the whole-body vibration controls are working

Periodically, employers will need to review any whole-body vibration controls to ensure they are still relevant and effective. They should:

- check regularly that workers (including managers and supervisors) are still carrying out any controls that have been introduced;
- talk regularly to all workers, safety personnel and worker representatives about any vibration or postural problems with the vessels or machinery or the way they are being used, and ask workers if they are experiencing shocks and jolts and whether there are reports of back pain;
- check the results of health monitoring or health surveillance, and discuss with

the health service provider whether the controls appear to be effective or need to be changed.

7.4.2 When should the risk assessment be repeated?

Employers will need to reassess risks from vibration, and the necessity to control them, whenever there are changes in the workplace that may affect the level of exposure, such as:

- the introduction of new or modified craft, machinery or operating conditions;
- changes in the work schedule or working methods;
- changes in the number of hours worked on a craft or with machinery that produces vibration;
- the introduction of any new vibration control requirements.

Employers will also need to reassess the risks if there is evidence (e.g., from health surveillance) that the existing controls are not effective.

It is good practice to review risk assessments and work practices at regular intervals, even if nothing obvious has changed. There may be new technology available that could allow you to reduce risks further.

8 Health Surveillance

The 2007 Vibration Regulations require employers to provide health surveillance for workers who are at risk from vibration injury where:

- the exposure of workers to vibration is such that a link can be established between that exposure and an identifiable illness or harmful effects on health;
- it is probable that the illness or the effects occur in a worker's particular working conditions;
- there are tested techniques for the detection of the illness or the harmful effects on health.

Although there is no reliable indicator of the onset of low back pain specifically related to workplace risk factors such as whole-body vibration, the HSE recommend that employers at least "put in place a simple system of health monitoring to provide a means of obtaining early reports of back complaints that can be investigated and acted upon as appropriate (e.g., by revision of control methods)" (Health and Safety Executive, 2008).

MCA Marine Guidance Note 353 (M+F) also recommends that a system of health surveillance is set up for workers whose jobs carry a higher than average risk of exposure to vibration .

8.1 When is health surveillance required?

Employers should provide appropriate health surveillance where the risk assessment indicates a risk to workers' health. In any event, workers whose daily vibration exposure exceeds the daily exposure action value are entitled to appropriate health surveillance.

8.2 How is health surveillance managed?

Basic health surveillance for whole-body vibration may consist of a simple health monitoring system for the self-reporting of symptoms of low back pain using a questionnaire.

The Health and Safety Executive (2008) suggest that "Where possible, any health monitoring should be under the responsibility of an occupational health professional. However, an employer can implement a simple annual questionnaire for all workers at risk of back pain without any other support".

Examples of questionnaires that can be used by employers or by health professionals are available from the following websites:

- http://www.hse.gov.uk/msd/wbv.htm
- http://www.vibrisks.soton.ac.uk/index.html (see Epidemiological Tools)

Further information on the implementation of health surveillance for whole-body vibration is provided in Appendix F.

8.3 What to do if injury is identified?

Where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect that is considered by a doctor or occupational health-care professional to be the result of exposure to mechanical vibration at work, then certain duties fall upon the employer.

8.3.1 Information for the worker

The worker must be informed, by the doctor or other suitably qualified person, of the results of their own personal health surveillance. In particular, workers shall be given information and advice regarding any health surveillance that they should undergo following the end of exposure.

8.3.2 Employer actions

The employer must be informed of any significant findings from the health surveillance, taking into account any medical confidentiality. The employer should then:

i. Review the whole-body vibration risk assessment;

ii. Review the measures provided to eliminate or reduce risks from whole-body vibration exposure;

iii. Take into account the advice of the occupational healthcare professional or other suitably qualified person or the competent authority in implementing any measures required to eliminate or reduce risks from whole-body vibration exposure, including the possibility of assigning the worker to alternative work where there is no risk of further exposure;

iv. Arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health care professional or the competent authority may propose that exposed persons undergo a medical examination.

9 Responsibility (persons on whom duties are imposed)

9.1 Employers' duties

The vibration regulations place duties on employers to ensure that risks to seamen from whole-body vibration are eliminated or reduced to a minimum. There may be several different employers responsible for the crew of a ship, and not all of them will have control of the operation of the ship or the activities of the crew.

When an employer does not have direct control of activities that impose a risk due to whole-body vibration the responsibility for ensuring that the duties outlined in this Code of Practice are carried out is extended to any other persons that do have control or responsibility for such activities.

9.2 Workers' duties

As well as the responsibilities placed on the employer, the vibration regulations place a responsibility on every worker to make full and proper use of all protective clothing and equipment provided by the employer, and to follow all the instructions and training that the employer has provided.

9.3 Prohibition of levy on any worker

Regulation 21 of the vibration regulations makes it clear that the costs of anything done or provided in pursuance of any specific requirement of the Regulations cannot be passed on to any worker.

10 Definitions

Certain definitions from the 2007 Vibration Regulations are given immediately below.

Civil protection services

Include the fire and rescue services, ambulance services, and search-and-rescue services provided by any other person or organisation.

Employer

A person or corporate body by whom a worker is employed on a ship under a contract of employment.

Public service activities

Include the activities of HM Coastguard, HM Revenue and Customs, the armed forces, immigration officers, police, prison officers, and the security and intelligence services

Worker

Any person employed on a ship under a contract of employment, including a trainee or apprentice other than any person who is training in a commercial yacht or sail training vessel.

The remainder of the definitions deal with whole-body vibration and are arranged alphabetically.

Daily vibration exposure, A(8)

The 8-hour energy equivalent vibration total value for a worker in meters per second squared (m/s^2 r.m.s.), including all whole-body vibration exposures during the day.

Declared vibration emission

The vibration value provided by manufacturers to indicate the vibration likely to occur on their machines. Wherever possible, the vibration emission value should be obtained using a standardised test code, and should be included in the machine's instructions.

Exposure action value

A value for a worker's daily exposure to whole-body vibration, $A(8)$ of 0.5 m/s^2 r.m.s., above which the risks from vibration exposure must be controlled.

Exposure limit value

A value for a worker's daily exposure to whole-body vibration, $A(8)$ of 1.15 m/s^2 r.m.s., above which workers should not be exposed.

Exposure duration

The duration per day that a worker is exposure to a vibration source.

Frequency weighting

A filter applied to vibration measurements to reflect the frequency-dependence of the risk of damage to the body. Two weightings (defined in ISO 2631-1:1997) are used for whole-body vibration:

- W_d for vibration in both the fore-aft (*x*-axis) and side-to-side (*y*-axis) axes;
- W_k for the vertical (*z*-axis).

Health monitoring

An informal non-statutory method of surveying your workforce for symptoms of ill health including low back pain.

Health surveillance

Putting in place systematic, regular and appropriate procedures for the detection of work-related ill health, and acting on the results.

Manual handling

Any operation that includes transporting or supporting a load, lifting, putting down, pushing, pulling, carrying or moving by hand or by bodily force.

Partial vibration exposure

The contribution of an operation to the daily vibration exposure in m/s^2 r.m.s.. The partial vibration exposure relates to the daily exposure from an individual machine or process. Where a worker is only exposed to vibration from one machine or process then the daily vibration exposure is equal to the partial vibration exposure.

Whole-body vibration

Mechanical vibration (or shock) transmitted to the body as a whole. Whole-body vibration is often due to the vibration of a surface supporting the body.

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Appendix A. Summary of responsibilities defined by The Merchant Shipping and Fishing Vessels (Control of Vibration at Work) Regulations 2007

Regulation no.	Responsible person	When	Requirement
Regulation 6	Employer	Potential risk from whole-body vibration	**Determination and assessment of risk:** Use someone who is competent to assess the whole-body vibration risk. Be in possession of the risk assessment. Identify measures required for control of exposure and worker information and training. Keep the risk assessment up to date.
Regulation 7	Employer	Risks from vibration	**Removing or reducing exposure:** Take general actions to eliminate risks or reduce them to a minimum
		Exposures above the **exposure action value**	Establish and implement programme of measures to eliminate, or reduce to a minimum, exposures to whole-body vibration
		Exposures above the **exposure limit value**	Take immediate action to prevent exposure above the limit value Identify why the exposure limit value has been exceeded
		Workers at particular risk	Adapt to requirements of workers at particular risk
Regulation 8	Employer	Workers at risk from whole-body vibration	**Worker information and training:** For all workers exposed to whole-body vibration risks.
Regulation 10	Employer	Workers at risk from whole-body vibration	**Worker consultation and participation:** To consult, in a balanced way and in good time, workers and their representatives on risk assessment, control measures, health surveillance and training.
Regulation 9	Doctor or suitably qualified person	Where ill-health is identified	**Health Monitoring and Surveillance:** Inform worker of results of health surveillance or health monitoring Provide information and advice to worker on health surveillance necessary when exposure to whole-body vibration has finished. Provide significant findings of health surveillance to employer
	Employer	Where ill-health is identified	Review risk assessment Further eliminate or reduce risks Review the health status of similarly exposed workers.
	Employer	Exposures above the exposure action value	Workers are entitled to appropriate health surveillance

Appendix B. Daily Exposure Worked Examples

B.1 Where just one source of vibration

The daily vibration exposures in the three directions, x, y and z, for a worker exposed to a single source of vibration can be calculated from the frequency weighted vibration magnitudes and exposure time, using the following equations:

$$A_x(8) = 1.4a_{wx}\sqrt{\frac{T}{T_0}}$$

$$A_y(8) = 1.4a_{wy}\sqrt{\frac{T}{T_0}}$$

$$A_z(8) = a_{wz}\sqrt{\frac{T}{T_0}}$$

where T is the daily duration of exposure to the vibration and T_0 is the reference duration of eight hours. Like vibration magnitude, the daily vibration exposure has units of metres per second squared (m/s²).

The daily vibration exposure, $A(8)$, is then given by the highest value of $A_x(8)$, $A_y(8)$ and $A_z(8)$.

Example 1

The helmsman of a small launch operates the craft in open water for 2 hours a day.

Step 1: The vibration values on the seat, measured over a typical 2-hour exposure, are:

v. x-axis: 0.5 m/s² r.m.s.

vi. y-axis: 0.4 m/s² r.m.s.

vii. z-axis: 1.2 m/s² r.m.s.

Step 2: The x-, y- and z- axis daily exposures are then:

viii. $A_x(8) = 1.4 \times 0.5\sqrt{\frac{2}{8}} = 0.35$ m/s² r.m.s.

ix. $A_y(8) = 1.4 \times 0.4\sqrt{\frac{0.5}{8}} = 0.28$ m/s² r.m.s.

x. $A_z(8) = 1.2\sqrt{\frac{2}{8}} = 0.60$ m/s² r.m.s.

Step 3: The daily vibration exposure, A(8) is the highest of these values. In this case it is the z-axis: 0.60 m/s² (i.e. above the exposure action value).

B.2 Where there is more than one source of vibration

If a person is exposed to more than one source of vibration (perhaps because they use two or more different machines or activities during the day) then a *partial vibration exposure* is calculated from the magnitude and duration for each axis and for each exposure. The partial vibration values are combined to give the overall daily exposure value, $A(8)$, for that person, for each axis. The daily vibration exposure is then the highest of the three single axis values.

Determine the three frequency weighted r.m.s acceleration values a_{wx}, a_{wy} and a_{wz}, for each task or vehicle, from manufacturer's data, other sources, or measurement.

For each vehicle or task, find the partial daily exposures (i) in the x, y and z directions using:

$$A_{x,i}(8) = 1.4 a_{wx} \sqrt{\frac{T}{T_0}}$$

$$A_{y,i}(8) = 1.4 a_{wy} \sqrt{\frac{T}{T_0}}$$

$$A_{z,i}(8) = a_{wz} \sqrt{\frac{T}{T_0}}$$

where T is the daily duration of exposure to the vibration and T_0 is the reference duration of eight hours.

Each partial vibration exposure represents the contribution of a particular source of vibration (machine or activity) to the worker's total daily exposure. Knowledge of the partial exposure values will help you decide on your priorities: the activities or processes with the highest partial vibration exposure values are those that should be given priority for control measures.

For each axis (j), the overall daily vibration exposure can be calculated from the partial vibration exposure values, using:

$$A_j(8) = \sqrt{A_{j1}(8)^2 + A_{j2}(8)^2 + A_{j3}(8)^2 + \ldots}$$

where $A_{j1}(8)$, $A_{j2}(8)$, $A_{j3}(8)$, etc. are the partial vibration exposure values for the different vibration sources.

The daily vibration exposure, $A(8)$, is the highest value of $A_x(8)$, $A_y(8)$ and $A_z(8)$.

Example 2

An engineer on an offshore supply vessel spends 1 hour per day in a mess area in the bow of a ship, where there is structural vibration due to the operation of thrusters while the vessel is on station, and 6 hours per day in the engine room.

The vibration values on the deck are:

Mess area	Engine room
x-axis: 0.5 m/s² r.m.s.	*x*-axis: 0.2 m/s² r.m.s.
y-axis: 0.3 m/s² r.m.s.	*y*-axis: 0.2 m/s² r.m.s.
z-axis: 0.7 m/s² r.m.s.	*z*-axis: 0.4 m/s² r.m.s.

The *x*-, *y*- and *z*-axis daily exposures are then:

Mess area	Engine room
$A_{x,mess}(8) = 1.4 \times 0.5\sqrt{\frac{1}{8}} = 0.25$ m/s²	$A_{x,engine}(8) = 1.4 \times 0.2\sqrt{\frac{6}{8}} = 0.24$ m/s²
$A_{y,mess}(8) = 1.4 \times 0.3\sqrt{\frac{1}{8}} = 0.15$ m/s²	$A_{y,engine}(8) = 1.4 \times 0.2\sqrt{\frac{6}{8}} = 0.24$ m/s²
$A_{z,mess}(8) = 0.7\sqrt{\frac{1}{8}} = 0.25$ m/s²	$A_{z,engine}(8) = 0.4\sqrt{\frac{6}{8}} = 0.35$ m/s²

Daily vibration exposures, for each axis are:

$A_x(8) = \sqrt{0.25^2 + 0.24^2} = 0.35$ m/s² r.m.s.

$A_y(8) = \sqrt{0.15^2 + 0.24^2} = 0.28$ m/s² r.m.s.

$A_z(8) = \sqrt{0.25^2 + 0.35^2} = 0.43$ m/s² r.m.s.

The engineer's daily whole-body vibration exposure is the highest axis A(8) value. In this case, the value for *z*-axis: 0.43 m/s² r.m.s. (i.e., just below the exposure action value).

Appendix C. Vibration exposure calculators

C.1 Daily exposure graph

The graph in Figure C.1 provides a simple method for looking up daily exposures or partial vibration exposures. Simply look on the graph for the A(8) line at or just above where your vibration magnitude value $(ka_w)_{max}$ and exposure time lines meet (the factor *k* is either 1.4 for the x- and y-axes or 1.0 for the z-axis i.e. vertical direction).

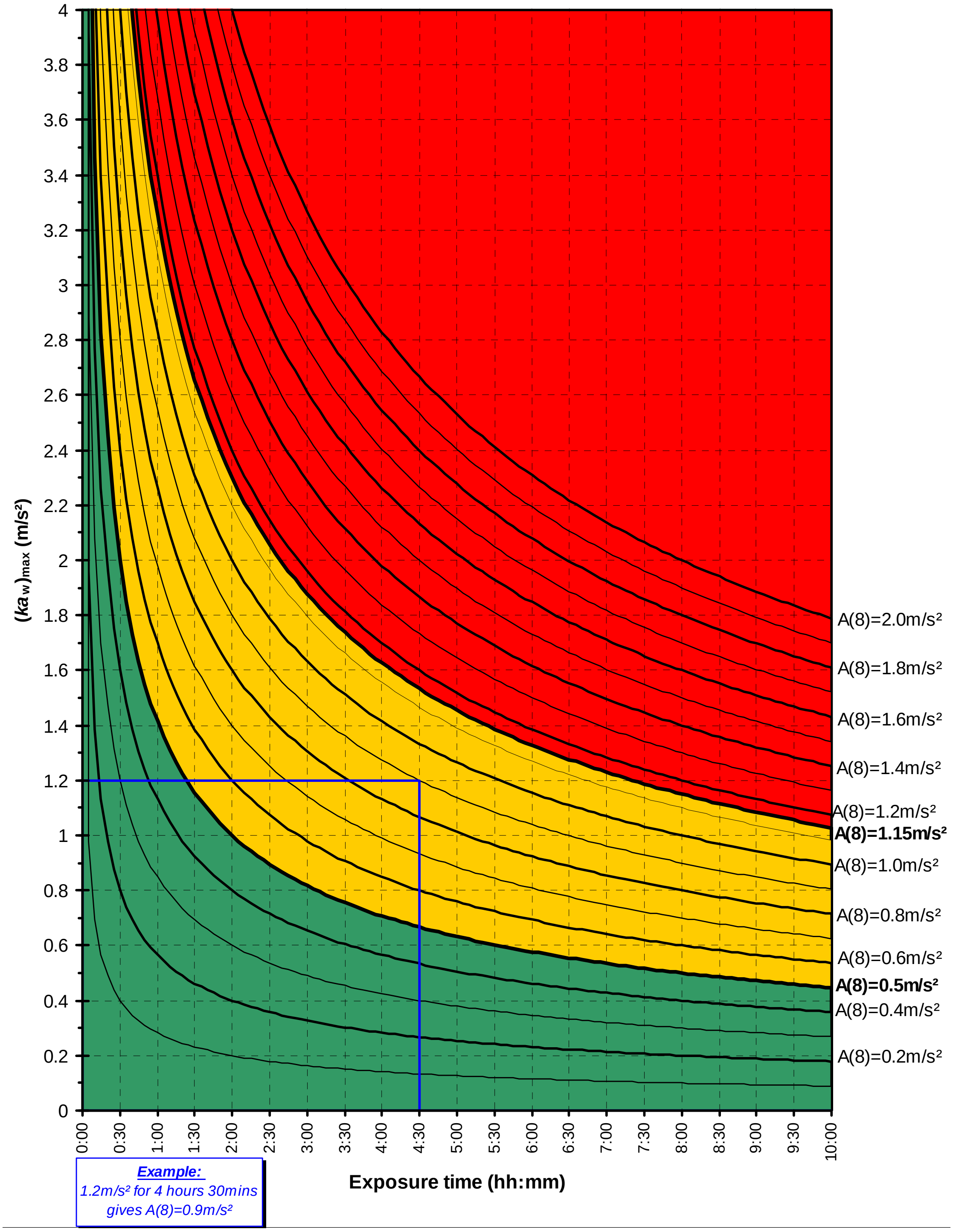

Figure C.1 Daily exposure graph (after European Commission, 2008)

The green area in Figure C.1 indicates exposures likely to below the exposure action value. These exposures must not be assumed to be "safe". There may be a risk of whole-body vibration injury for exposures below the exposure action value, and so some exposures within the green area may cause vibration injury in some workers, especially after many years of exposure.

C.2 Exposure points system

Whole-body vibration exposure management can be simplified by using an exposure "points" system. For any vehicle or machine operated, the number of exposure points accumulated in an hour ($P_{E,1h}$ in points per hour) can be obtained from the vibration magnitude a_w in m/s² and the factor *k* (either 1.4 for *x*- and *y*-axes or 1.0 for the z-axis) using:

$$P_{E,1h} = 50(ka_w)^2$$

Exposure points are simply added together, so you can set a maximum number of exposure points for any person in one day.

The exposure scores corresponding to the exposure action and limit values are:

- exposure action value (0.5 m/s²) = 100 points;
- exposure limit value (1.15 m/s²) = 529 points.

Alternatively Figure C.2 provides a simple lookup table for exposure points.

C.3 Calculators available on the internet

Some web-based calculators, that simplify the process of doing daily vibration exposure calculations, are available free on the internet, e.g.:

http://www.hse.gov.uk/vibration/wbv/wholebodycalc.htm

Acceleration × *k* (m/s²)	15m	30m	1h	2h	3h	4h	5h	6h	8h	10h	12h
2	50	100	200	400	600	800	1000	1200	1600	2000	2400
1.9	45	90	180	360	540	720	905	1100	1450	1800	2150
1.8	41	81	160	325	485	650	810	970	1300	1600	1950
1.7	36	72	145	290	435	580	725	865	1150	1450	1750
1.6	32	64	130	255	385	510	640	770	1000	1300	1550
1.5	28	56	115	225	340	450	565	675	900	1150	1350
1.4	25	49	98	195	295	390	490	590	785	980	1200
1.3	21	42	85	170	255	340	425	505	675	845	1000
1.2	18	36	72	145	215	290	360	430	575	720	865
1.1	15	30	61	120	180	240	305	365	485	605	725
1	13	25	50	100	150	200	250	300	400	500	600
0.9	10	20	41	81	120	160	205	245	325	405	485
0.8	8	16	32	64	96	130	160	190	255	320	385
0.7	6	12	25	49	74	98	125	145	195	245	295
0.6	5	9	18	36	54	72	90	110	145	180	215
0.5	3	6	13	25	38	50	63	75	100	125	150
0.4	2	4	8	16	24	32	40	48	64	80	96
0.3	1	2	5	9	14	18	23	27	36	45	54
0.2	1	1	2	4	6	8	10	12	16	20	24

Daily Exposure time

Figure C.2 Exposure points lookup table for whole-body vibration (the values are rounded to the nearest whole number), after European Commission (2008).

Appendix D. Format for reporting results of a survey of shipboard whole-body vibration

Whilst the 2007 Vibration Regulations do not specify the format for a whole-body vibration survey report, it is suggested that a report in the form set out below might usefully be carried onboard the vessel to which it applies.

A whole-body vibration assessment should be planned and carried out by a competent person, who then prepares a suitable and sufficient report of the findings. The vibration assessment should identify workers by name or by task, and report the frequency-weighted vibration magnitudes to which they are exposed and for how long. The assessment should pinpoint the location of the workers when they are at risk from whole-body vibration.

Table D.1 provides information about the survey, including characteristics of the vessel, the person carrying out the assessment, and the equipment used to measure whole-body vibration. Enter the acceleration magnitudes indicated from each accelerometer during calibration checks carried out before the measurements: this demonstrates that a calibration check was actually performed.

Sketches or drawings should be provided to show numbered positions of the vibration measurement locations, which are referred to in the tables below.

Table D.2 is a worksheet for recording whole-body vibration measurements for crew members during each daily activity that involves exposure to whole-body vibration. Partial vibration exposures should be entered for each activity, as well as the overall $A(8)$ daily vibration exposures calculated from the partial $A(8)$ values.

Table D.3 is intended to summarise measurements in individual locations during the stated measurement conditions (e.g. sea state, speed, heading relative to wind and sea direction). The maximum recorded frequency-weighted vibration magnitudes should be entered for each measurement axis, as well as the overall a_w.

Based on observations made during the measurements, the whole-body vibration assessor may be able to recommend measures for controlling the vibration exposures. Recommendations for vibration reduction measures should be listed in Table D.4.

Table D.5 provides a summary of the daily exposures to whole-body vibration from the individual worksheets (Table D.2), and indicates whether these exceed either the exposure action value (EAV) or exposure limit value (ELV) in the 2007 Vibration Regulations.

If frequency analysis is available, it is recommended that example frequency spectra of the unweighted accelerations in each axis should be included with the report.

Table D.1 Summary information about the whole-body vibration survey

OCCUPATIONAL HEALTH AND SAFETY INSPECTION
WHOLE-BODY VIBRATION ASSESSMENT
UNITED KINGDOM REGISTERED VESSELS

Name of vessel		Type of vessel	
Company or owner		Port of registry	
Official number		IMO number	

Main engine		Main engine Type	
Power output		Number of engines	
Number of cylinders (and bore)		Running speed (RPM)	

Propulsion system		Number of shafts or outputs	

Generator engine		Generator engine type	
Generator engine Output		Number of generators	
Number of cylinders (and bore)		Running speed (RPM)	

Accelerometers (make and model)		Serial numbers	
Vibration meter / amplifiers / recorder (make and model)		Serial numbers	
Acquisition and analysis software		Version number	

Calibrator (make and model)		Serial Number	
Calibration frequency (Hz)		Calibration magnitude (ms^{-2})	
Recorded calibration magnitude (ms^{-2})	*x*-axis:	*y*-axis:	*z*-axis:

Date of vibration measurements		Start Time and Finish Time	

Calibration dates and traceability

Vibration assessor		Official Stamp
Assessor’s signature		
Assessor’s office address		
Date of report		

General Notes/Comments
create more space as needed

Table D.2 Worksheet for recording whole-body vibration measurements and assessments for crew members

vessel:	
date:	surveyor:
vessel location during measurements:	

name of crew member or job	measurement location (state if on seat or deck) and measurement conditions	position on ship plan	time of measure-ment	sample duration (s, m or h)	frequency-weighted acceleration in each axis (ms^{-2} r.m.s.)			a_w (ms^{-2} r.m.s.)	exposure duration (s, m or h)	$A(8)$ (ms^{-2} r.m.s.)	see remarks below
					a_{wx}	a_{wy}	a_{wz}				
Daily vibration exposure $A(8)$:											

remark number (from above)	remarks

Table D.3 Summary of whole-body vibration magnitudes

location (state if on seat or deck) and measurement conditions	position on ship plan	frequency-weighted acceleration in each axis (ms^{-2} r.m.s.)			a_w (ms^{-2} r.m.s.)
		a_{wx}	a_{wy}	a_{wz}	
create more rows as needed					

Table D.4 Vibration reduction measures

Location	position on ship plan	technical measures	organisational measures
create more rows as needed			

Table D.5 Daily exposures to whole-body vibration

name of crew member or job	activity making greatest contribution to whole-body vibration exposure	position on ship plan	daily vibration exposure, $A(8)$ (ms^{-2} r.m.s.)	is EAV exceeded? (yes/no)	is ELV exceeded? (yes/no)
create more rows as needed					

Appendix E. Health risks, signs and symptoms

This appendix is reproduced from the Non-binding guide to good practice with a view to implementation of Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibrations) (European Commission, 2008). The text in square brackets has been altered so as to make it applicable to the maritime sector.

E.1 Effects of whole-body vibration on the human body

The transmission of vibration to the body is dependent on body posture. The effects of vibration are therefore complex. Exposure to whole-body vibration causes motions and forces within the human body that may:

- cause discomfort;
- adversely affect performance;
- aggravate pre-existing back injuries;
- present a health and safety risk.

Low-frequency vibration of the body can cause motion sickness.

Epidemiological studies of long-term exposure to whole-body vibration have shown evidence for an elevated risk to health, mainly in the lumbar spine but also in the neck and shoulder. Some studies have reported evidence of effects on the digestive system, the female reproductive organs and the peripheral veins.

E.2 Lower-back pain and back, shoulder or neck disorders

The results of epidemiological studies show a higher prevalence rate of low-back pain, herniated disc and early degeneration of the spine in whole-body vibration exposed groups. Increased duration of vibration exposure and increased intensity are assumed to increase the risk, while periods of rest reduce the risk. Many [workers exposed to whole-body vibration or repeated shocks] complain also about disorders in the neck-shoulder although epidemiological researches are inconclusive on this effect.

Low-back pain and back, shoulder or neck disorders are not specific to vibration exposures. There are many confounding factors such as working posture, anthropometric characteristics, muscle tone, physical workload, and individual susceptibility (age, pre-existing disorders, muscle force, etc.).

[Operation of small craft, or of machinery and other equipment on a larger vessel] not only involves exposure to whole-body vibration but may also involve several other factors that put strains on the back, shoulder or neck. The most important being:

- prolonged sitting in poor postures;
- frequent twisting of the spine;
- frequent lifting and material handling;

- traumatic injuries;
- unexpected movements;
- unfavourable climatic conditions;
- stress.

E.3 Other disorders

The question of whether whole-body vibration exposure might lead to other disorders such as digestive or circulatory problems or adverse affects on the reproductive system remains open. In some cases an increased prevalence of gastro-intestinal complaints, peptic ulcer and gastritis have been reported in drivers of vibrating vehicles. Whole-body vibration seems to be a factor that in combination with the long-term sitting posture of drivers contributes to the occurrence of varicose veins and haemorrhoids. Some studies have reported evidence of effects on the digestive system, the female reproductive organs and the peripheral veins. One study showed a greater than expected incidence of stillbirth among women [regularly exposed to vibration].

Appendix F. Health monitoring for whole-body vibration

The following appendix is reproduced from Health and Safety Executive (2008). The text in square brackets has been altered so as to make it applicable to the maritime sector.

F.1 Health monitoring for back pain

Health monitoring is an informal, non-statutory method of surveying your workforce for symptoms of ill health including low back pain. This type of occupational health management system can enable you as an employer to be aware of health problems and intervene to prevent their problems being caused or made worse by work activities. Another important role of health monitoring is to feedback into a system that reviews current control methods in place.

This guidance focuses on the risk of low back pain as the main health effect of concern for [crew members who are exposed to whole-body vibration or repeated shocks at work].

As part of an overall strategy for occupational health management, health surveillance may be appropriate to ensure control methods in place are working and to detect any incidence of ill health. However, at present it is not considered that any methods exist for the detection of changes in people's backs which can reliably indicate the early onset of low back pain that are specifically related to workplace risk factors. Therefore no formal health surveillance programme can be required for specific causes of back pain, such as whole-body vibration (WBV), manual handling or posture.

Valuable information can be obtained from less precise measures than those provided for by a formal health surveillance approach, such as reporting, monitoring and investigation of symptoms. This is known as "health monitoring". It is good practice to put in place this type of system to allow individuals to make early reports of low back pain. All workers at risk of back pain should be encouraged to report to their employer/ manager any symptoms that they may be suffering at any time.

There are specific regulations dealing with Manual Handling and whole-body vibration in the workplace. To ensure you are complying with your duties under these regulations you should refer to HSE guidance if manual handling or whole body vibration are risks in your workplace. There is also guidance available on how to deal with low back pain in the workplace these are available at:

http://www.hse.gov.uk/msd/backpain/index.htm

F.2 What is health monitoring?

Health monitoring enables you to check the effectiveness of any control measures by assessing the presence of relevant symptoms in your employees and using this information to inform the risk management process. Health monitoring does not lead to a diagnosis. However it allows information to be collected from your employees and when reviewed this may help to identify potential problems in the workplace.

F.3 Why conduct health monitoring?

Health monitoring will help you, as an employer, to take action to prevent back pain being caused or aggravated by work activities. It provides a means of obtaining early reports of back complaints which can be investigated and acted upon as appropriate e.g. revision of control methods.

F.4 When would health monitoring be appropriate?

Health monitoring could play an important part of your overall strategy to manage the risks of developing back pain in [workers]. A risk assessment will indicate whether or not you may have a problem with back pain in your [crew members]

Examples of situations where the risk to [crew members] may be considered high are:

- [Operating small craft at high speeds on open sea conditions];
- [Operating craft in conditions for which they were not designed];
- Having to stretch and twist to operate [controls];
- Significant manual handling of loads by [crew who are also exposed to whole-body vibration or repeated shocks] ;
- Static postures (i.e. remaining in the same position for long periods).

You should also identify high risk groups. This will include pregnant workers. Young workers may be particularly susceptible to the risk factors for back pain and workers with previous back problems would also be considered to be at higher risk.

Those workers identified as being at higher risk of back pain in the workplace should be subject to health monitoring. All other workers should be encouraged to report any low back pain symptoms as soon as possible. It will be important to allay worker's fears of reporting symptoms so that they may be helped in their work environment where possible. You should discuss this issue with worker and safety representatives to ensure cooperation.

F.5 How to carry out health monitoring

A health monitoring regime for low back pain in [crew members] should involve a structured system for the self-reporting of symptoms. This system should allow the individual to describe the symptoms that they are suffering or have suffered in the recent past.

It is important to involve your employees and their representatives early on in the development of your health monitoring programme. This can overcome any problems with employees not reporting symptoms because they do not understand why the programme has been introduced and that it is in place to protect their health. Where trade unions are recognised, consult safety representatives in good time.

Where possible, any health monitoring should be under the responsibility of an occupational health professional. However, an employer can implement a simple annual questionnaire for all workers at risk of back pain without any other support.

An example of a simple questionnaire which you as an employer could use alone for the purpose of health monitoring is given in:

http://www.hse.gov.uk/msd/pdfs/wbvtable.pdf

In most cases where significant symptoms of back pain are reported this will require further investigation by referral to a GP or occupational health professional. If in doubt about any aspect of a person's health, the individual should be referred on for further advice from a health professional.

If you are an occupational health provider involved in health monitoring for low back pain then you should be aware of the following questionnaires.

http://www.hse.gov.uk/msd/pdfs/wbv.pdf

F.6 What to do with the information

i. Use the information from health monitoring to check trends in back pain in your [crew members]

ii. If you have [more than one vessel] it may be worth analysing the data from each [vessel] separately; for example, do [crew] report more ill health than [crew of other craft]?

iii. If the data suggests your [crew members] (or groups of them) are reporting similar symptoms, investigate. Look for risk factors in the work, or evidence that control measures are not working as intended. It may be worth reviewing the risk assessment to help find out what the problem is, and decide on corrective action.