Maritime & Coastguard Agency

MARINE GUIDANCE NOTE

MGN 436 (M+F) Amendment 4 Whole body vibration: guidance on mitigating against the effects of shocks and impacts on small vessels

Notice to all operators, managers, owners and builders of small vessels

This notice should be read with MGN 636 (M) amendment 3 the merchant shipping and fishing vessels (health and safety at work) regulations 1997 and MGN 353 amendment 2 the merchant shipping and fishing vessels (control of vibration at work regulations 2007 and replaces MGN 436 amendment 3.

Summary

This guidance note provides guidance on mitigating the risk of injury from whole body vibration (WBV) on small vessels, and in particular severe and repeated shocks (RS) as a result of impacts.

Guidance is provided to assist in improving the design of vessels to reduce the severity of the impact and to provide a suitable postural position for those on board to enable them to brace effectively.

There is also guidance for operators on reducing the risk of injury through training, predeparture briefing and ensuring that the vessel is operated considering vessel design, sea conditions and the health and experience of those onboard.

Amendment 4 reflects evolving knowledge and best practice including the use of shock mitigating technology and data.

1. Introduction

1.1 There have been a number of incidents involving small craft, travelling at a wide range of speeds, receiving predominantly vertical shock impact when coming off a wave, resulting in injury to one or more persons on board. The effects of crossing seas and side-on waves can also cause injury. Incidents have occurred on inland waters and estuaries as well as at sea, and to a wide range of people. Injuries sustained include spinal compression injuries, serious damage to joints and fractures in the leg and feet. When such injuries occur, they can be life-changing for those injured.

1.2 It should be recognised that the sea and inland waters are inherently risky places in which to work or spend time for sport and pleasure. This guidance note does not aim to provide a solution to preventing all further accidents, because not all circumstances can be foreseen. Instead, it aims to provide some basic guidance, where there is risk of injury from impacts from waves, on best practice for boat designers, builders, managers and operators to reduce the likelihood of such injuries occurring.

1.3 Consideration should be given to the vessel moving not just vertically, but also fore-and-aft, laterally, and in roll, pitch and yaw. Persons onboard a vessel operating in waves will experience complex multidimensional impacts and these may be more likely to cause harm than purely vertical motions. Consideration should be given to the ability of passengers and crew to maintain a good posture when operating in challenging conditions.

1.4 Designers and operators should consider typical rather than ideal usage of the vessel. As an example, shock mitigating seating will only be effective when passengers and crew are seated. If typical operations include standing or moving around the vessel when underway in waves, mitigating design and procedures should be appropriate for those situations.

1.5 Whilst this guidance primarily covers mitigation of shocks during normal operating conditions, risk assessments should also consider how vessel design and operating practices may affect crew and passengers in the event of emergency situations, including, but not limited to, high-speed collisions.

1.6 The merchant shipping and fishing vessels (control of vibration at work) regulations 2007 (“the vibration regulations”) apply equally to powered and sailing vessels of all sizes. This guidance applies to powered craft of various speeds and power, however it is primarily focused on high-speed craft, which is the marine vessel type where most injuries from repeated shocks and whole-body vibration are seen.

1.7 The terms coxswain or helmsman are used by various sectors, which can imply higher levels of qualification or experience. For this guidance the term boat driver is used to identify the person controlling the vessel by operating the steering wheel or joystick and throttles.

1.8 Where it is recommended to obtain subject matter expertise, it is important that you ensure the consultant or adviser you use is competent and suitable. This means they have evidence of relevant training and knowledge, such as formal qualifications or practical experience of providing advice in your industry or area of work and are adequately insured.

1.9 Decision makers onshore should be aware that voyages in waves will take significantly longer than in flat sea conditions and there is increased risk to all onboard. It should be noted that decision makers onshore may not have experience of operating a

similar vessel, so clarity in communication is essential on both the part of onshore staff and the boat driver.

2. Background

2.1 When a boat comes off a wave and falls into a trough or impacts the next wave, the forces and accelerations generated have been shown to be much higher than those found in other modes of transport.

2.2 Current research suggests that there is no definitive design of craft or seating which is guaranteed to mitigate all the effects of whole-body vibration (WBV). There are, however, some basic principles which, if followed, may assist in reducing the effects of whole-body vibration and in particular the impact of the craft slamming.

2.3 Vessel operators should have a strategy for mitigating risk from exposure to whole body vibration and shocks, which should be specific to operational needs, the vessel and equipment used, and the people involved (both crew and passengers). Dynamic risk assessments based on specific conditions should be undertaken.

3. Vibration Exposure

3.1 **Repeated shock (RS)**

3.1.1 A single or repeated shock on a small craft is usually caused by vessel interaction with waves including head sea impacts, crossing seas and overtaking following seas. Although high speed typically worsens the impact(s), these events can occur at relatively low speeds, even on rivers and estuaries.

3.1.2 The environment in a marine vehicle can typically be considered a repeated shock environment. Marine subject matter experts should be consulted when applying vibration standards and regulations.

3.1.3 When operating a vessel in flat sea conditions, vibration from the engine has limited effect on boat occupants. Wave slams can still occur in otherwise flat conditions, for instance when encountering the wash of another vessel. There may be an increased risk of injury if the crew or passengers are not prepared for an impact.

3.2 **Whole body vibration (WBV)**

3.2.1 People that spend long periods on vessels that experience repeated low-level impacts, may not receive a serious, acute injury on any single voyage but, over time, the cumulative effects of whole-body vibration exposure can result in chronic musculoskeletal injuries.

4. Posture

4.1 Posture and stability of the spine are important for mitigating risk from shocks and impacts. The design of the craft should allow the occupants to maintain their postural stability at all times during a voyage. Operational needs may mean that this is not always possible for all occupants, and time outside of postural stability should be reduced where possible.

4.2 Design features to support the individual's postural stability should be provided. This may include seating, foot straps and handholds.

4.3 An upright posture, with the spine in neutral alignment (natural 'S' shape) should be maintained whilst facing in the direction of travel. Sitting or standing sideways should be avoided as this generally results in the occupant adopting a twisted upper body thus increasing the stress on the spine and subsequently the risk of injury.

5. Vessel design

5.1 Layout of the vessel

5.1.1 By design, the vertical motion experienced onboard a powered craft is generally greater in the bow area than at the stern. When small craft are designed with the driving position towards the stern with seating in front for passengers, the person driving the vessel has less exposure to the vertical impacts than others on board and may drive the vessel in a manner comfortable for themselves rather than those other persons. Vessel design should take into account the type of operations it is intended to be used for.

5.1.2 By moving the driving position forward, the person at that position is exposed to the greatest forces and will adjust the speed and movement of the vessel accordingly to reach a comfortable level for themselves. Others on board should then experience a lower level of vertical impact than the person at the driving position. It should however be remembered that this increases the risk to workers who may spend long periods of time on board the vessel. For solo operators this forward position limits their supervision of passengers behind. To enable the boat driver to keep a look out, especially in waves, it is preferable that another responsible person is overseeing the passengers.

5.2 Hull shape

5.2.1 The shape and hydrodynamic performance of the hull can reduce the impact of vertical movements. A deep-V shape hull will cut through the water better than a flatter bottomed vessel. However, if a V hulled vessel heels significantly as it falls off a wave the vessel may land on a flatter section of the hull and a severe slam may still be experienced.

5.2.2 Vessels should be used as they were designed to be used. Hazardous situations may occur when a vessel is operated beyond design and/or structural limits. Operators should consider manufacturers operating instructions, limits and recommendations regarding safe speed and adverse conditions.

5.2.3 The use of multihulls, hydrofoils, active trim tabs, fins or interceptors may be considered with the intention of improving ride comfort. However, it should be ensured that such design features are compatible with the overall purpose and environment of the vessel's operation.

5.3 Seating

5.3.1 A wide range of seat designs are available for small craft including jockey or straddle seats where the occupant is in a partially standing posture and seats where the occupant is fully seated. Each type of seating should be suitable for the application for which it was designed and the conditions it will be used in. Seating should be appropriate for the vessel and the size / weight of the user.

5.3.2 Choosing the correct type of seating for the craft's intended operation may reduce the likelihood of injury to those on board. The greater the exposure to repeated shock and

whole-body vibration, the greater the requirement for the adoption of shock mitigation equipment and systems specifically designed to cope with the level of exposure experienced.

5.3.3 Due to better understanding of the effects of wave slams and a requirement for higher operational speeds, operators are now considering mechanical suspension seating or other energy-attenuating designs. The objective of a suspension seat is to separate the occupant from the worst effects of vibration and impact. Suspension seating may have feet on or off the deck. As the performance of suspension seats varies greatly, industry testing standards are being developed. An unsuitable suspension seat may increase rather than reduce exposures.

5.3.4 When choosing seating, the manufacturer's advice should be sought, and the type of craft and the intended usage patterns and operating conditions should be considered. It should be borne in mind that if the boat driver/crew have different seating from the passengers this may affect their perception of the vibration exposure for others onboard.

5.3.5 Each seat should provide an appropriate amount of postural stability and lateral support.

5.3.6 Seating should be situated correctly to allow the person occupying the seat to be in the best possible posture. Fitting an extra seat into the bow of a vessel, for instance, may leave the occupant in an awkward or twisted position which means that they will not be able to brace themselves effectively. Where occupants are expected to conduct tasks from the seat (for example navigation), it should be possible for the full size-range of expected occupants to do this while maintaining good posture. Fore-aft and height adjustable seating may be appropriate to facilitate this.

5.3.7 Instructions should be provided for adjustable suspension seats. If a seat is adjustable for weight and/or height of occupant, the crew must ensure this adjustment is carried out correctly before departure.

5.3.8 For suspension seating there should be a maintenance schedule along with ongoing visual inspection of moving parts to ensure that the seats remain fit for purpose.

5.3.9 In some circumstances it may be appropriate to fit seatbelts/restraints. The design, operation and use of such restraints should be appropriate to the design and use of the craft. The crew and passengers should receive the appropriate training on their use. Consideration should be given to any possible consequences of their use, including how to ensure that users can escape quickly in an emergency.

5.4 **Handholds and foot-straps**

5.4.1 Handholds and foot-straps can assist in the maintenance of postural stability and enable persons to brace themselves effectively when underway. This should be demonstrated to new crew and infrequent passengers.

5.4.2 Handholds should be situated to allow various size occupants of a seat to take up a suitable posture. In the event of a sudden deceleration, handholds should have suitable anchoring and strength to allow a person to brace themselves, with the upper body maintained firmly upright and facing in the direction of travel.

5.4.3 The position of the handholds should also provide the appropriate lateral and longitudinal postural stability. This may be achieved by having the handholds in front of the body roughly shoulder-width apart and at a height between the shoulders and abdomen of

the seat occupants. Expert advice should be sought to ensure that handholds and foot-straps are appropriate for the size and height of intended users.

5.4.4 The material from which handholds are made should take into account the extremes of the operating temperatures in which the vessel will be used. They should also have a texture suitable for providing a secure and comfortable grip by users of various physical builds.

5.4.5 Appropriate foot positioning is important to enable the occupant to brace themselves when standing, or using seat types with feet on the deck. If they are able to hold on with their hands but their legs are not firmly positioned this can cause injury. If seat heights are adjustable, they should be positioned to enable the occupant to firmly ground their feet on the deck. Foot pegs or land points may be provided to enable the occupant to brace themselves.

5.4.6 If used, foot-straps need to be placed in a suitable position and with a suitable anchoring point to allow the person occupying that position to take up the correct posture and to enable them to brace themselves. Two positions of foot-straps may be required as the feet change position when sitting and standing. Consideration should also be given to emergency escape. If foot-straps and handholds are adjustable they should be fit for purpose and maintained appropriately.

5.5 **Decking**

5.5.1 Deck surfaces should be covered in a non-slip coating or grip material to allow persons onboard to maintain traction between their footwear and the deck, especially when wet.

5.5.2 Decks made of aluminium, fibreglass and composite materials transmit shocks and vibration. Specialist impact mitigating decking materials are designed to be stable and reduce vibration exposure.

5.5.3 Operators should be aware that crew or passengers leaving their seats to stand or walk around the deck do not have the same level of protection from wave impacts as those seated in appropriate seating. If a person is out of their seat in wave conditions, then the driver should consider reducing speed or stopping to minimise vessel motions. Briefing or training on movement around deck may be appropriate.

5.5.4 Standing on soft foam or rubber flooring may reduce vibration at low speed, however these materials do not mitigate the effects of wave impacts and can lack stability, which causes fatigue.

5.6 **Wheelhouses**

5.6.1 Attachment of wheelhouse to deck via resilient mounts can reduce the effects of vibration and noise from hull and engine room machinery. Flexible mounts may improve comfort but are unlikely to reduce risk of injury from wave impacts.

5.7 **Cockpits and workstations**

5.7.1 The equipment provided to control the vessel or carry out a task should be positioned to enable a person to keep a suitable posture in all conditions without leaning, twisting or adopting an awkward posture.

5.7.2 Suspended cockpits and suspended workstations may provide adjustable, multi-axis mechanical shock mitigation for vessel occupants, equipment and electronics.

5.8 Vessel controls

5.8.1 Positioning of steering wheel (or equivalent), throttles and controls should take into account different heights and sizes of boat drivers. Large ranges of movement can affect posture, from neutral to full ahead on throttle and from side to side on wheel. Where shock mitigation seats are fitted, mounting controls and/or displays on the armrests may be beneficial.

5.8.2 Boat drivers should maintain one hand on the wheel and the other on the throttle when travelling at speed. Consideration should be given to the ability of the driver to stabilise themselves and avoid involuntary throttle and wheel movement when impacted by waves. Where a sensitive or “fly by wire” throttle and/or a sensitive wheel offers limited resistance, body stabilisation can be provided by the legs bracing and interacting with the seating arrangement.

5.9 Instruments and navigation

5.9.1 Instrumentation should be positioned to enable a person to maintain a suitable posture when reading instrumentation relevant to their task without leaning, twisting or adopting an awkward posture.

5.9.2 The instrumentation should provide a display that is of a size to allow the person driving the vessel to easily read the icons, text and images when the vessel is underway. This allows them to spend more time concentrating on the water they are about to travel across, including waves and sea conditions.

6. Operating the vessel

6.1 Training and competence

6.1.1 The person driving the vessel should undertake training in handling vessels at a range of speeds in a range of operating conditions. Understanding vessel handling characteristics and limitations, assessing weather and matching boat speed to sea conditions and passenger comfort can reduce the likelihood of an incident occurring.

6.1.2 Training should also incorporate an awareness of the requirement under health and safety, maritime and local authority regulations for the operator and boat driver to provide duty-of-care for the crew and passengers. This includes assessing the risks of repeated shocks (RS) and whole-body vibration (WBV) exposure, and practicable means of reducing them, then taking action to reduce the risks.

6.1.3 Competence includes understanding the implications of manoeuvres on all people onboard and having the knowledge and skills to assess risk and mitigate accordingly.

6.1.4 Provision of adequate manning should take into consideration not only competency but also the speed of the vessel, passenger safety and requirement to maintain a good lookout at all times and in all conditions. For example, when operating in waves the boat driver may need their full attention for assessing the sea conditions

6.2 Use of throttle and steering

6.2.1 Combined use of throttle and steering are essential skills for boat handling in all conditions. Investigation has been undertaken which indicates that throttle use has a greater effect on reducing the impact of vertical movement of the vessel than steering the vessel. Attention should therefore be given to improving the driver's throttle and trim control when operating in waves or choppy conditions.

6.2.2 For the boat driver, a power assisted steering wheel and "fly by wire" throttles may result in unstable handholds. In waves this can result in reduced vessel control. Throttles with a solid heel-of-hand support can provide stability. Following a wave impact, an unstable posture may cause the driver to make unintended course or speed alterations.

6.2.3 In extreme sea conditions a secure, seated posture, possibly with seatbelts, and armrest mounted controls may help to maintain control.

6.3 Pre-departure briefing

6.3.1 Operators of all vessels should consider appropriate weather forecasts, then brief passengers on expected sea conditions including the effects of waves on the vessel and occupants.

6.3.2 As part of the usual pre-departure safety briefing, operators of all vessels should brief those onboard prior to departure on the inherent risk and the correct posture, along with use of handholds and foot-straps, to reduce the likelihood of injury.

6.3.3 The importance of observation should be highlighted to all onboard, encouraging both crew and passengers to take personal responsibility for preparing for shocks (e.g. bracing), and maintaining good posture and stability. However, boat drivers should consider that an inexperienced passenger should not be relied upon to know when to brace, without clear instructions.

6.3.4 Throughout the voyage, boat drivers should maintain communication with all onboard. All people on board should be able to raise concerns and voice discomfort, and the driver should react accordingly.

6.4 Endurance and fatigue

6.4.1 Risk of injury to those on board may be reduced by breaks from travelling at speed in waves or rough weather conditions. During voyages it may be appropriate to provide opportunities to allow those on board to rest and adjust their posture when the vessel is slowed or where it is safe do so.

6.4.2 Operators should be aware that long duration passages, on vessels travelling at speed in waves or rough weather, may be in excess of a person's physical fitness and/or stamina. In these circumstances operators should consider slowing the vessel or not undertaking the passage. Cold exposure may accelerate the onset or worsen the severity of back pain. Cold exposure may also affect the person's ability to hold on and maintain good posture. It is good practice to ensure that those working in the cold are provided with warm, waterproof clothing.

6.5 Speed perception

6.5.1 t should be noted by operators that are providing "experience rides" that those on board are likely to perceive that they are going considerably faster than they are. Therefore, boat drivers should consider travelling at slower speeds than they themselves may perceive as fast, which may also reduce the vibration exposure for others onboard. Building up speed

gradually, with reduced time at maximum speed will minimise the effects of repeated shocks and whole-body vibration for everyone onboard.

6.6 Reactions and bracing

6.6.1 Pre-departure briefings should highlight the importance of self-awareness, especially when underway in waves. Passengers should have the means to raise a concern. These concerns should be addressed appropriately, which may include the boat driver slowing down.

6.6.2 The level of passenger experience should be considered, and communication may be required to prepare passengers for a manoeuvre. Experienced crew members and regular passengers are more likely to anticipate a wave slam and brace accordingly. Novice crews and passengers will have slower reactions and need to learn how to brace. The boat driver should give loud, clear warnings, allowing time for all onboard to prepare for manoeuvrers. Pre-agreed terms could include ‘brace’ and ‘hold on’.

7. Individuals at increased risk of injury from vibration and shocks

7.1 When planning a voyage of any kind, the range of people on board should be considered, as some individuals are at increased risk of injury. Whilst every effort must be taken to allow all individuals to participate, in the interests of safety, in some cases, it may be necessary to refuse to allow certain people onboard the vessel or it may be necessary to adjust the voyage style to suit those onboard. This refers to both crew and passengers.

7.2 Even with adjustment, people of certain body sizes may not be able to make effective use of the foot-straps and handholds, and may be unable to maintain the necessary postural stability. Older adults may be at greater risk as they may be less mobile, and their bones can be more brittle.

7.3 Operators should ask passengers whether they have any health condition for which the motions of the vessel may present a risk and then carefully consider their susceptibility to injury, adjust the voyage accordingly.

7.4 Persons that have certain medical conditions, such as osteoporosis, may be more likely to be injured. Those that have been taking certain types of medication, such as steroids, may also be more susceptible to injury. Operators should consider how to mitigate risk to passengers and crew who are particularly vulnerable to injury. This includes, but is not limited to, people with blood circulatory diseases, musculoskeletal problems and pregnant, young or older people.

7.5 Operators should make those using the vessel aware of the risks from exposure to repeated shock and whole-body vibration. In some cases, it may be appropriate for operators to refuse to take certain people on a voyage, or for individuals to decide not to board the vessel.

7.6 The reporting and monitoring of workers’ symptoms suspected to be due to vibration exposure can support operators in mitigating risk appropriately for individuals. Guidance on health monitoring for those at risk from whole body vibration, including the use of health monitoring questionnaires to monitor seafarers’ symptoms, is available on the Health and Safety Executive website. Risk assessments will also provide information to determine whether health surveillance is appropriate (see code of safe working practices, chapter 7,

health surveillance) and marine guidance note 353 (M+F) the merchant shipping and fishing vessels (control of vibration at work) regulations 2007 provides a more in-depth explanation.

8. Vibration data

8.1 Use of vibration data

8.1.1 It should be noted that vibration exposure action values (EAV) and exposure limit values (ELV) mandated by the merchant shipping and fishing vessels (control of vibration at work) regulations 2007 are established to protect users of all types of vehicles, including marine craft, from the effects of shock and vibration. See MGN 353 (M+F) for further information.

8.1.2 Care should be taken when comparing vibration levels with those quoted for other sectors. In many other sectors such as air and land transport, vibration will be quoted in units not appropriate for measurement at sea. Other transport sectors are more mature than the marine sector with well-defined tests, data collection and products. Small craft at sea, in varying conditions, are less predictable than other transport sectors, however research has begun to address these needs. British Standards and Health and Safety Executive guidance can be used for measuring vibration containing multiple shocks.

8.1.3 Vibration data can be of use to those operating small craft. It is not a requirement of the legislation to carry out surveys of vibration exposure. However, where it is suspected that the exposure action value is exceeded, measurement and data may be of value to allow specific equipment or working practices to be optimised, especially with unique vessels or novel hull forms.

8.2 Collecting data

8.2.1 Vibration data is normally measured in terms of acceleration, recorded with accelerometers. Accelerometers must be suitable for the task in hand, be capable of appropriate performance levels and be fitted by subject matter experts. Accelerometers can be attached to various parts of a vessel including hull, deck, seats and sensitive equipment. Accelerometers can be used to capture the input accelerations into parts of a vessel where crews and passengers stand, sit or rest. Data can be interpreted in real time or recorded for later analysis.

8.2.2 One method for calculating exposure is using the average (A) exposure over an eight-hour (8) day. The use of A(8) values is generally appropriate for most shock and vibration environments but there are some situations where the risk to marine craft crew and passengers may be severe despite the overall A(8) exposure being below the mandated values. vibration dose value (VDV) is an alternative way of expressing the exposure to vibration. If quoting vibration levels in risk assessment, for instance to demonstrate the effectiveness of a mitigation technology or policy, VDV may be more appropriate. Section 9 includes further guidance on evaluating exposure.

8.2.3 Subject matter expertise should be sought before embarking on a programme of data collection to ensure relevance of any measurements.

8.3 Real time data

8.3.1 Sensors can provide real time vibration data that enables the person driving the vessel understand the impact of their driving, and to slow down or alter course to reduce the effects of repeated shocks and whole-body vibration on crew and passengers.

8.3.2 Displays showing incremental numbers or lights, for example green -amber -red, can provide warnings that support decisions to protect crew, passengers and vessels against the effects of vibration and shocks. Subject matter expertise should be sought before setting levels. Different pre-set levels may be required to be appropriate to the voyage, for example considering the experience and capabilities of crew and passengers.

8.3.3 Training and/or company policy on the correct use of this information is recommended.

8.4 **Data analysis**

8.4.1 Data can be used to monitor the forces that crew, passengers and vessels have been subjected to. Historic data can be used to improve future operations and passage planning. As with data collection, subject matter expertise is of value when interpreting this data.

9. Regulations and further guidance

9.1 This provides a non-comprehensive list of suggested reading, with the sole purpose of providing further information on whole body vibration. Regarding materials not created by the Maritime and Coastguard Agency (MCA), the MCA are not recommending the purchase of any publications, nor endorsing the guidance within (unless MCA involvement is specified within the resource).

9.2 The merchant shipping and fishing vessels (control of vibration at work) regulations 2007, provides the requirements which the advice above may be used to meet.

9.3 Marine guidance note 353 (M+F) Amendment 2 the merchant shipping and fishing vessels (control of vibration at work) regulations 2007, provides guidance on the requirements for the protection of workers from the risks related to exposure to vibration at work.

9.4 The MCA has also published the code of practice for controlling risks due to whole-body vibration on ships (ISBN No. 9780115530760) which is the official guide to complying with the merchant shipping and fishing vessels (control of vibration at work) regulations 2007. This document also provides a bibliography for further guidance. It can be purchased from The Stationery Office (TSO).

9.5 BS ISO 2631-1:1997 mechanical vibration and shock. Evaluation of human exposure to whole-body vibration is an appropriate standard to refer to regarding vibration measurement, and can be used to identify the most appropriate exposure value.

9.6 Health and Safety Executive webpage, muscloskeletal disorders: health monitoring and support for workers: https://www.hse.gov.uk/msd/health-monitoring.htm

9.7 Passenger safety on small commercial high speed craft & experience rides, a voluntary code of practice, 2019, produced by British Marine, Royal Yachting Association and the Passenger Boat Association.

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