Technical Documentation

Human Vibration Analyzer Type 4447

User Manual

Brüel & Kjær

English BE 1772 – 14

Human Vibration Analyzer
Type 4447

User Manual

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Safety Considerations

This apparatus has been designed and tested in accordance with IEC/EN 61010 – 1 and ANSI/ UL 61010 – 1 *Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use*. This manual contains information and warnings which must be followed to ensure safe operation and to retain the apparatus in safe condition. Special note should be made of the following:

Safety Symbols

The apparatus will be marked with this symbol when it is important that you refer to the associated warning statements given in the manual.

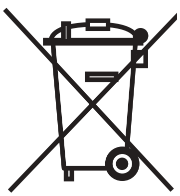
Protective Earth Terminal   Hazardous Voltage

Explosion Hazard

The equipment is not designed to be used in potentially explosive environments. It should not be operated in the presence of flammable liquids or gases.

Warnings

- Switch off all power to equipment before connecting or disconnecting their digital interface. Failure to do so could damage the equipment
- Whenever it is likely that the correct function or operating safety of the apparatus has been impaired, it must be made inoperative and be secured against unintended operation
- Any adjustment, maintenance and repair of the open apparatus under voltage must be avoided as far as possible and, if unavoidable, must be carried out only by trained service personnel



- Do not dispose of electronic equipment or batteries as unsorted municipal waste
- It is your responsibility to contribute to a clean and healthy environment by using the appropriate local return and collection systems
- Hazardous substances in electronic equipment or batteries may have detrimental effects on the environment and human health
- The symbol shown to the left indicates that separate collection systems must be used for any discarded equipment or batteries marked with that symbol
- Waste electrical and electronic equipment or batteries may be returned to your local Brüel & Kjær representative or to Brüel & Kjær Headquarters for disposal

Trademarks

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Table of Contents

Chapter 1

Introduction

Thank you for purchasing Human Vibration Analyzer Type 4447. This instrument measures and objectively evaluates human vibration.

1.1 About this Manual

This user manual describes Type 4447 from firmware version 3.0.1 and associated BZ-5623 4447 Vibration Explorer Software version 2.0.0 and on.

This manual is divided into the following sections:

- Chapter 1 – Introduction: Brief overview of Human Vibration measurements, basic features and parameters of Type 4447
- Chapter 2 – Measuring Human Vibration: The theory behind the measurements
- Chapter 3 – Using Type 4447: Instructions on how to work with Type 4447
- Chapter 4 – Measuring Human Vibration: Instructions on how to measure Human Vibration
- Chapter 5 – Post-processing: How to transfer data from Type 4447 to your computer for processing
- Chapter 6 – Maintenance and Service: Instructions for taking care of your instrument
- Chapter 7 – Specifications: Technical specifications for Type 4447

Note: Type 4447 measures translational vibration and presents results using different units, (see Section 3.3). This manual is written using m/s^2, which is the default unit for the instrument.

1.1.1 Conventions Used in this Manual

Instructions and descriptions that refer to Type 4447 pushbuttons are shown with the pushbuttons as on the instrument. See Section 3.2 for a list of pushbutton icons and their functions.

Menu Items

In this manual, menu items are indicated by bold type face (for example, ‘can be found under the **Calibration** menu’).

Displayed Parameters and Text Appearing on the Screen

Displayed parameters, on-screen text and mathematical variables are indicated by italics (for example, ‘*Weighting*’, ‘*Whole-body*’).

1.2 What is Human Vibration?

Human vibration is defined as the effect of mechanical vibration in the environment on the human body. During our normal daily lives, we are exposed to various sources of vibration, for example in buses, trains and cars. Many people are also exposed to other vibrations during their working day, for example vibrations produced by hand-tools, stationary and mobile machinery or heavy vehicles.

Just as sound can be either music to the ear or irritating noise, human vibration can either be pleasant or unpleasant. Gentle vibrations, such as that experienced when sitting in a rocking chair, dancing or running can be pleasant. More violent vibrations, for example that experienced when travelling in a car down a bumpy road or when operating a power tool, can be unpleasant and even imply health risks

There are many aspects of human vibration. This manual focuses on the aspects of human vibration that are of an interest from the perspective of occupational health and safety: whole-body and hand-arm vibration. Whole-body vibration is transmitted to the body as a whole, mainly through a supporting surface (such as a floor, seat, back rest, etc.). Prolonged exposure to whole-body vibration can cause permanent physical damage or disturb the nervous system. Hand-arm vibration is experienced through the hand and arm. Daily exposure to hand-arm vibration over a number of years can cause permanent physical damage, such as what is commonly known as vibration white finger or damage to the joints and muscles of the wrist and/or elbow.

Much research and many studies have been made to evaluate the effect of over exposure to human vibration, especially in working environments. The results have been used to establish international standards that allow human exposure to vibration to be evaluated.

EU Directive 2002/44/EC introduced minimum Health and Safety requirements for workers to protect them when they are exposed to risks arising from vibration in the course of their work. The requirements standards involve measurements of whole-body vibration and hand-arm vibration using instruments that fulfil the requirements of the standards. Human Vibration Analyzer Type 4447 is such an instrument.

From a measurement and post-processing point of view, we can look at the problem in the classical way, from source to transmission path to receiver. At the source is a process, operation or machine that causes vibrations. Ideally vibrations at source should be avoided altogether or suitably minimised, but sometimes it is simply not possible to reduce source vibration to an acceptable level. The next step is to attempt to attenuate the vibration before it enters the human body or hand-arm system. The attenuation is achieved through seat constructions, gloves or other damping systems. Unfortunately the ability to attenuate the vibration is also limited, and the operator, or receiver, will feel what cannot be suppressed.

Measurements can and should be done to determine what a particular machine's emission is. It's the footprint of that machine. Doing such measurements in a standardised way helps comparing machines with one another. However, very seldom will real operation conditions give the same results: trucks may drive on a tapered surface, many real surfaces are rough and may lead to excitation at frequencies where the tool/machine/structure has a resonance, tools wear out, etc. Therefore, measurements under real conditions must be carried out. The same holds for determination of a seat's attenuation efficiency, which varies greatly with frequency and level of excitation and depends on the weight and posture of the driver.

Thus emission measurements may be used to get a first impression and rough feeling for the vibration exposure to expect. However, the actual exposure should be determined by measuring human vibration at the particular working place and it is of great importance to accurately monitor the actual exposure time.

1.3 What is Type 4447?

Human Vibration Analyzer Type 4447 is a small, lightweight, easy-to-use analyzer designed primarily for use in Health and Safety at Work applications. It is a rugged, robust and versatile instrument that can be carried by a worker to assess his or her vibration exposure.

The instrument is targeted at EU Directive 2002/44/EC and complies with the technical requirements of ISO 8041:2005, Human response to vibration – Measuring instrumentation, and can measure according to the following standards that relate to human vibration:

- ISO 5349–1 Mechanical Vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements
- ISO 5349–2 Mechanical Vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 2: Practical guidance for measurement at the workplace
- ISO 2631–1 Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration – Part 1: General requirements
- EN 14253 Mechanical vibration – Measurement and calculation of occupational exposure to whole-body vibration with reference to health – Practical guidance

In order to fulfil specific measurement needs, Type 4447 can be ordered in four configurations. (See Chapter 7, Ordering Information for specifics on instrument parts and configurations.) The full parts list is shown in Fig. 1.1.

Fig. 1.1
*Type 4447 parts list**

1) Type 4447 Human Vibration Analyzer with wrist strap.
2) Mounting accessories.
3) Type 4524-B-001 Miniature Triaxial DeltaTron® with LEMO 4-pin connector cable.
4) BZ-5623 4447 Vibration Explorer software.
5) USB standard A to USB mini-B interface cable.
6) Charger.
7) Type 4515-B-002 Seat Pad including Type 4524-B Accelerometer and strap for Seat Pad accelerometer.
8) Type 4294 Calibration Exciter with small calibration clip.*

A colour display is provided to show details of the instrument configuration and the resulting vibration parameters. An easy to understand control panel, comprising four pushbuttons, allows you to operate the instrument with minimum learning time (see Fig. 1.2). The two pushbuttons on either side of the display are used to select (highlight) or change items (values) on the display, confirm selections, or cancel changes and return to the previous menu (see Table 3.1).

* KE-0455 Travelling Bag is included but not pictured.

Fig. 1.2
Type 4447 Human Vibration Analyzer:
1) Display
2) Single-axis input
3) Three-axis input
4) Mini-B USB port
5) Four-pushbutton control panel

The instrument has two analogue inputs and one digital input/output. The analogue input sockets have a three-axes and a single-axis input respectively (see Fig. 1.2).

The two analogue inputs are on the bottom of the instrument and use different LEMO sockets, selected to provide reliable and simple connections and avoid wrong connections. They are used as follows:

- The three-axis input is for simultaneous measurement in three orthogonal directions with a triaxial accelerometer

  The three-channel input (consisting of a four-pin socket) is intended for connection of a triaxial DeltaTron® accelerometer. The recommended sensitivities are 1.00 mV/(m/s^2) for hand-arm measurements and 10.0 mV/(m/s^2) for whole-body, which covers most applications in the field of human vibration
- The single-axis input is used for measurements in one direction with a single-axial accelerometer

  The single-channel input (consisting of a two-pin socket) is intended for use with a single axial accelerometer. When equipped with a single axial accelerometer, Type 4447 can be used as a single-channel vibration meter, or for simplified measurement of high-level hand-arm vibration along one dominant axis
- The single-axis and triaxial inputs can be used together for Seat Effective Amplitude Transmissibility (SEAT) measurements

Both input sockets are equipped with a CCLD power supply for DeltaTron transducers. The supply can be switched on or off.

The miniature B1 USB input (lower left-hand side of the instrument, detail 4 in Fig. 1.2) has two purposes:

- Charging Type 4447
- Communicating with a computer

A clip on the rear of the instrument enables you to secure the instrument to a belt or waistband.

1.4 Features of Human Vibration Analyzer Type 4447

The main features of the instrument are:

- Hand held and easy to use
- Triaxial, single-axis or 3+1 measurements
- Simultaneous measurement of:
  - Time-averaged weighted acceleration value (*Total RMS*)
  - Running RMS acceleration value (*Curr RMS*)
  - Maximum transient vibration value (*MTVV*)
  - Peak vibration value (*Peak*)
  - Vibration Dose Value (*VDV*)
- SEAT factor measurement
- While measuring, calculation of combined axis vibration total value (*VTV*), and for whole-body, the vibration dose value (*VDV and* $VDV(8)_k$)
- After measurement the calculation of daily exposure value, normalised for 1 hour, 4 hours and 8 hours (*A(1)*, *A(4)* and *A(8)*) is saved
- One measurement range from 1.0 mV to 3.2 V, which corresponds to 1 m/s^2 to 3200 m/s^2, when a 1 $mV/(m/s^2)$ hand-arm accelerometer is used and 0.1 m/s^2 to 320 m/s^2 when a 10 $mV/(m/s^2)$ whole-body accelerometer is used
- For hand-arm measurements, frequency weighting W_h is used
- For whole-body measurements, frequency weighting W_d is used for the X- and Y-axis, and W_k is used for the Z-axis
- For building vibration, frequency weighting W_m is used
- *RMS*, *MTVV*, *Peak* and *VDV* logging at a 1 s interval
- Memory capacity for:

  750 three-axis measurements

  Approximately 4.7 h of three-axes logging (*RMS*, *MTVV*, *Peak* and *VDV*)
- After saving the measurement all parameters are available with exception of *Curr RMS*
- Transfer of measured results via the USB port to a PC for further calculation

1.5 Memory

The instrument has an internal, non-volatile memory for storing calibration and measurement results – it can store up to 750 triaxial measurements or approximately 4.7 h of triaxial logging. The instrument can also maintain both measurement types simultaneously in memory, but the logging time and number of measurements will be reduced.

1.6 What is Vibration Explorer Software?

Vibration Explorer Software BZ-5623, included with Type 4447, enables the transfer of measured data to a PC for post-processing. Vibration Explorer lets you model hand-arm and whole-body vibration exposure for workers. A comprehensive model can be created to determine the exposure level for the tested situation, as well as to simulate different scenarios. Based on those scenarios, decision makers can manage the health risk for any employee due to exposure to hand-arm or whole-body vibration. Both raw measurement data and complex exposure calculations can be exported for reporting.

1.6.1 Features of Vibration Explorer Software BZ-5623

The main features of Vibration Explorer Software BZ-5623 are:

- Easy-to-use interface
- Transfer of measurement and logging data from Type 4447
- Import of data from existing projects
- Post-processing of logging data
- Flexible, comprehensive modelling of hand-arm and whole-body vibration exposure
- Colour coding of exposure calculation results
- Use of Exposure Point system
- Export of measurement and logging data, as well as full exposure model to text files and Excel® spread sheets
- Customisable Excel® report templates
- Instrument maintenance

Chapter 2

Measuring Human Vibration: Theory

Human vibration is the effect of mechanical vibration on the human body; that effect can both be positive or negative.

Vibrations can, in fact, be desired and perceived as pleasant or give useful feedback over ongoing processes. However, just as often they are undesired, are irritating, cause stress, induce panic, and lead to physical reactions such as sweating, nausea and vomiting. While these can be extremely unpleasant experiences and strongly influence a person’s life and mental state, for most people the effect of vibrations will only be temporary or, once the exposure to the vibrations is stopped, the physical effects will disappear over time.

Unfortunately though, the physical effect of vibrations on the human body may also be permanent. The risk for irreparable injuries is especially high for human vibration occurring in context with work, where the vibration magnitudes can be substantial, the exposure times long and the vibration exposure may occur regularly or even daily. Typical risk groups are drivers of lorries, trucks, agricultural/farming, construction site and forest machinery, pilots of certain helicopters, and workers operating hand-fed machines, hand-guided machines or hand-held power tools and who need to hold workpieces. During their work, a worker's entire body or parts of it – especially the hand-arm region – may be exposed to excessive vibrations.

Unfortunately, the relation between vibration exposure and health damage is often not that obvious. Injuries may develop over a long period time and other activities, such as lifting heavy loads, could be the reason for the injury (e.g., lower back pain). A worker may feel numbness or fatigue after a working day while exposed to intensive vibrations, but initially these effects will only be temporary and the next day everything will seem fine. However, once these effects are permanent (such as cold fingers, lower back pain, etc.) it is often too late. Many of these injuries are irreversible.

It is therefore of the utmost importance to prevent excessive vibration exposure. In Europe, the Vibration Directive (Directive 2002/44/EC) has been introduced in order to set minimum standards for controlling the risks, both from hand-arm and whole-body vibration. The directive sets action values, above which it requires employers to control the vibration risks, and limit values, above which workers must not be exposed.

For hand-arm vibrations these values are:

- A daily exposure action value of 2.5 m/s^2
- A daily exposure limit value of 5 m/s^2

For whole-body vibrations these values are:

- A daily exposure action value of 0.5 m/s^2 (or, at the choice of the individual EU Member State, a vibration dose value of 9.1 $m/s^{1.75}$)
- A daily exposure limit value of 1.15 m/s^2 (or, at the choice of the individual EU Member State, a vibration dose value of 21 $m/s^{1.75}$)

Employers are obliged to determine and assess the risk resulting from both hand-arm and whole-body vibrations and ensure that the exposure values are not exceeded. If analysis suggests that workers are at risk, employers should set a management program into action to keep the exposure to vibration at a minimum and prevent the development and progression of injury.

At the first stage, the analysis can be based on emission values, i.e., data of vibration magnitudes that occur when operating or working with a particular tool, vehicle or machinery. Today such data is often provided by manufacturers of machines and vehicles but can also be found in databases maintained by independent organisations and institutes. However, employers must be aware that these data have been determined following harmonised codes. Emission data determined according to such standards are primarily meant to allow the customer direct comparison of similar products. In practice, however, the emission values occurring under real conditions may be significantly greater.

The reason for this can be wear, overly rough road surfaces, operating vehicles or mobile machinery on sloped surfaces, and other factors of real, every day usage. Therefore, measurements at the site are highly recommended to validate and verify that using the tool or machine in that particular context does not lead to larger vibration magnitudes than specified by the producer.

Whether data are taken from databases or collected by carrying out vibration measurements at the site, it is very important to perform a detailed analysis of the precise exposure times at the specific working place. This is not only important for finding the actual daily vibration exposure for the current situation, but also to have sufficiently precise data with which to work when making suggestions to reduce exposure and risk.

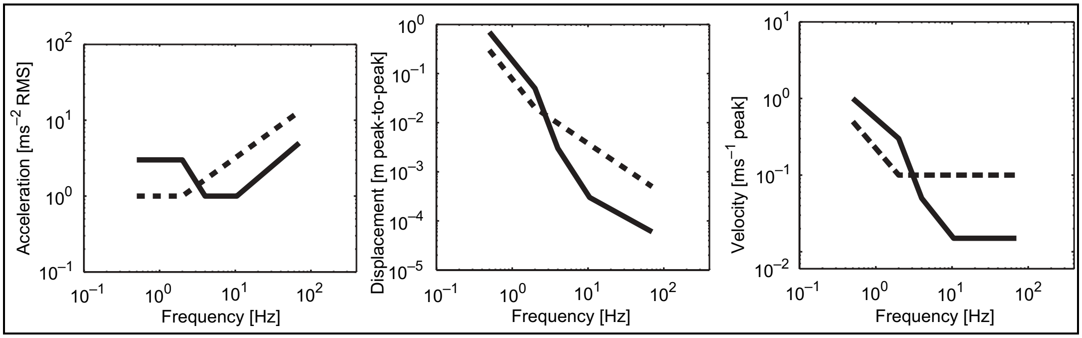
2.1 Parameters Measured When Assessing Human Exposure to Vibration

To determine a person's vibration exposure, you need to collect information about the vibration magnitude and duration of the various working processes, i.e., for how long and often the person is exposed to vibrations of a certain type and magnitude.

2.1.1 Vibration Magnitude

Vibration magnitude could be expressed in terms of acceleration, velocity or displacement observed for a vibration process. All three make sense because the human body responds to any of the them, depending on the frequency of motion, see Fig. 2.1.

Fig. 2.1 *Response to vibration may be expressed in terms of acceleration (left), displacement (centre) and velocity (right)*

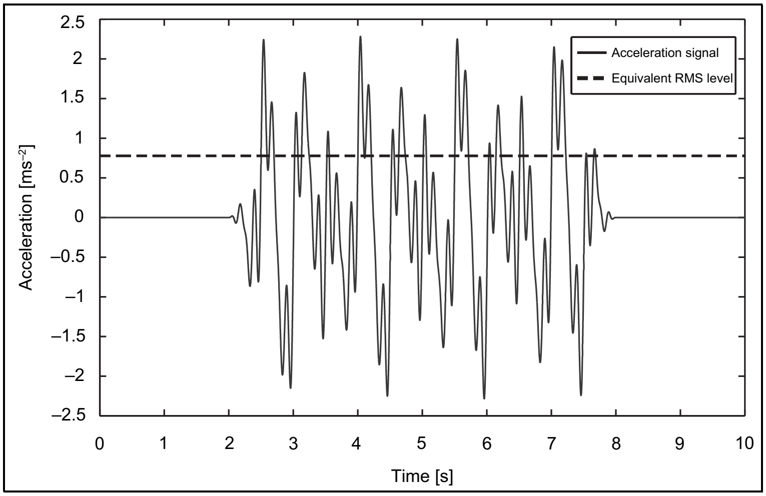


However, in many standards related to the measurement of human vibration, acceleration is the agreed upon quantity for expressing magnitudes. This is mainly a matter of convenience since the classical vibration sensor is the accelerometer; which delivers the signal proportional to acceleration.

In general, accelerometer signals will be filtered and frequency weighted before further processing. Filtering is applied because the analysis should only include those frequencies that are thought to be important for hand-arm or whole-body vibration. Further, the frequencies included are weighted differently. The weighting reflects the likelihood of damage from vibrations at different frequencies. Therefore, depending on where (e.g., feet, seat, backrest, palms) and in which direction (e.g., front and back vs. side to side) the measurement is taken, different frequency weightings may be used. The reason is that the 'human' dynamic system reacts differently depending on where and in which direction the vibrations enter the body. For example, fore and aft motion of a seated person is very different from side-to-side motion for the same person.

The purpose of the subsequent analysis is to quantify the acceleration appropriately. Typically the so-called time-averaged weighted acceleration value, a frequency-weighted root mean square (RMS) of a vibration signal, is determined and reported in order to quantify the vibration to which a worker would be exposed. In context with human vibration, it is a measure for the average amount of vibration energy that would enter the human body, see Fig. 2.2.

Fig. 2.2
A vibration signal and its equivalent RMS level



RMS vibration magnitude is a good representation of processes whose vibrations are continuous or intermittent rather than shock like. Tools such as drilling machines, chain saws and vibrating plate tampers fall into that category. Even impact-wrenches can be well described with RMS vibration magnitude even though each single operation cycle (tightening a single nut or a series of tightenings) may last only a few seconds. Whole-body vibrations, such as driving a bus or lorry over a standard, well-maintained road or sitting in a train or other railway transport, are also well described with an RMS value.

However, care must be taken when investigating shocks and processes with transients (i.e., sudden changes in the acceleration) – particularly when dealing with whole-body vibrations. For example, a vehicle driving across bumps in the road or construction machines operated (e.g., cutting and loading trees or crushing concrete) may easily cause shock-like vibrations. For such events, averaging across times much longer than the event's duration (e.g., taking RMS measurement over the entire working period) would not capture the essence of the problem. The intensity (magnitude) of a single shock, a few shocks or the sudden changes in acceleration may be beyond what the human body can accommodate, but if they are averaged out over a long period of time, their significance would be missed. Therefore, we have to look at the total energy in the event and the maximum vibration values reached during the operation.

Better descriptors for such vibration scenarios are the Vibration Dose Value (VDV), which is a cumulative measure (i.e., sum up the energy, rather than calculate an average), and the Maximum Transient Vibration Value (MTVV), which is the maximum of the so-called running RMS acceleration value, an RMS vibration magnitude with 1 s integration time.

Since MTVV is based on a short integration interval, it will indicate the top vibration magnitudes to which the worker would be exposed. This parameter is especially useful when logged with a short (1 s) interval because the logging profile quickly gives an overview, whether any large vibration magnitude was an exception, appeared often or was constant.

VDV is well suited to reflect the total exposure; it accumulates the vibration energy the worker would be exposed to, thereby putting more weight on peaks and/or sudden changes in the acceleration.

ISO 2631–1:1997 (section 6.3.3) – Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-body Vibration, gives guidelines for which value (RMS, MTVV or VDV) best characterises a particular vibration history. (More information will be given in Section 2.3: Assessment of Daily Vibration Exposure: Whole-body Vibrations).

2.1.2 Duration

For a correct assessment of human exposure to vibration, a precise determination of the duration of vibration exposure is as critical as a correct determination of the vibration magnitude. Estimation of the duration should be based on a detailed observation of the working process. A stop watch or video recording may be used to capture the duration of operations that lead to vibration exposure. In addition, interviews with the workers should be carried out.

When determining exposure duration, it is important to keep in mind the approach used to measure the vibration magnitude. Some operations can be consistent over a period of one or several hours, such as operating a vibrating plate tamper or driving a lorry. Other operations are intermittent or change character after short periods, such as using chain saws, operating fork lifts, etc. Finally, for some tools, a single operation cycle may only last a few seconds, such as using impact wrenches. In general, one could follow one of two approaches:

- Only measure while the person is exposed to vibrations. Each single measurement would then give a representative quantification of the vibration magnitude observed with a particular machine or vehicle operating in a certain mode (e.g., a chain saw running idle, cleaning the stem, cutting through small branches and stems or cutting through a big stem; or a lorry driving on a well maintained road, through a city with stop-and-go, bumps or over the rough surfaces in a sand pit). In these cases, the duration to be inserted in the final analysis should just comprise those periods where the worker is really exposed to vibrations from the machine, work piece or vehicle
- Carry out a single measurement including different modes of operation and breaks, work piece or tool 'shifts'. Such measurements would give a representative average over an entire working day or a complex working process. The duration to insert in the exposure analysis is then the total time used for this process, including both actual vibration exposure periods and breaks

Both approaches have advantages and disadvantages. When following the first approach, determining the exact exposure durations requires a detailed study of the working processes. Workers should be interviewed to collect information about the various operations on a typical working day. However, it is also required to identify and verify the duration of exposure through direct observation because the duration often is overestimated by workers; they report how long they are with a vehicle or hold a machine in their hand rather than the actual period where the machine or vehicle was emitting vibrations.

In contrast, determining the duration for a measurement following the second approach is much easier. However, the result does not provide detailed information about to what degree a particular operation, machine, road surface, etc., is responsible for the vibration exposure. Detailed information is drowned in the average, making it impossible to find and calculate where an improvement (in terms of reduced risk) can be achieved. Also, events such as putting down the tool or when a driver is rising from a seat will add significantly to the recorded vibration magnitude, even though such events have nothing to do with the human exposure to vibration.

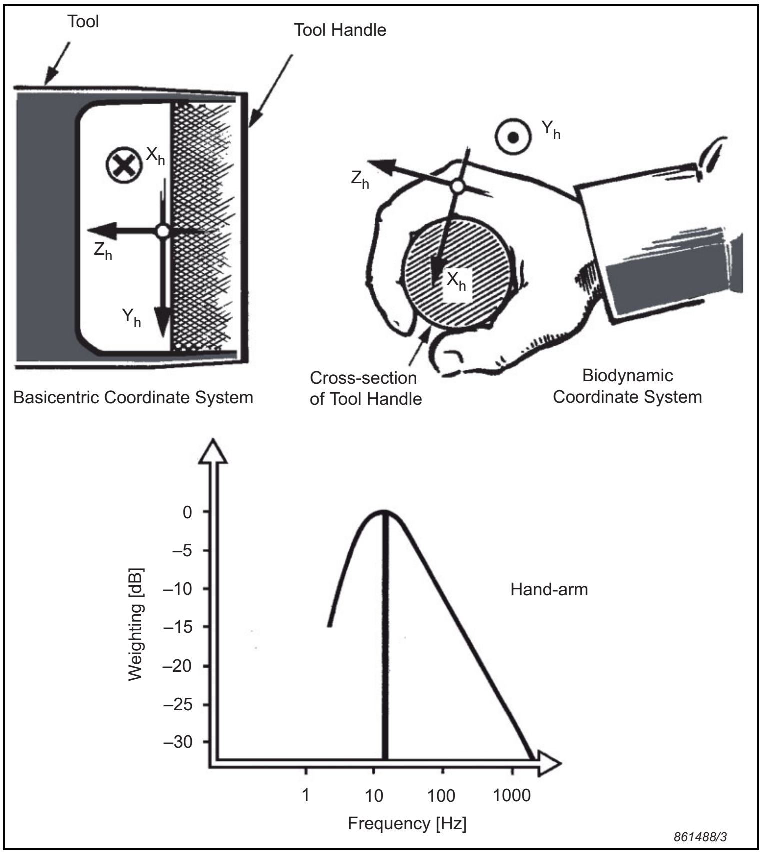
2.2 Assessment of Daily Vibration Exposure: Hand-arm Vibrations

Please refer to ISO 5349–2:2001 before making hand-arm measurements. Information is also contained in ISO 20643:2005 – Mechanical Vibration, Hand-held and Hand-guided Machinery – Principles for Evaluation of Vibration Emission. Specific additional information can be found in the ISO 8662 series (to be replaced by ISO 28927 series) and EN 60745 series.

Regardless of which approach is used, when carrying out hand-arm measurements, the total measuring time should be at least 1 minute. Further, at least three measurements should be completed for each operation. Measurement blocks shorter than 8 s should be avoided because they would not correctly capture low-frequency content.

Measurements of hand-arm vibrations are to be carried out at the interface between hand and tool grip, see Fig. 2.3. Therefore, the measurement equipment should be light in comparison to the mass of the tool handle or working piece. Further, it must be ensured that the transducer is mounted as rigidly as possible. If the mounting is too heavy or too springy, local mass and spring effects will falsify the measurement.

Fig. 2.3
Principle measurement location and axis orientation for hand-arm measurements



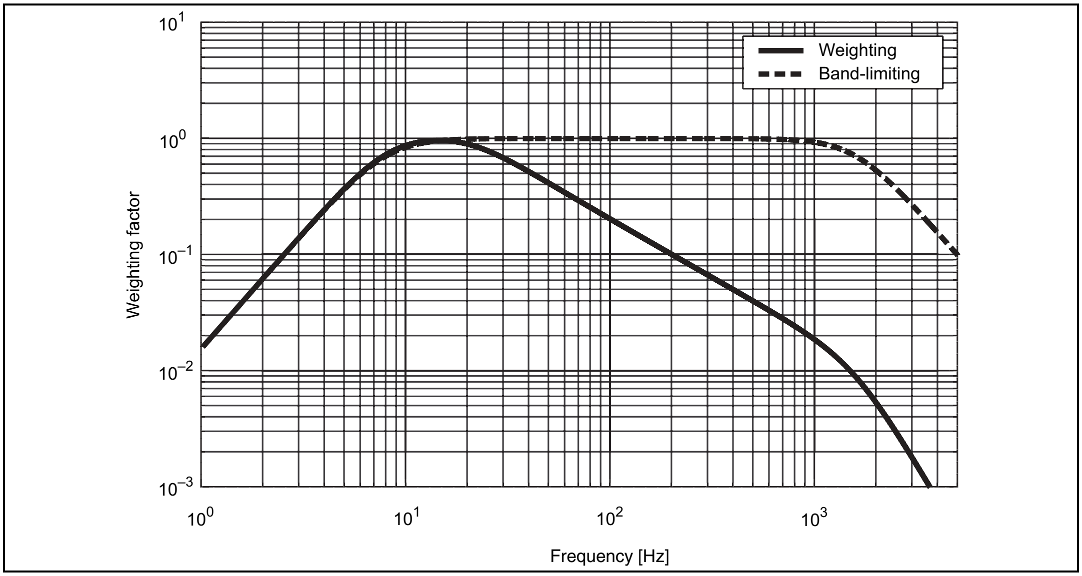
Note: While the mounting position should be as close as possible to (if not directly on) the contact surface during normal operation, no part of the mounting system and cables should interfere with the safety of machine operation. For example, the transducer should not block power-off switches or be positioned so that cables would be able to swing into rotating parts.

ISO 5349–1:2001 recommends determining the frequency-weighted RMS acceleration in three directions: On axis with the arm and in two other directions in the plane between hand and grip. The best solution is using a miniature triaxial accelerometer, which picks up the vibration in all three directions at the same point, and only adds a few grams of transducer mass.

Note: When addressing root mean square values of acceleration in human vibration, ISO standards use lowercase '*a*'. The ISO notation style is followed in this chapter; however, Type 4447 root mean square acceleration is denoted as '*RMS*' (see Chapter 3 and Chapter 4).

The frequency range included in the analysis is 8–1000 Hz. Frequency weighting W_h (see Fig. 2.4) is used for all three axes, even though the anatomy and thus sensitivity of the hand-arm system differs along the arm and in transverse direction.

Fig. 2.4 *Magnitude of frequency weighting* W_h *for hand-arm vibration, all directions, (based on ISO 5349–1 or ISO 8041, respectively)*



The three frequency weighted acceleration components are denoted a_{hwx}, a_{hwy} and a_{hwz}. These are then combined with the so-called vibration total value, a_{hv}, the root-sum-of-squares of the three components:

$$a_{hv} = \sqrt{(k_x a_{hwx})^2 + (k_y a_{hwy})^2 + (k_z a_{hwz})^2} \qquad \text{Eq 2.1}$$

Note: In contrast to whole-body vibrations, when calculating the root sum of squares for hand-arm vibrations, all axes are, theoretically, multiplied with the same weighting factor, k=1.0. Usually, to simplify the equations, the factors will be dropped.

The daily vibration exposure $A(8)$ is calculated from this vibration total value:

$$A(8) = a_{hv}\sqrt{\frac{T_{\text{exp}}}{T_0}} \qquad \text{Eq 2.2}$$

Where T_0 is the reference duration of 8 hours and T_{exp} is an estimate of the time that the tool operators are exposed to the vibration or the duration of the entire operation including breaks (see Section 2.1). If a person is exposed to more than one source of vibration, a partial vibration exposure $A_i(8)$ for each operation 'i' is to be calculated:

$$A_i(8) = a_{hv,\,i}\sqrt{\frac{T_{\text{exp},i}}{T_0}} \qquad \text{Eq 2.3}$$

The partial vibration exposure values are then combined to give the overall daily exposure value $A(8)$, for that person:

$$A(8) = \sqrt{A_1^2(8) + A_2^2(8) + \ldots + A_n^2(8)} \qquad \text{Eq 2.4}$$

When using Type 4447 to determine vibration exposure at a working place, you first make all the necessary measurements. The flexibility of Type 4447 allows you to utilise the methods best suited to the work conditions that need evaluation. Once the data have been acquired, enter them into Vibration Explorer, combine them, apply an exposure time for each operation, and Vibration Explorer will calculate the total daily exposure. If the exposure is beyond acceptable working condition limits, simply use Vibration Explorer Software to model different scenarios that would lead to a reduced exposure and then export the data and create the reports.

Type 4447 may also be used to determine the vibration emission of a particular machine so that it can be entered in the product data sheet. In this case, carry out the measurement following the particular standard. Often these require the measurements to be taken several times and then to report an average of these measurements. Vibration Explorer also supports this function.

2.3 Assessment of Daily Vibration Exposure: Whole-body Vibrations

Human exposure to whole-body vibration should be evaluated using the method defined in ISO 2631–1:1997. Whole-body vibration is applicable to motions transmitted from workplace machines and vehicles to the human body through a supporting surface. For health and safety evaluations this is through the buttocks and feet of a seated person or the feet of a standing person.

When carrying out whole-body measurements, it is preferable to measure over the entire exposure time. If that is not possible or necessary, measurements should be made over periods of at least 20 minutes. Where short measurements are necessary, they should be at least three minutes long and should be repeated to achieve a total measurement time of more than 20 minutes. Longer measurements of 2 hours or more are preferable (half or full working day measurements are sometimes possible).

When assessing whole-body vibrations, acceleration should be picked up at the seat surface for a seated person or underneath the feet of a standing person. The accelerometer should be placed in a Seat Pad, which is preferably fixed to the floor or seat using tape or a strap to ensure that the accelerometer remains at the desired position and is able to withstand any position changes of the driver or operator of a machine. However, for correct results the Seat Pad must be loaded during the measurement by the worker, who should stand or sit on the pad.

RMS vibration magnitude, Peak value, MTVV and VDV of the frequency-weighted acceleration should be measured simultaneously in all three directions, where Z-direction is always along the main body axis (i.e., for measurements at the feet and seat it is vertical to the seat and floor plane), the X-direction is aligned with the fore-and-aft motion and the Y-direction with side-to-side motion.

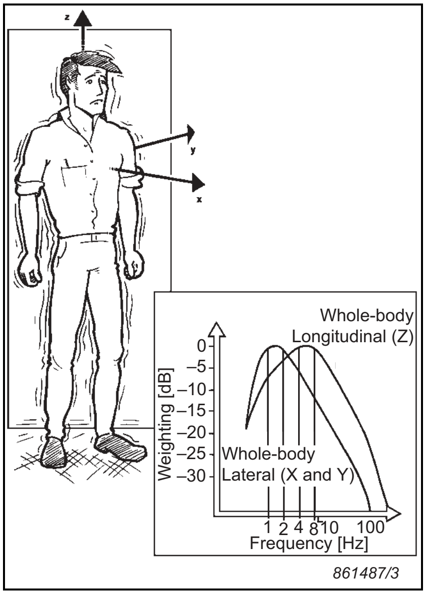


Fig. 2.5
X-, Y- and Z-axes orientations when carrying out whole-body measurements

In contrast to hand-arm vibration assessment, frequency weightings are different for X-, Y- and Z-direction, respectively. In the context of health risk assessment, when measuring whole-body vibration at the feet and seat, ISO 2631–1:1997 requires the use of W_k in the Z-direction, whereas W_d is used for the acceleration in the X- and Y-directions, see Fig. 2.6 and Fig. 2.7.

Fig. 2.6 *Magnitude of frequency weighting* W_k *for vertical whole-body vibration, Z-axis, seated, standing or recumbent person (based on ISO 8041 and ISO 2631—1)*

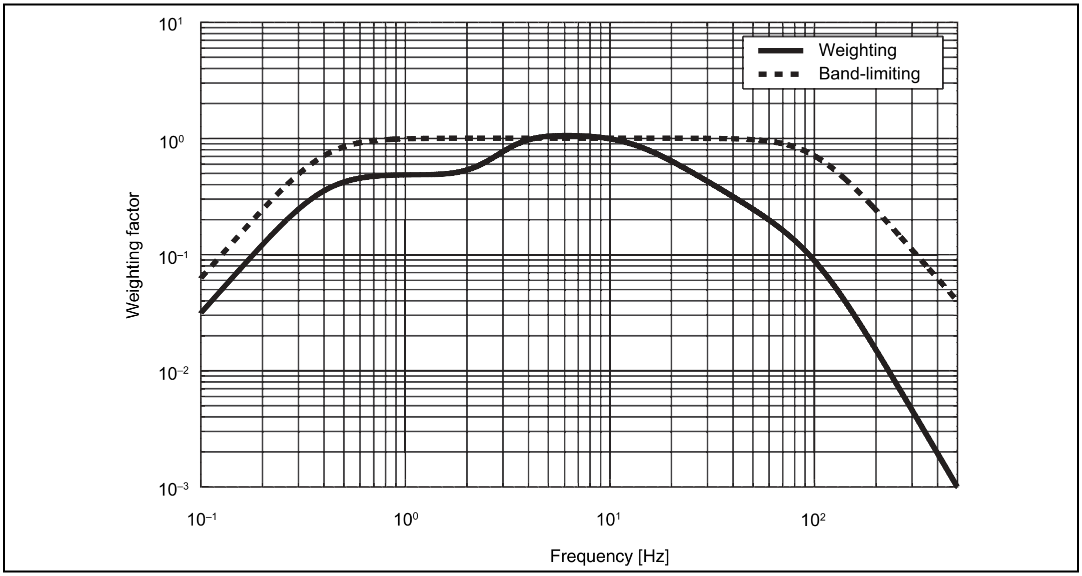
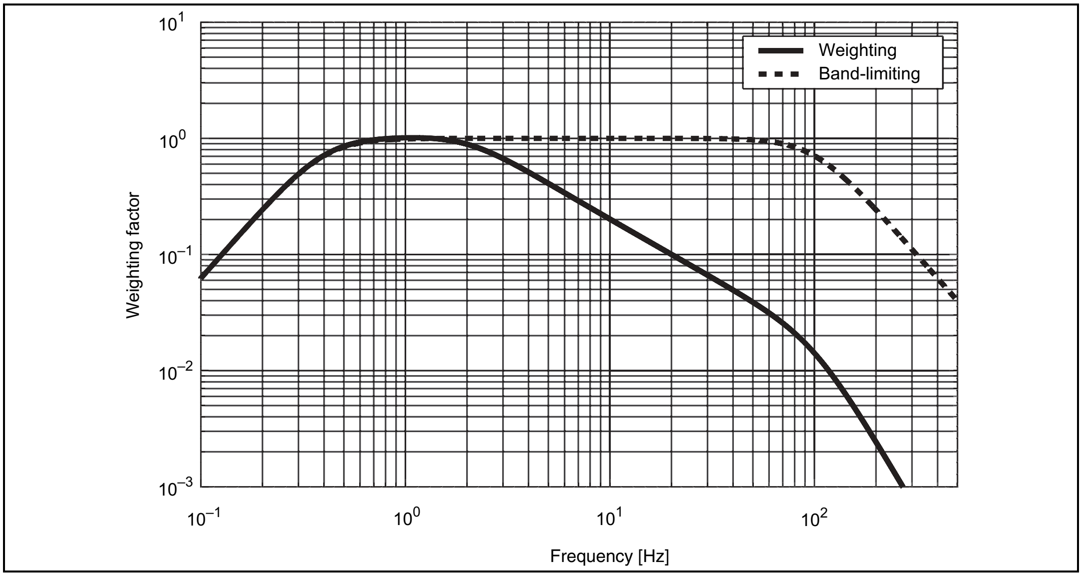


Fig. 2.7 *Magnitude of frequency weighting* W_d *for horizontal whole-body vibration, X- or Y-axis, seated, standing or recumbent person (based on ISO 8041 and ISO 2631–1)*



Based on the frequency-weighted acceleration signals, the daily vibration exposure is determined by calculating the exposure for each of the three axes separately and then selecting the highest of the three values. This necessitates an additional factor, k_i, that must be applied to the measured vibration values. For the X- and Y-directions the factor is 1.4. For the Z-direction, the factor is 1.0:

$$A_x(8) = a_{wx} \cdot 1.4\sqrt{\frac{T_{exp}}{T_0}}$$

$$A_y(8) = a_{wy} \cdot 1.4\sqrt{\frac{T_{exp}}{T_0}} \qquad \text{Eq 2.5}$$

$$A_z(8) = a_{wz} \cdot 1.0\sqrt{\frac{T_{exp}}{T_0}}$$

The maximum of these three values will then be the daily vibration exposure:

$$A(8) = \max\{A_x(8), A_y(8), A_z(8)\} \qquad \text{Eq 2.6}$$

Note 1: This is significantly different than the procedure used to determine hand-arm vibration exposure, where the three axes were combined to a single, total vibration value. However, according to ISO 2631–1:1997, Section 6.5, a vibration total value may be used if no dominant axis of vibration can be found. The vibration total value for whole body vibration is calculated according to the following equation:

$$a_v = \sqrt{k_x^2 a_{wx}^2 + k_y^2 a_{wy}^2 + k_z^2 a_{wz}^2} \qquad \text{Eq 2.7}$$

Note 2: Note the *k*-factors in the root-sum-of-squares.

Note 3: In some countries, different exposure limit values are given for different axes. Therefore, a paradox may occur such that, while the axis with the largest exposure value will not be found critical, another axis with a smaller exposure value will be above the limit for this axis. The report, based on the axis with the highest value, would not indicate a risk, even though the limit is violated for another axis.

If a worker is exposed to more than one source of vibration, the partial vibration exposure $A_{j,i}(8)$, for each axis 'j' and operation 'i', is to be calculated first:

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

$$A_{y,i}(8) = a_{wy,i} \cdot 1.4\sqrt{\frac{T_{exp}}{T_0}} \qquad \text{Eq 2.8}$$

$$A_{z,i}(8) = a_{wz,i} \cdot 1.0\sqrt{\frac{T_{exp}}{T_0}}$$

The partial vibration exposures are then added for each of the three axes separately, and the total daily vibration exposure is found as the maximum of these three sums:

$$\left.\begin{aligned} A_x(8) &= \sqrt{A_{x,1}^2(8) + A_{x,2}^2(8) + \ldots + A_{x,n}^2(8)} \\ A_y(8) &= \sqrt{A_{y,1}^2(8) + A_{y,2}^2(8) + \ldots + A_{y,n}^2(8)} \\ A_z(8) &= \sqrt{A_{z,1}^2(8) + A_{z,2}^2(8) + \ldots + A_{z,n}^2(8)} \end{aligned}\right\} A(8) = \max\{A_x(8), A_y(8), A_z(8)\} \qquad \text{Eq 2.9}$$

The total daily vibration dose, $A(8)$, applies well if the vibration history is rather smooth, free of shocks or other sudden changes or peaks in the acceleration. However, when, for example, driving a vehicle over rough surfaces, such as found on construction sites and sand pits, shock-like events may occur and an assessment based on RMS values may no longer be appropriate.

The fourth power vibration dose value (*VDV*) has been developed to take such transients into account. Unlike RMS vibration magnitude, the measured *VDV* is a cumulative value – it increases with the measurement time. It is, therefore, important for any measurement of *VDV*, to know the period over which the value was measured. Further, due to the fourth power, transients and peaks are given more weight in the integration.

If the measurement time is shorter than the estimated exposure time, the measured *VDV* must be expanded to the actual exposure time:

$$\begin{aligned} VDV_{\exp,x} &= VDV_x \cdot 1.4\left(\frac{T_{\exp}}{T_{\text{meas}}}\right)^{1/4} \\ VDV_{\exp,y} &= VDV_y \cdot 1.4\left(\frac{T_{\exp}}{T_{\text{meas}}}\right)^{1/4} \qquad \text{Eq 2.10} \\ VDV_{\exp,z} &= VDV_z \cdot 1.0\left(\frac{T_{\exp}}{T_{\text{meas}}}\right)^{1/4} \end{aligned}$$

Where T_{meas} is the measurement period and $T_{\exp}$ is the full expected exposure time, and note again the k-factors (1.4, 1.4 and 1.0). Further, if a person is exposed to more than one vibration source, the total *VDV* is to be calculated from the partial vibration dose values for each axis:

$$\left.\begin{aligned} VDV_x &= \left(VDV_{x,1}^4 + VDV_{x,2}^4 + \ldots + VDV_{x,n}^4\right)^{1/4} \\ VDV_y &= \left(VDV_{y,1}^4 + VDV_{y,2}^4 + \ldots + VDV_{y,n}^4\right)^{1/4} \\ VDV_z &= \left(VDV_{z,1}^4 + VDV_{z,2}^4 + \ldots + VDV_{z,n}^4\right)^{1/4} \end{aligned}\right\} (\text{daily}\, VDV) \qquad \text{Eq 2.11}$$

$$= \max\{VDV_x, VDV_y, VDV_z\}$$

The highest of the three individual *VDV*s gives the daily *VDV*.

Another useful quantity when investigating human vibration with transients is the running RMS. It has a short integration time of 1 s and, thus, is well suited to indicate the magnitude of short events. The so-called maximum transient vibration value (MTVV) represents the maximum running RMS value found over one measurement period.

ISO 2631–1:1997 provides some guidelines concerning when it is recommended to consider *VDV*, running RMS and MTVV instead of the vibration magnitude, a_w:

- Appendix B.3.2: If $CF = \frac{Peak}{RMS} > 9$, *VDV* should be considered in addition to RMS
- Section 6.3:

If $\frac{MTVV}{RMS} > 1.5$, MTVV should be considered in addition to RMS

If $\frac{MTVV}{RMS \cdot T^{1/4}} > 1.75$, *VDV* should be considered in addition to RMS

If one of these conditions is given, it indicates that the vibration history had peaks significantly above the general average vibration level.

Note: The ratio between Peak value and RMS vibration magnitude, the crest factor (CF), is considered to be a rather uncertain criteria because the peak may have occurred at a different time – ranging from minutes to hours before or after the vibration event that determined the RMS.* In case of doubt, the other two criteria are preferred.

2.4 The Exposure Point System

The measurement engineer, or any other professional, dealing regularly with vibration measurements will easily develop a good feeling for quantities such as the Daily vibration exposure value ($A(8)$) and *VDV*. However, to the layman, exposures expressed in units such as m/s^2 and $m/s^{1.75}$ will usually be difficult to grasp. If this person then must make decisions based on such quantities, those decisions may become needlessly difficult.

In order to facilitate those decisions, a more simple and intuitive means to express daily vibration exposure $A(8)$ has been introduced, exposure points. For the user or decision maker, expressing exposure with the point system has two advantages:

1) The point system avoids units: The critical vibration magnitudes for hand-arm and whole-body vibrations differ (the hand-arm system can cope with larger magnitudes). In contrast, the exposure point system is defined in such a way that, in both cases (hand-arm and whole-body vibrations), the exposure action value is reached at 100 points.

2) Once exposure is expressed in points, there is no need for complicated power laws: Exposure points are simply added together. If a worker is exposed to several vibration sources, the total number of exposure points is simply the sum of the exposure points for the sources. This also means that exposure points change simply with time – twice the exposure time, twice the number of points.

* The best evaluation is based on a detailed logging profile.

For hand-arm vibrations, exposure points are calculated for the combined three axes (vibration total value, see equation 2.1), as follows:

$$P_E = \left(\frac{a_{hv}}{2.5\ \mathrm{m/s}^2}\right)^2 \frac{T_{\exp}}{T_0} 100 \qquad \text{Eq 2.13}$$

Where a_{hv} is the vibration total value (RMS VTV, see equation 2.1), $T_{\exp}$ the exposure time in hours and T_0 the reference duration of 8 hours. Note that the vibration magnitude of 2.5 m/s^2 corresponds to the action value for hand-arm vibrations. As a consequence, the conversion between $A(8)$ and P_E will be such, that the exposures equal to the action value (2.5 m/s^2 $A(8)$) will give 100 points, and exposures equal to the limit value (5 m/s^2 $A(8)$) will give 400 points.

It is also possible to directly convert between $A(8)$ and P_E:

$$P_E = A(8)^2 \frac{100}{(2.5\ \mathrm{m/s}^2)^2} \qquad \text{Eq 2.14}$$

For whole-body vibrations, exposure points are calculated for each of the three axes separately, as follows:

$$P_{E,j} = \left(\frac{k_j a_{wj}}{0.5\ \mathrm{m/s}^2}\right)^2 \frac{T_{\exp}}{T_0} 100 \qquad \text{Eq 2.15}$$

Where k_j is the weighting factor for the X-, Y- or Z-axis respectively; a_{wj} is the vibration magnitude (RMS value) of either the X-, Y- or Z-axis; $T_{\exp}$ is the exposure time in hours; and T_0 is the reference duration of 8 hours. Note that the vibration magnitude of 0.5 m/s^2 corresponds to the action value for whole-body vibrations. Also in the case of whole-body vibrations, the conversion between $A(8)$ and P_E is such that an exposure action value of 0.5 m/s^2 would be equal to 100 points. However, the exposure limit value of 1.15 m/s^2 will be equal to 529 points.

To directly convert between $A(8)$ and P_E:

$$P_E = A(8)^2 \frac{100}{(0.5\ \mathrm{m/s}^2)^2} \qquad \text{Eq 2.16}$$

2.5 Measurements of Seat Effective Amplitude Transmissibility (SEAT)

In contrast to the measurements discussed in Section 2.2 and Section 2.3, determination of Seat Effective Amplitude Transmissibility (SEAT) does not directly give information about human exposure to vibration. Instead, the goal of the measurement is to determine the capability of a seat design to attenuate the vibrations present in a vehicle, i.e., to protect the driver from excessive vibrations.

The measurement therefore involves determination of the vibration magnitude at two positions:

1) On the seat pan.
2) Directly on the floor of the vehicle right underneath the seat.

Measurement at these two points is done simultaneously and the SEAT is computed as the ratio between these two magnitudes. To express SEAT, one may use the frequency-weighted RMS vibration magnitudes (a_w) or the *VDV*s. Further, rather than just using the ratio (a SEAT factor), one may multiply the result with 100 to express the seat effective vibration amplitude in percent.

Whether to use RMS or *VDV* depends on the vibrations encountered during the measurement. If the vibration history was rather smooth, then RMS vibration magnitude is preferable. If, however, the vibrations included transients and shocks, it is recommended to compute SEAT based on *VDV*s.

$$SEAT_{RMS} = \frac{a_{w,\text{ seat}}}{a_{w,\text{ floor}}}$$

$$SEAT_{VDV} = \frac{VDV_{\text{seat}}}{VDV_{\text{floor}}} \qquad \text{Eq 2.17}$$

$$SEAT\% = SEAT \times 100$$

Clearly, a seat would improve ride comfort when *SEAT* is smaller than 1 or, expressed in percentage, when *SEAT*% is less than 100%. If the value exceeds these limits, the seat actually amplifies vibrations and, thus, worsens ride comfort.

Note: In context with health risk assessment, frequency weighting used for SEAT measurements is the same as for whole-body measurements, see Section 2.3.

When assessing a seat’s ability to attenuate vibrations, it is important to keep in mind that seat and driver must be seen as one system. The driver will add mass to the seat, which preloads the seat springs, and changes the resonance behaviour. Further, depending on posture, the seat-driver combination will lead to a more or less stiff system (e.g., vibrations will be different if the driver sits relaxed or if feet are pressed against the floor).

Thus, depending on the driver's body and posture, the performance of seats can be very different. As a consequence, several measurements with different drivers and postures should be carried out to get the full picture.

Standards for laboratory SEAT measurements define exact masses to be used, specific seat adjustments, and detailed procedure, including processes such as warming up the seat, etc. However, this is not the intended application for Type 4447. Instead focus is on the assessment of SEAT factors under real working conditions, with real workers and no warm-up times. Nevertheless, SEAT assessment standards may and should be consulted because they provide useful guidance.

An additional benefit of SEAT measurement with Type 4447 is the ability to perform two tasks at once. SEAT measurement and seated whole-body vibration testing can be performed with one measurement set. And by performing multiple sets of tests with different drivers, the requirement for multiple sessions for shorter time durations will also be met.

Chapter 3

Getting Started Using Type 4447

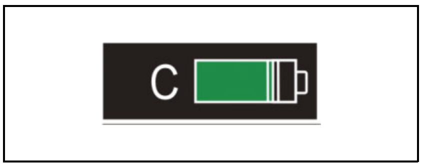
This chapter details how to charge Type 4447, set up and make measurements and transfer data. Further descriptions of the user interface, how to calibrate and measure will be given.

3.1 Battery

Before the first use of the instrument, one full charging cycle is recommended. The initial charging should last at least 6 hours. A longer charging time will not harm the battery.

The energy source for Type 4447 is an integrated, compact, rechargeable battery. When Type 4447 is switched on, the battery status is displayed in the upper right corner of the display as an icon with a green field, see Fig. 3.1. For more detail, see list item 3, page 40.

Fig. 3.1
Battery status indicator while charging



The battery is charged through the USB port. Charging is initiated as soon as the instrument is connected to Charger ZG-0459 or a PC, using USB Cable AO-1476.

Charging with the Charger ZG-0459 is, however, much quicker than charging through a PCs USB socket. Further, while charging (with the charger), Type 4447 should be turned off as this will increase the efficiency of the charging cycle.

Note 1: Charging should not be done during measurements as this can influence the results.

When the battery is fully charged a battery icon appears in the instrument's display (see Fig. 3.2). As noted above, the first charging cycle should be at least 6 hours. A longer charging time will not harm the battery. During regular use of the instrument, the charging time should be about 4 hours for a fully discharged battery (i.e., the instrument has turned itself off). If the battery is not fully discharged, charging should last at least 3 hours to ensure a fully charged battery.

Fig. 3.2
Display icon for a fully charged battery

During operation, when battery has about 3% of its capacity left, the warning *Battery low* appears. When you receive this warning, you should save the measurement and recharge the battery. To prevent loss of measured data due to a low battery, the instrument automatically saves the data before shut-down.

3.2 Basic Operation

3.2.1 Instrument Pushbuttons

The instrument is controlled using four pushbuttons (see Fig. 3.3). They are located on both sides of the instrument display: two arrow keys left of the display and two multi-function keys right of the display. The function of each key is explained in the Table 3.1.

Fig. 3.3
Pushbuttons on Type 4447

Table 3.1 *Instrument pushbuttons*

Pushbutton	Function
	This is a multifunction pushbutton, which enables you to: • Turn on the instrument by pressing and holding the button for more than 3 s • Accept the selected parameter • Stop the measurement (press and hold the key for at least 3 s) • Make a hard instrument reset. If a hard reset is required (i.e., the instrument is not responding), press and hold the button for approximately 10 s
	This pushbutton has the following functions: • Return to the previous menu • Make a pause in a measurement • Restart measurement by pressing twice within a second (Restart not available when logging)
	This pushbutton is used to step through the various fields in a upward direction and change parameter values
	This pushbutton is used to step through the various fields in an downward direction and change parameter values

Turn on Type 4447

Hold for more than 3 seconds and Type 4447 will switch on and go through a short start up -process. After a few seconds the instrument will be ready for use.

Getting Around in Type 4447

Type 4447 has a colour dot matrix display. It gives instant information about the setup, measurement status, input channel status, battery status of the instrument and the results of the measurement in progress.

At start up, Type 4447 will go to the **Main** menu. Use / to change the selection in the menu, to enter a submenu or confirm a choice/setting/change, and to leave a sub menu or discard changes you made.

Some Type 4447 menus are circular. If the last menu item on the screen is highlighted and you press selection will jump up to the first item. Vice versa if the first item is selected and you press selection will jump to the last item. At some menu levels, there will be more menu items than are able to fit on the screen. In this case, pushing or respectively will open another page with the remaining menu items. When reaching the end or beginning of this new page, the original menu page will be displayed and the first or last item, respectively on this page selected.

Shut Down Type 4447

To switch 4447 off, using /, select **Shut down** from the **Main** menu and confirm by pressing or press to cancel and return to the **Main** menu.

When not measuring, Type 4447 will automatically shut down if left unattended for more than 15 minutes. While measuring, Type 4447 will only shut down when it runs out of battery power. In the event of an automatic shut down, the analyzer will automatically save the measurement before shutting down.

3.3 Basic Settings: Display Units, Date, and Time

When delivered, Type 4447 is preset to a default date and time and a default unit display (m/s^2). See below to change the default settings.

3.3.1 Set Preferred Display Units

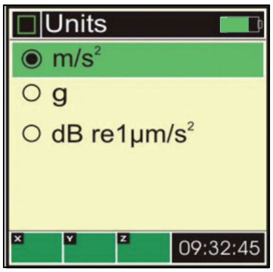
The default Type 4447 unit format is metric (m/s^2 and $m/s^{1.75}$). However, it is also possible to have results displayed in ‘g and $gs^{0.25}$’ or ‘dB ref 1µm/s^2’.

Note: This manual is written using m/s^2 as the display unit.

Change the Display Units

1) From the **Main** menu, select **Setup** and then **Display units**.
2) Choose the preferred units using / and press to confirm the selection.

Fig. 3.4
Selecting the measurement units



3) After confirming the display will jump back to the **Setup** menu.

3.3.2 Adjust Date and Time

1) From the **Main** menu, select **Setup** and then **Set Time**.

   Note: Set Time is on the second page of the Setup menu.
2) Set the time using / and press to confirm each unit (hour, minutes, seconds, day, month and year) of the selection.
3) After confirming the year, the display will jump back to the **Setup** menu.

3.4 Front-end Setup

3.4.1 Selecting, Connecting and Disconnecting Accelerometers

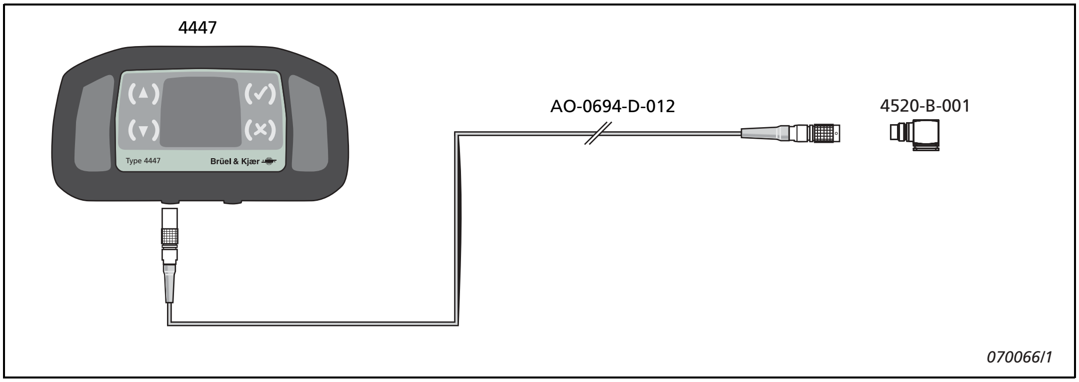
The accelerometer(s) purchased with Type 4447 has (have) been specifically selected to fit the particular human vibration applications supported by Type 4447.

See below for appropriate accelerometer selection:

- For whole-body vibration measurements for a seated or standing person, use the rubber seat pad Type 4515-B-002, equipped with an accelerometer Type 4524-B
- For hand-arm measurements, triaxial accelerometer Type 4520-B-001 is usually a good choice. However, when measuring on power tools that cause extreme acceleration at the hand, Type 4520-004 should be used instead. Type 4520-004 is specially designed for high-g measurements and can be used with a mechanical filter (WA-0224), which removes high frequency components. These frequencies are beyond the frequency range considered to be of interest in context with hand-arm vibrations. Removing them makes the signal less peaky, thus preventing unnecessary overloads
- For building vibration (comfort) measurements, use a high-sensitivity triaxial accelerometer (provided with the appropriate package)

To connect triaxial accelerometers, use Cable AO-0694-D-012. The LEMO connector of this cable fits into the left, four pole socket of Type 4447. The Microdot connector fits onto the transducer, see Fig. 3.5.

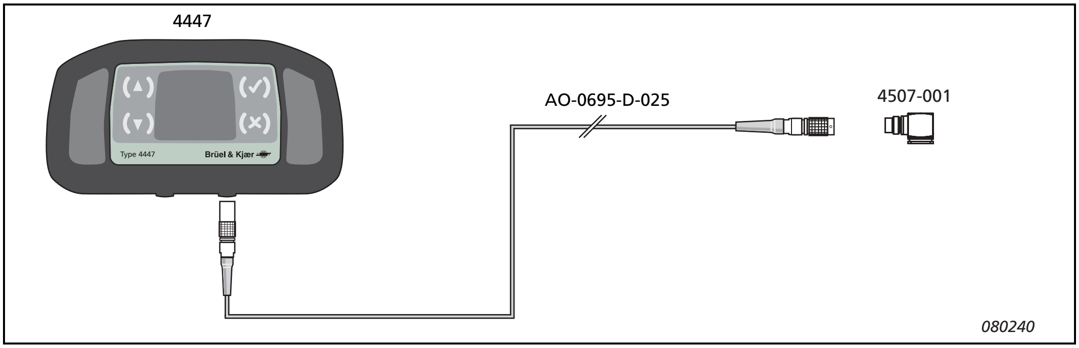
Fig. 3.5 Connecting a triaxial accelerometer (Type 4520-B-001) to Type 4447



In addition to these triaxial accelerometers, Type 4447 also supports single-axis accelerometers. These may be used if only vibrations in a single direction are important, but also to measure vibration at the vehicle floor in addition to measuring with the seat pad when measuring SEAT (see Chapters 2 and 4).

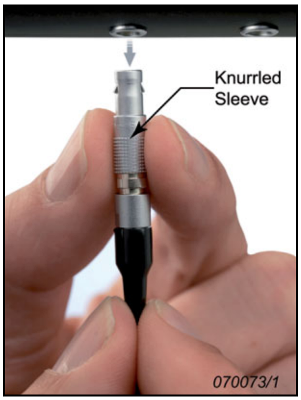
To connect a single-axis accelerometer to Type 4447 use cable AO-0695-D-025. The LEMO connector of this cable fits into the right, two pole socket of Type 4447. The Microdot connector fits onto the transducer, see Fig. 3.6.

Fig. 3.6 *Connecting a single-axis accelerometer to Type 4447*



Caution: When removing the LEMO connector from the socket, do so by pulling on the knurled sleeve **only**, see Fig. 3.7. Do not try to twist the connector or remove it by pulling on the cable, since damage can result.

Fig. 3.7
Removing the LEMO connector using the knurled sleeve



3.4.2 Setting Input Signal Options for Power and Type

The next step is to adjust the input signal options, i.e., whether Type 4447 should measure using the triaxial input, the single-axis input or both at the same time (3+1 axes). Type 4447 supports charge/piezoelectric accelerometers as well as DeltaTron® accelerometers (piezoelectric accelerometers with integral preamplifiers); therefore, you need to specify whether transducer power supply should be activated or not.

Setting the Input Signal Option for Transducer Power

All accelerometers delivered with Type 4447 are DeltaTron accelerometers. When using one of these, 4447 must be set up to supply current for the accelerometer:

1) From the **Main** menu, select **Setup** then **Transd. power** menu.
2) Using / , select *CCLD ON* (see Fig. 3.8) and confirm selection by pressing . This returns you to the **Setup** menu.

Fig. 3.8
Transd.power *menu*

Selecting *CCLD ON* means that the supply current for the transducer is provided from the input socket. Use this setting whenever a DeltaTron accelerometer or Charge to Voltage Converter Type 2647 is connected to the input. When *CCLD OFF* is selected, no current is provided from the input. Use this setting when a voltage source is connected to the input.

Setting the Input Signal Option for the Transducer Type

In addition to the power option Type 4447 must be set up with respect to whether a triaxial accelerometer, a single-axis accelerometer or both simultaneously are used. To choose the type of accelerometer:

1) From the **Main** menu, select the **Setup** menu and then the **Transducer** menu.
2) Use / to select from the three options:
   - Triaxial
   - Single axis
   - 3+1 axes

   and confirm the selection by pressing .

Note 1: As will be discussed in Section 3.5, Type 4447 contains a small database with calibration data for 5 triaxial and 5 single-axis transducers. The triaxial accelerometers are stored under indices 1-5, with position 5 reserved for an accelerometer with a very high sensitivity. Single-axis accelerometers are stored at positions 6-10, with position 10 reserved for an accelerometer with a very high sensitivity (for more information, see Section 3.5).

3.5 Calibration and Accelerometer Database

If standards in your country require: Calibration should be performed before and after each series of measurements using a Brüel & Kjær Vibration Calibrator Type 4294. If calibration is not required before and after each measurement, the system should at least be checked before each measurement to ensure faultless operation. The **Calibration** menu is found on the **Main** menu, and consists of *Sel. transd.* and *Calib. transd.*, which are described below.

Type 4447 contains a small database that can hold calibration data for five triaxial and five single-axis transducers. The triaxial accelerometers are stored under indices 1-5. Single-axis accelerometers are stored in positions 6-10.

Positions 5 and 10 are reserved for high-sensitivity accelerometers primarily intended for building vibrations. Due to the comparable large mass of these transducers (up to 200 g each), they require a different version of the accelerometer calibrator, Type 4294-002 (different from the one used for the miniature accelerometers), which generates a lower excitation level. Type 4447 automatically accounts for that when calibrating accelerometer 5 or 10 in the database.

When carrying out a measurement with the *3+1 axes* option, the triaxial and single-axis transducers can only be chosen pair wise following the scheme 1+6, 2+7 etc. This should be kept in mind when placing calibration data for the triaxial and single-axis accelerometers in the database, i.e. when assigning an index to the triaxial and single-axis accelerometer, respectively.

Both calibration and transducer selection are done through the **Calibration** menu (see Fig. 3.9), which is accessed through the **Main** menu.

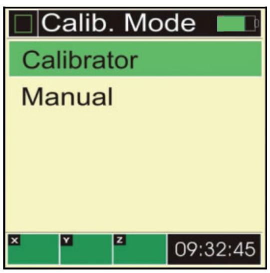
Fig. 3.9
Calibration menu

The database can be populated with calibration data either by manual input or by carrying out a calibration with the accelerometer directly connected to Type 4447. Once calibration data for a specific transducer is up to date in the database, you can simply select that data to the active data. Selecting *Calib. transd.* takes you to the **Calib. Mode** screen (see Section 3.5.1).

3.5.1 Calibrate Transducer (Accelerometer)

The **Calib.transd./Calib. Mode** menu allows you to perform two types of calibration: *Calibrator* and *Manual* as shown in Fig. 3.10.

Fig. 3.10
Selecting the Calibration Mode



Calibration with a Calibrator

Many standards require a calibration to be performed before and after each series of measurements:

- To calibrate the miniature accelerometers Type 4524-B (seat pad accelerometer) and Type 4524-B-001 (hand arm vibration) use the Brüel & Kjær Vibration Calibrator Type 4294. However, the high-g accelerometer Type 4520-004 cannot be calibrated using Brüel & Kjær Vibration Calibrator Type 4294, since the generated vibration level is under range
- To calibrate the larger, heavier building vibration accelerometer, use the Brüel & Kjær Vibration Calibrator Type 4294-002

Note: During calibration, previously selected weighting filter is temporarily turned off.

Before starting calibration:

1) Connect the accelerometer to Type 4447, see Section 3.4.1.

2) Make sure the transducer type (triaxial, single axis, 3+1 axes and transducer power) is set appropriately.

   Note 1: To calibrate the seat pad accelerometer, the accelerometer must be unmounted from the seat pad and unclipped from its adaptor before calibration. Use the supplied screwdriver to remove the mounting plate. Care must be taken when disconnecting the cable from the accelerometer.

   Note 2: When Transducer type is 3+1, Type 4447 provides the means to calibrate both, the triaxial and the single axis accelerometer, in one calibration sequence.

After calibration of the Seat Pad Accelerometer, replace the accelerometer on the clip of the mounting plate, ensuring the orientation as instructed by the sticker showing. Side with logo upwards. Carefully reconnect the cable and reassemble the seat pad

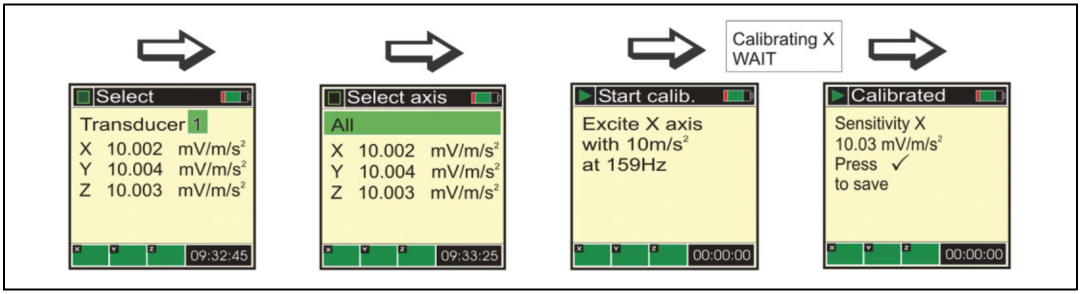
Calibrating a Triaxial Accelerometer

To simplify calibration of triaxial accelerometers, Type 4447 offers a calibration sequence, where you are guided (interactively) through the calibration of the X-, Y- and Z-axis. Alternatively you can select to calibrate a particular axis explicitly.

To calibrate a triaxial accelerometer following the automatic procedure/calibration sequence (after step 1) refer to the calibration steps in Fig. 3.11):

1) From the **Main** menu select **Setup**, **Transducer** and *Triaxial*, then return to the Main menu and select **Calibration**, **Calib. transd.** and then **Calibrator**.

Fig. 3.11 *Calibration steps*



2) On the screen that appears use / to select which of the accelerometers you want to calibrate. While browsing through the database, Type 4447 will show the current calibration data stored for the particular accelerometer. To select the desired accelerometer, press .

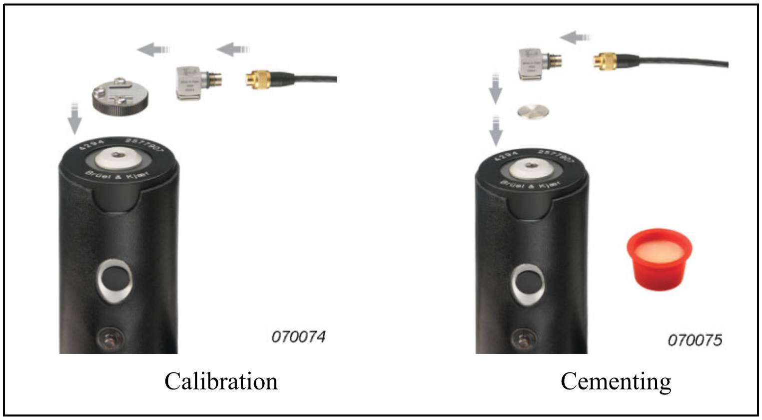
3) Use / to select *All* and press . This will start the interactive process.

4) You are first prompted to excite the X-axis with 10 m/s^2 at 159.2Hz.

   Note: If the selected transducer is one of the first four, calibrator Type 4294 must be used and Type 4447 expects an excitation level of 10 m/s^2. However, when calibrating accelerometer 5, calibrator Type 4294-002 must be used and Type 4447 expects the calibration level to be 3.16 m/s^2.

5) Mount the accelerometer on Calibration Adaptor DV-0459 (or on the cementing stud DB-0756 with Beeswax) along the X-axis, see Fig. 3.12.

Fig. 3.12
Left: Calibration Adaptor DV-0459
Right: Cementing stud DB-0756 with beeswax



6) Once the transducer is mounted, start the calibrator and press on Type 4447. It takes 12 s to complete the calibration of an axis. The sensitivity of the axis is displayed. Check this against the specification of the transducer and save the sensitivity by pressing .

   Note: The calibration signal must be stable during the whole calibration interval (12 s) or else an error warning is displayed: *Signal level unstable*. If that was the case, press to close the message and repeat the steps in 6). Reasons for an unstable signal could be that the calibrator switched off before the 12 seconds were gone or that the transducer was loose, i.e. not properly mounted.

7) After completing the calibration of the axis, change orientation of the accelerometer so that it is excited in the next direction. If the calibrator was turned off, turn it on again and follow the procedure in 6) for any remaining axes.

After accepting the sensitivity for the final axis Type 4447 will return to the **Main** menu. At this point, the new calibration data have been saved and the just-calibrated-transducer becomes the default transducer. This means that this accelerometer will be automatically selected in a measurement task.

Note: during calibration, sensitivity is displayed rounded to two decimals. Calibration data stored in the database have a better precision.

To only calibrate a particular axis of a triaxial accelerometer:

1) Follow steps 1) and 2) from above. In step 3), rather than selecting *All*, select the axis to calibrate.

2) Then follow step 4) to 6) for the chosen axis.

On accepting the calibration/sensitivity, Type 4447 will save data for this axis and return to the **Main** menu.

Note: The default calibration values for all accelerometers are 0mV/ms^{-2}. Until all three axes of an accelerometer have been really calibrated the first time, the accelerometer cannot be used in measurements. Therefore, when only calibrating one or two of the three axes, the transducer will not be made the selected transducer yet. However, after the third axis has been calibrated, calibrating any of the axes will make the transducer the default/selected one.

Calibrating a Triaxial and a Single Axis Accelerometer in 3+1 Axes Mode

If the transducer type has been set to *3+1 axes* (from **Main** menu, select **Setup**, **Transducer** and *3+1 axes*), Type 4447 offers calibrating the triaxial and single-axis accelerometer in a single calibration sequence. Calibration is similar to the process for a triaxial accelerometer. You can choose to calibrate all axis in one sequence or do so for one selected axis only.

Manual Calibration

An alternative to using a calibrator is manual calibration using the pushbuttons. The transducer does not need to be connected during manual calibration. Manual calibration requires knowledge of the accelerometer sensitivity, which can be obtained from the calibration chart of the individual accelerometer.

1) Ensure that the correct type of accelerometer (from **Main** menu, select **Setup**, **Transducer** and *Triaxial*, *Single axis* or *3+1 axes*) is selected.

2) From the **Main** menu select **Calibration**, **Calib. transd.** and then *Manual*.

3) You are now prompted to select the transducer (transducer pair), which you want to set sensitivity for. Use / to select which of the accelerometers you want to calibrate and press .
4) The cursor will jump to the first digit of the selected transducer's first axis' sensitivity. Use / to set the value.
5) Press to advance to the next digit. If you need to move backwards press .
6) Repeat the actions in steps 4) and 5) for each digit in a line. Once the last digit of an axis is set the cursor will jump to the next line.
7) On completing the last axis Type 4447 will return to the **Main** menu.

At this point, the new calibration data have been saved and the just-calibrated transducer(s) become(s) the default transducer(s). This means that the required accelerometer(s) will be automatically selected in a measurement task.

3.5.2 Selecting a Transducer (Accelerometer) in the Database

On Type 4447, the calibration data for up to five triaxial (numbered 1 to 5) and five single-axis accelerometers (numbered 6 to 10) are stored in a small database. If you connect another accelerometer to Type 4447, for which the calibration data are already stored in the instrument, the only remaining task is to select the accelerometer's data from the database.

To recall an accelerometer's sensitivity and select it:

1) Ensure that the correct type of accelerometer (from **Main** menu, select **Setup**, **Transducer** and *Triaxial*, *Single axis* or *3+1 axes*) is selected.
2) From the main menu select **Calibration/Select transd.** You are now prompted to select a transducer or transducer pair from the database: 1-5 if the type is set to triaxial, 6-10 if it set to single axis, and 1+6 to 5+10 if transducer option 3+1 is chosen.
3) Use / to select the accelerometer and press to confirm the selection.

Type 4447 will then return to the **Main** menu.

3.6 Choosing Weighting/Application

Depending on, whether 4447 is to be used to measure hand-arm, whole-body vibrations or building vibrations, it must be set up appropriately by selecting the weighting filter for the respective application:

- **Whole-body:** In order to comply with ISO 2631–1:1997, the input signals for the X- and Y-axes are weighted using the W_d weighting curve, and Z-axis using the W_k weighting (see Fig. 3.13 and Fig. 3.14)
- **Hand-arm:** In order to comply with ISO 5349–1:2001, the input signals from all measurement channels are frequency weighted with the W_h weighting (see Fig. 3.15)
- **Building vibration:** In order to comply with ISO 2631–2:2003, the input signals from all measurement channels are frequency weighted with the W_m weighting (see Fig. 3.16)

Fig. 3.13 *Magnitude of frequency weighting* W$_d$ *for horizontal whole-body vibration, X- or Y-axis, seated, standing or recumbent person (based on ISO 8041 and ISO 2631–1)*

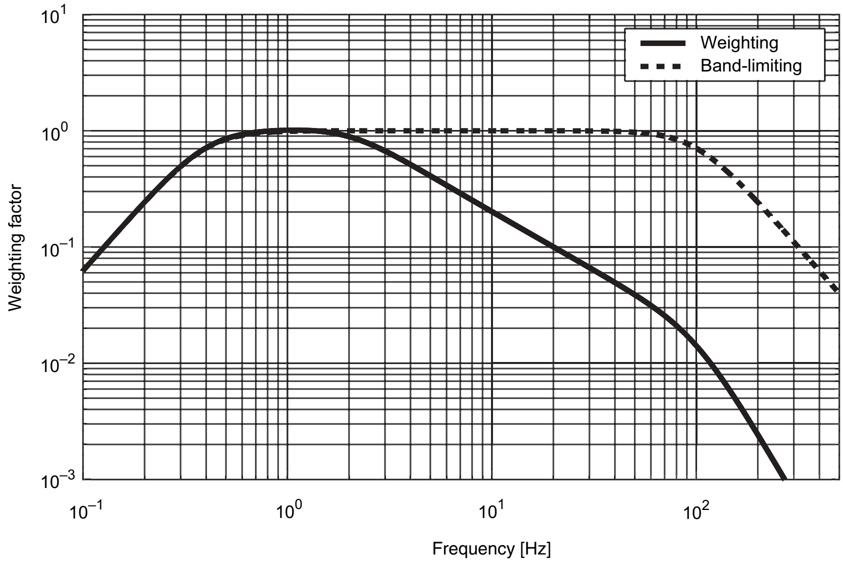


Fig. 3.14 *Magnitude of frequency weighting* W$_k$ *for vertical whole-body vibration, Z-axis, seated, standing or recumbent person (based on ISO 8041 and ISO 2631—1)*

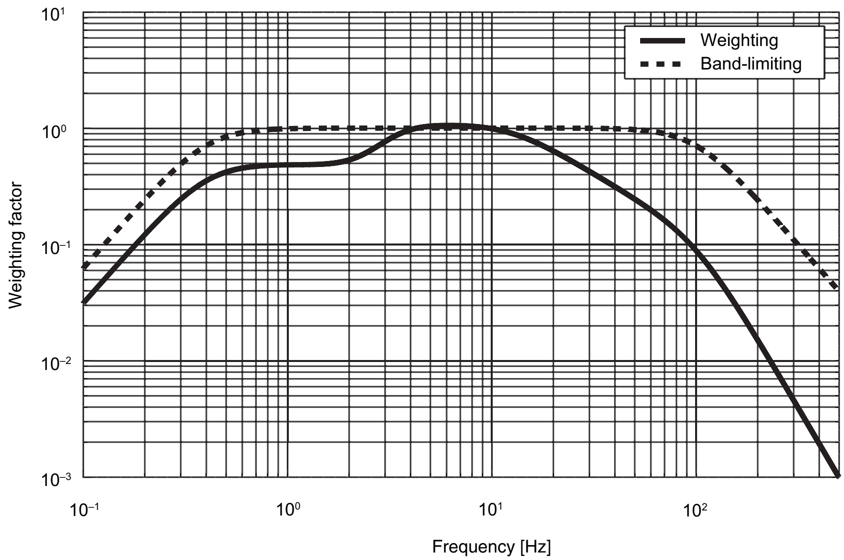


Fig. 3.15 *Magnitude of frequency weighting* W_h *for hand-arm vibration, all directions, (based on ISO 8041 and ISO 5349 – 1)*

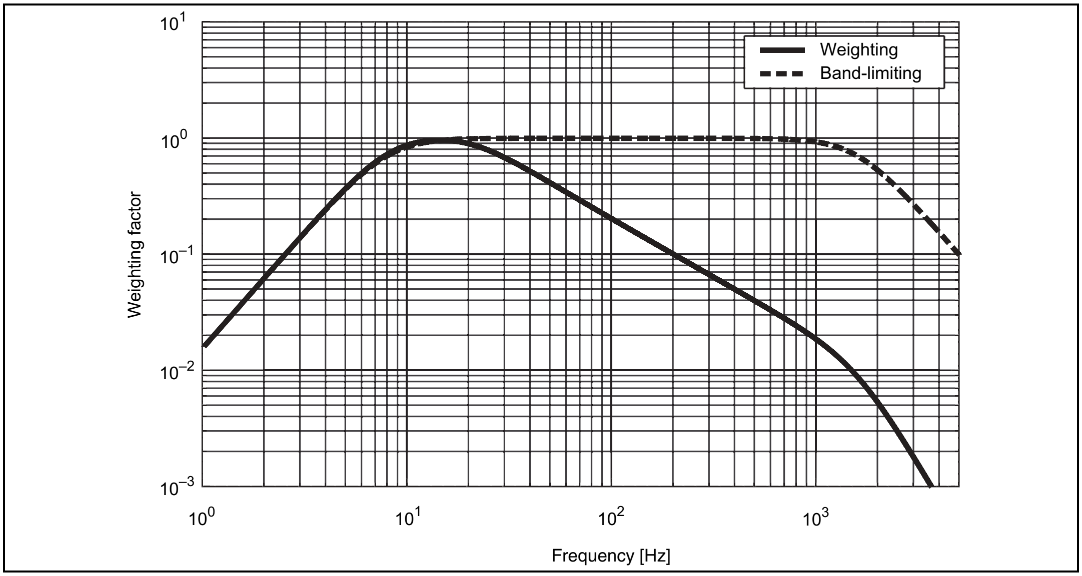
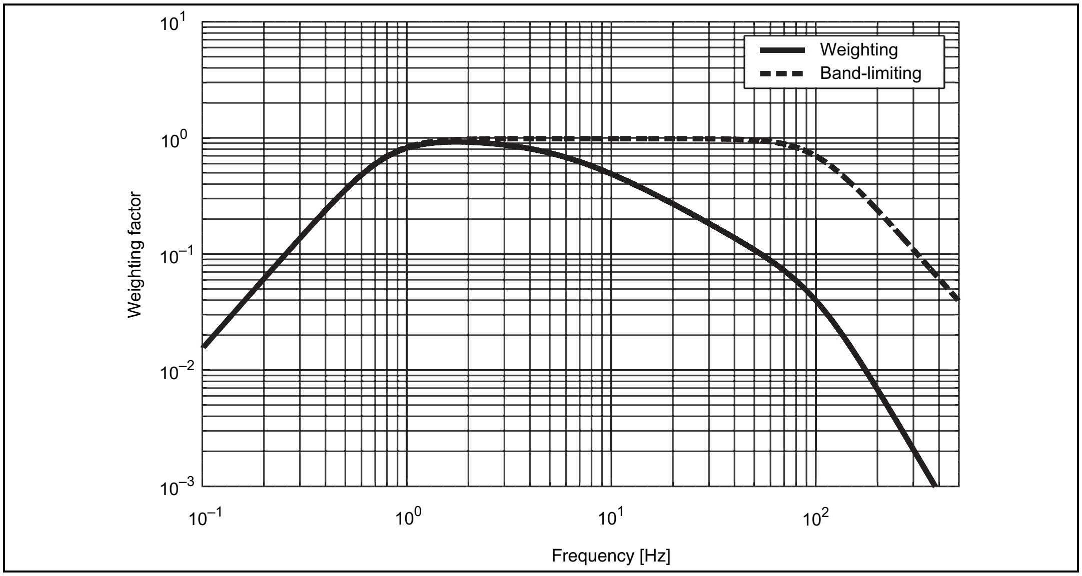


Fig. 3.16 *Magnitude of frequency weighting* W_m *for building vibration, all directions, (based on ISO 8041 and ISO 5349 – 1)*



Type 4447 offers all filters in band-limiting form. These filters have the same cut-off frequencies as the whole-body, hand-arm and building vibration weightings, respectively. However, within the pass band, no further weighting is applied, i.e., within the pass band, the filters have a flat response. The nominal frequency range of the band-limiting filters is 8–1000 Hz for hand-arm measurements, 0.5–80 Hz for whole-body measurements and 1–80 Hz for building vibrations.

When switching to a different filter, Type 4447 will automatically select the *k*-factors that comply with the relevant standard, see Chapter 2:

- Whole-body weighting: $k_x = 1.4$, $k_y = 1.4$ and $k_z = 1.0$
- Hand-arm and building vibration weighting: all three *k*-factors are set to 1.0

The k-factors are displayed when selecting the frequency weighting.

3.7 Logging

With Type 4447 any measurement type can be carried out in normal or logged measurement mode. In logged mode, Type 4447 will, in addition to the standard measurement, store the *RMS*, *Peak*, *MTVV* and *VDV* value for each axis at a 1 s interval. Within the interval linear averaging is used for *RMS*. Such a logging profile gives you a more detailed picture of the vibration exposure over the course of the measurement and provides more freedom in post-processing.

To carry out logging measurements:

1) Prepare Type 4447 as discussed in Section 3.1 through Section 3.6.
2) From the **Main** menu, select **Setup** and then **Logging**. The **Logging** menu indicates the remaining logging capacity in hours and minutes and lets you choose to activate or deactivate logging.
3) Use / to select *Enabled* and press to confirm the selection.

If you now start a measurement, Type 4447 will carry out the total measurement and, in addition, log the vibration data.

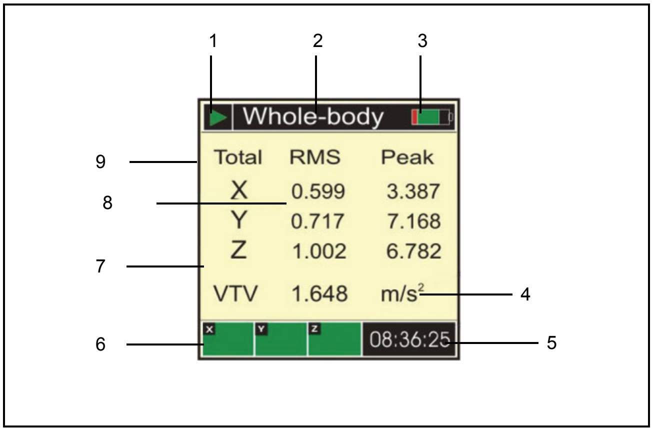
During measurement, a red dot rather than a green arrow will be displayed in the upper left corner.

Note: If during a logging measurement, Type 4447 runs out of logging memory, measurement will be stopped. Measurement data are saved and *Log full* will be displayed until you press any button.

3.8 The Display

During measurements, Type 4447's display gives instant information about the setup, measurement status, input channel status, battery status of the instrument and the results of the measurement in progress. Fig. 3.17 shows a display during a measurement and is followed by a description of the various fields.

Fig. 3.17
Example display during a measurement



1) **Measurement Status field:** A measurement in progress is indicated by the symbol (a red dot is used when logging); a paused measurement by the symbol ; and a measurement that has been stopped by the symbol .

2) **Weighting field:** This field shows the frequency weighting/type of measurement which has to be selected prior to measurement in **Setup/Weighting**. It can be:

   - **Whole-body:** The input signals are frequency weighted with the standardised whole-body curves W_d and W_k (see Fig. 3.13 and Fig. 3.14)
   - **Hand-arm:** The input signals are frequency weighted with the standardised hand-arm curve, W_h (see Fig. 3.15)
   - **Building vibration:** The input signals are frequency weighted with the standardised building vibration curve, W_m

   When the weighting field has a black background, standard weighting is used. When the background is yellow, the band-limiting versions of the filters are used. In this case, the signal will be filtered using the band width of the standardised filters for hand-arm, whole-body or building vibration, respectively, but within the pass band the filter response is flat.

   Note: The band-limiting filters are introduced for your convenience. However, measurements, according to ISO 5349 and ISO 2631, should always be done with full weighting applied. Therefore, as a reminder, on Type 4447's display and in the accompanying PC software, Vibration Explorer, data collected with a band-limiting filter will always be marked with a yellow background.

3) **Battery icon:** Shows the available battery capacity. The green colour (fully charged) changes to orange when the battery has approximately 40% of its capacity left, and to red when only 20% of its capacity is left. When the battery has only 3% of its capacity, *Battery low* is displayed. Please refer to Chapter 7 for the battery time.

   During charging the icon shows a green line moving back and forth. If the letter *C* is beside the icon, it means that the battery is charging from a wall charger, see Fig. 3.1. When Type 4447 is connected to a PC, rather than *C,* the letter *U* will initially be displayed and then the entire display area will be replaced by a large USB symbol.

Please note that the charging process is not very efficient when the PC is the power supply source.

4) **Unit:** Displayed unit corresponds to selected measurement parameter. It can be, for example, m/s^2 for *RMS* and *Peak* parameters, and $m/s^{1.75}$ for *VDV* and $VDV(8)_k$.

   Note: When position 5 or 10 is selected, the units change to mm/s^2 or $mm/s^{1.75}$.

5) **Timer indication:** When no measurement is taking place, it shows the real time in hours, minutes and seconds. During a measurement it shows the elapsed time of the measurement, in minutes and seconds.

6) **Status indication:** of the input channels is shown at the bottom of the screen. Depending on the chosen transducer, the indicator uses either two or three status fields.

   When triaxial is selected, three fields are shown, one for each axis.

   When single 3+1 axis is selected, two fields are shown (left – single-axis status (*AUX*); right – triaxial status (*XYZ*)). If there is a problem (e.g., settling, under range, overload or cable breakage) with the triaxial status in any of the three channels, the problem will be indicated in the triaxial status field; i.e., you will be alerted to the problem, but not the specific channel in which the problem has occurred.

   When single axis is selected, two fields are shown but only the left status field (*AUX*) is used – the right status field (*XYZ*) is shown but not active.

   There are four colour codes: purple, green, red and yellow:

   - **Purple:** The instrument is settling after a change in the setup
   - **Green:** Everything is OK. If **CCLD** is set to *CCLD Of*, then the input is in voltage mode and this is indicated with a *V*
   - **Red:** There is an error. If *O* is indicated, there is an Overload. If **CCLD** is set to *CCLD On*, then *B* or *S* can also be indicated: *B* stands for cable break, *S* stands for cable short-circuit and both indicate errors in the accelerometer or the cabling to the instrument
   - **Yellow:** Warning. *U* stands for under-range and indicates that the measurement results are below the lower limit of the Linear Operating Range – can only occur during a measurement

7) **Axis:** Direction of measurement.

8) **Screen:** The central part of the screen displays results for the selected parameters (see Chapter 4).

9) **Measurement parameter field:** The following parameters can be toggled during measurement:

   - *Current RMS & MTVV* and *Total RMS & Peak* for hand-arm measurements
   - *Current RMS & MTVV*, *Total RMS & Peak*, and *Total VDV &* $VDV(8)_k$ for whole-body and building vibration measurements, in any of the selected units
   - When measuring SEAT, an additional page is displayed. The additional page shows the *Total RMS* and $VDV(8)_k$ for the auxiliary channel and the seat pad's Z-direction as well as the *SEAT* value

3.9 Control the Measurement Process

3.9.1 Start Measurements

To start a measurement, from the **Main** menu select **Measure** using / and confirm by pressing .

Note: In cases where you have changed the weighting filter or transducer type before measurement, the filters will need a few seconds to settle. After that, the measurement starts and the real-time display changes to elapsed time.

3.9.2 Follow the Measurement Process on the Display

During measurement or while measurement is running, using /, scroll through the display and observe the different measurement parameters. The displayed parameters will depend on the type of weighting selected, either *Hand-arm*, or *Whole-body* and the selection of transducer, *Triaxial* or *Single axis*. *VDV* and $VDV(8)_k$ are only available for *Whole-body* weighting.

Note: All the measured *RMS*, *MTVV* and *VDV* values for the different axes are displayed and stored **without** multiplication by the k-factors. In *VTV*, *A(1)*, *A(4)*, *A(8)* and $VDV(8)_k$, the different axes are multiplied with their respective k-factors. For more details on k-factors (see Chapter 2).

3.9.3 Pause Measurements

Any measurement can be paused at any time. To pause a measurement press . The *Elapsed Time* indication stops, and the results can be viewed by scrolling the display. Press again to continue the measurement, or press for 3 seconds to stop the measurement.

3.9.4 Stop Measurements

Stop the measurement by pressing for 3 seconds. When a measurement is stopped, two options are available:

- Press to save the results
- Press to discard the measurement

Note: Logged data will always be kept regardless of whether you press or .

3.9.5 Restart Measurements

A measurement (either hand-arm or whole-body) can be restarted at any time; it is not necessary to halt the measurement. To restart a measurement, press twice within 1 second. Measured values on the display are reset to 0.000 and time will be set to 00:00:00. If an *Overload* indication is present, it will be reset as well. A new measurement starts immediately after reset has completed. There is no delay.

Note: When carrying out logging measurements, restart is not possible.

3.10 Manage Measurement Data

All saved measurements are available at any time to be recalled and displayed or transferred to a PC for further calculation and reporting. Each measurement is identified by a unique number and the date and time when it was saved.

Note: Only total measurement data can be recalled or displayed on Type 4447's screen. To view logged data, the data first need to be transferred to a PC.

3.10.1 Recalling Results from Memory

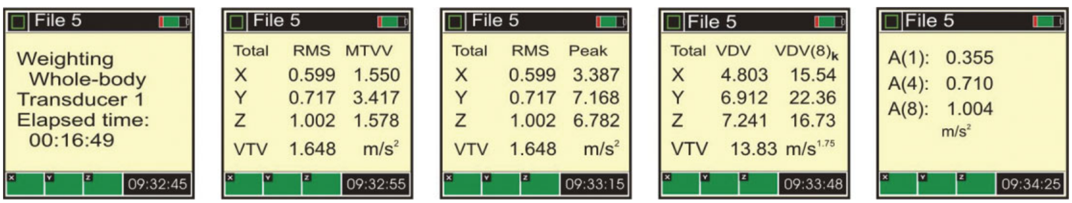
To recall saved results from memory:

1) From the **Main** menu, select **File manager**, then **Recall saved**.
2) A list of measurements currently stored on Type 4447 will be displayed. The measurements are identified by a number, date and time (see Fig. 3.18).
3) Use / to select the measurement to recall and press to select it.

Fig. 3.18
File Manager, Recall Saved

The information available for display depends on the application. As an example for whole-body measurements, five different displays of the results are available as shown in Fig. 3.19.

Fig. 3.19 *File Manager, Recall Saved (with whole-body measurements)*



When recalling the results, *A(1)*, *A(4)*, *A(8)* will also be available. They represent/indicate the daily vibration exposure values for a 1-, 4- and 8-hour exposure to vibration. Thus, *A(4)* equals *A(8)* multiplied by the square root of *4 h/8 h*. *A(1)* equals *A(8)* multiplied by the square root of *1 h/8 h*. *In hand-arm results*, *A(n)* equals the *Total RMS VTV*. In *whole-body results*, *A(n)* equals the maximum of the three axes, *Total RMS* multiplied by their respective k-factors.

Note: All the measured *RMS*, *MTVV*, *Peak* and *VDV* values for the different axes are displayed and stored without multiplication by the k-factors. In *VTV*, *A(8)*, *A(4)*, *A(1)* and $VDV(8)_k$, the different axes are multiplied with their respective k-factors.

3.10.2 Erase Data from Memory

To erase measurements and logging data from memory:

1) From the **Main** menu, select **File manager** then *Erase all*.

   Note: Type 4447 does not support the deletion of individual files, so this action will remove all stored measurements and logging data at once.

2) If you are sure that you want all files to be removed confirm this by pressing .

3.11 Hardware, Firmware Information and Upgrade

To display information about the instrument's serial number, hardware and firmware, from the **Main** menu, select **Setup** then **About...** to view the following information:

- Hardware version – **HW**
- Firmware version – **FW**
- Serial number – **Serial no.**

Upgrading the firmware is done using the PC software, Vibration Explorer, which accompanies Type 4447. For more information refer to Chapter 5.

Chapter 4

Measuring with Type 4447

Prior to any measurement, check the following setup parameters; they are critical for a correct measurement and its results:

- Transducer selection (**Transducer**): *Triaxial, Single axis or 3+1 axes*
- Weighting filter for the measurement (**Weighting**): *Hand-arm, Whole-body or its Band-limiting versions*
- Logging (**Logging**): *enabled or disabled*
- Front-end configuration (**Transd. power**): *CCLD ON/OFF*
- The selected transducer and its calibration (**Calibration**)

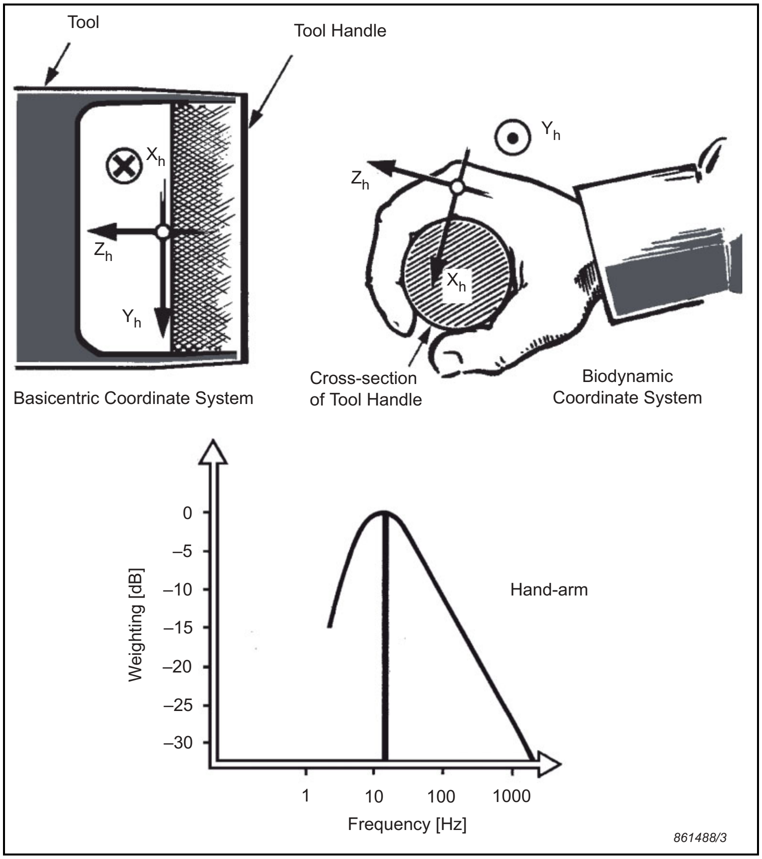
Note: it is not possible to measure with Type 4447 while it is connected to a PC. Note also that it is not recommended to use the external power supply (Charger ZG-0459) while making measurements as it may introduce noise.

4.1 Making hand-arm Measurements

Please refer to ISO 5349–2:2001 before making hand-arm measurements. Information is also contained in ISO 20643:2004, Mechanical vibration, Hand-held or hand-guided machinery, Principles for evaluation of vibration emission. Specific additional information can be found in the ISO 8662 series (to be replaced by the ISO 28927 series) and EN 60745 series (also see Chapter 2).

When making hand-arm measurements, the accelerometer must be positioned on the interface between hand and handle surface, and as close as possible to the centre of the grip area, see Fig. 4.2. Please refer to ISO 5349–2:2001 for a number of suggestions concerning where to mount the accelerometer on a particular tool, hand-grip or machine.

Fig.4.1
Principle measurement location and axis orientation for hand-arm measurements



4.1.1 Steps to Make a Hand-arm Measurement with Type 4447

To make a hand-arm measurement with Type 4447:

1) Turn on the instrument by pressing [✓] for at least 3 seconds.
2) From the **Main** menu, select **Setup**, **Transducer** and then *Triaxial* using [▲]/[▼]. Confirm the selection by pressing [✓].
3) Choose the most suitable accelerometer for the measurement and connect it to Type 4447, see Section 3.4.1:
   - If the chosen accelerometer is already calibrated, make sure it is activated. Select **Calibration**, **Select Transducer** and then the desired transducer using [▲]/[▼]. Confirm the selection by pressing [✓].
   - If you need to calibrate the accelerometer follow the steps in Section 3.5.
4) From the **Main** menu, select **Setup**, **Weighting** and then *Hand-arm* using [▲]/[▼]. Confirm the selection by pressing [✓].
5) Exit to **Setup** by pressing [✕].

6) Mount the transducer on one of the hand-arm measurement adaptors that follow with Type 4447. An overview of the adapters and a description of the situations in which each should be used is given later in this section.

7) Position the adaptor as close as possible to the normal hand grip position used when operating the tool. Please refer to ISO 5349–2:2001.

8) Route the transducer cable away from potential hazards by strapping it to the operator’s arm with the supplied VELCRO® brand strap, DG-0517.

9) Ask the person to be evaluated to start operation of the tool. If the Hand or Handle Adaptor is used, the operator has to hold the adaptor against the surface of the tool with a firm, constant grip.

10) Using /, select **Measurements** in the **Main** menu and press to start the measurement.

    If you changed the weighting before starting the measurement, it may take a few seconds for any new filters to apply; otherwise, the measurement will start immediately.

11) While a hand-arm measurement is in progress, *Curr RMS, MTVV, Total RMS* and *Peak* value for X-, Y- and Z-directions can be monitored:
    - In the first measurement display (no action required), *Curr RMS* and *MTVV* are shown separately for the X-, Y- and Z-axes
    - In the second measurement display (press once to navigate to this display), the time-averaged weighted vibration acceleration value (denoted as *Total RMS*) and the *Peak* value for the X-, Y- and Z-directions are shown. In addition it shows *VTV* at the bottom of the screen. On this screen, *VTV* is the root sum of squares of *Total RMS* values for all three axes

    Note: When data are saved and recalled, the daily vibration exposure values $A(8)$, $A(4)$ and $A(1)$ are calculated.

12) To stop the measurement press for a few seconds. You will be prompted to save or discard the data. Press once more to save the measurement or to discard it.

Refer to Section 3.10.1 for how to recall the measurement on Type 4447. See Section 5.3.5 on how to transfer data for archiving and post-processing.

4.1.2 Adaptors for Hand-arm Measurements

Accelerometer mounting should be as rigid as possible. If mounted loosely, the accelerometer will bounce around[*] and the measured acceleration will not be that of the tool’s grip surface. To assist in achieving the correct mounting, Type 4447 comes with three different adapters:

1) Cube Adaptor UA-3017 for direct mounting on a surface located at the handle/grip position (where there is enough space), see Fig. 4.2, left.

2) Hand Adaptor UA-3015 for holding between two fingers with the base plate in contact with the tool surface (where direct mounting is not possible), see Fig. 4.2, middle.

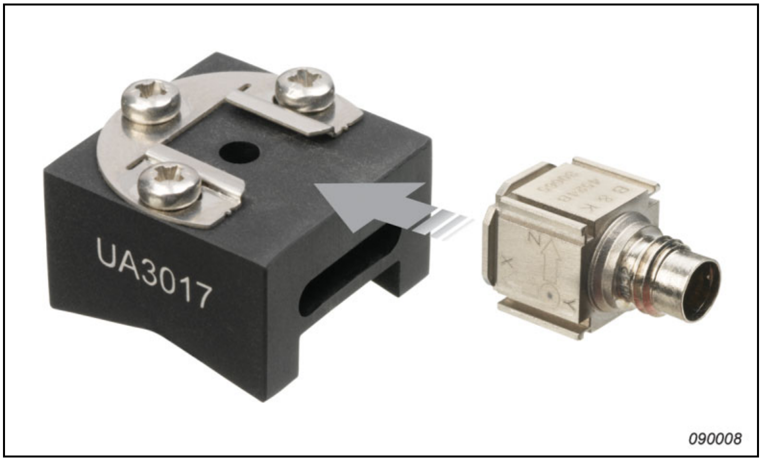
[*] Even though not visible to the naked eye, loose mounting can give erroneous results.

3) Handle Adaptor UA-3016 for placing on the tool handle where the hand grips the tool (where direct mounting is not possible), see Fig. 4.2, right.

Fig. 4.2 *The adaptors used with Type 4447*

Each adaptor has a clip on the top of the head where the transducer is mounted, see Fig. 4.3.

Fig. 4.3
Mounting the transducer in the clip on the adaptor



For hand-arm measurements to determine the VTV, orientation of the transducer is not important because all axes have the same weighting. However, because the vibration values in each orthogonal axis may be important, it is therefore always good practice to correctly orient the transducer.

If space allows, use Cube Adaptor UA-3017 and fix it to the handle or the vibration source. If there is no space for direct mounting, use Hand Adaptor UA-3015, or Handle Adaptor UA-3016. Examples of using the adaptors are shown in Fig. 4.4. Additional examples of accelerometer mounting locations are described in ISO 5349–2:2001, Annex A. For detailed guidance on attaching the transducer to different hand tools or work pieces, refer to ISO 5349.2:2001.

Fig.4.4
Examples of Cube Adaptor, Hand Adaptor and Handle Adaptor

When mounting the accelerometer in the adaptors you need to loosen the screws a little with the screwdriver, then place the accelerometer in the slide and fasten the screws again (see Fig.4.5).

Fig.4.5
Mounting accelerometer in adaptor

4.2 Whole-body measurements

Please refer to ISO 2631–1:1997 before making whole-body measurements. According to the international standard ISO 2631–1:1997, vibration is measured along three orthogonal directions defined relative to the surface at which the vibration comes into contact with the human body, see Fig. 4.6.

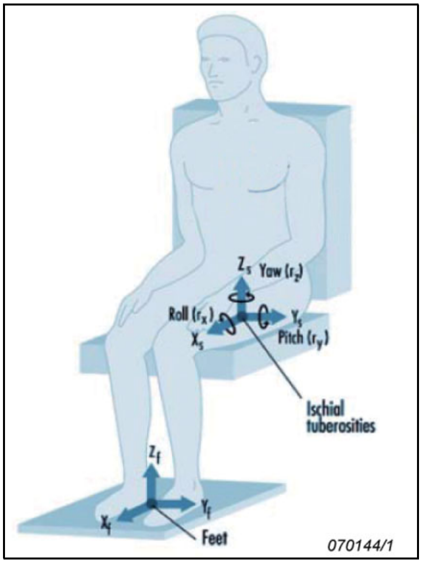


Fig. 4.6
Biodynamic coordinate system with axes relative to the body

The accelerometer should be placed in a Seat Pad that is preferably fixed to the floor or seat using tape or a strap. This ensures that the transducer remains at the desired position, withstanding position changes of the driver or operator. However, for correct results, the Seat Pad must be loaded by the worker during the measurement. The worker should stand or sit on the pad, as appropriate, see Fig. 4.7.

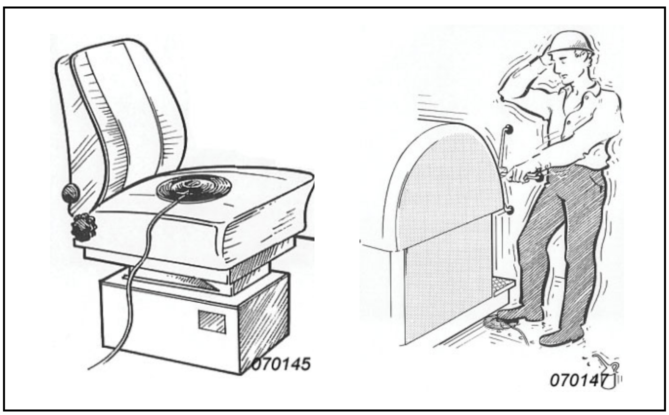


Fig. 4.7
Different Seat Pad locations

4.2.1 Measurement of Whole-body Vibration Using Type 4447

To make a whole-body vibration measurement:

1) Turn on the instrument by pressing for at least 3 seconds.
2) From the **Main** menu, select **Setup**, **Transducer** and then *Triaxial* using /. Confirm the selection by pressing .
3) Exit to **Setup** by pressing .
4) Connect the Seat Pad to Type 4447, see Section 3.4.1:
   – If the chosen accelerometer is already calibrated, make sure it is activated. Select **Calibration**, **Select Transducer** and then the desired transducer using /. Confirm the selection by pressing .
   – If you need to calibrate the accelerometer follow the steps in Section 3.5.
5) From the **Main** menu, select **Setup**, **Weighting** and then *Whole body* using /. Confirm the selection by pressing .
6) Exit to **Setup** by pressing .
7) Position the Seat Pad:
   a) Place the Seat Pad adaptor on the seat or floor where the measurement is to be made.
   b) Position the Seat Pad adaptor in such a way that the transducer is positioned to follow the biodynamic coordinate directions ('X' is back to chest, 'Y' is right to left and 'Z' is from foot (or buttocks) to head.
   c) Tape the Seat Pad adaptor in place such that it is beneath the ischial tuberosities of the pelvis or under the foot.
8) Ask the person to be evaluated to sit down on or stand on the Seat Pad adaptor.
9) Using /, select **Measurements** from the **Main** menu and press to start the measurement. If you changed the weighting shortly before starting the measurement, Type 4447 may first need to wait a few seconds for any new filters to apply. Otherwise the measurement will start immediately.
10) While a whole-body measurement is in progress, *Curr RMS*, *MTVV*, *Total RMS*, the *Peak* value, *Total VDV* and $VDV(8)_k$ for X-, Y- and Z-directions can be monitored. In addition the *Vibration Total Value* (*VTV*) is displayed:
    - In the first measurement display (no action required), *Curr RMS* and *MTVV* are shown separately for the X-, Y- and Z-axes
    - In the second measurement display (press once to navigate to this display), the time-averaged weighted vibration acceleration value (denoted as *Total RMS*) and the *Peak* value for the X-, Y- and Z-directions are shown. In addition it shows *VTV* at the bottom of the screen. On this screen, *VTV* is the root sum of squares of *Total RMS* values for all three axes

- In the third measurement display (press once more (for a total of twice) to navigate to this display), *Total VDV* and *VDV(8)*$_k$ are shown together with the *VTV*, which on this display is the root sum of squares of the *Total VDV* values for all three axes

Note 1: When data are saved and recalled, *A*(8), *A*(4) and *A*(1) are calculated.

Note 2: Recalled data for whole-body measurements differ from hand-arm in the segment where *A*(8), *A*(4) and *A*(1) are calculated. When evaluating whole-body measurements the whole-body vibration magnitude is first calculated for each axis separately, multiplying each axis' RMS value with the corresponding k-factor, see Chapter 2. The highest out of the three orthogonal directions is then used to calculate the *A*(8) parameter. In contrast, when evaluating hand-arm measurements *A*(8) is calculated based on the *Vibration Total Value*.

11) To stop the measurement press for a few seconds. You will be prompted to save or discard the data. Press once more to save the measurement or to discard it.

Refer to Section 3.10.1 for how to recall the measurement on Type 4447. See Section 5.3.5 on how to transfer data for archiving and post-processing.

4.3 SEAT-factor Measurements

SEAT-factor measurements with Type 4447 are intended for broad-band laboratory and field assessment of vibration transmission through vehicle seats to the occupant. The result of such a measurement will give an overall evaluation of whether or not the seat helps attenuate the vibrations.

Mounting accelerometers on the seat and on the vehicle floor should follow the definitions in ISO 10326-1. One transducer shall be located on the platform at the place of the vibration transmission to the seat. The other accelerometer shall be mounted in a seat pad and located at the interface between the human body and the seat on the seat pan, see Fig. 4.8.

Note: Type 4447 is only set up to evaluate SEAT in the vertical direction; i.e., it compares the vertical vibration at the floor with vibrations along the Z-axis of the Seat Pad.

SEAT-factor measurements belong in the category of whole-body measurements. Therefore, in Type 4447, whole-body weighting (W_d for X and Y, and W_k for Z and the Auxiliary) is applied when carrying out SEAT measurements. In addition to the results of the SEAT factor measurements, Type 4447 will also save data from the Seat Pad. Those data can be used to evaluate human exposure to whole-body vibration. Thus two measurements can be taken in one run.

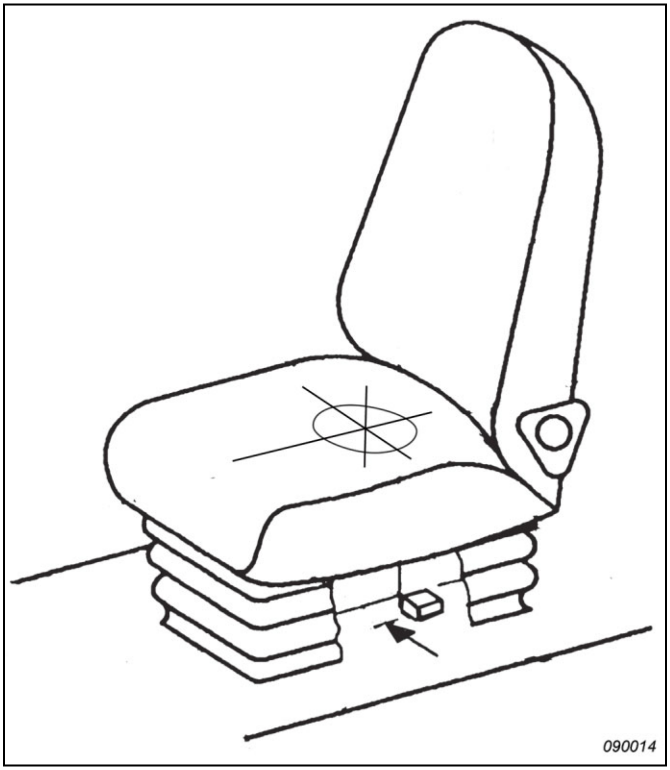


Fig.4.8
Mounting locations for seat pad and auxiliary accelerometer when measuring SEAT factor

4.3.1 SEAT-factor Measurement Using Type 4447

To measure the SEAT factor:

1) Turn on the instrument by pressing for at least 3 seconds.
2) From the **Main** menu, select **Setup**, **Transducer** and then *3+1* axes using /. Confirm the selection by pressing .
3) Exit to **Setup** by pressing .
4) Connect the Seat Pad to Type 4447 through the four-pin-socket and the single-axis accelerometer through the two-pin-socket, see Section 3.4.1.
   - If the chosen accelerometers are already calibrated, make sure they are activated. Select **Calibration**, **Select Transducer** and then the desired transducer using / . Confirm the selection by pressing
   - If you need to calibrate the accelerometers follow the steps in Section 3.5

5) Position the Seat Pad and auxiliary accelerometer:
   a) Place the Seat Pad adaptor on the seat, position the Seat Pad adaptor in such a way that the transducer is positioned to follow the biodynamic coordinate directions ('X' is back to chest, 'Y' is right to left and 'Z' is from buttocks to head) and tape the Seat Pad adaptor in place such that it is beneath the ischial tuberosities of the pelvis.
   b) Place the auxiliary accelerometer on the floor where the measurement is to be made.
6) Ask the person to be evaluated to sit down on the Seat Pad adaptor.
7) Using ▲/▼, select **Measurements** from the **Main** menu and press ✓ to start the measurement. If you changed the weighting shortly before starting the measurement, Type 4447 may first need to wait a few seconds for any new filters to apply. Otherwise the measurement will start immediately.
8) While a SEAT factor measurement is in progress, *Curr RMS*, *MTVV, Total RMS*, the *Peak* value, *Total VDV* and a $VDV(8)_k$ for X-, Y- and Z-directions of the Seat Pad accelerometer. In addition *VTV* is displayed for the Seat Pad. The first three screens display information for the seat pad. Display number four shows *Total RMS* and *VDV* for the Seat Pad's Z-axis, AUX-axis and the resulting SEAT factors.

   Note: When data are saved and recalled, *A*(8), *A*(4) and *A*(1) are calculated.
9) To stop the measurement press ✓ for a few seconds. You will be prompted to save or discard the data. Press ✓ once more to save the measurement or ✕ to discard it.

Refer to Section 3.10.1 for how to recall the measurement on Type 4447. See Section 5.3.5 on how to transfer data for archiving and post-processing.

4.3.2 Mounting Accelerometers

For seat mounting, place the Seat Pad on the surface of the seat pan and tape or strap it to the cushion in such a way that the accelerometer is located midway between the ischial tuberosities of the seat occupant. See also Section 4.2 on how to properly mount the Seat Pad onto the seat.

For floor mounting, place the accelerometer on the floor within a 200 mm diameter circle, centred directly below the seat accelerometer, measured perpendicularly to the floor, see Fig. 4.8. The accelerometer is best mounted on a rigid part of the floor using glue, a strong magnet or double-sided, thin adhesive tape (EN 14253–2004 suggests a force of at least 1 kN).

4.4 Logging Measurements

Measurements can also be carried out as a logging measurement, see Section 3.7. Also SEAT measurements can be done with logging activated. However, only the vibrations sensed with the Seat Pad will be logged, not the AUX channel; i.e., the SEAT measurement itself will not be logged.

Logging data (*RMS*, *VDV*, *MTVV* and *Peak*) will be performed with a 1 s interval and carried out in addition to the standard measurement. This means that when logging is activated, Type 4447 will create two files: one with the standard total measurement and the other with logging data. To make a measurement with logging:

1) Set up Type 4447 for the measurement following the procedures in Section 4.1, Section 4.2 or Section 4.3, respectively, but do not start the measurement yet.
2) From the **Main** menu, select **Setup** then **Logging** to enter the logging setup screen. Note the available logging time in hours and minutes at the bottom of the display, and make sure that there is enough logging capacity for the planned task before starting the measurement.
3) Using /, select *Enabled*. Confirm the selection by pressing .
4) Exit to the **Main** menu by pressing .
5) From the **Main** menu, select **Measurements** and press to begin the measurement.

Note 1: While logging, a red circle will be displayed in the upper left corner of the display. Should Type 4447 run out of logging memory while measuring, the instrument will stop the measurement.

Note 2: It is not possible to reset Type 4447 while carrying out a logging measurement. Instead, stop the measurement and start it from the beginning.

Chapter 5

Post-Processing with Vibration Explorer Software

Vibration Explorer Software BZ-5623, included with Type 4447, enables the transfer of results to a PC and subsequent data manipulation.

5.1 System Requirements

The system requirements for Vibration Explorer Software BZ-5623 are as follows:

- Recommended PC:
  - Pentium® III (or equivalent) processor
  - 256 MB RAM
  - SVGA graphics display/adaptor
  - CD ROM drive
  - mouse
  - USB 2.0
- Operating System:
  - Windows® XP (preferably with the latest Service Pack)
  - Internet Explorer 5 or higher

Note: The PC should have at least one available USB 2.0 port. A power surge error may occur if used through a USB hub. Type 4447 should be connected directly to a USB 2.0 port on the PC.

5.2 Vibration Explorer Installation

On the supplied CD you will find:

- 4447 Vibration Explorer Software (PC software)
- Type 4447 Instrument software (the driver and firmware)
- Guide to good practice on hand-arm vibration
- Guide to good practice on whole-body vibration

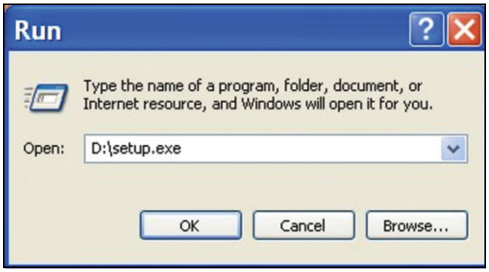
5.2.1 Vibration Explorer Software Installation

Note: To install/uninstall, you must be logged on the PC as an administrator.

1) If there is a previous version of Vibration Explorer installed on your PC:
   a) Press **Start, Control Panel** and then **Add or Remove Programs**.
   b) Select the 4447 Vibration Explorer listing and then click the **Remove** button.
2) Insert the CD into your CD-ROM drive, and installation should begin automatically.

   If it does not start automatically:
   a) Click **Start** and then **Run**. The dialogue box in Fig. 5.1 will be displayed.
   b) Click **Browse**... and select the drive in which the Installation CD is loaded.
   c) From the file list, select *Setup.exe* and click **OK** to run the file.

Fig. 5.1
Run dialogue



3) Installation will start, and you will be asked for confirmation at different stages of the installation progress.

   Note: Though most of the screenshots shown in this manual are from Windows® Vista, the wizard that guides you through installation is similar regardless of the operating system (Windows® XP, Windows Vista and Windows® 2000). Differences mainly relate to graphical appearance of the installation wizard. In cases where differences have an influence on the installation procedure, it is mentioned and explained if relevant.
4) When you install 4447 Vibration Explorer for the first time you may be asked to install Windows® Installer 3.1. In this case, the dialogue in Fig. 5.2 may appear.

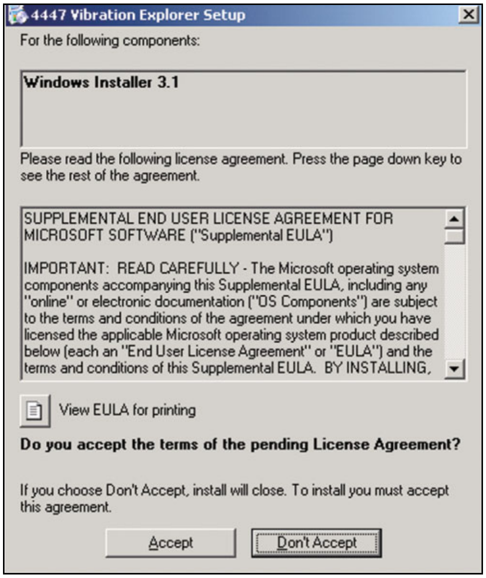


Fig. 5.2
License agreement dialogue

Note: Windows® Installer 3.1 is a programme requested by Microsoft® and is not related to 4447 Vibration Explorer as such. It needs to be installed only once. You must accept the terms of pending License Agreement in order to continue the installation.

a) Click **Accept**.
b) Once it has been installed, you must restart the PC.
c) After restarting, repeat steps 2a) through 2c).

For more information on Windows® Installer 3.1, visit www.microsoft.com.

5) The installation wizard will then start (see Fig. 5.3).

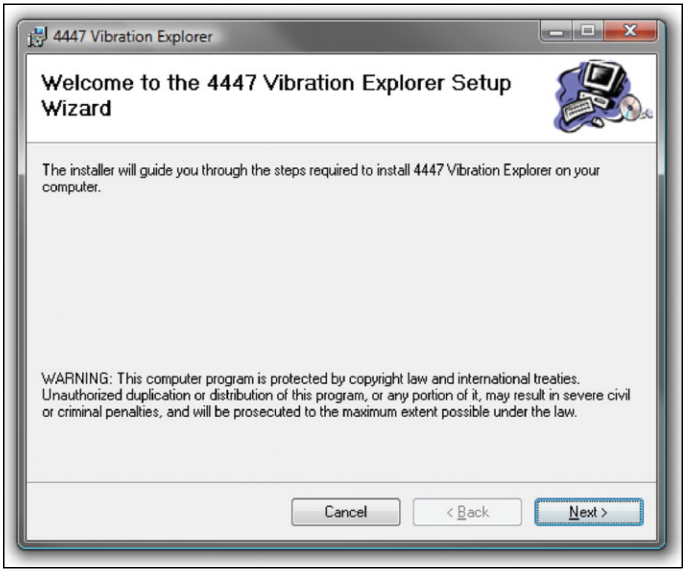


Fig. 5.3
4447 Vibration Explorer Setup wizard

6) Select the installation destination of the Vibration Explorer software on your PC. The default destination is suggested as shown in Fig. 5.4.

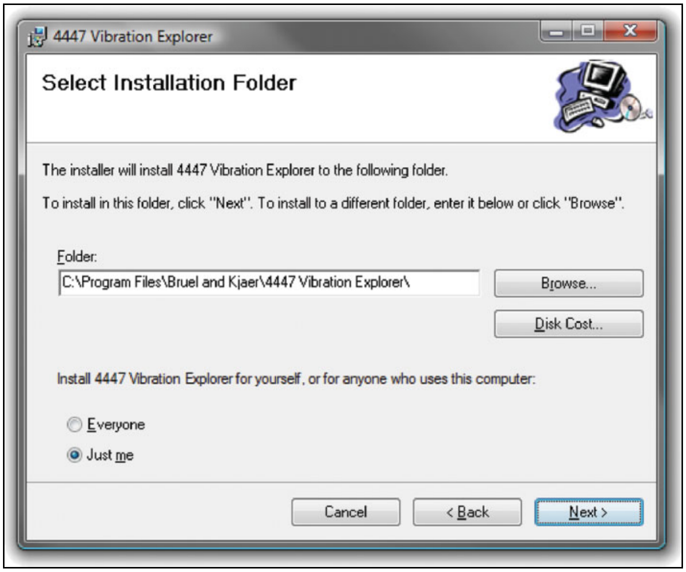


Fig. 5.4
Select the destination on your PC

7) Click **Next** when your selection is made and **Next** again to confirm the selection. Installation of Vibration Explorer will then begin.

8) If a warning about an unknown driver/device pops up (see example in Fig. 5.5), click *Install this driver software anyway*, as the Vibration Explorer software is both trusted and its driver is from a known source.

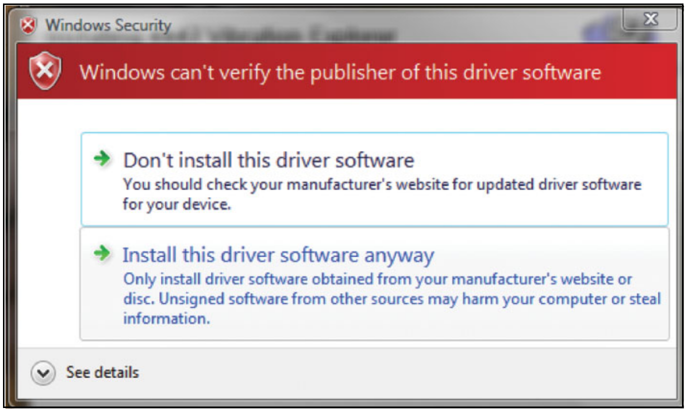


Fig. 5.5
Possible security warning about the software driver

9) Click **Close** to complete the installation of Vibration Explorer (see Fig. 5.6).

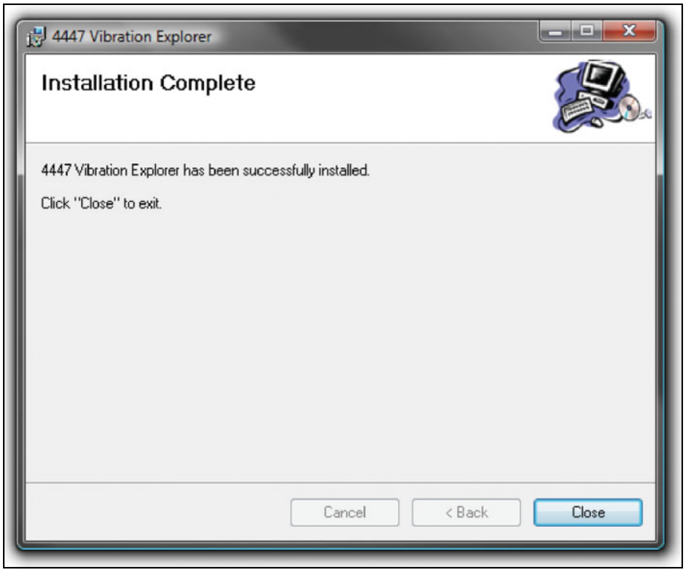


Fig. 5.6
Close the wizard

The computer is now ready to install the driver and be connected to Type 4447.

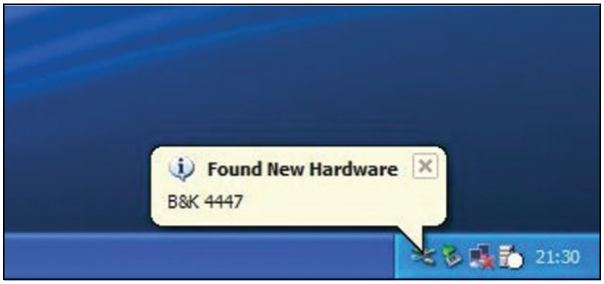
5.2.2 Type 4447 Driver Installation

When software BZ-5623 (4447 Vibration Explorer) is installed, you should establish communication between the PC and Type 4447 analyzer.

To install Type 4447's driver on a PC:

1) Turn on the analyzer by pressing  for 3 seconds, and then connect the supplied Cable, AO-1476, to the mini-USB connector on the side of Type 4447 and a USB socket on the PC. After a short while, a 'new device' will be detected by your PC (see Fig. 5.7).

Fig. 5.7
Example of new device detection alert



2) Depending on your operating system, either a wizard will be activated and 4447 Vibration Explorer's driver will be automatically detected (Windows® XP and Windows® Vista) or you will need to manually install the driver (Windows® 2000).

   Windows® XP and Windows® Vista:

   a) In the Found New Hardware wizard's welcome page, you have the option of using Windows® Update to detect updated software. Select *No, not this time* and click **Next**.

   b) If the Installation CD is not already loaded, insert it into your CD-ROM drive and ensure that *Install the software automatically (Recommended)* is selected, and click **Next**. The wizard will select and copy the appropriate driver.

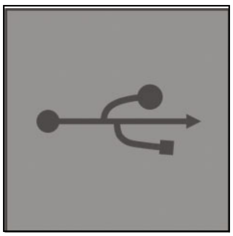
   c) There may be a warning dialogue (see Fig. 5.8) stating that the driver has not passed Windows® Logo testing. Select **Continue Anyway**.

Fig. 5.8
Example of warning. You can ignore this

d) In the final window of the wizard, click **Finish**. Type 4447's driver will now be fully installed, and the analyzer is now ready to interface with the PC.

e) Once the communication between analyzer and PC have been established, the analyzer's display will show a USB icon (see Fig. 5.9), indicating that it is still connected to the PC and no commands from the Type 4447 pushbuttons can be accepted. After disconnecting analyzer from the PC, the pushbuttons become active again and the Type 4447 display returns to the **Main** menu.

Fig. 5.9
Type 4447's display while connected to PC



Windows® 2000:

a) The Found New Hardware wizard initiates, and you are prompted to specify the path where the *dwusb.sys* driver software file is located.

b) Click **Browse** and find the driver file under *C:\Program Files\BRUEL AND KJAER\4447 Vibration Explorer\HBVDrv* (default location).

c) Run *dwusb.sys* and follow the wizard.

d) In the final window of the wizard, click **Finish**. Type 4447's driver will now be fully installed, and the analyzer is now ready to interface with the PC.

e) Once the communication between analyzer and PC have been established, the analyzer's display will show a USB icon (see Fig. 5.9), indicating that it is still connected to the PC and no commands from the Type 4447 pushbuttons can be accepted. After disconnecting analyzer from the PC, the pushbuttons become active again and the Type 4447 display returns to the **Main** menu.

Once installed, Type 4447 will not appear as a mass storage or other USB device in explorer or on the Windows® task bar; therefore, before unplugging Type 4447, it is not necessary to tell Windows® that you want to remove the device. However, always allow a few seconds between plugging in and unplugging or vice versa; otherwise, the system may become unstable.

Note: While connected to the PC you cannot use Type 4447 to carry out measurements. To reactivate the analyzer's measurement capabilities, disconnect it from the PC.

You are now ready to use Type 4447 together with Vibration Explorer Software.

5.3 Working with Vibration Explorer Software

5.3.1 Vibration Explorer Software Project Concept

In Vibration Explorer you work with projects. A project consists of two main parts:

1) A **collection of raw measurement data**. The data can be directly imported from Type 4447 or taken from already existing project files. Raw data can be total measurements or logged data. Total measurements only contain a set of data per axis for the entire elapsed measurement time. In contrast, logged data provide a history of the measured vibration event in 1 s intervals. For each second the RMS, VDV, MTVV and Peak value are stored for each axis.

2) A **model for the daily vibration exposure of workers**. In this part of the project the measurement data are combined and exposure durations are assigned, based on which Vibration Explorer will determine the daily exposure and indicate whether this exceeds the action or limit values given by legislation.

In addition to the vibration data you can add further information such as notes, images of workers, organisations, and tools or machinery. Everything will be stored in the project file.

Note: Pictures added through the properties dialogue will be saved with the project file, which means if you later delete the image on disc it will still be available in the project.

An important concept of the exposure calculation in Vibration Explorer is that it lets you focus on the person and the working day, instead of the 'standard'. Standards are written for hand-arm or whole-body vibrations; i.e., standards split the problem. Daily life is not so segregated.

For example, the operation of driving a fork lift can expose the driver to whole-body and hand-arm vibrations. To get the full picture, you may want to measure the vibrations at the steering wheel, at the feet, and seat pan as well as the seat's effective amplitude transmissibility (SEAT) for a specific vehicle and worker. With Type 4447 you can take all these measurements and import them into the same project, create a node in the project for the worker and drag all data that relate to the person's work into it. When calculating exposure and combining the fork lift operation with other processes, Vibration Explorer will keep track of which measurement data it will add to the hand-arm or whole-body exposure of the particular person. SEAT measurements would not directly contribute to the exposure calculation; however, since each

SEAT measurement also records data on the exposure (based on data from the Seat Pad), you may directly use this portion of the data, and it may be important to keep the data together with that particular worker.

Note: Type 4447 also offers all weighting filters in band-limiting form only (see Chapter 3). These filters have the same cut-off frequencies as the whole-body, hand-arm and building vibration weightings, respectively. However, within the pass band, no further weighting is applied; i.e., within the pass band, the filters have a flat response. Broadband measurements of this type are provided for your convenience. Vibration Explorer will permit the use of band-limited data for exposure calculations; however, to remind you that the filters differ from the standard types throughout, the user interface data from band-limited measurements will be clearly marked with a yellow background.

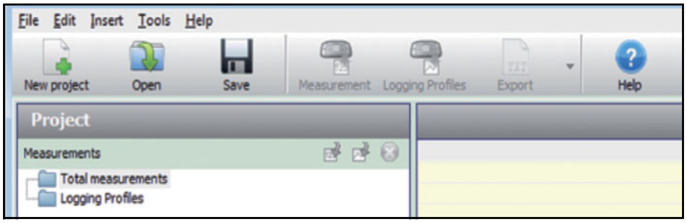
5.3.2 Starting Vibration Explorer

To start Vibration Explorer either:

- Double click the Vibration Explorer icon on the desktop
- From the **Start** menu select **Start, Programs, Brüel & Kjær Applications, 4447 Vibration Explorer,** and then **4447 Vibration Explorer X.X** (where 'X' is the installed version)

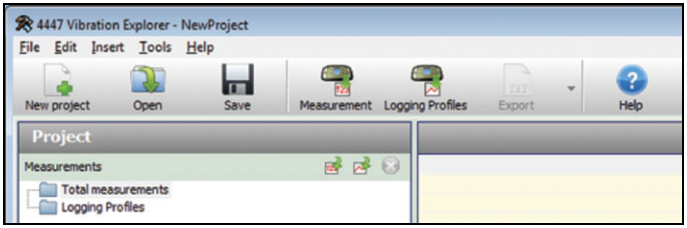
Vibration Explorer will open and create a new empty project, ready to receive data from Type 4447. If you started Vibration Explorer without having Type 4447 connected, buttons and menu commands that would trigger data transfer from Type 4447 or maintenance actions will be disabled, see Fig. 5.10.

Fig. 5.10
4447 Vibration Explorer interface with Type 4447 not yet connected



If Type 4447 is connected, the buttons and menus will be active, see Fig. 5.11. This indicates that connection to Type 4447 is established and you can begin transferring data from the instrument, update the firmware or change settings such as date and time.

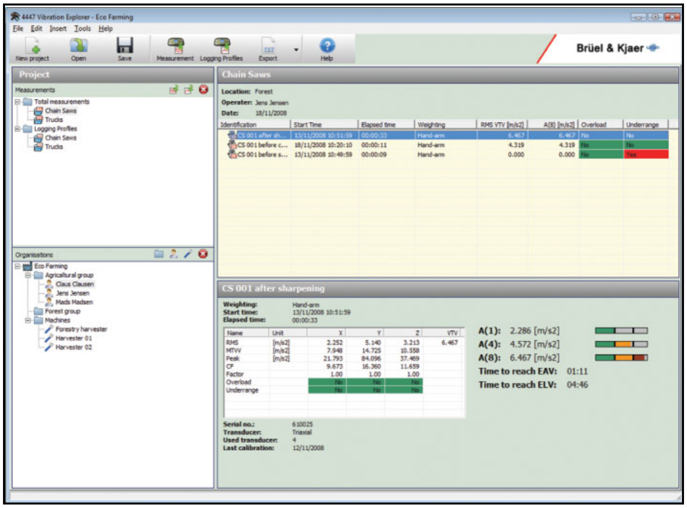
Fig. 5.11
Vibration Explorer with activated buttons



5.3.3 Vibration Explorer Interface

Fig. 5.12 depicts the Vibration Explorer interface showing data in measurement groups and their properties.

Fig. 5.12
Vibration Explorer with a typical project open



The application's interface is divided into two main sections:

1) **The Project section:** On the left side a tree-like, hierarchical view presents you with and lets you organise measurement data in the project and the organisation model.
2) **The Workspace:** The remaining part of the window on the right is where you view and edit data selected under **Project**.

Under **Project**, there are two subsections (quadrants):

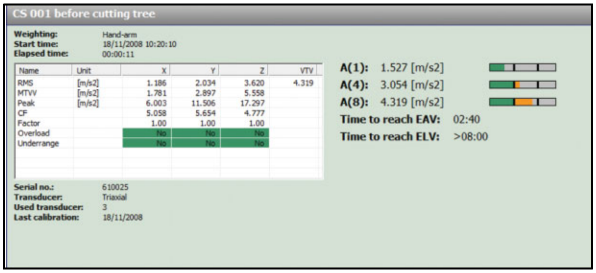
- **Measurements,** in the upper left quadrant of the interface, is where groups of measurements and logging profiles imported from Type 4447 are listed. Clicking on a *Total Measurements* or *Logging Profiles* group will show its contents in the workspace (upper right quadrant of the interface)
- **Organisations,** in the lower left quadrant, is where you organise data to determine the exposure of workers to hand-arm and/or whole-body vibration. You can structure your data by adding *Folders*, *Persons* and *Working Points* to this area. Once a *Folder*, *Person* or *Working Point* has been defined, measurements can be dragged and dropped into it. Further, *Working Points*, which provide a means to calculate the average over several measurements, can be dragged to a *Person*; i.e., they become part of the list of exposures. Clicking on a *Person* or *Working Point* icon will show its contents in the Workspace (upper right quadrant of the interface)

The **Workspace** is split into the following two parts:

1) In the upper quadrant a table is shown, listing the contents of the current selection in the project or organisation, see Fig. 5.12.

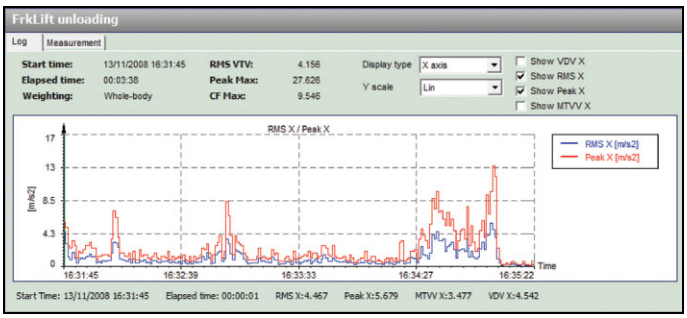
2) The lower quadrant displays more detailed information for the item selected in the upper quadrant. For total measurements a table is shown, providing detailed information for each axis, see Fig. 5.13. In the case of logging measurements, an additional tab is provided, where you can view the logging profile, see Fig. 5.14. Finally, once a measurement has been added to a person another tab is added, where you can set the exposure time, see Fig. 5.15.

Fig. 5.13 *Measurement information tab*



The displayed exposure is calculated based on the measured RMS and VDV, assuming an 8 hour exposure. The colour scales to the right provide a quick visual feedback of the exposure magnitude and vibration risk.* They are based on $A(1)$, $A(4)$, $A(8)$ and $VDV(8)_k$. Once an exposure time is defined (person), they are based on $A(8)$, P_E and VDV for that time.

Fig. 5.14 *Logging profile tab – use it to view logging data and extract sections*



* For more information, see Section 5.3.7.

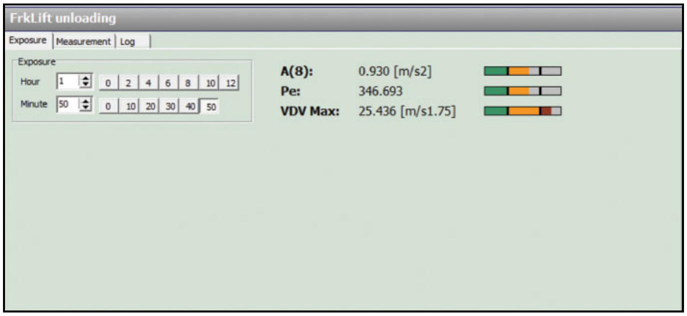


Fig. 5.15
The exposure tab – only shown when looking at a measurement inserted to a person

5.3.4 Creating, Opening and Saving Projects

Create New Projects

As already mentioned in Section 5.3.2, every time Vibration Explorer is started a new project is automatically created so that data from Type 4447 can be imported immediately.

However, you can create a new project at any time by selecting **File** then **New project** or clicking the **New Project** button on the toolbar (see Fig. 5.16).

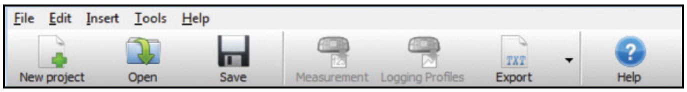


Fig. 5.16
Toolbar and file menu

Open Projects

Open existing projects by selecting **File** then **Open project** or clicking the **Open** button on the toolbar. Vibration Explorer will then display the Open project dialogue. Use the dialogue to navigate to the project, select it and click **OK**.

Since only one project can be open at a time, creating a new or opening another existing project will close the current one. If a project with unsaved data or changes is active, Vibration Explorer will show a dialogue asking whether changes should be saved before closing the project to open or create a new one.

Save Projects

You can save a project by selecting **File** then **Save project, File** then **Save project as …** or by clicking the **Save** pushbutton on the toolbar. The first time you save a project and whenever you choose **Save project as …** a dialogue will open, and you will be asked to specify a file name and choose a location for the project.

Close Projects

You may close the current project without quitting Vibration Explorer. Select **File** then **Close Project**. If you attempt to close a project and changes you made to the project have not been saved, Vibration Explorer will prompt you to do so.

5.3.5 Import and Manage Data

At any time, when a project is open, you can import data. Measurement data can be imported directly from Type 4447 or from another, already existing project on your hard drive.

Note: When making logging measurements on Type 4447, two files will be created: one containing the total result of the measurement and the other containing the logging profile. Once a measurement is saved on Type 4447, these two files exist independently from one another. Therefore, importing one – the total measurement or the logged data – will not automatically import the other; you must explicitly import both. After importing both, you can identify which measurement belongs to which logging profile by looking at their measurement start time (and date).

Import Total Measurements from Type 4447

There are four methods to import total measurements from Type 4447:

1) Click  on the toolbar.
2) Click the small button  in the **Project** section.
3) From the **Main** menu, select **Insert** then *New measurement group from instrument.*
4) Right click the **Measurements** node in the measurements sub-section of the Projects overview and choose *New measurement group from instrument.*

Any of these will import all measurements currently on your Type 4447 and place them in a new measurement group under 'Total Measurements'. Vibration Explorer will assign a default name to the new group. You change the name at any time by right-clicking it and selecting **Rename**.

Import Logging Profiles from Type 4447

There are four methods to import logged data from Type 4447:

1) Click  on the toolbar.
2) Click the small button  in the Project section.
3) From the **Main** menu, select **Insert** then *New log group from instrument*.
4) Right click the **Logging profiles** node in the measurements sub-section of the Projects overview and choose *New log group from instrument*.

This will import all logging profiles currently on Type 4447 and place them in a new logging group under 'Logging Profiles'. Vibration Explorer will assign a default name to the new group. You change the name at any time by right-clicking it and selecting *Rename*.

Import Data from Another Project File

You can import measurement and logging data from project files that already exist on your computer. To import measurement data from another project:

- From the **Main** menu, select **Insert** and then *Import measurement group(s) from file*, or
- Right click the *Total Measurements* node in the measurements sub-section of the Projects overview and choose *Import measurement group(s) from file*

To import logging data from another project:

- From the **Main** menu, select **Insert** and then *Import logging group(s) from file*, or
- Right click the *Logging Profiles* node in the measurements sub-section of the Projects overview and choose *Import logging group(s) from file*

A dialogue will be displayed from where you can choose the source file of the data to import. Once you selected a file and clicked **OK**, all measurement or logging groups in this file will be imported into the current project. The group name(s) from the source file will be used. As with new groups of measurement or logging data imported groups can be renamed.

Group Properties

To view and edit general information for a total measurement group or logging profile group:

1) In the project tree, right-click the group's icon or name.
2) From the subsequent menu, select *Properties*.
3) A dialogue appears, see Fig. 5.17. Most of the fields in this dialogue can be edited:
   - **Name** for the measurement group – it is also used as the group's label (i.e., it changes when you rename a group)
   - **Location** where the measurements were taken
   - **Operator** of the machine or vehicles during the measurement
   - **Date** to be associated with this group. The default date is the date when the group was created, not the date of the measurement because measurements in the same group can be taken periodically over several days
   - **Description** of the measurements

   Note: The *Serial no.* field is write-protected.
4) Press **Save** to keep changes made in this dialogue or **Cancel** to discard them.

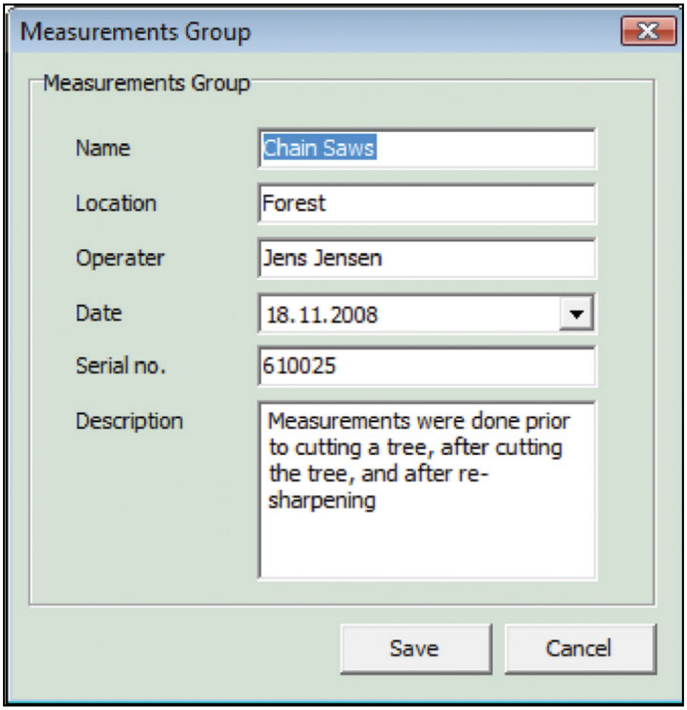


Fig. 5.17
Properties dialogue

Remove Data from Type 4447

After having imported measurements and logging profiles from Type 4447, the data will still be on the instrument. You need to remove them explicitly.

Note: It is not currently possible to remove selected measurements or logging profiles from Type 4447, they must be removed as a whole. However, using the PC software logging and measurements can be deleted independently of each other.

To remove all total measurements from the instrument and thus free memory on the instrument choose:

- **Tools** then *Erase all Measurements from Instrument* from the **Main** menu, or
- Right click the Total Measurements icon in the project organiser and select *Erase all Measurements from Instrument*

A dialogue will be displayed that will prompt you to confirm the action.

To remove all logging profiles from Type 4447, select:

- **Tools** then *Erase all Logs from Instrument* from the **Main** menu, or
- Right click the Logging Profiles icon in the project organiser and select *Erase all Logs from Instrument*

A dialogue will be displayed that will prompt you to confirm the action.

Remove Measurement or Logging Groups from a Project

To remove a measurement or logging group from the project, select it in the project section and:

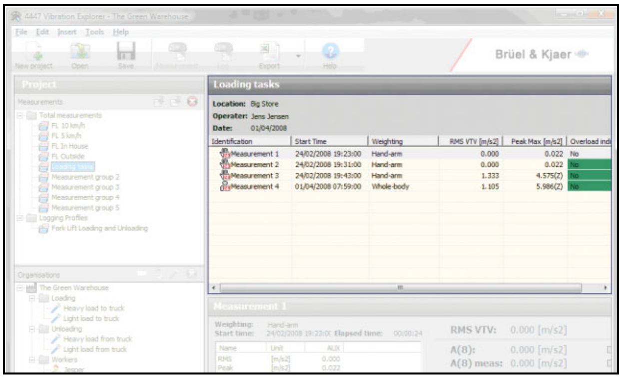
- Press the **Delete** button , or
- From the **Main** menu choose **Edit** and then *Delete*, or
- Right click the icon or label and, from the subsequent list, select *Delete*

A dialogue will be displayed that will prompt you to confirm the action.

5.3.6 Work with Data in Measurement and Logging Groups

Each *total measurement* and/or *logging profile* group contains one or several measurements or logging profiles, respectively. To expand the measurements or logging profiles group into a full list, select it in the project tree. Its content is then shown in a table in the upper quadrant of the workspace (see Fig. 5.18). The title bar of the quadrant shows the name of the selected project node, which can be the name of a *Measurement or Logging Profile group*.

Fig. 5.18
Table with group data



Each row represents one total or logging measurement. Measurements carried out with band-limiting filters only will be shown on yellow background:

- **Identification:** An icon and a name are shown. The icon indicates the type of measurement:
  - Total whole-body vibration measurement
  - Total hand-arm vibration measurement
  - SEAT measurement
  - Total building-vibrations measurement
  - Logged whole-body vibration measurement
  - Logged hand-arm vibration measurement
  - Logged building vibration measurement

  The ID label can be used to assign a unique name to each measurement; e.g., the name and type of a machine can be used. Vibration Explorer assigns a default name *Measurement#* or *Logging Profile#* respectively (# is an index number) when transferring data from Type 4447. The default name can be changed by clicking on the name (or anywhere in the item's row) and typing a new name or by right clicking and selecting from the displayed list

- **Start Time:** Shows date and time when the measurement was started and the total elapsed time
- **Weighting:** Shows which weighting filter was used for the measurement. This can be *Whole-Body* (for whole-body and SEAT measurements), *Hand-arm*, *Building* or the *Band-Limiting* version of these filters. In the case of SEAT measurements *(3+1)* is added to the weighting type
- This is followed by a number of columns showing the most important parameters of each measurement:
  - *RMS VTV*
  - *A(1)*
  - *A(4)*
  - *A(8)*
  - *CF Max*
  - *Peak Max*
  - *MTVV Max*
  - *VDV Max*
  - *VDV(8)$_k$ VTV*
  - *SEAT RMS*
  - *SEAT VDV*
  - *Overload*
  - *Underrange*

  See the glossary for a definition of the various terms.

Note: The table is customisable. With the exception of the *Identification* column, any column can be activated or deactivated. To do so, right click any of the column headers and a list of options will appear. To display a column check the corresponding item in the list. To hide the column, deselect the item, see Fig. 5.19.

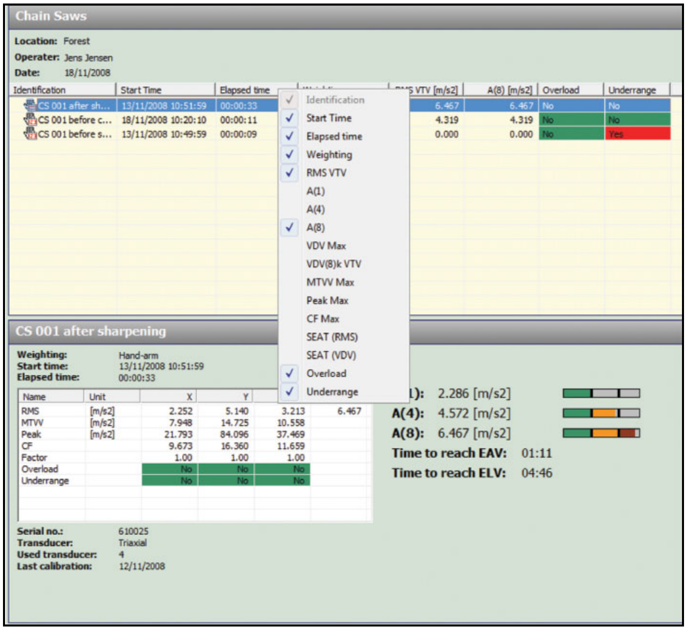


Fig. 5.19
Customising the table

Because a group will always contain all measurements that were on Type 4447 before transferring data, different types of measurements can appear in the same group. Therefore, not all columns will apply to each measurement in the group. If a certain parameter is not available for a particular measurement type, it will be indicated by '/'.

To remove a measurement from its group, select the measurement or logging profile entry in the table and:

- From the **Main** menu, select **Edit** then *Delete*, or
- Right click the row in the table, and from the subsequent list, select *Delete*

Measurement Details

To view the complete set of measured data for a particular measurement, select the corresponding row in the table. The lower right quadrant will then be updated, showing full information for the chosen item (see Fig. 5.20).

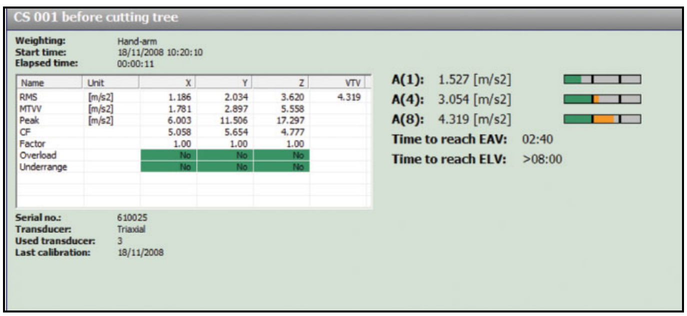


Fig. 5.20
Measurement details

For total measurements, a table is shown that reveals the measured parameters and the status for each axis. In addition, information about the instrument and accelerometer(s) used for the measurement is given. Finally the following values are shown to the right of the table:

- A set of *daily exposure values A(1), A(4)* and *A(8)*: These are based on the assumption of 1, 4 and 8 hours of exposure, respectively
- *Time to reach EAV* (exposure action value) and *Time to reach ELV* (exposure limit value): These give the time a tool, machine or vehicle may be operated before the action or limit value respectively is reached
- *SEAT RMS* and *SEAT VDV*: In the case of SEAT measurements the SEAT factors based on the RMS and VDV values, respectively, will be displayed

Note: The table and the information displayed vary depending on the type of measurement, i.e., whether the data represent a single or multiple axis, a whole-body, hand-arm or SEAT measurement.

The *daily vibration values* and *time to reach EAV* and *ELV* will give you a quick estimate of the risk of using the tool, vehicle or machine. In addition, colour scales are displayed for *A(1)*, *A(4)* and *A(8)* that give an even more intuitive quick feedback concerning the severity of the vibration risk from a tool or operation (see the upper right corner of Fig. 5.20). The scale is divided into three sections, and each section has an associated colour:

- Green: The leftmost section of the scale turns green as it fills. If green is the only visible colour in the scale, the calculated daily vibration exposure value is below the action value.
- Yellow: The centre section of the scale turns yellow as it fills. If green and yellow are the only visible colours, the vibration exposure is between the action and limit value
- Red: The rightmost section of the scale turns red as it fills. If this section contains red, vibration exposure exceeds the limit value

Logging Profile Details

For logged data, an additional tab with the profile itself is provided. To switch between the two views, simply select the appropriate tab, see Fig. 5.21. Depending on the type of measurement, i.e., whether you measured whole-body or hand-arm vibration and whether a single-axis or triaxial accelerometer was used, the following logging data can be displayed with a 1 s resolution:

- RMS profile
- MTVV profile
- Peak profile
- VDV profile

Data can be shown axis per axis or as the root sum of squares (VTV).

Note: While RMS, MTVV and Peak data can be displayed in the same graph, selecting to display VDV will disable RMS, MTVV and Peak. The reason is that VDV has different units than RMS, MTVV and Peak; i.e., they exclude each other.

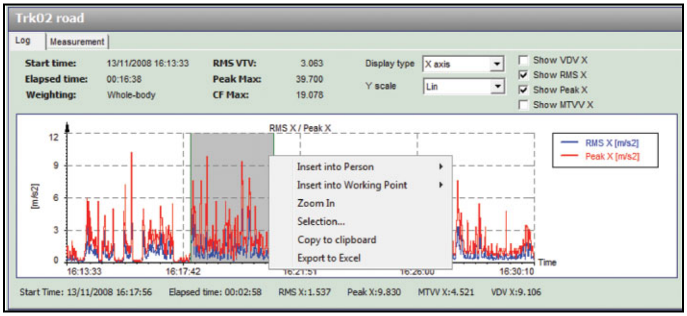


Fig. 5.21
A logging profile

To adjust the range of the graph's Y-axis left-click on the top value on the Y-axis. A text box will be shown, see Fig. 5.22. Type the new max-value for the Y-axis and press the **OK** button or hit the Enter key, and the graph will re-scale. Vibration Explorer will remember this setting for each logging profile until the project is closed.

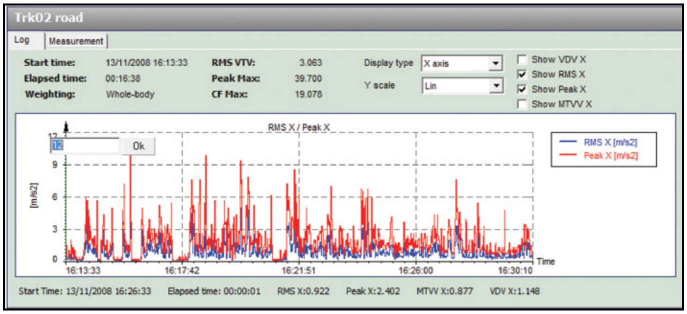


Fig. 5.22
Changing the scale

To zoom into a profile, left click in the profile where the section should start, hold the mouse button and drag it over the range. While doing this, the information below the graph will update to show the max Peak, the total RMS, and total VDV for the selected area of the profile. When you release the mouse button, a menu will appear and you may choose to:

- Adjust the selection
- Zoom into the selected range
- Export the selected range as numerical values to Microsoft® Excel
- Create a picture of the selected range in the background and place it on the clipboard

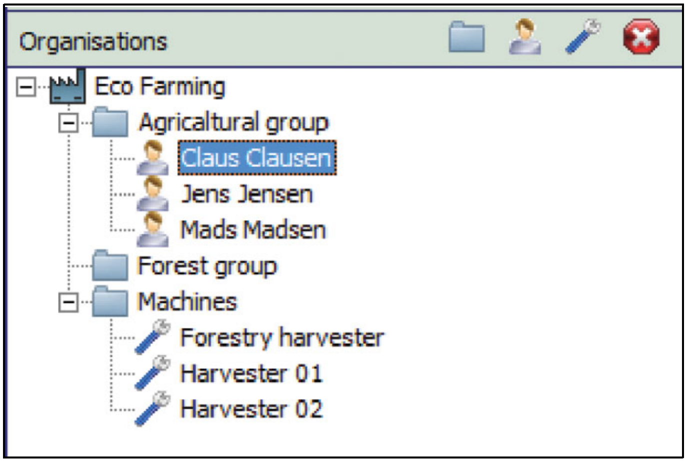
As soon as you have created working points or persons, you will also find commands in the menu that allow you to add the selected data or the entire profile to a particular person or working point.

When you choose to adjust the selection, a dialogue will appear where you can overwrite the start and end point of the selection. If you select *All*, the entire profile will be selected. Press **OK** to confirm the adjustments or **Cancel** to leave the dialogue and discard the changes. On return from this dialogue, the menu is shown again, so you can decide what to do with the adjusted selection.

5.3.7 Determine Vibration Exposure – The Organisation Model

Vibration Explorer lets you model hand-arm and whole-body vibration exposure for workers. A comprehensive model can be created to determine the exposure of workers for the current situation as well as simulate different scenarios based on which decision makers can manage any employee's health risk from exposure to hand-arm or whole-body vibration.

Fig. 5.23
Organisation tree



An organisation model may consist of the following elements:

- **Organisation:** Name of organisation
- **Folders:** Departments in the organisation, tool groupings or vehicles, for example
- **Working points:** Tools and vehicles operated by the employees
- **Person:** Worker(s) exposed to vibrations

Within a project, there can be only one Organisation. By default the Organisation node is labelled 'Organisation', but the label can be changed to something more specific. To do so, right click the Organisation label, select **Rename** and type a new name.

You can structure the organisation model using several folders and you can create folders within folders. Finally, you can add as many working points or persons to a folder as you need.

Working points are a means to manage sets of measurements performed on the same operation. There is always a certain amount of uncertainty in measurements, resulting both from variations in the working process, such as changes in the posture of the person, and from variations in the measurement set up, such as slight differences in the mounting position of the transducer. You will therefore find that, when carrying out several measurements of the seemingly same operation, the results will slightly or substantially differ from one another. It is therefore recommended to repeat a measurement a number of times and use an average over the results in the calculation of exposure.

Note: Different standards suggest different approaches for averaging across a set of measurements. Please make sure that the concept currently implemented in Vibration Explorer's working points is applicable for your project.

When averaging RMS values in a working point, Vibration Explorer follows the approach in Section 9.2.1 and Section 10.1 of EN 1032 (Mechanical Vibration – Testing of Mobile Machinery in Order to Determine the Vibration Emission Value), which suggests to report the mean value of a set of RMS measurements as the magnitude of vibration emission for a particular machine in a particular operation mode. The same rule is also applied for SEAT values and daily exposure values, $A(1)$, $A(4)$ and $A(8)$, and the eight hour vibration dose value, $VDV(8)_k$. In contrast, for *Peak*, *CF, MTVV* and *VDV* values, the maximum in the respective column is taken.

When inserting a working point into a person, it will be handled as a single measurement, using the RMS average and maximum values for *VDV* and *Peak* values, respectively determined in the working point.

Creating an Organisation Tree

To add a folder, working point or person directly under the organisation node, select the organisation node and press the *Add folder* , *Add person* or *Add Working Point* button, respectively in the small toolbar above the organisation tree. Alternatively right click the organisation node, select **New** and then the item that you want to add. The item will be created with a default name, but Vibration Explorer will select it so that you can rename it immediately.

Once you have created one or more folders you can add sub-folders, working points or persons to the folder. Vibration Explorer will assist you with context sensitive buttons in the organisation toolbar. Depending on the item currently selected in the organisation tree, pressing one of the buttons will add the new item either directly to the organisation or one of the sub-folders.

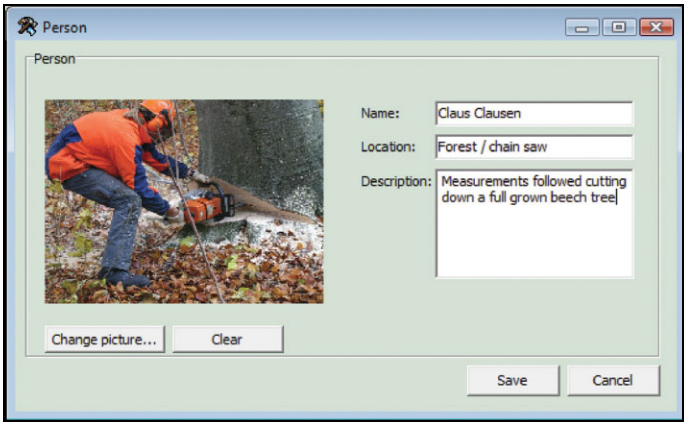
Note: It is not possible to add a working point under a person. However, you can drag a working point onto a person. This will add the result of the working point calculation to the list of vibration exposures. Working points added to a person will appear in the organisation tree underneath the person. However, a green arrow is added to the icon, indicating that a reference was added rather than a new working point.

Setting Properties for Each Node in the Organisation Tree

You can add further information to each node in the organisation tree (except folders themselves) using the node's properties dialogue. To open it, right click on the node and select properties:

- For the Organisation, you can specify name, address, zip code, town and telephone. In addition, a field for comments and notes is provided
- For Working points and Persons, you can specify the name, location and give a description. Further you can add a picture of the working point or person.

Fig. 5.24
Person-properties dialogue



Adding Measurement Data to Working Points and Persons

Once you have added working points and/or persons to the organisation model, you can populate them with one or several measurements or logging profiles.

Measurements can be added in two ways:

1) Select the measurement group to which the measurement belongs (the workspace will change to display the measurements in this group) and then drag the desired measurement from the table onto the person or working point.

2) Select the measurement group to which the measurement belongs (the workspace will change to display the measurements in this group), right click the measurement in the table to bring up a list of persons and working points currently in the project and then select the person or working point from the menu.

Note: You may very well add hand-arm as well as whole-body measurements to the same person or working point. Vibration Explorer will make sure they are treated separately.

After you have added a number of measurements to a person or working point, select its node. A table similar to that for the measurement groups will be shown in the upper quadrant of the workspace. However, when calculating exposure, hand-arm and whole-body vibration data must be handled separately. As a consequence, when looking at data for a person or working point, only data of the same type will be shown together. To switch between these different groups of data use the buttons above the table.

Note: Buttons are only shown for the type of measurements already added to a Person; i.e., if you only added hand-arm vibration data only one button is shown.

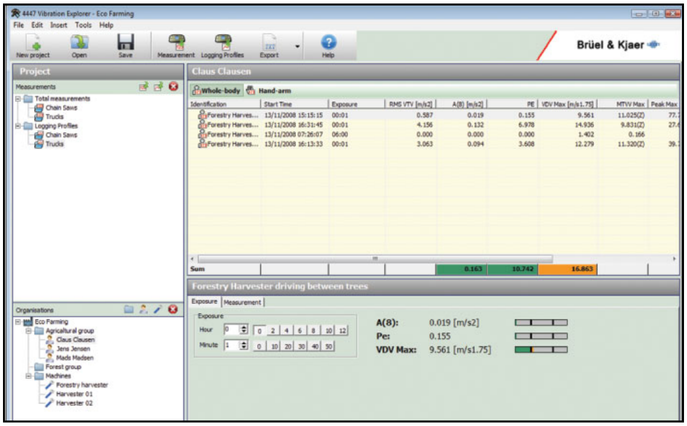


Fig. 5.25
List of operations

You can also copy measurements between working points and persons.

Measurements can be copied in two ways:

1) Drag it from its current location and drop it into the new one.
2) Right click the measurement and select the person or working point in which to place a copy of the data.

Assigning Logging Data to a Person or Working Point

In principle, the process for using logging data in the exposure calculation is exactly the same as for measurements. If you want to use a full logging profile, simply select it in the group of logging profiles and drag it onto the working point or person.

However, Vibration Explorer gives you much more flexibility; you can add just a section of a profile and use it as a self-contained operation or measurement. To do so, select the logged measurement so that its profile is displayed in the workspace. Then left-click and drag over the section of the profile that you would like to be inserted as a new item into a working point or person. Once you release the mouse button a menu will appear. If you need to refine the selection, click **Selection …** and enter the start and end times in the dialogue before you proceed. Otherwise select the working point or person to which you would like the profile section to be added.

Once this is done, in the organisation, select the person or working point, and in the table of exposure contributions, click on the item representing the recently added logging profile. You will see that only the section has been added.

Defining Exposure Duration

To calculate a person's daily exposure, you need to specify how long the person would perform each of the particular operations.

To set (or change) the exposure time:

1) In the table in the upper right quadrant (showing details of the selected person), select either *Hand-arm* or *Whole-body*.

2) Select the measurement representing the particular operation for which you would like to set the effective exposure time.

3) In the lower right quadrant, choose the **Exposure** tab and enter the time using the buttons (large step size) or the spinner buttons (smaller time steps).

When you change the duration of an operation, Vibration Explorer will recalculate the exposure for the particular operation. The result of this is displayed in the lower quadrant to the right of the buttons. In addition to the partial vibration value, *A(8)*, and the vibration dose value, *VDV*, for the operation, the exposure is given in exposure points, P_E. Further, the results are visualised with colour scales, see also Section 5.3.6 (page 75).

In addition to the partial exposure values, the combined daily vibration exposure for the person is recalculated and shown in the last row at the bottom of the table. These values are colour coded. The values will be marked:

– Green, if the vibration exposure is below the action value.
– Yellow, if the vibration exposure is between the action and limit value.
– Red, if the vibration exposure exceeds the limit value.

See Fig. 5.26 for an example of the display of an exposure calculation.

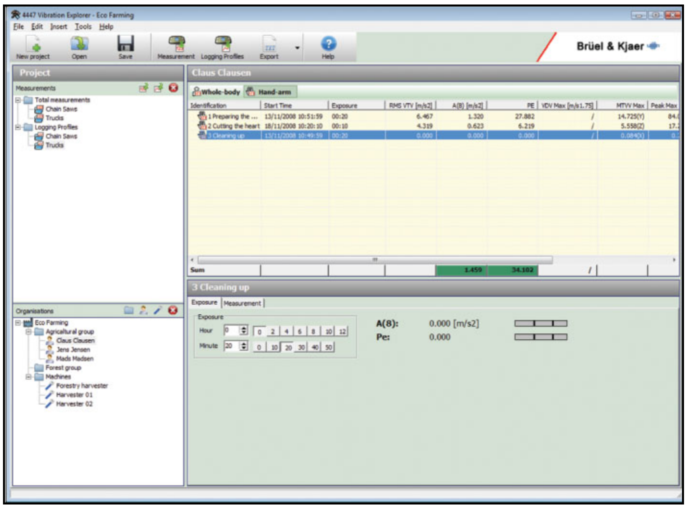


Fig. 5.26
Example of exposure calculation

5.4 Export Data and Create Reports

Reporting is done using the export facilities of Vibration Explorer. The most basic way is to export data to a tab separated text file, an HTML or XML file. However, Vibration Explorer can also export all data to Windows® Excel, giving you full control over the final format of the report and allowing additional calculations.

5.4.1 Export settings

Before exporting, use the export settings dialogue to define what should be exported. To open the dialogue, select **Tools** and then *Export Settings*. The dialogue (see Fig. 5.27) provides four tab sheets, because you can either export data for a person, a working point, an entire folder in the organisation tree or raw measurement data in a measurement or logging group, respectively. On each tab tick the data to be exported for the particular item in a project.

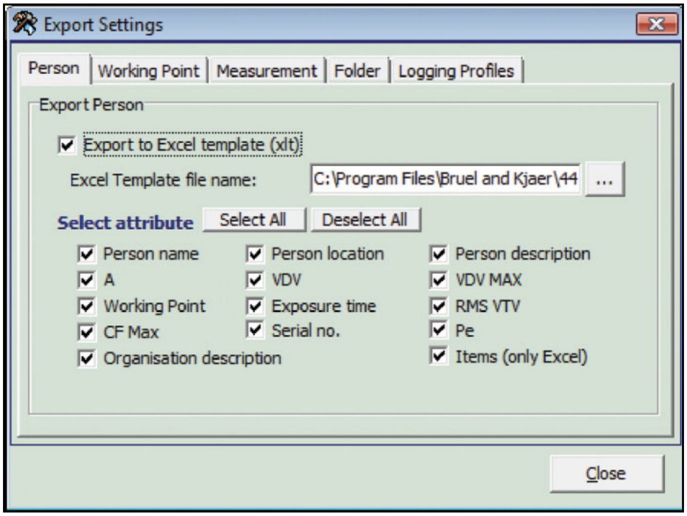


Fig. 5.27
Sample page of the Export settings dialogue

If you want to export to Excel®, you may also specify a template file (*.XLT) in which to insert data. For more information on how to utilise report templates in Excel, see the end of this section. Close the dialogue when you are done.

5.4.2 Exporting data

To export data:

1) Select the person, working point, folder, measurement or logging group you would like to export.

2) From the menu select **Tools**, **Export** and choose the most appropriate export option: *Text*, *HTML*, *XML* or *Excel*.

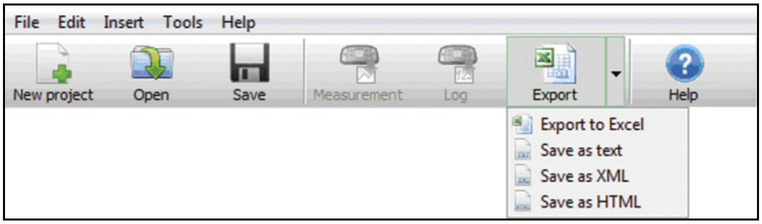
   Alternatively, select the desired export option from the **Export** button in the toolbar.

   Note: The export button in the toolbar will remember your last export choice.

If you choose to export to a text, HTML or XML file, you will be prompted to specify a file name. Vibration Explorer will then write data to this file.

If you choose to export to Excel®, Vibration Explorer will start a new session of Microsoft® Excel, create a new Excel® file (workbook) and places the Vibration Explorer data in it. The file will not be automatically saved. To save the file you need to switch to Excel® and select **File** and then *Save as* **….**

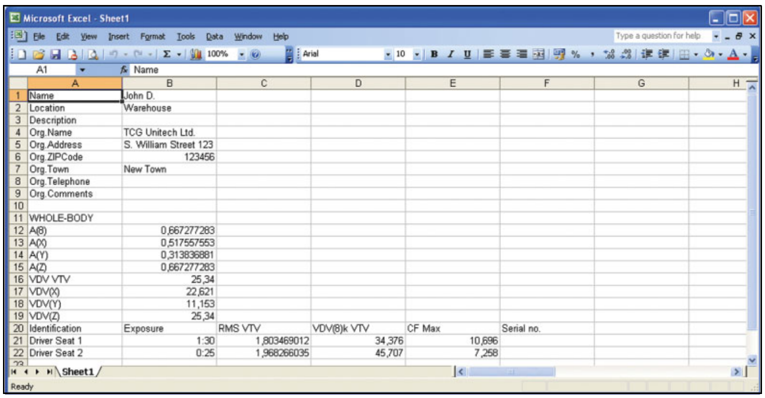
Fig. 5.28
Toolbar with the Export button selected



5.4.3 Working with Vibration Explorer data in Excel®

When exporting measurement groups, persons, working points and folders, Vibration Explorer will always place the data on ‘Sheet1’ of the new workbook. To manipulate data, it is recommended to insert a new Sheet. Right click the existing ‘Sheet1’ tab and select *Insert*. In the **Insert** menu, select *Worksheet*. The new sheet will be named ‘Sheet2’. In the following we will continue referring to this new sheet as 'Sheet2', but of course you can rename it, e.g., to ‘Report’.

Fig. 5.29
Example of data exported for a Person (John D.)



Cells in ‘Sheet2’ can be set up to refer to data in other sheets. As an example, Vibration Explorer placed *A(8)* in cell B12 on ‘Sheet1’. To refer to this value on ‘Sheet2’:

1) Select a cell on the second sheet and enter the following text:

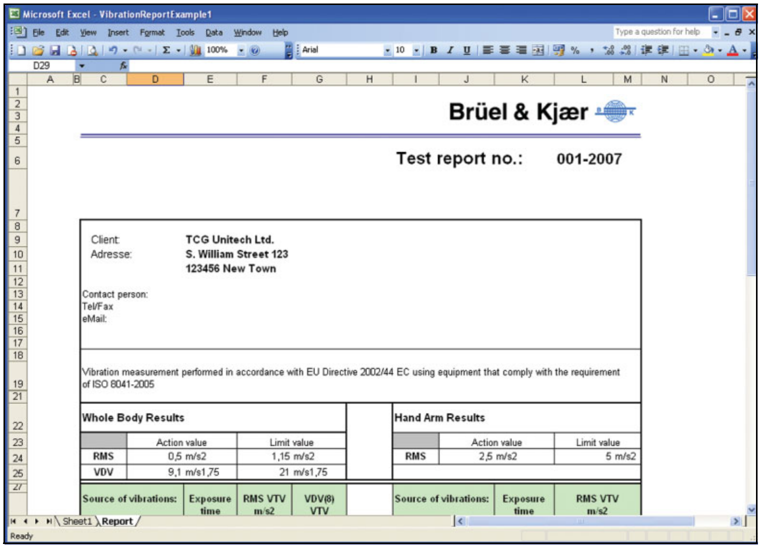
   =Sheet1!B12

2) Press Enter.

Excel® inserts the value from cell B12 on ‘Sheet1’ into the cell on ‘Sheet2’. Further, if you change the value on ‘Sheet1’, it will also change on ‘Sheet2’.

You can then arrange the cells in the newly inserted ‘Sheet2’ in such a way that it can be used for a report. Further formatting, layout and referencing can be done using all the standard Excel® options, like ***Insert Picture*** (your logo), ***Format Text***, ***Sheet appearance***, etc. See the Microsoft® Excel **Help** menu for assistance. When you are satisfied with the appearance of the sheet, select the cells that you want to include in the report then click **File***,* **Print Area**, *Set Print Area*. Open *Page Setup* (File/Page Setup) to ensure that margins, headers, footers, etc., are satisfactory. A sample report is shown in Fig. 5.30.

Fig. 5.30
Example of a report made in Microsoft® Excel



5.4.4 How to Create an Excel® Report Template (*.XLT)

When using the same export settings (see Section 5.4.1), Vibration Explorer will export data using the same structure on ‘Sheet1’. In case you need to create similar reports often, it is wise to create a template, which can be used any time data are exported to Excel®. The whole process of creating reports is then significantly reduced.

To create an Excel® report template:

1) Create a report as described in Section 5.4.3.
2) When you are satisfied with the appearance, size, links, logo etc., delete all data in ‘Sheet1’.
3) Save the spreadsheet as a template, by selecting **File** then *Save as*. In *Save as*, type, select Template (*.XLT). To make the access to the created template easier from Vibration Explorer, save it in the Data directory found in Vibration Explorer (see Fig. 5.31).

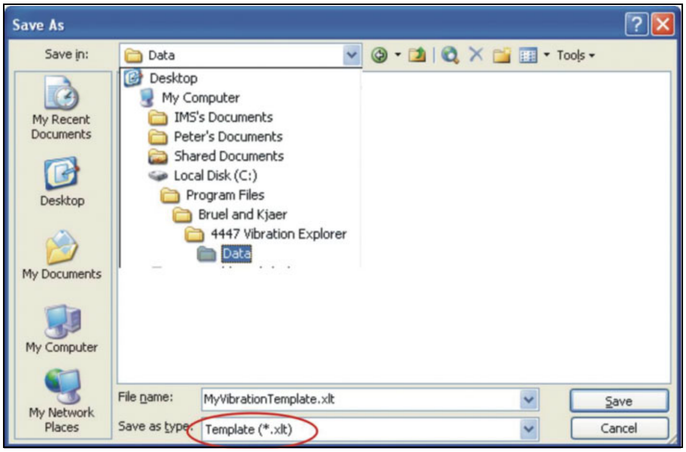


Fig. 5.31
Save template in Vibration Explorer's Data directory

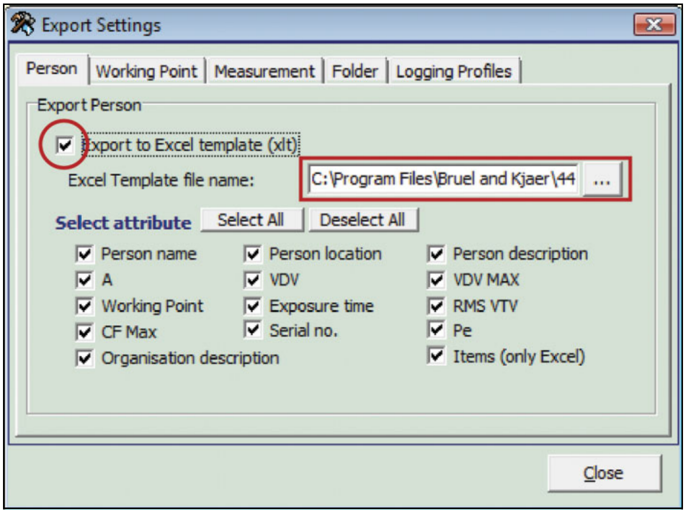


Fig. 5.32
Activating the report template for exporting data for a Person

The template can now be selected in **Export Settings** (see Fig. 5.32) whenever a predefined report is desired. Fig. 5.31 and Fig. 5.32 show the process in utilising a template for *Person* data export.

5.5 Software Settings

The **PC SW Settings** (see Fig. 5.33) dialogue is used to set up calculation parameters (such as hand-arm/whole-body exposure action and limit values); set daily exposure time; and change application languages. To open it, select **Tools/PC SW Settings ….**

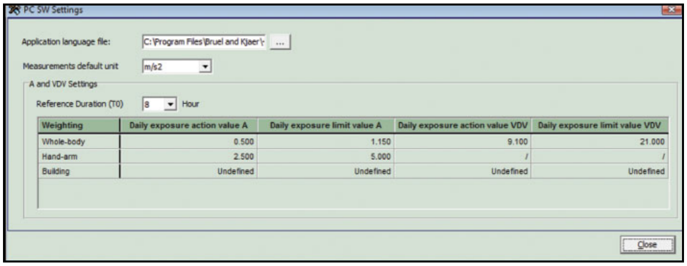


Fig. 5.33
PC SW Settings dialogue

Application Language File

The default language of Vibration Explorer is English. All supported languages can be found in LOCAL DRIVE *\PROGRAM FILES\BRUEL AND KJAER\4447 VIBRATION EXPLORER\LANGUAGE*. To change the language, select the appropriate .SWL file.

Measurements Default Unit

Results are expressed in m/s^2 as default but can be changed to g or dB.

Reference Duration (T_0)

The default value for Duration, which represents reference daily working time period expressed in hours, is 8 hours. It can be altered at any time before, during or after calculation process and has an instant effect on all results.

The Daily exposure Values Table

Shows the default daily exposure action and limit values for whole-body and hand-arm measurements and are taken from Directive 2002/44/EC. To change the values, double-click on a value in the table and enter a new one. The updated value will be used in the daily exposure calculations.

5.6 Using Vibration Explorer to Update the Firmware and set the Language on Type 4447

The *Instrument SW Upgrade* dialogue is used to set up and maintain Type 4447 (see Fig. 5.34). Connect Type 4447 to your computer. Then select **Tools, Maintenance** and then *Instrument SW Upgrade*.

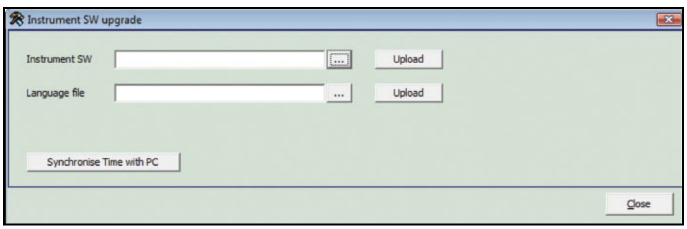


Fig. 5.34
The Instrument SW Upgrade dialogue

To upgrade to the latest firmware:

1) Click the **…** button to the right of the *Instrument SW* field. A standard Windows® *Open file* dialogue will be shown.
2) Browse to the new firmware file, select it and press the **Open** button.
3) On return to the Instrument SW Upgrade dialogue, press the **Upload** button.
4) A progress bar will indicate the progress.

Note: Uploads will take some time. Before uploading, ensure that Type 4447 is fully charged and the USB cable is tightly plugged into the instrument and computer. In case the process is interrupted (e.g., due to the cable becoming unplugged), Type 4447 will become locked. In this case, repeat the uploading process until the upload has been successful.

The most recent firmware can be downloaded from Brüel & Kjær's Web site (www.bksv.com).

To Change the Language on Type 4447

1) Click the … button to the right of the *Language file* field. A standard Windows® *Open file* dialogue will be shown.
2) Browse to the desired language file (extension .HWL), select it and press the **Open** button. By default, language files for Type 4447 are placed in the LANGUAGE folder in Vibration Explorer's home directory.
3) On return to the Instrument SW Upgrade dialogue press the language **Upload** button.
4) A progress bar will indicate the progress.

Note: Uploads will take some time. Before uploading, ensure that Type 4447 is fully charged and the USB cable is tightly plugged into the instrument and computer. In case the process is interrupted (e.g., due to the cable becoming unplugged), Type 4447 will become locked. In this case, repeat the uploading process until the upload has been successful.

To Synchronise Time Between Type 4447 and PC

To synchronise time and date between instrument and PC click **Synchronize Time with PC**. Synchronisation will be confirmed with the message *Synchronization OK*.

5.7 Help and About dialogue

To access online help, click the **Help** button on the toolbar or select **Help** then *Manual* from the menu.

The **About** menu (**Help** then *About 4447 Vibration Explorer*) gives you access to information on the 4447 Vibration Explorer version.

Chapter 6

Maintenance and Service

Type 4447 is designed and constructed to provide many years of reliable operation. However, if a fault occurs that impairs Type 4447 operation, turn it off and remove all cables to prevent the risk of further damage.

For more information about preventing faults or damage to your Type 4447, please read the Care, Cleaning and Storage section below.

For repair, contact your local Brüel & Kjær representative. Brüel & Kjær provides a high level of support and after-sales service to assist customers in the handling and operation of their instruments.

6.1 Care, Cleaning and Storage

Type 4447 is a delicate precision instrument. When handling, storing or cleaning your instrument, please take the following precautions.

Handling the Instrument

- Do not attempt to open the instrument. There are no user-serviceable parts inside. If you think your instrument requires service, please contact your Brüel & Kjær representative
- Do not allow the instrument to get wet
- Protect the instrument from impact. Do not drop it. Transport it in the supplied carrying pouch
- Only use the originally supplied charger to recharge the Li-Ion batteries

Master Reset

In the event that the instrument does not respond (that is, all the functions appear blocked), perform a master reset by pressing  for more than 10 seconds.

(After a reset, the clock will have to be reset to show the right time, and please check the **Setup** and **Calibration** menus before conducting a new measurement.)

6.1.1 Storing the Instrument

- Keep Type 4447 in a dry place, preferably within its carrying case
- Do not exceed storage temperature limits of –25 to +60° C (–13 to +140° F)

6.1.2 Cleaning the Instrument

If the instrument casing becomes dirty, then wipe it with a lightly dampened cloth. Do not use abrasive cleansers or solvents. Do not allow moisture to enter the connectors or casing.

6.1.3 Replacing the Battery

The battery cannot be replaced by the user. For battery replacement, the intact instrument must be sent to a Brüel & Kjær service centre.

Chapter 7

Specifications

Type 4447 complies with the relevant parts of following standards:

- ISO 8041:2005: Human response to Vibration – Measuring Instrumentation
- ISO 5349 – 1: 2001: Mechanical Vibration – Measurement and Evaluation of Human Exposure to Hand-transmitted Vibration – Part 1: General Requirements
- ISO 5349 – 2: 2001: Mechanical Vibration – Measurement and Evaluation of Human Exposure to Hand-transmitted Vibration – Part 2: Practical Guidance for Measurement at the Workplace
- ISO 2631 – 1: 1997: Mechanical Vibration and Shock – Evaluation
  of Human Exposure to Whole-body Vibration – Part 1: General Requirements
- EU Directive 2002/44/EC

SUPPLIED ACCELEROMETERS

	Transducer	Nominal Sensitivity	Filter	Frequency range	Linear Operating Range[a]	Instrument Noise
Hand-arm	4524-B-001	1 mV/(m/s^2)	W_h	2 Hz to 7 kHz	1 m/s^2 to 3200 m/s^2	<0.1 m/s^2
Whole-body	4515-B-002	10 mV/(m/s^2)	W_d, W_k	0.25 Hz to 900 Hz	0.1 m/s^2 to 320 m/s^2	<0.01 m/s^2

a. Linear operating range is the instrument's measuring range. It is specified according to ISO 8041:2005. Outside this range, either 'Overload' or 'Under-range' is indicated.

SHOCK LIMITS
Max. Shock level for recommended transducers (± peak): 50 km/s^2

DISPLAY
Colour graphical display: 124 × 124 pixel resolution
Basic information regarding the instrument status is shown through icons, including:

- Battery indicator
- Measurement status: Measure, Pause, Stop
- Channel status
- Elapsed time: hh:mm:ss

CLOCK
Real-time clock and time-stamped measurements

MEMORY
64 kB, equivalent to 750 (3 axes) measurements or 4.7 h logging can be stored in non-volatile memory

USB INTERFACE
Conforms to USB 2.0
Connector: Mini B

INPUT CHANNELS
Type 4447 has two analogue input channels and a USB digital I/O. The inputs are designed for triaxial and/or uniaxial accelerometers and are equipped with selectable CCLD power supplies. Input-channel sensitivity is designed for typical transducers used in human vibration measurements

CABLES
The maximum accepted accelerometer cable length is 3 m (9.84 ft)

FREQUENCY WEIGHTING
Filters for frequency weightings conform to ISO 8041:2005, including filters W_h, W_d, W_k and W_m

SETUP MODES
Weighting filters (measurement type)
Display units

DETECTOR
Simultaneous measurement of weighted RMS, MTVV, VDV and Peak vibration value for each channel

MEASURING PARAMETERS
Measured parameters are selected according to the selected setup mode. The following parameters are measured, calculated and displayed during or after measurement

BATTERY
Rechargeable Li-ion battery 3.7 V, 2600 mA. Up to 4 h continuous use at room temperature after more than 6 h charging with the supplied charger, ZG-0459*

Note 1: External Charger (ZG-0459) is not recommended for use during measurements as it may introduce noise

CALIBRATION
Calibration Check Vibration Value: 10 m/s^2 (3.16 m/s^2 for high-sensitivity accelerometers: positions 5 and 10)
Calibration Check Frequency: 159.2 Hz
Electrical Calibration Check Voltage: 100 mV for Type 4515-B-002 and 10 mV for Type 4524-B-001

PHYSICAL DIMENSIONS
Size: 70 × 135 × 28 mm (2.7 × 5.3 × 1.1 in)
Weight: 260 g (9.2 oz.), battery included

LANGUAGES
English, German, French, Spanish and Italian

Parameter	Symbol	Units
Time Averaged Weighted Acceleration Value over measurement duration using linear averaging	Total RMS X, Y, Z	m/s^2, g or dB[a]
Vibration Total Value of Total RMS (Root Sum of Squares): The 3 orthogonal values × their respective k-factors	Total RMS VTV	m/s^2, g or dB[a]
Running RMS. Acceleration Value: Frequency-weighted instantaneous vibration exponentially averaged with a time constant of 1 s	Curr RMS X, Y, Z	m/s^2, g or dB[a]
Maximum Transient Vibration: Maximum of Curr RMS during measurement duration	MTVV X, Y, Z	m/s^2, g or dB[a]
Peak Vibration Value: Maximum modulus of the instantaneous (positive and negative) peak values of the frequency-weighted acceleration. Measured over measurement duration	Peak X, Y, Z	m/s^2, g or dB[a]
Vibration Dose Value (VDV): The 4th root of the time integral of the 4th power of the instantaneous frequency-weighted vibration acceleration. Measured over measurement duration	VDV X, Y, Z	m/s$^{1.75}$, g·s$^{0.25}$ or dB[a]
Vibration Total Value of Total VDV: RMS of the 3 orthogonal values × their respective k-factors	Total VDV VTV	m/s^2, g or dB[a]
8-hour Vibration Dose Value: The VDV measured over the measurement duration is extrapolated/interpolated to the value that the same signal would have given if the measurement duration was 8 hours and multiplied by the respective k-factor	VDV(8)$_k$ X, Y, Z and VTV	m/s$^{1.75}$, g·s$^{0.25}$ or dB[a]
Measurement duration	Elapsed time	h:m:s
8-hour Daily Vibration Exposure A(8): In hand-arm results, A(8) = total RMS VTV. In whole-body results, A(8) = maximum of the three axes' total RMS × their respective k-factors	A(8)	m/s^2, g or dB[a]
4-hour Daily Vibration Exposure: A(8) recalculated to 4-hour exposure.	A(4)	m/s^2, g or dB[a]
1-hour Daily Vibration Exposure: A(8) recalculated to 1-hour exposure.	A(1)	m/s^2, g or dB[a]
SEAT computed as the ratio between values measured in the Z-directions at the top and bottom of the seat for RMS and VDV	SEAT RMS	–
	SEAT VDV	–

a. dB reference 1 μm/s^2 (for VDV: 1 μm/s$^{1.75}$)

*. If the instrument is operated at low temperatures, the operational time is reduced.

Ordering Information

Human Vibration Analyzer Type 4447-A, including:

Type 4515-B-002	Triaxial DeltaTron Seat Pad Accelerometer, with built-in Type 4524-B, 10 mV/(m/s^2), TEDS, with 3 m (9.84 ft) integral cable to 4-pin LEMO and Strap for Seat Pad Accelerometer, DH-0411
Type 4524-B-001	Miniature Triaxial DeltaTron Accelerometer, 1 mV/(m/s^2), TEDS
AO-0693-D-025	LEMO to 4-pin 1/4–28 MicroTech connector cable, 2.5 m (8.20 ft)

and the following accessories:
- AO-1476: USB standard A to USB mini-B interface cable, 1.8 m (5.90 ft)
- UA-3015: Hand Adaptor
- UA-3016: Handle Adaptor
- UA-3017: Cube Adaptor for direct fixation
- BZ-5623: Vibration Explorer Software, for data transfer, organising measurement site and calculation
- ZG-0459: Charger, 100 – 240 V, 50 – 60 Hz
- QA-0232: Screwdriver
- YJ-0216: Bees wax for mounting
- DB-0756: Cementing Stud, 10–32 UNF
- DH-0750: Wrist Strap for Type 4447
- DG-0517: Velcro Strap
- KE-0455: Travelling Bag

Human Vibration Analyzer Type 4447-B, including:
All Type 4447-A components and accessories **plus**:
- Type 4294: Calibration Exciter
- DV-0459: Small Calibration Clip

Human Vibration Analyzer – Hand-arm Type 4447-C, including:
All Type 4447-A components and accessories **except**:
- Type 4515-B-002: Triaxial DeltaTron Seat Pad Accelerometer
- DH-0411: Strap for Seat Pad Accelerometer

Human Vibration Analyzer – Whole-body Type 4447-D, including: All Type 4447-A components and accessories **except**:

Type 4524-B-001	Miniature Triaxial DeltaTron Accelerometer, 1 mV/(m/s^2), TEDS
AO-0693-D-025	LEMO to 4-pin 1/4–28 MicroTech connector cable, 2.5 m (8.20 ft)

- UA-3015: Hand Adaptor
- UA-3016: Handle Adaptor
- UA-3017: Cube Adaptor for direct fixation
- DG-0517: Velcro Strap

OPTIONAL ACCESSORIES

Type 4294	Calibration Exciter
DV-0459	Small Calibration Clip
Type 4515-B-002	Triaxial DeltaTron Seat Pad Accelerometer, with built-in Type 4524-B, 10 mV/(m/s^2), TEDS, with 3 m (9.84 ft) integral cable to 4-pin LEMO
Type 4524-B-001	Miniature Triaxial DeltaTron Accelerometer, 1 mV/(m/s^2), TEDS
Type 4507-001	Miniature Uniaxial DeltaTron Accelerometer, 1 mV/(m/s^2)
Type 4520-004	Miniature Triaxial Accelerometer, 0.1 mV/(m/s^2)
AO-0694-D-012	3 × 10 – 32 UNF to LEMO female adaptor, 1.2 m (3.94 ft)
AO-0695-D-025	LEMO male to 10–32 UNF cable, 2.5 m (8.29 ft), for single-axis measurements, 4th channel
DH-0411	Strap for Seat Pad Accelerometer
DV-0459	Small Calibration Clip (included with Type 4447-B)
DV-0463	Spring Clip for Adaptors UA-3015, UA-3016 and UA-3017
DV-0497	Belt Clip for Analyzer
UA-2085	10 × Screws for Seat Pad Accelerometer
WA-0224	Mechanical filter, 3 mm stud

SERVICE PRODUCTS

4447-A-CVF	Accredited Calibration of 4520-002, 4524-B, Verification of Analyzer and Battery Change
4447-A-CVI	Accredited Initial Calibration of 4520-002, 4524-B and Initial Verification of Analyzer
4447-B-CVF	Accredited Calibration of 4520-002, 4524-B, 4294, Verification of Analyzer and Battery Change
4447-B-CVI	Accredited Initial Calibration of 4520-002, 4524-B, 4294 and Initial Verification of Analyzer
4447-C-CVF	Accredited Calibration of 4520-002, Verification of Analyzer and Battery Change
4447-C-CVI	Accredited Initial Calibration of 4520-002 and Initial Verification of Analyzer
4447-D-CVF	Accredited Calibration of 4524-B, Verification of Analyzer and Battery Change
4447-D-CVI	Accredited Initial Calibration of 4524-B and Initial Verification of Analyzer
4447-RE3	4447 Battery Change
4447-TCF	Conformance Test with Certificate

Compliance with Standards

	CE-mark indicates compliance with: EMC Directive and Low Voltage Directive. C-Tick mark indicates compliance with the EMC requirements of Australia and New Zealand.
Safety	EN/IEC 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use. ANSI/UL 61010–1: Safety requirements for electrical equipment for measurement, control and laboratory use.
EMC Emission	EN/IEC 61000–6–3: Generic emission standard for residential, commercial and light industrial environments. EN/IEC 61000–6–4: Generic emission standard for industrial environments. CISPR 22: Radio disturbance characteristics of information technology equipment. Class B Limits. FCC Rules, Part 15: Complies with the limits for a Class B digital device.
EMC Immunity	EN/IEC61000–6–1: Generic standards – Immunity for residential, commercial and light industrial environments. EN/IEC 61000–6–2: Generic standards – Immunity for industrial environments. EN/IEC 61326: Electrical equipment for measurement, control and laboratory use – EMC requirements. **Note 1:** The above is only guaranteed using accessories listed in this manual
Temperature	IEC 60068–2–1 IEC 60068–2–2: Environmental Testing. Cold and Dry Heat. Operating Temperature: –10 to +50°C (+14 to +122°F) Storage Temperature: –25 to +70°C (–13 to +158°F)
Humidity	IEC 60068–2–78: Damp Heat: 93% RH (non-condensing at 40°C (104°F))
Mechanical	Non-operating: IEC 60068–2–6: Vibration: 0.3 mm, 20 ms^{-2}, 10 – 500 Hz IEC 60068–2–27: Shock: 1000 × 40 g IEC 60068–2–29: Bump: 6 × 1000 bumps at 40 g
Enclosure	IEC 60529 (1989): Protection provided by enclosures: IP 42

Chapter 8

Glossary

A(1), A(4), A(8): Daily vibration exposure value for 1 hour, 4 hours and 8 hours exposure to vibration. In hand-arm results, $A(8)$ equals the Total root mean square (RMS) vibration total value (VTV), and in whole-body results, $A(8)$ equals the maximum of the three axes Total RMS multiplied by their respective k-factors. $A(4)$ equals $A(8)$ multiplied by the square root of 4 h/8 h. $A(1)$ equals $A(8)$ multiplied by the square root of 1 h/8 h.

CF: Crest factor is the ratio of the Peak value to the root mean square (RMS) value of a quantity over a specified time interval. The crest factor is low if the Peak value is only slightly above the RMS value, indicating a rather smooth, steady vibration process. A large crest factor will indicate that the vibrations contained one or several strong transients, for example shocks.

Curr RMS: Running root mean square (RMS) acceleration value. The frequency-weighted running RMS vibration acceleration value is measured using exponential averaging with a time-constant of 1 second. This is an instantaneous value displayed during measurement; it is not stored in the final result. The purpose of displaying this value is that it enables the user to follow how the vibration level varies during measurement.

Elapsed time: Total measurement duration is counted from start to stop of the measurement, excluding the time when the instrument is paused. During measurement, elapsed time is shown in the lower right corner of the display.

MTVV: Maximum transient vibration value (MTVV). The maximum value of the running root mean square (RMS). acceleration value (with an averaging time constant of 1 second) measured over the elapsed time. When logging measurements the MTVV is determined for each logging interval.

***P_E*:** Exposure points, an alternative way to express daily vibration exposure, $A(8)$. The relation between exposure points P_E and daily vibration exposure $A(8)$ is defined in such a way, that 100 exposure points always correspond to the action value for daily vibration exposure (0.5 m/s^2 for whole-body vibrations and 2.5 m/s^2 for hand-arm vibrations). Further, exposure points are simply added together. Both features of the exposure point system make risk assessment much easier and more transparent for the non-specialist.

Peak: Peak vibration value. The maximum modulus of the instantaneous (positive and negative) peak values of the frequency-weighted acceleration measured over the elapsed time. During logging measurements a Peak value is also stored for each 1 second logging interval.

SEAT RMS: Seat Effective Amplitude Transmissibility (SEAT) is based on the time averaged weighted acceleration values. It is the ratio between the root mean square (RMS) measured in the Z-direction (vertical) on the seat pan and the RMS value measured in the Z-direction on the vehicle floor directly underneath the seat.

SEAT VDV: Seat Effective Amplitude Transmissibility (SEAT) is based on the vibration dose values (VDVs). It is the ratio between the VDV measured in the Z-direction (vertical) on the seat pan and the VDV value measured in the Z-direction on the vehicle floor directly underneath the seat.

Total RMS: Time-averaged weighted acceleration value. The frequency-weighted root mean square (RMS) vibration acceleration value is measured using linear averaging with an averaging time that is equal to elapsed time. During logging measurements the RMS value is also linearly averaged over and saved for each 1 second logging interval.

VDV: Vibration dose value (VDV). The fourth root of the time integral of the fourth power of the instantaneous frequency-weighted vibration acceleration. VDV is measured in $m/s^{1.75}$. The integration time for total measurements is the elapsed time; for logging measurements VDV is determined and saved for each 1 second logging interval.

VDV(8)$_k$: 8-hour vibration dose value. The vibration dose value (VDV) measured over elapsed time is extrapolated/interpolated to the value that the same signal would have given if elapsed time was 8 hours and multiplied by the respective k-factor.

VTV: Vibration total value (VTV). The combined vibration from the three axes defined as the root-sum-of-squares of the vibration values multiplied by the k-factors for the three axes. The k-factors are multiplying factors that depend on whether hand-arm or whole-body is measured. Two different VTVs are calculated: one for the Total RMS and one for Total VDV.

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Local representatives and service organisations worldwide