V. VIBRATION MONITORS

The following sections contain a brief discussion of various types of measurements that are of concern when measuring vibration. Human response to vibration is dependent on several factors including the frequency, amplitude, direction, point of application, time of exposure, clothing and equipment, body size, body posture, body tension, and composition. A complete assessment of exposure to vibration requires the measurement of acceleration in well-defined directions, frequencies and duration of exposure. The vibration will generally be measured along three (x, y and z) axes.

A typical vibration measurement system includes a device (accelerometer) to sense the vibration, a recorder, a frequency analyzer, a frequency-weighting network, and a display such as a meter, printer or recorder. The accelerometer produces an electrical signal in response to the vibration. The size of this signal is proportional to the acceleration applied to it. The frequency analyzer determines the distribution of acceleration in different frequency bands. The frequency-weighting network mimics the human sensitivity to vibration at different frequencies. The use of weighting networks gives a single number as a measure of vibration exposure (i.e., units of vibration) and is expressed in meters per second squared (m/s²).

A. HAND-ARM VIBRATION

Application and Principle of Operation

Hand-arm vibration will generally be measured when using a hand-held power tool. First, one must determine the type of vibration that will be encountered because a different accelerometer will be used depending on whether an impact (e.g., jackhammer or chipper) or non-impact (e.g., chain saws or grinders) tool is being used. The accelerometer will be attached to the tool (or held in contact with the tool by the user) so the axes are measured while the worker grasps the tool handle. The z axis is generally from the wrist to the middle knuckle, the x axis is from the top of the hand down through the bottom of the hand and wrapped fingers, and the y axis runs from right to left across the knuckles of the hand. The measurement should be made as close as possible to the point where the vibration enters the hand.

The frequency-weighting network for hand-arm vibration is given in the International Organization for Standardization (ISO) standard ISO 5349-1 (Mechanical Vibration - Measurement and Evaluation of Human Exposure to Hand-Transmitted Vibration – Part 1: General Requirements). The human hand does not appear to be equally sensitive to vibration energy at all frequencies. The sensitivity appears to be the highest around 8-16 Hz (Hertz or cycles per second), so the weighting networks will generally emphasize this range. Vibration amplitudes, whether measured as frequency-weighted or frequency-independent acceleration levels (m/sec²), are generally used to describe vibration stress (American National Standards Institute, American Conference of Governmental Industrial Hygienists, ISO, and the British Standards Institution). These numbers can generally be read directly from the human vibration meter used. The recommendations of most advisory bodies are based on an exposure level likely to cause the first signs of Stage II Hand-Arm Vibration Syndrome (white finger) in workers.

OSHA does not have standards concerning vibration exposure. The American Conference of Governmental Industrial Hygienists (ACGIH) has developed Threshold Limit Values (TLVs) for vibration exposure to hand-held tools. The exposure limits are given as frequency-weighted acceleration. The frequency weighting is based on a scheme recommended in ISO 5349-1. Vibration-measuring instruments have a frequency-weighting network as an option. The networks
list acceleration levels and exposure durations to which, ACGIH has determined, most workers can be exposed repeatedly without severe damage to the fingers. The ACGIH advises that these values be applied in conjunction with other protective measures, including vibration control.

B. WHOLE-BODY VIBRATION

Application and Principle of Operation

The measurement of whole-body vibration is important when measuring vibration from large pieces of machinery which are operated in a seated, standing, or reclined posture. Whole-body vibration is measured across three ($x$, $y$ and $z$) axes. The orientation of each axis is as follows: $z$ is from head to toe, $x$ is from front to back and $y$ is from shoulder to shoulder. The accelerometer must be placed at the point where the body comes in contact with the vibrating surface, generally on the seat or against the back of the operator.

The measurement device is generally an accelerometer mounted in a hard rubber disc. This disc is placed in the seat between the operator and the machinery. Care should be taken to ensure that the weight of the disc does not exceed more than about 10 percent of the weight of the person being measured.

Calibration

Vibration equipment will not generally be calibrated by the user. These devices will generally be sent back to the manufacturer for calibration on an annual basis.

Special Considerations

The most widely used document on whole-body vibration is ISO 2631-1 (Evaluation of Human Exposure to Whole-Body Vibration – Part 1: General Requirements). These exposure guidelines have been adopted as ACGIH TLVs.

The ISO standard suggests three different types of exposure limits for whole body vibration, of which only the third is generally used occupationally and is the basis for the ACGIH TLVs:

1. The reduced-comfort boundary is for the comfort of passengers in airplanes, boats, and trains. Exceeding these exposure limits makes it difficult for passengers to eat, read or write when traveling.

2. The fatigue-decreased proficiency boundary is a limit for time-dependent effects that impair performance. For example, fatigue impairs performance in flying, driving and operating heavy vehicles.

3. The exposure limit is used to assess the maximum exposure allowed for whole-body vibration. There are two separate tables for exposures. One table is for longitudinal (foot to head; $z$ axis) exposures, with the lowest exposure limit at 4 to 8 Hz based on human body sensitivity. The second table is for transverse (back to chest and side to side; $x$ and $y$ axes) exposures, with the lowest exposure limit at 1 to 2 Hz based on human body sensitivity. A separate set of "severe discomfort boundaries" is given for 8-hour, 2-hour and 30-minute exposures to whole-body vibration in the 0.1–0.63 Hz range.

The ACGIH recommendations are based on exposure levels that should be safe for repeated exposure, with minimal risk of adverse effects (including pain) to the back and the ability to operate
a land-based vehicle.

Some general considerations for using vibration equipment include:

- Batteries should always be checked prior to use.
- Be careful with electrode cables. Never kink, stretch, pinch or otherwise damage the cables.
- Remove the batteries from any meter that will be stored for more than a few days.
- Protect meters from extreme heat and humidity.

**HRT Availability**

The HRT maintains the following vibration analysis equipment:

**Larson Davis Human Vibration Meter - HVM100**

The Larson Davis HVM is a portable multipurpose meter which can be used for measurement of whole-body vibration, hand-arm vibration, hand-tool vibration, vibration severity and product compliance testing. It will collect and analyze data in accord with the most current ISO requirements for hand-arm vibration and whole-body vibration exposures. It measures three input channels simultaneously, and a fourth channel calculates and stores vector sum information. Single and triaxial accelerometers attach to specialized mechanical mounting adaptors to allow measurement on a wide variety of tools and surfaces.

**C. MECHANICAL FORCE GAUGE FOR ERGONOMIC EVALUATIONS**

*Application and Principle of Operation*

Mechanical force gauges are frequently used for a wide range of force testing applications including testing of compressive and/or tensile forces. The gauges may be mounted to a test stand for even greater control and consistent results in repetitive testing applications. An easy to read concentric dial measures clockwise direction only. The dial rotates 360-degrees for tarring. A peak hold button captures peak readings. Usually the gauges are available in pound (lb), kilogram (kg) or Newton units of measure.

*Calibration*

Gauge accuracy should be checked periodically to ensure that the gauge is within its calibration limits. The calibration can be verified by applying known weight (adjusted for local gravity) to the extension hook. If adjustment is required, the gauge should be returned to the manufacturer for calibration.