SAE International™ **SURFACE VEHICLE STANDARD**

SAE J1013

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Superseding J1013 AUG1992

Measurement of Whole Body Vibration of the Seated Operator of Off-Highway Work Machines

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1. Scope—This SAE Standard defines a method for the measurement of the whole body vibration to which the seated operator of off-highway self-propelled work machines is exposed while performing an actual or simulated operation. It applies to vibration transmitted to the operator through the seat. There are no equivalent ISO Standards.

1.1 Application—In the main body of this document, conditions are defined for measuring and recording while body vibration of the seated operator of off-highway self-propelled work machines. The specification of instruments, analytic methods, and description of site and operating conditions allows the measurements to be made and reported with an acceptable precision. The procedure includes means of weighting the vibration level at different frequencies as specified in ISO 2631. A standard format for reporting spectral data is recommended.

The definitions, instruments, and analytic methods also apply to simulated tests for operator vibration as performed in laboratories.

This procedure is a measuring method only and is not intended for the evaluation or selection of seating systems.

1.2 Rationale—Superseded by ISO 2631.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J711 MAR91—Tire Selection Tables for Agricultural Tractors of Future Design
SAE J751 APR86—Off-Road Tire and Rim Classification - Construction Machines

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2.1.2 ANSI AND ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI S2.2-1959 (R-1990)—Methods for Calibration of Shock and Vibration Pickups
ISO 2631-1:1985—Evaluation of human exposure to whole body vibration—Part 1: General requirements
ISO 2041-1975—Vibration and shock vocabulary
ISO 5008-1979(E)—Agriculture wheeled tractors and field machinery—Measurement of whole-body vibration of the operator

2.1.3 IRIG PUBLICATION—Available from Secretariat, Range Commanders Council, Attn: STEWS-SA-R, White Sands Missile Range, New Mexico 88002.

IRIG Document 106—Inter Range Instrumentation Group. Magnetic Tape Recorder Reproducer Standards

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE HS J6a—Ride and Vibration Data Manual

2.2.2 ANSI PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI S1.11-1986—Specifications for Octave Band and Fractional Octave Band Analog and Digital Filters
ANSI S2.4-1976 (R-1990)—Method for Specifying the Characteristics of Auxiliary Equipment for Shock and Vibration Measurement

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3. Definitions

3.1 Whole Body Vibration—As used in this document, this term means vibration transmitted to the body as a whole through the buttocks of a seated operator.

3.2 Operator Seat—Specifically for the purposes of this document, that portion of the machine provided for the purpose of supporting the buttocks of the seated operator, including the seat suspension system.

3.3 Frequency Analysis—Process of arriving at a quantitative description of the amplitude of a vibration as a function of frequency.

3.4 Measurement Interval—The time interval over which vibration data for analysis is obtained.

3.5 Average Ground Speed—Ratio of the distance traveled during the measurement interval to the length of the measurement interval.

Other terminology used in this recommendation is in accordance with ISO 2041.

4. Letter Symbols

a - instantaneous acceleration
a_f - rms value of 1/3 octave acceleration having center frequency f
a_w - frequency weighted acceleration signal
a_{wf} - weighted rms acceleration calculated as described in 6.4.1, 6.4.2, or 6.4.3
B_e - resolution bandwidth of a frequency analysis, Hz
f - frequency
rms - root-mean-square

T - analysis time duration, seconds
m/s^2 - acceleration units, meters per second squared
Hz - hertz, standard notation for frequency, cycles per second
W_f - frequency dependent, dimensionless weighting factor
G - acceleration of gravity, by international agreement equal to 9.80665 m/s^2 at sea level
PSD - Power Spectral Density expressed as mean square acceleration per unit bandwidth $(m/s^2)^2$ Hz

5. ***Vibration Measurement Axes***—The vibration shall be measured along three mutually perpendicular axes, passing through a point on the interface between the operator and the seat. These axes are substantially vertical, longitudinal, and lateral (a_z, a_x, and a_y) with respect to the orientation of the seated operator and are defined in Figure 1. The operator should sit in a typical upright position and should keep both hands in a normal position for operating the controls as suggested by Figure 1. The seat shall be adjusted per manufacturer's instructions.

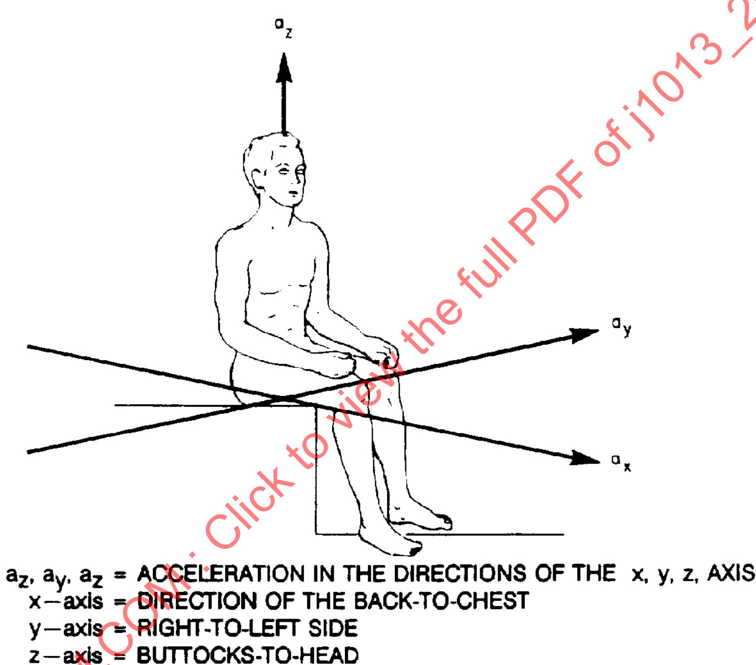

FIGURE 1—MEASUREMENT AXES

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6. *Instruments*

6.1 Acceleration Transducers—Vibration shall be sensed by acceleration transducers (accelerometers) in the mounting device described in 6.2.1. The accelerometers, together with their associated amplifiers, shall be capable of measuring rms acceleration levels ranging from 0.1 m/s^2 to 10 m/s^2 with a crest factor as great as three. During the test the accelerometer and amplifier, with proper calibration for the test, shall have an accuracy of at least ±2.5% of the actual rms vibration levels in the frequency range from 0.3 to 40 Hz and at least ±6% of the actual rms vibration levels in the frequency range from 40 to 80 Hz as calculated from the instrument specifications and the actual test conditions. See 6.5 for accuracy and frequency response requirements during calibration. The resonant frequency of the accelerometers shall be greater than 300 Hz. The accelerometers shall sustain instantaneous acceleration levels up to 100 m/s^2 without damage. Accelerometers in the mounting device (see 6.2.1) and on the seat mounting base (see 6.2.2) should be of similar type or model, with similar signal to noise ratios.

6.2 Transducer Mounting

6.2.1 VIBRATION TRANSMITTED TO THE OPERATOR—The accelerometers for sensing vibration transmitted to the operator shall be attached near the center of a thin disc 200 mm ± 5 mm in diameter placed between the operator and the seat cushion. The primary requirements for the disc are that it should provide a suitable mounting for the accelerometers, shall not adversely affect operator comfort, and shall not significantly distort the buttock-cushion load distribution. Either a rigid or semirigid disc may be used; however, the semirigid disc is recommended especially for soft or highly contoured cushions. Suggested disc designs are shown in Figures 2 and 3. Either disc shall be placed on the seat so that the accelerometers are located midway between the ischial tuberosities and are aligned parallel to the measurement axes (Figure 1). The disc should be taped or similarly attached to the cushion to maintain its location.

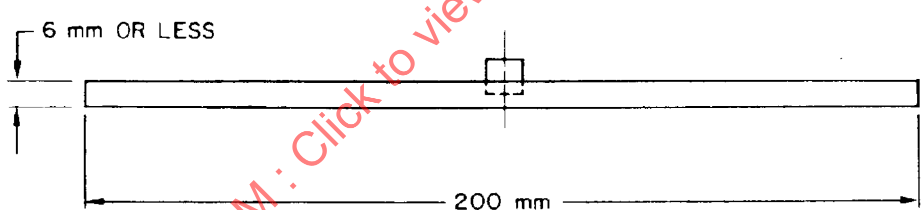

FIGURE 2—SUGGESTED DESIGN FOR RIGID DISC WITH ACCELEROMETER ASSEMBLY BONDED AT CENTER

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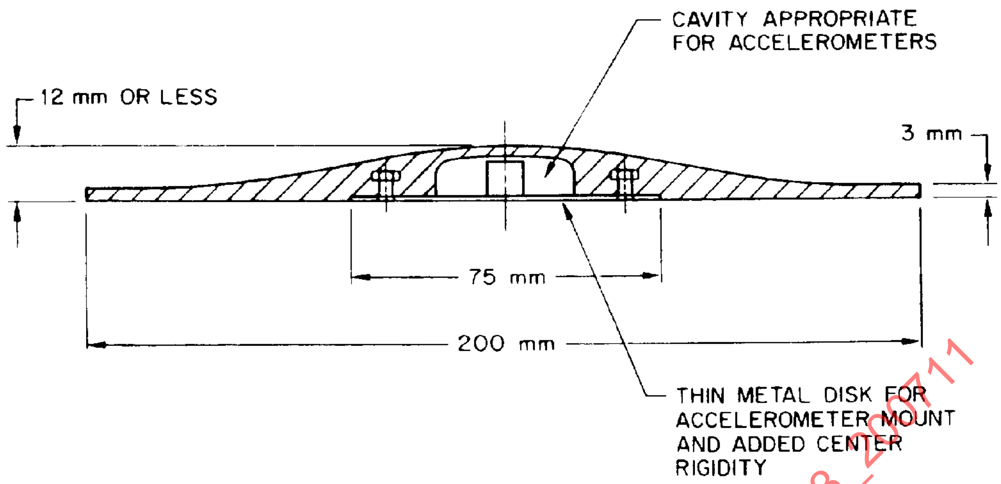

FIGURE 3—SUGGESTED DESIGN FOR SEMIRIGID DISC OF APPROXIMATELY 80 TO 90 DUROMETER (A-SCALE) MOLDED RUBBER, PLASTIC, ETC.

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6.2.2 VIBRATION AT THE SEAT MOUNTING BASE—The vibration of the machine at the base of the seat shall be sensed by accelerometers attached to a rigid portion of the machine or seat mounting base. The accelerometers shall be located within the vertical projection of seat cushion, not more than 100 mm from the vertical, longitudinal plane through the center of the seat, and shall be aligned parallel to the measurement axes (see Figure 1).

6.3 Magnetic Tape Recorder—The electrical signals generated by the transducers may be recorded on magnetic tape for later analysis. The magnetic tape recorder, with proper calibration for the test, shall be capable of a replay accuracy of at least ±3% of the rms value of the total signal within the frequency range from 0 to 80 Hz, as calculated from the instrument specifications and the actual test conditions. The tape recorder should meet current standards for alignment and distortion characteristics (see IRIG Document 106).

6.4 Frequency Weighting—Frequency weighting may be achieved in any of three ways: by digital analysis of the acceleration into constant bandwidth levels, weighting the levels in individual bands and recombination; by analysis of the acceleration into 1/3 octave band levels, weighting the levels in individual bands and recombination; or by the use of frequency weighting analog or digital filters. The three methods generally prescribe the calculation of the weighted acceleration over the range of 1 to 80 Hz; however, the weighted acceleration may be calculated over a reduced frequency range if such a range is specified by an approved standard that governs the conduct of the specific test. The three methods are described in 6.4.1, 6.4.2, and 6.4.3 in decreasing order of accuracy (accuracy as resulting from practical considerations of analysis equipment).

6.4.1 CONSTANT BANDWIDTH METHOD—Each vibration tape recording, or vibration signal where a tape recorder is not used, shall be analyzed into constant bandwidth acceleration levels over the frequency range from 1 to 80 Hz by appropriate digital methods. The length of the measurement interval, T (in seconds), and resolution bandwidth, B_e (in Hz), shall satisfy the following equation:

$$2B_eT \geq 140 \qquad B_e \leq 0.3\text{Hz} \qquad \text{(Eq. 1)}$$

The mean square value of the digitized time data (time domain) should be compared to the mean square value of the spectral estimate (frequency domain). If these values differ, then the analysis procedure should be reviewed and corrected as necessary for possible errors such as improper scaling, wrong correction factor for the data time window (sampling window), or program errors.

The constant bandwidth rms levels shall each be multiplied by weighting factors calculated for each center frequency from Figure 4 for a_z (vertical) vibration, or Figure 5 for a_x or a_y (horizontal) vibration. A weighted acceleration value, a_{wf}, shall be calculated as the square root of the sum of the squares of the weighted constant bandwidth levels over the range 1 to 80 Hz.

6.4.2 ONE-THIRD OCTAVE BANDWIDTH METHOD—Each vibration tape recording, or vibration signal where a tape recorder is not used, shall be analyzed into 1/3 octave component accelerations for the center frequencies of Table 1. The rms value of each component, a_f, shall be averaged over the duration specified for the measurement. The 1/3 octave values shall each be multiplied by the weighting factors, W_f, listed in Table 1, and a weighted acceleration, a_{wf}, value calculated for each recording as in the following equation:

$$a_{wf} = \left[\sum_{f=1}^{80} w_f^2 a_f^2\right]^{1/2} \qquad \text{(Eq. 2)}$$

To satisfy the following equation:

$$2B_eT \geq 140 \qquad \text{(Eq. 3)}$$

The minimum measurement interval, T, is 300 s to insure sufficient statistical precision.

Because of the bandwidth of 1/3 octave data, this method includes a slightly wider frequency range than the other methods. In practice, this will usually have a negligible effect on the results.

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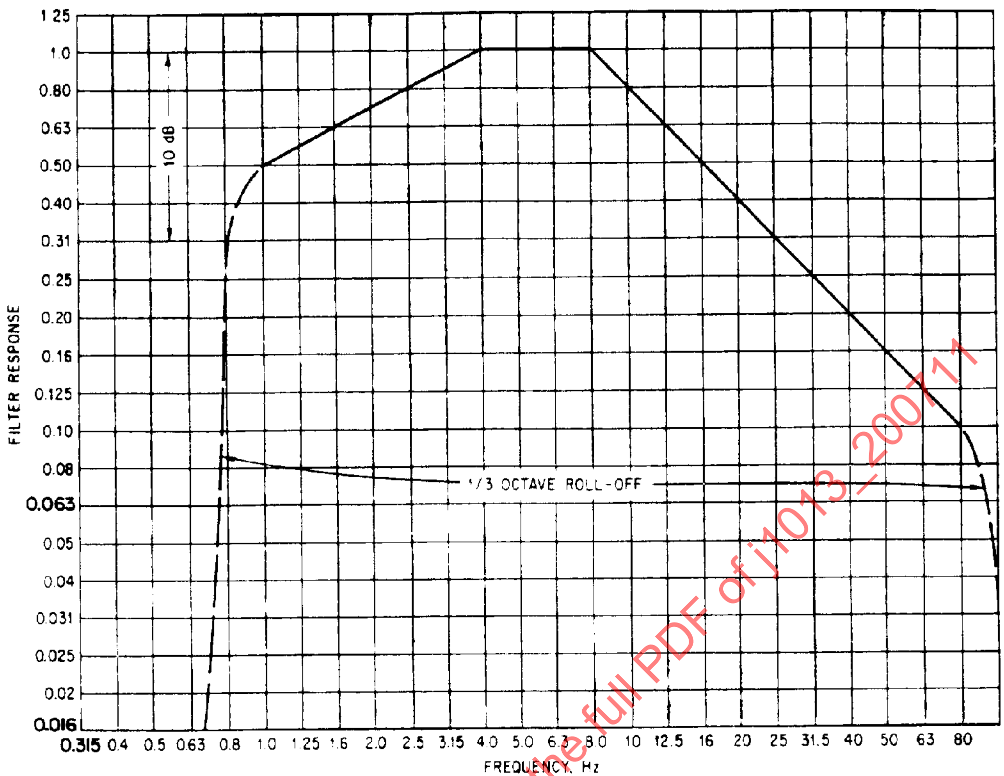

FIGURE 4—FILTER RESPONSE IN VERTICAL MODE, a_z

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TABLE 1—VIBRATION WEIGHTING FACTORS

1/3 Octave Center Frequency, f	Weighting Factor, W_f Vertical Vibration	Weighting Factor, W_f Horizontal Vibration	1/3 Octave Center Frequency, f	Weighting Factor, W_f Vertical Vibration	Weighting Factor, Wf Horizontal Vibration
1.0	0.50	1.00	10.0	0.80	0.20
1.25	0.56	1.00	12.5	0.63	0.16
1.6	0.63	1.00	16.0	0.50	0.125
2.0	0.71	1.00	20.0	0.40	0.100
2.5	0.80	0.80	25.0	0.315	0.080
3.15	0.89	0.63	31.5	0.25	0.063
4.0	1.00	0.50	40.0	0.20	0.050
5.0	1.00	0.40	50.0	0.16	0.040
6.3	1.00	0.315	63.0	0.125	0.0315
8.0	1.00	0.25	80.0	0.10	0.025

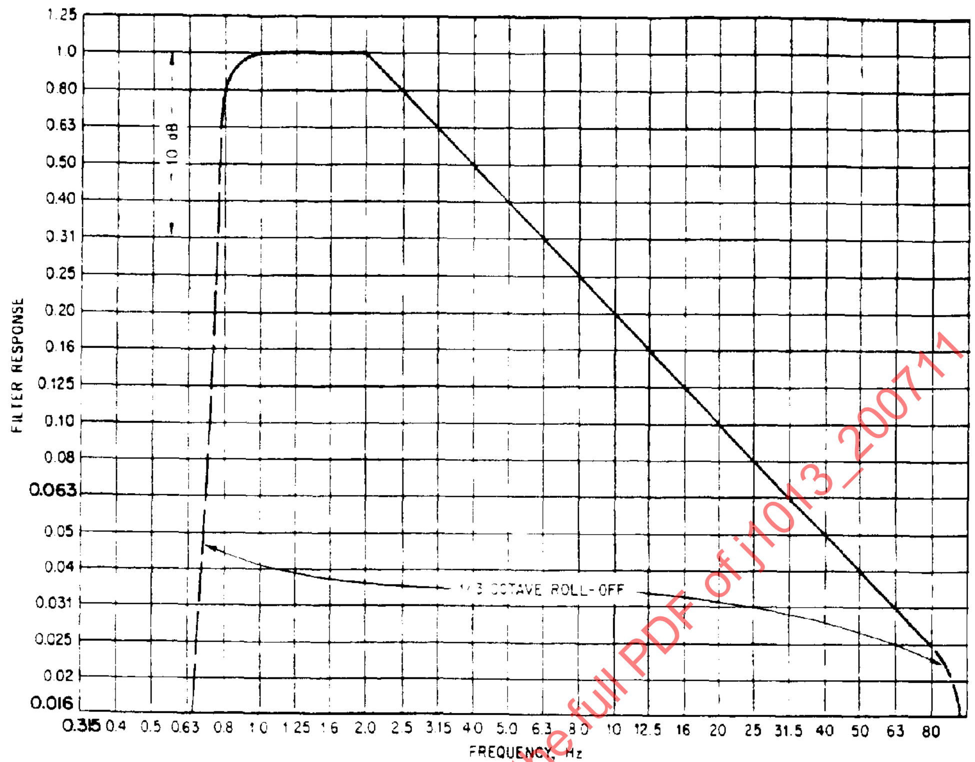

FIGURE 5—FILTER RESPONSE FOR a_x AND a_y

6.4.3 FREQUENCY WEIGHTING FILTERS—An analysis system based on this method shall consist of a frequency weighting filter incorporated between the transducer and a time integration stage. Both the filter and the integrator may be implemented by analog or digital means. The weighting network shall have an insertion loss conforming to the curve in Figure 4 for a_z (vertical) vibration, or Figure 5 for a_x or a_y (horizontal) vibration. The loss shall not deviate from the curve by more than ± 1 dB for frequencies between 1.1 and 10 Hz, and ± 2 dB at any other frequency. The integration stage shall be capable of indicating the integral of the square of weighted acceleration, a_w, for the measurement interval of the test. That is, for an analog integrator,

$$(a_{wf})^2 = \frac{1}{T}\int_{t=0}^{T} a_w^2 \cdot dt \qquad \text{(Eq. 4)}$$

and for a digital integrator,

$$(a_{wf}) = \frac{1}{N}\sum_{n=1}^{N} a_w(n)^2 \qquad \text{(Eq. 5)}$$

Where conditions permit, a minimum measurement interval of 300 s shall be used.

NOTE—The measurement interval (methods of 6.4.1, 6.4.2, and 6.4.3) when testing on a specific test track shall be the time required to traverse the track.

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