

**CLASSIFICATION OF EARTHMOVING MACHINES FOR
VIBRATION TESTS OF OPERATOR SEATS**

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. **Scope**—This SAE Recommended Practice pertains to operator seats for the earthmoving category of off-road self-propelled work machines as defined in SAE J1116 JUN81. This recommended practice defines classes of earthmoving machines having similar characteristics which affect the vibration transmitted to the operator through the operator seat. This recommended practice establishes input data parameters for conducting operator seat vibration tests for the various classes. The purpose is to aid in the selection of an operator seat for a specific machine model and to reduce the amount of testing necessary to determine compliance with applicable standards and/or recommendations. Test procedures are specified in SAE J1384. Instrumentation and measurement procedures are specified in SAE J1013 JAN80.

2. **References**

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

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

SAE J1013 JAN80—Measurement of Whole Body Vibration of the Seated Operator of Off-Highway Work Machines

SAE J1057 JUN81—Identification Terminology of Earthmoving Machines

SAE J1116 JUN81—Categories of Off-Road Self-Propelled Work Machines

SAE J1384—Vibration Performance Evaluation of Operator Seats

2.1.2 ISO PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ISO 7096—Earth-moving machinery—Operator sSeat—Measurement of transmitted vibration

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3. Definitions

3.1 Letter Symbols

B_e - resolution bandwidth of a frequency analysis, Hz

PSD - Power Spectral Density expressed as mean square acceleration per unit bandwidth $(m/s^2)^2/Hz$

rms - root-mean-square

T - analysis time duration, seconds

3.2 Operator Seat—That portion of the machine provided for the purpose of supporting the seated operator, including the seat suspension system, if any.

3.3 Earthmoving Machine Class—Machines having sufficiently similar vibration characteristics in representative working conditions that they can be represented by a standard vibration in a laboratory dynamic test for operator vibration.

4. Machine Classification

4.1 Basic specifications for machines defined as having similar vibration characteristics are identified by class in Table 1. The machine terminology is defined in SAE J1057 JUN81.

TABLE 1—EARTHMOVING MACHINE CLASSES

Class	Machine	Configuration
1	Tractor-Scraper	Open bowl or elevating Two axles, articulated steer Front axle or two axle drive No axle suspension and no vibration absorbing hitch
2	Tractor-Scraper	Same as Class 1, except with either front axle suspensions or vibration absorbing hitch
3	Wheel Loader Wheel Tractor	Rigid or articulated frame Two wheel or four wheel drive Excluding three wheel machines, skid-steer machines, and utility under 5000 kg operating weight Same configuration range as Wheel Loader
4	Crawler Tractor Crawler Tractor	All All

4.2 The earthmoving machine classes of Table 1 include a broad range of machine sizes within each class. The vibration spectra of Section 4 are representative envelopes for the various size machines within the class to allow a single test to evaluate a single operator seat suitable for use on any machine within the class.

5. Vibration Characteristics

5.1 The vibration spectra for each class of machine are shown in Figures 1–4. Exact equations for the acceleration power spectral density curves of Figures 1–4 are included as Tables 2 and 3. These curves, defined by these equations, are the target spectra to be produced at the base of the seat for the random vibration tests of SAE J1384.



FIGURE 1—CLASS 1 - 2.35 M/S² TRUE RMS ACCELERATION

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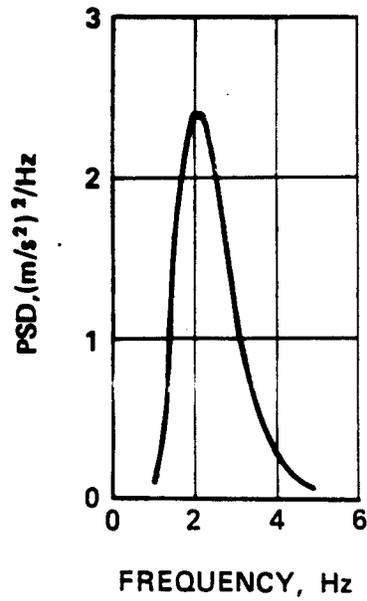


FIGURE 2—CLASS 2 - 2.05 M/S² TRUE RMS ACCELERATION

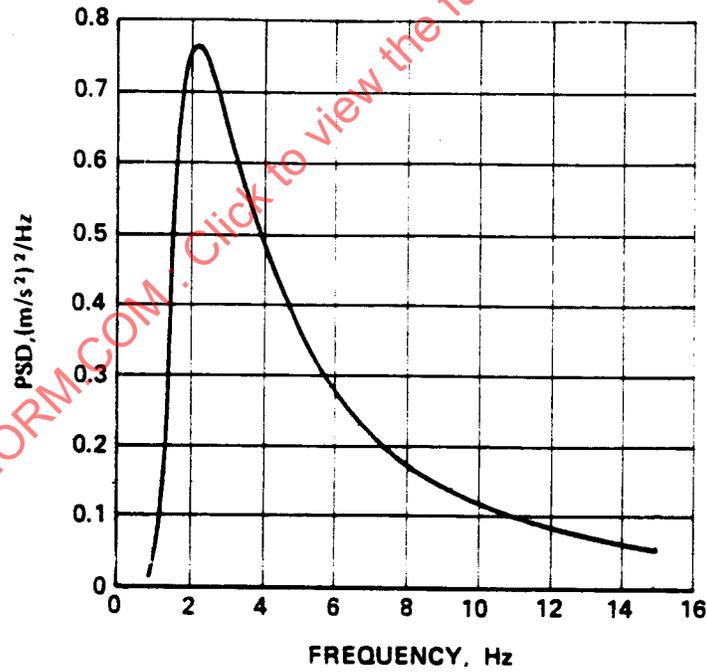
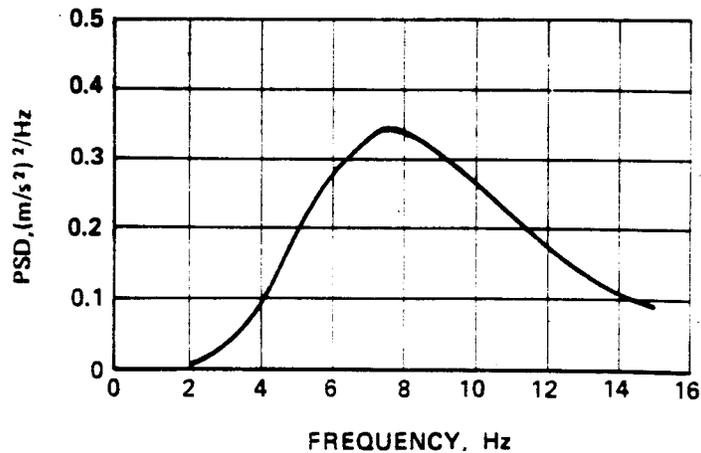


FIGURE 3—CLASS 3 - 1.90 M/X² TRUE RMS ACCELERATION

FIGURE 4—CLASS 4 - 1.60 M/S² TRUE RMS ACCELERATION**TABLE 2—EQUATIONS FOR PSD CURVES**

The PSD curves are defined by the magnitudes of the frequency response functions, shown below, of Butterworth type filters.

$$\text{Class 1 PSD} = 5.30 (\text{HP}_{24})^2 (\text{LP}_{24})^2$$

$$\text{Class 2 PSD} = 2.72 (\text{HP}_{24})^2 (\text{LP}_{24})^2$$

$$\text{Class 3 PSD} = 1.11 (\text{HP}_{24})^2 (\text{LP}_{24})^2$$

$$\text{Class 4 PSD} = 0.79 (\text{HP}_{12})^2 (\text{LP}_{12})^2$$

Where:

$$\text{LP}_6 = \frac{1}{1+S}$$

$$\text{LP}_{12} = \frac{1}{1 + 1.414S + S^2}$$

$$\text{HP}_{12} = \frac{S^2}{1 + 1.414S + S^2}$$

$$\text{LP}_{24} = \frac{1}{1 + 2.613S + 3.414S^2 + 2.613S^3 + S^4}$$

$$\text{HP}_{24} = \frac{S^4}{1 + 2.613S + 3.414S^2 + 2.613S^3 + S^4}$$

$$S = \frac{jf}{F_c} \quad j = \sqrt{-1} \quad f = \text{Frequency, Hz}$$

F_c = Filter Cut-Off Frequency, Hz, per Table 3

TABLE 3—FILTER CUT-OFF FREQUENCIES, HZ

Class	LP ₆	LP ₁₂	HP ₁₂	LP ₂₄	HP ₂₄
1	—	—	—	2.5	1.5
2	—	—	—	3.0	1.5
3	3.5	—	—	—	1.5
4	—	9.0	6.5	—	—

HP and LP designate high-pass and low-pass filters of the Butterworth type. The subscripts state the filter slope in dB/Oct. Therefore, the above table completely defines band-pass filters in terms of cut-off frequencies and slopes.

- 5.2 Table 4 further defines the test input levels and shows the tolerances allowed on the actual test input PSD at the base of the seat.

TABLE 4—TEST INPUT LEVELS AND TOLERANCES

1	2	3	4	5	6
Earth-moving Machine Class	Reference True rms Acceleration, m/s ²	Weighted rms Acceleration, m/s ²		Tolerance on Test Input PSD Curve ⁽¹⁾	Minimum % of Test True rms Within Frequency Bonds ¹
		Nominal Value	Tolerance		
1	2.35	1.73	±10%	±1 dB between 1.5 and 2.5 Hz ±2 dB between 1.0 and 3.0 Hz	70% between 1.5 and 2.5 Hz 95% between 1.0 and 3.0 Hz
2	2.05	1.59	±10%	±1 dB between 1.5 and 3.0 Hz ±2 dB between 1.0 and 3.5 Hz	80% between 1.5 and 3.0 Hz 95% between 1.0 and 3.5 Hz
3	1.90	1.65	±10%	±1 dB between 1.5 and 6.0 Hz ±2 dB between 1.0 and 11.0 Hz	70% between 1.5 and 6.0 Hz 95% between 1.0 and 11.0 Hz
4	1.60	1.40	±10%	±1 dB between 5.0 and 11.0 Hz ±2 dB between 3.0 and 13.0 Hz	80% between 5.0 and 11.0 Hz 95% between 3.0 and 13.0 Hz

FOR ALL TESTS: CURVE AND TOLERANCE FOR PROBABILITY DENSITY FUNCTION: Under the conditions that the acceleration at the base of the seat shall be sampled at a minimum of 50 data points per second and analyzed into amplitude cells of no greater than 50% of the total true rms acceleration, the probability density function must be within ±20% of the ideal Gaussian function between ±200% of the total true rms acceleration, with a minimum of 93% of the data within ±200% of the total true rms acceleration, and with no data exceeding ±400% of the total true rms acceleration.

NOTE 1—Column 2 is a reference value for the true rms acceleration defined by the curves and equations of Figures 1–4 and Tables 2 and 3.

NOTE 2—Column 3 is the target value for the frequency weighted rms acceleration test input at the base of the seat. Column 4 is the allowed tolerance on Column 3.

NOTE 3—Column 5 is the allowed tolerance on the actual test input PSD curve at the base of the seat. This includes a restrictive tolerance of ±1 dB on the PSD curve in the stated frequency range which contains the major part of the test vibration, and a less restrictive tolerance of ±2 dB on the PSD curve over a wider frequency range.

NOTE 4—Column 6 is an additional requirement which states the minimum percent of the actual test true rms acceleration which must be within the stated range of frequencies. The frequencies stated in Columns 5 and 6 are band-edge frequencies.

1. To be analyzed in accordance with the restrictions on time (T) and bandwidth (B_g) of paragraph 5.4.1 of SAE J1013 JAN80.

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- 5.3** Any means, including double integrators, analog signal generators and filters, and digital signal generators with digital to analog converters, may be used to produce the required PSD and rms characteristics at the base of the seat for the random vibration test.
- 5.4** Table 4 also specifies the acceleration probability density function required of the random vibration at the base of the seat during the test.

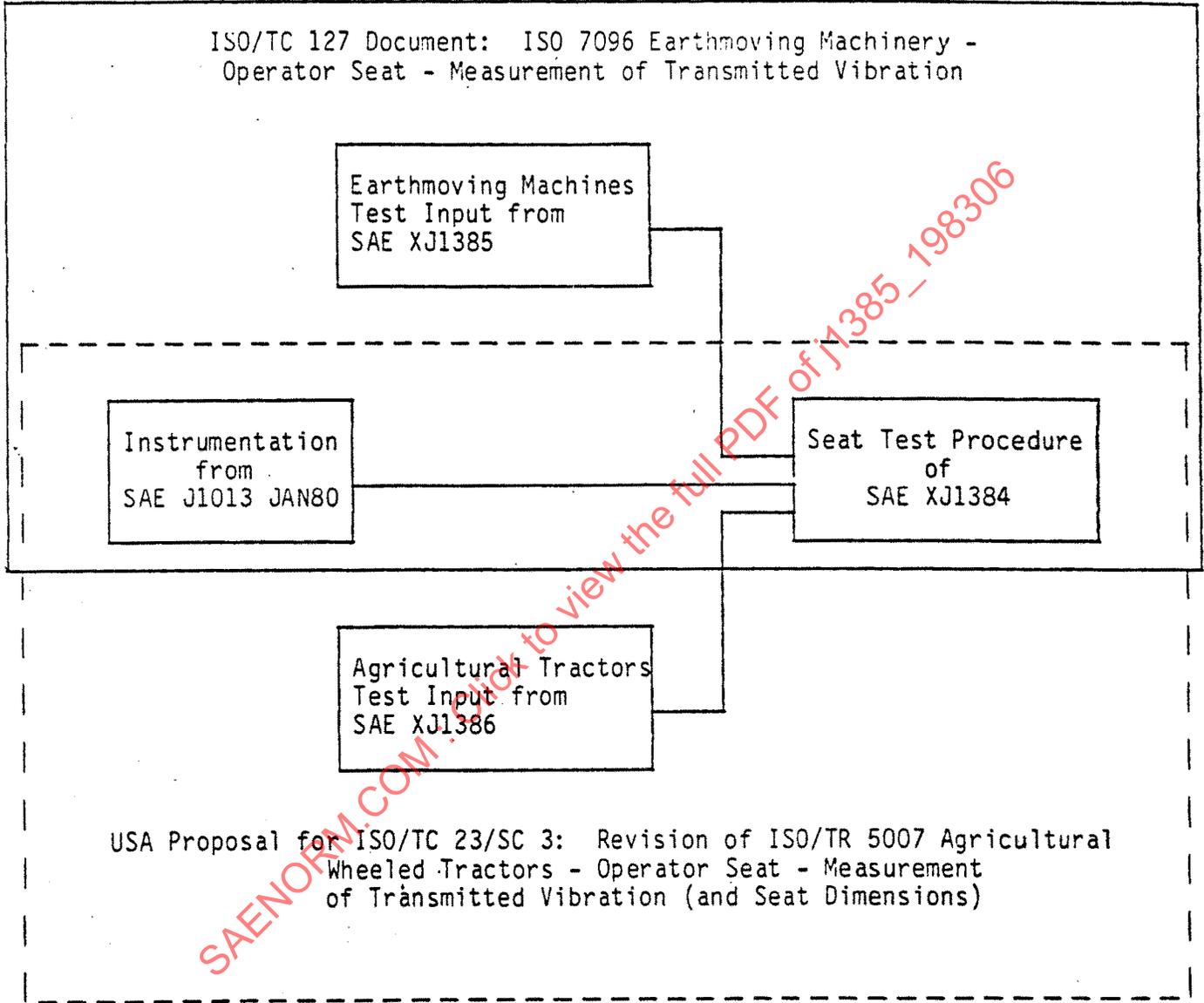
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Rationale—Introduction:

This document is to be used in combination with SAE J1013 JAN80—Measurement of Whole Body Vibration of the Seated Operator of Off-Highway Work Machines.



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Similarly, seat tests for other types of machines and vehicles can be developed within this system by adding documents corresponding to SAE XJ1385 and SAE XJ1386. SAE XJ1385 and SAE XJ1386 provide specific test inputs to allow operator seats to be evaluated per the procedure of SAE XJ1384.

One of the objectives of this document is to provide consistency of SAE recommended practices for all types of off-road machines and consistency of SAE and ISO standards.

Experience has shown that laboratory test results are more repeatable than test track results. Only the vertical direction is tested in this document. Although horizontal direction isolators for seats have some good applications, for various good reasons they are not included in the SAE test documents which consider more widespread and general application of seats.

General:

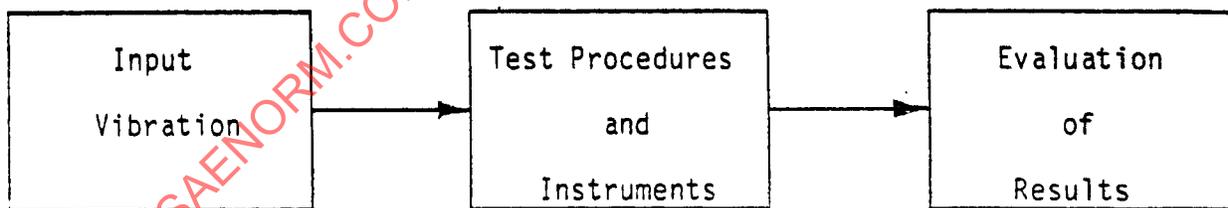
The design of seat systems for vibration isolation of the operator must take into account the following factors:

1. The vibration transmitted to the operator over the normal working day should be within reasonably tolerable levels.
2. The vibration isolation of the operator should not be such as to encourage traveling too fast for the terrain.
3. The vibration isolation of the operator should not be such that the operator does not have a good feel for the tractor or machine in precarious situations.
4. The seat suspension should be as simple as possible, consistent with the preceding items, for satisfactory reliability.

Overdesign of the seat system with a view only of providing maximum vibration isolation of the operator is inconsistent with the other three factors listed.

Technical Rationale:

The seat test can be represented by the flow diagram below.



This rationale statement is divided into sections in accordance with the flow diagram.

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Input Vibration:

SAE XJ1385, for earthmoving machines. The test input vibration specified in the document was derived by the following steps:

1. The vertical vibration was recorded on the machine at the base of the operator's seat during representative hardworking job cycles. During the tests for recording the data, operators were instructed to operate the machines in the most hardworking manner they believed they would maintain for a working day. Engineers experienced in the use of the machines monitored the tests to insure that the instructions were followed but not overdone to an extent abusive of the machines.
2. The data was digitally analyzed into power spectral density (PSD) estimated using 160 degrees of freedom to achieve a statistical precision of ± 0.75 dB at a confidence coefficient of 0.9 for each point on the PSD estimate of each individual machine tested.
3. For each machine class, a mean PSD was calculated from the data collection to provide a representation of the shape of the frequency content distribution across the spectrum.
4. The simplest bandpass filter that reasonably represented the mean PSD of step 3 was calculated. This was necessary to allow the freedom to use existing and less expensive analog methods of synthesizing command signals for the vibration test stand. The constraints on the filters were as follows:
 - a. Depending on the low frequency cutoff of the bandpass filter, the low frequency slope has to be steep enough to attenuate the very low frequency (below 1 Hz) acceleration to avoid creating large movements of the test stand at the very low frequencies. Such movements, if allowed, would not be relevant to vibration evaluation but would require excessive movement capability of the test stand.
 - b. The slopes of the PSD shape had to be 12, 24 or 48 dB/oct so that real time analog filters would be 6, 12 or 24/dB oct.
5. The PSD level of the filter shape was increased until the shape provided a reasonable envelope of the data collection for the machine class. A constraint was that the total rms content of the test PSD should not greatly exceed that of the most severe data. Necessarily in such a process, an individual PSD point from a given field test might exceed the PSD derived for the laboratory test input vibration. This was justified because the remainder of the PSD data points for such a given field test would fall sufficiently within the laboratory test values to compensate for the data point falling outside.

NOTE—It is possible in a field measurement to exceed the test input vibration of the document. However, where such a case arises, it will be observed that such a level is not representative of all day operation and less representative of operation day after day. The acceptance level of the document is based on reasonably tolerable vibration levels for eight hours per day vibration exposure every day of the operators' working years. Measured levels of machine seat base vibration during field tests may exceed the test input levels of the document during brief periods of the working day, but this has been accounted for in the test input for the document.

The test input vibration specified in SAE XJ1385 is identical to that specified in ISO 7096, which was found to be consistent with the data available from the member nations of ISO/TC 127.

For both SAE XJ1385 and SAE XJ1386, The test input is specified in terms of the acceleration power spectral density (PSD) and the acceleration probability density function (PDF). This is both the most simple and most accurate form of specifying the test input vibration. If tests at different laboratories produce the PSD and PDF test inputs of this document, then the tests are identical, regardless of how the vibration test stand signal was synthesized and regardless of the quality of the vibration test stand.