

# SURFACE VEHICLE RECOMMENDED PRACTICE

an American National Standard

**SAE** J1384

Issued 1983-05

## VIBRATION PERFORMANCE EVALUATION OF OPERATOR SEATS

### 1. PURPOSE:

The vibration performance of operator seats for agricultural tractors and earthmoving machines depends on the characteristics of the seat, the machine, and the operator. This recommendation defines a method utilizing human subjects (operators) for measuring and evaluating seat performance in the laboratory as a function of machine type and operator weight.

The method measures the frequency weighted root mean square acceleration transmitted to the operator at the seat/buttock interface (whole body vibration) during simulated machine vibration on a vibration test stand or ride simulator.

This procedure evaluates only the vertical vibration performance and should not be considered a comprehensive seat evaluation procedure.

### 2. SCOPE:

This recommendation applies to operator seats which may be fitted to agricultural wheeled tractors per SAE J1150 (December 1976) and/or earthmoving machines per SAE J1057 JUN81. Agricultural wheeled tractors and earthmoving machines having similar vibration spectra are grouped into defined classes with corresponding test vibration input spectra defined for each class in SAE J1385 and SAE XJ1386.<sup>1</sup> Performance for all applications within a defined class requires tests with subjects of specified weights.

The specified power spectral density at the seat mounting base defines the response required from the vibration test stand during a given laboratory seat test.

<sup>1</sup> Document unavailable for inclusion in the 1984 Handbook.

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## 3. DEFINITIONS:

## 3.1 LETTER SYMBOLS:

- $a_z$  = the vertical component of acceleration (See Figure 1, J1013 JAN80).
- rms = root-mean-square.
- $a_{wf}$  = weighted rms acceleration calculated as described in SAE J1013 JAN80.
- $a_{wFB}$  =  $a_{wf}$  at the base of the seat (7.3.2).
- $a_{wFS}$  =  $a_{wf}$  at the seat transducer disc (7.3.4).
- PDF = Probability Density Function of acceleration amplitudes, generally Gaussian.
- PSD = Power Spectral Density expressed as mean square acceleration per unit bandwidth  $(m/s^2)^2/Hz$ .
- SIP = Seat Index Point (J1163 JAN80).

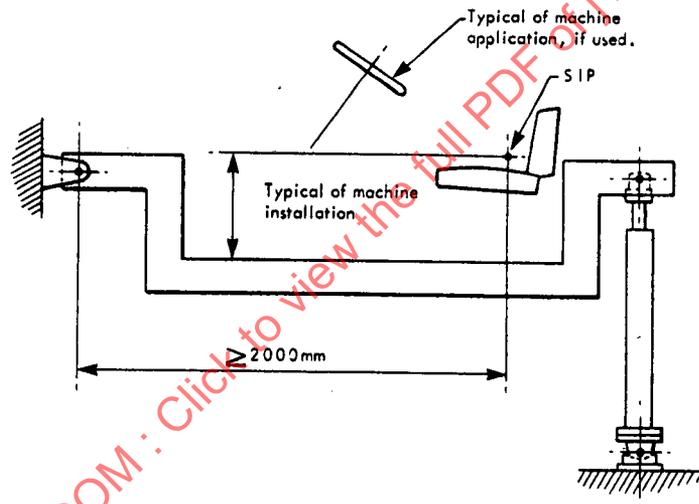


FIGURE 1 - Diagram of a Simple Pivoting Type Vibration Test Stand for Operator Seat Tests

- 3.2 Whole Body Vibration: Vibration transmitted to the body as a whole through the buttocks of a seated operator.
- 3.3 Agricultural Tractor Class: A group of agricultural wheeled tractors having similar vibration characteristics as defined in SAE XJ1386.
- 3.4 Earthmoving Machine Class: A group of earthmoving machines having similar vibration characteristics as defined in SAE J1385.
- 3.5 Operator Seat: That portion of the tractor or machine provided for the purpose of supporting the seated operator, including the seat suspension system, if any.

3.6 Suspension Oscillation Range: The vertical displacement of the suspended portion of the seat at approximately the fore and aft location of the SIP as the suspension is stroked from top-stop to bottom-stop, but not including any compression of the stops. Seat adjustments are to be in their center positions per Section 4 of SAE J1163 JAN80.

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

#### 4. TEST EQUIPMENT:

4.1 Instrumentation: Acceleration measuring equipment and procedures shall conform to SAE J1013 JAN80. This recommendation requires that the  $a_z$  component of acceleration be measured on the seat mounting base and at the seat/operator interface.

#### 4.2 Vibration Test Stand:

4.2.1 Physical Characteristics: The minimum required facility is an electrohydraulic feedback control system with one degree of freedom along the direction of  $a_z$ . The system shall have a dynamic response capable of driving the mounting base of the loaded seat in accordance with the defined seat spectra.

The transfer function characteristics of the facility may be compensated for during the synthesis of the command input signal in order that  $a_z$  output PSD and PDF requirements are satisfied at the seat mounting base. Any appropriate digital or analog method may be used to generate the command signal providing the output PSD and PDF requirements are satisfied at the seat mounting base.

The moving portion of the vibration test stand shall consist of a platform to provide for the seat mounting base and flat floor space for operator foot support. The stand shall be constrained to travel in an essentially vertical direction and be free from resonances and nonlinearities which would distort the output vibration beyond the correction capability of signal compensation.

If the vibration test stand is of the pivoting type shown in Figure 1, the radius from the arm pivot to the SIP shall be at least 2000 mm, and the seat mounting base accelerometer shall be mounted the same distance ( $\pm 20$  mm) from the pivot as the seat disc accelerometer. The following technical characteristics are only for the purpose of assisting in the selection of a vibration test stand.

Working frequency range = 0.5-20 Hz.

Piston stroke = 175 mm minimum (allowance for variable level at 0 Hz should be in addition to 175 mm).

4.2.2 Safety Recommendations: The vibration test stand should have failsafe provisions capable of automatic shutdown when the seat mounting base acceleration exceeds  $15 \text{ m/s}^2$  for any reason. (Maximum dynamic thrust force of  $1.5 \times$  mass of platform, seat and subject.) It is preferred that this provision be a hydraulic means, such as a supply pressure relief valve and/or a load limiting valve across the piston of the actuator cylinder. If an acceleration transducer is used as the sensor for safety purposes, its signal should be passed through a low pass filter with a 20 Hz cutoff frequency to avoid automatic shutdown from high frequency components beyond the hydraulic capability of the test stand. If the test stand is not of the hydraulic type, adequate safety devices should be used.

The pump and/or servo-valves should be sized to limit the test stand velocity to  $1.3 \text{ m/s}$ , and the accumulator should be of the minimum size required to provide the proper system response.

Failsafe shutdown switches should be provided to both the subject (operator) in the test seat and the operator of the test facility. The shutdown switches should shut down the hydraulic power supply and actuate a valve to release the system hydraulic pressure.

In all tests, the excitation vibration should be increased slowly to allow the test to be terminated at the request of the person in the seat.

## 5. TEST ARRANGEMENT:

5.1 Test Seats: The operator seat shall be representative of actual or intended series production with regard to construction, static and vibration characteristics and other features which may affect the vibration test results.

The seat shall be mounted on the vibration test stand at a height above the platform representative of the machine installation.

Before the test, suspension seats shall be run-in under the conditions set forth by the manufacturer. If the manufacturer does not state such conditions, then the seat shall be run-in for a minimum time duration of 5 h. For this purpose, the seat buttock cushion shall be loaded with a 75 kg mass such as lead shot (equivalent to 100 kg operator), and a sinusoidal input vibration shall be applied at approximately the suspension natural frequency and of an amplitude to cause full motion of the seat suspension. Care must be taken to insure against overheating the shock absorber during the run-in.

The seat shall be adjusted for the stature and weight of the subject (operator) according to the manufacturer's instructions.

5.2 Test Subjects: Tests shall be carried out with two test persons: one with a total mass of 55 kg (-0%, +10%) of which not more than 5 kg may be carried in a weighting belt around the waist; the other with a total mass of 98 kg (-0%, +10%) of which not more than 8 kg may be carried in the belt.

## 5.2 (Continued):

Persons shall sit naturally in the seat with feet flat on the platform and hands folded on the lap. If a simulated steering wheel is provided on the platform, it should be representative of the machine layout, and the hands should be placed on the steering wheel as typical of machine operation.

The persons shall be properly instructed to insure a passive behavior with respect to the seat during all tests.

6. TEST INPUT VIBRATION:

- 6.1 SAE XJ1386 defines the test input vibration for tests of seats for agricultural wheeled tractors. SAE J1385 defines the test input vibration for tests of seats for earthmoving machines.
- 6.2 Seats for agricultural wheeled tractors or earthmoving machines meeting the criteria of a class per SAE XJ1386 or SAE J1385, respectively, shall be tested using the corresponding  $a_z$  test spectrum defined for the class.
- 6.3 Test input vibrations for agricultural wheeled tractors or earthmoving machines not in a defined class per SAE XJ1386 and SAE J1385, respectively, may be obtained by actual field or work site tests. It is recommended that the machines be operated in several typical work situations while tape recording  $a_z$  acceleration on the seat mounting base per SAE J1013 JAN80. PSD spectra from reasonably stationary segments of this data shall be selected and averaged together in proportion to the actual time spent in each such segment during a typical working day. The resulting PSD spectra representing typical all-day machine operation shall be used for vibration test stand duplication and seat evaluation.

Alternately, for agricultural wheeled tractors not in a defined class, the PSD spectra per SAE J1013 JAN80 procedures may be obtained while operating the tractor on the OECD "smooth" test track at a speed of  $12 \pm 0.5$  km/h. The test track and the tractor operating procedures are defined in Ref. 8. It is, however, recommended that the seat test itself still be conducted on a vibration test stand reproducing this PSD (and PDF) in accordance with the procedures set forth herein.

7. TEST PROCEDURE:

- 7.1 Test Arrangement: The seat to be tested shall be mounted on the vibration test stand of 4.2 in accordance with the test seat arrangement of Section 5. The measurement instruments shall be selected, arranged and calibrated according to SAE J1013 JAN80.
- 7.2 Test for Damping: For suspension seats only, the seat shall be loaded with a 75 kg mass such as lead shot (equivalent to 100 kg operator). The shot may be contained equally in two equal-size bags, suitable for secure and symmetrical placement on the seat buttock cushion in the approximate operator seating location.

- 7.2.1 A sinusoidal vibration with a peak-to-peak displacement amplitude of 40% of the suspension oscillation range shall be applied to the base of the seat at the resonant frequency of the suspension ( $\pm 0.1$  Hz). If the resonant frequency is greater than 2 Hz, the excitation input shall be a sinusoidal vibration with a peak-to-peak acceleration amplitude in  $m/s^2$  equal to:
- 0.16 x (40% of the suspension oscillation range measured in millimeters).
- 7.2.2 The test shall be repeated to obtain three consecutive test runs in which the frequency weighted rms acceleration values ( $a_{wf}$  according to SAE J1013 JAN80), measured at the seat transducer disc of SAE J1013 JAN80, are within  $\pm 5\%$  of their arithmetical mean. This arithmetical mean shall be recorded.
- 7.2.3 For the three runs of record according to 7.2.2, the arithmetical mean of the three values of the frequency weighted rms acceleration values ( $a_{wf}$  according to SAE J1013 JAN80), measured at the base of the seat, shall be recorded.
- 7.2.4 For purposes of 7.2.2 and 7.2.3, any of the methods of J1013 JAN80 may be used to obtain  $a_{wf}$ , the frequency weighted rms acceleration, but the same method shall be used for both 7.2.2 and 7.2.3.
- 7.2.5 The maximum transmissibility of the seat is calculated as the ratio of the recorded values of 7.2.2 and 7.2.3 as follows:

$$\text{Maximum Transmissibility} = \frac{\text{Recorded Value of 7.2.2}}{\text{Recorded Value of 7.2.3}}$$

- 7.3 Random Vibration Test: Each test subject shall be positioned in the seat according to 5.2. The vibration test stand shall be operated to produce the appropriate test input target vibration spectra of Section 6 at the base of the seat and according to the class of tractor or machine to which the operator seat is to be fitted.

The test input vibration shall be continuous for sufficient time during each test run to provide at least 5 min of actual data. The instruments shall be nulled and calibrated before and after each test run in accordance with SAE J1013 JAN80.

- 7.3.1 For each mass of test person (5.2) the test shall be repeated to obtain three consecutive test runs in which the frequency weighted rms acceleration values ( $a_{wf}$  according to SAE J1013 JAN80) measured at the seat disc of SAE J1013 JAN80 are within  $\pm 5\%$  of their arithmetical mean. This arithmetical mean shall be recorded as  $a_{wfs}$ .
- 7.3.2 For the runs of record according to 7.3.1, the vibration at the seat mounting base during each test must be within the allowed values for the particular class as specified in SAE J1385 or SAE XJ1386. For each test person, the arithmetical mean of the three test values for the frequency weighted rms acceleration values ( $a_{wf}$  according to SAE J1013 JAN80) measured at the base of the seat shall be recorded as  $a_{wfb}$ .

7.3.3 For purposes of 7.3.1 and 7.3.2, any of the methods of SAE J1013 JAN80 may be used to obtain the frequency weighted rms acceleration, but the same method shall be used for both 7.3.1 and 7.3.2.

7.3.4 The frequency weighted rms acceleration transmitted to the test person, ( $a_{wfs}$  according to 7.3.1) shall be corrected if  $a_{wfb}$  (according to 7.3.2) differed from the specified target input value for the test class. The correction calculation is as follows:

Corrected operator  $a_{wfs}$

$$= a_{wfs} \frac{\text{Target value for the Class (J1385 or XJ1386)}}{a_{wfb}}$$

8. RECOMMENDED LEVELS:

8.1 The maximum transmissibility of 7.2.5 should not exceed a value of 2.0.

8.2 The corrected value of frequency weighted rms acceleration transmitted to the operator (corrected operator  $a_{wfs}$  of 7.3.4) should not exceed 1.25 m/s<sup>2</sup>.

9. REPORT OF RESULTS:

1. Name and address of seat manufacturer.
2. Model of seat.
3. Date of test.
4. Time duration of pretest run-in = \_\_\_\_\_ hours.
5. Machine or tractor class number of test input = \_\_\_\_\_.
6. Maximum transmissibility in damping test (7.2.5):

Value of transmissibility, frequency, and input peak-to-peak amplitude at which measured.

7. Height of the SIP above platform for test.
8. Type of transducer mounting disc used, rigid or semi-rigid.
9. Vibration transmitted to the operator.

<u>Operator Mass</u>	<u>Operator Vibration<sup>a</sup> Weighted rms</u>
. . . . .kg	. . . . . m/s <sup>2</sup>
. . . . .kg	. . . . . m/s <sup>2</sup>

<sup>a</sup>The corrected operator  $a_{wfs}$  of 7.3.4.

10. Test by . . . .

10. REFERENCES:

1. SAE J1150 DEC76, Terminology for Agricultural Equipment
2. SAE J1057 JUN81, Identification Terminology of Earthmoving Machines
3. SAE J1013 JAN80, Measurement of Whole-Body Vibration of the Seated Operator of Agricultural Equipment
4. ISO 2041, Vibration and Shock Terminology
5. SAE XJ1386, Classification of Agricultural Tractors for Vibration Tests of Operator Seats
6. SAE J1385, Classification of Earthmoving Machines for Vibration Tests of Operator Seats
7. SAE J1163 JAN80, Determining Operator Seat Location of Off-Road Work Machines
8. The Official Journal of the European Communities, No. L255/11, September 18, 1978

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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.

ISO/TC 127 Document: ISO 7096 Earthmoving Machinery - Operator Seat - Measurement of Transmitted Vibration

Earthmoving Machines  
Test Input from  
SAE XJ1385

Instrumentation  
from  
SAE J1013 JAN80

Seat Test Procedure  
of  
SAE XJ1384

Agricultural Tractors  
Test Input from  
SAE XJ1386

USA Proposal for ISO/TC 23/SC 3: Revision of ISO/TR 5007 Agricultural Wheeled Tractors - Operator Seat - Measurement of Transmitted Vibration (and Seat Dimensions)

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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.

The seat test procedure of SAE XJ1384 is a laboratory test of the ride vibration performance of the seat. 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:

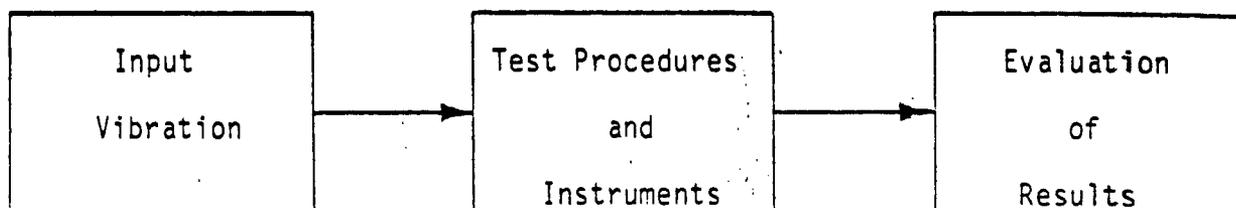
The design of seat systems for vibration isolation of the operator must take into account the following factors:

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. Therefore, SAE XJ1384 specifies an acceptable level of vibration of the operator in a test of the seat under realistically severe vibration conditions, and thereby provides the freedom to design for all of the above four factors.

#### 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.

#### TEST PROCEDURES AND INSTRUMENTS:

1. The laboratory test procedure of SAE XJ1384 is almost identical to that of ISO 7096. The only difference is in 7.2.1 of SAE XJ1384. The SAE document proposes that the sinusoidal vibration input for the damping test shall have a peak-to-peak displacement amplitude of 40% of the suspension oscillation range. ISO 7096 fixes the value at 50 mm. This difference in the document makes it more universally applicable to seats for earthmoving machines, agricultural tractors, etc.
2. The test procedure of ISO 7096 has been reviewed by ISO/TC 108/SC 2/WG 4 who found it to be consistent with their work.
3. The test procedure is similar in approach to that of ISO/TC 23/SC 3 in their document ISO/TR 5007. The differences between SAE XJ1384 and ISO/TR 5007 are the subject of a USA proposal to ISO/TC 23/SC 3.
4. The instrumentation and analysis is specified as being that of SAE J1013 JAN80. That instrumentation is available and in use in many places, and is good state-of-the-art instrumentation for purposes of this test document.
5. The safety recommendations of 4.2.2 of SAE XJ1384 are for the purpose of suggesting design guidelines for the test facility to prevent injury to the subject or operator.

#### EVALUATION OF RESULTS:

The frequency weighting of the vibration transmitted to the operator, the combination of the weighted vibration into a single number, and the recommended level of  $1.25 \text{ m/s}^2$  (SAE XJ1384, 8.2) are in accordance with ISO 2631. These factors are all identical to those in ISO 7096, which has been reviewed with regard to these factors by ISO/TC 108/SC 4 and approved by them as being consistent with their work and with ISO 2631.

The recommended level of clause 8.1 of SAE XJ1384 is a purely mechanical consideration (i.e., not a human exposure level) to insure a reasonable amount of damping in the seat system.

#### RELATIONSHIP OF SAE STANDARD TO ISO STANDARD:

Not applicable.

REFERENCE SECTION:

SAE J1150 DEC76, Terminology for Agricultural Equipment

SAE J1057 JUN81, Identification Terminology of Earthmoving Machines

SAE J1013 JAN80, Measurement of Whole-Body Vibration of the Seated Operator of Agricultural Equipment

ISO 2041, Vibration and Shock Terminology

SAE XJ1386, Classification of Agricultural Tractors for Vibration Tests of Operator Seats

SAE J1385, Classification of Earthmoving Machines for Vibration Tests of Operator Seats

SAE J1163 JAN80, Determining Operator Seat Location of Off-Road Work Machines

The Official Journal of the European Communities, No. L255/01, September 18, 1978

APPLICATION:

This recommendation applies to operator seats which may be fitted to agricultural wheeled tractors per SAE J1150 (December 1976) and/or earthmoving machines per SAE J1057 JUN81. Agricultural wheeled tractors and earthmoving machines having similar vibration spectra are grouped into defined classes with corresponding test vibration input spectra defined for each class in SAE J1385 and SAE XJ1386.<sup>1</sup> Performance for all applications within a defined class requires tests with subjects of specified weights.

The specified power spectral density at the seat mounting base defines the response required from the vibration test stand during a given laboratory seat test.

COMMITTEE COMPOSITION:

DEVELOPED BY THE SAE HUMAN FACTORS TECHNICAL COMMITTEE:

<sup>1</sup>Document unavailable for inclusion in the 1984 Handbook.