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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

SURFACE VEHICLE STANDARD

An American National Standard

SAE J1384 REV. JUN93

Issued 1983-05
Revised 1993-06

Superseding J1384 MAY83

(R) VIBRATION PERFORMANCE EVALUATION OF OPERATOR SEATS

There are no equivalent ISO standards.

Foreword—This document has also changed to comply with the new SAE Technical Standards Board format. This included making Definitions Section 3.

1. Scope—This SAE Standard describes a procedure for the evaluation of operator seats which may be fitted to agricultural wheeled tractors per SAE J1150 and/or earthmoving machines per SAE J1057. This procedure evaluates only the vertical vibration performance and should not be considered a comprehensive seat evaluation procedure.

1.1 Purpose—The purpose of this document is to establish a method for testing the seats of agricultural tractors and earthmoving machines. The method recognizes that the vibration performance of operator seats for agricultural tractors and earthmoving machines depends on the characteristics of the seat, the machine, and the operator. As such, this document describes a procedure utilizing human subjects (operators) for measuring and evaluating seat performance in the laboratory as a function of machine type and operator weight.

Agricultural wheeled tractors and earthmoving machines having similar vibration spectra are grouped into defined classes with corresponding test vibration input spectra specified for each class in SAE J1385 and SAE J1386. 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.

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. Performance for all applications within a defined class requires tests with subjects of specified weights.

2. References

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. The latest issue 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 Agricultural Equipment
SAE J1057 JUN81—Identification Terminology of Earthmoving Machines
SAE J1150 OCT92—Terminology for Agricultural Equipment
SAE J1163 JUN91—Determining Seat Index Point
SAE J1385 JUN83—Classification of Earthmoving Machines for Vibration Tests of Operator Seats
SAE J1386 JAN86—Classification of Agricultural Tractors for Vibration Tests of Operator Seats

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

ISO 2041-1990—Vibration and shock—Vocabulary
ISO/DIS 10326-1 (1992)—Mechanical vibration—Laboratory methods for evaluating seat vibration—Part 1: Basic requirements

2.1.3 OTHER PUBLICATION

The Official Journal of the European Communities, No. L255/11, September 18, 1978

3. Definitions

3.1 Letter Symbols

a_z = the vertical component of acceleration (see Figure 1, SAE J1013)
rms = root-mean-square
a_{wf} = weighted rms acceleration calculated over the frequency range prescribed for the test input vibration using one of the methods as described in SAE J1013
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 (SAE J1163 JUN91)
OECD = Organization for Economic Cooperation and Development

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 J1386.

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 3 of SAE J1163.

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. This document 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 (within ± 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.

a. Working frequency range = 0.5 to 20 Hz.
b. 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 fail-safe provisions capable of automatic shutdown when the seat mounting base acceleration exceeds 15 m/s^2 for any reason. (Maximum dynamic thrust force of 1.5 x 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.

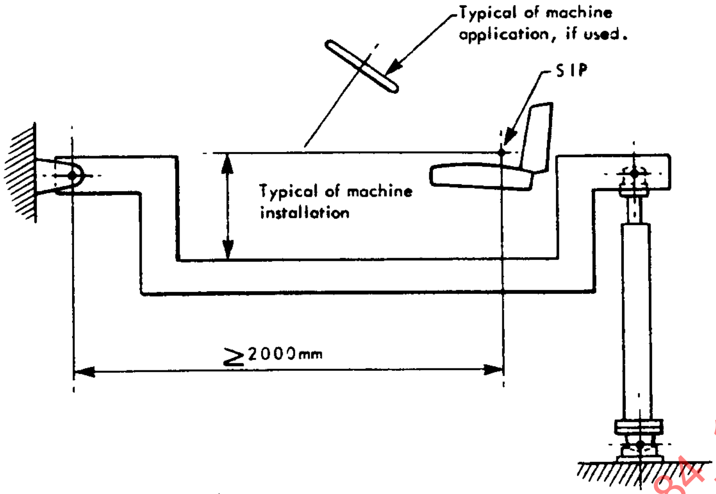


FIGURE 1—DIAGRAM OF A SIMPLE PIVOTING TYPE VIBRATION TEST STAND FOR OPERATOR SEAT TESTS

The pump and/or servovalves should be sized to limit the test stand velocity to 1.3 m/s, and the accumulator should be of the minimum size required to provide the proper system response.

Fail-safe 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 metal 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—Test 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.

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 J1386 defines the test input vibrations 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 J1386 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 J1386 or 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 the a_z acceleration on the seat mounting base per SAE J1013. PSD spectra from reasonable 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.

Alternatively, for agricultural wheeled tractors not in a defined class, the PSD spectra per SAE J1013 procedures may be obtained while operating the tractor on the OECD (Organization for Economic Cooperation and Development) "smooth" test track at a speed of 12 km/h ± 0.5 km/h. The test track and the tractor operating procedures are defined in SAE J1163. It is, however, recommended that the seat test itself be conducted on a vibration test stand reproducing this PSD (and PDF) in accordance with the procedures set forth herein.

6.4 Unless otherwise specified for the test input vibrations, the frequency weighted rms acceleration shall be calculated over a frequency range of 0.89 to 17.8 Hz (corresponding to the frequency range covered by the 1 through 16 Hz one-third octave bands).

6.5 For agricultural wheeled tractors or earthmoving machines not in a defined class, the frequency weighted rms acceleration shall be calculated over a frequency range of 0.89 to 17.8 Hz (corresponding to the frequency range covered by the 1 through 16 Hz one-third octave bands).

7. Test Procedures

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.

7.2 Test for Damping—For suspension seats only, the seat shall be loaded with a 75 kg mass such as metal shot (equivalent to a 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 (± 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), measured at the seat transducer disk of SAE J1013, are within ±5% of their arithmetic means. This arithmetic mean shall be recorded.

7.2.3 For the three runs of record according to 7.2.2, the arithmetic mean of the three values of the frequency weighted rms acceleration values (a_{wf} according to SAE J1013), 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 SAE J1013 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 acceleration transmissibility of the seat is calculated as the ratio of the recorded values of 7.2.2 and 7.2.3 as follows:

$$\text{Maximum Acceleration Transmissibility} = \frac{\text{Recorded Value of 7.2.2}}{\text{Recorded Value of 7.2.3}} \quad \text{(Eq. 1)}$$

7.2.6 For a heavily damped suspension seat, it may be difficult to determine the resonant frequency because the magnification near resonance is small and occurs over a relatively broad frequency range. For the purposes of 7.2.1, the resonant frequency of such a system can be determined by minimizing the effect of the damping mechanism. The preferred way of doing this is to disconnect the damping mechanism, but if the damping mechanism is adjustable and disconnecting it would entail significant disassembly and reassembly of the seat suspension, the damping adjustment may be set to the minimum damping position. The damped natural frequency is then determined by noting the frequency where the ratio of (seat acceleration)/(base acceleration) is a maximum as the frequency is varied. The damping mechanism is then reconnected and/or set to the desired level, and the maximum acceleration transmissibility measured at the frequency so noted.

This procedure simplifies the determination of the resonant frequency and should yield a value for the maximum acceleration transmissibility that is within 4% of the true value.

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 vibrations 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.

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) measured at the seat disc of SAE J1013 are within ±5% of their arithmetic mean. This arithmetic 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 J1386. For each test person, the arithmetic mean of the three test values for the frequency weighted rms acceleration values (a_{wf} according to SAE J1013) 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 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:

$$\text{Corrected operator } a_{wfS} = a_{wfS} \frac{\text{Target value for the Class (SAEJ1385 or SAEJ1386)}}{a_{wfB}} \quad \text{(Eq. 2)}$$

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^2.

9. Report of Results—(See Figure 2.)

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 at which measured =
   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

Operator Mass	Operator Vibration Weighted[1] rms
________ kg	____________________ m/s^2
________ kg	____________________ m/s^2
________ kg	____________________ m/s^2

[1] The corrected operator a_{wfS} of 7.3.4.

10. Analysis frequency range
11. Test by ______________________________

FIGURE 2—REPORT OF RESULTS

10. Notes

10.1 Marginal Indicia—The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. An (R) symbol to the left of the document title indicates a complete revision of the report.

PREPARED BY THE SAE HUMAN FACTORS TECHNICAL COMMITTEE SC4—
OPERATOR SEATING AND RIDE

Rationale—This rationale statement consists of two sections. Section 1 is an edited version of the Rationale statement that accompanied SAE J1384 MAY83. Section 1 provides information of a historical nature regarding the concerns and approach that was used in developing the original SAE J1384 document. Section 2 provides information on the changes that were made during the 1991 revisions of the document.

1. Rationale Statement, J1384 MAY83

1.1 Introduction — This document is to be used in combination with SAE J1013.

Similarly, seat tests for other types of machines and vehicles can be developed within this system by adding documents corresponding to SAE J1385 and SAE J1386. SAE J1385 and SAE J1386 provide specific test inputs to allow operator seats to be evaluated per the procedure of SAE J1384.

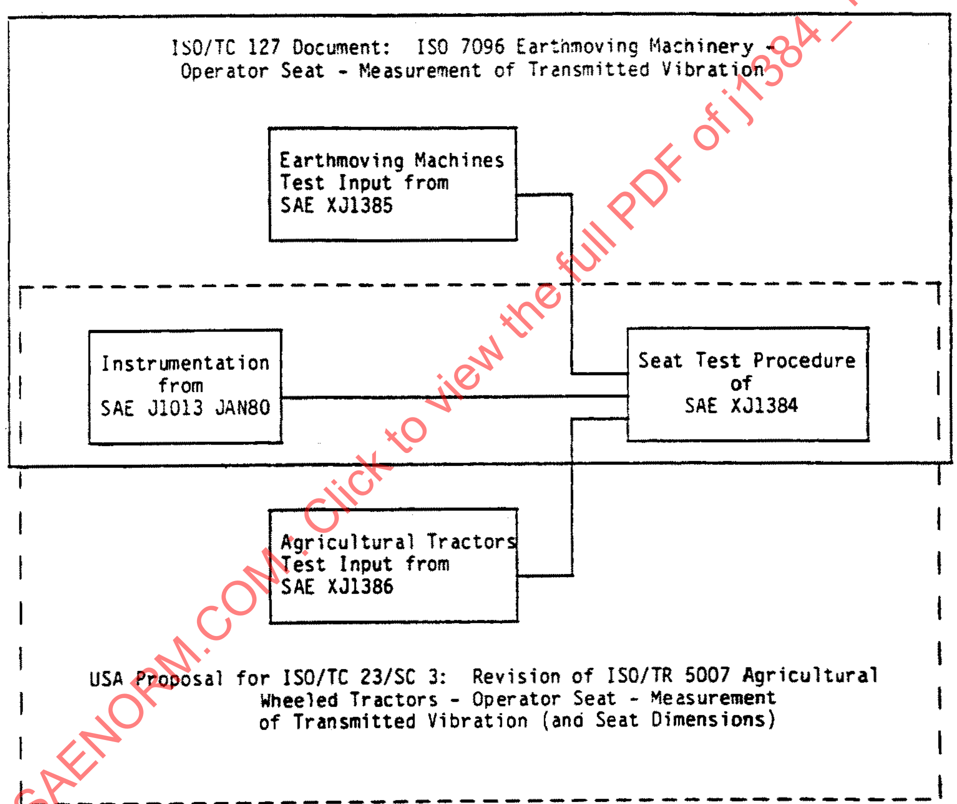


FIGURE 1

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 J1384 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.

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

1.2.1 The vibration transmitted to the operator over the normal working day should be within reasonably tolerable levels.

1.2.2 The vibration isolation of the operator should not be such as to encourage traveling too fast for the terrain.

1.2.3 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.

1.2.4 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, J1384 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.

1.3 Technical Rationale — The seat test can be represented by the flow diagram below (Figure 2).

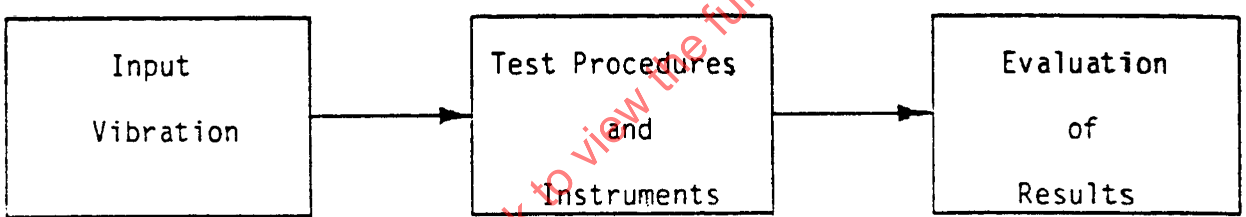


FIGURE 2

The technical rationale is divided into sections in accordance with the flow diagram.

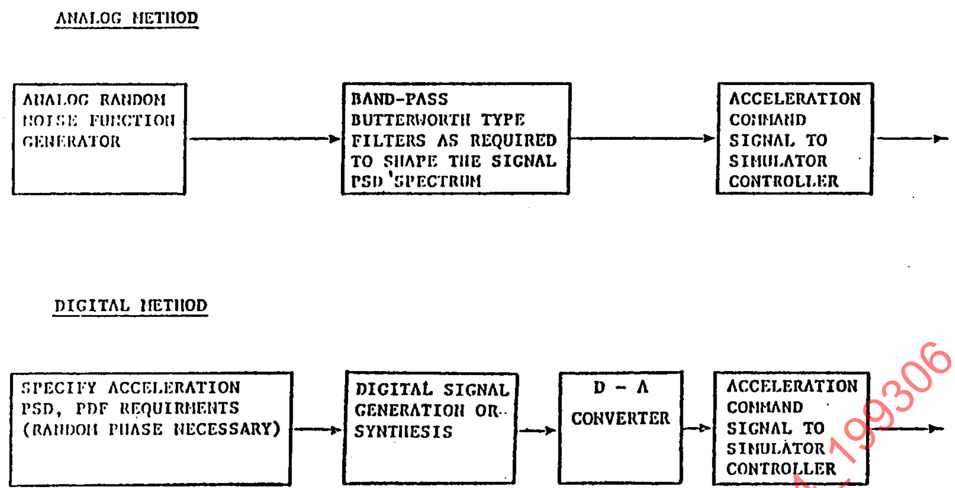
1.3.1 Input Vibration — Control of the simulator may be based on either acceleration feedback (Figure 3) or displacement feedback (Figure 4). In either case, the input vibration signals can be generated using analog and/or digital methods.

1.3.2 Test Procedures and Instruments

1.3.2.1 The laboratory test procedure of SAE J1384 is almost identical to that of ISO 7096. The only difference is in 6.2.1 of SAE J1384. 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.

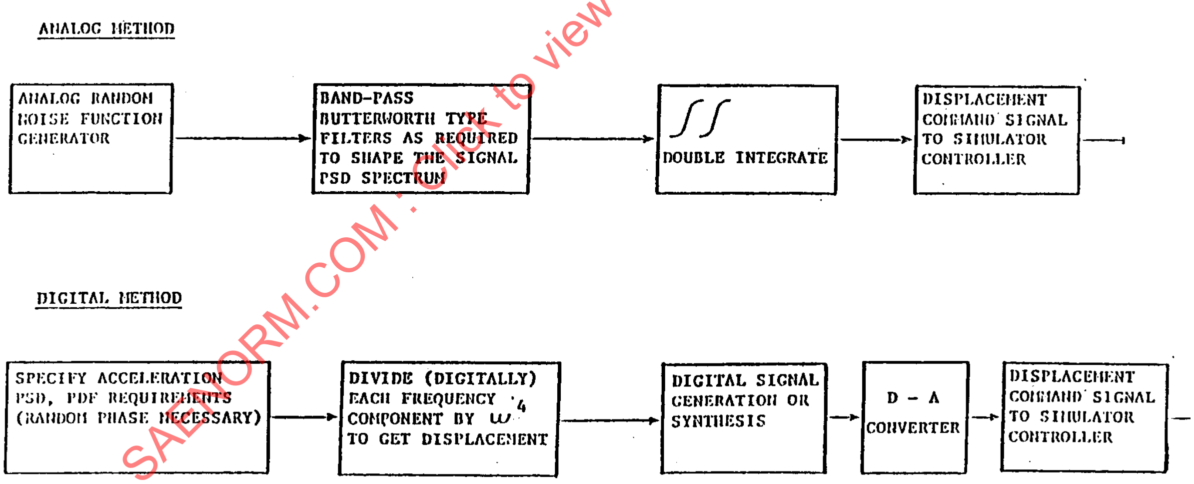
1.3.2.2 The test procedure of ISO 7096 has been reviewed by ISO/TC 108/SC 2/WG 4 who found it to be consistent with their work.

1.3.2.3 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 J1384 and ISO/TR 5007 are the subject of a USA proposal to ISO/TC 23/SC 3.



Possible methods for controlling acceleration feedback type ride simulator tables to produce the required acceleration spectra for input to test seats.

FIGURE 3—SIMULATORS WITH ACCELERATION FEEDBACK CONTROL



Possible methods for controlling displacement feedback type ride simulator tables to produce the required acceleration spectra for input to test seats.

FIGURE 4—SIMULATORS WITH DISPLACEMENT FEEDBACK CONTROL

1.3.2.4 The instrumentation and analysis is specified as being that of SAE J1013. That instrumentation is available and in use in many places, and is good state-of-the-art instrumentation for purposes of this test document.

1.3.2.5 The safety recommendations of 4.2.2 of SAE J1384 are for the purpose of suggesting design guidelines for the test facility to prevent injury to the subject or operator.

1.3.3 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 m/s^2 (SAE J1384, 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 J1384 is a purely mechanical consideration (i.e., not a human exposure level) to insure a reasonable amount of damping in the seat system.

2. Rationale Statement, J1384 1991 Revisions

2.1 A number of the changes to this revision were made in the attempt to make the revised document conform to the format specified in SAE J2259. The old Purpose and Scope sections have been revised to better follow the new format, and the references (previously Section 10) have been relocated to Section 2.

2.2 The definition of a_{wf} (in 3.1) has been modified to allow for the calculation of the weighted rms values over a frequency range that is more appropriate for simulator tests. SAE J1013 calls for an analysis range of 1 to 80 Hz which is excessive considering that the simulator itself need only respond over a frequency range of 0.5 to 20 Hz (4.2.1). Furthermore, the test inputs defined in SAE J1385 and J1386 do not have any significant energy above 16 Hz.

2.3 Paragraphs 6.4 and 6.5 have been added to further clarify the appropriate analysis range for both the defined (6.4) and undefined (6.5) vehicle classes.

2.4 In the test for damping (7.2), a method for defining the resonant frequency of a highly damped suspension has been added (see 7.2.6). The basis for this recommendation is as follows:

2.4.1 The seat suspension system can be viewed as a base-excited one degree-of-freedom system as shown in Figure 5 of this Rationale statement. The base is excited with a displacement (measured relative to ground) of x_1; the suspension responds such that the displacement of the seat (also measured relative to ground) is x_2. The relative motion of the suspension is then (x_2-x_1).

2.4.2 The acceleration of the base (measured relative to ground) is then a_1 and the acceleration of the seat (again measured relative to ground) is a_2.

2.4.3 Paragraph 7.2 of SAE J1384 calls for the determination of the maximum transmissibility of the suspension. Transmissibility is defined as the nondimensional ratio of the response amplitude of a system in steady-state forced vibration to the excitation amplitude. The ratio may be one of forces, displacements, velocities, or accelerations. Clearly, the methodology in 6.2 indicates that the acceleration transmissibility (a_2/a_1) at resonance is to be determined.

2.4.4 Figure 6 of this Rationale statement shows the response of the simple base-excited system as a function of frequency. The frequency axis is shown in terms of the frequency ratio; i.e., the ratio of the forcing frequency to the undamped natural frequency of the system.

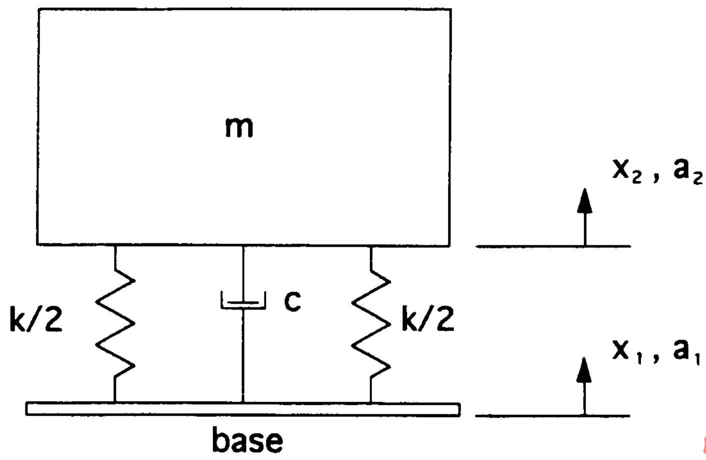


FIGURE 5—BASE-EXCITED SYSTEM

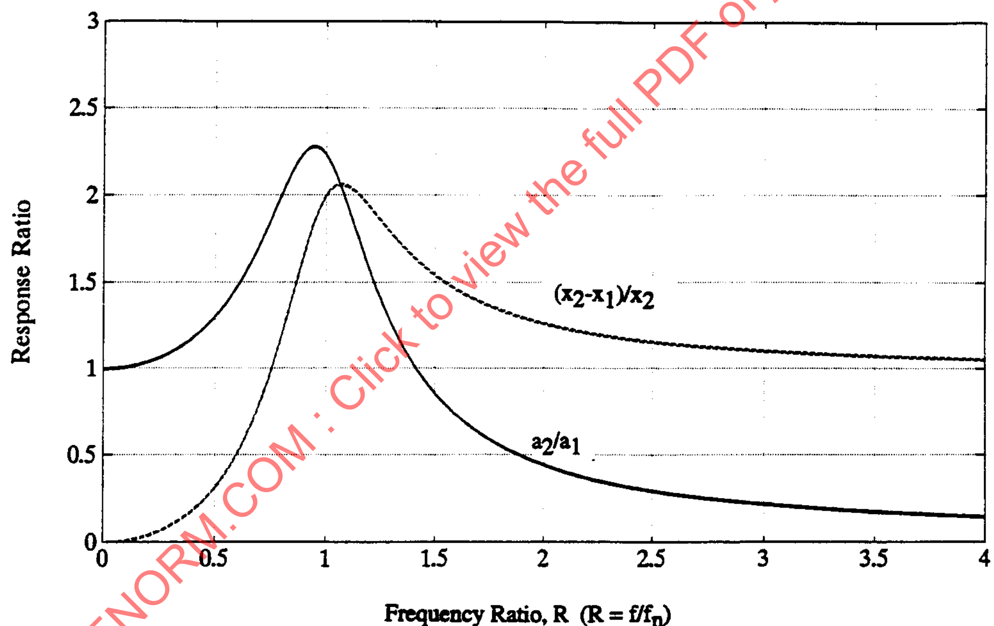


FIGURE 6—RESPONSE OF A BASE-EXCITED SYSTEM (DAMPING RATIO = .25)

In that figure, two ratios are shown:

a. The ratio of the suspension displacement (x_2-x_1) divided by the input displacement (x_1).
b. The ratio of the acceleration at the top of the suspension (a_2) divided by the base acceleration (a_1).

Note that the two curves are different and peak at different frequencies. SAE J1384 specifies the acceleration transmissibility at resonance, and thus the displacement ratio is not appropriate. For the relatively lightly damped system (damping ratio = 0.25), the peak in the acceleration response is well defined and would be fairly easy to determine.