SAE International

SURFACE VEHICLE RECOMMENDED PRACTICE

J1490 MAY2011

Issued 1987-01
Stabilized 2011-05

Superseding J1490 SEP1999

Measurement and Presentation of Truck Ride Vibrations

RATIONALE

The Vehicle Characterization Committee which owned the report has become inactivated and the technical expertise for the subject report within the Truck-Bus Council is not available at this time.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE Truck and Bus Total Vehicle Steering Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. Scope—There are two ways to assess the characteristics of ride vibrations of a vehicle during its operation. Subjective evaluation and objective measurement. Subjective assessments of the ride vibrations experienced by drivers during ride evaluations are generally performed by a panel of drivers and/or passengers who are instructed to operate or ride a group of vehicles in a predetermined manner in order to subjectively assess the levels and characteristics of ride vibrations. Figures 6A through 6C show examples of subjective evaluation forms presently in use. The disadvantages of the subjective method include need for careful experimental design, need for statistically unbiased samples, complexity of human perceptions of vibrations, and difficulty in comparing qualitative data of vehicles evaluated at different times and/or by different groups of people. Often ride characterization is not an easy task using only qualitative or descriptive terms. Therefore, it is necessary and desirable to develop objective techniques to enable ride engineers and others to measure ride vibrations during ride assessment in a quantitative manner.

This recommendation details a uniform method for the measurement of ride vibrations of all Class 7 and 8 commercial vehicles, including both combination vehicles and straight trucks. Vibrations are to be measured utilizing cab and seat-pad mounted accelerometers in vertical (z axis) and fore/aft (x axis) directions. The measurement in lateral direction (y axis) is optional as these vibrations from a ride assessment standpoint are seldom significant in commercial vehicles. Several currently utilized methods of displaying, analyzing, and combining the measured accelerations are presented.

This recommendation does not make any statements concerning how well any of the objective ride measures will correlate to subjective evaluations of ride, nor does it deal with any limits or establish any desirable values for acceptable ride.

It is recognized that objective ride evaluation methods have some disadvantages due to the complexities of these measures, sophistication of instrumentation and analysis techniques, etc. Therefore, it is recommended that technically trained personnel conduct the objective tests and analyze the data.

1.1 Purpose—This SAE Recommended Practice establishes the test procedure, environment, instrumentation, and methods for the measurement, analysis, and presentation of the ride-related vibrations to which seated occupants of Class 7 and 8 commercial vehicles are exposed during actual or simulated vehicle operation. It is intended that this recommendation will provide a degree of uniformity sufficient to allow characterization of ride needed for industry-wide communication of ride testing. Also presented are objective ride measures which have been suggested as having some degree of correlation to subjective ride evaluations. It is further intended that the use of this document will eventually result in objective ride measures being established as a generally accepted quantifier of subjective ride evaluations.

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 version of SAE publications shall apply.

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

SAE J1013—Measurement of Whole Body Vibration of the Seated Operator of Off-Highway Work Machines
SAE J1060—Subjective Rating Scale for Evaluation of Noise and Ride Comfort Characteristics Related to Motor Vehicle Tires
SAE 680091—“Analytical Analysis of Human Vibration,” F. Pradko and R. A. Lee, 1968.

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

“Guide for Evaluation of Human Exposure to Whole Body Vibration,” ISO 2631, 1974 and 1978.

2.1.3 OTHER PUBLICATIONS

Bendat and Piersol, Random Data: Analysis and Measurement Procedures, Wiley Interscience, 1971.

3. *Definitions*

3.1 Vibration Measurement Axis Reference—The axis references will follow the convention established in Figure 1 where positive x is forward, positive y is right and positive z is down, all relative to the seated driver.

3.2 Terminology

3.2.1 OVERLAP PROCESSING—Overlapping of time domain data blocks to which a window has been applied. Overlap processing is necessary to achieve a precise spectral representation of short time records of data which have been windowed. The optimum overlap percentage is dependent on the type of window used (see 3.2.10).

3.2.2 PSD—Power Spectral Density—Acceleration spectrum normalized by filter bandwidth and scaled in g^2/Hz, such that integration by frequency yields the mean squared acceleration. The square root of the PSD ($g\ Hz^{-1/2}$) can also be displayed for ride work.

3.2.3 RIDE VIBRATIONS—Mechanical vibrations expressed in terms of accelerations in the 1 to 25 Hz bandwidth measured at the specified locations in the cab interior.

3.2.4 RMS—Root mean square magnitude of a signal.

3.2.5 SEAT PAD—Molded rubber pad that encapsulates the accelerometer that the occupant sits on.' The specifications of the pad are outlined in SAE J1013.

3.2.6 SIGNAL-TO-NOISE RATIO—The ratio of the value of a recorded signal channel to that of a simultaneously-recorded shorted channel.

3.2.7 SPECTRUM—Magnitude versus frequency display.

3.2.8 TEST SECTION—A well-defined section of road surface that exhibits uniform surface characteristics upon which ride tests are performed.

3.2.9 TRANSVERSE SENSITIVITY—Fraction of accelerometer sensitivity which will apply to acceleration orthogonal to its principle axis. Also referred to as cross axis sensitivity.

3.2.10 WINDOWING—The process equivalent to weighting a time domain acceleration record prior to transformation to the frequency domain.

3.3 Letter Symbols

3.3.1 Hz = Hertz, unit of frequency, cycles per second

3.3.2 f_i = frequency in Hz of the i^{th} spectral line

3.3.3 P = absorbed power in watts

3.3.4 A_i = g^2/Hz spectral magnitude at frequency f_i

3.3.5 W_i = angular frequency in sec-1, $2\pi f_i$

3.3.6 g = acceleration of gravity, 9.8 m sec-2

4. General Test Design—A typical ride test consists of running vehicle(s) over selected well-defined sections of road at constant speed(s), while measuring cab and seat pad accelerations. A subjective evaluation of the ride by the driver may be simultaneously performed. Each acceleration should be displayed in one of the manners in 8.1 and further analyzed and presented as numerical measure(s) of the ride vibrations of 8.2.

Ride vibration magnitudes can be sensitive to road speed, so generally each road section should be tested at several speeds. The validity of the comparison of objective ride vibration measurements is increased by averaging the independent measurements from several repeat tests at each speed.

The validity of subjective ride evaluations is increased as the number of evaluators is increased since body weight, build, age, and many other factors affect a person's perception of ride vibrations. The inherent variability of subjective evaluations makes it advisable to always make simultaneous objective measurements.

5. Test Preparation and Documentation—The usefulness of any data will be enhanced by a thorough test preparation and documentation using the following format. Photographs of the vehicle, driver, accelerometers in their mounted positions and test site should be taken to supplement the written documentation.

5.1 Vehicle—The test vehicle should be described by recording the information contained in the test vehicle description sheets shown in Figures 2 through 5. The drawings can be altered as needed to match a particular vehicle configuration, but all the information should be included. Fuel tank level should be noted when measuring the center of gravity and maintained as close as possible to this level throughout the test. Actual accelerometer positions should be noted on Figure 4C.

5.2 Test Site—Documentation should include written descriptions and photographs of exact site location with landmarks, description of the road surface types of test section, expansion joint (if any) spacing, and posted speed limit. For future comparisons, it is recommended that the profile of the test surface(s) be documented.

5.3 Operator—The height, seated height (floor to ear), sex, chest circumference, waist circumference, hip circumference, and weight of the operator who is sitting on the seat pad accelerometers should be documented. A photograph is suggested. The seat, if adjustable, should be properly adjusted per manufacturer's specifications, and the driver's posture should be consistent from test to test.

5.4 Operating Conditions—The weather and vehicle operation factors should be documented to the extent that they affect the vehicle ride. Some possible factors are: test date, time of day, personnel, ambient temperature, presence of rain or snow, wind velocity, and direction relative to vehicle direction and velocity of vehicle during test.

6. Subjective Ride Evaluations—Subjective ride evaluations are often conducted in conjunction with objective ride measurements. The subjective evaluations are generally conducted by having a jury of several members rate different aspects of ride using scales such as those illustrated in Figures 6A through 6C. The different categories for which individual rating values may be requested include: ride comfort (an overall rating), seat vertical vibrations, seat fore/aft vibrations, seat lateral vibrations, steering wheel vibrations, and cab shake.

The rating tests are conducted over a selected test section(s) of road surface at constant speed(s). The means of the ratings among evaluators or among ride categories are used to compare vehicles under the same test conditions. The validity of the comparison may be established by statistical tests, but will generally improve with the size of the rating jury.

7. Instrumented Ride Vibration Measurements—Ride vibration measurements are obtained by measuring accelerations on the vehicle cab and on a “seat pad” placed between the driver and the seat. The output of each acceleration transducer is analyzed and the results are utilized to produce one or more numerical measures of ride vibration magnitude.

This document provides only guidelines for the measurement and analysis of ride vibrations. To avoid potential errors, only technically trained personnel current in the latest techniques of vibration measurement and analysis should select the instrumentation used and supervise equipment installation, calibration, operation, and data analysis.

7.1 Measurement Instrumentation

7.1.1 ACCELEROMETERS AND SIGNAL CONDITIONING—Ride vibration shall be measured using accelerometers capable of withstanding instantaneous acceleration as great as 100 m/s^2 without damage and transverse sensitivity of no greater than 7%. To assure that engine and other high frequency vibrations will not be amplified, accelerometers with sufficiently high natural frequency and appropriate internal damping shall be used. The accelerometers are mounted as described in 7.2.

The accelerometers, together with their associated signal conditioning, shall be capable of measuring rms accelerations in the 1.0 to 25 Hz bandwidth ranging in amplitude from 0.1 m/s^2 to 10 m/s^2 with a crest factor as great as 3. Acceleration amplitudes within the previous ranges shall be measured with at least ±5% accuracy.

If time domain Exceedance values are to be calculated (reference 7.3.2.5), then the variation in the phase response of the total data acquisition and analysis system shall either:

1. Be no greater than 20 degrees between 1.0 and 25 Hz.
   or
2. Be linear with frequency within ± 5%.

7.1.2 ACCELERATION DATA RECORDING—Ride vibration measurements may be real time analyzed using one or more of the data analysis procedures described in 7.3, or recorded for subsequent analysis. Recording has the advantage of providing a record of the acceleration data and system calibration signals which can then be analyzed and checked using different methods.

A suitable recording device shall be capable of reproducing the acceleration signal within ±1 dB in amplitude. If time domain values are to be calculated, and if the total system phase response varies by greater than 20 degrees over the 1 to 25 Hz bandwidth, then on all data channels the phase variation shall be linear with frequency within ±5%.

System calibration and sense should be verified using a lg rollover or equivalent procedure, prior to actual data recording. Vehicle vibration, transient power conditions, etc., may affect the accuracy of the data recording equipment; a waveform of known magnitude and phase within the 1 to 25 Hz bandwidth should be recorded during each data recording. The recorded known signal shall be analyzed to ensure that the recording accuracy requirements were met.

7.1.3 INSTRUMENTATION DATA SHEET—To document the performance of the instrumentation used for ride vibration measurements, an instrumentation data sheet, similar to the example shown in Figure 7, shall be included in the test report. Included on this sheet should be the linear response range, natural frequency, and nominal output of all accelerometers along with the frequency response, measurement range accuracy of each instrument or filter in the system. Alternatively, the instruments can be identified by their generic name, commercial manufacturer, and model number.

7.2 Accelerometer Location—Accelerometers shall be oriented to measure both vertical (z-direction) and fore-aft (x-direction) acceleration as defined by the measurement axis (Figure 1). One pair of accelerometers, integrated in a seat pad transducer (described in SAE J1013); shall be centered on the top of the driver's seat. A second pair of accelerometers should be mounted in the interior of the cab structure near the driver's side rear door frame. They should be located as closely as possible to the point, 700 mm to the rear of the y-z vertical plane through the steering wheel centerline and 1150 mm above the floor (forward control cabs should use the floor at the pedal positions as reference.) These accelerometers should be mounted to a solid portion of the cab (not on interior trim panels). An optional accelerometer to measure the lateral (y-direction) acceleration can be mounted at this same position.

The actual location (X, Y, Z) of all accelerometers shall be documented when reporting the data (Figure 4C). The seat pad transducer location should be documented at the seat setting which will be used to conduct the test (important consideration with air seats with fore-aft isolation.) The fore-aft (x-direction) reference should be the center of the steering wheel hub (at the driving position). The lateral (y-direction) reference should be the centerline of the vehicle. The vertical (z-direction) reference should be the cab floor, at the pedal position.

7.3 Data Analysis—Since ride vibrations are limited by definition to the 1 to 25 Hz frequency range, all test data shall be analyzed such that only acceleration data within this passband is used to determine the acceleration measures described in 7.3.2. The entire acceleration time record from each test shall be analyzed unless noted when reporting the data. As applicable for the specific data analysis method employed, the data analysis parameters listed in 7.3.3 shall be included when reporting the data. The data analysis system shall be calibrated using a known random signal, such as a white noise generator, over the 1 to 25 Hz frequency range. The known waveform recorded in 7.1.2 shall be analyzed and be within ±0.5 dB of the original known input level.

7.3.1 STATIONARITY OF DATA—The stationarity of the ride vibration data shall be reported as the smallest nominal level of significance (0.01, 0.025, 0.05, etc.) at which the hypothesis that the data are stationary is not rejected. (For example, as calculated from a run or trend test of sample mean and mean square values, see reference 2.1.3, p. 234). The number of observations and the time interval used in calculating each set of observed values shall be reported along with a description of the stationary test employed.

7.3.2 ACCELERATION MEASURES (TABLE 1)

7.3.2.1 *g(rms)*—The square root of the mean square value of the ride vibration data.

7.3.2.2 *Weighted g(rms)*—The square root of the mean square value of the ride vibration data, which is frequency weighted by the factors described in Table 2. Ride vibration data in the z direction shall be weighted using the vertical factors. Ride vibration data in the x and y directions shall be weighted using the fore/aft factors. Figures 8 and 9 show the shape of the weighting functions.

7.3.2.3 *1/3 Octave Peak g(rms)*—The largest unweighted g(rms) value measured in the 1/3 octave bands described in Table 3.

7.3.2.4 *ISO 1/3 Octave Peak*—The largest weighted value measured in one of the 1/3 octave bands described in Table 3. Weighted values are calculated by multiplying the g(rms) values described in 7.3.2.3 by the ISO factors listed in Table 3. Ride vibration data in the z direction shall be weighted using the vertical factors. Ride vibration data in the x and y directions shall be weighted using the fore/aft factors.

7.3.2.5 *Exceedance*—The instantaneous acceleration magnitude in g's that exceeds a specified percentage of the duration of a data record. For example, Exceedance (10) of a 60 s data record is the acceleration magnitude in g's that is exceeded for 10% of the 60 s, (or 6 s). Typically 20, 10, 5, 1, and 0.1% exceedance magnitudes are used to quantify ride vibrations.

7.3.2.6 *Absorbed Power*—Estimate of the rate at which energy is being absorbed by the average seated person subjected to ride vibration. Absorbed power shall be calculated using formula (see SAE 680091.)

where:

$$P = \sum_{i=1}^{N} (C_i)\ A_i^2 \qquad \text{(Eq. 1)}$$

A_i = RMS acceleration value in ft/s^2 within ith spectral band.

$$C_i = K_1 K_0 \frac{(F_1 F_4 - F_2 F_3)}{F_3^2 + W_i^2 F_4^2} \qquad \text{(Eq. 2)}$$

W_i = Frequency in rad/s

F and K values are calculated from Table 4. Figures 11 and 12 display the PSD of the resulting C_i, absorbed power constants.

7.3.3 DATA ANALYSIS PARAMETERS—To document the specific data analysis method and equipment used to calculate the acceleration measures described in 7.3.2, a data analysis flow chart, similar to the example shown in Figure 8, shall be included when reporting the data. As applicable for the specific data analysis method(s) employed, the parameters listed in 7.3.3.1 through 7.3.3.8 shall be included when reporting the data.

7.3.3.1 *Data Duration*—The total duration of the acceleration data analyzed.

7.3.3.2 *Preprocessing Filters*—Filter type, 3 dB cut-off frequencies, slope (in decibel/octave) and phase linearity (in %). In the case of digital analysis, the anti-aliasing and detrending filters (if employed) should be included.

7.3.3.3 *Sampling Frequency*—The rate at which the acceleration data is sampled expressed in number of samples per second (for digital analysis only).

7.3.3.4 *Sampling Accuracy*—The quantization accuracy in the analog to digital conversion expressed in g's per bit (for digital analysis only).

7.3.3.5 *Sampling Window*—The shape of the time domain amplitude weighting function and the frequency domain magnitude correction factor. If the analysis equipment employed automatically scales the spectrum to account for data windowing, the equipment manufacturer, model number, and windowing function employed (if variable) shall be included when reporting data (for digital analysis only).

7.3.3.6 *Frequency Resolution*—The frequency range and resolution bandwidth employed in the spectral analysis. In the case of proportional bandwidth analysis, it is sufficient to state the center frequencies and the value of the proportion.

7.3.3.7 *Overlap Percentage*—If overlap processing is used, the percent of overlap will be included when reporting data.

7.3.3.8 *Precision of Spectral Estimates*—The statistical precision of spectral estimates shall be stated when reporting data as the ± percent value, calculated for a 95% confidence level on the basis of random error, i.e., the stated statistical precision shall be 1.96 times the normalized standard error (see reference 2.1.3, pp. 113, 170, 184).

8. *Data Presentation*

8.1 Graphic Presentation—Visual presentation of the frequency content of a ride acceleration record is useful both to verify the validity of the data and help determine the nature of the ride phenomenon. Magnitude distribution plots are also valuable in determining the validity and character of ride acceleration data.

When using the following graphic presentations, all appropriate data analysis parameters as described in 7.3.3 shall be reported. Weighted or unweighted data in the 1–25 Hz bandwidth shall be presented. If weighted data is presented, the weighting function used shall be reported.

8.1.1 POWER SPECTRAL DENSITY—A PSD plot displays mean squared acceleration versus frequency and thus gives a visual indication of the frequency content of each acceleration record. A PSD is calculated in units of g^2/Hz. The PSD shall be plotted with a logarithmic ordinate and linear abscissa (see Figure 13). For stationary data, the integral over the 1–25 Hz bandwidth of the PSD is equal to the mean squared acceleration. Therefore, the square root of this value will equal the RMS value as calculated in 7.3.2.1.

8.1.2 SQUARE ROOT OF POWER SPECTRAL DENSITY—The square root of PSD display results in a better visual representation of the relative magnitude at each frequency within the 1–25 Hz bandwidth and is displayed in units of $g/(\sqrt{Hz})$ plotted on a linear-linear scale (see Figure 14).

8.1.3 TIME DOMAIN HISTOGRAM—Expresses the percent of the time during which the instantaneous magnitude in g's of the acceleration time history is within a specific range. The percentage shall be plotted linearly on the ordinate and the instantaneous acceleration magnitude linearly on the abscissa. The data shall be plotted at the center of the magnitude window (see Figure 15).

8.2 Ride Measures Presentation—There are many possible objective ride measures reported as having some degree of correlation to subjective evaluations. Standardized acronyms are listed in Tables 1A and 1B for the more common measures in use. These measures are calculated using the procedures described in 7.3.2. The combined measures in the second part of Table 1 are obtained by combining the values in the first part of this Table, as shown in the equation contained in Table 1. For example, the vector sum combining the cab vertical and cab fore/aft using the unweighted rms measure would be calculated as follows:

$$CR = [(CZ)^2 + (CX)^2]^{1/2} \qquad \text{(Eq. 3)}$$

These measures shall be presented as in the following example for the cab vertical unweighted rms measure.

SAE J1490 CZ = _______

SAE J1490 CX = _______

Etc. etc.

ANALYSIS PARAMETERS:

Data Duration - __________
Processing Filters.
Sampling Frequency = ______
Sampling Accuracy = _______
Sampling Window.
Frequency Resolution = ______
Etc.

TABLE 1A—ACRONYMS FOR RIDE VIBRATION MEASURES INDIVIDUAL MEASURES

Weighting	Section	Vibration Measurement Cab Vertical	Vibration Measurement Cab Fore/Aft	Vibration Measurement Seat Vertical	Vibration Measurement Seat Fore/Aft
RMS	7.3.2.1	CZ	CX	SZ	SX
SAE J1013 Weighted RMS	7.3.2.2	CZS	CXS	SZS	SXS
1/3 Octave Peak	7.3.2.3	CZ3	CX3	SZ3	SX3
ISO (1/3 Octave Peak)	7.3.2.4	CZI	CXI	SZI	SXI
Exceedance	7.3.2.5	CZE (n) (1)	CXE (n)(1)	SZE (n)(1)	SXE (n)(1)
Absorbed Power	7.3.2.6	CZP	CXP	SZP	SXP

1. where n = 20, 10, 5, 1, or 0.1

TABLE 1B—ACRONYMS FOR RIDE VIBRATION MEASURES COMBINED MEASURED

Combination	Weighting	Vibration Measurement Cab	Vibration Measurement Seat
Vector Sum	None	CR	SR
$\sqrt{(Z^2 + X^2)}$	SAE J1013	CRS	SRS
	ISO	CRI	SRI
Weighted Vector Sum	None	CR'	SR'
$\sqrt{(Z^2 + (1 \times 4x)^2)}$	SAE J1013	CRS'	SRS'
	ISO	CRI'	SRI'
Absorbed Power (Z + X)	Pradko & Lee	CP	SP

TABLE 2—SAE J1013 (g)rms SPECTRUM WEIGHTING FACTORS

Frequency	Vertical	Fore/Aft
1.0–2.0 Hz	$\sqrt{(f/4)}$	1.0
2.0–4.0 Hz	$\sqrt{(f/4)}$	2/f
4.0–8.0 Hz	1.0	2/f
8.0–25.0 Hz	8/f	2/f

Where f = frequency in Hz.

TABLE 3—1/3 OCTAVE BANDS AND ISO FACTORS TO BE APPLIED TO (g)rms

Minimum Frequency (Hz)	Center Frequency (Hz)	Maximum Frequency (Hz)	Band Width (Hz)	ISO Factor (Z) Vertical	ISO Factor X Fore/Aft
1.10	1.25	1.40	0.30	0.56	1.00
1.40	1.60	1.80	0.40	0.63	1.00
1.75	2.00	2.25	0.50	0.71	1.00
2.20	2.50	2.80	0.60	0.80	0.80
2.80	3.15	3.50	0.70	0.90	0.63
3.55	4.00	4.45	0.90	1.00	0.50
4.40	5.00	5.60	1.20	1.00	0.40
5.55	6.30	7.05	1.50	1.00	0.315
7.05	8.00	8.89	1.90	1.00	0.25
8.85	10.00	11.15	2.30	0.80	0.20
11.05	12.50	13.95	2.90	0.63	0.16
14.15	16.00	17.85	3.70	0.50	0.125
17.7	20.00	22.30	4.60	0.40	0.10

TABLE 4—ABSORBED POWER CONSTANTS

	Vertical (Z)	Fore/Aft (X)
K_0	4.3537	4.3532
K_1	1.356	1.356
W_i	$2 \pi f_i$	$2 \pi f_i$
F_1	$-0.10245x10^{-9}W^6 + 0.17583x10^{-5}W^4$ $-0.44601x10^{-2}W^2 + 1$	1.0
F_2	$+0.12882x10^{-7}W^4 - 0.93394x10^{-4}W^2$ $+ 0.10543$	0.21911
F_3	$-0.45416x10^{-9}W^6 + 0.37667x10^{-5}W^4$ $-0.56104x10^{-2}W^2 + 1$	$-0.01853W^2 + 1$
F_4	$-0.21179x10^{-11}W^6 + 0.51728x10^{-7}W^4$ $-0.17947x10^{-3}W^2 + 0.10543$	$-0.00061893W^2 + 0.219106$

f_i = Center frequency in Hz of i^{th} spectral band.

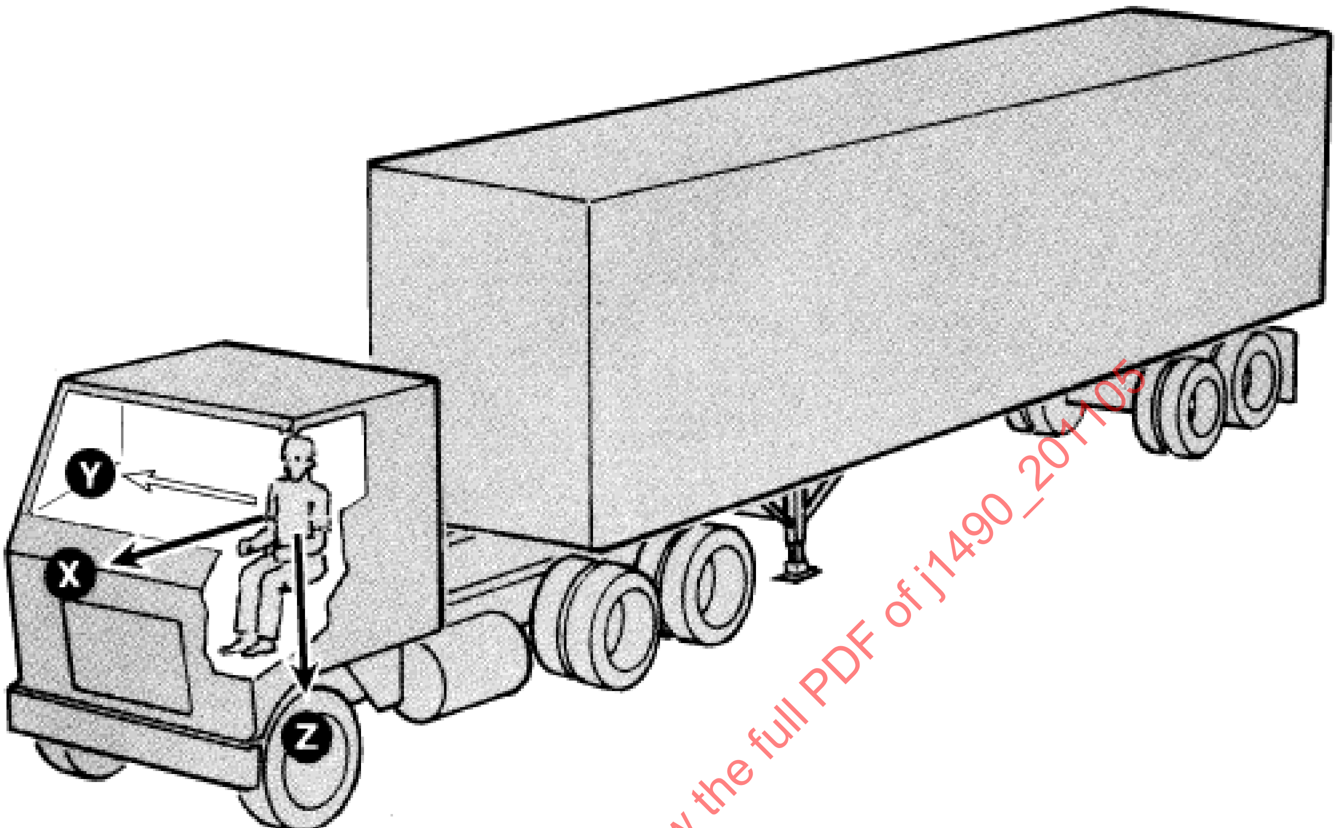

FIGURE 1—MEASUREMENT AXES

Manufacturer______________________ Model & Year_________________

VIN/Sr. No.___________________ COE______________ Conv._________

Mileage_____________ BBC_________ WB___________ GVWR__________

GCWR______________

Test Weight: Total_______ Front_______ Rear_______ Trailer______

Engine_____________ _________h.p. @ ______________RPM

No. of Cylinder___________ Cycle__________ Displacement________

Transmission______________ Auto/Manual___________ Speed__________

Aux. Transmission________________ Transfer Case_________________

Frame Section____________________ Material______________________

Front axle: Model____________________Driving/Nondriving__________

Rear axle: Model_____________________Model_______________________

Wheels: - Cast spoke____________ Disc___________ Size___________

Tire Size: Front_____________________ Rear_______________________

Tire Type: Front______________________ Rear_______________________

Tire Pressure: Front_________________Rear_______________________

Aux. Axle: Model_________________Location: TAG______ Pusher______

Liftable_________

Brakes Type: Front__________________ Rear_______________________

Brakes Size: Front__________________ Rear_______________________

Front Suspension: Type________ Capacity________ Mfgr.____________

Rear Suspension: Type________ Capacity________ Mfgr.____________

Seats: Driver________________ Passenger_________________________

Cab Mounting:___________________________

Steering: Mfgr/Model___________________ Power/Manual____________

FIGURE 2—TEST VEHICLE DESCRIPTION SHEET 1
TRACTOR

Trailer Type: Stake___ Van___ Flat__ Tanker___ Other_____

Manufacturer__________________ Model Year____ VIN/Ser.No.________

Length__________ Height_________ Width________ Axle No.__________

Tire Size___________

Tire Type___________

Wheels: Cast spoke_____ Disc_____ Size__________________________

Trailer Suspension: Manufacturer/model___________________________

Type___________________ Capacity___________________

Brake Type____________________

Brake Size_____________________

FIGURE 3—TEST VEHICLE DESCRIPTION SHEET 2
TRAILER

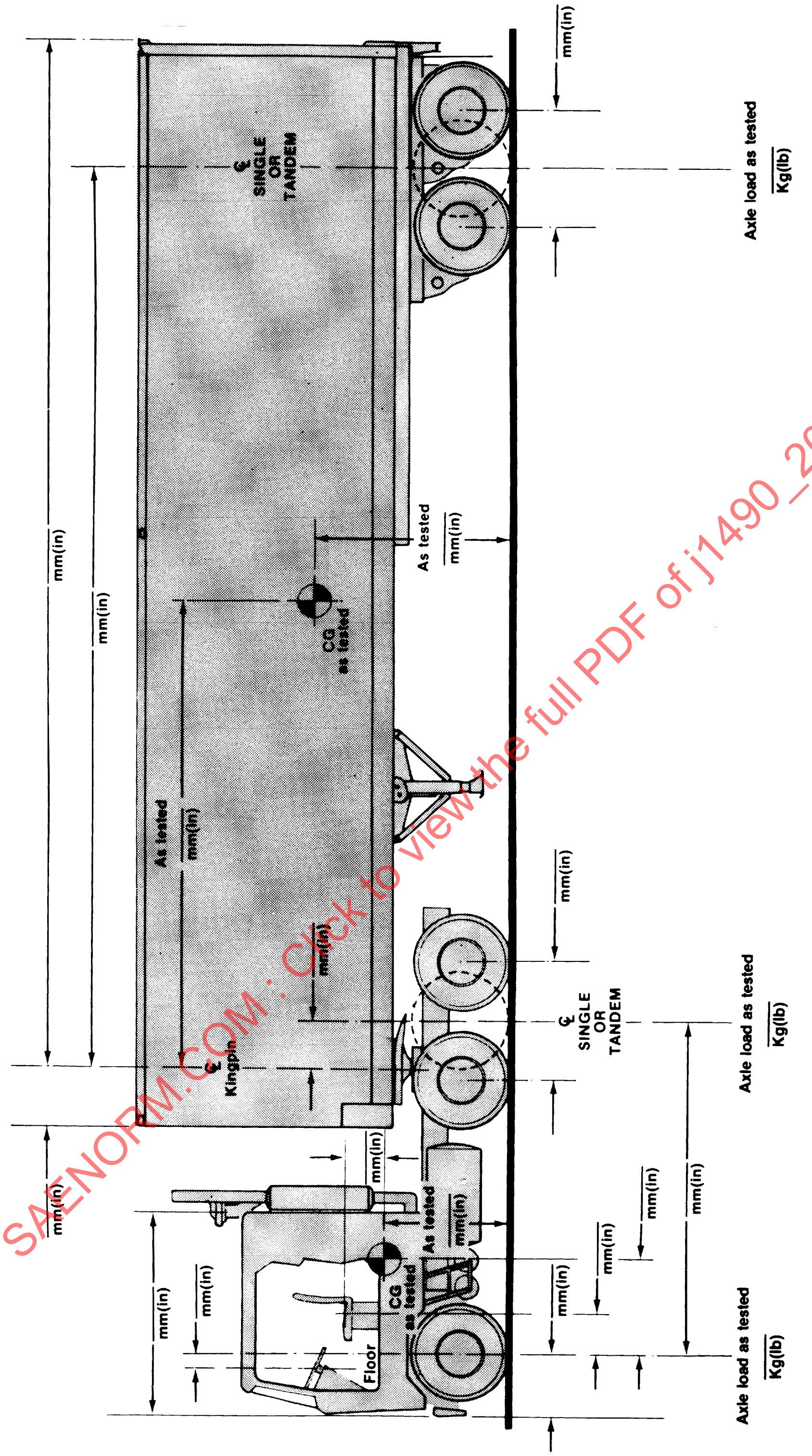

FIGURE 4A—TEST VEHICLE DESCRIPTION SHEET 3A

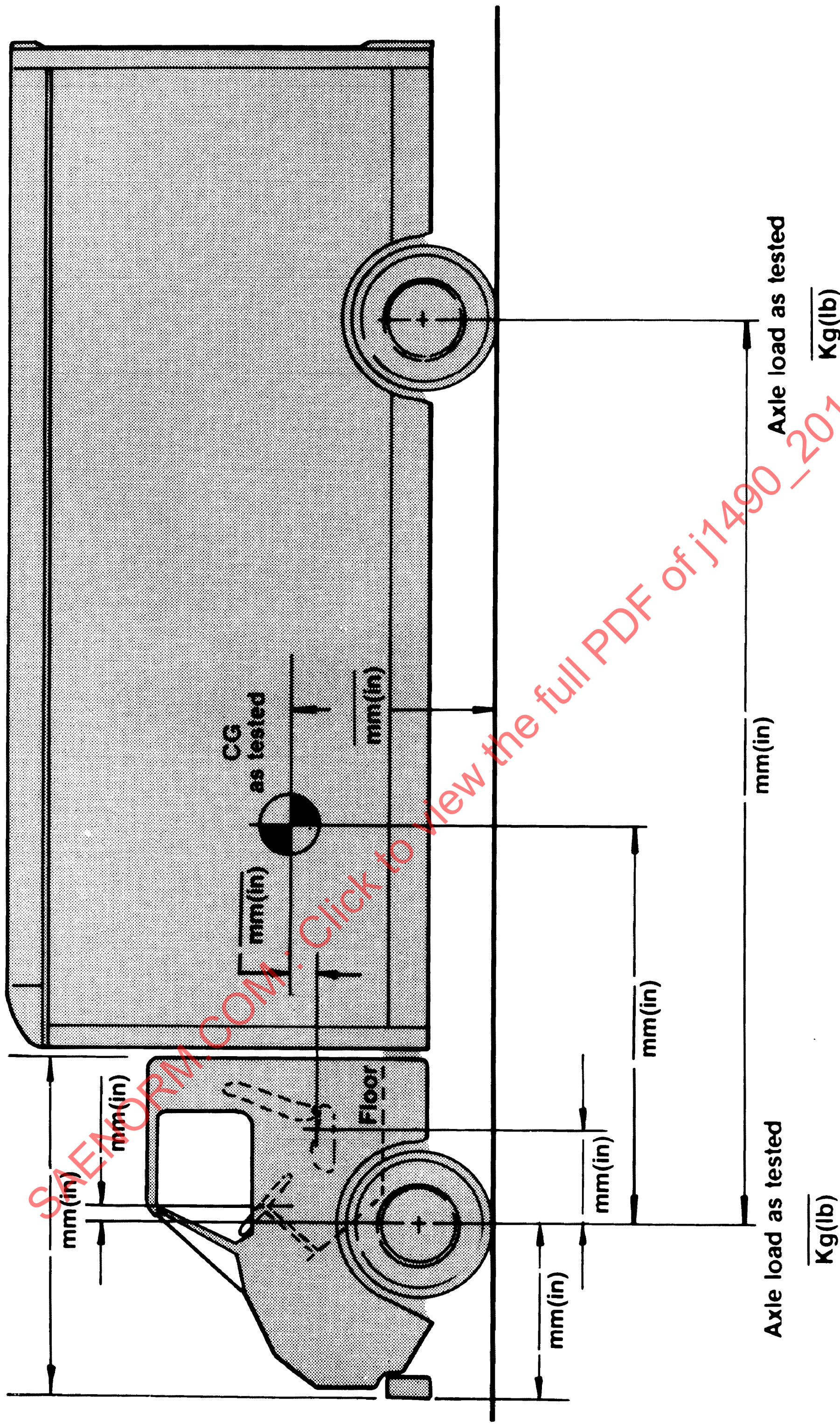

FIGURE 4B—TEST VEHICLE DESCRIPTION SHEET 3B

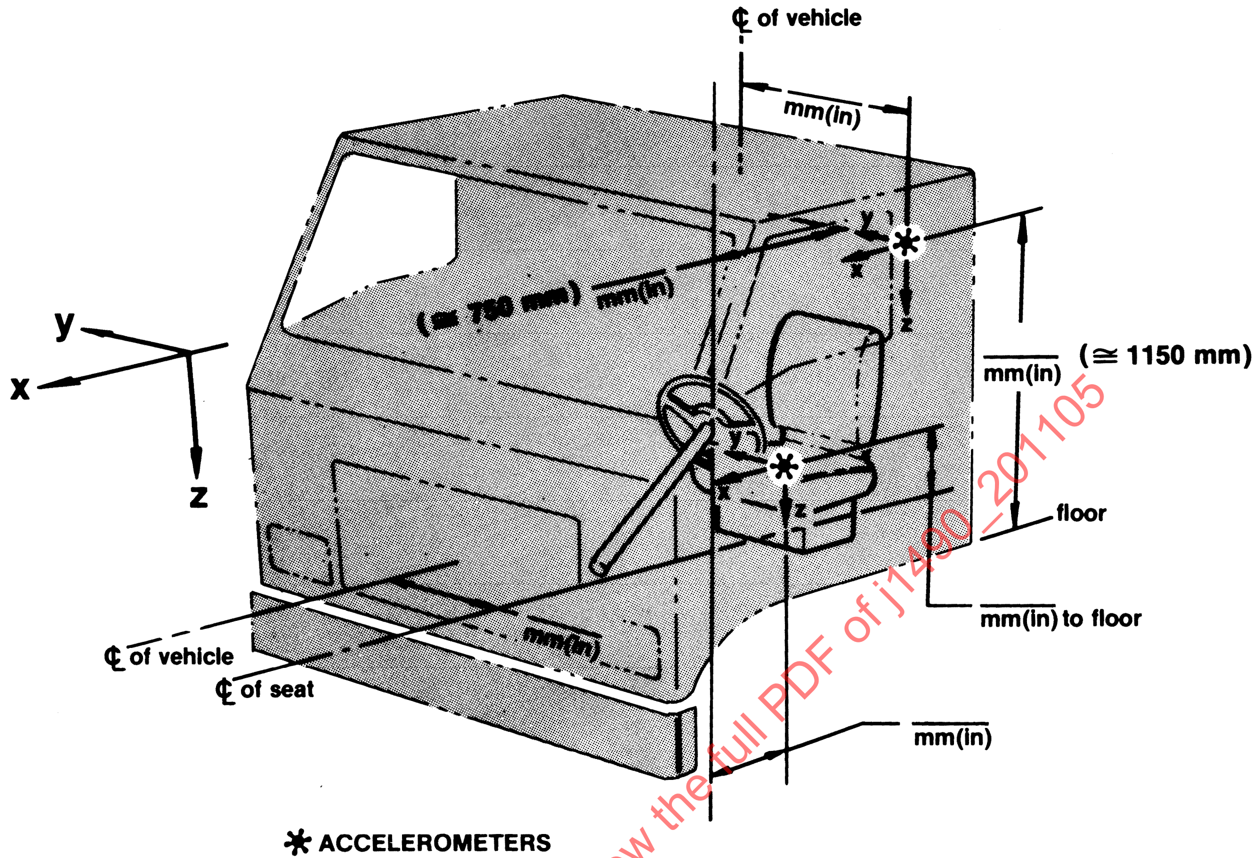

FIGURE 4C—TEST VEHICLE DESCRIPTION SHEET 3C ACCELEROMETER LOCATIONS WITHIN TEST VEHICLE CAB

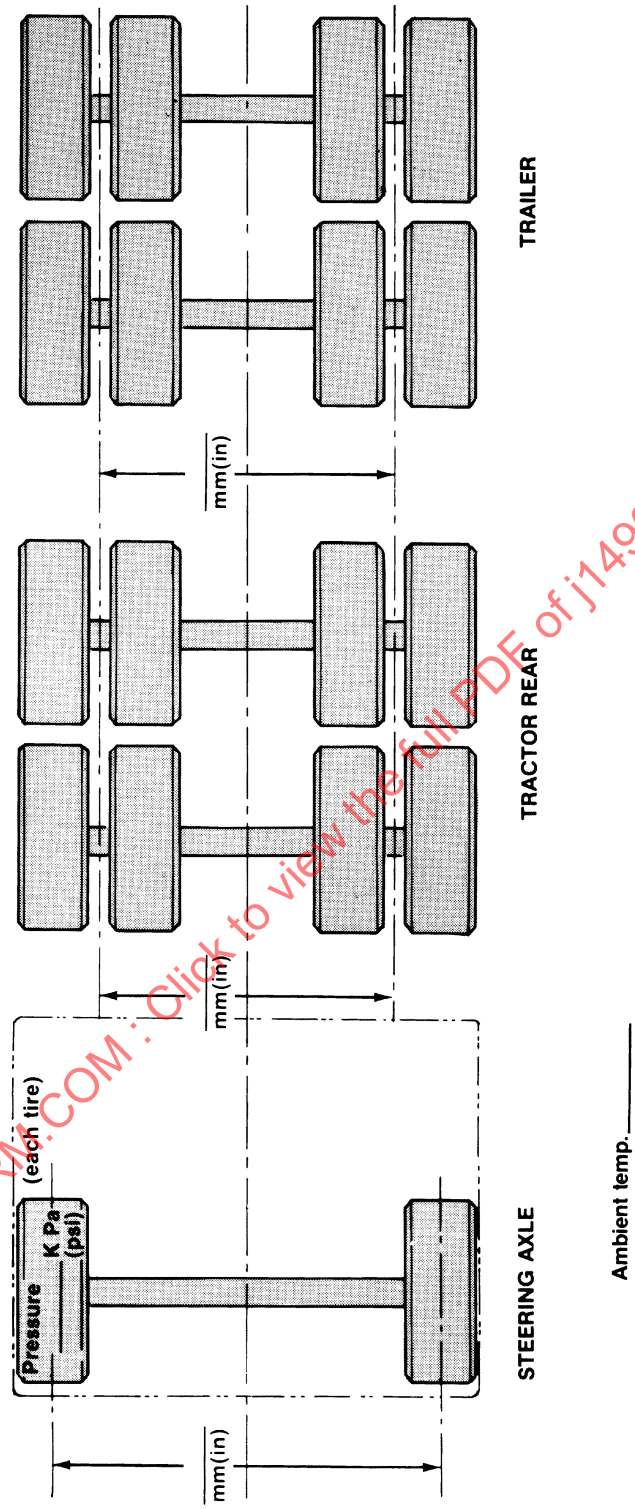

FIGURE 5—TEST VEHICLE DESCRIPTION SHEET 4

SAMPLE SUBJECTIVE EVALUATION SCALE

Please rate the truck in which you have just ridden with respect to its overall ride quality. Use the scale of 1 to 11 that is shown below.

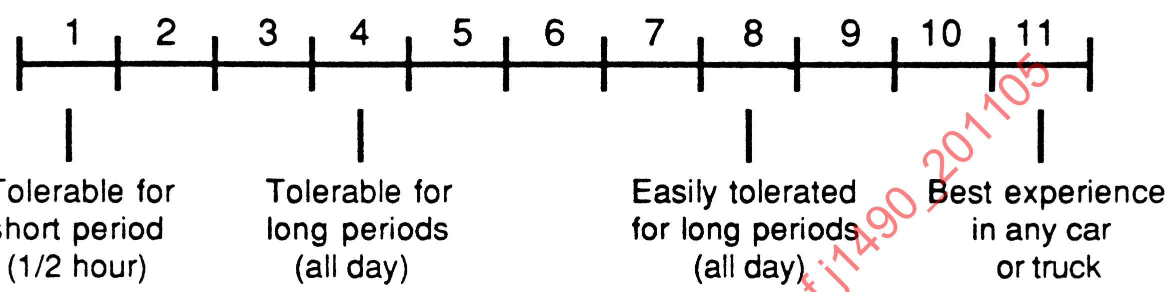

FIGURE 6A—SAMPLE SUBJECTIVE EVALUATION SCALE

1	2	3	4	5	6	7	8	9	10
UNACCEPTABLE				BORDER LINE	ACCEPTABLE				
CONDITION NOTED BY									
ALL OBSERVERS		MOST OBSERVERS		SOME OBSERVERS	CRITICAL OBSERVERS		TRAINED OBSERVERS		NOT OBSERVED
INTOLER-ABLE	SE-VERE	VERY POOR	POOR	MARGINAL	BARELY ACCEPT-ABLE	FAIR	GOOD	VERY GOOD	EXCELLENT
1	2	3	4	5	6	7	8	9	10

FIGURE 6B—SAMPLE SUBJECTIVE EVALUATION FROM SAE J1060

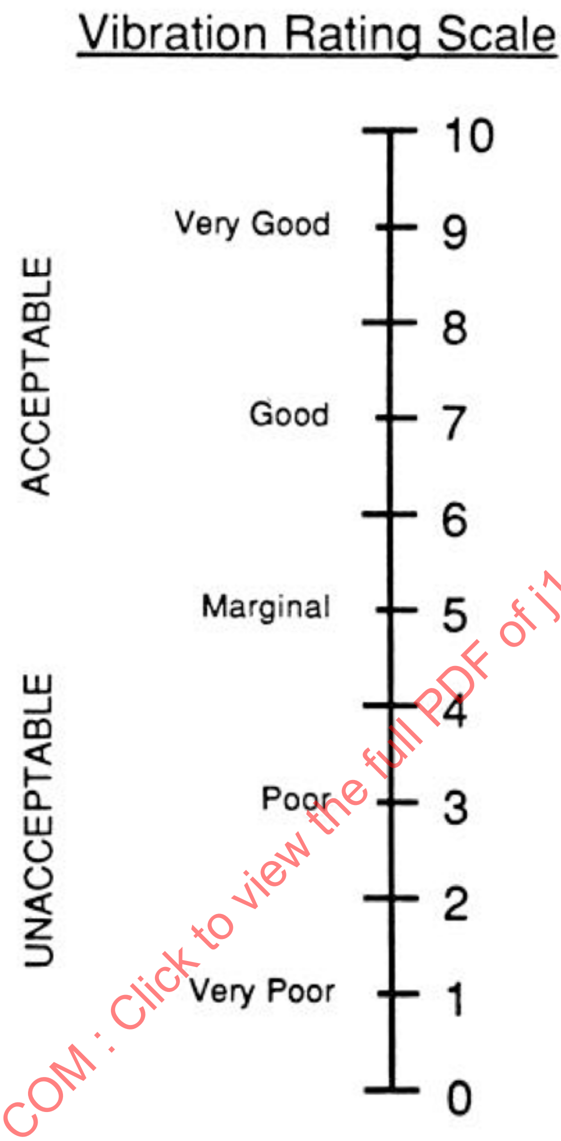

FIGURE 6C—SAMPLE SUBJECTIVE EVALUATION SCALE

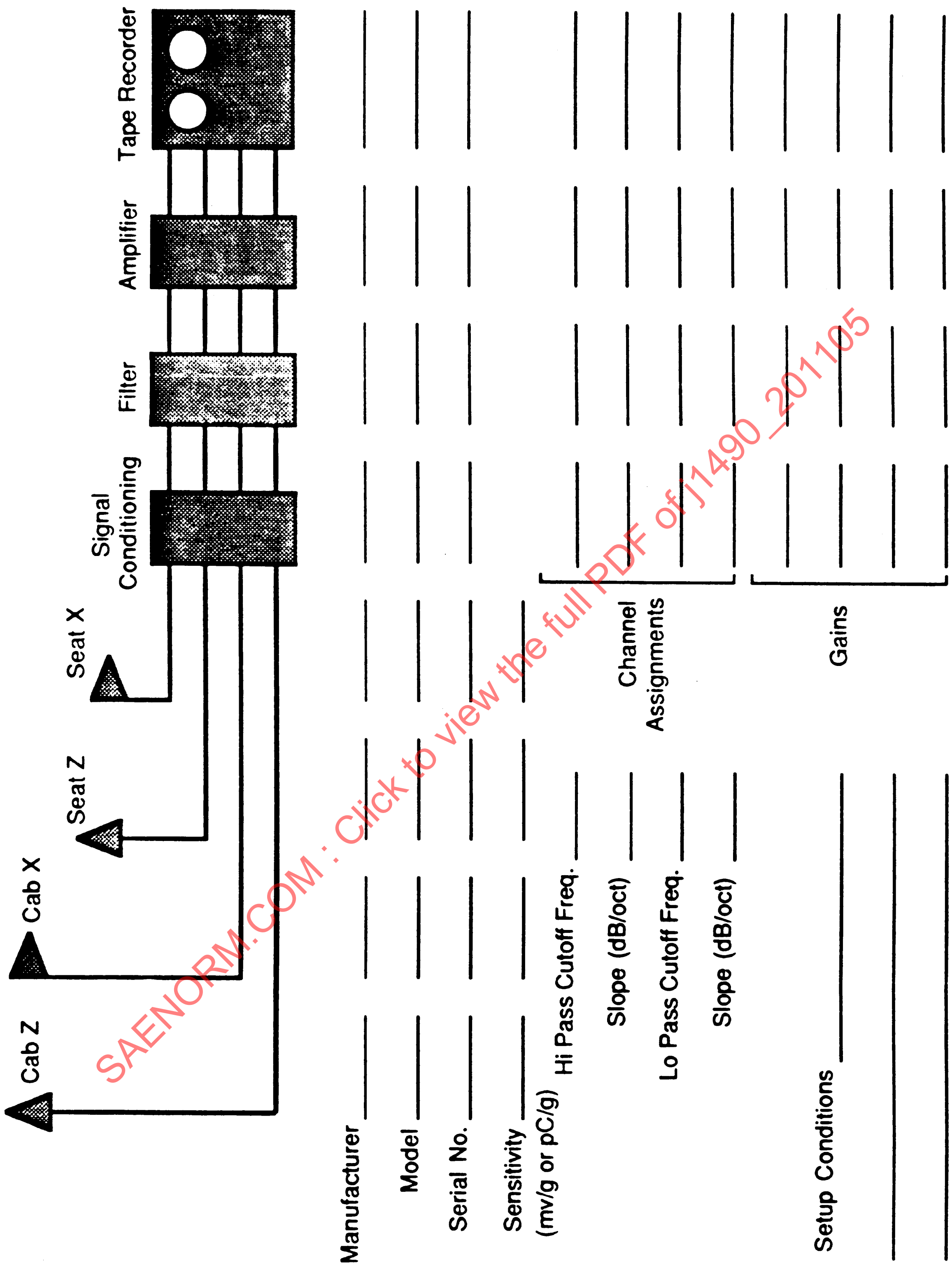

FIGURE 7—INSTRUMENTATION DATA SHEET

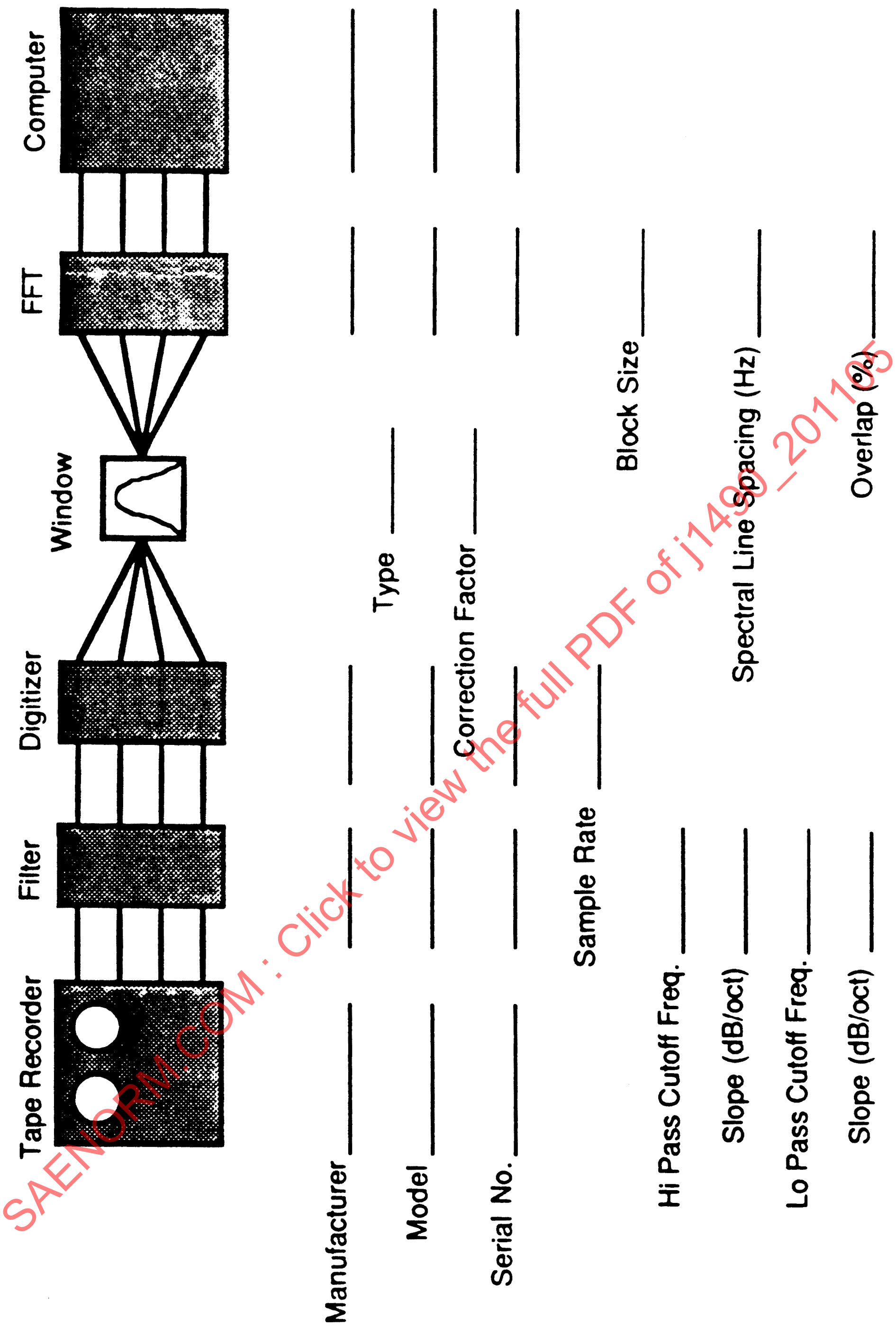

FIGURE 8—DATA ANALYSIS DATA SHEET

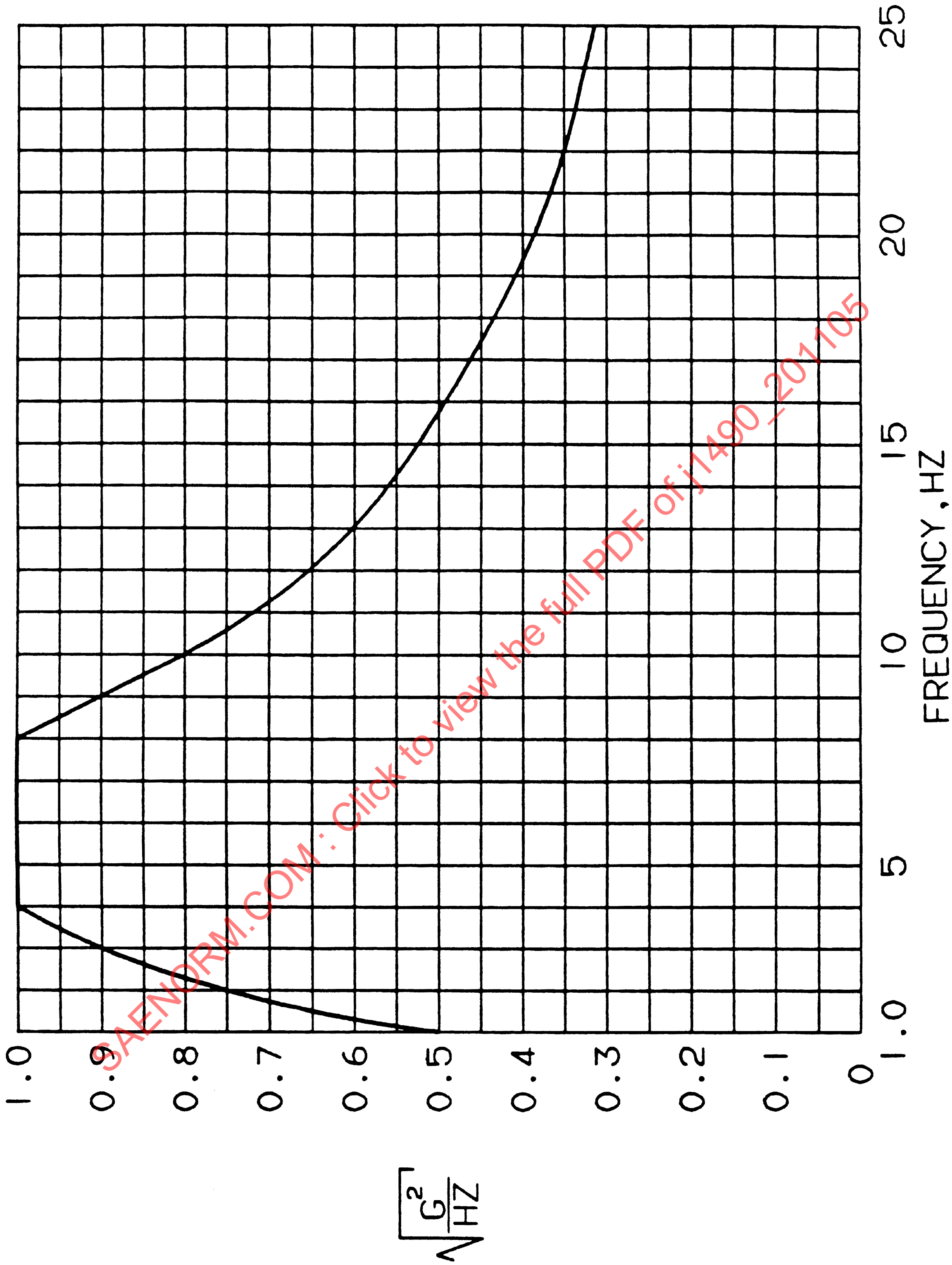

FIGURE 9—VERTICAL SAE J1013 WEIGHTING CURVE (Z) TO BE APPLIED TO RMS ACCELERATION