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Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles

International Union of Railways

Leaflet to be classified in Volume:

V - Rolling Stock

Amendments

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Preliminary remark:

The double vertical line (||) in the margin indicates modifications introduced on the date shown at the foot of the page.

Enforcement of this leaflet is subject to the conditions stipulated under the heading "application" at the end of the document.

Note

This leaflet is one of a series which also includes:

Leaflet 515	:	Coaches - Running gear
Leaflet 518	:	Testing and approval of railway vehicles from the point of view of their dynamic behaviour Safety - Track fatigue - Ride quality.
Leaflet 565-1	:	Special comfort and constructional characteristics for sleeping-cars accepted in international traffic.
Leaflet 565-2	:	Special comfort and constructional characteristics and rules of hygiene for restaurant-cars accepted in international traffic.
[illegible]	:	Loadings of coach bodies and their components.
Leaflet 567-1	:	Standard and X and Y coaches accepted for running on international services - Characteristics.
Leaflet 567-2	:	Standard Z-type coaches accepted for running in international traffic - Characteristics.

Reference may also be made to the following ISO standards:

ISO 2631	:	Vibrations and impacts - Guidelines for evaluating the effects of whole body vibrations on the human body
ISO 2041	:	Vibrations and impacts - vocabulary
ISO 4865	:	Vibrations and impacts - method of analysis and presentation of data
ISO 5805	:	Mechanical vibrations and impacts which have adverse effects on the human body - vocabulary
ISO 8002	:	Mechanical vibrations of land vehicles - methods of presenting the measured results
ISO 8041	:	Measuring instruments for vibrations perceived by persons
ISO 5347	:	Methods of calibrating impact and vibration pick-ups
ISO 5348	:	Mechanical fastening of accelerometers

ISO DP 9629 :	Characterisation of track irregularities[1]
ISO DIS 10326-1:	Mechanical vibrations: laboratory method for evaluating vehicle vibrations Part 1: Basic requirements
ISO CD 10326-2 :	Mechanical vibrations: laboratory method for evaluating vehicle vibrations Part 2: Application to rail vehicles

1) Currently in draft form only.

Contents

1 - Purpose

The purpose of this leaflet is to define the following:

- the conditions for performing tests designed to evaluate passenger ride comfort (passengers are all those on trains, including train crews),
- the parameters which should be measured, together with the means of determining the evaluation factors,
- a passenger comfort evaluation scale.

Since this leaflet specifies only how tests should be conducted and measurements processed, it is necessary to supplement it by a test specification suitable for the test vehicle and taking specific account of the conditions under which the vehicle operates.

This test specification should give the running conditions (track and vehicle characteristics, running speeds etc.) which, in combination with the conditions set out in section 5 below, make it possible to define the test programme in full, including in particular the test sections, speeds and areas where the parameters are recorded.

2 - Scope of application

ISO standard 2631 "Effects of whole body vibrations on the human body" is a document of general character capable of application to any situation which may be encountered by human beings in the course of normal activities (work, travel, etc.).

It describes the measurement of whole body vibrations and their effects.

This UIC leaflet is an application-specific document for the railway environment covering measurement, analysis and evaluation of vibrations, to allow for the fact that mechanical vibrations in railway vehicles have specific characteristics.

Based on the measurement of certain accelerations, the use of this leaflet should make it possible to evaluate passenger comfort in a specific vehicle and under given operating conditions (speed, type of track, etc.).

Evaluation of the ride of a specific vehicle under specified operating conditions (speed, type of track, etc.) is dealt with in UIC Leaflet 518.

The use of this leaflet may be useful in identifying the causes of discomfort (excessive vibration at floor level; exaggerated amplification through the seat, etc.).

This leaflet may be applied to the vibrations normally encountered on railways. A correct evaluation of comfort based on this leaflet will only be possible if there is strict observance of its specifications. It proposes a method which takes into account the non-stationary character of these vibrations.

In order to characterise behaviour in the range of very low frequencies on curved track in connection with certain vehicles (tilting body trains, active suspensions, etc.), additional measurements may be necessary.

This leaflet also suggests a way of presenting data to evaluate vibration comfort.

It is not concerned with any appreciation of working conditions in railway vehicles.

It is also not concerned with any effects of vibrations on the health of people on board railway vehicles.

This leaflet applies only to people in good health.

3 - Average vibration comfort - Definition

Vibration comfort is perceived differently by each individual. It is therefore impossible to find an evaluation scale which can be applied to each individual.

Consequently the evaluation of vibration comfort used in this leaflet is based on the relationship, obtained over 5-minute periods, between the accelerations measured in the vehicle and the average of the vibration comfort ratings given by a representative group of passengers.

4 - Methods of evaluation

4.1 - Principles

The principles underlying the tests of passenger comfort in order to propose evaluation methods are based on:

- the vibration environment of the railways, which has the following characteristics:
- low level of vibration
- a large part of the energy contained below 3 Hz

- physiological weightings have been made, in particular in the 0.5 to 5 Hz frequency range, to take account of this environment.

- measurements of translation acceleration at standard points on the vehicle and the seat, with no allowance for rotary accelerations on account of their minimal contribution

- a statistical evaluation method obtained with the aid of correlations between objective measurements and subjective impressions of passengers in railway vehicles.

Since the vibrations of railway vehicles are not stationary but instead tend to fluctuate, the chosen statistical analysis is made with the aid of the weighted RMS values, calculated for a period of 5 seconds. Based on this statistical analysis, the value which contains the fluctuation, i.e. the 95% percentile, is calculated.

Currently, two methods of evaluation are possible:

- a simplified method, based solely on accelerations measured at floor level

- a fuller method, based on accelerations measured at floor level and at the seat (seat pan and seat back).

In the statistical method of characterising comfort, use is made of the weighted RMS values of these accelerations.

4.2 - Procedure

The evaluation of the average vibration comfort of a passenger in a railway vehicle comprises:

- acceleration measurements at the interfaces between the vehicle and the passenger.

  The main axes of the human body in seated and standing position are shown in Appendix 1.

  The principles for acceleration measurement are set out in Appendix 2.

- processing of the signals thus measured as described in Appendix 3, including:

  - a frequency weighting

  - a calculation of the RMS values evaluated every 5 seconds and a statistical analysis of these RMS values for a period of 5 minutes

  - a calculation of mean comfort indices.

The measurements are conducted with two test persons respectively weighing 52 kg (+/- 5%) - representative of the 5th percentile of women - and 90 kg (+/- 5%) - representative of the 95th percentile of men - or with two test persons with the same weight of 70 kg (+/- 5%), representative of the 50th percentile of the population in general.

The duration of the measuring period depends on the objective of the tests. It will in any event be a multiple of 5 minutes, the basic sequence which makes use of the method possible. A period of 4 sequences of 5 minutes which are representative of the operating conditions is the minimum.

4.3 - Simplified method

The comfort of a seated passenger may be determined approximately from measurements at floor level alone.

The position of the measuring points is shown in Figures 4 and 5 of Appendix 2.

4.4 - Full method

The evaluation is made at the interfaces with the test person (Appendix 1), i.e.:

- in standing position, based on acceleration measurements at floor level
- in seated position based on acceleration measurements at the seat pan, seat back and floor.

These measurements are made with the aid of sensors, the characteristics of which are described in Appendix 2.

5 - Test conditions

5.1 - Running conditions

The comfort of the passenger is evaluated at the various operating speeds of the vehicle which actually occur in service, and in particular at the maximum operating speed.

5.2 - Selection of test lines

The test lines should be selected so that provision is made for the operating conditions representative of the use of the test vehicle (e.g. deployment on high-speed lines, on lines with normal speeds, on lines with small-radius curves).

For each type of line thus defined, at least 4 blocks each of 5 minutes shall be defined as test zones. These zones may be separate, but each zone shall be of 5 minutes' continuous duration.

5.2.1 - Track geometry

(Open)

A test zone should be chosen in which the geometrical characteristics of the track correspond to those defined for the desired running speed.

N.B:

Since there is at present no international criterion for defining a track, it is not possible to give a standard definition of track quality. However, since each railway has its own definition criteria, it is possible to specify routes which produce equivalent effects as regards vehicles.

The track characteristics of the zones used shall be set out in the test report.

Appendix 4 provides a specimen of the presentation of the geometrical characteristics of the track.

5.2.2 - Wheel-rail contact geometry

On straight track and on curves with radius $R > 2500$ m, the equivalent conicity should not normally exceed the following maximum values:

- 0.40 at $v < 200$ km/h
- 0.30 at $v > 200$ km/h.

The determination of comfort will inevitably be made with wheel profiles with an equivalent conicity of at least 0.10 with rail cant of 1:20, and of at least 0.15 with rail cant of 1:40. This so-called "wear profile" may be obtained naturally or by machining.

A test shall be made on characteristic rails, the profiles of which have been recorded over the test zones.

The equivalent conicity for which allowance is to be made is that obtained with actual wheel profiles and rail profiles of the test zone, taking into consideration the lateral movement of the wheelset in the 0 +/- 3 mm range.

The definition and the various methods of measuring and calculating equivalent conicity are contained in RP 3 of ERRI Committee C 116.

The characteristics of the wheel-rail contact geometry are to be set out in the test report.

5.3 - Condition of the vehicle

The vehicle tested should conform in every respect to the definition specification. Checking of those characteristics of the vehicle in its normal state of maintenance which are of importance for its dynamic behaviour, such as the characteristics of the shock absorbers, vertical and lateral elasticities, should take place before the ride test on the line.

In view of the wide range of different bogie types and of linkage between coach body and bogie, it is not possible to give a list of characteristics to be checked in this document. Such a list should be drawn up in each case prior to the ride test, and as part of the detailed specification for test implementation.

The vehicle will inevitably be tested empty in ready-for-service condition; it may also be tested with the normal payload.

5.4 - Other conditions

The position of the vehicle in the train has no effect on the application of the method.

However, it can be stated that, in the case of a specific vehicle, comfort in vehicles at the end of the train may be different. The tightening of the couplings should be regular.

In the case of a motor trainset, whether articulated or not, the designation of the vehicles for which comfort is determined, needs to be set out precisely in the test specification. The choice depends on the design of the train; measurements should therefore be made in a vehicle of each possible type, depending on the bogies on which they are mounted and on the coach body - bogie linkages.

6 - Measured variables

The comfort of passengers is determined on the basis of acceleration measurements. These are taken at various points on the floor and on the seat (seat and back).

The conditions of measurement are set out in Appendix 2.

7 - Calculated variables

7.1 - Symbols and indices

7.1.1 - Symbols

a = effective value of the acceleration
N = comfort index

7.1.2 - Indices

- w_i This upper index relates to frequency-weighted values according to the weighting curve i (i = b,c,d):
  b: vertical
  c: seat back
  d: horizontal

- σ,j These lower indices relate to the interfaces:

  (σ: direction of the sensitive axis of the sensor)

  (j: A for seating surface, P for floor, D for seat back)

- k This lower index relates to the percentile used:

  (k = 50 for the 50th percentile and k = 95 for the 95th percentile)

- ℓ: This lower index relates to the type of comfort):

  ℓ = MV (simplified method)
  ℓ = VA (passenger in seated position)
  ℓ = VA (passenger in standing position)

7.2 - Average passenger comfort

The filtering and processing conditions are described in Appendix 3.

7.2.1 - Simplified formula in seated or standing position

a) Variables used

At floor level a_{XP}, a_{YP}, a_{ZP}

b) Simplified formula

$$N_{MV} = 6\sqrt{\left(a_{XP95}^{W_d}\right)^2 + \left(a_{YP95}^{W_d}\right)^2 + \left(a_{ZP95}^{W_d}\right)^2}$$

In order to be able to use this formula at the vehicle end, allowance should be made for the value, $a_{XP95}^{W_d}$ which is obtained in the vehicle centre.

7.2.2 - Full method in seated position

a) Variables used

At floor level	:	a_{ZP}
At seat pan level	:	a_{YA}, a_{ZA}
At seat back level	:	a_{XD}

b) Comfort formula

$$N_{VA} = 4 \cdot \left(a_{ZP95}^{W_b}\right) + 2 \cdot \sqrt{\left(a_{YA95}^{W_d}\right)^2 + \left(a_{ZA95}^{W_b}\right)^2} + 4 \cdot \left(a_{XD95}^{W_c}\right)$$

7.2.3 - Full method in standing position

a) Variables used

At floor level a_{XP}, a_{YP}, a_{ZP}

b) Comfort formula

$$N_{VD} = 3 \cdot \sqrt{16 \cdot \left(a_{XP50}^{W_d}\right)^2 + 4 \cdot \left(a_{YP50}^{W_d}\right)^2 + \left(a_{ZP50}^{W_b}\right)^2} + 5 \cdot \left(a_{YP95}^{W_d}\right)$$

In order to be able to use this formula at the vehicle end, allowance should be made for the value $a_{XP50}^{W_d}$, which is obtained in the vehicle centre.

8 - Evaluation scale

The proposed scale, in comfort units with a maximum class interval of the comfort unit of 0.10, is as follows:

N < 1	very good comfort
1 < N < 2	good comfort
2 < N < 4	moderate comfort
4 < N < 5	poor comfort
N > 5	very poor comfort

9 - Recommended limiting values

In seated and standing position and when the simplified method is used, the following provisional limit values are recommended:

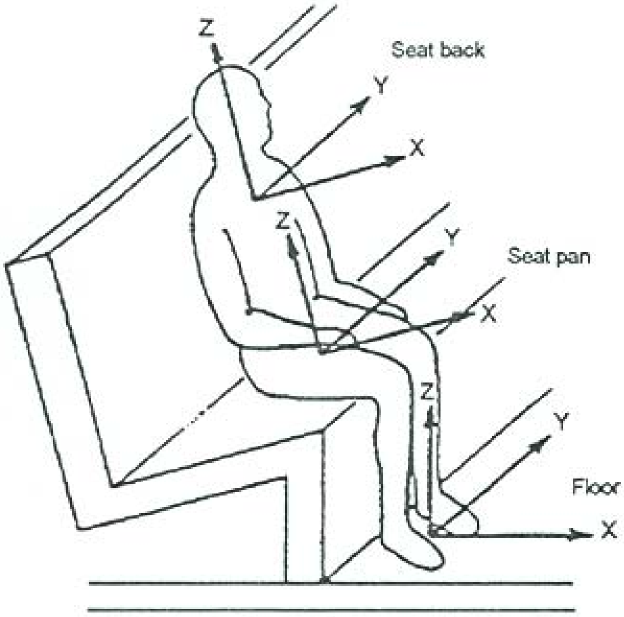
Suburban	4
Conventional rolling stock	3
De-luxe rolling stock	2

10 - Test report

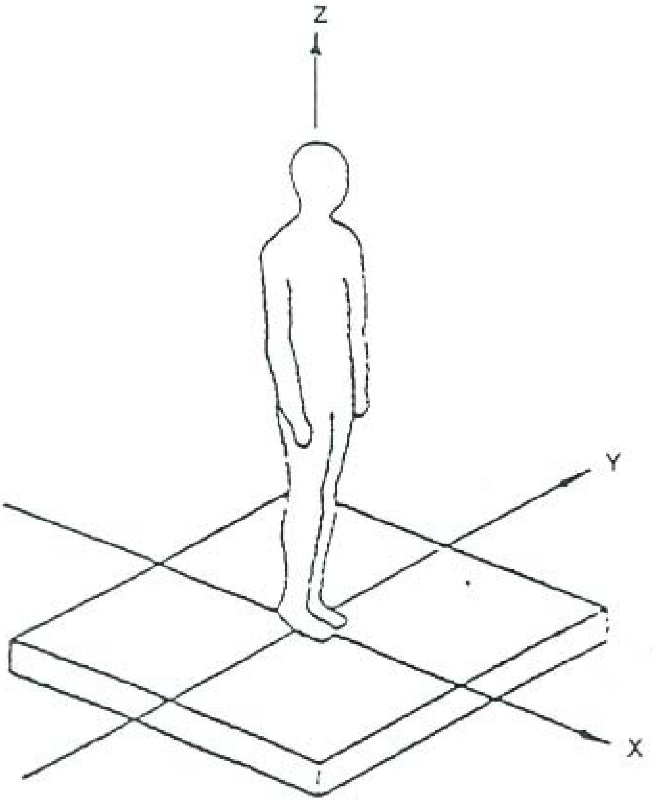
The test report should refer to the test specification, set out the characteristics of the vehicle and seat tested and the track used, and precisely describe the test conditions with all measurements in proof.

A specimen presentation is shown in Appendix 5.

Principle axes of the human body



Seated position



Standing position

APPENDIX 2

Measurement of the vibrations

1 - Variables to be measured

In accordance with the chosen evaluation method, the physical variables to be measured are the translation accelerations at floor level or (and) at the seat/person interfaces.

The term "measuring equipment" used below relates to all the instruments which make it possible to measure and record the signals.

"Measuring method" describes the mode of use of the measuring equipment in order to bring together the data which constitute the subject of the test.

2 - Measuring equipment

The measuring equipment comprises the following:

- sensors (accelerometers)
- conditioning amplifiers and filters
- recorders (if required)

This equipment taken together represents a measuring chain. The characteristics o. this equipment should be consistent. The accuracy of the measuring chain should be defined not only by the characteristics of each component but also by specific characteristics of the measuring chain as a whole.

The calibration of the equipment is to be checked regularly in acordance with the relevant standards.

2.1 - Accelerometers and conditioning amplifiers

In general it is not possible to separate the sensor from its conditioning amplifier, and therefore these components are dealt with together; they should satisfy the following conditions:

- the global transfer function should be flat between 0.4 and 00 Hz at +/- 0.5 Db,
- non-linearity + hysteresis: ≤ 0.3% of the measuring range,
- cross-axis sensitivity: ≤ 0.05 (m/s2)(m/s2),

- effect of temperature:

  . on the zero ≤ 3% of the measuring range
  . on the sensitivity ≤ 5.10-4/°C.

2.2 - Magnetic tape unit

The magnetic tape recorder should meet the following specifications:

- flat bandpass between 0 and 100 Hz

- at 100 hz, reduction of the lower band limit to 1 dB on account of the filter.

Care should be taken to ensure that the recorded signal level is such that the analysis can be performed under satisfactory conditions.

3 - Method of measuring acceleration

Accelerations are measured at floor level and/or at the person/seat interface using the method chosen.

3.1 - Measurement of acceleration

3.1.1 - Conditions to be maintained during measurements at the person/seat interface

Measuring equipment at the seat pan

A semi-rigid moulding of slight thickness and specially shaped as shown in Figures 1 and 2 is placed at the interface between the seat par and the bottom of the individual person.

The shaped part is positioned so as not to cause discomfort to the person sitting: its shape and the material it is made of should enable it to adapt to the morphology of different inividuals.

The shaped part is provided with accelerometers in the transverse direction y and the vertical direction z.

The alignment of these axes in the y and z direction of the seated person should be made prior to the test, after any creep in the seat material has taken place; it should be checked at the end of the test.

Measuring equipment at the seat back

A single-direction acceleration sensor oriented in the x direction is attached to the seat back at the interface with the test person, at the maximum point of pressure of the back on the seat back. It should be fitted into a disc of resilient material (Fig. 3), to ensure the natural alignment of the sensor.

This equipment may be fitted either between the test person and the seat back or in the infrastructure of the seat itself.

3.1.2 - Measurements at floor level

In fixing an accelerometer to the floor, the following precautionary measures should be taken:

- the motion of the accelerometer should as far as possible be identical to that of the part of the structure to which the seat is secured
- the signal coming from the accelerometer should not be distorted either by a function which too strongly resembles its initial resonant frequency on fastening, or by local vibration zones of the fastening surfaces. It is therefore necessary to ensure that the fastening system of the accelerometer and the fastening points themselves are as rigid as possible.

More detailed recommendations are contained in draft standard ISO/DIS 5349.

3.2 - Location of the measuring points

The accelerations at any point of the vehicle depend heavily on the position of this point. This is due to the resilient characteristics of the vehicle. Consequently, measurements should be made in the coach body centre and at both ends at seat level in the immediate vicinity of these positions.

Fig. 4 shows the position of the measuring points on the floor of a conventional vehicle, and Fig. 5 the position of the measuring points on the floor of a double-deck coach.

Depending on the method employed and the type of vehicle, the following measuring points should be taken into consideration:

- Single-deck vehicle:
  - simplified method:
    one point in the centre and one point at each end
  - full method:
    one point in the centre and one point at each end

- Double-deck coach:
  - simplified method:
    one point in the centre and one point at each end of the lower deck
    one point in the centre of the upper deck
  - full method:
    one point in the centre and one point at each end of the lower deck
    one point in the centre of the upper deck.

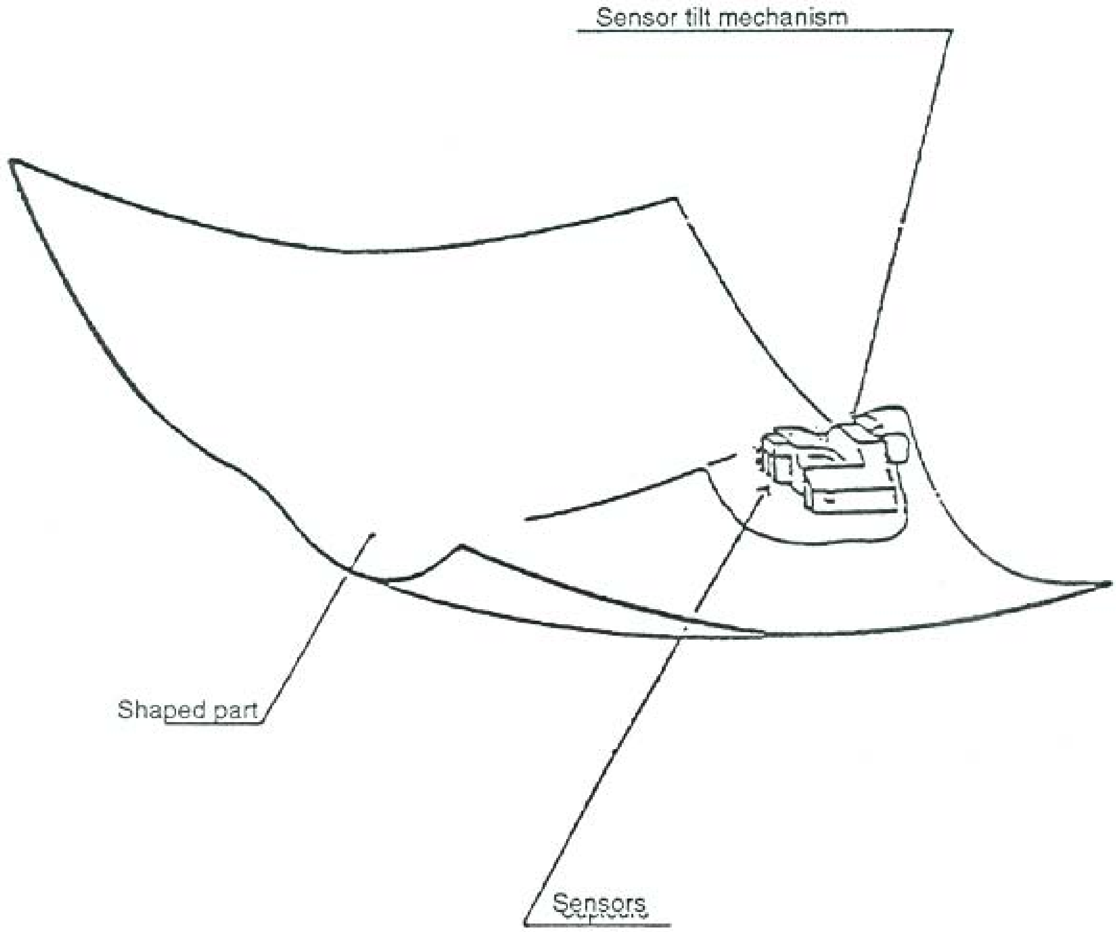
The accelerometers should be fastened to the floor in the immediate vicinity (if possible no more than 100 mm from) the vertical projection of the centre point of the seat pan and, for the test of the standing position in urban transport, on the platform.

Further measuring points may be selected depending on the test objective.

APPENDIX 2
Fig. 1

Measuring equipment at the seat pan

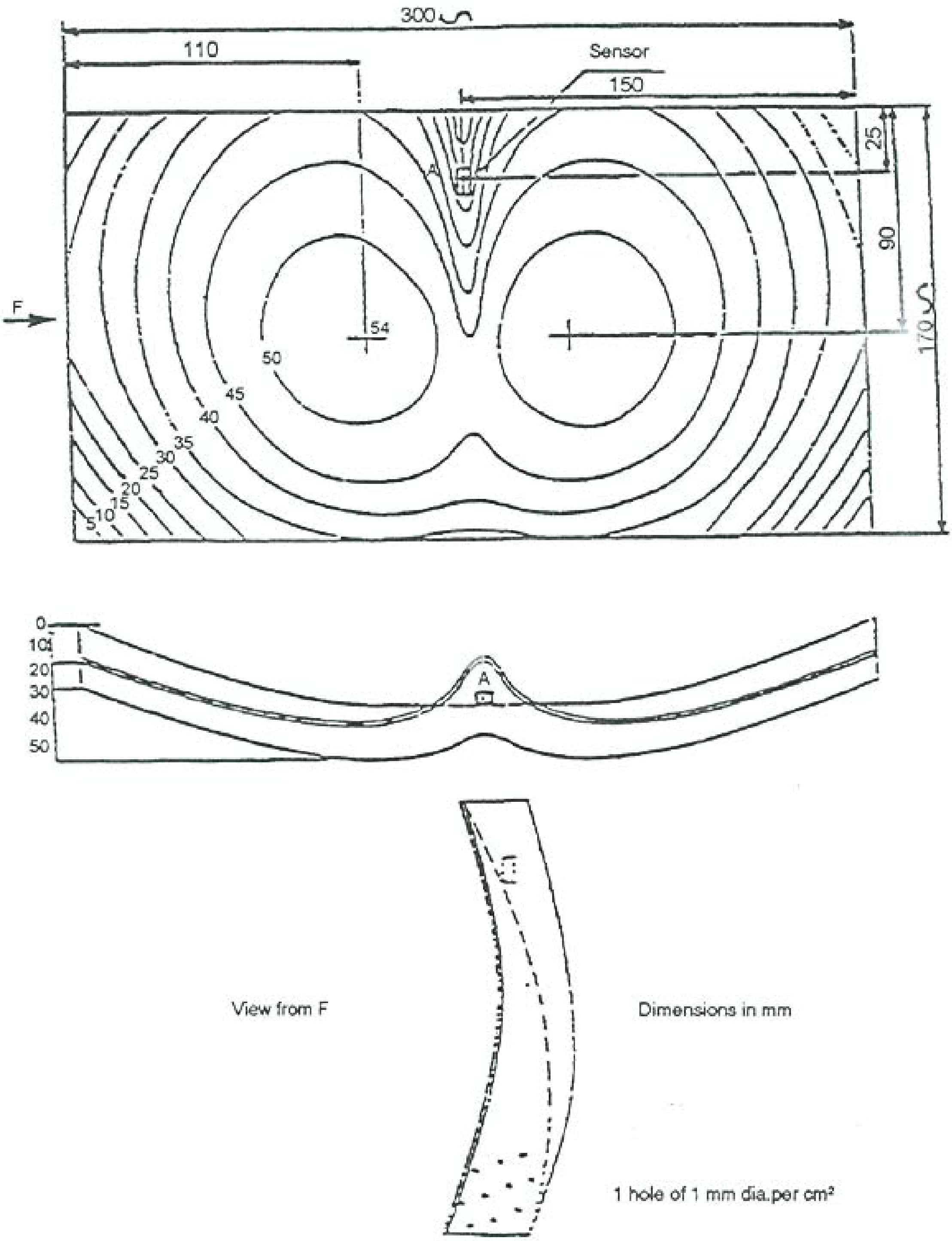
(y and z directions)



APPENDIX 2
Figure 2

Measuring equipment at the seat pan

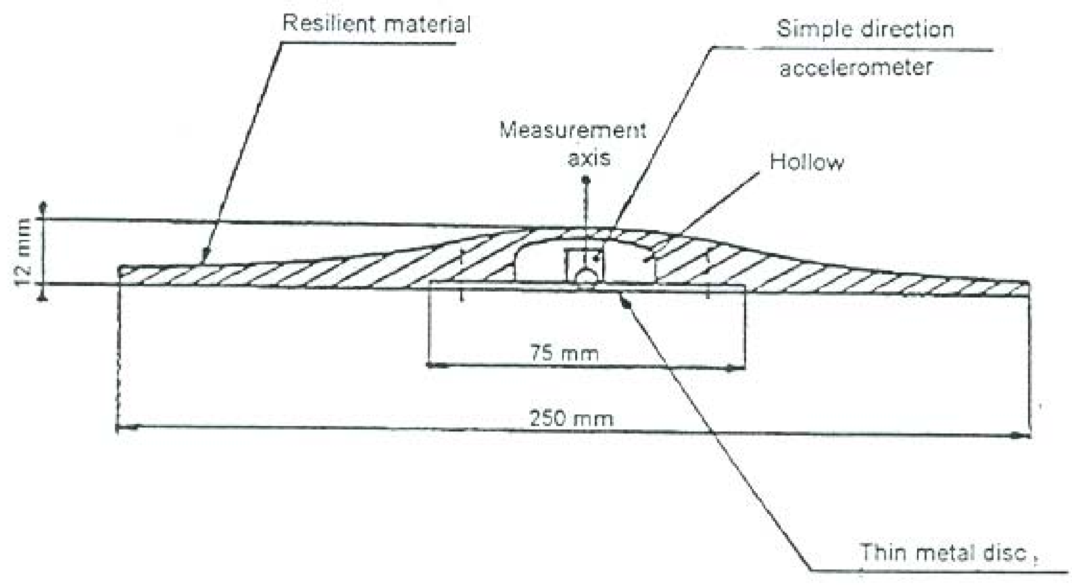
(y and z directions)



APPENDIX 2
Figure 3

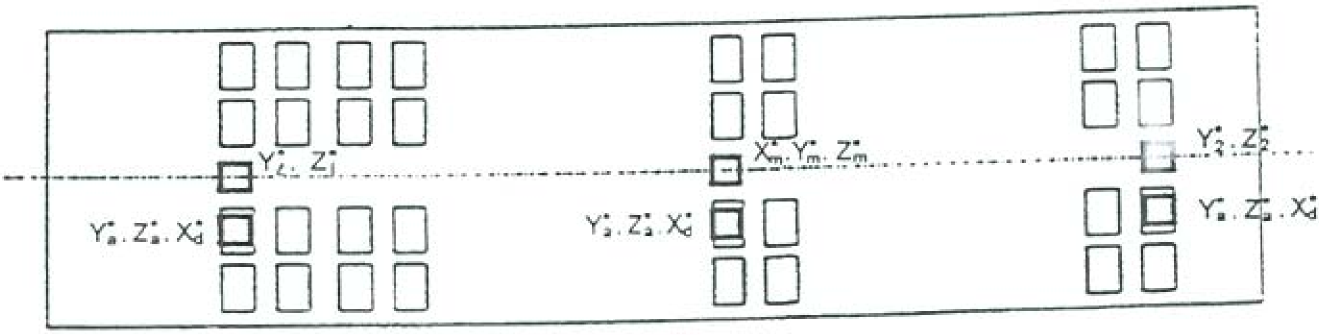
Measuring equipment at the seat back

(x direction)



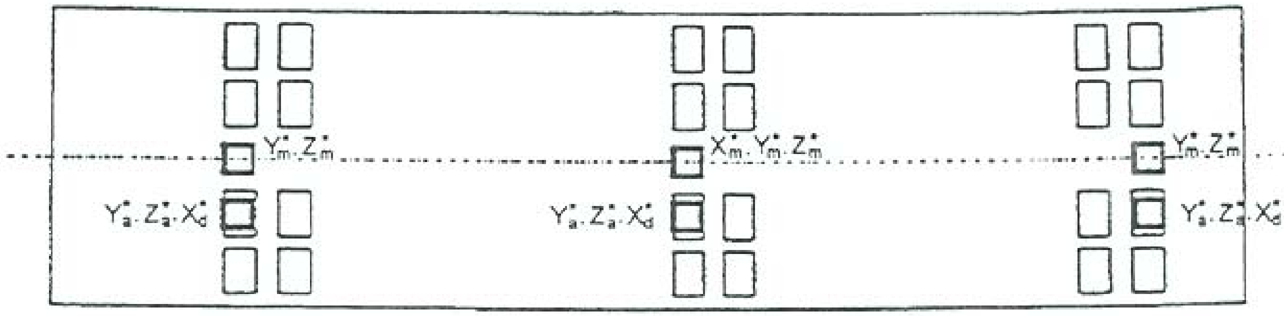
APPENDIX 2
Figure 4

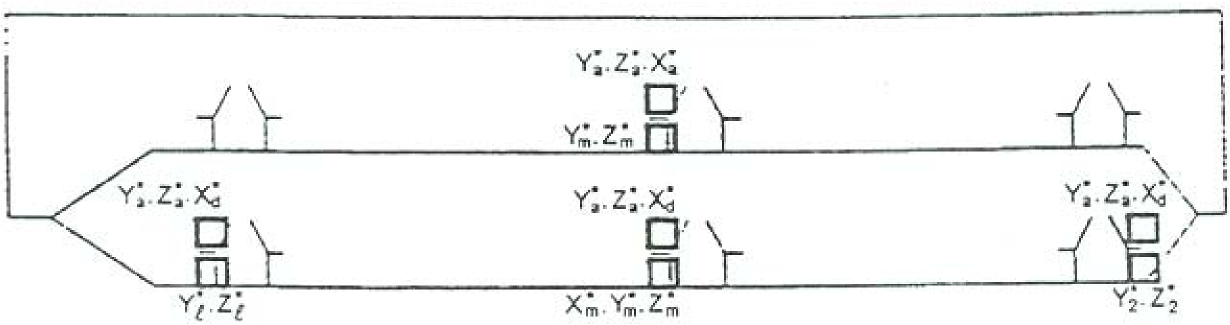
Passenger coach (conventional or articulated trainsets)



APPENDIX 2
Figure 5

Double-deck passenger coach (conventional or articulated trainsets)





Processing of the measurements

1 - Symbols and indices

1.1 - Symbols

t	=	time (s)
f	=	frequency (Hz)
$a(t)$	=	acceleration amplitude as a function of time (m/s^2)
Δt	=	sampling interval (s)
τ	=	duration of a basic sequence (s)
N_b	=	number of basic sequences (s)
b	=	class interval in m/s2
X	=	Fourier transformation of the acceleration (m/s^2)
h	=	histogram of the effective values of the accelerations
N_e	=	number of samples per basic sequence

1.2 - Indices

- index w

  This superscript relates to frequency-weighted variables: a^w

- index ℓ

  This subscript relates to the basic sequence ℓ: a_ℓ $a^w{}_\ell$)

- index k

  This index relates to the class k of the observation: h(k)

- index *

  This superscript describes the complex conjugated factor of the number to which it is appended.

- index c

This superscript relates to the cumulative frequency diagram.

2 - Calculation of the weighted effective values

In order to calculate the weighted effective values of the accelerations, it is necessary to process the recorded signals using the following methods:

- analog method
- hybrid method (analog - digital)
- digital method.

These methods are described in Figs. 1, 2 and 3 of this appendix.

3 - Weighting curves

To allow for variations in individual sensitivity depending on frequency (ISO TC 108 and ERRI B 153 Committee), weighting curves have been produced for the acceleration signals in the vertical and horizontal directions. These curves are defined in Figs. 4 to 6 and illustrated in Figs. 7 and 8 of this appendix. The tolerances to be maintained are set out in Figs. 9 to 11.

These curves are defined for sinusoidal vibrations. Their validity for broad-band static vibrations is accepted.

Although each individual has his/her own weighting curves, the curves chosen are optima for th evaluation of average vibration comfort.

4 - Statistical analysis method

This method is based on the following principle:

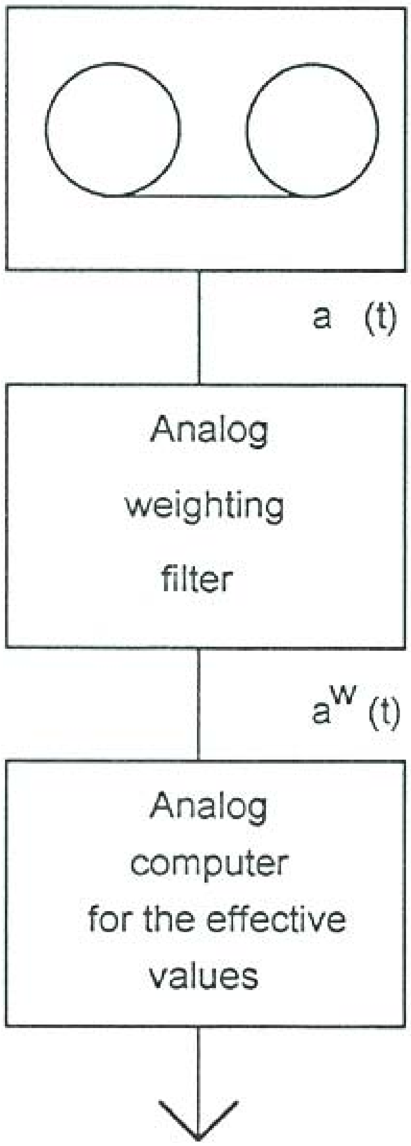
In order to allow for the fluctuating pattern of the vibrations, the vibration comfort perceived by the passenger depends on the extremes of the effective values evaluated for the passenger in seated position, together with the median of the effective values determined for passengers in standing position.

Consequently, the effective value of the vibrations is determined for a period of 5 seconds in each direction and at each interface as recommended in Appendix 1.

This period of 5 seconds represents the best compromise which allows for the lowest frequencies and makes it possible to obtain adequate variability of the effective values.

The various types of histogram of the effective values weighted and calculated every 5 seconds are produced and the 50 and 95 percentiles determined. These values are required for calculation of the various comfort indices N_{MV}, N_{VA}, N_{VD}.

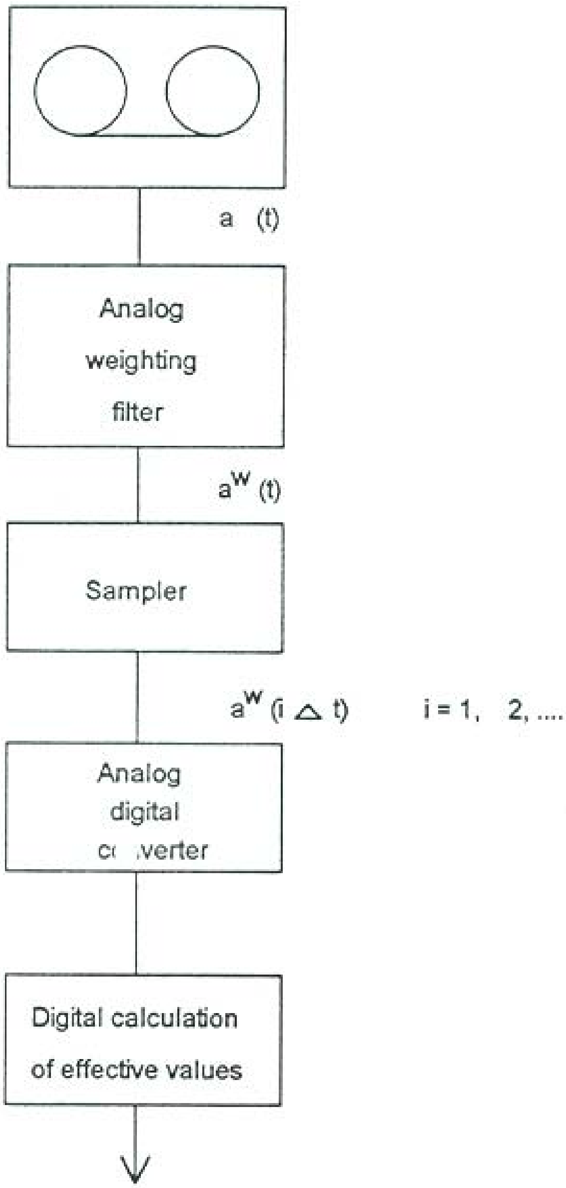
Figure 1 - Analog method



with $\left(a_1^w\right) = \sqrt{\frac{1}{\tau}\int_{(\ell-1)\tau}^{\ell\tau}(a^w(t))^2\,dt}$

1	=	1,2 ...N_b
τ	=	5 seconds

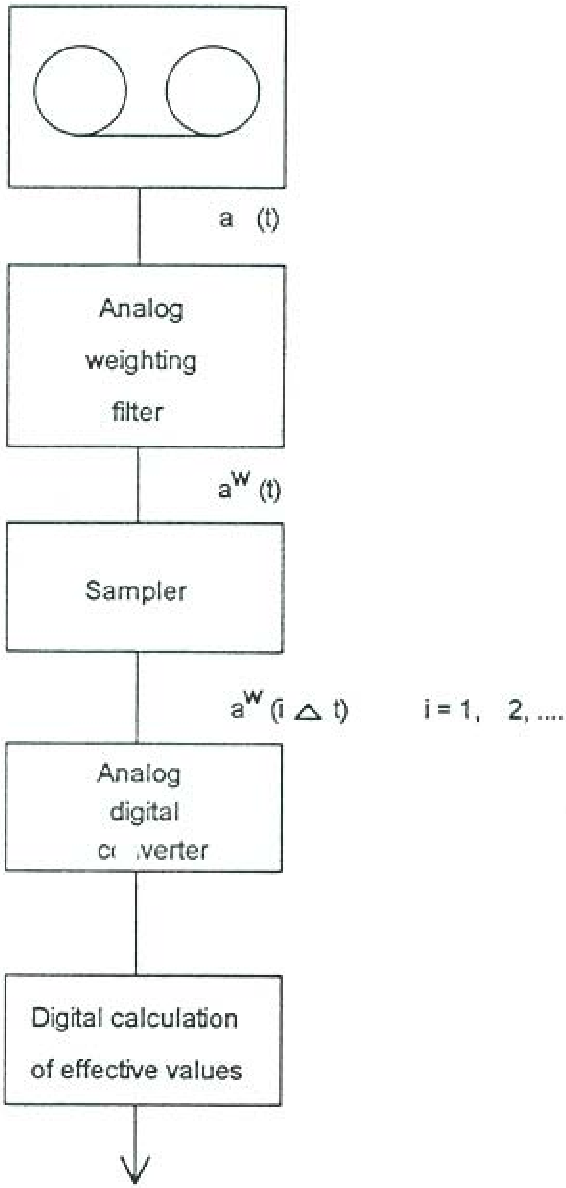
Figure 2 - Hybrid method (Analog - digital)



(a_1^w) $1 = 1, 2, \ldots N_b$

with $(a_1^w) = \sqrt{\frac{1}{N_e} \sum_{i=(1-1)\times N_e+1}^{i=1\times N_e} [a^w(i\Delta t)]^2}$

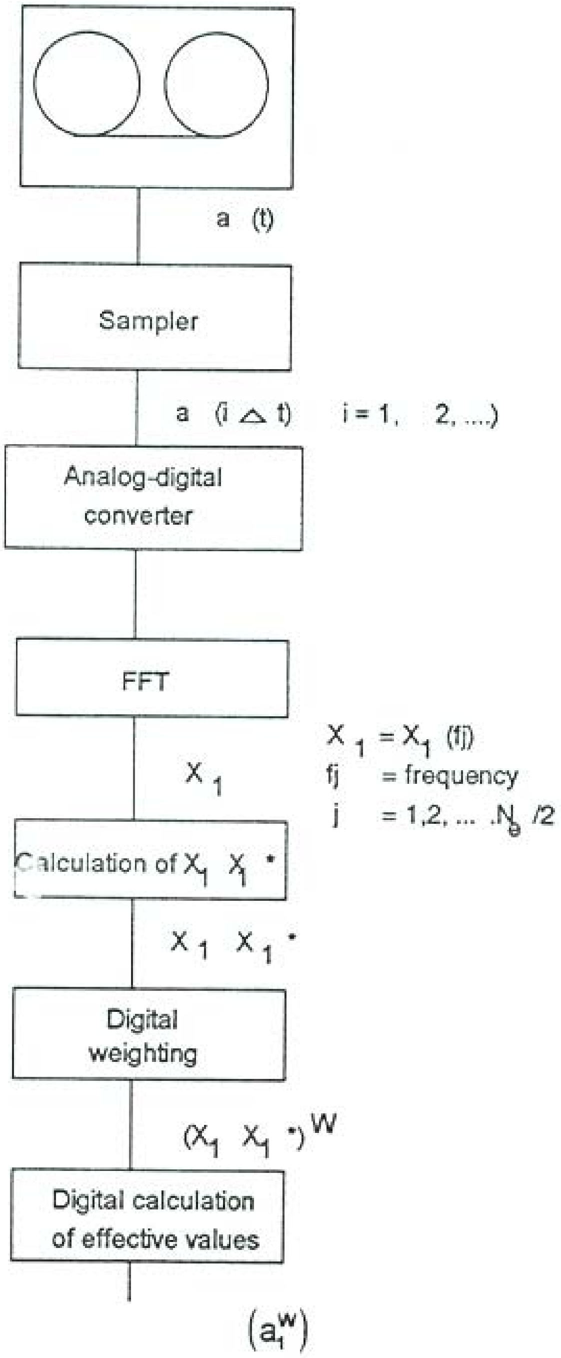
Figure 2 - Hybrid method (Analog - digital)



(a_1^w) 1=1, 2, ...N_b

with $(a_1^w) = \sqrt{\frac{1}{N_a} \sum_{i=(1-1)\times N_a+1}^{i=1\times N_a} [a^w(i\Delta t)]^2}$

Figure 3 - Digital method



with $$(a_i^w) = \sqrt{\sum_{i=i_1}^{i=i_2} [X_1(fi)\, X_1^*(fi)]^w}$$ $f_{i_1} = 0{,}4$ Hz, $f_{i_2} = 80$ Hz

Weighting curves - comfort

Weighting curves	Ride comfort (simplified method)	Passenger comfort Seated position (full method)	Passenger comfort Standing position (full method)
Wa	Band filter	Band filter	Band filter
Wb	z floor	z floor z seat	z floor
Wc		x seat back	
Wd	x floor y floor	y seat pan	x floor y floor

The following weightings should therefore be applied:

- at the floor level — Wa - Wb; Wa - Wd
- at the seat pan — Wa - Wb; Wa - Wd
- at the seat back — Wa - Wc

APPENDIX 3
Figure 5

Transfer functions of the frequency weightings

$H_A(s)$, transfer function of the band filter W_a

$$H_A(s) = \frac{s^2 \cdot 4\pi^2 \cdot f_2^2}{\left(s^2 + \frac{2\pi f_1}{Q_1} \cdot s + 4\pi^2 f_1^2\right)\left(s^2 + \frac{2\pi f_2}{Q_1} \cdot s + 4\pi^2 f_2^2\right)}$$

$H_B(s)$, transfer function of the weighting filter in vertical direction W_B

$$H_B(s) = \frac{(s + 2\pi f_3)\left(s^2 + \frac{2\pi f_5}{Q_3} \cdot s + 4\pi^2 f_5^2\right)}{\left(s^2 + \frac{2\pi f_4}{Q_2} \cdot s + 4\pi^2 f_4^2\right)\left(s^2 + \frac{2\pi f_6}{Q_4} \cdot s + 4\pi^2 f_6^2\right)} \cdot \frac{2\pi K f_4^2 \cdot f_6^2}{f_3 \cdot f_5^2}$$

$H_C(s)$, transfer function of the seat back weighting filter W_C

$H_D(s)$, transfer function of the horizontal direction weighting filter W_D

$$\begin{matrix} H_C(s) \\ H_D(s) \end{matrix} = \frac{(s + 2\pi f_3)}{\left(s^2 + \frac{2\pi f_4}{Q_2} \cdot s + 4\pi^2 f_4^2\right)} \cdot \frac{2\pi K f_4^2}{f_3}$$

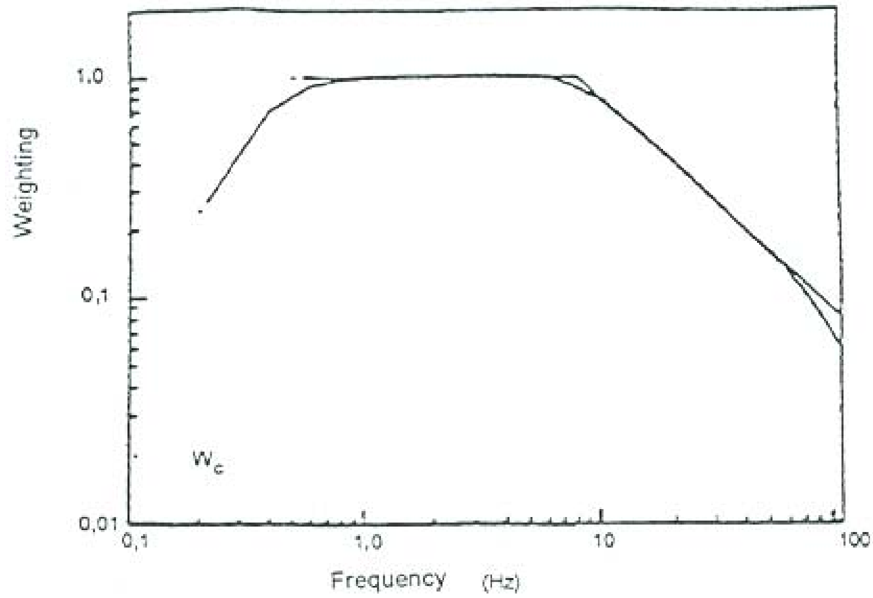
APPENDIX 3
Figure 6

Coefficients of the filters

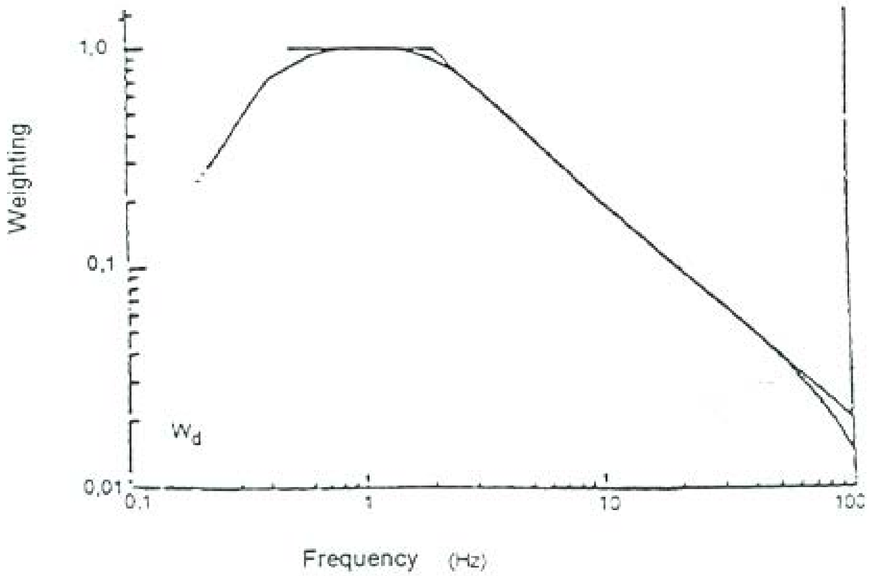
Weight -ing	Band limits			Weighting curve parameters							
	f_1 (Hz)	f_2 (Hz)	Q_1	f_3 (Hz)	f_4 (Hz)	f_5 (Hz)	f_6 (Hz)	Q_2	Q_3	Q_4	K
W_a	0.4	100	0.71	-	-	-	-	-	-	-	-
W_b	0.4	100	0.71	16	16	2.5	4	0.63	0.8	0.8	0.4
W_c	0.4	100	0.71	8	8	-	-	0.63	-	-	1.0
W_d	0.4	100	0.71	2	2	-	-	0.63	-	-	1.0

APPENDIX 3
Figure 8

Weighting curves



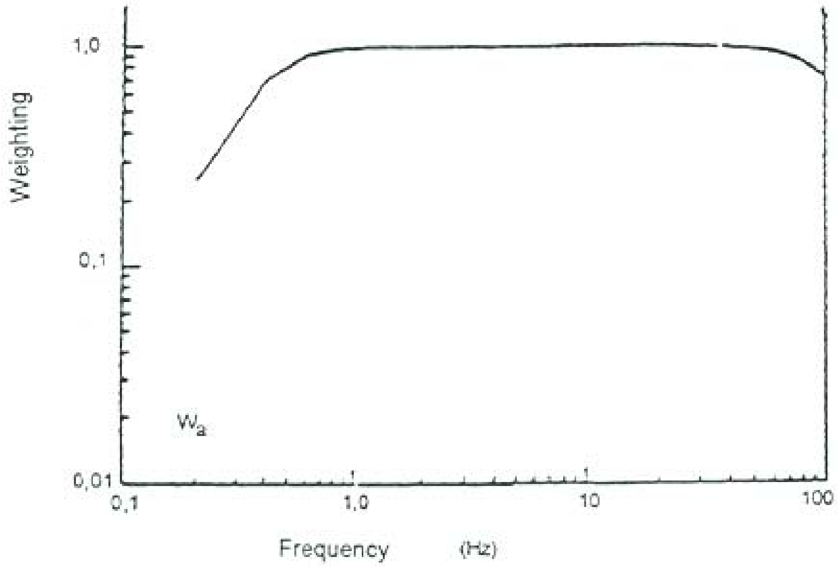
Weighting curve
$W_c - W_a$



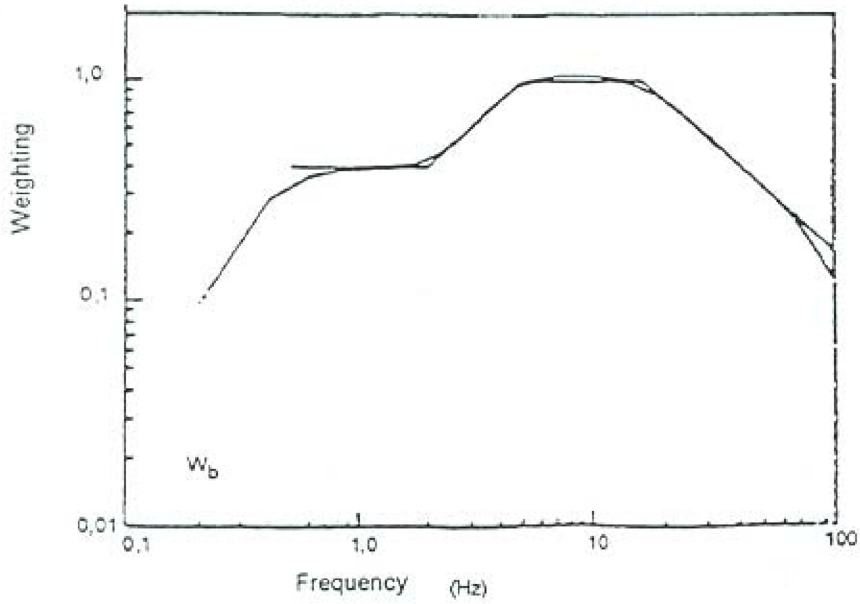
Weighting curve
$W_d - W_a$

APPENDIX 3
Figure 7

Weighting curves



Weighting curve
W_a



Weighting curve
W_b - W_a

Tolerances

The specific features of the filters to be used should conform to the following requirements:

- within the nominal frequency band, the overall tolerance of the processing filter and the weighting filter subsequently used to process the signals should lie below +/- 0.5 dB.

- outside this frequency band, the tolerance should be less than +/- 1 dB. One octave outside the nominal frequency band, damping may approach infinity, but should not be below 12 dB per octave.

- if only a single bandpass processing filter is used, this should have the characteristics of the Wa filter.

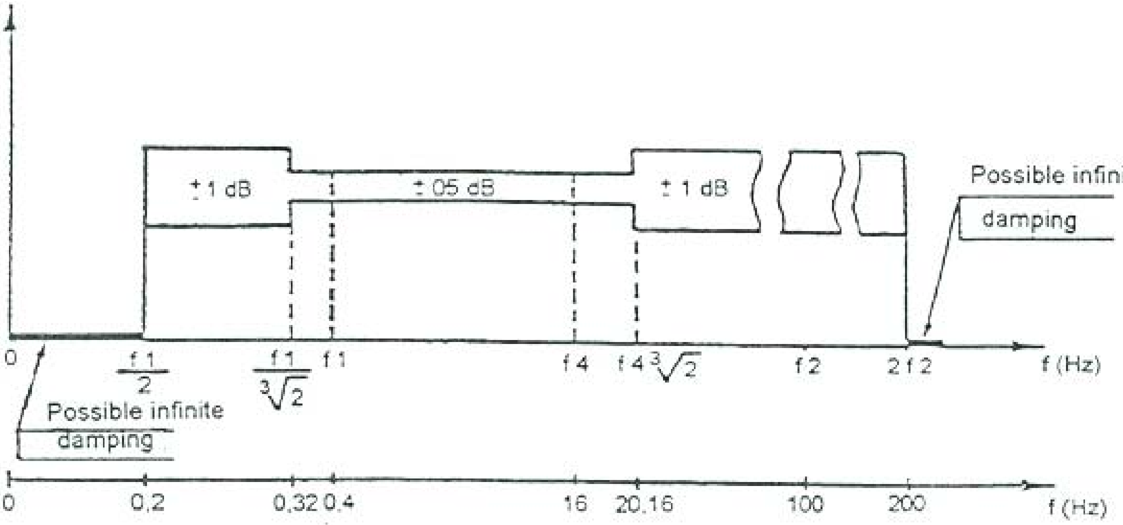
- the upper limit of the frequency range may be reduced to 40 Hz, if this has been justified by prior testing.

APPENDIX 3
Figure 10

Tolerances

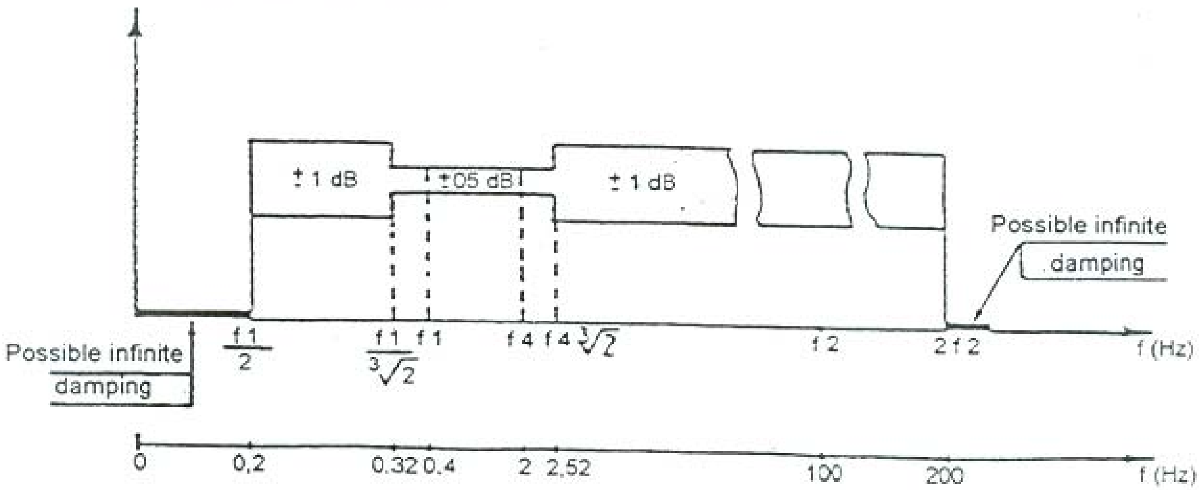
Weighting in the vertical direction (floor and seat pan)

Tolerances for: (WA-WB) digital
(WA-WB) analog
(WA analog) x (WB digital)



Weighting in the horizontal direction (floor and seat pan)

Tolerances for: (WA-WD) digital
(WA-WD) analog
(WA analog) x (WD digital)



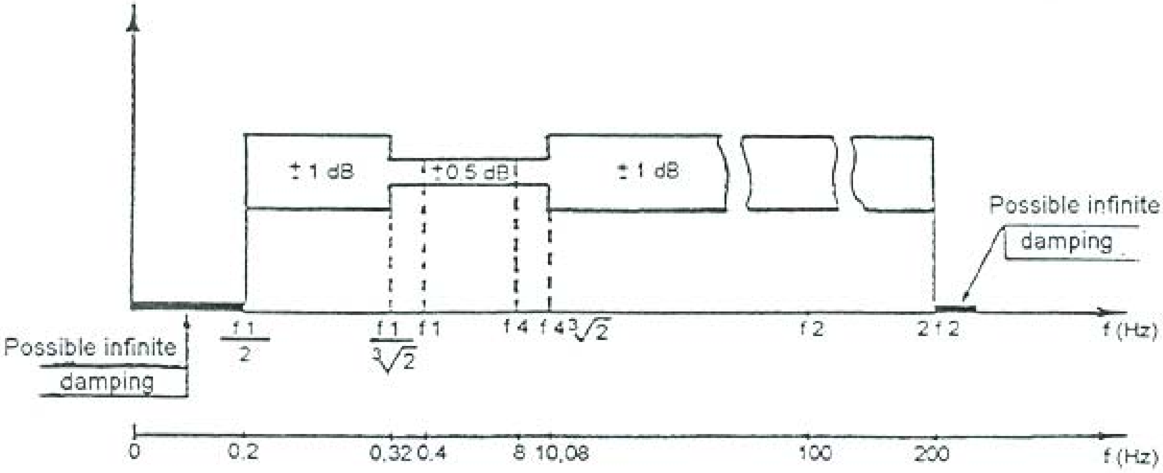
The tolerance +/- 0.5 dB corresponds to the resultants of imperfections in the filter (frequency weighting) and the band limit (damping at the edge frequencies). It represents, for each frequency, the maximum deviation between the the vertical value and the value actually obtained.

APPENDIX 3
Figure 11

Tolerances

Weighting in the longitudinal direction (seat back)

Tolerances for: (WA-WC) digital
WA-WC) analog
WA analog) x (WC digital)



The tolerance +/- 0.5 dB corresponds to the resultants of imperfections in the filter (frequency weighting) and the band limit (damping at the edge frequencies). It represents, for each frequency, the maximum deviation between the the vertical value and the value actually obtained.

Geometrical characteristics of the track

Example showing typical characteristics as a function of speed

Line speed (in km/h)	Longitudinal level			Curve lining Peak value relative to mean value (in mm)	Twist (based on roughly 3m) peak value (in mm/m)
	Peak value (in mm)		Standard deviation over 250 m (in mm)		
	Normal value	Isolated defects			
v ≤ 100	± 10	± 12	2.5	± 12	± 5
100 < v ≤ 120	± 7	± 9	2.2	± 9	± 4
120 < v ≤ 140	± 5	± 7.5	1.6	± 7	± 3
140 < v ≤ 160	± 4	± 6	1.6	± 5	± 2
160 < v ≤ 200	± 3	± 5	1.2	± 5	± 2
200 < v ≤ 300	± 2.5	± 5	1.0	± 3.5	± 1.5

These values are used on the SNCF network and relate to normal track, excluding switches and crossings.

APPENDIX 5

Specimen presentation of the test report

The results are to be presented in accordance with standard ISO/DIS 8002, adapted to railway vehicles.

The following information should be provided:

1 - Subject of the test

2 - Method of evaluation

Simplified or full.

3 - Test conditions

The following information, which is of interest in connection with test conditions, should be given (see example in Figs. 1 and 2).

3.1 - Description of vehicle

All factors which may influence vibration patterns should be set out in detail, in particular:

- vehicle (motor trainset, passenger coach, locomotive, etc.),
- type (saloon, compartment, couchette, etc.),
- vehicle loading conditions (tare weight, laden weight, etc.)
- structural details (steel, aluminium, type of suspension and bogies, wheelset mileage, etc.)
- wheel tyre profiles and actual conicity.

5 - Vibrations characterisation

In particular cases, it may be helpful to provide additional information:

5.1 - Spectral analyses

Representative mean spectra of the vibrations at the various interface points of the seat pan and the seat back or (and) the floor.

A typical example is shown in Figs. 5 and 6.

5.2 - Statistical results

Statistical results, calculated on the basis of the effective values:

- histogram of the distribution and any cumulative histogram of the frequencies with their presentation
- class interval and number of classes.

Weighted statistical parameters may also be given (mean value, standard deviation, maximum value, etc.).

A typical example is shown in Figs 7 and 8.

6 - Comfort rating

The following results are to be given:

- values of the comfort indices obtained
- any other parameters which might provide useful evaluation data.

3.1 - Description of vehicle

Passenger coach VVV of type A 10rtu

Vehicle empty and in running order

Kms covered by wheelset between 210,000 and 320,000 km.

Initial profile of wheel tyres: UIC S 1002

Bogies: YYY

The vehicle tested was third in the test train which comprised 7 coaches.

Equivalent conicity.

3.2 - Description of seat

Individual seat with arm-rests

Fabric covering

In rows, at the centre and at the end of the coach.

3.3 - Seat occupant

Test person 1 (coach centre)

Height	:	1.72 m	Weight	:	68 kg
Age	:	52 years	Sex	:	male

Test person 2 (coach end)

Height	:	1.76 m	Weight	:	72 kg
Age	:	40 years	Sex	:	male

3.4 - Track

The principal characteristics of the track are summarised in the example in the table which follows. Presentation is not standard.

Zone 1 - AAAA - BBBB (30 km)	
Average track gauge	Straight track : 1437 mm
	Curves : 1450 mm
Levelling at low points (normal values)	Straight track : 3 mm
	Curves : 3 mm
Variations in deflection/sag (10 m base)	Straight track : ± 2.5 mm
	Curves : ± 2.5 mm
Curve radius	Average: 2000 m - Average cant: 65 mm
	Mini : 658 m - Cant : 160 mm
Track equipment UIC 50 continuous welded rail (CWR)	
Running speed	120 km/h
Zone 2 : BBBB - CCCC (35 km)	
Average gauge	Straight track : 1442 mm
	Curves : 1450 mm
Levelling atow points (normal values)	Straight track : 4 mm
	Curves : 3 mm
Variations in deflection/sag (10 m base)	Straight track : ± 3 mm
	Curves : ± 3 mm
Curve radius	Average: 1500 m - Average cant: 105 mm
	Mini: 885 m - Cant: 130 mm
Track equipment UIC 50 continuous welded rail (CWR)	
Running speed	140 km/h

APPENDIX 5
Figure 3

4 - Measuring chain

4.1 - Accelerometers

- Type	DUPONT no......
- Measuring capacity	50 m/s^2
- Band width	0 - 300 Hz
- Non-linearity	0.15 m/s^2
- Cross-axis sensitivity	0.03 $m/s^2/°m/s^2$
- Influence of temperature	
- on the zero	0.01 $m/s^2/°C$
- on sensitivity	0.0025/°C

4.2 - Processing filter (low-pass 0-100 Hz)

The characteristics of the filters used conform to those of ISO standard 2631. Their tolerances are as follows:

- overall tolerance within the band	0.5 dB
- tolerance outside the band	0.5 dB
- damping outside the band	36 dB/octave

4.3 - Magnetic recorders

- Type	JULES no. ...
- FM recorder	FM-IRIG intermediate
- Pass band	0 - 1250 Hz (0.5 dB)

3.2 - Description of the seat (for evaluation of passenger comfort in seated position)

- type (individual seat, bench seat, couchette berth, etc.)
- covering (artificial leather, fabric)
- special features (arm-rest, foot-rest, head-rest, table)
- position (in rows, face-to-face) and location in vehicle.

3.3 - Description of seat occupant

If measurements are made at the interfaces (indirect or direct method), the height and weight of the seat occupant are given. Age and sex may also be stated.

3.4 - Description of the track

- geographical position and kilometric points of measurement (PK)
- track type: gauge, type of sleeper, type and laying of rails
- description of track quality
- special track features (switches and crossings, track curve radii, level crossings, etc.)

3.5 - Running speed

Running speeds during testing.

4 - Measuring chain

The measuring chain, together with its specifications, should be described in accordance with standard ISO/DIS 8002.

An example is given in Figs. 3 and 4.

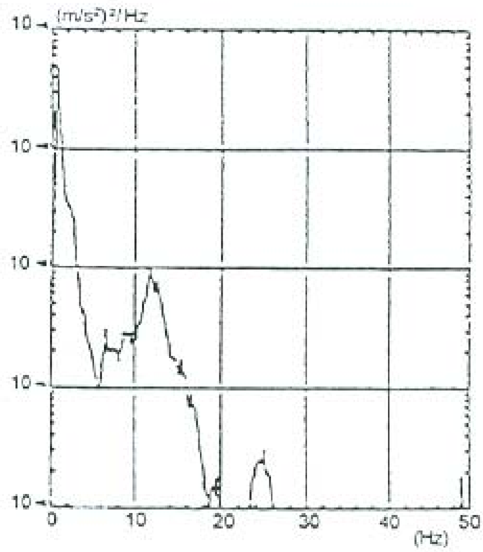
APPENDIX 5
Figure 5

5.1 - Spectral analysis

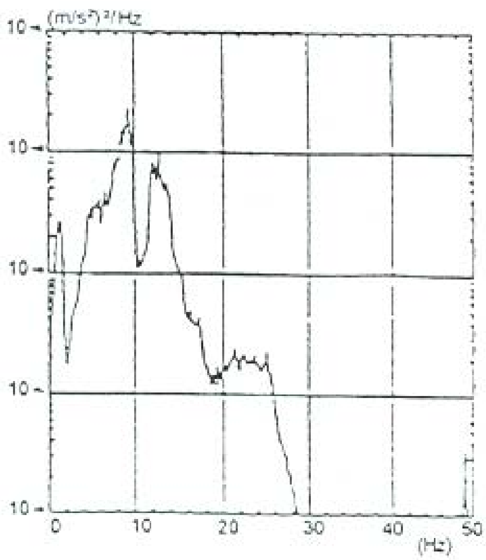
The figures below show the power density spectra recorded at the seat pan (a_{ZA}, a_{YA}) and at the seat back (a_{XD}) and weighted in accordance with the weighting curves of ISO standard 2631. Also shown are the power density spectra recorded at floor level (a_{XP}, a_{YP} and a_{ZP}) without weighting.

Weighted power density spectra

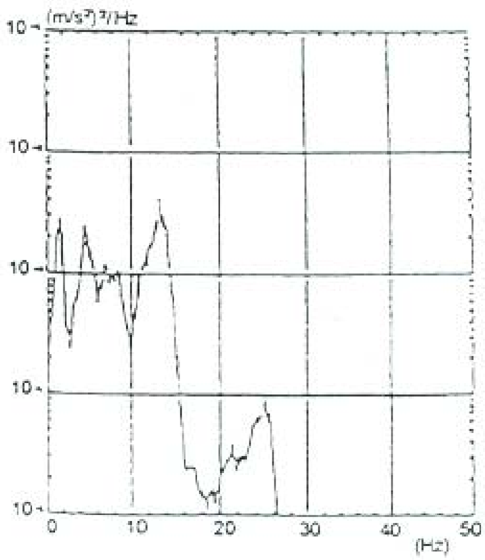
Seat pan - Y direction



Seat pan - Z direction



Seat back - X direction



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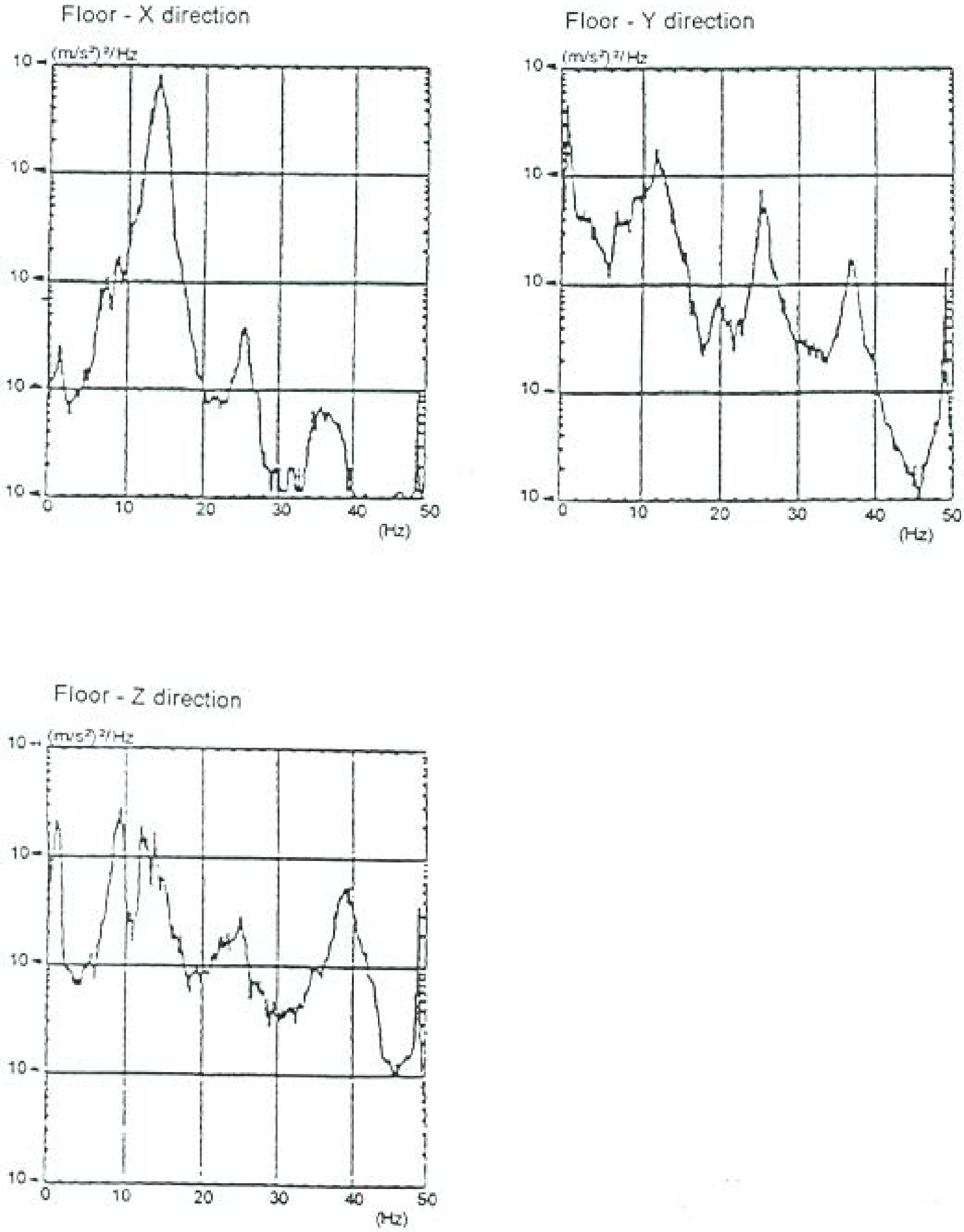
R

APPENDIX 5
Figure 6

Unweighted power density spectra

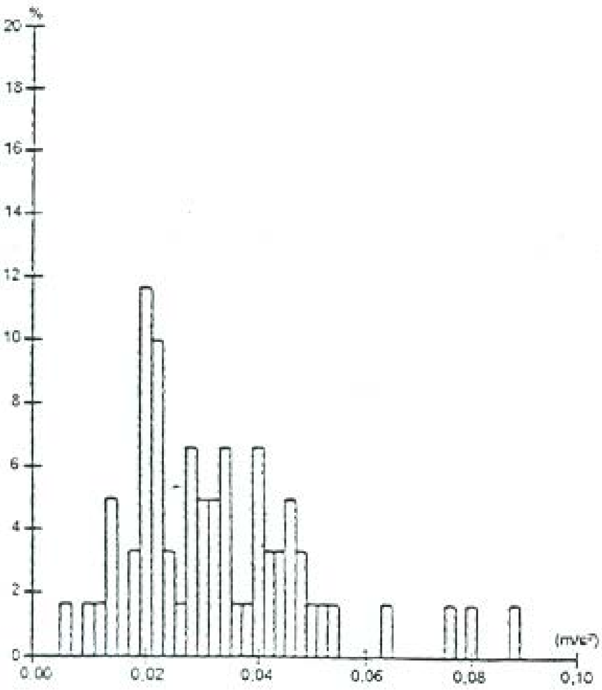


5.2 - Statistical results

The figures below show the distribution histograms of the weighted effective values calculated over 5 seconds, and produced for 5 minutes for the seat pan and seat back interfaces, together with the results of a number of statistical parameters.

Distribution histogram of the effective values, produced for 5 minutes

Seat pan - Y direction



Number of samples: 60
Minimum value: 0.005 m/s²
Maximum value: 0.089 m/s²

Value of the distribution function

for: 50%: 0.029 m/s²

5%: 0.074 m/s²

Standard deviation: 0.016 m/s²

Class interval: 0.002 m/s²

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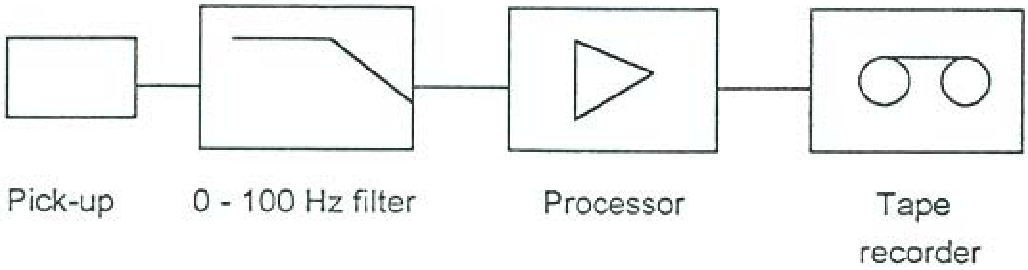
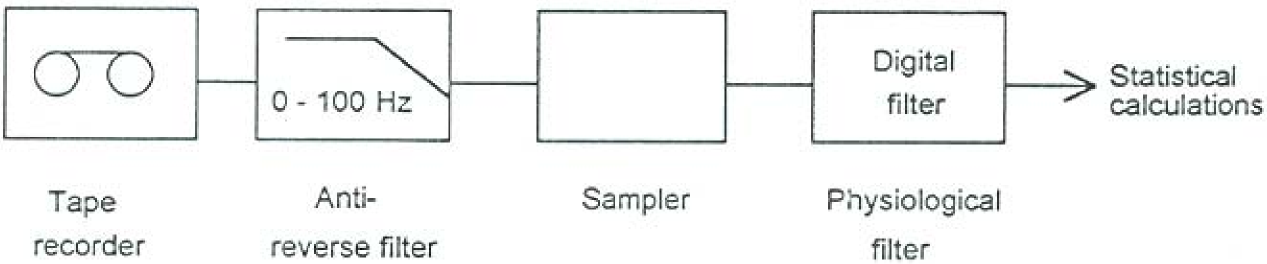
APPENDIX 5
Figure 4

Simplified diagram

- for recording



- for evaluation



Application

From 1 July 1994

All UIC members

Record references

Headings under which this question has been dealt with:

- *Question 45/A/24* - Item 21.1 - Leaflet 513 "Guidelines for evaluating passenger comfort in relation to vibration in railway vehicles"
(Traction and Rolling Stock Committee: Paris, June 1994)

16, rue Jean Rey - 75015 Paris (France)
N° 2-901585-31-0 - Dépôt Légal n° 147 - February 1995

	FlangeLubricator	روانکاری فلانج چرخ	
	Brake system	سیستم ترمز	
		سازنده ترمز	
		مسافت ترمز	
		مینیمم زمان عملکرد سیستم ترمز	
		جنس دیسک ترمز	
		قطر دیسک ترمز	
		عرض دیسک ترمز	
		جنس لنت ترمز	
		سطح عملکرد لنت ترمز	
		ضخامت لنت ترمز کهنه / نو	
	Magnetic Track Brake	ترمز مغناطیسی	
	Unsprung mass	جرم غیر فنری	
[illegible]	سیستم تعلیق، عمودی، افقی، [illegible]	ماکزیمم دامنه حرکت تعلیق اولیه ، سختی کلی (نهایی)	
		نوع فنرهای تعلیق اولیه، تعلیق محور	
		انعطاف پذیری سیستم تعلیق اولیه	
		ماکزیمم حرکت عمودی بالستر	
		سختی فنر بالستر	
	Bolster suspension	نوع فنرهای تعلیق ثانویه، تعلیق ثانویه	
	Secondary suspension	انعطاف پذیری سیستم تعلیق ثانویه	
		نوع و تعداد میرا کننده‌ها	
		تعداد فنرهای هر بوژی	
		سیستم فنر هوابی بالستر	
		تعداد میرا کننده های هیدرولیکی	
		مستهلک کننده های افقی	
		فنرهای الاستومریک	
	Tilting	تیلتینگ	
		وزن بوژی بدون ترمز مغناطیسی	
		وزن نهایی قطعات ریخته گری شده	

		وزن نهایی قطعات آهنگری شده	
		وزن نهایی بالستر	
		جنس قطعات آهنگری شده	
		قیمت	
		عمر بوژی تا قبل از تعمیر اساسی	
		کیلومتراژ عمر کارکرد کلی	
		سال طراحی بوژی	
		سال ساخت بوژی	
		هزینه های عملکرد به صورت	
		لیست استفاده کنندگان	
		تیراژ ساخته شده	
		بوژی فرمان پذیر	
		وضعیت ظاهری	
		طریقه اتصال بوژی به شاسی واگن	
		آشکار سازهای گرمایی یاتاقان‌ها	
		ارتفاع کاسه بوژی از ریل	
		شتاب عرضی در بدنه واگن	
	Spare parts lists	لیست قطعات بوژی	
		جعبه دنده	
	Driving Bogie	بوژی محرک	
	Trailer Bogie	بوژی حمال	
		ایمنی، صلبیت، تعمیرات،	
		استانداردهای مربوطه	

سازگاری در محیط راه آهن
قطعات استاندارد و قابل تعویض

1/3

ردیف	عنوان	عنوان انگلیسی	استانداردهای
	فاصله بین دو ریل (گیج)	Track gauge	
	ماکزیمم بار محوری	Maximum axle load	
	مینیمم قوس قابل چرخش		
	سرعت ماکزیمم طراحی	Maximum design speed	
	سرعت بحرانی با چرخ نو و کهنه	hunting	
	سرعت ماکزیمم در قوس مینیمم		
	سرعت ماکزیمم با ترمز مغناطیسی		
	سرعت ماکزیمم بدون ترمز مغناطیسی		
	سرعت ماکزیمم با مستهلک کننده Yaw		
	سرعت ماکزیمم بدون مستهلک کننده Yaw		
	ضریب راحتی سواری عمودی	Vertical ride quality	
	ضریب راحتی سواری افقی	Horizontal ride quality	
	ضریب خروج از خط		
	نوع بانداژ چرخ مونوبلوک / بانداژی		
	قطر چرخ نو / کهنه	Tread Diameter new/worn	
	طول کلی، فاصله دو محور بوژی	Wheel base	
	جنس محور، چرخ		
	نوع پروفیل چرخ		
	نیروهای بین ریل و چرخ		
	قطر بلبرینگ		
	نوع بلبرینگ		
	مقاومت الکتریکی چرخ و محور		
	ماکزیمم اختلاف قطر دو محور یک بوژی		
	نامیزانی محوری، شعاعی		
	ماکزیمم اختلاف قطر یک محور بوژی		
	هسته چرخ، لقی طوقه		
	شیب، ارتفاع، ضخامت فلانج چرخ		
	سایش چرخ و ریل، سختی سطح		
	میزان جرم خارج از مرکز	Out of Balance	