INTERNATIONAL STANDARD

ISO 8528-9

First edition
1995-12-15

Reciprocating internal combustion engine driven alternating current generating sets —

Part 9:
Measurement and evaluation of mechanical vibrations

Groupes électrogènes à courant alternatif entraînés par moteurs alternatifs à combustion interne —

Partie 9 Mesurage et évaluation des vibrations mécaniques

Reference number
ISO 8528-9 1995(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 8528-9 was prepared by Technical Committee ISO/TC 70, *Internal combustion engines*, Subcommittee SC 2, *Performance and tests*.

ISO 8528 consists of the following parts, under the general title *Reciprocating internal combustion engine driven alternating current generating sets*:

— *Part 1: Application, ratings and performance*

— *Part 2: Engines*

— *Part 3. Alternating current generators for generating sets*

— *Part 4. Controlgear and switchgear*

— *Part 5: Generating sets*

— *Part 6: Test methods*

— *Part 7: Technical declarations for specification and design*

— *Part 8: Requirements and tests for low-power generating sets*

— *Part 9: Measurement and evaluation of mechanical vibrations*

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

— *Part 10: Measurement of airborne noise by the enveloping surface method*

— *Part 11: Dynamic uninterruptible power supply systems*

— *Part 12: Emergency power supply to safety services*

Annexes A, B, C, D and E of this part of ISO 8528 are for information only

Reciprocating internal combustion engine driven alternating current generating sets —

Part 9:
Measurement and evaluation of mechanical vibrations

1 Scope

This part of ISO 8528 describes a procedure for measuring and evaluating the external mechanical vibration behaviour of generating sets at the measuring points stated in that International Standard

It applies to RIC engine driven AC generating sets for fixed and mobile installations with rigid and/or resilient mountings. It is applicable for land and marine use, excluding generating sets used on aircraft or those used to propel land vehicles and locomotives

For some specific applications (essential hospital supplies, high rise buildings, etc.) supplementary requirements may be necessary. The provisions of this part of ISO 8528 should be regarded as a basis

For generating sets driven by other reciprocating-type prime movers (e.g. sewage gas engines, steam engines), the provisions of this part of ISO 8528 should be regarded as a basis.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8528. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8528 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2041:1990, *Vibration and shock — Vocabulary*

ISO 5348:1987, *Mechanical vibration and shock — Mechanical mounting of accelerometers.*

ISO 8528-5 1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 5: Generating sets.*

IEC 34-7 1992, *Rotating electrical machines — Part 7 Classification of types of constructions and mounting arrangements (IM Code).*

3 Definitions

For the purposes of this part of ISO 8528, the definitions given in ISO 2041 and the following definition apply.

3.1 vibration severity: A generic term that designates a value or set of values, such as a maximum value, average value or rms value, or other parameter that is descriptive of the vibration.

NOTES

1 It may refer to instantaneous values or average values

2 ISO 2041 includes two notes in the definition These notes do not apply in this part of ISO 8528

4 Symbols and abbreviations

For the purposes of this part of ISO 8528 the following symbols apply.

a	Acceleration
$\hat{a}$	Peak value of acceleration
f	Frequency
s	Displacement
$\hat{s}$	Peak value of displacement
t	Time
v	Velocity
$\hat{v}$	Peak value of velocity
x	Axial co-ordinate
y	Transverse co-ordinate
z	Vertical co-ordinate
ω	Angular velocity

The following subscripts are used in conjunction with the vibration quantities v, s and a.

rms	Value of vibration quantity
x	Measured value of vibration quantity in the axial direction
y	Measured value of vibration quantity in the transverse direction
z	Measured value of vibration quantity in the vertical direction
1, 2 . n	Progressive values

The following abbreviation is used.

IMB	Type or construction and mounting arrangement of generators according to IEC 34-7

5 Regulations and additional requirements

5.1 For a.c. generating sets used on board ships and offshore installations which have to comply with rules of a classification society, the additional requirements of the classification society shall be observed. The classification society shall be stated by the customer prior to placing the order.

For a.c. generating sets in unclassed equipment, such additional requirements are in each case subject to agreement between the manufacturer and customer.

5.2 If special requirements from regulations of any other authority, e.g. inspecting and/or legislative authorities, have to be met, the authority shall be stated by the customer prior to placing the order

Any further additional requirements shall be subject to agreement between the manufacturer and customer.

6 Measured values

Acceleration, velocity and displacement are measured variables for the vibrations (see clause 10)

In the general case of any vibration over time interval t_1 to t_2, the rms velocity is given by

$$v_{rms} = \sqrt{\frac{\int_{t_1}^{t_2} v^2 dt}{t_2 - t_1}} \quad \ldots (1)$$

In the particular case of sinusoidal vibration the rms velocity is given by

$$v_{rms} = \frac{\hat{s}\omega}{\sqrt{2}} = \frac{\hat{v}}{\sqrt{2}} = \frac{\hat{a}}{\omega} \times \frac{1}{\sqrt{2}} \quad (2)$$

If the vibration characteristics are analysed and if for angular frequencies ω_1, ω_2, , ω_n, the vibration velocities $\hat{v}_1$, $\hat{v}_2$, .. , $\hat{v}_n$ are available, then the following relationships can be used to determine the rms velocity

$$v_{rms} = \frac{\sqrt{\hat{v}_1^2 + \hat{v}_2^2 + \ldots + \hat{v}_n^2}}{\sqrt{2}} \quad \ldots (3)$$

$$v_{rms} = \sqrt{v_{rms1}^2 + v_{rms2}^2 + \ldots + v_{rmsn}^2} \quad (4)$$

NOTE 3 For acceleration and displacement rms values are calculated in the same manner

7 Measuring devices

The measuring system shall provide the rms values of displacement, velocity and acceleration with an accuracy of $\pm$ 10 % over the range 10 Hz to 1 000 Hz and an accuracy of $^{+10}_{-20}$ % over the range 2 Hz to 10 Hz. These values may be obtained from a single sensor whose signal is either integrated or differentiated, depending on the outcome of the measuring device, to derive the quantities not directly measured, provided the accuracy of the measuring system is not adversely affected.

NOTE 4 The accuracy of measurement is also affected by the method of connection between the transducer and the object being measured Both the frequency response and the measured vibration are affected by the method of attaching the transducer. It is especially important to maintain good attachment between the transducer and the point on the generating set being measured when vibration levels are high

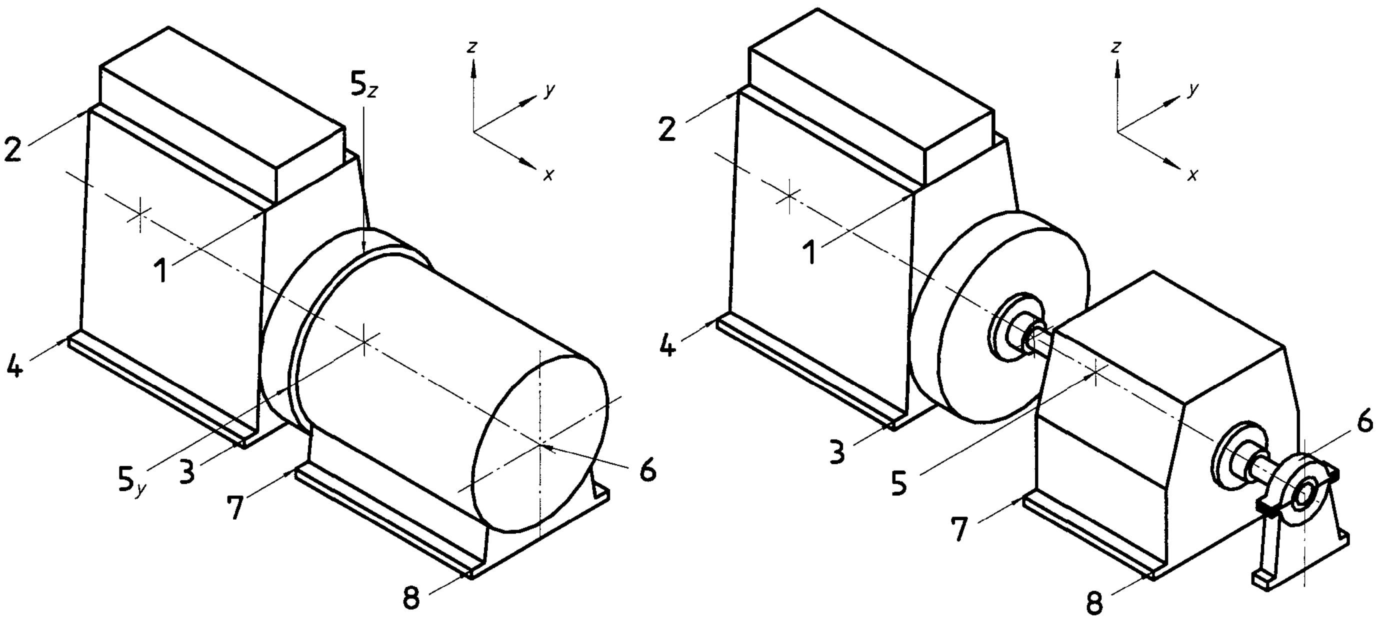
Refer to ISO 5348 for guidance on the mounting of accelerometers

8 Location of measuring points and direction of measurements

Figure 1 shows the recommended points of vibration measurement in generating sets. The specifications apply as appropriate for other types of design. If possible, measurements shall be taken at these points in the three main directions, defined by x, y and z.

Figure 1 shows the approximate positions of the measuring points which have to be located on the solid engine block and on solid areas of the generator frame in order to avoid measuring local structural vibrations.

If experience with similar generating sets has shown at which points the maximum vibration severity is to be expected, not all the points given in figure 1 need necessarily be measured.



a) Generating set driven by a vertical in-line engine with flange housing coupled generator with integral bearings

b) Generating set driven by a vertical in-line engine and a generator with pedestal bearings

Key

1, 2	Front end top edge and back end top edge
3, 4	Front and rear end of engine base
5, 6	Generator main bearing housing
7, 8	Generator base

NOTE — The vertical in-line engine shown is given as an example only Measuring points 1 to 4 are applicable as appropriate for other types of engine, e g V-engines, horizontal engines

Figure 1 — Arrangement of measuring points

9 Operating conditions during measurement

The measurements shall be taken with the generating set at its operating temperature and rated frequency, at both zero power and rated power. If the rated power of the generating set is not attainable, it should be tested at the maximum power that can be attained.

10 Evaluation of results

The main excitation frequencies of the RIC engine itself are found in the range 2 Hz to 300 Hz. However, when considering the overall generating set structure and components, a range of 2 Hz to 1 000 Hz is required to evaluate the vibration.

Additional testing may be necessary to ensure that no local structural resonances contribute to the measurement result.

Assessment of the potential effects of vibration are made by reference to table C.1 which gives rms values of vibration displacement, velocity and acceleration These values can be used as guidelines for evaluating the measured vibration levels

Experience has shown that with a standard design of generating set structure and components, damage would not be expected if vibration levels remain below value 1.

If the vibration levels fall between values 1 and 2, assessment of the generating set structure and components may be required along with an agreement between the generating set manufacturer and the component supplier in order to ensure reliable operation.

In some cases vibration levels can be above value 2 but only if individual special designs of generating set structure and components are applied

In all cases the generating set manufacturer remains responsible for the compatibility with each other of the generating set components (see ISO 8528-5:1993, 15 10).

11 Test report

The indicated measurement results shall include the main data of the generating set and the measuring equipment used These data are to be recorded using annex D

Annex A
(informative)

Typical generating set configurations

There are a number of possibilities for the assembly of a reciprocating internal combustion engine and a generator Figures A.1 to A.6 show examples of typical configurations

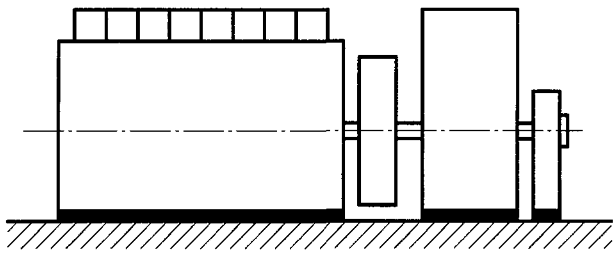


Figure A.1 — Engine and generator rigidly mounted

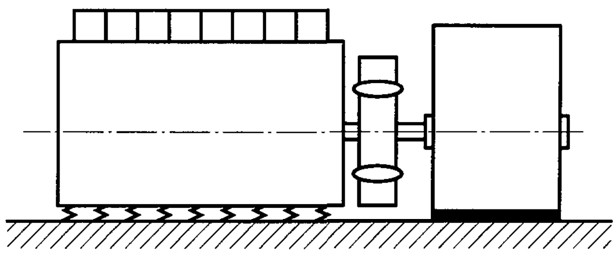


Figure A.2 — Engine resiliently mounted, generator rigidly mounted, flexible coupling

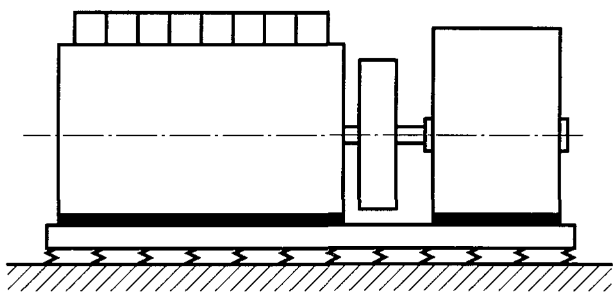


Figure A.3 — Engine and generator rigidly mounted on resiliently mounted base frame

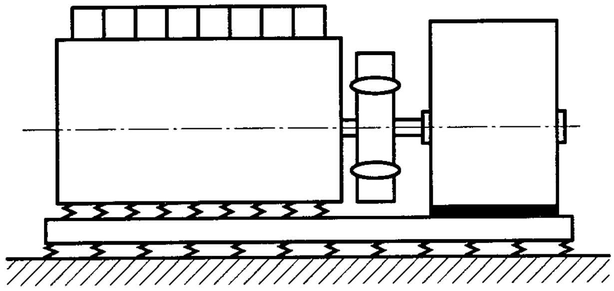


Figure A.4 — Engine resiliently mounted, generator rigidly mounted on resiliently mounted base frame, flexible coupling

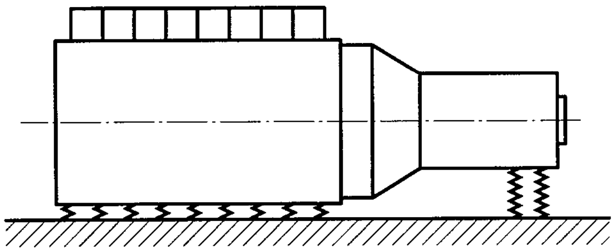


Figure A.5 — Assembly with flange housing and resilient mounting on the engine and generator

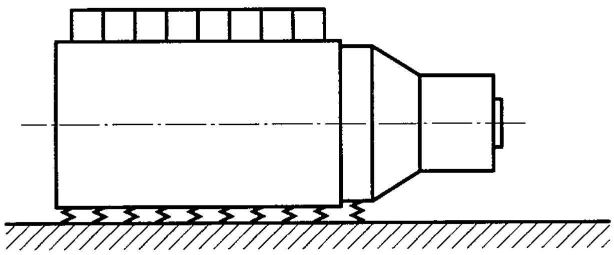


Figure A.6 — Assembly with flange housing and resilient mounting of the engine

Annex B
(informative)

Remarks on the assessment of vibrations of the generating set

It has been found that generators operating in generating sets suffer higher values of vibration severity compared with those running independently.

Typical features of RIC engines are the oscillating masses, torque fluctuation and pulsating forces in the associated pipe-work All these features exert considerable alternating forces on the main supports and give rise to high vibration amplitudes on the main frame The vibration amplitudes are generally higher than those for rotating machinery, but since they are largely influenced by the design features of the generating sets, they tend to remain more constant over the life of the RIC engine than they do for rotating machinery

The vibration values determined by using this part of ISO 8528 allow us to make a general statement on the vibrational behaviour of the generating set and a general assessment of the running behaviour and the vibration interactions of the total set However, the determined vibration values do not allow us to make a statement on the mechanical stresses of fixed or moving parts of the generating sets

Neither do the determined values of vibration severity allow us to make a statement of the torsional and linear vibrational behaviour of the shaft system

Even if accurate assessment of mechanical stresses in the generating set by using vibration measurement is not possible, experience has shown that the vibration level above which important parts of the generating set are mechanically damaged by undue vibration stress is usually significantly higher than the level which is accepted as "usual" from experience with similar generating sets

However, if the above "usual" ranges are exceeded, damage to additional attachments and connecting parts of the generating set, as well as to governing and monitoring devices, etc., may occur

The sensitivity of these components depends on their design and how they are mounted Thus, in some individual cases, it may be difficult to avoid problems even when the assessment value lies in the "usual" range. Such problems have to be rectified by specific "local measures" on the generating set (e g. by elimination of mounted component resonances)

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Annex C
(informative)

Vibration values

Table C.1 — Rms values for vibration velocity, displacement and acceleration of RIC engine driven AC generating sets (see clause 10)

Declared engine speed	Rated power output of the generating set		Vibration displacement[1)], s_{rms}			Vibration velocity, v_{rms}			Vibration acceleration[1)], a_{rms}		
	(cos φ = 0,8)		RIC engine [2) 3)]	Generator [2)]		RIC engine [2)3)]	Generator [2)]		RIC engine [2)3)]	Generator [2)]	
				value 1	value 2		value 1	value 2		value 1	value 2
min^{-1}	kV·A	kW	mm	mm	mm	mm/s	mm/s	mm/s	m/s^2	m/s^2	m/s^2
⩾ 2 000 but ⩽ 3 600	⩽ 15 (1-cylinder engine)	⩽ 12 (1-cylinder engine)	—	1,11	1,27	—	70	80	—	44	50
	⩽ 50	⩽ 40	—	0,8	0,95	—	50	60	—	31	38
	> 50	> 40	—	0,64 [4)]	0,8 [4)]	—	40 [4)]	50 [4)]	—	25 [4)]	31 [4)]
⩾ 1 300 but < 2 000	⩽ 10	⩽ 8	—	—	—	—	—	—	—	—	—
	> 10 but ⩽ 50	> 8 but ⩽ 40	—	0,64	—	—	40	—	—	25	—
	> 50 but ⩽ 125	> 40 but ⩽ 100	—	0,4	0,48	—	25	30	—	16	19
	> 125 but ⩽ 250	> 100 but ⩽ 200	0,72	0,4	0,48	45	25	30	28	16	19
	> 250	> 200	0,72	0,32	0,45	45	20	28	28	13	18
> 720 but < 1 300	⩾ 250 but ⩽ 1 250	⩾ 200 but ⩽ 1 000	0,72	0,32	0,39	45	20	24	28	13	15
	> 1 250	> 1 000		0,29	0,35		18	22		11	14
⩽ 720	> 1 250	> 1 000	0,72	0,24 (0,16) [5)]	0,32 (0,24) [5)]	45	15 (10) [5)]	20 (15) [5)]	28	9,5 (6,5) [5)]	13 (9,5) [5)]

NOTE — The relationship between vibration velocity and vibration frequency is shown in figure C.1

1) The values of s_{rms} and a_{rms} are determined from the following equations by using the values given in the table for v_{rms}.

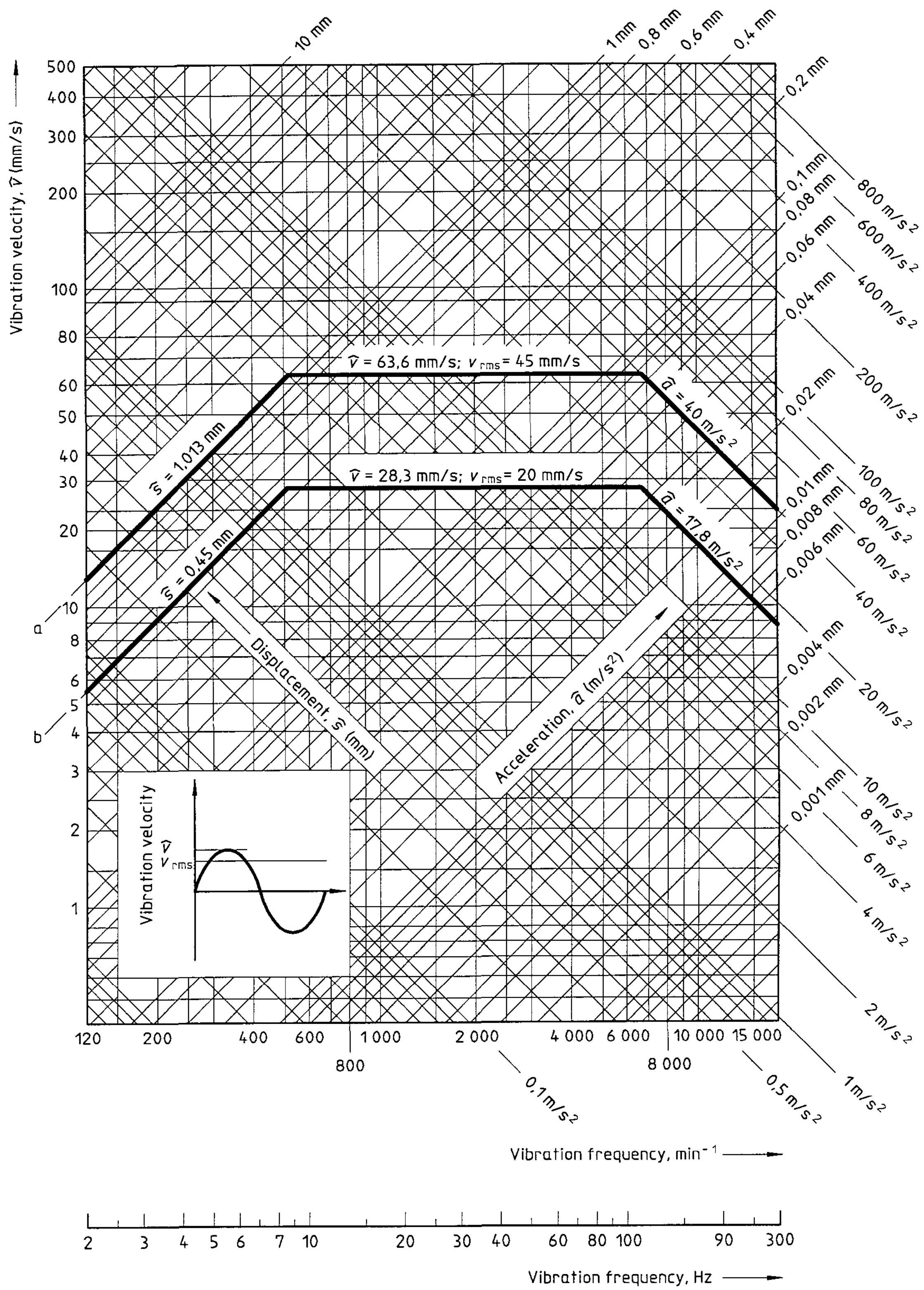
$$s_{rms} = 0{,}0159 \times v_{rms}$$
$$a_{rms} = 0{,}628 \times v_{rms}$$

2) In the case of flange housing coupled generating sets the values measured at point 5 [see figure 1 a)] shall meet the values for generators.

3) The stated values for RIC engines are applicable for engines with power outputs of more than 100 kW. For smaller engines with power outputs below 100 kW, no typical values exist.

4) These values are subject to agreement between the manufacturer and customer.

5) The values given in parentheses are applied to generators mounted on solid concrete foundations. In these cases the axial measurement for points 7 and 8 in figure 1 a) and b) shall be 50 % of the values given in parentheses.



Examples for limiting curves for sinusoidal vibrations

Curve a Example RIC engine (see table C.1), $v_{rms} = 45$ mm/s

Curve b Example generator (see table C 1), $v_{rms} = 20$ mm/s

Figure C.1 — Relationship between vibration velocity and vibration frequency

Annex D
(informative)

Measuring report

D.1 General data

Company responsible for the measurement	Customer/User
Report No	Place of measurement
Date	Operator

Data of the RIC engine and generator to be measured

	RIC engine	Generator
Manufacturer		
Type		
Manufacturing No		
Declared or rated power	. kW	. . kV A cos φ =
Declared or rated speed Declared or rated frequency	. min^{-1}	min^{-1} . Hz
Construction design	☐ In-line engine ☐ V-engine	☐ IMB 20 [1)] ☐ IMB 520 ☐ IMB 16 ☐ Others ☐ IMB 3 . .
Number of	Cylinders .	Bearings
Operating system	☐ Two-stroke ☐ Four-stroke	☐ Synchronous ☐ Asynchronous
Coupling arrangement	☐ Flexible plate coupling ☐ Direct coupling ☐ Elastic coupling	
1) Abbreviation for type of construction and mounting of generators according to IEC 34-7, code I		

D.2 Data of configuration

Foundation drawing

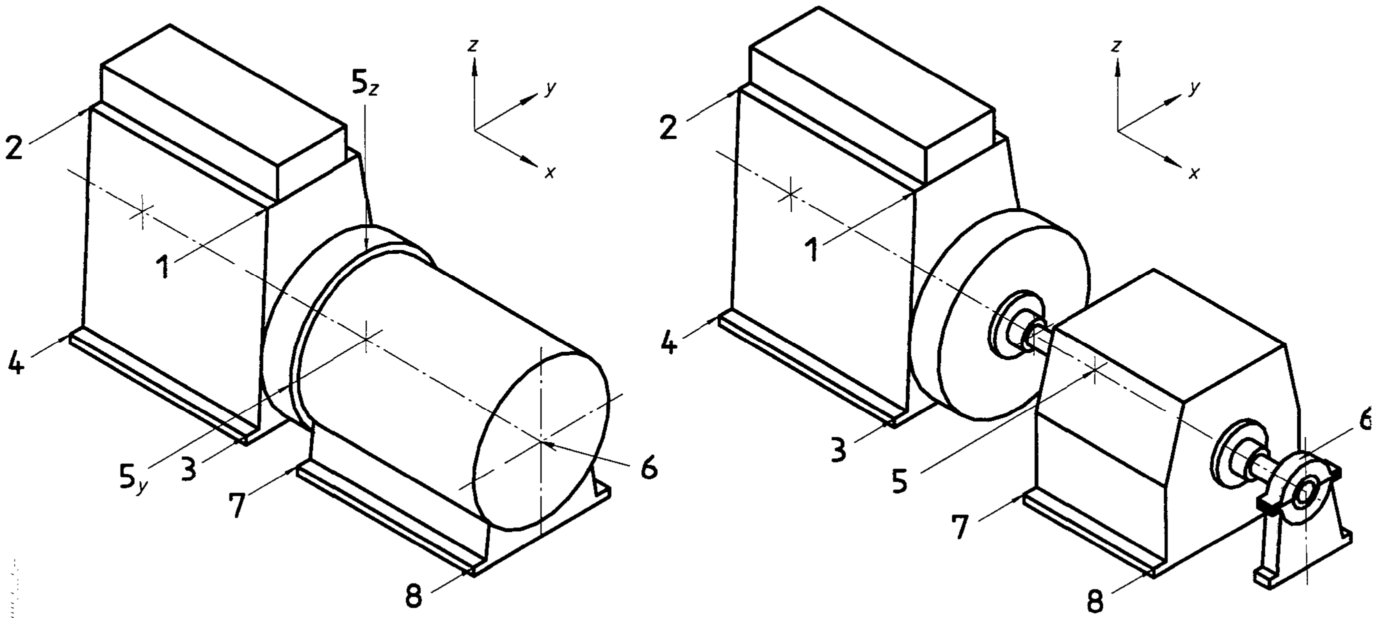
No.. ....

Company responsible . ...

Types of configuration

Engine	Generator	Foundation	Base frame (if applicable)	Flange housing
☐ rigid ☐ resilient	☐ rigid ☐ resilient	☐ rigid ☐ resilient	☐ rigid ☐ resilient	☐ yes ☐ no

D.3 Measuring positions



The measuring positions and their numbering conform to those shown above Additional measuring positions should be numbered continually and must be marked on a drawing. It is recommended that all measuring positions be inserted in a detailed drawing.

D.4 Measurement results

Data records, diagrams and spectra, when applicable and required, must be attached.

Measurement equipment

Component	Manufacturer	Type	Remarks
Sensor			
Measuring indicator set			
Recording instruments			
Calibration apparatus			
NOTE — Terms are according to ISO 2954			

Particulars of measuring equipment

Mechanical connection	☐ screwed	☐ hand held	☐ cemented	☐ magnetic
Measured value	☐ displacement	☐ velocity	☐ acceleration	
Recorded value	☐ displacement	☐ velocity	☐ acceleration	
Measuring range	amplitude		frequency	
Frequency analyser/filter	linear range		pass-band	
Data for evaluation of measuring records (e g amplification, rate of feed)				
Remarks				

Measurement results

Power: kW	Ambient temperature °C
Speed min^{-1}	Type of fuel

Measuring point No.	rms overall values (2 Hz to 300 Hz)[1]									Remarks
	Direction of measurement									
	axial (x)			transverse (y)			vertical (z)			
	s mm	v mm/s	a m/s^2	s mm	v mm/s	a m/s^2	s mm	v mm/s	a m/s^2	

1) Either measured or calculated

Annex E
(informative)

Bibliography

[1] ISO 2954:1975, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity.*

[2] ISO 8528-1:1993, *Reciprocating internal combustion engine driven alternating current generating sets — Part 1: Application, ratings and performance.*

[3] ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines.*

[4] ISO 10816-6:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 6: Reciprocating machines with power ratings above 100 kW*

ICS 29.160.40

Descriptors: motor generator sets, vibration, vibration tests

Price based on 14 pages