INTERNATIONAL STANDARD

ISO 10816-1

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Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 1:
General guidelines

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les parties non tournantes —

Partie 1: Directives générales

Reference number
ISO 10816-1:1995(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 10816-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

This first edition of ISO 10816-1 cancels and replaces ISO 2372:1974 and ISO 3945:1985, which have been technically revised.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

— *Part 1: General guidelines*

— *Part 2: Large land-based steam turbine generator sets in excess of 50 MW*

— *Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15000 r/min when measured in situ*

— *Part 4: Gas turbine driven sets excluding aircraft derivatives*

— *Part 5: Machine sets in hydraulic power generating and pumping plants*

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Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 1:
General guidelines

1 Scope

This part of ISO 10816 establishes general conditions and procedures for the measurement and evaluation of vibration using measurements made on non-rotating and, where applicable, non-reciprocating parts of complete machines. The general evaluation criteria, which are presented in terms of both vibration magnitude and change of vibration, relate to both operational monitoring and acceptance testing. They have been provided primarily with regard to securing reliable, safe, long-term operation of the machine, while minimizing adverse effects on associated equipment. Guidelines are also presented for setting operational limits.

The evaluation criteria relate only to the vibration produced by the machine itself and not to vibration transmitted to it from outside.

This part of ISO 10816 does not include any consideration of torsional vibration.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this part of ISO 10816. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10816 are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7919-1:—[1]), *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines.*

3 Measurements

This clause describes the measurements, procedures and operating conditions recommended for assessing machine vibration. The guidelines given will permit the evaluation of vibration in accordance with the general criteria and principles given in clause 5.

3.1 Measurement parameters

3.1.1 Frequency range

The measurement of vibration shall be broad band, so that the frequency spectrum of the machine is adequately covered.

The frequency range will depend on the type of machine being considered (e.g. the frequency range necessary to assess the integrity of rolling element bearings should include frequencies higher than those on machines with fluid-film bearings only).

Guidelines for instrumentation frequency ranges for specific machine classes will be given in the appropriate parts of ISO 10816.

1) To be published. (Revision of ISO 7919-1:1986)

NOTE 1 In the past, vibration severity was often related to broad-band vibration velocity [mm/s (r.m.s.)] in the range 10 Hz to 1 000 Hz. However, different frequency ranges and measurement quantities may apply for different machine types.

3.1.2 Measurement quantity

For the purposes of this part of ISO 10816, the following can be used:

a) vibration displacement, measured in micrometres;

b) vibration velocity, measured in millimetres per second;

c) vibration acceleration, measured in metres per square second.

The use, application and limitations of these quantities are discussed further in clause 5.

Generally, there is no simple relationship between broad-band acceleration, velocity and displacement; nor is there between-peak (0-p), peak to peak (p-p), root mean square (r.m.s.) and average values of vibration. The reasons for this are briefly discussed in annex A, which also defines some precise relationships between the above quantities when the harmonic content of the vibration waveform is known.

In order to avoid confusion and to ensure correct interpretation, it is important at all times to identify clearly the measurement units [e.g. µm (p-p), mm/s (r.m.s.)].

3.1.3 Vibration magnitude

The result of measurements made with an instrument which complies with the requirements of clause 4 is called the vibration magnitude at a specific measuring position and direction.

It is common practice, based on experience, when evaluating broad-band vibration of rotating machinery to consider the r.m.s. value of vibration velocity, since this can be related to the vibration energy. However, other quantities such as displacement or acceleration and peak values instead of r.m.s. values may be preferred. In this case, alternative criteria are required which are not necessarily simply related to criteria based on r.m.s. values.

3.1.4 Vibration severity

Normally measurements are made at various measuring positions and in two or three measuring directions, leading to a set of different vibration magnitude values. The maximum broad-band magnitude value measured under agreed machine support and operating conditions is defined as the vibration severity.

For most machine types, one value of vibration severity will characterize the vibratory state of that machine. However, for some machines this approach may be inadequate and the vibration severity should then be assessed independently for measurement positions at a number of locations.

3.2 Measuring positions

Measurements should be taken on the bearings, bearing support housing, or other structural parts which significantly respond to the dynamic forces and characterize the overall vibration of the machine. Typical measurement locations are shown in figures 1 to 5.

To define the vibrational behaviour at each measuring position, it is necessary to take measurements in three mutually perpendicular directions. The full complement of measurements represented in figures 1 to 5 is generally only required for acceptance testing. The requirement for operational monitoring is usually met by performing one or both measurements in the radial direction (i.e. normally in the horizontal-transverse and/or vertical directions). These can be supplemented by a measurement of axial vibration. The latter is normally of prime significance at thrust bearing locations where direct axial dynamic forces are transmitted.

Detailed recommendations for specific machine types are provided in the additional parts of ISO 10816.

3.3 Machine support structure for acceptance testing

3.3.1 *In situ* tests

When acceptance tests are carried out *in situ*, the support structure shall be that supplied for the machine. In this case it is important to ensure that all the major components of the machine and structure are installed when testing is carried out.

It should be noted that valid comparisons of vibration for machines of the same type but on different foundations or sub-foundations can only be made if the foundations concerned have similar dynamic characteristics.

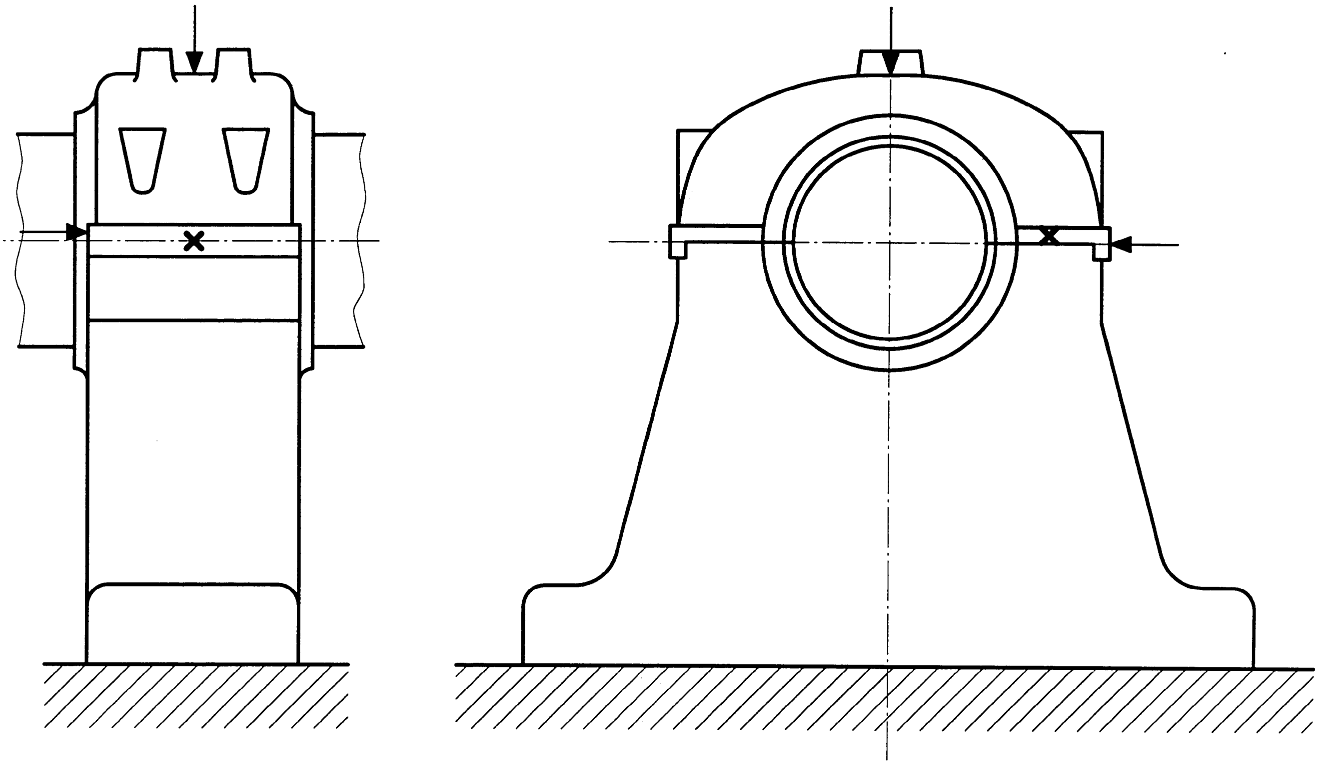

Figure 1 — Measuring points for pedestal bearings

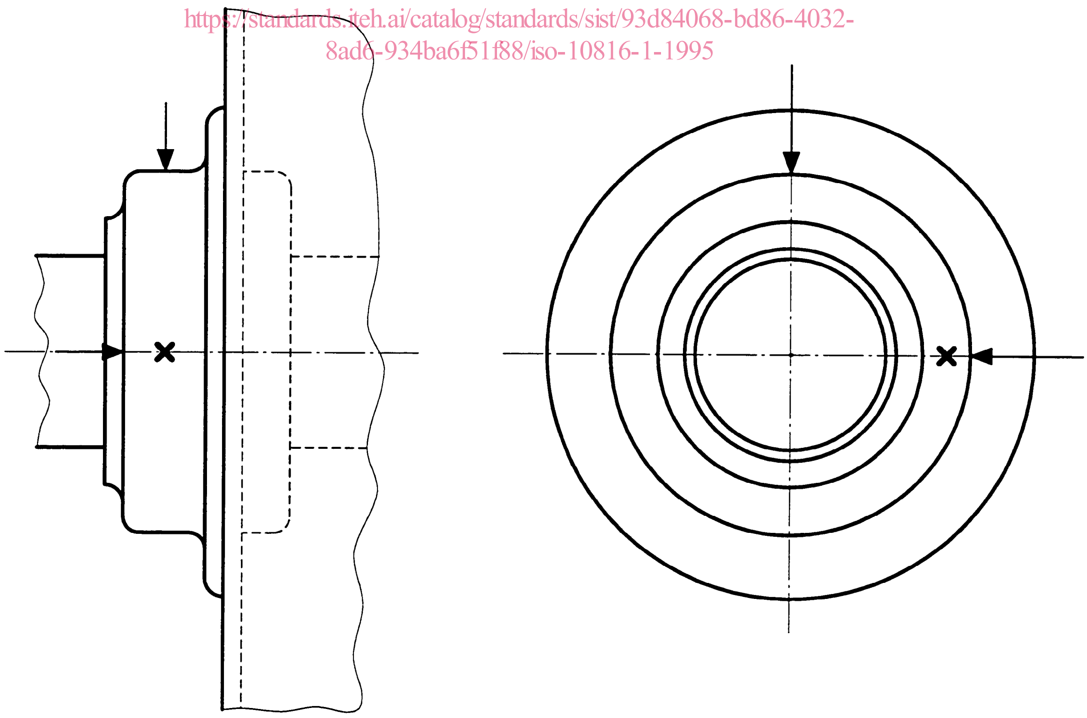

Figure 2 — Measuring points for housing-type bearings

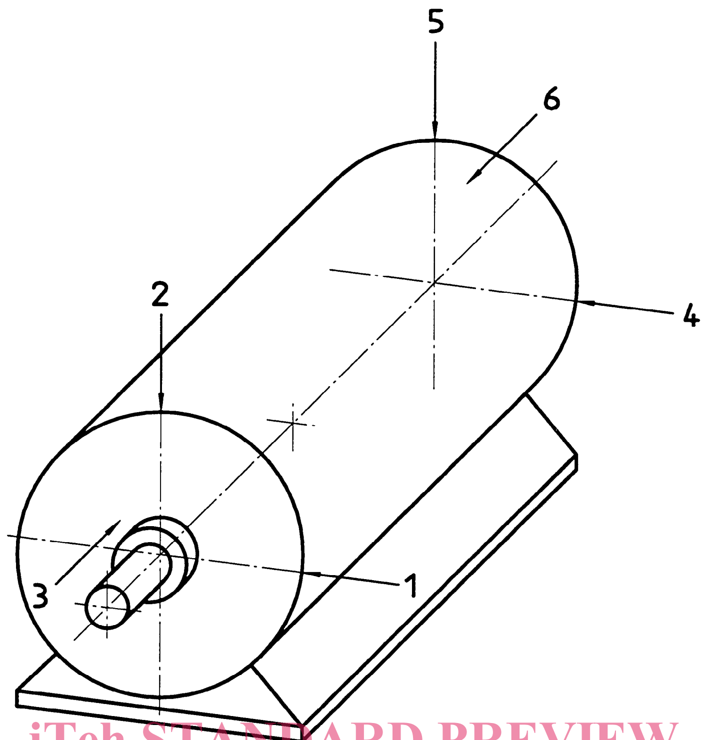

Figure 3 — Measuring points for small electrical machines

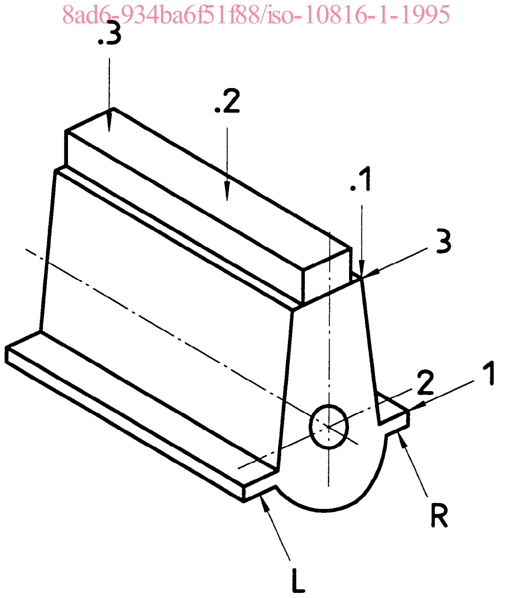

Figure 4 — Measuring points for reciprocating engines

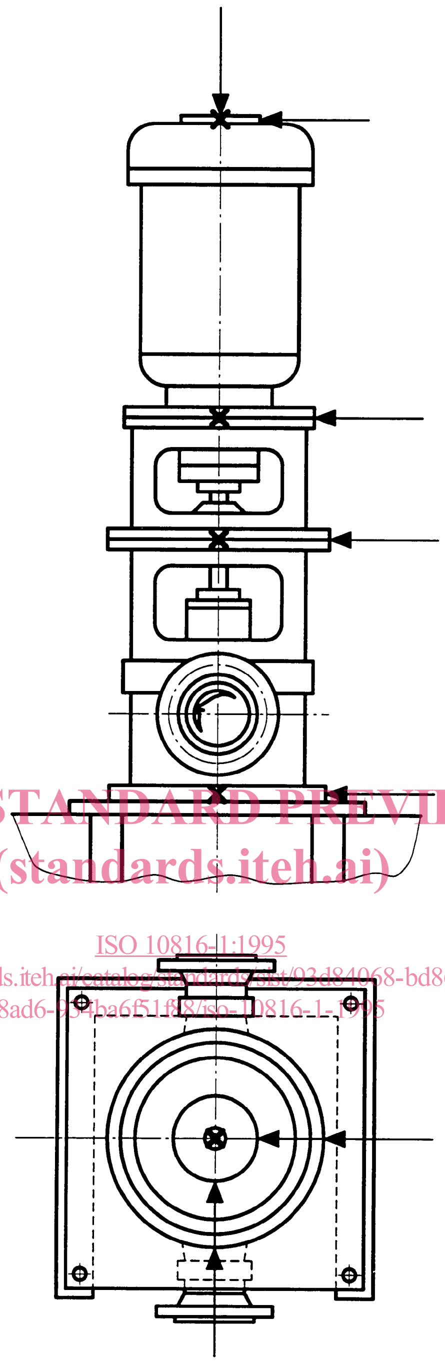

Figure 5 — Measuring points for vertical machine sets

3.3.2 In a test facility

There are many classes of machines for which, because of economic or other reasons, acceptance tests are carried out on a test bed which may have different support structure characteristics from those at the site. The support structure can significantly affect the measured vibration and every attempt should be made to ensure that the natural frequencies of the complete test arrangement do not coincide with the rotational frequencies of the machine or with any of its significant harmonics.

The test arrangement will normally meet these requirements if the vibration magnitude measured in the horizontal and vertical directions at the machine feet, or at the base frame near the bearing support or stator feet, does not exceed 50 % of the vibration magnitude measured in the same measuring direction at that bearing. Additionally, the test arrangement shall not cause a substantial change in any of the major resonance frequencies.

If a significant support resonance is present during acceptance testing and it cannot be eliminated, the vibration acceptance tests may have to be carried out on the fully installed machine *in situ*.

For some classes of machines (e.g. small electrical machinery), acceptance tests can be carried out when machines are supported by a resilient system. In this case, all the rigid body mode frequencies of the machine on its support system shall be less than one-half of the lowest significant excitation frequency of the machine. Appropriate support conditions can be achieved by mounting the machine on a resilient support baseplate or by free suspension on a soft spring.

3.4 Machine support structure for operational monitoring

Operational monitoring is carried out on fully installed machines *in situ* (i.e. on their final support structure).

3.5 Machine operating conditions

Vibration measurements shall be made after achieving agreed normal operating conditions. Additional vibration measurements that may be taken under other conditions are not applicable for evaluation in accordance with clause 5.

3.6 Environmental vibration evaluation

If the measured vibration magnitude exceeds the recommended limit, it may then be necessary to take measurements of environmental vibration with the machine shut down to ensure that this is not making a significant contribution to the observed vibration. Where possible, steps should be taken to reduce the magnitude of environmental vibration if it is greater than one-third of the recommended limits.

4 Instrumentation

The instrumentation used shall be designed to operate satisfactorily in the environment for which it is to be used, for example with respect to temperature, humidity, etc. Particular attention shall be given to ensuring that the vibration transducer is correctly mounted and that its presence does not affect the vibration response characteristics of the machine.

Two instrument systems presently in common use to monitor broad-band vibration are acceptable, namely:

a) instruments which incorporate r.m.s. detector circuits and display the r.m.s. values;

b) instruments which incorporate either r.m.s. or averaging detector circuits, but are scaled to read peak-to-peak or peak values. The scaling is based on an assumed sinusoidal relationship between r.m.s., average, peak-to-peak and peak values.

If the vibration evaluation is based on more than one measurement quantity (i.e. displacement, velocity, acceleration), the instrumentation used shall be able to characterize all the relevant quantities.

It is desirable that the measurement system should have provision for on-line calibration of the readout instrumentation and, in addition, have suitable isolated outputs to permit further analysis as required.

5 Evaluation criteria

5.1 General

This clause specifies general criteria and principles for the evaluation of machine vibration. The evaluation criteria relate to both operational monitoring and acceptance testing, and they apply only to the vibration produced by the machine itself and not to vibration transmitted from outside. For certain classes of machinery, the guidelines presented in this part of ISO 10816 are complemented by those given for shaft vibration in ISO 7919-1. If the procedures of both standards are applicable, the one which is more restrictive shall generally apply.

Specific criteria for different classes and types of machinery will be given in the relevant parts of ISO 10816 as they are developed.

5.2 Criteria

Two evaluation criteria are used to assess vibration severity on various classes of machines. One criterion considers the magnitude of observed broad-band vibration; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

5.3 Criterion I: Vibration magnitude

This criterion is concerned with defining limits for absolute vibration magnitude consistent with acceptable dynamic loads on the bearings and acceptable vibration transmission into the support structure and foundation. The maximum vibration magnitude observed at each bearing or pedestal is assessed against four evaluation zones established from international experience. This maximum magnitude of vibration measured is defined as the vibration severity (see 3.1.4).

5.3.1 Evaluation zones

The following typical evaluation zones are defined to permit a qualitative assessment of the vibration on a given machine and to provide guidelines on possible actions. Different categorization and number of zones may apply for specific machine types, which are covered by the additional parts of ISO 10816. Interim values for the zone boundaries are presented in annex B.

Zone A: The vibration of newly commissioned machines would normally fall within this zone.

Zone B: Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C: Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D: Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

Numerical values assigned to the zone boundaries are not intended to serve as acceptance specifications, which shall be subject to agreement between the machine manufacturer and customer. However, these values provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided. In certain cases, there may be specific features associated with a particular machine which would require different zone boundary values (higher or lower) to be used. In such cases, it is normally necessary to explain the reasons for this and, in particular, to confirm that the machine will not be endangered by operating with higher vibration values.

5.3.2 Evaluation zone limits

The vibration of a particular machine depends on its size, the characteristics of the vibrating body and mounting system, and the purpose for which it is designed. It is therefore necessary to take account of the various purposes and circumstances concerned when specifying ranges of vibration measurement for different machine types. For nearly all machines, regardless of the type of bearings used, measurements of the broad-band r.m.s. vibration velocity on structural parts such as bearing housings will, in general, adequately characterize the running conditions of the rotating shaft elements with respect to their trouble-free operation.

In most cases, it has been found that vibration velocity is sufficient to characterize the severity of vibration over a wide range of machine operating speeds. However, it is recognised that the use of a single value of velocity, regardless of frequency, can lead to unacceptably large vibration displacements. This is particularly so for machines with low operating speeds when the once-per-revolution vibration component is dominant. Similarly, constant velocity criteria for machines with high operating speeds, or with vibration at high frequencies generated by machine component parts can lead to unacceptable accelerations. Consequently, acceptance criteria based on velocity will take the general form of figure 6. This indicates the upper and lower frequency limits f_u and f_l and shows that below a defined frequency f_x and above a defined frequency f_y the allowable vibration velocity is a function of the vibration frequency (see also annex C). However, for vibration frequencies between f_x and f_y, a constant velocity criterion applies. The r.m.s. velocities listed in annex B refer to this constant velocity region. The precise nature of the acceptance criteria and the values of f_l, f_u, f_x and f_y for specific machine types will be given in the additional parts of ISO 10816.

For many machines, the broad-band vibration consists primarily of a single frequency component, often shaft rotational frequency. In this case, the allowable vibration is obtained from figure 6 as the vibration velocity corresponding to that frequency.

For less-common machines, where there may be significant vibratory energy beyond the breakpoints f_x and f_y of figure 6, a number of different approaches are possible. Examples are the following.

a) In addition to the usual broad-band velocity, broad-band displacement may be measured when there is significant energy below f_x. Similarly, broad-band acceleration may be measured when there is significant energy above f_y. The allowable vibration displacement and acceleration should be consistent with the velocity corresponding to the sloped portions of figure 6.

b) The velocity, displacement or acceleration at each significant component throughout the frequency spectrum may be determined using a frequency analyser. The equivalent broad-band velocity can be obtained using equation (A.2) after applying appropriate weighting factors, consistent with figure 6, for those components whose frequencies are below f_x or above f_y. This value should then be evaluated relative to the constant velocity between f_x and f_y. It should be noted that, except for the case when the broad-band vibration consists primarily of a single frequency component, a direct comparision of the frequency spectrum components with the curves of figure 6 would yield misleading results.

c) A composite broad-band measurement encompassing the entire spectrum may be carried out using an instrument incorporating weighting networks consistent with the shape of figure 6. This value should then be evaluated relative to the constant velocity between f_x and f_y.

The evaluation criteria for specific machine types will be given in the additional parts of ISO 10816 as they become available. Annex C provides additional guidance. For certain machine types, it may be necessary to define further criteria beyond those described by figure 6 (see for example, 5.6.3).

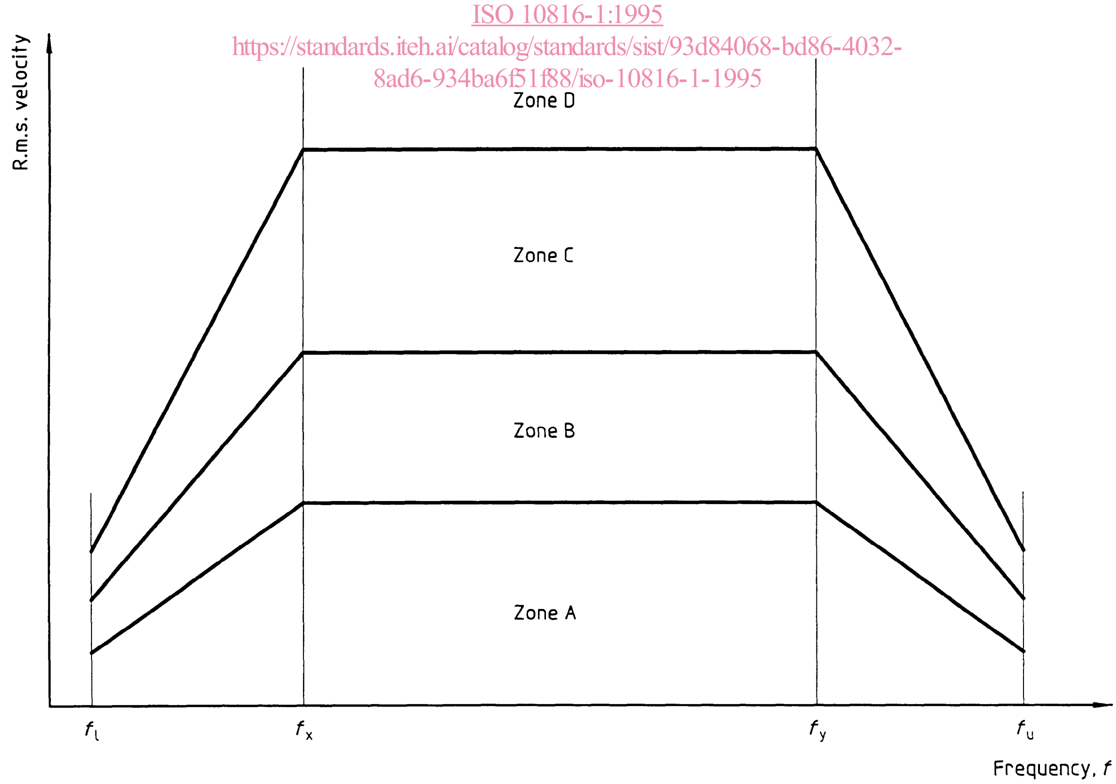

Figure 6 — General form of vibration velocity acceptance criteria

5.4 Criterion II: Change in vibration magnitude

This criterion provides an assessment of a change in vibration magnitude from a previously established reference value. A significant increase or decrease in broad-band vibration magnitude may occur which requires some action even though zone C of Criterion I has not been reached. Such changes can be instantaneous or progressive with time and may indicate that damage has occurred or be a warning of an impending failure or some other irregularity. Criterion II is specified on the basis of the change in broad-band vibration magnitude occurring under steady-state operating conditions.

When Criterion II is applied, the vibration measurements being compared shall be taken at the same transducer location and orientation, and under approximately the same machine operating conditions. Significant changes from the normal vibration magnitudes should be investigated so that a dangerous situation may be avoided.

Criteria for assessing changes of broad-band vibration for monitoring purposes are given in the additional parts of ISO 10816. However, it should be noted that some changes may not be detected unless the discrete frequency components are monitored (see 5.6.1).

5.5 Operational limits

For long-term operation, it is common practice for some machine types to establish operational vibration limits. These limits take the form of ALARMS and TRIPS.

ALARMS: To provide a warning that a defined value of vibration has been reached or a significant change has occurred, at which remedial action may be necessary. In general, if an ALARM situation occurs, operation can continue for a period whilst investigations are carried out to identify the reason for the change in vibration and define any remedial action.

TRIPS: To specify the magnitude of vibration beyond which further operation of the machine may cause damage. If the TRIP value is exceeded, immediate action should be taken to reduce the vibration or the machine should be shut down.

Different operational limits, reflecting differences in dynamic loading and support stiffness, may be specified for different measurement positions and directions.

Where appropriate, guidelines for specifying ALARM and TRIP criteria for specific machine types are given in the additional parts of ISO 10816.

5.5.1 Setting of ALARMS

The ALARM values may vary considerably, up or down, for different machines. The values chosen will normally be set relative to a baseline value determined from experience for the measurement position or direction for that particular machine.

It is recommended that the ALARM value should be set higher than the baseline by an amount equal to a proportion of the upper limit of zone B. If the baseline is low, the ALARM may be below zone C. Guidelines for specific machine types are given in the additional parts of ISO 10816.

Where there is no established baseline, for example with a new machine, the initial ALARM setting should be based either on experience with other similar machines or relative to agreed acceptance values. After a period of time, a steady-state baseline value will be established and the ALARM setting should be adjusted accordingly.

If the steady-state baseline changes (for example after a machine overhaul), the ALARM setting should be revised accordingly. Different operational ALARM settings may then exist for different bearings on the machine, reflecting differences in dynamic loading and bearing support stiffnesses.

5.5.2 Setting of TRIPS

The TRIP values will generally relate to the mechanical integrity of the machine and be dependent on any specific design features which have been introduced to enable the machine to withstand abnormal dynamic forces. The values used will, therefore, generally be the same for all machines of similar design and would not normally be related to the steady-state baseline value used for setting ALARMS.

There may, however, be differences for machines of different design and it is not possible to give guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D.

5.6 Additional factors

5.6.1 Vibration frequencies and vectors

The evaluation considered in this basic document is limited to broad-band vibration without reference to frequency components or phase. This will in most cases be adequate for acceptance testing and oper-