INTERNATIONAL STANDARD

ISO 10816-2

Third edition
2009-10-01

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

Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min

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

Partie 2: Turbines à vapeur et alternateurs excédant 50 MW pour applications terrestres, avec des vitesses normales de fonctionnement de 1 500 r/min, 1 800 r/min, 3 000 r/min et 3 600 r/min

Reference number
ISO 10816-2:2009(E)

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Published in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10816-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

This third edition cancels and replaces the second edition (ISO 10816-2:2001), of which it constitutes a technical revision. It also incorporates the Technical Corrigendum ISO 10816-2:2001/Cor.1:2004. The main changes are:

— emphasis on acceptance specifications always being agreed on between the supplier and the purchaser of the steam turbine and generator prior to installation;

— recommendation for setting the ALARM limit for steady-state operation of new machines at the zone B/C boundary when no established baseline data are available;

— introduction of a new annex providing cautionary notes about the use of constant vibration velocity criteria at low frequencies;

— closer alignment of this part of ISO 10816 with ISO 7919-2, ISO 7919-4 and ISO 10816-4.

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: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

— *Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured* in situ

— *Part 4: Gas turbine sets with fluid-film bearings*

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

— *Part 6: Reciprocating machines with power ratings above 100 kW*

— *Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts*

Introduction

ISO 10816-1 is the basic part of ISO 10816 giving the general requirements for evaluating the vibration of various machine types when the vibration measurements are made on non-rotating parts. This part of ISO 10816 gives specific provisions for assessing the severity of vibration measured on the bearing housings or pedestals of large steam turbines and generators. Measurements at these locations characterize the state of vibration reasonably well. Evaluation criteria, based on previous experience, are presented. These can be used for assessing the vibratory condition of such machines.

Two criteria are provided for assessing the machine vibration when operating under steady-state conditions. One criterion considers the magnitude of the observed vibration; the second considers changes in the magnitude. In addition, different criteria are provided for transient operating conditions. However, vibration on non-rotating parts does not form the only basis for judging the severity of vibration. For large steam turbines and generators, it is also common to judge the vibration based on measurements taken on the rotating shafts. For shaft vibration measurement requirements, see ISO 7919-1 and ISO 7919-2.

The evaluation procedures presented in this part of ISO 10816 are based on broad-band measurements. However, because of advances in technology, the use of narrow-band measurements or spectral analysis has become increasingly widespread, particularly for the purposes of vibration evaluation, condition monitoring and diagnostics. The specification of criteria for such measurements is beyond the scope of this part of ISO 10816. They are dealt with in greater detail in ISO 13373 (all parts), which establish provisions for the vibration condition monitoring of machines.

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

Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min

1 Scope

This part of ISO 10816 establishes provisions for evaluating the severity of *in-situ*, broad-band vibration measured radial (i.e. transverse) to the shaft axis on all main bearing housings or pedestals and in the axial direction on thrust bearings. These are in terms of:

— vibration under normal steady-state operating conditions;

— vibration during other (non-steady-state) conditions when transient changes are taking place, including run up or run down, initial loading and load changes;

— changes in vibration which can occur during normal steady-state operation.

This part of ISO 10816 is applicable to land-based steam turbines and generators with power outputs greater than 50 MW and a normal operating speed of 1 500 r/min, 1 800 r/min, 3 000 r/min or 3 600 r/min. It is also applicable to steam turbines and/or generators which are directly coupled to a gas turbine (such as for combined-cycle applications). In such cases, the criteria of this part of ISO 10816 apply only to the steam turbine and the generator (including synchronizing clutches). ISO 7919-4 and ISO 10816-4 are applicable to the evaluation of the gas turbine vibration.

The evaluation criteria in this part of ISO 10816 are not applicable to the electromagnetic excited vibration with twice line frequency at the generator stator core and housing.

The numerical values specified are not intended to serve as the only basis for judging the severity of vibration. For large steam turbines and generators, it is also common to judge the vibration based on measurements taken on the rotating shafts. For such vibration measurement requirements, see ISO 7919-1 and ISO 7919-2.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7919-2, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

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

3 Measurement procedures

The measurement procedures and instrumentation shall comply with the general requirements of ISO 10816-1 and are as follows.

For monitoring purposes, the measurement system shall be capable of measuring broad-band vibration over a frequency range from 10 Hz to at least 500 Hz. If, however, the instrumentation is also used for diagnostic purposes, a wider frequency range and/or spectral analysis can be necessary. For example in cases where the frequency corresponding to the first critical speed of the generator and/or low-pressure rotors is below 10 Hz, the lower limit of the linear range of the measurement system shall be reduced accordingly. In special cases where significant low-frequency vibration can be transmitted to the machine, such as in earthquake regions, it can be necessary to filter the low-frequency response of the instrumentation and/or implement an appropriate time delay. If measurements from different machines are compared, care should be taken to ensure that the same frequency range is used.

The locations of vibration measurements should be such that they provide adequate sensitivity to the dynamic forces of the machine. Care should be taken to ensure that the measurement equipment is not unduly influenced by external sources, such as airborne and structure-borne noise. Typically, this requires measuring in two radial directions on each main bearing cap or pedestal with a pair of orthogonal transducers, as shown in Figure 1. The transducers may be placed at any angular location on the bearing housings or pedestals, although vertical and horizontal directions are usually preferred.

A single radial transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information on the magnitude of the machine vibration. In general, however, caution should be observed when evaluating vibration from a single transducer at a measurement plane, since it might not be oriented to provide a reasonable approximation of the maximum value at that plane.

It is not common practice to measure axial vibration on the main radial load carrying bearings of steam turbines and generators for continuous operational monitoring. Such measurements are primarily used during periodic vibration surveys or for diagnostic purposes. Hence, in this part of ISO 10816, axial vibration criteria are only provided for thrust bearings where the vibration severity can be judged using the same criteria as for radial vibration (see Table A.1). For other bearings, where there are no axial restraints, a less stringent requirement may be used for the evaluation of axial vibration.

The characteristics of the measurement system should be known with regard to the effects of the environment, including:

a) temperature variations;

b) magnetic fields;

c) airborne and structure-borne noise;

d) power source variations;

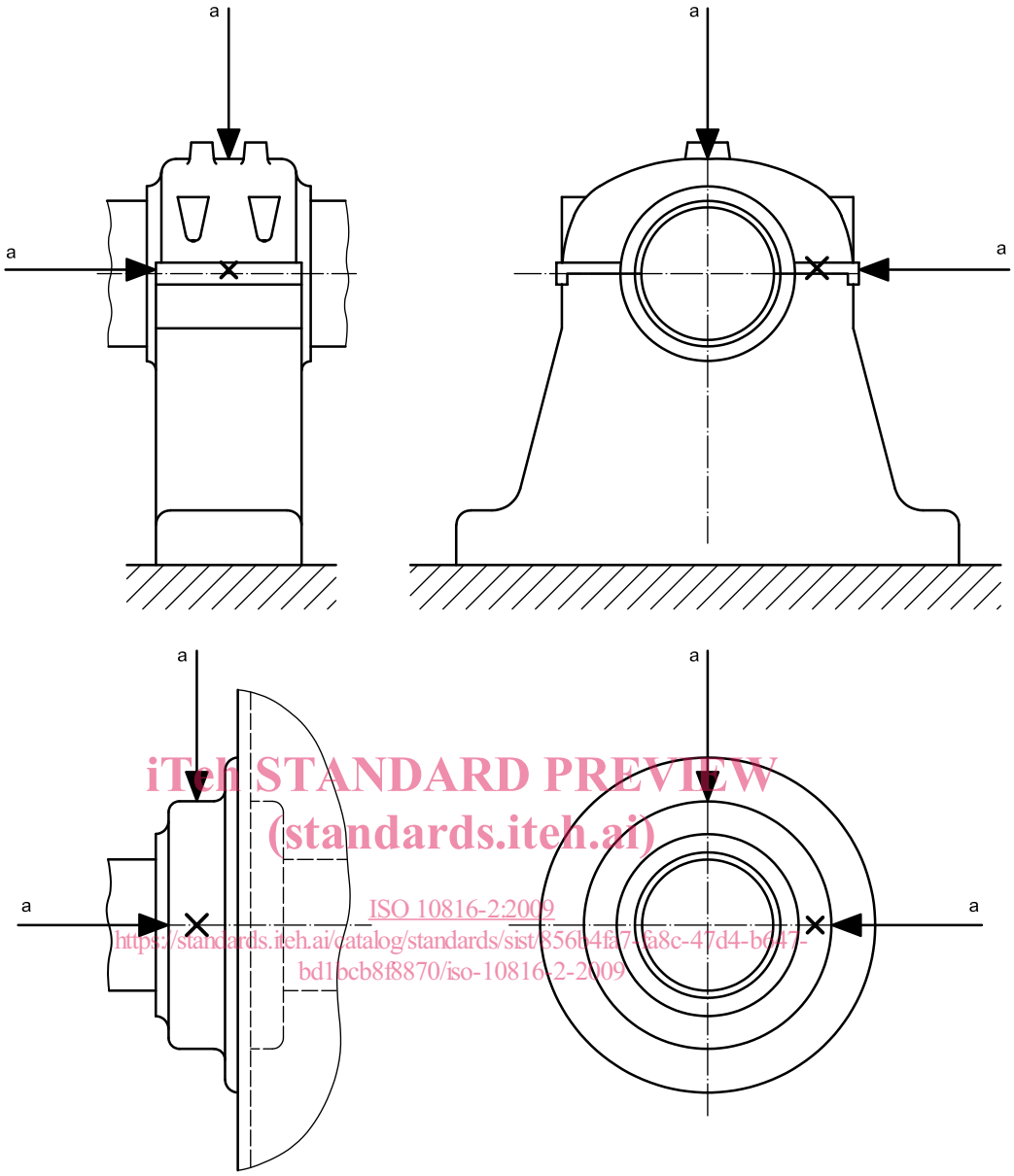
e) cable impedance;

f) transducer cable length;

g) transducer orientation;

h) stiffness of the transducer attachment.

Particular attention should be given to ensuring that the vibration transducers are correctly mounted and that the mounting arrangement does not degrade the accuracy of the measurement (see for example ISO 2954 and ISO 5348).



NOTE The evaluation criteria in this part of ISO 10816 are applicable to radial vibration on all main bearings and to axial vibration on thrust bearings.

[a] Direction of measurement.

Figure 1 — Typical measuring points and directions on bearing pedestals and bearing caps

4 Evaluation criteria

4.1 General

ISO 10816-1 provides a general description of the two evaluation criteria used to assess the vibration severity on various classes of machines. One criterion considers the magnitude of the observed broad-band vibration; the second criterion considers changes in magnitude, irrespective of whether they are increases or decreases.

The maximum magnitude of vibration measured is defined as the vibration severity. The values presented are the result of experience with machinery of this type and, if due regard is paid to them, acceptable operation can be expected.

NOTE These values are based on previous International Standards, on the results of a survey which was carried out when ISO 7919 (all parts) and ISO 10816 (all parts) were initially developed and on the feedback provided by the experts of ISO/TC 108.

Criteria are presented for steady-state operating conditions at the specified normal operating speed and load ranges, including normal slow changes in electrical load of the generator. Alternative criteria are also presented for other non-steady-state conditions when transient changes are taking place. The vibration criteria represent target values which give provisions for ensuring that gross deficiencies or unrealistic requirements are avoided. They serve as a basis for defining acceptance specifications (see 4.2.2.3).

The criteria relate to the vibration produced by the steam turbine and/or generator and not to vibration transmitted from outside the machinery set. If it is suspected that there is a significant influence due to transmitted vibration (either steady-state or intermittent), measurements should be taken with the machinery set shut down. If the magnitude of the transmitted vibration is unacceptable, steps should be taken to remedy the situation.

It should be noted that an overall judgement of the vibratory state of a machine is often made on the basis of measurements made on both non-rotating parts and rotating shafts.

4.2 Criterion I: Vibration magnitude

4.2.1 General

This criterion is concerned with defining values for absolute vibration magnitude consistent with acceptable dynamic loads on the bearings and acceptable vibration transmission into the support structure and foundation.

4.2.2 Vibration magnitude at normal operating speed under steady-state operating conditions

4.2.2.1 General

The maximum vibration magnitude observed at each bearing or pedestal is assessed against four evaluation zones established from international experience.

4.2.2.2 Evaluation zones

The following evaluation zones are defined to permit an assessment of the vibration of a given machine under steady-state conditions at normal operating speed and to provide guidelines on possible actions.

Zone A: The vibration of newly commissioned machines normally falls 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.

NOTE For transient operation, see 4.2.4.

4.2.2.3 Acceptance criteria

Acceptance criteria shall always be subject to agreement between the machine supplier and purchaser prior to installation. The evaluation zones provide a basis for defining acceptance criteria for new or refurbished machines.

NOTE Historically, for new machines, acceptance criteria have been specified in zone A or zone B, but would normally not exceed 1,25 times the zone A/B boundary.

4.2.2.4 Evaluation zone boundaries

The zone boundary values are given in Table A.1. They apply to radial vibration measurements on all bearings and to axial vibration measurements on thrust bearings when taken under steady-state conditions at normal operating speed. The numerical values assigned to the zone boundaries were established from representative data provided by manufacturers and users. There was inevitably a significant spread in the data. The values given in Table A.1 do nevertheless give provisions for ensuring that gross deficiencies or unrealistic requirements are avoided.

Higher vibration is permitted at other measurement positions and during transient conditions (see 4.2.4).

In most cases, the values given in Table A.1 are consistent with ensuring that the dynamic loads transmitted to the bearing support structure and foundation are acceptable. However, in certain cases, there can be specific features or available experience associated with a particular machine type which can require other values (higher or lower) to be used for the zone boundaries. The following are examples.

a) The machine vibration can be influenced by its mounting system and coupling arrangement between rotors. Higher bearing vibration may therefore be permitted for flexible bearing supports when the shaft relative vibration in the measurement direction is low, indicating that the dynamic forces transmitted to the support structure are also low. It may then be acceptable, based on demonstrated satisfactory operating history, for the zone boundary values given in Table A.1 to be increased.

b) For relatively lightly loaded bearings (e.g. exciter rotor steady bearings and synchronizing clutch bearings) or other more flexible bearings, other criteria based on the detailed machine design may be used.

c) For some large 1 500/1 800 r/min steam turbines, lower zone boundary values may apply.

NOTE 1 Different values can apply for measurements taken at different bearings on the same rotor line.

In general, when higher zone boundary values are used it can be necessary for technical justification to be provided to confirm that the machine's reliability is not compromised by operating with higher vibration. This could be based, for example on the detailed features of the machine or on successful operating experience with machines of similar structural design and support.

NOTE 2 This part of ISO 10816 does not provide different evaluation zone values for steam turbines and generators mounted on rigid and flexible foundations. This is consistent with ISO 7919-2, which deals with shaft vibration measurements for the same class of machines. However, it is possible that this part of ISO 10816 and ISO 7919-2 will be revised in the future to give different criteria with respect to support flexibility, if additional analysis of survey data on such machines shows it to be warranted.

The common measurement parameter for assessing machine vibration severity is velocity. Table A.1 presents the evaluation zone boundaries based on broad-band r.m.s. (root-mean-square) velocity measurements. In some cases, however, it was customary to measure vibration with instruments scaled to read peak rather than r.m.s. vibration velocity values. If the vibration consists mainly of one frequency component (e.g. for steam turbines and generators, it is common for the vibration to be predominantly at the operating frequency of the machine), a simple relationship exists between the peak and r.m.s. values and the zone boundaries of Table A.1 can be readily expressed as zero-to-peak values by multiplying by $\sqrt{2}$. Alternatively, the measured peak vibration values can be divided by $\sqrt{2}$ and judged against the r.m.s. criteria of Table A.1.

NOTE 3 A different factor can be required if instrumentation measuring true peak values is used.