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Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria —

Part 2:
Large land-based steam turbine generator sets

Vibrations mécaniques des machines non alternatives — Mesurages sur les arbres tournants et critères d'évaluation —

Partie 2: Turbo-alternateurs installés sur fondation radier

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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.

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 7919-2 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*.

ISO 7919 consists of the following parts, under the general title *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria*:

- *Part 1: General guidelines*
- *Part 2: Large land-based steam turbine generator sets*
- *Part 3: Coupled industrial machines*
- *Part 4: Gas turbine sets*
- *Part 5: Machine sets in hydraulic power generating and pumping plants*

Annex A forms an integral part of this part of ISO 7919.

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Introduction

This part of ISO 7919 deals with the special features required for measuring transverse shaft vibration on the coupled rotor system of steam turbine generator sets for power stations. Evaluation criteria, based on previous experience, are presented which may be used as guidelines for assessing the vibratory conditions of such machines.

A general description of the principles which are generally applicable for the measurement and evaluation of shaft vibration of non-reciprocating machines is given in ISO 7919-1.

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Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria —

Part 2:
Large land-based steam turbine generator sets

1 Scope

This part of ISO 7919 gives guidelines for applying evaluation criteria for shaft vibration under normal operating conditions, measured at or close to the bearings of steam turbine generator sets. These guidelines are presented in terms of both steady running vibration and any magnitude changes which may occur in these steady values. The numerical values specified are not intended to serve as the only basis for vibration evaluation since, in general, the vibratory condition of a machine is assessed by consideration of both the shaft vibration and the associated structural vibration (see the introduction to ISO 7919-1).

This part of ISO 7919 applies to large land-based steam turbine generator sets for power stations, having rated speeds in the range 1 500 r/min to 3 600 r/min, and power outputs greater than 50 MW.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 7919. 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 7919 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 7919-1:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines*.

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

ISO 10816-2:1996, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Large land-based steam turbine generator sets in excess of 50 MW*.

3 Measurement procedures

The measurement procedures to be followed and the instrumentation used shall be as described in ISO 7919-1.

Early experience on large steam turbine generator sets was restricted to the measurement of absolute shaft vibration using shaft-riding transducers. More recently, as non-contacting transducers were developed, relative shaft vibration measurements have become more common but, if required, the absolute shaft vibration can be obtained by vectorially combining the outputs of a non-contacting transducer and a seismic transducer on a common mounting which measures the structural vibration. Both approaches are at present in common use and measurements of relative shaft or absolute shaft vibration are therefore equally acceptable for the purposes of this part of ISO 7919.

For monitoring purposes, the measuring system shall be capable of covering overall vibration up to a frequency of not less than 160 Hz, which is the practical limit for most shaft-riding transducers. However, it should be noted that for diagnostic purposes it may be desirable to cover a wider frequency range.

Prior to running large steam turbine generator sets up to speed, slow-roll measurements of shaft displacement may be carried out. The results obtained are compared with expected values and may be used as a basis for judging whether the state of the rotor line is satisfactory; for example whether a temporary bend is present in the rotor or whether there is a degree of bearing-support misalignment. Such measurements cannot normally be regarded as giving a valid indication of shaft runout under normal operating conditions since they can be affected by, for example, temporary bows, erratic movements of the journal within the bearing clearance, axial movements, etc. In particular, it is recommended that vector subtraction of slow-roll measurements from rated speed vibration measurements should not be carried out without consideration of the above factors, since the results may provide a misleading interpretation of the machine vibration (see ISO 7919-1).

NOTE 1 If slow-roll measurements are taken, it is important to ensure that the low-frequency characteristics of the measuring system are adequate.

4 Evaluation criteria

Criteria for vibration magnitude, changes in vibration magnitude and operational limits are presented in annex A.

The vibration magnitude is the higher value of the peak-to-peak displacement measured in two selected orthogonal measurement directions. The values presented are the result of experience with machinery of this type and, if due regard is paid to them, acceptable operation may be expected. If only one measuring direction is used, care should be taken to ensure that it provides adequate information (see ISO 7919-1).

The criteria are presented for the specified steady-state operating conditions at the rated speed and load ranges. They apply for normal slow changes in electrical loading of the generator but do not apply when different conditions exist or during transient changes, for example during start-up and shut-down and when passing through resonance ranges. In these cases alternative criteria are necessary.

It should be noted that an overall judgement of the vibratory state of a machine is often made on the basis of both shaft vibration as defined above and of measurements made on non-rotating parts (see ISO 10816-1 and ISO 10816-2).

Annex A
(normative)

Evaluation criteria for shaft vibration of large steam turbine generator sets under specified operating conditions

A.1 General

Two evaluation criteria are used to assess the shaft vibration of large steam turbine generator sets, measured at or close to the bearings. One criterion considers the magnitude of the observed broad-band shaft vibration; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

A.2 Criterion I: Vibration magnitude at rated speed under steady operating conditions

This criterion is concerned with defining limits for shaft vibration magnitude consistent with acceptable dynamic loads on the bearing, adequate margins on the radial clearance envelope of the machine, and acceptable vibration transmission into the support structure and foundation. The maximum shaft vibration magnitude observed at each bearing is assessed against four evaluation zones established from international experience.

A.2.1 Evaluation zones

The following typical evaluation zones are defined to permit a qualitative assessment of the shaft vibration on a given machine and provide guidelines on possible actions.

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.

A.2.2 Evaluation zone limits

Recommended values for the zone boundaries are given in table A.1 for relative shaft vibration and table A.2 for absolute shaft vibration. These values are based on present accumulated experience of shaft vibration measurements in this field. They 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. For example, with a tilting pad bearing it may be necessary to specify alternative vibration values, whilst in the case of an elliptical bearing, different vibration criteria may apply for the directions of maximum and minimum bearing clearances. In particular, it should be recognized that the allowable vibration may be related to the journal diameter since, generally, running clearances will be greater for larger diameter bearings. Consequently different values may apply for measurements taken at different bearings on the same rotor line. 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.

Higher values of vibration can be permitted at other measuring positions and under transient conditions, such as start-up and run-down (including passage through critical speed ranges). Furthemore, for other comparatively lightly loaded bearings (for example exciter rotor steady bearings), other criteria based on the detailed machine design may be necessary.

Table A.1 — Recommended values for maximum relative displacement of the shaft for large steam turbine generator sets at the zone boundaries

Peak-to-peak values in micrometres

Zone boundary	Shaft rotational frequency, r/min			
	1 500	1 800	3 000	3 600
	Maximum relative displacement of shaft			
A/B	100	90	80	75
B/C	200	185	165	150
C/D	320	290	260	240

Table A.2 — Recommended values for maximum absolute displacement of the shaft for large steam turbine generator sets at the zone boundaries

Peak-to-peak values in micrometres

Zone boundary	Shaft rotational frequency, r/min			
	1 500	1 800	3 000	3 600
	Maximum absolute displacement of shaft			
A/B	120	110	100	90
B/C	240	220	200	180
C/D	385	350	320	290

A.3 Criterion II: Change in vibration magnitude

This criterion provides an assessment of a change in vibration magnitude from a previously established reference or baseline value. A significant increase or decrease in shaft 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 shaft vibration magnitude occurring under steady-state operating conditions.

The reference value for this criterion is the typical, reproducible normal vibration, known from previous measurements for the specific operating conditions. If this reference value changes by a significant amount, and certainly if it exceeds 25 % of the upper limiting value for zone B, regardless of whether this increases or decreases the magnitude of vibration, steps should be taken to ascertain the reasons for the change. A decision on what action to take, if any, should then be made after consideration of the maximum value of vibration and whether the machine has stabilized at a new condition.

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.

It is necessary to appreciate that a criterion based on change of vibration has limited application, since significant changes of varying magnitude and rates can and do occur in individual frequency components, but the importance of these is not necessarily reflected in the broad-band shaft vibration signal (see ISO 7919-1). For example, the propagation of a crack in a rotor may introduce a progressive change in vibration components at multiples of rotational frequency, but their magnitude may be small relative to the amplitude of the once-per-revolution rotational frequency component. Consequently, it may be difficult to identify the effects of the crack propagation by looking at the change in the broad-band vibration only. Therefore, although monitoring the change in broad-band vibration will give some indication of potential problems, it may be necessary in certain applications to use measuring and analysis equipment which is capable of determining the trends of the vector changes that occur in individual frequency components of the vibration signal. This equipment may be more sophisticated than that used for normal supervisory monitoring and its use and application requires specialist knowledge. Hence, the specification of detail criteria for measurements of this type is beyond the scope of this part of ISO 7919.

A.4 Operational limits

For long-term operation, it is common practice 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.

A.4.1 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 25 % of the upper limit of zone B. If the baseline is low, the ALARM may be below zone C.

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, the 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.

A.4.2 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 more precise guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D.