INTERNATIONAL STANDARD

ISO 7919-5

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

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

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

Partie 5: Machines équipant les centrales hydroélectriques et les stations de pompage

Reference number
ISO 7919-5:1997(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 7919-5 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. Annexes B and C are for information only.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet: central@iso.ch
X.400: c=ch; a=400net; p=iso; o=isocs; s=central

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

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

1 Scope

This part of ISO 7919 gives guidelines for applying shaft vibration evaluation criteria, under normal operating conditions, measured at or close to the bearings of machines or machine sets in hydraulic power generating and pumping plants. These guidelines are presented in terms of both steady-state running vibration and any amplitude 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 ISO 7919-1).

This part of ISO 7919 applies to machines or machine sets in hydraulic power generating and pumping plants where the hydraulic machines have speeds from 60 r/min to 1 800 r/min, shell- or shoe-type sleeve bearings, and main engine power of at least 1 MW. The position of the shaft line may be vertical, horizontal or at an arbitrary angle between these two directions.

Machine sets covered by this part of ISO 7919 may be a combination of

— hydraulic turbines and generators,
— pumps and electrical machines operating as motors,
— pump-turbines and motor-generators,

including auxiliary equipment (e.g. starting turbines or exciters lying in the shaft line).

This part of ISO 7919 is also applicable to turbines or pumps connected to generators or electrical motors via gears and/or radially flexible couplings. However, electrical machines with speeds between 1 000 r/min and 1 800 r/min should be evaluated according to the criteria specified in ISO 7919-3.

This part of ISO 7919 is not applicable to

— pumps in thermal power plants or industrial installations (for these machines, see ISO 7919-3),
— hydraulic machines or machine sets having rolling element bearings, or
— hydraulic machines having water-lubricated bearings.

Consistent with ISO 7919-1, shaft vibration of machines or machine sets in hydraulic power generating and pumping plants may be determined with regard to the following tasks:

— task A: changes in vibrational behaviour;
— task B: excessive kinetic load;
— task C: the monitoring of radial clearance.

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 10817-1:—[1], *Rotating shaft vibration measurement systems — Part 1: Relative and absolute signal sensing of radial vibration from rotating shafts.*

IEC 994:1991, *Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines).*

3 Measurement procedures

The measurement procedures to be followed and the instrumentation used shall be as described in ISO 7919-1 and IEC 994.

3.1 Measurement type

Relative and absolute shaft vibration measurements are carried out on hydraulic machine sets using non-contacting transducers. Shaft-riding probes with seismic transducers cannot generally be used due to the very-low-frequency range of the measuring equipment required for low-speed hydraulic machinery.

For relative measurements, transducers should be mounted directly on the bearing shell or the bearing pad. If the transducers are installed on the bearing support structure or bearing housing, as it is common for vertical machines, care shall be taken that the relative motion between the bearing shell or pad and the transducer itself is small compared with the shaft motion. If this is not so, the measured signal cannot be said to be representative of the relative movement between the shaft and bearing shell or bearing pad, respectively. This requirement may be assessed by static analysis of the structure or additional measurement; the latter is usually difficult and expensive.

For absolute vibration measurements, non-contacting transducers shall be installed on rigid frameworks, fixed to the turbine or generator pit wall. Signals from these transducers can only be regarded as representative of the absolute shaft vibration when the absolute vibration of the supporting structure itself at the point of attachment of the transducer is less than 10 % of the measured peak-to-peak value, with 25 µm as an upper limit.

With regard to the transducer support structures, it is advisable that the lowest natural frequency of those vibration modes which create significant movements in the working direction of shaft displacement transducers should be greater than seven times the synchronous rotational frequency and should not be a direct multiple of the synchronous rotational frequency.

The absolute vibration of the support frame should always be measured using seismic transducers installed on the support frame as close as possible to the shaft movement transducer and in the same direction of action. The readings from the seismic transducers may be used after conversion into displacements to evaluate the absolute shaft displacement.

NOTE — Apart from the shaft vibration, the vibration of the bearing support is frequently monitored as well. The vibration measurement at the lower guide bearings of vertical machines may, however, be misinterpreted; the vibration value measured at the bearings and their supports which are rigidly embedded in the building is sometimes produced by hydraulic forces, directly transmitted from the hydraulic machine via the foundation, and is not produced by radial shaft vibration.

1) To be published.

3.2 Measurement planes

Measurement tasks A and B in clause 1 require measurements to be taken at all main bearings of the machine set. If possible, the setting of the transducers at the different bearings should be in line. For vertical machines, in most cases the preferred measurement directions are upstream and 90° apart in the direction of rotation. For horizontal machines, for practical reasons the measurement directions are often chosen to be ± 45° from the vertical.

For monitoring purposes (task A) only, in some cases measurement planes can be reduced to the most important ones, mainly at machine sets with four or more bearings. The selection should be based on vibration performance analyses, simulating all types of faults or disturbing events. Preferred measurement planes should be those where possible disturbing events produce significant shaft amplitudes.

Measurement task C requires the installation of transducers near to or inside the hydraulic machine seals or labyrinths, or at positions from where it is possible to reconstruct the shaft line deflection within the hydraulic machine for all relevant vibration modes. Appropriate measurements are, in special cases, part of the commissioning of a machine set. They may yield transfer functions for the different permanent measurement planes.

NOTE — When judging the behaviour of the whole machine, it is important to measure also at a distance from the bearings (e.g. in the coupling area) to obtain information about the amplitude distribution along the shaft line. If a bearing plane is near to a vibration node, the vibration behaviour and the actual shaft line deflection can be underestimated.

3.3 Measuring equipment

The measuring equipment performance should be in accordance with the requirements of ISO 10817-1 and IEC 994.

The frequency range of the measuring equipment shall correspond to the wide excitation spectrum of shaft vibration in hydraulic machines. It should be from a quarter of the nominal rotational frequency of the machine up to two times the bucket or blade passing frequency.

The amplitude range of the measurement system should be at least two times the values of the borderline between zones C and D (see clause A.2), so that transient operating conditions can be accurately monitored.

4 Evaluation criteria

4.1 Turbine operation conditions

Evaluation criteria for vibration magnitude and changes in vibration magnitude for machine sets in turbine operation conditions are presented in annex A. They are in accordance with the general guidelines given in ISO 7919-1.

With respect to the special nature of the vibration orbits of vertical shaft hydromachines, the preferred measurement quantity shall be the maximum vibratory displacement S_{max}. Since most of the monitoring systems display displacement amplitudes as $S_{(p\text{-}p)}$ values (vibratory displacement peak-to-peak in the direction of measurement; see ISO 7919-1), the evaluation criteria are specified for both measurement quantities. Application of these criteria is valid for machine sets with nominal speeds between 60 r/min and 1 800 r/min operating within the contractually permissible steady-state load range as well as at other load conditions, if the machine has been made suitable for these particular conditions.

The limiting values are applicable for all kinds of turbine-driven machine sets independent of the type, head and power except for the restrictions stated in clause 1. For hydromechanically smoother running turbine types (e.g. Pelton turbines), lower shaft vibration amplitudes can normally be expected.

In the case of pump-turbines, higher shaft vibration amplitudes than normally expected for zone A can occur due to the runner design, which is a compromise of the optimal design for turbine and pump runner.

4.2 Pump operation conditions

At present, insufficient data are available to prepare criteria for machine sets in pump operation conditions. They will be added to a future edition of this part of ISO 7919.

4.3 Special operating conditions

Attention should be paid to the following operating conditions:

a) steady-state operating conditions at low partial load, at overload, and the frequent transient operating conditions during start-up and shut-down;

b) rare transient operating conditions such as emergency shut-down, no discharge operation, and running through the brake quadrant with pumps and pump-turbines.

The evaluation of such processes is much more difficult than that of operation in the specified load range. At present there are insufficient values determined from experience to establish limiting curves for these operating conditions. The less the operating condition corresponds to the nominal conditions, the more the flow within the hydraulic machine is disturbed; disturbances such as separation and swirl generate violent stochastic excitation. Due to the density of water, the forces caused by the stochastic excitation are much greater than in thermal turbomachines.

Therefore, during operations outside the specified load range, the shaft vibration caused by mass unbalances are, as a rule, totally masked by the stochastic components. Because of these large stochastic components in extraordinary operating conditions, one should rely less on the instantaneous value and more on the mean value over at least 10 rotations of the shaft.

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

Annex A
(normative)

Evaluation criteria for relative shaft vibration of hydraulic turbine sets under specified operating conditions

A.1 General

The relative shaft vibration of hydraulic machine sets measured at or close to the bearings should be evaluated on the basis of the following two criteria.

Criterion I: The reliable and safe running of a machine under normal operating conditions requires that the vibration magnitude should remain below certain limits consistent with, for example, acceptable kinetic loads and adequate margins on the radial clearance envelope for the machine. Generally, this criterion will be taken as the basis for evaluation of machines in the absence of any other established knowledge of the satisfactory running characteristics for machines of that type (e.g. for new machine types).

Criterion II: Changes in vibration magnitude, even though the specified limits are not exceeded, may point to incipient damage or some other irregularity. Consequently, such changes relative to a reference value should not be allowed to exceed certain limits.

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

Recommended values are given in figure A.1 for the maximum vibratory displacement in the plane of measurement, S_{max}, and in figure A.2 for the vibratory displacement peak-to-peak in the direction of measurement, $S_{(p\text{-}p)}$, as a function of the maximum service speed. Both quantities are measured in the radial direction at or close to the main load-carrying journal bearings at rated speed(s) under steady-state operation conditions as defined in 4.1. Higher values of vibration can be permitted at other measurement positions and under conditions described in annex B.

NOTE 1 The values in figures A.1 and A.2 are based on statistical analyses of more than 900 data sets collected worldwide from machines of all types, speeds and power. Measurements were made on machines running in normal operation without problems for a long time. The analysis was therefore used to establish the borderline between zones B and C.

The vibration magnitudes given in figures A.1 and A.2 relate to four zones which are defined as follows.

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.

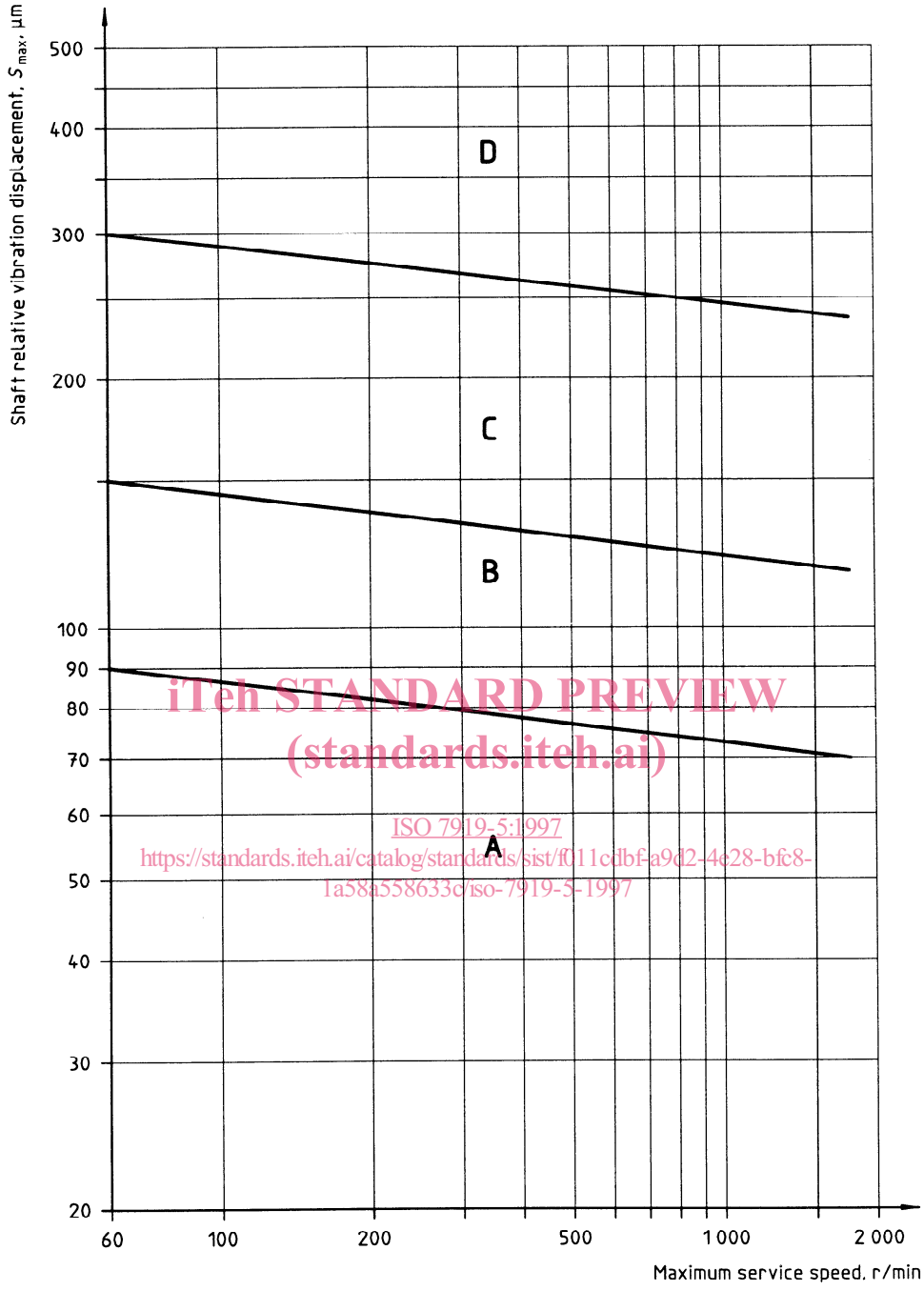

Figure A.1 — Recommended evaluation zones for the maximum vibratory displacement in the plane of measurement, S_{max}, of hydraulic machines or machine sets, valid for turbine operation within the contractually permissible steady-state load range

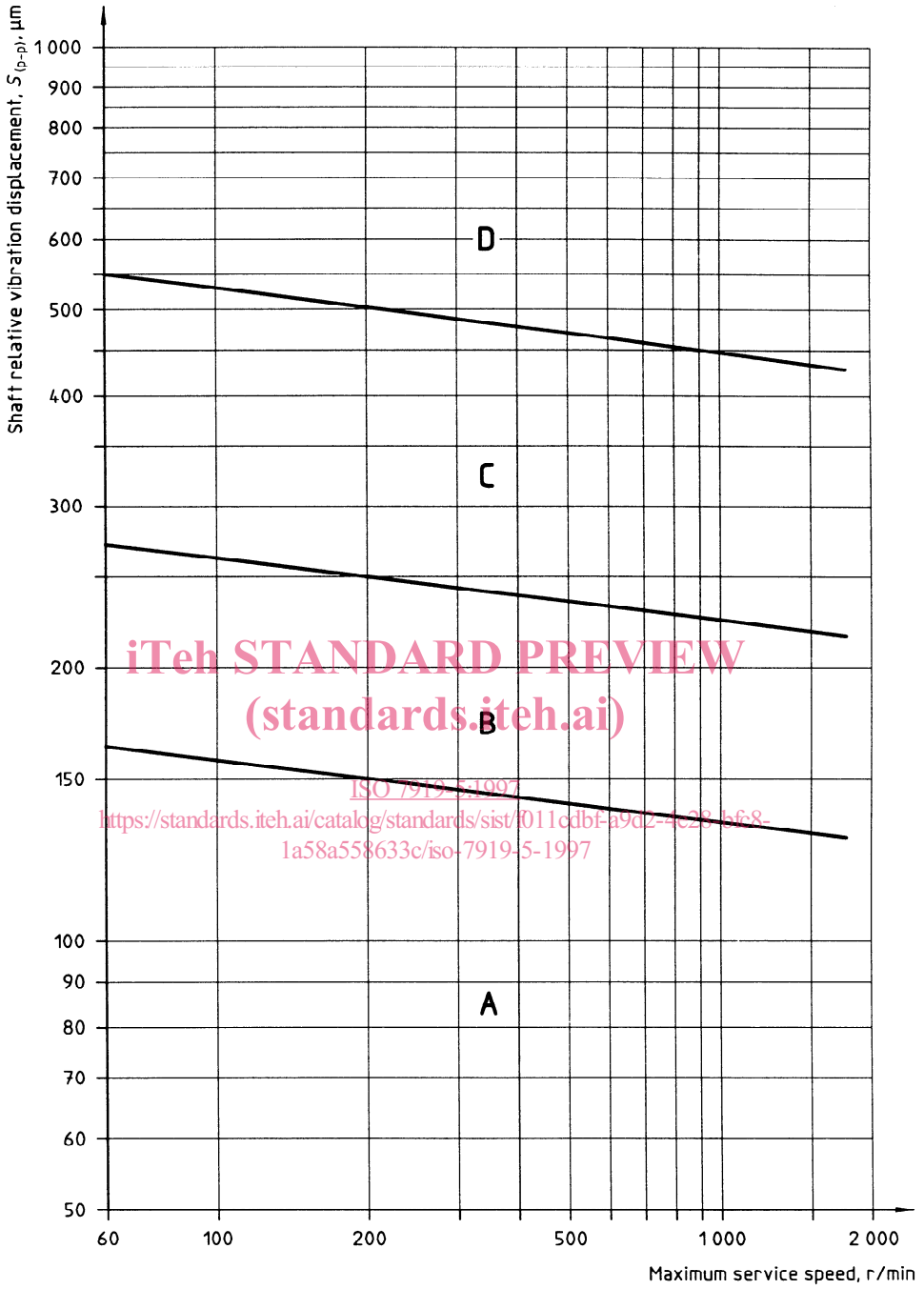

Figure A.2 — Recommended evaluation zones for the vibratory displacement peak-to-peak in the direction of measurement, $S_{(p-p)}$, of hydraulic machines or machine sets, valid for turbine operation within the contractually permissible steady-state load range