INTERNATIONAL STANDARD

**ISO 20816-5**

First edition
2018-07

# Mechanical vibration — Measurement and evaluation of machine vibration —

## Part 5: Machine sets in hydraulic power generating and pump-storage plants

*Vibrations mécaniques — Mesurage et évaluation des vibrations des machines —*

*Partie 5: Groupes de machines équipant des centrales hydroélectriques et des stations de pompage et de stockage*



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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.



This document was prepared jointly 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*, and Technical Committee IEC/TC 4 *Hydraulic turbines*. The draft was circulated for voting to the national bodies of both ISO and IEC.



This first edition of ISO 20816-5 cancels and replaces ISO 7919-5:2005 and ISO 10816-5:2000, which have been technically revised. The main changes are:

— Vibrations of different type of machines and different shaft orientation are clearly identified.

— Demonstration that for each machine type, the vibration follows a similar statistical distribution profile (Burr distribution), which resulted in revised vibration values.

— A strong recommendation to look at both shaft vibration and the vibration of non-rotating parts together with physical parameters like bearing metal temperature and physical bearing clearances in order to obtain a complete assessment of the machine health.

— Recommendation of a collaborative approach between supplier and customer to investigate cases where vibration is larger than the statistical values instead of a rigid approach based only on vibration values.

A list of all parts in the ISO 20816 series can be found on the ISO website.

# Introduction

ISO 20816-1 is the basic document which specifies the general requirements for evaluating vibration of various machine types. The present document provides specific guidance for the vibration of housings and shafts of machine sets installed in hydraulic power generating and pump-storage plants.

Two criteria are provided for assessing machine vibration:

a) the first criterion considers the magnitude of the measured vibration;

b) the second criterion considers changes in the magnitude and phase of the measured vibration.

This document covers the analysis of both shaft vibration and vibration of fixed, non-rotating parts.

Vibration criteria have been established for horizontal axis and vertical axis machines and have been developed for each type of turbine (Bulb, Francis, Pelton, Kaplan) when used for generating and also for pumping where appropriate. The vibration magnitudes criteria provided in this document are guidelines based on statistics; the magnitude values given should not be used as guarantees. It is recommended that the vibration assessment is performed by a vibration expert selected in common agreement by all parties. To identify the good behaviour of a hydraulic machine, it is essential to look at the following points together:

— the magnitude of the relative shaft vibration;

— the magnitude of the bearing housing vibration;

— the percentage of the guide bearings cold diametral clearance that is used;

— the operating temperature of the metal parts of the guide bearings;

— the operating regime (head and flow or head and power), to make sure the machine is operating within the normal operating range.



Recommended actions are given for those cases where the vibration magnitudes are above the action limits given in the tables in Annex A in order to establish if the machine is suitable for continued long-term operation without restriction.



Guidelines are presented both for the vibrations present when machines are operating and also for any changes in the amplitude or phase of those vibration values which can occur. The numerical values given in Annex A for vibration are intended to serve as the basis for the evaluation for the condition of the machine and, if required, further investigation. It is recommended in this document that the machine condition is assessed by considering both the bearing housing vibration and shaft vibration.

# Mechanical vibration — Measurement and evaluation of machine vibration —

## Part 5: Machine sets in hydraulic power generating and pump-storage plants

## 1 Scope

This document provides guidelines for evaluating the vibration measurements made at the bearings, bearing pedestals or bearing housings and also for evaluating relative shaft vibration measurements made on machine sets in hydraulic power generating and pump-storage plants when the machine is operating within its normal operating range. The normal operating ranges for each type of turbine covered by this document are defined in Annex A.

This document is applicable to machine sets in hydraulic power generating plants and in pump-storage plants with typical rotational speeds of 60 r/min to 1 000 r/min fitted with shell or pad (shoe) type oil-lubricated bearings.

NOTE The current database includes machine speeds ranging from 60 r/min to 750 r/min (with a very small sample of 1 000 r/min machines).



This document defines different limit values of bearing housing and shaft vibration depending on the type of turbine, the orientation of the shaft (i.e. horizontal or vertical) and for each of the bearing locations.

This document is based on statistical analysis and provides criteria for the most common types of turbines, pump-turbines and pumps. For specific information on which types of units are covered in this document, see Annex A.

Machine sets covered by this document can have the following configurations:

a) generators driven by hydraulic turbines;

b) motor-generators driven by pump-turbines;

c) motor-generators driven by hydraulic turbines and separate pumps;

d) pumps driven by electric motors.

This document is not applicable to the following unit configurations, parameters and operating conditions:

— hydraulic machines with water-lubricated bearings;

— hydraulic machines or machine sets having rolling element bearings (for these machines, see IEC 62006 and/or ISO 10816-3);

— pumps in thermal power plants or industrial installations (for these machines, see ISO 10816-7);

— electrical machines operating as motors except for the use of these machines in pump-storage applications;

— hydro generators operating as synchronous condensers (with the water in the turbine depressed by compressed air);

— assessment of absolute bearing housing vibration displacement;

— assessment of axial vibration;

— assessment of transient conditions;

— non-synchronous operation;

— assessment of vibration of the generator stator core or the stator frame level.

Measurements made of the bearing housing vibration and shaft vibration occurring in machine sets in hydraulic power generating and pump-storage plants can be used for the following purposes:

1) Purpose A: to prevent damage arising from excessive vibration magnitudes;

2) Purpose B: to monitor changes in vibrational behaviour in order to allow diagnosis and/or prognosis.

The criteria are applicable for the vibration produced by the machine set itself. Special investigation is needed for vibration transmitted to the machine set from external sources, e.g. transmitted to the machine via the station foundations.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 20816-1, *Mechanical vibration — Measurement and evaluation of machine vibration — Part 1: General guidelines*

IEC 60994, *Guide for field measurement of vibrations and pulsations in hydraulic machines (turbines, storage pumps and pump-turbines)*



## 3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

## 4 Machine arrangements

The large variety of arrangements of hydraulic machine sets means that separation into four principal groups is useful when considering bearing arrangements and the locations where vibration measurements should be taken. These four principal groups are as follows:

— **Group 1**: Horizontal machine sets with the generator equipped with end-shield or pedestal bearings mounted on a rigid foundation.

— **Group 2**: Horizontal machine sets with bearing housings which are braced against the casing of the hydraulic machine.

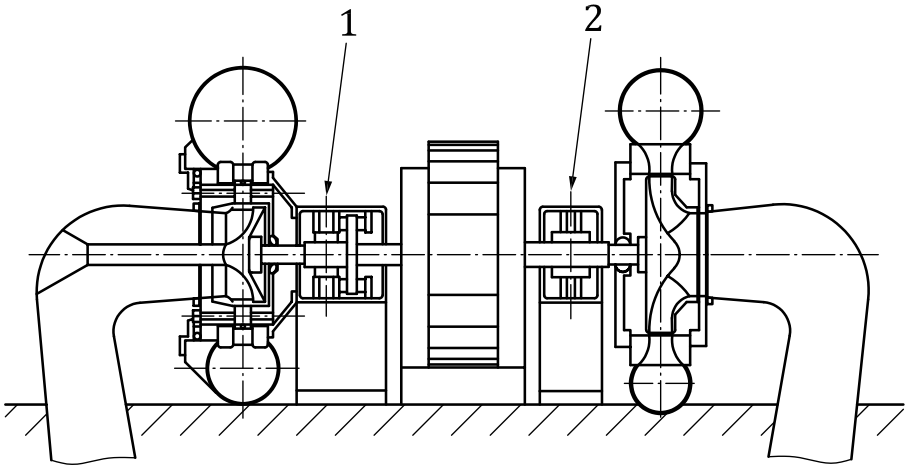
— **Group 3**: Vertical machine sets where all the bearing housings are supported by the station foundations.

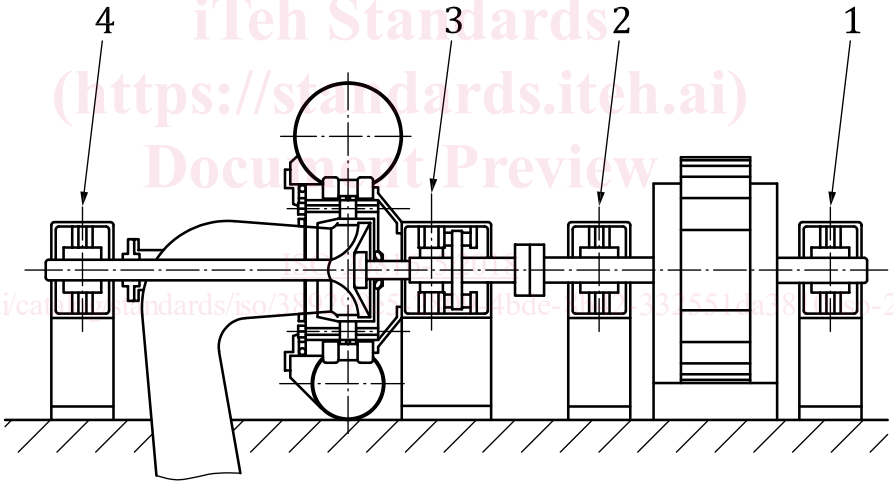
— **Group 4**: Vertical machine sets where the lower bearing housing is supported by the station foundations and the upper bearing housing is supported by the stator frame of the generator.

Figures 1 to 5 show examples for each group. The numbers given in each figure indicate suitable locations for mounting the vibration transducers that are used for the measurement of vibration.

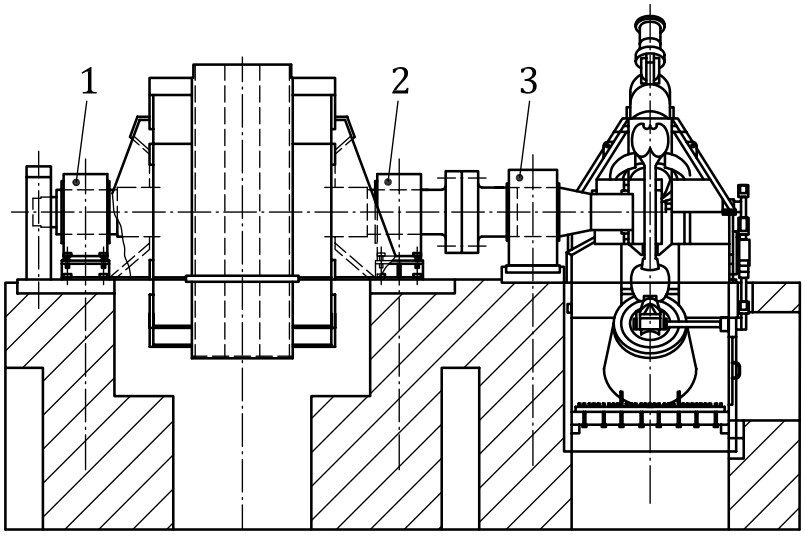
Vibration transducers should be mounted on the bearings at the locations given in Figures 6 and 7.




**a) Two-bearing set with a motor-generator and separate pump and turbine**




**b) Four-bearing set with the generator driven by a Francis turbine**

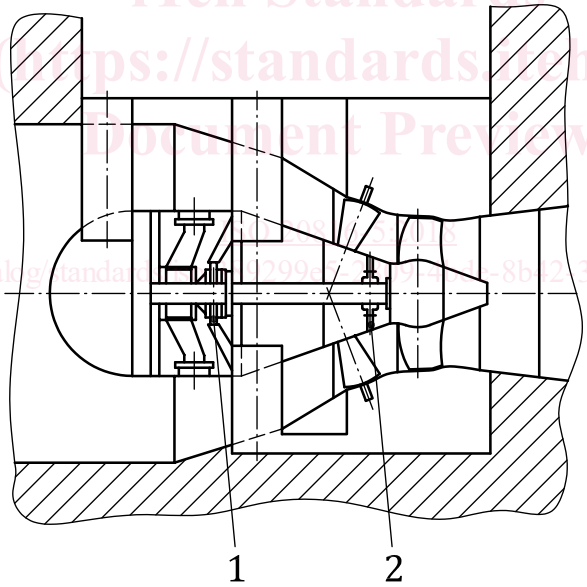



**c) Three-bearing set with the generator driven by a Pelton turbine**

NOTE The numbers indicate suitable locations for the vibration transducers.

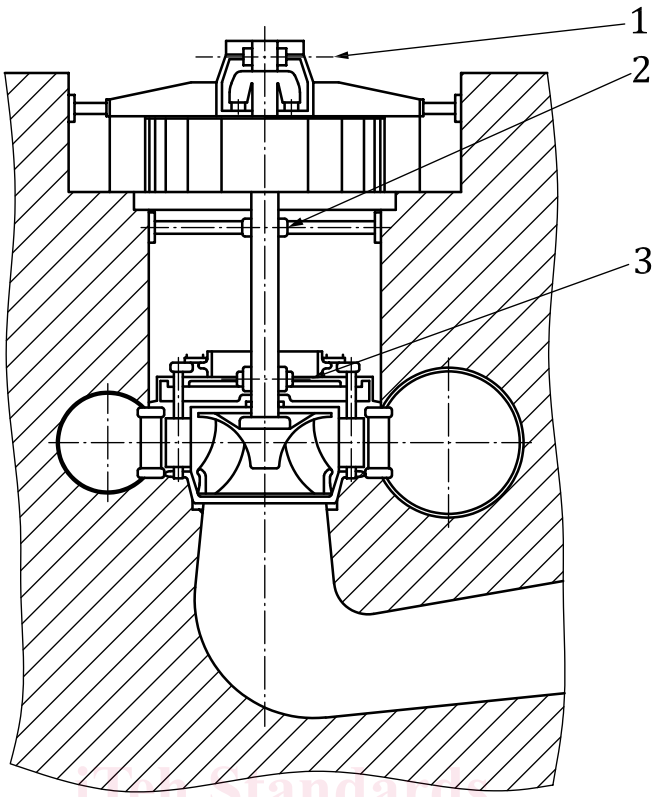
**Figure 1 — Group 1: Horizontal machine sets with pedestal or end-shield bearings mounted on rigid foundation**





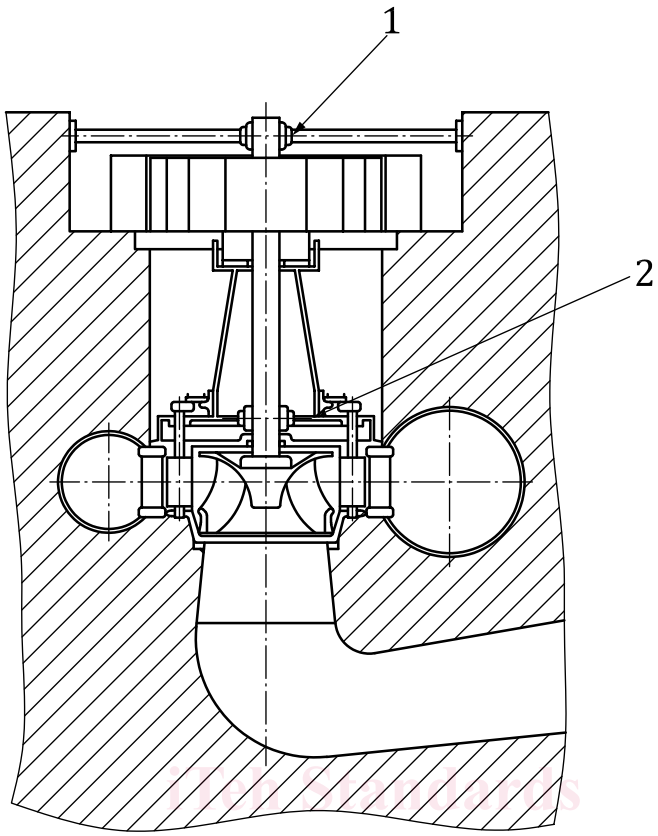

NOTE The numbers indicate suitable locations for the vibration transducers.

**Figure 2 — Group 2: Horizontal machines with the bearings braced against the casing of the hydraulic machine**




NOTE The numbers indicate suitable locations for the vibration transducers.

**Figure 3 — Group 3: Vertical machine sets where all bearing housings are braced against the station foundations and/or concrete pit surrounding the generator (vertical load supported by the generator stator frame)**

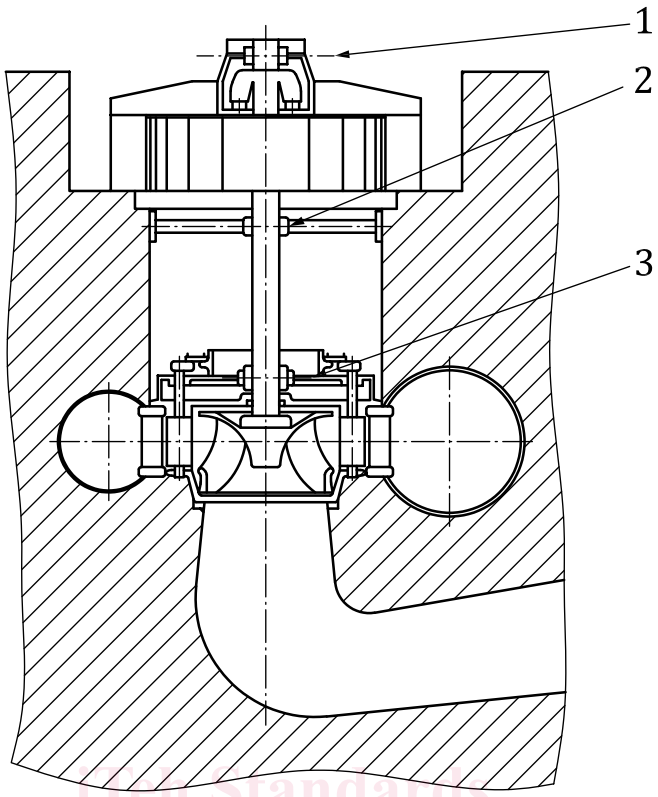



NOTE The numbers indicate suitable locations for the vibration transducers.

**Figure 4 — Group 3: Other example of vertical machine sets where all the bearing housings are braced against the station foundations and/or concrete pit surrounding the generator (vertical load supported by the head cover)**






NOTE The numbers indicate suitable locations for the vibration transducers.

**Figure 5 — Group 4: Vertical machine sets where the generator lower bearing housing is braced against the station foundation and the generator upper bearing housing is supported by the generator stator frame**



# 5 Measurement procedures and conditions

## 5.1 General

### 5.1.1 Bearing housing vibration measurements

ISO 20816-1 gives general guidelines that shall be followed when taking measurements of bearing housing vibration. IEC 60994 provides guidance on taking measurements of vibration in the field. ISO 2954 specifies the measuring instrumentation that should be used. ISO 5348 provides guidance for the mounting of accelerometers. Further recommendations are given in 5.2 to 5.5.

### 5.1.2 Shaft vibration measurements

The measurement procedures that shall be followed are described in ISO 20816-1 and IEC 60994. ISO 10817-1 specifies the measuring instrumentation that should be used. Further recommendations are given in 5.2 to 5.5.

## 5.2 Measurement types

### 5.2.1 Absolute bearing housing vibration

Absolute bearing housing vibration measurements are commonly made on hydraulic machine sets using seismic transducers (electrodynamic velocity transducers or piezoelectric accelerometers with integration) to measure the root-mean-square (RMS) vibration velocity $v_{rms}$ in mm/s.

### 5.2.2 Radial shaft vibration

#### 5.2.2.1 General

Relative and absolute shaft vibration measurements are made on hydraulic machine sets using non-contacting transducers to measure the shaft peak-to-peak displacement $S_{p-p}$ in µm. Shaft riding probes with seismic transducers cannot generally be used due to the very low frequency range required for measurements taken on low-speed hydraulic machines.

$S_{max}$ is not recommended for shaft vibration measurements; see 5.4.4.

#### 5.2.2.2 Relative shaft vibration measurements

For relative measurements, it is common to install the transducers on the bearing housings as close as possible to the guide bearings. They can then read directly on the bearing journals or, alternatively, on special shaft areas (i.e. machined tracks) that have been prepared to limit the total electrical and mechanical runout. In the case of segmental guide bearings, transducers can be mounted between the bearing pads using the guide bearing housing for support or directly on top of the pads but these latter methods are less frequently used.

Care should always be taken to ensure that the support for the shaft vibration transducers is very rigid. If this is not the case, the measured signal will not be representative of the relative movement between the shaft and bearing housing. This requirement can be assessed by static analysis of the structure or verification of the natural frequency of the supports of the vibration transducers by an impact test. The lowest natural radial frequency of the transducer mounting structure should be at least 10 times greater than the synchronous rotational frequency in order to eliminate any chance of resonance in the mounting support. If there is evidence of resonance in the supporting structure on which the shaft vibration transducer is mounted, this needs to be addressed before any signal measurement is taken. In addition, the structure or bearing housing on which the transducer is to be mounted should have a lowest natural radial frequency at least 10 times the synchronous rotational frequency.

Care should be exercised to comply with any specifications stated by the transducer manufacturer to maintain a free space around the transducer to avoid magnetic interference. Care should also be exercised in setting the gap between the transducer and the shaft to ensure that it is greater than twice the maximum radial bearing clearance in order to avoid damage to the transducer. If electrical cables are running inside the shaft and close to the surface, inductive sensors can be affected by stray magnetic fields.

It is important that the shaft surface where the vibration is being measured is free from blemishes, scratches, dents or any other surface defects. It is normal for the shaft track to be specially prepared for use with shaft displacement transducers so as to limit the combined electrical and mechanical runout to a very low value. Ideally the shaft track for vibration measurement should be prepared at the same time as the bearing journals.

#### 5.2.2.3 Absolute shaft vibration measurements

Absolute vibration displacement $S_{p-p}$ can be measured directly using displacement transducers where a rigid support for the transducer can be arranged, e.g. a stiff steel support structure mounted from the turbine or the generator pit wall. Absolute shaft vibration measurements are not common because the requirement to provide a rigid support structure to mount the transducers is difficult to fulfil.

Another possibility is to carry out a vector summation of the relative shaft vibration using non-contacting transducers and the absolute vibration of the support frame using seismic transducers. If this is to be done, the seismic transducers should be installed on the support frame as close as possible to the shaft transducers so that both transducers are measuring in the same radial direction. A calculation with integration and taking into account the amplitude and phase of the vibration signals can then be carried out to determine the magnitude of the absolute shaft vibration. At very low frequencies (below 60 r/min), the stability of double integrated seismic transducers becomes a concern.