## 4.1 Classification according to machine type, rated power or shaft height

Significant differences in design, type or bearings and support structures require a separation into different machine groups (for shaft height *H*, see ISO 496). Machines of these four groups may have horizontal, vertical or inclined shafts and can be mounted on rigid or flexible supports.

**Group 1**: Large machines with rated power above 300 kW; electrical machines with shaft height $H \geq 315$ mm.

These machines normally have sleeve bearings. The range of operating or nominal speeds is relatively broad and ranges from 120 r/min to 15 000 r/min.

**Group 2**: Medium-size machines with a rated power above 15 kW up to and including 300 kW; electrical machines with shaft height 160 mm $\leq H <$ 315 mm.

These machines normally have rolling element bearings and operating speeds above 600 r/min.

**Group 3**: Pumps with multivane impeller and with separate driver (centrifugal, mixed flow or axial flow) with rated power above 15 kW.

Machines of this group may have sleeve or rolling element bearings.

**Group 4**: Pumps with multivane impeller and with integrated driver (centrifugal, mixed flow and axial flow) with rated power above 15 kW.

Machines of this group mostly may have sleeve or rolling element bearings.

NOTES

1 The shaft height *H* of a machine is defined in ISO 496 as the distance, measured on the machine ready for delivery, between the centreline of the shaft and the base plane of the machine itself (see figure 1).

2 The shaft height of a machine without feet, or a machine with raised feet, or any vertical machine, is to be taken as the shaft height of a machine in the same basic frame, but of the horizontal shaft foot-mounting type. When the frame is unknown, half of the machine diameter should be used.

## 4.2 Classification according to support flexibility

Two conditions are used to classify the support assembly flexibility in specified directions:

- rigid supports;
- flexible supports.

These support conditions are determined by the relationship between the machine and foundation flexibilities. If the lowest natural frequency of the combined machine and support system in the direction of measurement is higher than its main excitation frequency (this is in most cases the rotational frequency) by at least 25 %, then the support system may be considered rigid in that direction. All other support systems may be considered flexible.

As typical examples, large- and medium-sized electric motors, mainly with low speeds, would normally have rigid supports, whereas turbo-generators or compressors with power greater than 10 MW and vertical machine sets would usually have flexible supports.

In some cases, a support assembly may be rigid in one measuring direction and flexible in the other. For example, the lowest natural frequency in the vertical direction may be well above the main excitation frequency, while the horizontal natural frequency may be considerably less. Such a system would be stiff in the vertical plane but flexible in the horizontal. In such cases, the vibration should be evaluated in accordance with the support classification which corresponds to the measurement direction.

If the class of a machine-support system cannot be readily determined from drawings and calculation, it may be determined by test.

## 5 Evaluation

ISO 10816-1 provides a general description of the two evaluation criteria 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.

### 5.1 Criterion I: Vibration magnitude

This criterion is concerned with defining limits for vibration magnitude consistent with acceptable dynamic loads on the bearings and acceptable vibration transmission into the environment through the support structure and foundation. The maximum vibration magnitude observed at each bearing or pedestal is assessed against the evaluation zones for the support class. The evaluation zones have been established from international experience.

#### 5.1.1 Evaluation zones

The following evaluation zones are defined to permit a qualitative assessment of the vibration of 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.

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 for the machine manufacturer to explain the reasons for this and, in particular, to confirm that the machine would not be endangered by operating with higher vibration values.

#### 5.1.2 Evaluation zone limits

The values for the zone boundaries which are given in tables A.1, A.2, A.3 and A.4 are based on the maximum broad-band values of velocity and displacement when measurements are taken from two orthogonally oriented radial transducers. Therefore when using these tables, the higher of each of the values measured from the two transducers in each measurement plane should be used. When the maximum measured values of velocity and displacement are compared to the corresponding values in table A.1, A.2, A.3 or A.4, the severity zone which is most restrictive shall apply.

#### 5.1.3 Axial vibration

It is not common practice to measure axial vibration on main radial load-carrying bearings during continuous operational monitoring. Such measurements are primarily used during periodic vibration surveys or for diagnostic purposes. Certain faults are more easily detected in the axial direction. Specific axial vibration criteria are at the moment only given in the case of thrust bearings where axial vibration correlates with axial pulsations which could cause damage to the axial load-carrying surfaces. The criteria of tables A.1, A.2, A.3 and A.4 apply to radial vibration on all bearings and to axial vibration on thrust bearings.

#### 5.1.4 Pump vibration

The evaluation criteria in tables A.3 and A.4 apply for operation at the rated flow rate of the pump. Higher vibration values may occur at other than rated flow conditions due to increased hydraulic forces in partial flow. These values may be permissible for short-term operation, but could cause damage or accelerated wear over sustained periods. ALARM and TRIP values may be adjusted accordingly based upon experience.

It should be noted that there are some pumps for special applications which have specific features in their construction which permit values of vibration higher than those given in tables A.3 and A.4 to be tolerated without problem (see notes 2 and 4 to the tables in annex A).

For installation of pumps, it is important that special care be taken to avoid resonances in the connected piping system and foundation with the normal excitation frequencies (e.g. one- or two-times the running frequency or blade-passing frequency) as such resonances can cause excessive vibration.

## 5.2 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 change 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 incipient damage 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. Steady-state operating conditions should be interpreted to include small changes in the machine power or operational 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. Obvious changes in the normal vibration magnitudes, regardless of their total amount, should be investigated so that a dangerous situation may be avoided. When an increase or decrease in vibration magnitude exceeds 25 % of the upper value of zone B, as defined in table A.1, A.2, A.3 or A.4, such changes should be considered significant, particularly if they are sudden. Diagnostic investigations should then be initiated to ascertain the reason for the change and to determine what further actions are appropriate.

NOTE The 25 % value is provided as a guideline for a significant change in vibration magnitude, but other values may be used based on experience with a specific machine, e.g. a larger deviation may be permitted for some pumps.

## 5.3 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.

### 5.3.1 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 for 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.

It is recommended that the ALARM value should not normally exceed 1,25 times the upper limit of zone B.

If the steady-state baseline changes (for example after a machine overhaul), the ALARM setting should be revised accordingly.

### 5.3.2 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 clear guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D, but it is recommended that the TRIP value should not exceed 1,25 times the upper limit of zone C.

## 5.4 Supplementary procedures/criteria

The measurement and evaluation of machine vibration given in this part of ISO 10816 may be supplemented by shaft vibration measurements and the applicable criteria given in ISO 7919-3. It is important to recognize that there is no simple way to relate bearing housing vibration to shaft vibration, or vice versa. The difference between the shaft absolute and shaft relative measurements is related to the bearing housing vibration but may not be numerically equal to it because of phase angle differences. Thus, when the criteria of this part of ISO 10816 and those of ISO 7919-3 are both applied in the assessment of machine vibration, independent shaft and bearing housing (or pedestal) vibration measurements shall be made. If application of the different criteria leads to different assessments of vibration severity, the more restrictive zone classification is considered to apply.

## 5.5 Evaluation based on vibration vector information

The evaluation considered in this part of ISO 10816 is limited to broad-band vibration without reference to frequency components or phase. This will, in most cases, be adequate for acceptance testing and for operational monitoring purposes. However, for long-term condition monitoring purposes and for diagnostics, the use of vibration vector information is particulary useful for detecting and defining changes in the dynamic state of the machine. In some cases, these changes would go undetected when using only broad-band vibration measurements (see, for example, ISO 10816-1).

Phase- and frequency-related vibration information is being used increasingly for monitoring and diagnostic purposes. The specification of criteria for this, however, is beyond the present scope of this part of ISO 10816.

# Annex A
(normative)

# Evaluation zone boundaries

It has been found that vibration velocity is sufficient to characterize the zone boundary values of vibration over a wide range of machine types and machine operating speeds. The main evaluation quantity is therefore the overall r.m.s. value of vibration velocity.

NOTE In many cases, it was customary to measure vibration with instruments scaled to read peak rather than r.m.s. vibration values.

If the vibration wave form is basically a single sinusoid, a simple relationship exists between peak and r.m.s. values and the zone boundaries in the tables may be readily expressed in zero-to-peak values by multiplying by $\sqrt{2}$ or in peak-to-peak values by multiplying by $2\sqrt{2}$. Alternatively, the measured zero-to-peak vibration values may be divided by $\sqrt{2}$ and judged against the r.m.s. criteria of tables A.1, A.2, A.3 or A.4.

For many machines, it is common for the vibration to be predominantly at the running frequency of the machine and in the case of pumps sometimes at blade passing frequency. For such cases and when peak rather than r.m.s. values of vibration are being measured, tables equivalent to tables A.1, A.2, A.3 and A.4 can be constructed. The zone boundaries of the given tables are multiplied by a factor of $\sqrt{2}$ to produce such equivalent tables for assessing peak vibration severity if only one frequency is present.

It is recognized that the use of a single value of vibration 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 a significant vibration energy concentrated in a high-frequency range, can lead to unacceptably high acceleration values. Ideally, acceptance criteria should be provided in terms of displacement, velocity and acceleration, depending on the speed range and type of machine. At present, however, vibration zone boundary values are given only in terms of velocity and displacement. They are presented in the general form of tables A.1, A.2, A.3 and A.4 for the four machine groups covered by this part of ISO 10816.

The limits apply to the broad-band r.m.s. values of vibration velocity and displacement in the frequency range from 10 Hz to 1 000 Hz, or for machines with speeds below 600 r/min from 2 Hz to 1 000 Hz. In most cases, it is sufficient to measure only vibration velocity. If the vibration spectrum is expected to contain low-frequency components the evaluation should be based on broad-band measurements of both velocity and displacement.

Machines of all four groups can be installed on rigid or flexible supports. For both, different evaluation zone values are provided in tables A.1, A.2, A.3 and A.4. Guidelines for the support classification are given in clause 4.

**Table A.1 — Classification of vibration severity zones for machines of Group 1: Large machines with rated power above 300 kW (402 HP) and not more than 50 MW; electrical machines with shaft height $H \geq 315$ mm (12")**

| Support class | Zone boundary | R.m.s. displacement | R.m.s. velocity | | |
|---|---|---|---|---|---|
| | | µm | in/sec | mm/s | 0-peak in/s |
| Rigid | A/B | 29 | 0.090 | 2,3 | 0.127 |
| | B/C | 57 | 0.177 | 4,5 | 0.250 |
| | C/D | 90 | 0.280 | 7,1 | 0.396 |
| Flexible | A/B | 45 | 0.138 | 3,5 | 0.195 |
| | B/C | 90 | 0.280 | 7,1 | 0.396 |
| | C/D | 140 | 0.433 | 11,0 | 0.612 |

1 kw = 1.341 hp

**Table A.2 — Classification of vibration severity zones for machines of Group 2: Medium-size machines with rated power above 15 kW (20 HP) up to and including 300 kW; (402 HP) electrical machines with shaft height 160 mm ≤ $H$ < 315 mm (6.3" – 12")**

| Support class | Zone boundary | R.m.s. displacement µm | mils | 0-P mils | R.m.s. velocity mm/s | in/s | 0-peak in/sec |
|---|---|---|---|---|---|---|---|
| Rigid | A/B | 22 | 0.86 | 1.22 | 1,4 | 0.055 | 0.078 |
| | B/C | 45 | 1.77 | 2.5 | 2,8 | 0.11 | 0.156 |
| | C/D | 71 | 2.8 | 4.0 | 4,5 | 0.18 | 0.25 |
| Flexible | A/B | 37 | 1.46 | 2.06 | 2,3 | 0.09 | 0.127 |
| | B/C | 71 | 2.8 | 4.0 | 4,5 | 0.18 | 0.255 |
| | C/D | 113 | 4.45 | 6.29 | 7,1 | 0.28 | 0.396 |

**Table A.3 — Classification of vibration severity zones for machines of Group 3: Pumps with multivane impeller and with separate driver (centrifugal, mixed flow or axial flow) with rated power above 15 kW (20 HP)**

| Support class | Zone boundary | R.m.s. displacement µm | R.m.s. velocity mm/s | in/s | 0-Peak in/s |
|---|---|---|---|---|---|
| Rigid | A/B | 18 | 2,3 | 0.09 | 0.127 |
| | B/C | 36 | 4,5 | 0.18 | 0.254 |
| | C/D | 56 | 7,1 | 0.28 | 0.400 |
| Flexible | A/B | 28 | 3,5 | 0.14 | 0.200 |
| | B/C | 56 | 7,1 | 0.28 | 0.400 |
| | C/D | 90 | 11,0 | 0.43 | 0.608 |

**Table A.4 — Classification of vibration severity zones for machines of Group 4: Pumps with multivane impeller and with integrated driver (centrifugal, mixed flow or axial flow) with rated power above 15 kW**

| Support class | Zone boundary | R.m.s. displacement µm | R.m.s. velocity mm/s | in/seg | 0-Peak in seg |
|---|---|---|---|---|---|
| Rigid | A/B | 11 | 1,4 | 0.055 | 0.0778 |
| | B/C | 22 | 2,8 | 0.11 | 0.1555 |
| | C/D | 36 | 4,5 | 0.18 | 0.260 |
| Flexible | A/B | 18 | 2,3 | 0.09 | 0.130 |
| | B/C | 36 | 4,5 | 0.18 | 0.260 |
| | C/D | 56 | 7,1 | 0.28 | 0.405 |

NOTES to tables A.1 to A.4

1 These values apply to radial vibration measurements on all bearings, bearing pedestals, or housings of machines and to axial vibration measurements on thrust bearings under steady-state operating conditions at rated speed or within the specified speed range. They do not apply when the machine is undergoing a transient condition (i.e. changing speed or load).

2 Different and/or higher values may be permissible for specific machines or special support and operating conditions. All such cases should be subject to agreement between the manufacturer and customer.

3 At present it is not common practice to monitor the acceleration value of these machines. Information on acceleration values will be welcomed and should be communicated to the national standards body in the country of origin for transmission to the secretariat of ISO/TC 108/SC 2.

4 For pumps with special impeller for non-clogging or similar operation, higher magnitudes normally can be expected (e. g. up to 3 mm/s for single-vane impeller).

(mm/s) 25.4 = in/s    1 kw = 1.341 HP

(0-Peak) Vel = (RMS) Vel $\sqrt{2}$    $\sqrt{2} = 1.414$

µm x 0.0393701 = mils (0.001 in)