MACHINE VIBRATION STANDARDS: OK, GOOD, BETTER & BEST

Part 3 – Absolute, Machine Specific Standards

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Different Types Of Vibration Standards

1) ABSOLUTE, GENERAL (OK)

2) ABSOLUTE, MACHINE SPECIFIC (GOOD)

3) COMPARATIVE (BETTER)

4) HISTORICAL (BEST)

Absolute, Machine Specific Vibration Standards

These machine-specific standards improve in relevance versus general standards for most real problems as they are adjusted to best fit the unique design and operation of specific types of machinery. They are typically based on real historical data from equipment fitting the description involved. Some examples are as follows:

1) Technical Associates Standards
2) Sohre-Erskine R/C Standards (shaft vibration, fluid film bearings)
3) ISO 7919 (shaft vibration, fluid film bearings)
4) OEM Specifications

PROS:

a) Can be applied to plant equipment from the beginning of a condition monitoring program. No prior machine history is necessary to make a basic assessment of a machine's condition.
b) b) Takes into account the basic differences between different types of machinery & base types (ie: pump versus fan, rigid versus isolated base, etc).

CONS:

Your plant's machinery, process, loading, speed, mounting, etc is no doubt unique in some ways that can make your final vibration levels end up on the high or low side of these standards without anything being wrong with the equipment or in some cases with a whole lot wrong with the equipment.

Technical Associates Machine Specific Standards[12]

- These standards account for both the machine type & base type of rotating equipment.
- In the opinion of the author, these standards represent an excellent starting point for overall vibration alarm levels on machinery.
- In addition to these overall standards, recommendations for the levels of common parameters such as 1x rpm, 2x rpm, vanepass frequencies, bearing frequencies, etc are made.

TABLE II
TECHNICAL ASSOCIATES OF CHARLOTTE, P.C.

CRITERIA FOR OVERALL CONDITION RATING (PEAK OVERALL VELOCITY, IN/SEC)*

1. Assuming Machine Speed = 600 to 60,000 RPM.
2. Assuming Measurements by Accelerometer or Velocity Pickup securely mounted as Close as Possible to Bearing Housing.
3. Assuming Machine Is Not Mounted on Vibration Isolators (for Isolated Machinery - Set Alarm 30% to 50% Higher).
4. Set Motor Alarms the Same as that for the Particular Machine Type unless Otherwise Noted.
5. Consider Setting Alarms on Individual External Gearbox Position about 25% Higher than that for a particular Machine Type.

MACHINE TYPE	GOOD	FAIR	(WARNING) ALARM 1	(FAULT) ALARM 2
COOLING TOWER DRIVES				
Long, Hollow Drive Shaft	0 - .375	.375 - .600	.600	.900
Close Coupled Belt Drive	0 - .275	.275 - .425	.425	.650
Close Coupled Direct Drive	0 - .200	.200 - .300	.300	.450
COMPRESSORS				
Reciprocating	0 - .325	.325 - .500	.500	.750
Rotary Screw	0 - .300	.300 - .450	.450	.550
Centrifugal With or W/O External Gearbox	0 - .200	.200 - .300	.300	.450
Centrifugal - Integral Gear (Axial Meas.)	0 - .200	.200 - .300	.300	.450
Centrifugal - Integral Gear (Radial Meas.)	0 - .150	.150 - .250	.250	.375
BLOWERS (FANS)				
Lobe-Type Rotary	0 - .300	.300 - .450	.450	.675
Belt-Driven Blowers	0 - .275	.275 - .425	.425	.650
General Direct Drive Fans (with Coupling)	0 - .250	.250 - .375	.375	.550
Primary Air Fans	0 - .250	.250 - .375	.375	.550
Vacuum Blowers	0 - .200	.200 - .300	.300	.450
Large Forced Draft Fans	0 - .200	.200 - .300	.300	.450
Large Induced Draft Fans	0 - .175	.175 - .275	.275	.400
Shaft-Mounted Integral Fan (Extended Motor Shaft)	0 - .175	.175 - .275	.275	.400
Vane-Axial Fans	0 - .150	.150 - .250	.250	.375
MOTOR/GENERATOR SETS				
Belt-Driven	0 - .275	.275 - .425	.425	.675
Direct Coupled	0 - .200	.200 - .300	.300	.450
CHILLERS				
Reciprocating	0 - .250	.250 - .400	.400	.600
Centrifugal (Open-Air) - Motor & Compressor Separate	0 - .200	.200 - .300	.300	.450
Centrifugal (Hermetic) - Motor & Impellers Inside	0 - .150	.150 - .225	.225	.350
LARGE TURBINE/GENERATORS				
3600 RPM Turbine/Generators	0 - .175	.175 - .275	.275	.400
1800 RPM Turbine/Generators	0 - .150	.150 - .225	.225	.350
CENTRIFUGAL PUMPS				
Vertical Pumps (12' - 20' Height) } Height from Grade to Top Motor Bearing. May be Necessary to Spec. Lower Alarm for Lower Motor Bearing & for Upper Pump Bearing (depending on height)	0 - .325	.325 - .500	.500	.750
Vertical Pumps (8' - 12' Height)	0 - .275	.275 - .425	.425	.650
Vertical Pumps (5' - 8' Height)	0 - .225	.225 - .350	.350	.525
Vertical Pumps (0' - 5' Height)	0 - .200	.200 - .300	.300	.450
General Purpose Horizontal Pump - Direct Coupled	0 - .200	.200 - .300	.300	.450
Boiler Feed Pumps - Horizontal Orientation	0 - .200	.200 - .300	.300	.450
Piston Type Hydraulic Pumps - Horizontal Orientation (under load)	0 - .150	.150 - .250	.250	.375
MACHINE TOOLS				
Motor	0 - .100	.100 - .175	.175	.250
Gearbox Input	0 - .150	.150 - .225	.225	.350
Gearbox Output	0 - .090	.090 - .150	.150	.225
Spindles:				
a. Roughing Operations	0 - .065	.065 - .100	.100	.150
b. Machine Finishing	0 - .040	.040 - .060	.060	.090
c. Critical Finishing	0 - .025	.025 - .040	.040	.060

*NOTE: The "ALARM 1" and "ALARM 2" overall levels given above apply only to in-service machinery which has been operating for some time after initial installation and/or overhaul. They do not apply (and are not meant to serve as) Acceptance Criteria for either new or rebuilt machinery.

 R-200002-PK

FIGURE 24
CRITERIA FOR OVERALL CONDITION RATING
(PEAK OVERALL VELOCITY, IN/SEC)

Sohre-Erskine R/C Method[13]

Machine Condition	Allowable R/C	
	3,600 rpm	10,000 rpm
Normal	0.3	0.2
Surveillance	0.3 – 0.5	0.2 – 0.4
Shut down at next convenient time	0.5	0.4
Shut down immediately	0.7	0.6

R = Shaft Vibration (pk-pk)

C = Diametral Bearing Clearance

R/C Method (fluid-film bearings) Erskine & Sohre have suggested the use of relative shaft vibration (R) and bearing clearance (C) for the evaluation of the condition of machines with fluid film bearings. The state of the bearing is judged by the ratio R/C and rotor speed. This provides a basis that is directly applicable to the specific machine in question. Erskine divided his results into two speed categories — turbine generators (3,600 RPM) and centrifugal compressors (10,000 RPM). These could also be applied to other machines such as motors & pumps with similar speeds. The work of Erskine was refined by Eshleman and Jackson.

ISO 7919: Shaft Vibration[13 & 16]

- Chart at right is from ISO 7919 and relates relative shaft vibration severity to shaft speed.
- All vibration is relative to bearing (ie: from proximity probes).
- Shaft vibration is expressed in displacement, micrometers pk-pk
- 100 micrometers ~ 4 thous of an inch.

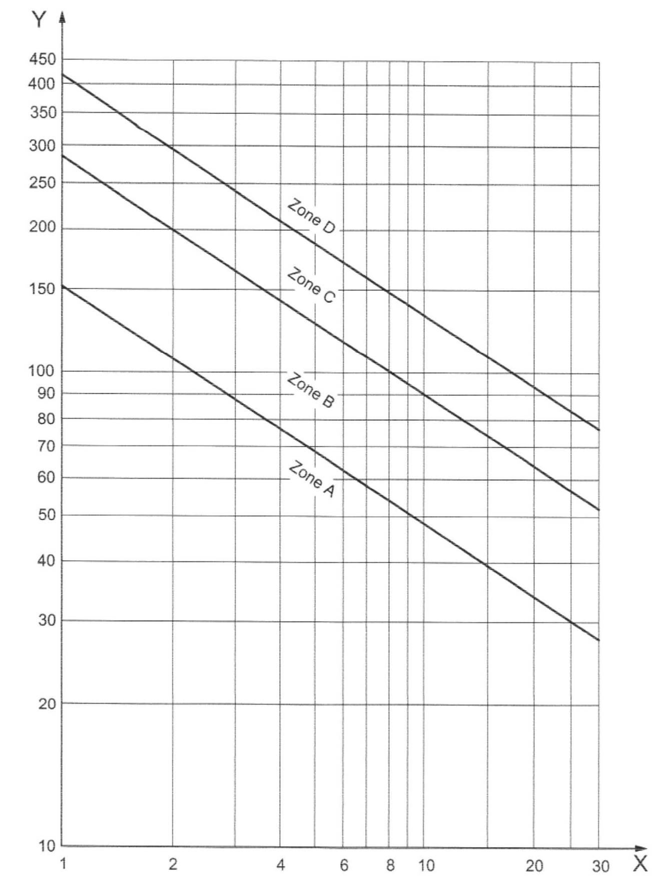
Zone Descriptions :

Zone A – Newly commissioned machinery.

Zone B – Acceptable for unrestricted, long-term operation.

Zone C – Unsatisfactory for long-term operation.

Zone D – Damage likely occurring to machine.



Key

Y peak-to-peak shaft vibration displacement, relative to bearing (μm)

X maximum operating speed of the shaft × 1 000 (r/min)

Figure A.1 — Recommended values for maximum relative displacement of the shaft as a function of the maximum service speed for coupled industrial machines

A complete copy of this vibration standard is available from the ANSI website at the following: **http://webstore.ansi.org/**

ISO 7919: Shaft Vibration[16] (cont):

Below are the formulas from ISO 7919 that define the vibration Zone boundary limits as a function of machine operating speed (rpm).

Zone A/B boundary limit (micrometers, pk-pk)	$S_{(pk-pk)} = 4{,}800/\sqrt{rpm}$
Zone B/C boundary limit (micrometers, pk-pk)	$S_{(pk-pk)} = 9{,}000/\sqrt{rpm}$
Zone C/D boundary limit (micrometers, pk-pk)	$S_{(pk-pk)} = 13{,}200/\sqrt{rpm}$

100 micrometers ~ 4 thousandths of an inch

A complete copy of this vibration standard is available from the ANSI website at the following: **http://webstore.ansi.org/**

ISO 7919: Shaft Vibration[15] (cont):

Three different approaches to defining the vibration level (S_{max}) used in the chart are suggested by the ISO as follows:

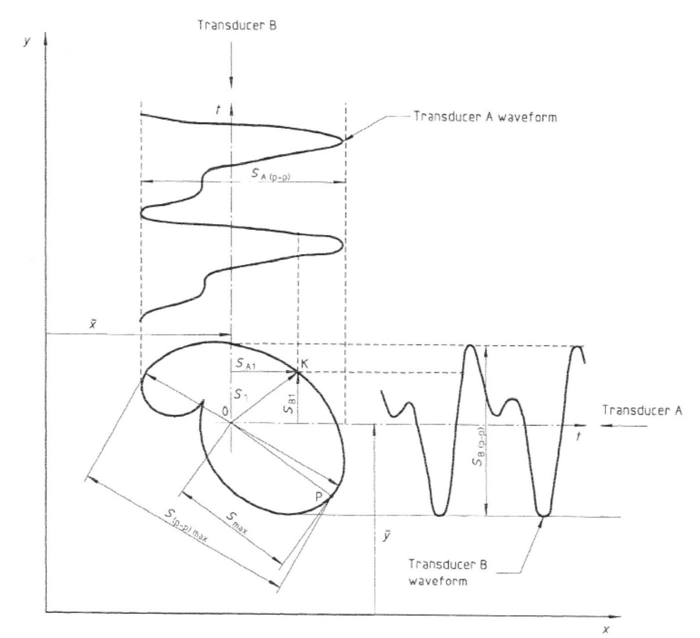
1) The maximum of the two orthogonal measurements (X & Y).

$$S_{max} = S_X \text{ or } S_Y$$

2) The result of the following calculation:

$$S_{max} = \sqrt{S_X{}^2 + S_Y{}^2}$$

3) Measuring the real maximum displacement (S_{max}) directly from the orbit as shown at right.



x, y	Fixed reference axes
0	Time-integrated mean position of orbit
$\bar{x}$, $\bar{y}$	Time-integrated mean values of shaft displacement
K	Instantaneous position of shaft centre
P	Position of shaft for maximum displacement from time-integrated mean position
S_1	Instantaneous value of shaft displacement
S_{max}	Maximum value of shaft displacement from time-integrated mean position 0
S_{A1}, S_{B1}	Instantaneous values of shaft displacement in directions of transducers A and B, respectively
$S_{(p-p)max}$	Maximum value of peak-to-peak displacement
$S_{A(p-p)}$, $S_{B(p-p)}$	Peak-to-peak values of shaft displacement in directions of transducers A and B, respectively

Figure B.2 — Kinetic orbit of shaft — Definition of displacement

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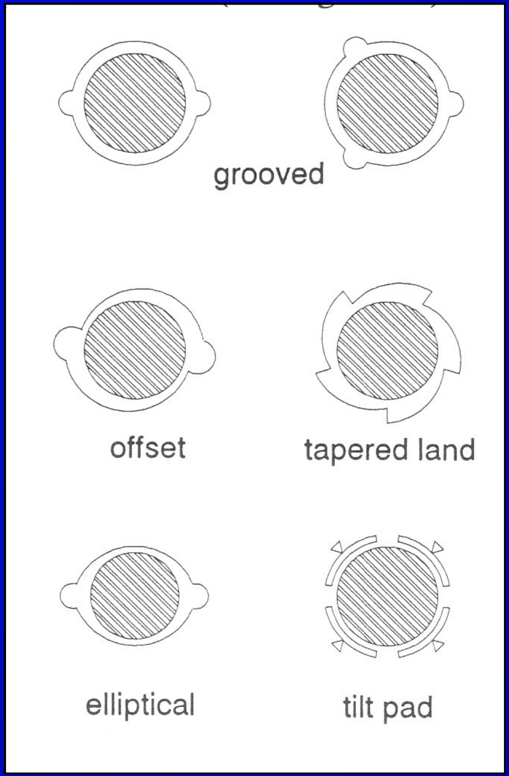
ISO 7919: Shaft Vibration (cont):

- Before applying these shaft vibration standards, please take into account both the available bearing clearance & the type of fluid film bearing used (use common sense).
- For example, if the standard says 100 micrometers vibration is ok and you only have 120 micrometers bearing clearance to work with, you may want to shift the boundary zones as needed (ie: B becomes C or C becomes D, etc).
- Be aware of not only how much vibration is occurring, but where it is occurring relative to the bearing geometry (shaft position + orbit).
- Examples of fluid-film bearing profiles are shown at right[17]:



Examples Of Fluid-Film Bearing Designs[17]

Example Of OEM Standards: Lufkin Industries[14]

- The OEM's of most rotating equipment today have their own vibration standards used to aid both customers and technical personnel in determining machine condition.
- Most of the time OEM's have unique knowledge of their equipment and can be of great assistance in both determining machine condition as well as aid in solving problems – why not ask their opinion.

Table 2
Lufkin Industries, Inc.
Gear Housing Velocity Levels

Peak Velocity Level, Inch per Second (ips)[2]		
High Speed Gear Units (e.g., per API 613 Specification)	Gear Units for Low Speed Drive, Extruders, Bandbury, Mixers, Reciprocating Machinery, Etc.	Vibration Classification Performance and Recommended Action[3]
Less than 0.1	Less than 0.2	Smooth; no correction necessary
0.1 to 0.2	0.2 to 0.3	Acceptable; correction not necessary (wastes money)
0.2 to 0.3	0.3 to 0.4	Marginal; action taken or not depending on circumstances
0.3 to 0.5	0.4 to 0.g	Rough; planned shutdown for repairs
Greater than 0.5	Greater than 0.6	Extremely rough; immediate shutdown necessary

NOTES:

1, The data in this table apply to gear units only; they are not applicable to other types of machinery.

2. The peak velocity levels listed represent housing velocity vibration levels as measured on the bearing caps of the gear unit.

3. Vibration classifications and recommended courses of action listed in relation to peak housing velocity levels are intended as general guidelines for evaluation only. There are no absolutes in vibration severity analysis. All environmental factors, such as the peculiarities of adjacent equipment and the gear unit foundation, in addition to the basic characteristics of the gear unit itself, must be taken into account whenever attempting to evaluate vibration severity

Additional example of OEM general standards, The Falk Corporation

We can offer the following suggestions for the baseline measurement that will act as a starting point in a trending program. These levels are estimates for a 'typical' industrial gear drive on a 'typical'' solid foundation where all vibration is measured on a rigid structural component of the gearbox and expressed in velocity units of inches/second-Peak.

Vibration Level IPS-P	Gearbox Health Assessment	Required Action
Less than 0.2	Normal operational levels	None
0.2 to 0.3	Slightly elevated, long term life may be compromised	Investigate source, watch for upward trends
0.3 to 0.5	Elevated, some components are trending to a failure condition	Correct cause at future maintenance outage
Above 0.5	High, some components are at or near a 'failure' point	Correct causes very soon

Based on the above discussion I suggest the following levels for 'typical' industrial equipment:

- Alarm --- 0.35 IPS-P
- Shut down --- 0.5 IPS-P

We recommend using velocity as the vibration measurement unit for most equipment since it can be a single limit value over the frequency range of most gearbox mechanical defects.

REFERENCES, PART 3:

12) Berry, Jim, Analysis 1 Manual – How To Implement An Effective Condition Monitoring Program Using Vibration Analysis, 2nd Edition, Chapter 7, Proven Method For Specifying Spectral Alarm Band Levels & Frequencies Using Today's Predictive Maintenance Software Systems, Technical Associates Of Charlotte, PC, 1997

13) Eshleman, Ron, "Shaft Vibration Standards & Specifications", Mini-Course Notes, 2009 Vibration Institute Symposium

14) Eshelman, Ron, Machinery Vibration Analysis 2, Gears & Gearboxes, p.326, VI Press, IL, 1996

15) ISO 7919 Mechanical Vibration Part 1: General guidelines

16) ISO 7919 Mechanical Vibration – Evaluation of machine vibration by measurements on rotating shafts Part 3: Coupled industrial machines

17) Crawford, Art & Steve, The Simplified Handbook Of Vibration Analysis, Volume 1, CSI, Knoxville, TN, 1992