



Engineering Report

SAER-5659

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Guidelines for Setting Acceptable,
Alarm and Shutdown Vibration Limits

Document Responsibility: Consulting Services Department

Saudi Aramco Desktop Standards

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This document is a general guideline to establish acceptable, alarm and shutdown vibration limits; and shall not be used as acceptance criteria for equipment factory tests or commissioning.

The purpose of this document is to lay down guidelines for acceptable, alarm, and shutdown vibration limits for rotating equipment and allowable piping and valve vibration levels throughout Saudi Aramco. This will ensure that similar equipment throughout the Company will be set to the same alarm and shutdown limits. However, for special cases or unusual equipment, Consulting Services Department/Dynamic Analysis Unit will assist in selecting the acceptance, alarm, and shutdown limits which may vary significantly from the values shown in this document, depending on equipment design, operating experience and/or vendors recommendations.

1 Definitions

The definitions of "Acceptable", "Alarm" and "Shutdown" limits are as follows:

1.1 *Acceptable Level*

This is the vibration level (displacement, velocity, or acceleration) at which a machine can run indefinitely without inducing vibration related maintenance at normal operating condition.

1.2 *Alarm Level*

This is the vibration level at which an equipment is considered to have developed a defect that will result in related downtime. This level is usually higher than the acceptable level to allow for conservatism and machinery variance and is recommended as 1.5 times the acceptable level.

1.3 *Shutdown Level*

This is the vibration level at which an equipment should be shutdown as continued running could lead to accelerated degradation and possible catastrophic failure. This is recommended as 2.0 times the acceptable level.

1.4 *Allowable Vibration Levels*

This is the vibration level (displacement or velocity) at which a piping/valve may operate below the fatigue threshold limit.

2 Recommended Acceptable Vibration Levels

2.1 Shaft Journal Vibration Displacement

The acceptable level for shaft relative displacement (non-contacting) sensors is calculated as follows:

Acceptable Level is equal to $\sqrt{12000 / RPM}$ mils (pk – pk).

e.g., for a 3,600 RPM machine, the acceptable level will be:

$$\sqrt{12000 / RPM} = 1.83 \text{ mils (pk – pk)}.$$

Only 0.25 mils pk-pk may be added to this level to compensate for shaft runout which should be within the limits specified in Section 4. This may also be added to alarm and shutdown levels if applicable.

2.2 Bearing Housing Seismic Vibration (Coupled)

A. *Motors, Generators, Compressors, and Steam Turbines*

The acceptable overall vibration level should be 0.18 in/s RMS.

B. *Vertical Motors*

The acceptable overall vibration level should be as detailed in Appendix A or:

1.0 g's RMS on any bearing housing in any direction.

C. *Pumps*

The acceptable overall vibration level should be 0.22 in/s RMS for horizontal double casing (barrel) pumps and 0.25 in/s RMS for all other pumps.

Vane pass related frequency vibration should not exceed 0.15 in/s RMS.

D. *Fin Fans*

The acceptable vibration level should be 1.0 g's RMS, 0.18 in/s RMS on the bearing housing, and 10.0 mils pk-pk on the supporting structure.

E. *Gear Units*

The acceptable vibration level should be 7.0 g's RMS and 0.20 in/s RMS measured on any bearing housing in any direction.

F. *Reciprocating Machines*

For reciprocating pumps and compressors and for diesel engines, the acceptable vibration level, measured on the crankcase, adjacent to the main crankshaft bearings and on a plane perpendicular to the crank axis, should not exceed 0.5 in/s RMS.

G. *Combustion Gas Turbines*

The acceptable vibration level should be:

0.30 in/s RMS for industrial types

0.35 in/s RMS for aero-derivatives

3 Recommended Workshop Acceptable Vibration Levels

A. *Horizontal Electric Motors*

Where shaft relative displacement (non-contacting) sensors are installed, the acceptable displacement is:

$$\sqrt{7200 / \text{RPM}} \text{ mils (pk - pk)}$$

The overall acceptable vibration levels measured on any bearing housing in any direction should not exceed 0.13 in/s RMS.

B. *Vertical Electric Motors*

The overall acceptable vibration level measured at the top bearing should be less than the 75% of the levels detailed in Appendix A.

C. *Steam Turbines*

Where shaft relative displacement (non-contacting) sensors are installed, the overall acceptable level at maximum rated speed is:

$$\sqrt{7200 / \text{RPM}} \text{ mils (pk - pk)}$$

The acceptable overall vibration level measured on any bearing housing in any direction should be 0.13 in/s RMS.

D. *Combustion Gas Turbines*

The overall acceptable casing vibration should be 0.25 in/s RMS.

4 **Runout (Total)**

All equipment with installed shaft relative (non-contacting) vibration sensors should meet the following criteria for shaft total combined electrical and mechanical runout:

- 0.35 mils for rated shaft speeds up to 1,800 RPM
- 0.25 mils for rated shaft speeds exceeding 1,800 RPM.

5 **Axial Rotor Displacement Settings**

Equipment manufacturer limits shall be considered for axial rotor displacement settings for all bearing types.

However, if these limits are not available, then in the case of tilting-pad thrust bearings having babbit thickness between 25 to 40 mils, the following limits may be applied:

When zero thrust position is the center of the float of the machine, then axial setting is:

½ cold float	plus 10.0 mils for normal setting
	plus 5.0 mils on normal for alarm
	plus 5.0 mils on alarm for shutdown

These limits are graphically shown on Appendix B.

The active (normal) thrust direction is the direction of the rotor axial thrust load expected by the machinery vendor during normal operating conditions. The active (normal) thrust is the plus side of the monitor.

When specifying thrust position monitors, the location of each of the dual sensors must be considered before applying dual voting logic to the system. If both probes are observing the shaft end or an integral thrust collar, then dual voting logic is acceptable and will result in a system of maximum reliability. However, if either sensor observes a removable thrust collar, then voting logic results in a system that fails to protect the machinery under all malfunction conditions, i.e., if the thrust collar comes loose and allows the shaft to move axially. Therefore, if sensors observe different surfaces and, if one of the surfaces is a removable thrust collar, the system must be configured to shutdown from only the sensor observing the shaft end (or other surface that cannot move under the influence of thrust loading). With existing dual voting thrust position monitors, internal options are

available to employ either dual voting logic or single probe shutdown logic with a choice of either sensor as the shutdown transducer.

6 Allowable Piping Vibration Levels

The maximum overall allowable vibration levels for piping with reinforced and without reinforced branch piping are:

- 1.0 in/s RMS with reinforced branch piping
- 0.75 in/s RMS without reinforced branch piping

Provided that the overall displacement does not exceed 100.00 mils pk-pk and specific frequencies do not exceed the marginal level as indicated in Appendix C.

7 Valve Vibration Levels

The acceptable vibration on a valve body should not exceed 0.5 in/s RMS measured in any direction.

8 Shaft Relative Displacement (Non-Contacting) Sensor Orientation

Shaft relative displacement sensors should be identified as X/Y, not horizontal and vertical and should be oriented as shown in Appendix D when viewed from driver end.

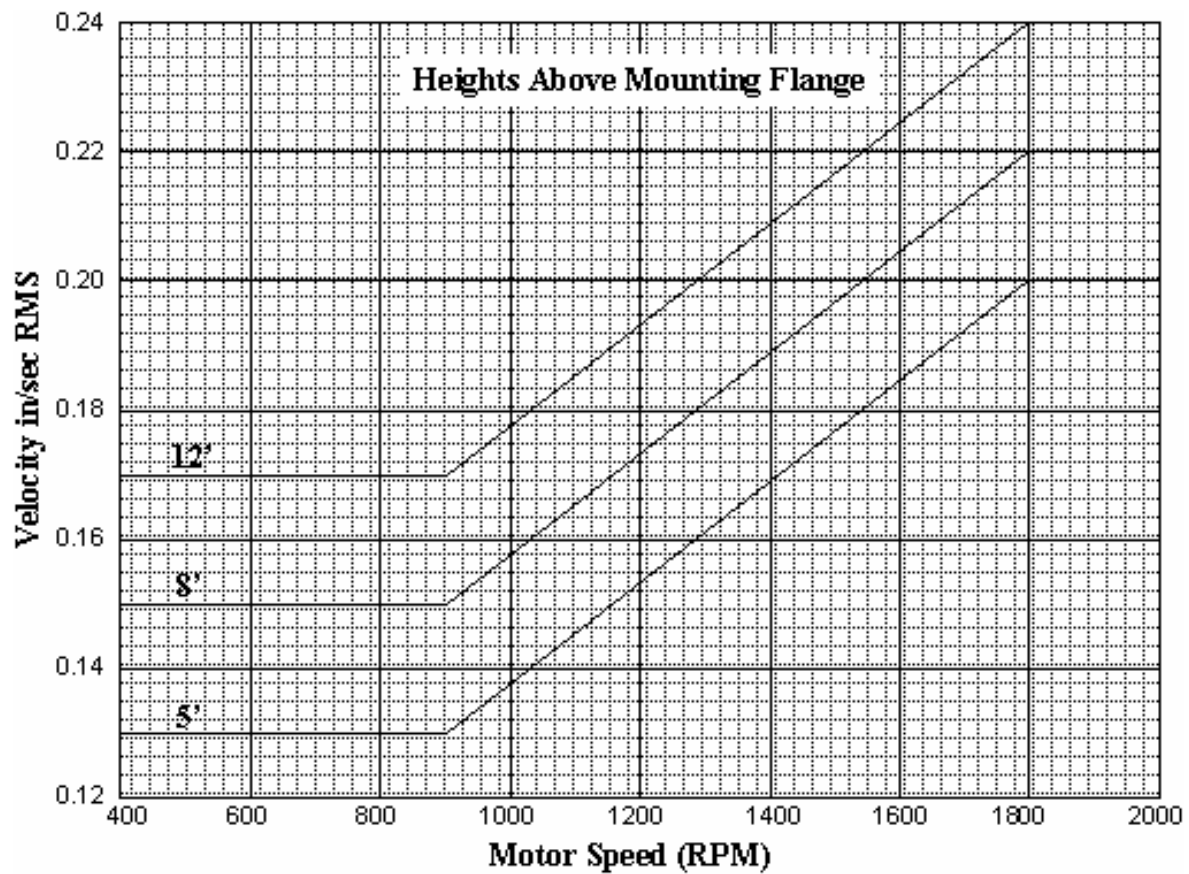
9 Alignment Tolerances

Alignment tolerance figures are presented in Appendix E. These figures are intended as a general guide rather than a standard, since actual cases will vary significantly depending on the coupling type, application and even the time of the day. Although this graph in Appendix E presents an acceptable region, the aim should always be for zero.

Revision Summary

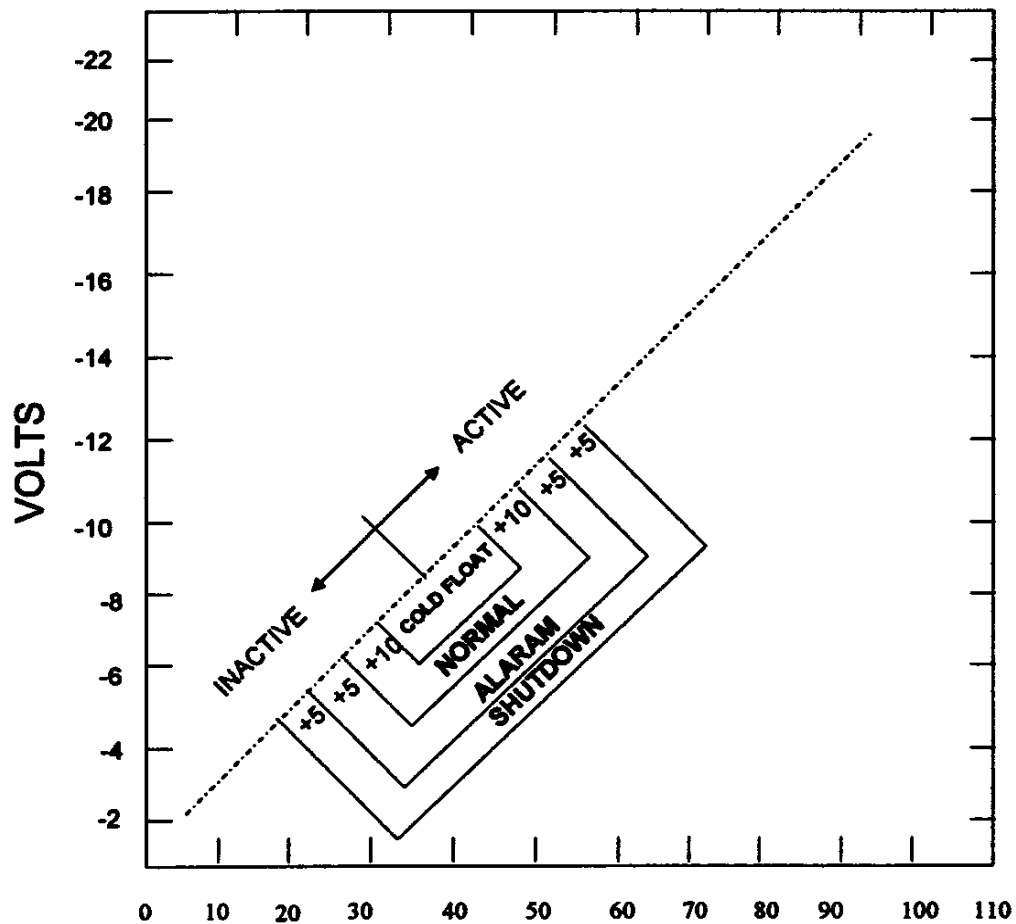
26 February 2003	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with minor changes.
30 June 2004	Minor revision.

Appendix A – Vertical Motor Vibration Limits

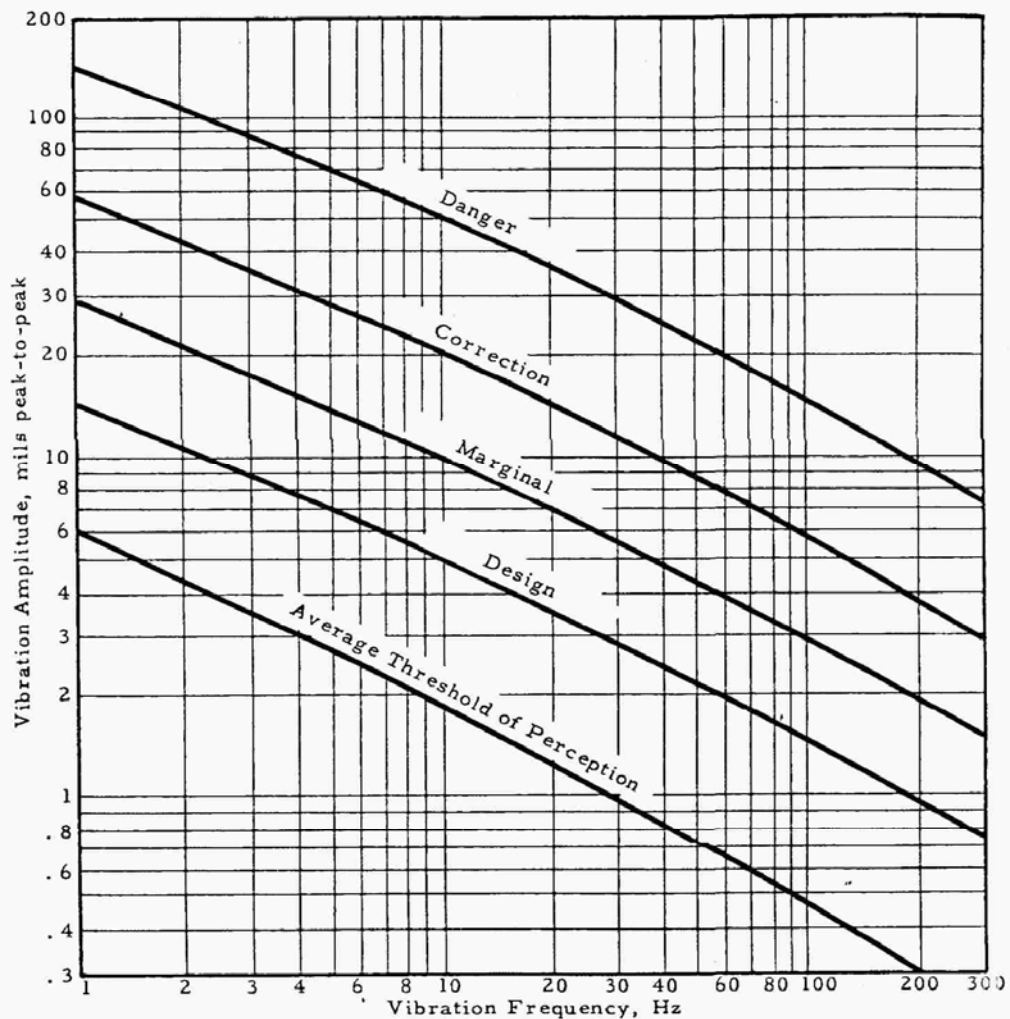


Appendix B – Thrust Position Settings

Referenced to 200 mV/mil



Appendix C – Allowable Piping Vibration Levels

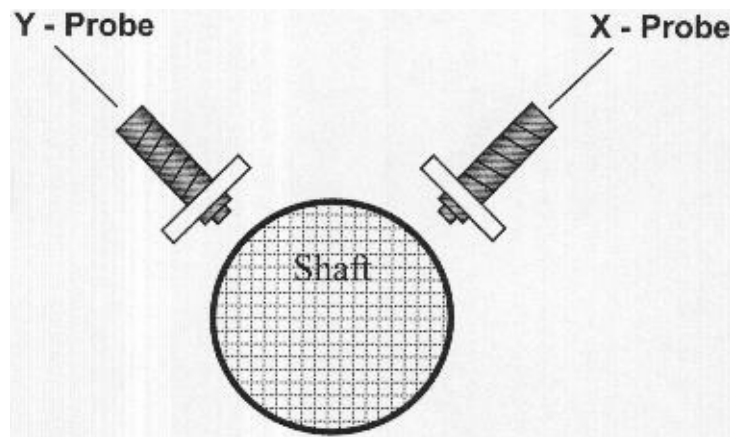


Allowable Piping Vibration Levels¹

¹ EDI Report 85-305, Vibration in Reciprocating Machinery and Piping System, San Antonio, October 1985.

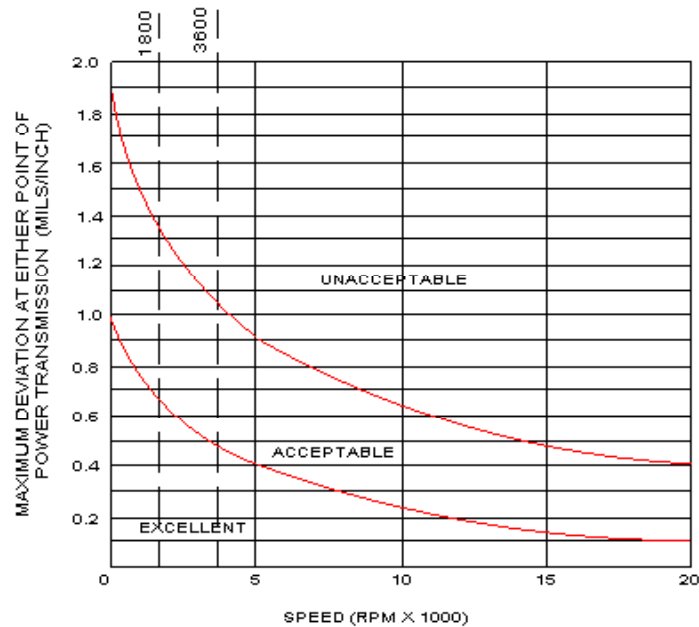
Appendix D – Noncontact Probe Orientation

Orientation of Proximity Probes Viewed Along Train from Driver-NDE
Regardless of Direction of Rotation



Note: The preferred proximity probe orientation is as shown above. However, if this cannot be achieved, the probes may be oriented at any position around the shaft, provided that the included angle between the probes is always 90 ° and that the "X" probe is always positioned in a clockwise direction, relative to the "Y" probe.

Appendix E – Alignment Tolerances



Hot Alignment Tolerances T.I.R.²

² Pitorowski, J. "Shaft Alignment Handbook", Marcel Dekker Inc., New York. 2nd Ed., 1995.