CONSTRUCTION STANDARD SPECIFICATION

SECTION 15200

VIBRATION LIMITS AND CONTROL

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PART 1 - GENERAL

1.01 SUMMARY

Section includes types of vibration isolators required for different systems, and establishes maximum acceptable limits for vibration of machines with five horsepower or greater, in terms of:

A. Balance level in displacement (mils) as filtered measurement at rotating speed.

B. Overall velocity (in/sec) in 10 - 1,000 Hz band.

C. Bearing quality or condition by measuring overall acceleration in 0 - 5,000 Hz band, which indicates severity of metal-to-metal contact by detecting shock pulses. This measurement is normalized to speed.

1.02 REFERENCES

American National Standards Institute (ANSI)

S2.2-1959 (R1990) Methods for the Calibration of Shock and vibration Pickups

1.03 SUBMITTALS

A. General: Submit the following items in accordance with the Conditions of Contract and Section 01330, "Submittal Procedures."

B. Vibration Report: Submit in accordance with specified requirements of Part 3.

1.04 QUALITY ASSURANCE

Contractor is required to demonstrate to Sandia that equipment complies with requirements of this specification. Measurements can be taken elsewhere, and documents submitted as evidence of passage; but final acceptance judgement shall be made from measurements taken on site in equipment's final, installed location and operating configuration. Equipment shall not be accepted until fully compliant with specified requirements.

PART 2 - PRODUCTS

2.01 VIBRATION ISOLATORS

Spring and Resilient Pad Hangars: Stable steel spring and neoprene isolator placed in series, and encased in welded steel bracket, with allowance for rod misalignment up to 15 degrees without short-circuiting. Provide Mason Industries, Inc., Model PC30N, or approved equal.

2.02 VIBRATION MEASUREMENT DEVICE

A. General

1. Capable of filtered displacement readings at rotational speed.

   a. Provide separate speed-measuring device, such as strobe light, photo tachometer, or mechanical tachometer, to measure rotating speed of belt-driven or variable-speed machines.

   b. Displacement Readings: Mils (0.001 inch), peak-to-peak.

   c. Filter Bandwidth: Sufficiently narrow to achieve accuracy of ± 10 percent from absolute value.

2. Velocity Measurement: Overall in 10 to 1,000 Hz bandwidth, readings in inches per second, peak.

3. Acceleration Measurement: Overall in 0 to 5,000 Hz bandwidth, readings in *g*, peak.

   a. Capability to record and plot waveform with 100-microsecond resolution (5,000-Hz frequency span and 500 lines with Fast Fourier Transform (FFT) analyzer).

   b. Record and plot waveform for acceleration level failures to aid analysis.

4. FFT analyzer with accelerometer can meet the above requirements.

B. Calibration of Complete Instrumentation System: Includes transducer, signal conditioning, cable, and readout instrument. Calibrate in accordance with one of the methods in ANSI S2.2.

1. Comparison calibration is acceptable.

2. Calibration of transducer alone is unacceptable; final reading is dependent on settings in readout instrument (like windows, filters, averaging method, calibration constants, and frequency span).

C. Frequency Response: Linear (within ± 10 percent) in 1 to 5,000 Hz range.

Internally generated noise or external signals that are not vibration, shall be less than 1 percent of upper limit under test (signal-to-noise ratio shall be 100 to 1). Noise is defined as any signal level displayed that is not vibration.

D. Recording and Plotting Capability: Capable of recording frequency spectrum and time plot, and plotting on paper.

1. Both plots unfiltered below 5,000 Hz.

2. Spectrum Frequency Resolution: No coarser than 1/200 of full span frequency (200-line spectrum analyzer or finer is suitable).

3. Digital integration of accelerometer signal to velocity or displacement is acceptable.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Piping Systems: Connect refrigerant piping to compressors with refrigerant-rated, flexible metallic sections, oriented parallel to crankshaft.

1. Use flexible connections parallel to crankshaft to connect building air piping to air compressors.

2. When piping vibration hangars are specified, provide spring hanger isolators as described in Part 2.

B. Ductwork: Attach to fans with weatherproof, flame-retardant flexible connections.

When duct vibration hangars are specified, provide spring hanger isolators described in Part 2.

3.02 VIBRATION TESTING

A. Perform vibration testing after equipment alignment and balance.

B. Obtain vibration measurements after Test and Balance is complete. The machines shall be at their normal operating conditions (such as normal speed, normal loading, and producing flow or energy) for which the system was designed.

C. Determine and record equipment operating speeds with tachometer or strobe. Indicate both driving and driven speeds.

D. Check isolation system for proper operation, if applicable:

1. Visually inspect equipment installation. Verify that isolators supporting piece of equipment have approximately the same deflection.

2. Apply unbalanced load and verify that system moves freely.

3. Determine actual isolator deflection and compare to specified value.

E. Vibration Measurements: Obtain at each bearing, or as close to bearing on structure as practical. For machines housed in rigid casing, such as electric motors or vaneaxial fans, obtain measurements at each end of machine.

1. Obtain three orthogonal measurements at each bearing, typically in horizontal, vertical, and axial directions. For unusual configurations, three orthogonal measurements in other orientations are allowed.

2. Hand-held probing is allowed. Magnetic mounting of transducers is preferred. Adjust magnet on rough surfaces so that it is stable and does not rock.

F. Safety: Exercise extreme caution when obtaining vibration measurements on operating machinery.

1. Measurement points may be deleted if it poses unnecessary risk, in the opinion of person taking measurements.

2. Judgement of equipment's vibration acceptability will be made from pattern of remaining measurements by the Sandia Delegated Representative (SDR).

3. If necessary, machine may be stopped to attach transducers and secure cables, and this stop-start pattern repeated for each measurement point.

4. Obtain SDR's approval prior to deleting measurement points, and stopping and starting equipment.

G. Operate variable-speed machines throughout their entire range, at each measurement point, and observe for resonance. Measure and record vibration at minimum of three operating speeds. Vibration levels must be acceptable at all three test speeds.

1. Maximum speed.

2. Speed which produces highest reading at each measuring point.

3. Expected normal operating speed.

H. It is acceptable to take measurements over a period of time and statistically average the readings. It is recognized that vibration is mostly steady state, but it is also dynamic, changes with time, and external transients can influence readings.

Digital and analog readings can be averaged visually. Summation averaging with FFT analyzer is acceptable. Time period of observation, or averaging, shall be minimum of 10 seconds.

3.03 VIBRATION LIMITS

A. Maximum allowable measurements for various pieces of equipment are shown below:

TABLE 1
Vibration Limits

Equipment	**Balance Condition Displacement** (mils, P-P at 1X rpm)	**Overall Velocity** (in/sec, Peak 10 - 1,000 Hz)	**Overall Acceleration** (g, Peak 0 - 5,000 Hz)
Electric Motors:			
1,000 - 2,000 rpm	2.0	0.2	0.5
> 2,000 rpm	1.0	0.2	1.0
VSD Driven Motors:			
1,000 - 2,000 rpm	2.0	0.2	0.5*
> 2,000 rpm	1.0	0.2	1.0*
Generators	2.0	0.2	0.5
Centrifugal Fans			
< 600 rpm	4.0	0.3	0.5
600-1,000 rpm	3.0	0.3	1.0
1,000-2,000 rpm	2.0	0.3	1.5
> 2,000 rpm	1.0	0.3	2.0
Vaneaxial Fans	1.0	0.2	0.5
Blowers	1.0	0.3	0.5
Pumps			
1800 rpm	2.0	0.2	0.5
3600 rpm	1.0	0.2	1.0
Centrifugal Compressors	1.0	0.2	3.0
Cooling Tower Gearboxes	3.0	0.4	2.0
Reciprocating Engines Gas or Diesel	5.0	1.0	10.0
Turbines	1.0	0.2	0.5
Gearboxes	1.0	0.4	2.0
Twin Screw Compressors	1.0	1.0	15.0

* High reading is acceptable if due to electronic noise as determined by adjusting vibration analyzer to view time waveform. Equipment is non-compliant if high reading is due to bearing shock pulse.

B. Displacement measurements at operating speeds shall not exceed values in Table 1, or reduced values if equipment is mounted on inertia block. Values in Table 1, multiplied by displacement ratio will give maximum allowable peak-to-peak displacements for equipment on inertia blocks.

Displacement Ratio = ((MB/M) + 1) where:

M = Supported equipment and fluid weight

MB = Inertia base weight

C. Machines driven by reciprocating engines, such as pumps or generators, shall only be required to pass higher limits of reciprocating engines.

. Non-Compliance: Equipment that does not comply with specified vibration tolerances shall be corrected at manufacturer's expense. Retest equipment and submit measurement results report in accordance with requirements of following article.

3.04 VIBRATIONS MEASUREMENT REPORT

A. Submit written report that includes the following:

1. Description of instruments used, their last calibration date, and calibration method.

2. Actual vibration measurements and rotating speed at each point in tabular form. Table 2 is a sample report.

3. State whether each machine passes or fails based upon vibration limits listed in Table 1. Analysis of defective condition and recommendations for corrective action are optional.

4. See Table 2 for sample report.

B. Vibration Spectrum Plots: Include with written report minimum of plots for each machine (in velocity units); one plot for driver machine and another for driven machine.

For machines that pass, choice of which point to plot is at discretion of analyst. Plots are intended to serve as evidence of passing, and as baseline data for future analysis.

TABLE 2
Sample Vibration Report

Equipment	**Location**	**Balance Displacement** (mil, P-P)	**Overall Velocity** (in/sec Peak 10-10,000 Hz)	**Overall Acceleration** (*g*, Peak 0 - 5,000 Hz)	**Pass or Fail**
MAU-1 Opposite Drive End Bearing 1,200 rpm	Horizontal Vertical Axial	1.2 0.9 0.4	0.09 0.12 0.08	0.8 0.7 0.8	Pass
Drive End Bearing 1,200 rpm	Horizontal Vertical Axial	1.1 0.8 0.6	0.13 0.15 0.10	0.9 1.0 0.9	
Motor Drive End 1,770 rpm	Horizontal Vertical Axial	0.9 0.7 0.5	0.10 0.12 0.09	0.2 0.3 0.1	Pass
Opposite Drive End 1,770 rpm	Horizontal Vertical Axial	1.0 0.8 0.2	0.09 0.11 0.09	0.2 0.15 0.11	

3.05 RESONANCE

A. Resonating components on machines or other supplied equipment, such as pipes, panels, or ducts, are equipment flaws. Contractor shall bear full burden of stiffening components or other corrective action, until vibration measurements at bearings pass balance limits listed in Table 1.

B. If equipment vibration testing failures are related to foundation or building resonance, Contractor shall demonstrate this basis to SDR. SDR shall do one of the following:

1. Accept the vibration.

2. Require additional corrective work on Contractor's part to compensate, such as better balancing or alignment, or softer springs.

3. Move the machine.

4. Stiffen the structure.

END OF SECTION