SPECIAL SPECIFICATIONS

SECTION 15070S

VIBRATION LIMITS AND CONTROL

PART 1 - GENERAL

1.01 SECTION INCLUDES

A. Vibration isolators for rotary, dynamic, or reciprocating equipment or components; and establishes maximum acceptable limits for vibration of machines with one (1) horsepower or greater. Include

1. Inertia bases.

2. Vibration isolation.

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

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

D. 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

A. ASHRAE - Guide to Average Noise Criteria Curves.
American National Standards Institute (ANSI)
S2.2-1959 (R1990) Methods for the Calibration of Shock and vibration Pickups

1.03 SUBMITTALS

A. Indicate isolation base dimensions.

B. Indicate vibration isolator locations, with static and dynamic load.

C. Include calculations required to certify compliance with specified requirements.

D. Submit manufacturer's certificate that isolators are properly installed and properly adjusted to meet or exceed specified requirements.

E. Comply with 01300.

F. Submit the following items in accordance with the Conditions of Contract and Division 1, Section "Descriptive Submittals."

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

1.04 QUALITY ASSURANCE

A. Maintain ASHRAE criteria for average noise criteria curves for all equipment at full load condition.

B. Provide vibration isolation devices, including auxiliary steel bases and pouring forms, from a single manufacturer or supplier who will be responsible for complete coordination of all phases of this work.

C. 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 MANUFACTURERS

A. Amber-Booth Company.

B. Korfund Dynamics Corporation.

C. Mason Industries.

2.02 ISOLATION BASES

A. Type A: Integral structural steel fan and motor base with motor slide rails.

B. Type B: Slung structural steel base with gussetted brackets.

C. Type C: Reinforced 3,000 pounds per square inch concrete base set in full depth perimeter structural steel channel frame, with gussetted brackets and anchor bolts.

D. Type D: Reinforced 3,000 pounds per square inch concrete base with chamfered edges without channel frame.

2.03 VIBRATION ISOLATORS

A. Type 1: Closed spring mount with top and bottom housing separated with neoprene rubber stabilizers. 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.

B. Type 2: Open spring mount with stiff springs (horizontal stiffness equal to vertical stiffness).

C. Type 3: Open spring mount with stiff springs, heavy mounting frame, and limit stop.

D. Type 4: Closed spring hanger with acoustic washer. 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

E. Type 5: Closed spring hanger with 1 inch thick acoustic isolator. 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

F. Type 6: Rubber waffle pads, 30 durometer, minimum 1/2-inch thick, maximum loading 40 pounds per square inch. Use neoprene in oily or exterior locations.

G. Type 7: 1/2-inch thick rubber waffle pads bonded each side of 1/4-inch thick steel plate.

H. Type 8: Type BRD-1 rubber-in-shear isolators. Size isolator for 0.35-inch deflection.

2.04 DEFLECTION

A. Piping Isolation: Provide spring isolators on piping connected to isolated equipment as follows: up to 4-inch diameter, first three points of support; five to 8-inch diameter, first four points of support; 10-inch diameter and over, first six points of support. Static deflection of first point to be twice the deflection of isolated equipment.

When hanging from a structure with a vibration specification, use stiffer members such as beams and not thinner floor sections between beams.

1. Use a minimum 1-inch deflection Type 1 spring hangers to support pipe diameters greater than 4" or racks having greater than 4" of accumulative equivalent diameters, from sensitive waffle floors.
2. Vacuum, compressed air, gas, gravity drain, fire protection piping, and steam lines are exempt from vibration isolation requirements. Piping less than 1 inch in diameter is exempt.
3. Isolate pipes greater than 4" diameter mounted to racks supported by columns with fiberglass or neoprene isolators. Pads should have a natural frequency less than 12 Hz or a static deflection of more than 0.1". Alternate is a 1-inch thick fiberglass or neoprene pipe insulation with 10% compression.
4. Vibration-isolated equipment within the column lines defining the floor area with vibration specifications.
    a. For pipe diameters greater than 1½ inches, provide resilient hangers of same type and deflection as equipment support isolator for first three supports. For equipment supported on Type 6 or Type 7 isolators, provide Type 8 hangers; for equipment supported on spring-type isolators, provide Type 1 hangers with deflection equal to equipment support isolator.
    b. If pipe diameter is less that 1½ inches, provide vibration isolation flexible pipe connection.
5. Provide flexible pipe connections to isolated piping connected to rigidly supported piping.

B. Sheet Metal Ducting

1. Steel framing between columns supports metal ductwork within the Micro Fab building having a vibration specification of 250 u"/sec. The isolation between these ducts and steel frame can consist of:
    a. Type 6, rubber waffle pad having a minimum static deflection of 0.1" or a natural frequency less than 12 Hz.
    b. Insulation having a thickness and density necessary to limit compression to 10%.
2. When hanging from structures above with floor vibration specifications.
    a. Use 1-inch static deflection Type 1 hangers if equivalent duct diameter greater than 24 Inches. Use flexible connectors to attach isolated metal work with rigidly supported metal work.

3. Schedule: Process Duct Isolation Requirements – MicroFab

Exhaust System	***Isolator Deflection -Inches***	***Application***	***Reference Dwg***
Ammonia	*4*	*50 feet North and 20 feet South of Column 9.*	*MJ1050585EF, Seq 104 and MJ1001858EF, Seq 091*
Acid	*4*	*50 feet North and 20 feet South of Column 9.*	*MJ1050585EF, Seq 104 and MJ1001858EF, Seq 091*
General	*4*	*50 feet North and 20 feet South of Column 9. Duct on roof South of Column 9.*	*MJ1050585EF, Seq 104 and MJ1001858EF, Seq 091*
Solvent	*4*	*50 feet North and 20 feet South of Column 9.*	*MJ1050585EF, Seq 104 and MJ1001858EF, Seq 091*

Notes: 1. Vibration isolators shall be installed in both vertical and horizontal duct runs North of Column 9.

2. Vibration isolators shall be installed in the first 20 lineal feet of duct runs in the basement South of Column 9.

3. Provide all supplemental steel required for installation of vibration isolators.

4. Provide all calculations from manufacturer for design and selection of vibration isolators and support steel. Manufacturer shall have a licensed professional engineer stamp on all calculations.

C. VAV boxes: Provide a minimum of four hangers.

1. Provide Type 1, spring isolators for each box with a motor larger than ½ horsepower attached to floor with vibration specification.

2. Provide Type 8, rubber in shear isolators for boxes with ½ horsepower and smaller motors.

3. Use flexible connection between box and inlet and discharge sides.

4. Isolate ductwork to each box inlet under a vibration sensitive floor with the same type isolator as box if equivalent duct diameter greater than 24".

5. Attach equipment without motors such as cooling coils, filter boxes, etc. to vibration isolated sheet metal work with flexible connectors.

D. Electrical Equipment

1. Support transformers greater than 200 kVA on a Type 9, ribbed or waffle type neoprene pad with a minimum thickness of 2" and a natural frequency of 12 Hz or less.
2. Use flexible conduit at service connections and provide a minimum 90 degree turn and flexible connection.

2.05 FABRICATION

A. Provide pairs of neoprene side snubbers or restraining springs where side torque or thrust may develop.

B. Color code spring mounts.

C. Select springs to operate at two-thirds maximum compression strain, with 1/4-inch ribbed neoprene pads.

2.05 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. Install vibration isolators for motor driven equipment.

B. Set steel bases for 1-inch clearance between housekeeping pad and base. Set concrete inertia bases for 2-inch clearance. Adjust equipment level.

C. Provide spring isolators on piping connected to isolated equipment as follows: up to 4-inch diameter, first three points of support; five to 8-inch diameter, first four points of support; 10-inch diameter and over, first six points of support. Static deflection of first point to be twice deflection of isolated equipment. Pipe, ducts and equipment supported from waffle slabs shall have spring isolators isolating them from the waffle slab.

D. Provide minimum of four hangers for each fan coil unit and VAV box. Provide isolators for each hanger.

E. 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.

F. 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 SCHEDULE

Isolated Equipment	Base Type	Isolator Type
Class III	A & C	1
Air Compressors & Water Chillers	C & D	1
Engine Driven Generators & Pumps	C & D	1 or 3
Centrifugal Chillers		
Slab on Grade	D	6
Other than Slab on Grade	C	1
Pumps		
3 horsepower & Smaller	B	6 or 7
5 horsepower & Over	C	2
Piping		4
Ductwork		4
VAV Boxes		8
Fan Coil Units		8
Process Vacuum	C	3
House Clean Vacuum	C	3
*Internal isolated units do not require external spring isolator. Mount directly to housekeeping pad.		

3.03 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: Use manufacturers specification if more stringent.

TABLE 1
Vibration Limits

	MicroFab	*MicroLab, WIF Under vibration rated floor*	*MicroLab, WIF, CUB-1, 2*
Equipment	*Overall Velocity (in/sec, Peak 10 - 1,000 Hz)*	*Overall Velocity (in/sec, Peak 10 - 1,000 Hz)*	Overall Velocity (in/sec, Peak 10 - 1,000 Hz)
Electric Motors			
1,000 - 2,000 rpm	*0.1*	*0.1*	0.2
> 2,000 rpm	*0.1*	*0.1*	0.2
Generators	*0.1*	*0.1*	0.2
Centrifugal Fans	*0.1*	*0.1*	
< 600 rpm	*0.1*	*0.1*	0.3
600-1,000 rpm	*0.1*	*0.1*	0.3
1,000-2,000 rpm	*0.1*	*0.1*	0.3
> 2,000 rpm	*0.1*	*0.1*	0.3
Vaneaxial Fans	*0.1*	*0.1*	0.2
Blowers	*0.1*	*0.1*	0.3
Pumps	*0.1*	*0.1*	
1800 rpm	*0.1*	*0.1*	0.2
3600 rpm	*0.1*	*0.1*	0.2
Centrifugal Compressors	*0.1*	*0.1*	0.2
Cooling Tower Gearboxes	*0.4*	*0.4*	0.4
Reciprocating Engines Gas or Diesel	*none allowed*	*none allowed*	1.0
Turbines	*0.2*	*0.2*	0.2
Gearboxes	*0.4*	*0.4*	0.4
Twin Screw Compressors	*0.1*	*0.1*	1.0

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.

$$\text{Displacement Ratio} = \frac{1}{((MB/M) + 1)}$$ where:

M = Supported equipment and fluid weight

MB = Inertia base weight

C. Axial vibration measurement shall not exceed maximum radial (vertical or horizontal) vibration at same location.

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

E. 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