CAGI / BL 100-2023

COMPRESSED AIR AND GAS INSTITUTE

Mechanical Vibration – Evaluation of Machine Vibration by Measurements on Non-Rotating Parts – Rotary Positive Displacement and Centrifugal Blowers

Compressed Air and Gas Institute

Sponsor:

Compressed Air & Gas Institute

1300 Sumner Ave
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CAGI / BL 100-2023

COMPRESSED AIR AND GAS STANDARD

Mechanical Vibration – Evaluation of Machine Vibration by Measurements on Non-Rotating Parts – Rotary Positive Displacement and Centrifugal Blowers

Sponsor

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CAUTION NOTICE:

This standard may be revised or withdrawn at any time. CAGI endeavors to review standards on a five-year cycle to determine whether standards should be reaffirmed, revised, or withdrawn.

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Suggestions for improvement of this standard will be welcome. They should be sent to the Compressed Air & Gas Institute.

Foreword

BL 100, *Mechanical Vibration—Evaluation of Machine Vibration by Measurements on Non-Rotating Parts—Rotary Positive Displacement and Centrifugal Blower* has been developed by the Blower Section of the Compressed Air and Gas Institute with the intention of covering general and specific points relative to rotary positive displacement blowers, and single stage or multistage centrifugal blowers not addressed in ISO 20816-1, Mechanical Vibration – Measurement and Evaluation of Machine Vibration – Part 1: General Guidelines in order to provide clarification of vibration criteria and evaluation.

This standard provides practical information on installation, application, and vibration readings of blowers.

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Appendices

COMPRESSED AIR AND GAS INSTITUTE

Mechanical Vibration – Evaluation of Machine Vibration by Measurements on Non-Rotating Parts – Rotary Positive Displacement and Centrifugal Blowers

1. Introduction

It is recognized that manufacturers of rotary positive displacement blowers or single stage (integrally geared or high-speed motor) turbo blowers, or multistage centrifugal blowers recommend the ISO 20816-1, Mechanical Vibration – Measurement and Evaluation of Machine Vibration – Part 1: General Guidelines to provide the general guideline for vibration criteria and evaluation. However, due to nuances inherent to the above referenced products, there are certain aspects regarding machine vibration measurement and evaluation to which manufacturers of the above referenced products either take exception or provide clarification. It is the intent of this standard to cover general and specific points relative to rotary positive displacement blowers and single stage or multistage centrifugal blowers.

2. Scope

This standard defines the basis for specifying the rules to be employed in evaluating the mechanical vibration of machines in the operating range of 600 to 30,000 RPM in such a way that comparison is possible with similar measurements obtained from other like machines.

This vibration standard <u>is not intended for bearing and gear diagnostic</u>.

3. Installation

During blower installation, special care must be taken with piping system and foundation to avoid resonance due to blower natural frequencies (e. g., 1x to 2x blade/lobe passing frequency), as such resonance can cause excessive vibration.

$$F = \frac{N \cdot R}{60}$$

Where:

F = Basic rotational frequency in Hertz

N = number of elements passing the discharge port per shaft rotation
2-Lobe Rotor = 4
3-Lobe Rotor = 6
Centrifugal/Regenerative/turbo = Number of Blades

R = rotational speed of the rotor in RPM

3.1 Multiple installations of blowers in a single location

When more than a single blower package is installed in a particular location, each blower package should have an independent foundation that is isolated from the floor, or each blower package should be installed on vibration isolators.

4. Measurements

This standard defines the basis for the rules to be employed in measuring mechanical vibration of the machinery defined in the scope in such a manner that comparison is possible with similar measurements obtained from equivalent machines.

4.1 Measurement Parameters

4.1.1 Frequency Range

This standard is intended to apply to rotary positive displacement blowers, and multistage centrifugal or single stage blowers operating between 600 RPM (10 Hz) and 30,000 RPM (500 Hz). Vibration monitoring equipment shall measure broadband frequencies between 10 to 1,000 Hz for all blower types. Some types of blower have internal components that will generate higher frequencies than 1000Hz. As an example, a PD blower operating at 1800 RPM and fitted with gears having 60 teeth will generate a gear meshing frequency of 1800Hz. However, this standard sets top of the range frequency at 1000 Hz because of limitations due to instrumentation used in the field. When performing vibration surveys, handheld vibration probe equipped with a magnetic base provide accurate readings only up to 1000 Hz.

4.1.2 Measurement Quantity

As per ISO 20816-1, Paragraph 4.3.1 it can be stated that the preferred measurement quantity for the measurement of vibration of non-rotating parts is RMS velocity.

RMS vibration velocity is expressed in either inches per second or millimeters per second. Velocity measurement is an attractive mode of vibration measurement over a wide speed range suitable for all types of blowers. Vibration velocity is also a form of energy. It has been shown that if one inch per second of vibration velocity is damaging at 10,000 RPM, it is also damaging at 1000 RPM. Average RMS velocity is a simple yet efficient way to evaluate vibration severity without having to perform discrete vibration analysis at every speed. It is therefore possible to set a vibration limit which will be good for a wide range of speed. Vibration acceptance criteria listed in Appendix B and Appendix B1 are expressed in RMS vibration velocity, and both mm/sec and inches/sec. They shall be used to determine acceptable vibration set alarm and shutdown set points.

4.1.3 Vibration Magnitude

In many cases, it is customary to measure vibration velocity with instruments scaled to read peak-to-peak rather than RMS vibration values. These readings are unfiltered values.

If the vibration waveform is sinusoidal and a single harmonic (single frequency), a simple relationship exists between the peak and RMS values. RMS is equal to half of the square root of two times the peak value (RMS = 0.707 x peak).

It is important to note that such simple conversion can only be performed for single harmonic vibration signal (like in a spectrum analysis). In the case of mechanically complex rotating equipment, parts in rotation will generate a multitude of frequencies that will superimpose and form a non-harmonic vibration signal. The relationship between peak vibration velocity and RMS vibration velocity, as explained above, is a rough approximation when dealing with non-harmonic, broadband vibration and the reader should use unfiltered vibration reading with extreme care.

Modern vibration instruments can measure broadband RMS vibration velocity, which is the preferred way of analyzing broadband, non-harmonic signals. Refer to ISO standard 20816-1:2016 (paragraphs 4.3.1 and 6.3.2.1 and Annex A.1) for more details on this topic and justification for using RMS instead of peak units.

4.1.4 Vibration Severity

The severity charts in Appendix B and B1 are not intended to serve as acceptance specifications. Acceptance criteria are subject to agreements between the machine manufacturer and the customer. However, these values provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided. In such cases, there may be specific features associated with an individual machine that would require different zone boundaries (either higher or lower) to be used. When use of a zone boundary that results in a higher degree of vibration than specified in the severity chart and classification, it is the responsibility of the machine manufacturer to explain clearly to the customer the reason for such deviation, and confirm that operation of the machine in question under the deviation is not detrimental to its long-term operation.

The severity chart in Appendix B is based on equipment rigidly mounted, or grouted to its support foundation (as described in Appendix A2). Appendix B1 is based on equipment that is resilient mounted (as described in Appendix A1 and A3).

Measuring Positions

Measurements shall be taken using the type of probe, frequency bands and at the locations shown on the Appendix applicable to the type of machine. Values recorded on the appropriate Vibration Data Recording Sheet in Appendix C shall be compared to the severity chart in Appendix B.

Appendix C1 applies to rotary positive displacement blowers.

Appendix C2 applies to multistage centrifugal blowers.

Appendix C3 applies to single stage centrifugal blowers.

APPENDIX A1

TYPICAL RESILIENT MOUNTED BLOWER PACKAGE ON COMMON CONCRETE SLAB

A good foundation is very important to ensure proper installation and long equipment life. Blower package weight and size generally dictates the type of foundation required. Always follow recommendations from blower manufacturer.

CONCRETE SLAB PREPARATION

Pour a concrete slab over concrete floor to raise blower package by approximately 6” from concrete floor. Concrete slab overall dimensions shall exceed blower base-frame dimensions by approximately 6’’ to 10’’ to facilitate blower installation. Concrete slab surface should be leveled and smooth to avoid distorting blower base-frame. Before setting blower base-frame on concrete slab, the parts in contact with concrete must be free of any oil or grease. If required, insert shims between concrete slab and resilient pads to correct any uneven concrete surface. NEVER INSERT SHIMS BETWEEN BLOWER AND BLOWER BASE PLATE TO CORRECT ANY LEVELING DEFECTS**.**

RESILIENT MOUNTED BLOWER PACKAGE (See Figures A1-1 and A1-2)

1. Install resilient pads under blower base plate.
2. Drill holes in concrete floor and use suitable anchor bolts (Hilti or equivalent) to attach resilient pads to concrete floor

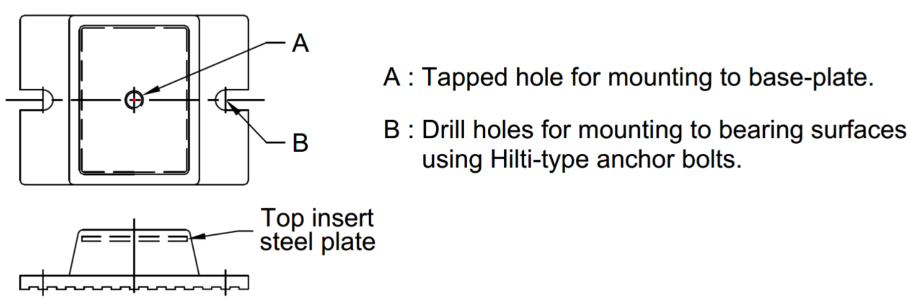
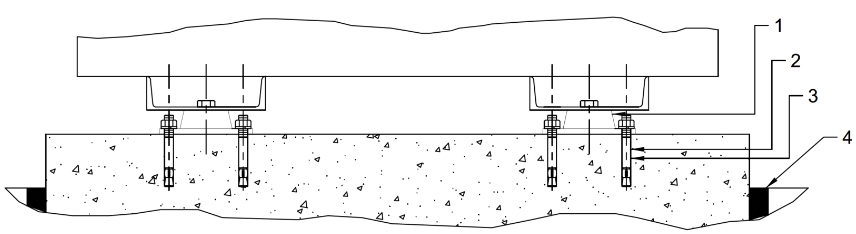


Fig.A1-1 Resilient pad



1. Resilient pad
2. Drill concrete
3. Anchor Bolt
4. Elastomer (optional when using resilient pads)

Fig.A1-1 Installation details

APPENDIX A2

TYPICAL RIGID MOUNTED MACHINE INSTALLATION ON AN ISOLATED CONCRETE FOUNDATION

(More common for machines 500 HP and over, for refinery or other heavy industrial use).

This type of foundation isolates blower package from the rest of the building and reduces vibration transmission to the building and other nearby rotating equipment. However, this type of concrete foundation is more complex and requires thorough civil engineering work. The use of anchor bolts requires a concrete foundation that is isolated from the rest of the building. This will prevent transmitting vibration to the rest of the building. Isolated concrete foundation shall weigh at least 1.5 times more than blower package. An elastomer barrier is used to isolate concrete pad from the rest of the building. Blower base-plate shall be fitted in accordance with the following instructions:

- The surfaces shall be left rough to provide a better adhesion for grouting
- Concrete surfaces are to be levelled transversally and longitudinally following very stringent tolerances to avoid distorting blower package.
- Install blower package using the levelling screws provided and a precision laser levelling tool. Levelling screws should rest on metal plates, not directly on the concrete pad. Leave sufficient gap between blower base-frame and concrete pad to allow for proper grouting. Follow the grout manufacturer's recommendations.
- Clean the surfaces of the pad and prepare it for grouting. Provide an enclosure as shown in Figure A2-1. Pour grout under blower base-frame with the use of bars or chains instead of mechanical vibrators.
- Cure the grout adequately for an appropriate number of days.
- Drill the holes as per the anchor bolt manufacturer's recommendation. Install suitably sized anchor bolts, tighten anchor bolts before loosening leveling screws.
- Size of anchor bolts and leveling screws are indicated on blower general arrangement drawing.

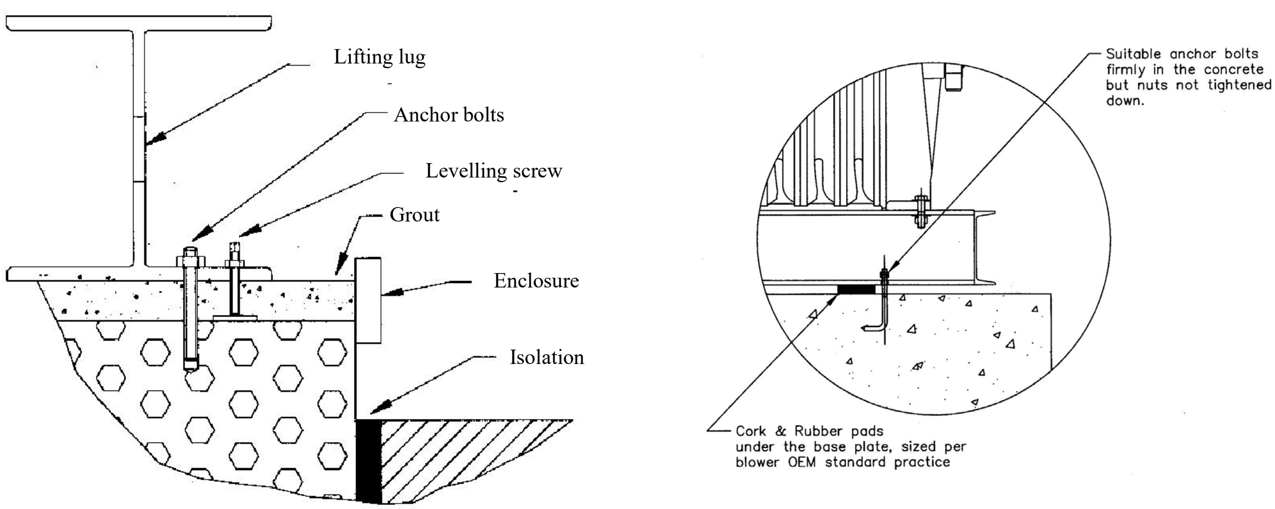


Fig. A2-1- Installation details

APPENDIX A3

TYPICAL RESILIENT MOUNTED BLOWER PACKAGE ON AN ELEVATED STRUCTURE (multi-stage blower represented)

This type of foundation is not common. It is only used where floor space is very limited and blower system is installed in modules. Civil work and detailed design of the foundation shall be conducted by civil engineers. Figures A3-1 and A3-2 below are provided for reference only.

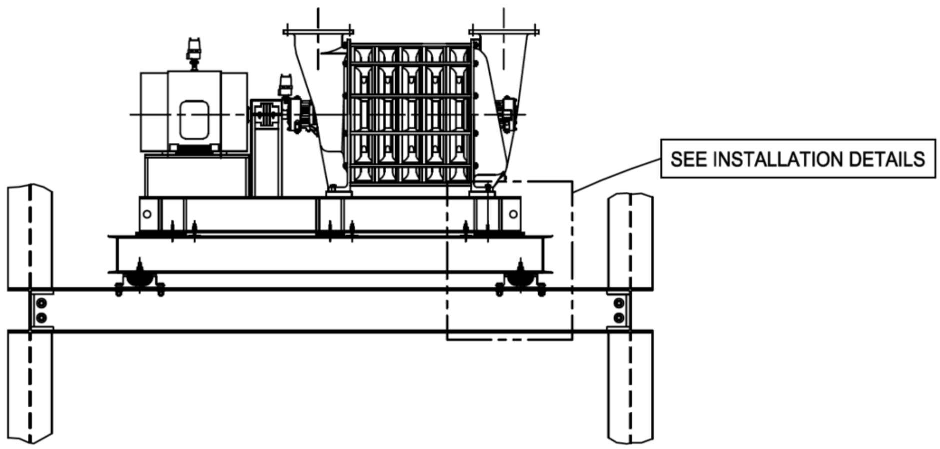


Fig. A3-1 – General arrangement

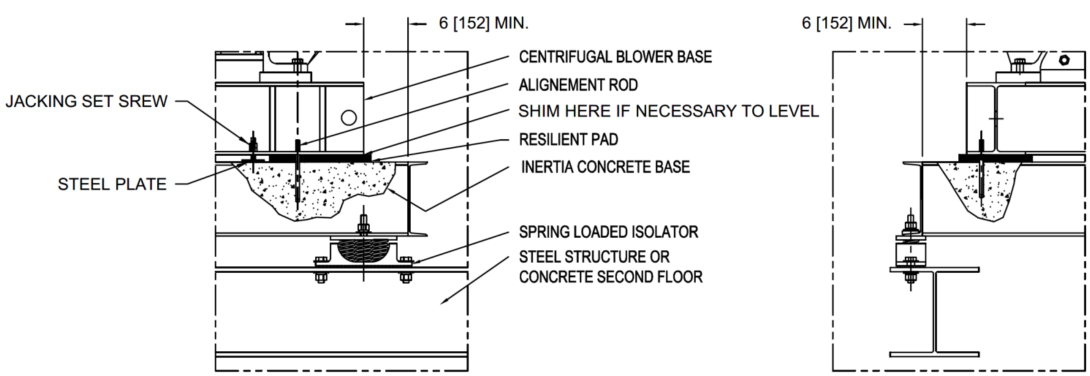


Fig. A3-2 – Installation details

APPENDIX B

Vibration severity ranges and examples of their application

FASTENED TO A LARGE AND RIGID FOUNDATION AS DEFINED IN APPENDIX A.

<table>
<tr><th colspan="2">Range of vibration severity</th><th colspan="2">Examples of quality judgment for separate classes of machines</th></tr>
<tr><th>Range</th><th>Velocity at the range limits in mm/sec (in inch/sec)
RMS</th><th>Single or Multi-stage</th><th>Rotary Positve Displacements</th></tr>
<tr><td>0.28 (0.011)</td><td>0.28 (0.011)</td><td rowspan="7">A & B</td><td rowspan="9">A & B</td></tr>
<tr><td>0.45 (0.017)</td><td>0.45 (0.017)</td></tr>
<tr><td>0.71 (0.028)</td><td>0.71 (0.028)</td></tr>
<tr><td>1.12 (0.044)</td><td>1.12 (0.044)</td></tr>
<tr><td>1.80 (0.071)</td><td>1.80 (0.071)</td></tr>
<tr><td>2.80 (0.110)</td><td>2.80 (0.110)</td></tr>
<tr><td>4.50 (0.177)</td><td>4.50 (0.177)</td></tr>
<tr><td>7.10 (0.280)</td><td>7.10 (0.280)</td><td rowspan="2">C</td></tr>
<tr><td>11.2 (0.441)</td><td>11.2 (0.441)</td></tr>
<tr><td>18.0 (0.709)</td><td>18.0 (0.709)</td><td rowspan="4">D</td><td>C</td></tr>
<tr><td>28.0 (1.102)</td><td>28.0 (1.102)</td><td rowspan="3">D</td></tr>
<tr><td>45.0 (1.772)</td><td>45.0 (1.772)</td></tr>
<tr><td>71.0 (2.795)</td><td>71.0 (2.795)</td></tr>
</table>

A or B: Acceptable
C: Further evaluation may be required. Contact manufacturer.
D: High concern for machine damage. Discontinue operation and contact manufacturer.

Double click in Charts for Clearer View of Appendices B & C.

APPENDIX B1

Vibration severity ranges and examples of their application

RESILIENT MOUNTED EQUIPMENT AS DEFINED IN APPENDIX A1

Range of vibration severity		Examples of quality judgment for separate classes of machines	
Range	Velocity at the range limits in mm/sec **(in inch/sec)** **RMS**	Single or Multi-stage	Rotary Positve Displacement
0.28 **(0.011)**	0.28 **(0.011)**		
0.45 **(0.017)**	0.45 **(0.017)**		
0.71 **(0.028)**	0.71 **(0.028)**		
1.12 **(0.044)**	1.12 **(0.044)**	A & B	
1.80 **(0.071)**	1.80 **(0.071)**		A & B
2.80 **(0.110)**	2.80 **(0.110)**		
4.50 **(0.177)**	4.50 **(0.177)**		
7.10 **(0.280)**	7.10 **(0.280)**		
11.2 **(0.441)**	11.2 **(0.441)**	C	
18.0 **(0.709)**	18.0 **(0.709)**		
28.0 **(1.102)**	28.0 **(1.102)**		C
45.0 **(1.772)**	45.0 **(1.772)**	D	
71.0 **(2.795)**	71.0 **(2.795)**		D

A or B: Acceptable
C: Further evaluation may be required. Contact manufacturer.
D: High concern for machine damage. Discontinue operation and contact manufacturer.

Double click in Charts for Clearer View of Appendices B & C.

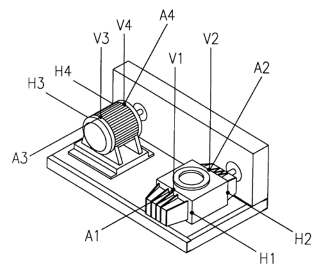
APPENDIX C1

Vibration data recording sheet
Positive Displacement Blower

Vibration readings

Use a magnetic accelerometer type probe.
The frequency bands measured are 10 to 1000 Hz and the results are in RMS .
Measuring points shown are presented on figure below.
The values shall be compared with the table in Appendix B or B1 (B for rigid mount , B1 for resilient mount)

Measuring Points:
A: Axial
H: Horizontal
V: Vertical



Blower Model.:________________ **Blower Serial Number:** ________________
Motor Horsepower: ________________ **Motor Serial Number:** ________________

		Test 1	Test 2	Test 3	Test 4
Time Stamp HR:MIN					
Bower RPM					
Temperature	Inlet				
☐ ºC ☐ ºF	Outlet				
Pressure (absolute)					
☐ Psia ☐ Kpa	Inlet				
☐ In Hg	Outlet				
Barometric pressure					
☐ psia ☐ Kpa					
Relative humidity (%)					
RMS Vibration velocity Unit ☐ mm/sec ☑ in/sec		**RMS Vibration velocity (Measured)**			
A1					
H1					
V1					
A2					
H2					
V2					
A3					
H3					
V3					
A4					
H4					
V4					

Notes:

Instrumentation	**Make**	**Model**	**Serial Number**	**Calibration Date**
Vibration meter				
Temperature meter				
Relative humidity meter				

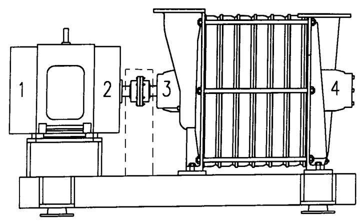
APPENDIX C2

Vibration data recording sheet
Multistage Centrifugal Blower

Vibration readings

Use a magnetic accelerometer type probe.
The frequency bands measured are 10 to 1000 Hz and the results are in RMS .
Measuring points shown are presented on figure below.
The values shall be compared with the table in Appendix B or B1 (B for rigid mount, B1 for resilient mount) .

Measuring Points:
A: Axial
H: Horizontal
V: Vertical



Blower Model.:______________________________ **Blower Serial Number:** ______________________________
Motor Horsepower: ______________________________ **Motor Serial Number:** ______________________________

		Test 1	Test 2	Test 3	Test 4
Time Stamp HR:MIN					
Bower RPM					
Temperature	Inlet				
☐ ºC ☐ ºF	Outlet				
Pressure (absolute)					
☐ Psia ☐ Kpa	Inlet				
☐ In Hg	Outlet				
Barometric pressure					
☐ psia ☐ Kpa					
Relative humidity (%)					
RMS Vibration velocity Unit ☐ mm/sec ☑ in/sec		**RMS Vibration velocity (Measured)**			
A1					
H1					
V1					
A2					
H2					
V2					
A3					
H3					
V3					
A4					
H4					
V4					

Notes:

Instrumentation	**Make**	**Model**	**Serial Number**	**Calibration Date**
Vibration meter				
Temperature meter				
Relative humidity meter				
Pressure meter				

Signature Block		**Report Date**
Service Technician Name Signature		

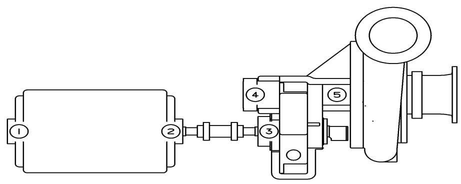
APPENDIX C3

Vibration data recording sheet
Integrally Geared Single Stage Turbo Blower

Vibration readings

Use a magnetic accelerometer type probe
The frequency bands measured are 10 to 1000 Hz and the results are in RMS .
Measuring points shown are presented on figure below.
The values shall be compared with the table in Appendix B or B1 (B for rigid mount, B1 for resilient mount)

Mearuring Points:
A: Axial
H: Horizontal
V: Vertical



Blower Model.:____________________ **Blower Serial Number:** ____________________
Motor Horsepower: ____________________ **Motor Serial Number:** ____________________

		Test 1	Test 2	Test 3	Test 4
Time Stamp HR:MIN					
Bower RPM					
Temperature	Inlet				
☐ ºC ☐ ºF	Outlet				
Pressure (absolute)					
☐ Psia ☐ Kpa	Inlet				
☐ In Hg	Outlet				
Barometric pressure					
☐ psia ☐ Kpa					
Relative humidity (%)					
RMS Vibration velocity Unit ☐ mm/sec ☑ in/sec		**RMS Vibration velocity (Measured)**			
A1					
H1					
V1					
A2					
H2					
V2					
A3					
H3					
V3					
A4					
H4					
V4					
A5					
H5					
V5					

Notes:	

Instrumentation	**Make**	**Model**	**Serial Number**	**Calibration Date**
Vibration meter				
Temperature meter				
Relative humidity meter				
Pressure meter				

Signature Block		**Report Date**
Service Technician Name		
Signature		