CITY OF TULSA

PUBLIC WORKS
Engineering

DATE: February 10, 2026

TO: PAUL ZACHARY, PUBLIC WORKS DEPUTY DIRECTOR

FROM: HAS H. SOMDECERFF, PUBLIC WORKS DESIGN MANAGER

The Specification Review Committee recommends and asks the Public Works Deputy Director to approve the following:

1. New Division 7 - Standard Maintenance Guideline. AM_SMG_705 - Vibration Monitoring of Rotating Equipment, Predictive Maintenance (PdM).

Please call Marqua Jimmerson at (918) 596-7355 If you have any questions.

Thank you,

APPROVED:

Paul Zachary, Deputy Director

02.11.24
Date

Cc: Public Works Engineering Services Specification Review Committee

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705 Vibration Monitoring of Rotating Equipment, Predictive Maintenance (PdM)

705.1 Practical Guidelines for Measurement and Interpretation of Vibration Levels of Rotating and Reciprocating Equipment

705.1.1 Scope

This document provides guidelines for monitoring the condition of selected rotating equipment by measuring the vibration levels at various equipment locations, and analysis of the data as part of the predictive maintenance activities at City of Tulsa facilities. The vibration data are obtained from a vibration meter or a data collector/analyzer that measures the mechanical motion of equipment. Knowledge of vibration amplitudes and trends enables maintenance personnel to determine the extent of equipment wear so corrective action or possible upgrades can be made. The main goal is to prevent failures, and to extend equipment life, leading to long term reliability.

705.1.2 Selection of Rotating Equipment for Vibration Monitoring

This guideline applies to pumps, blowers, fans, mixers, gearboxes, electric motors, etc. that have a motor nameplate rating of 25 HP or greater and have a Consequence of Failure (COF) score of 7, 8, 9, or 10. The Maintenance Supervisor or Plant Engineer to make any exceptions. This guideline can be applied to reciprocating engines. Submersible motor pumps are excluded.

705.1.3 Definitions

1. Vibration Meter – A small, basic instrument that can store a limited amount of vibration data and has limited or no built-in diagnostic capability.
2. Vibration Data Collector/Analyzer – A portable computer that has a large amount of data storage and usually has built-in diagnostic capability. This data is stored in a spectrum of frequencies (speeds). E.G., the VibrAlign FixturLaser Smart Machine Checker (SMC).
3. Vibration Levels – Alarm – Alarm levels can be entered into the vibration instrument and also into the Lucity "TMUA Equipment Inspection Reading or Monitoring View" form. The recommended alarm levels are in Tables 1, 2, 3, and 4.
4. Vibration Levels – Shutdown – Shutdown vibration levels are from ANSI/Hydraulic Institute 9.6.4 "Rotodynamic Pumps for Vibration Measurements and Allowable Values" and are found in Tables 1, 2, 3, and 4. (Engines are not included in these Tables. Engine baseline vibration readings are taken and compared to subsequent readings.)
5. Lucity "TMUA Equipment Inspection Reading or Monitoring View" form – A form for specific equipment that lists the vibration alarm and shutdown levels, and field vibration

amplitudes taken at pre-determined measurement points. Field vibration levels that

exceed vibration alarm and shutdown levels are captured in separate Lucity data drills.

705.1.4 Maintenance Responsibilities

1. Maintenance Team Member has been trained to use the vibration instrument, computer software, and to diagnose problems. (Refer to paragraphs 705.4 and 705.5 for details.)
2. Maintenance Supervisor's responsibilities are:
   A. Assist the Maintenance Team Member to set-up the PM's, vibration routes (rounds), and to analyze the vibration data and trends in HachWims or Power BI.
   B. Initiate Corrective WO's as required for problematic equipment.
3. Operations Supervisor's responsibilities are:
   A. Make equipment available to the Maintenance Team Member to take vibration measurements. Make available the equipment that was not previously available.
   B. Commence operation within 1-2 months of equipment listed in the Lucity "Vibration 90-Day Overdue Report". Notify the Maintenance Team Member when operational.

705.2 Design Engineering responsibility

1. Assuring all consultants and contractors are required to follow the vibration specifications and testing protocols:
   a. 705.6 Vibration Data Storage, Analysis, and interpretation
   b. 705.6 Table 1,2,3,4,5
   c. 705.6 Figure 1,2,3
   d. 705.6 Figure 1 installed vibration sensor location
2. All newly installed rotating assets will have vibration sensors included in bid specified by the MRT.
3. Baseline vibration testing estimate will be included on all rotating asset in the bid from consultants and contractors
4. Baseline vibrations reading and records will be provided to the plant or facility by assigned Lucity asset number in excel spreadsheet format.

705.3 Frequency of Testing

1. Weekly or Monthly – Appropriate for close monitoring due to probable equipment failure.
2. Quarterly – Normal interval for equipment. Operations will attempt to have all overdue equipment placed into service for the next scheduled vibration round. Vibration measurements are bypassed when equipment is seasonally inactive, down for repair, etc.
3. Bi-Yearly – Equipment that is of lesser criticality, and/or is infrequently operated.
4. Contracted 24/7 vibration monitoring required where applicable in all Water and Sewer Facilities

705.4 Preparations and Recording Vibration Measurements

1. Preparations for Recording Vibration Measurements

A. The Maintenance Team Member ensures the vibration instruments are calibrated per the manufacturer's time interval, or a minimum of once every two years.
B. Set-up the vibration routes with assistance of Maintenance Supervisor (para. 805.2.2.2.A)

to include all necessary rotating equipment. The vibration routes (rounds) are pre-determined lists of equipment requiring vibration Predictive Maintenance (PdMs) measurements be taken. Run a Lucity data drill to determine what equipment will be due.

C. Check the vibration instrument, transducer, and cable for proper operation. Before starting a vibration route, upload the appropriate route into the instrument.

D. Vibration readings shall be measured from the same exact locations on the outside of the rotating equipment every time. Positively identify the locations where the vibration probe will be placed on each piece of equipment with a paint pen, tag, dimple, etc. Refer to Figure 1 for preferred locations, and this figure can be applied to all rotating and reciprocating equipment. Both inboard and outboard vibration measures to be taken

on single stage horizontal pump bearing housings, horizontal motors, vertical motors, etc. Referring to Figure 2 for electric motors.

2. Recording Vibration Measurements

The Maintenance Team Member shall refer to the City of Tulsa Safety and PPE procedures. Additional safety procedures are listed, but are not limited to the following:

i. Do not take any vibration readings on, nor contact rotating shafts, etc.
ii. Gloves shouldn't be worn while working close to rotating equipment in operation.
iii. Install breakaway lanyard(s) on any equipment to be attached to one's body.
iv. Don't wrap extra transducer cord around one's clothing, neck, arm, hand, or fingers.
v. Do not allow transducer cords to contact rotating shafts, keys, couplings, fans, etc.
vi. Be wary of keys on the shafts as they are nearly not visible during rotation.
vii. Be wary of coupling guards that are open on the bottom – a safety hazard.
viii. If area classification is NEMA Cl. 1, Div. 2 (flammable gases are likely to exist), verify the vibration instrument is rated for the area.

A. Inspect equipment to be measured and the immediate area to ensure that it's safe to take vibration measurements. Be aware of unusual noises, leaks, lubricant level / condition, temperatures, pressures, operating conditions, etc. Record unusual conditions in Lucity.

B. The vibration transducer's magnetic base shall be kept clean, and it shall be "rolled" onto the surface to avoid vibration spikes. The surface shall be flat to prevent it from "rocking." Refer to Figure 3. Don't attach magnetic-mount transducer to flimsy sheet metal shrouds.

C. Equipment that operates at speeds of 100-1000 RPM can have vibration readings measured in displacement, units of Mils (0.001 inch) Peak-To-Peak, or in velocity, units of Inches / Second Peak. Refer to Tables 1, 2, 3, and 4 for alarm and shutdown levels.

D. Equipment that operates at speeds of 1000-5000 RPM is to have vibration readings measured in velocity, units of Inches / Second Peak. Refer to Tables 1, 2, 3, and 4 for alarm and shutdown levels.

E. Equipment that operates at speeds above 5000 RPM, refer to manufacturer's specs.

F. Allow vibration readings to stabilize. If reading doesn't stabilize, use average readings.

G. Horizontal equipment – take vibration readings in both vertical and horizontal directions.

Vertical equipment – take vibration readings in-line with and 90° to the discharge nozzle.

E. Perform vibration measurements on all equipment currently in service listed for the route. For equipment that is not operational, notify the Operations Supervisor.

F. Perform non-routine vibration analysis of equipment as required.

H. Equipment that was on the Lucity data drill "Vibration 90-Day Overdue Report", but is now available, should soon be operated and vibration data taken within 1-2 months. The Maintenance Team Member and Operations Supervisor should coordinate this effort.

705.5 Vibration Data Storage, Analysis, and Interpretation

1. Vibration Data Storage

A. Record vibration data electronically into the data fields of the "Vibration Readings" portion of the Lucity "TMUA Equipment Inspection Reading or Monitoring View" form for each asset. (Exception in para. 705.5.1.C) Data will allow trending in HachWims or Power BI.

B. Data to also be entered into the vibration instrument manufacturer's program storage.

C. Equipment with permanently installed, continuously monitored vibration equipment (for example, blowers and motors at NSWWTP and SSWWTP, pumps and motors at the Flowline Oologah Pump Station, high speed blowers with shaft proximity probes at HCWWTP, etc.) should have data automatically recorded in HachWims (as available) to significantly aid trending and analysis in HachWims or Power BI. Otherwise, data to be recorded in Lucity "TMUA Equipment Inspection Reading or Monitoring View" form.

D. Maintain the vibration database by reviewing the data collected for validity. Adjust the vibration routes for new or de-commissioned equipment, construction, seasonal use, etc.

2. Vibration Data Analysis and Interpretation

A. The Vibration Meter's amplitudes (all frequencies/speeds combined) or the Vibration Data Collector/Analyzer's amplitudes (spectrum of discreet frequencies / speeds) are analyzed by the Maintenance Team Member to aid in determining the source(s) of vibration.

B. Table 5 lists probable vibration sources at various multiples of operating speed.

C. Analyze the equipment vibration data to determine the trends and the cause(s) of the change in vibration. Document in Lucity any major changes in readings. Discuss with the Maintenance Supervisor any readings that exceed the alarm or shutdown levels.

D. Only the Maintenance Team Member or the Maintenance Supervisor is to change vibration alarm or shutdown levels in Lucity. When making a change, add a note describing the reason, duration, and initials of person making the change. Do not exceed vibration alarm or shutdown levels found in Tables 1, 2, 3, and 4.

E. Vibration alarm and shutdown level changes for continuously monitored equipment (para. 805.5.1.C) shall require review and agreement involving the Maintenance Team Member, Maintenance Supervisor, Mechanics, Operations Supervisor, and/or Plant Engineer.

F. Run Lucity data drill "Vibration 90-Day Overdue Report". Copy Operations Supervisor.

Note: The City of Tulsa Plant Engineer's input is needed regarding the following 2 paragraphs:

AM-SMG-705.1.2, and AM-SMG-705.5.2.E.

Table 1 – Maximum Acceptable Field Vibration Levels of Rotating Equipment – 100-1000 RPM Operating Speed (1 Mil = 0.001 in.)

Driver Size, HP	Vibration Levels – Alarm Preferred Vibration Levels Inches / Sec. Peak Velocity or Mils Peak-to-Peak Displcmt.	Vibration Levels – Shutdown ANSI / Hydraulic Institute Inches / Sec. Peak Velocity or Mils Peak-to-Peak Displcmt.
Less than 33 (25 kW)	0.07 Inches / Sec. or 2 Mils	0.21 Inches / Sec. or 5 Mils
Above 33 (25 kW) and below 268 (200 kW)	0.11 Inches / Sec. or 3 Mils	0.21 Inches / Sec. or 5 Mils
Greater than 268 (200 kW)	0.18 Inches / Sec. or 5 Mils	0.27 Inches / Sec. or 7 Mils

Table 2 – Maximum Acceptable Field Vibration Levels of Rotating Equipment – 100-5000 RPM Operating Speed

Driver Size, HP	Vibration Levels – Alarm Preferred Vibration Levels Inches / Sec. Peak Velocity	Vibration Levels – Shutdown ANSI / Hydraulic Institute Inches / Sec. Peak Velocity
Less than 33 (25 kW)	0.07	0.21
Above 33 (25 kW) and below 268 (200 kW)	0.11	0.21
Greater than 268 (200 kW)	0.18	0.27

Table 3 – Maximum Acceptable Field Vibration Levels of 100-1000 RPM Operating Speed (1 Mil = 0.001 in.)

Driver Size, HP	Vibration Levels – Alarm Preferred Vibration Levels Inches / Sec. Peak Velocity or Mils Peak-to-Peak Displcmt.	Vibration Levels – Shutdown ANSI / Hydraulic Institute Inches / Sec. Peak Velocity or Mils Peak-to-Peak Displcmt.
Less than 33 (25 kW)	0.17 Inches / Sec. or 5 Mils	0.35 Inches / Sec. or 9 Mils
Above 33 (25 kW) and below 100 (75 kW)	0.20 Inches / Sec. or 5 Mils	0.40 Inches / Sec. or 9 Mils
100 (75 kW) and above	0.22 Inches / Sec. or 6 Mils	0.44 Inches / Sec. or 10 Mils

Table 4 – Maximum Acceptable Field Vibration Levels of 100-5000 RPM Operating Speed

Driver Size, HP	Vibration Levels – Alarm Preferred Vibration Levels Inches / Sec. Peak Velocity	Vibration Levels – Shutdown ANSI / Hydraulic Institute Inches / Sec. Peak Velocity
Less than 33 (25 kW)	0.17	0.35
Above 33 (25 kW) and below 100 (75 kW)	0.20	0.40
100 (75 kW) and above	0.22	0.44

Table 5 – Vibration Source Identification Chart – Informative per Appendix D ANSI/Hydraulic Institute 9.6.4-2016 Rotodynamic Pumps for Vibration Measurements and Allowable Values

High Pump Vibration Source Identification			
Symptom(s)	Frequency (CPM)	Possible Cause	Comments
Radial plane vibration, proportional to unbalance and/or speed	1 × rpm	**Imbalance** • Impeller imbalance • Clogging • Weak foundation • Bad pipe support • Bent shaft • Coupling misalignment	Common source of vibration
Vibrates at one speed only	1 × rpm	**Mechanical Resonance** • Motor imbalance • Impeller imbalance • Pump design • Weak foundation • Bad pipe support	Confirm by bump test Natural frequency at run speed
	N × rpm		Confirm by bump test Natural frequency at blade-pass frequency N = Blade-pass frequency
	N × rpm	Acoustic Resonance	Confirm by waveform testing N = Blade-pass frequency
	N × rpm	Acoustic Resonance	Use pressure transducers to measure fluid pressure pulsations in the piping N = Blade-pass frequency
Axial vibration is greater than 50% of radial vibration levels	1 × rpm V × rpm	Vortexing Intake	Observe intake flow for stability V = number of impeller vanes
	1 × rpm 2 × rpm	Coupling Misalignment Bent Shaft	Confirm with dial indicators to document shaft runout
Erratic vibration	High > 6 × rpm	Bad Antifriction Bearings	Use velocity to measure Listen at bearing housings
Vibration stops instant power is shut off	1 × rpm 1 or 2 × Synch speed	Electrical	Check motor, power source, or variable-frequency drive

Figure 1 – Measurement Locations and Directions per Figure 9.6.4.2.3.1 from ANSI/Hydraulic Institute 9.6.4-2016 Rotodynamic Pumps for Vibration Measurements and Allowable Values Both Inboard (IB) and Outboard (OB), Horizontal and Vertical Equipment (in-line with and 90° to discharge nozzle of Vertical Equipment) (Refer to Fig. 5 for Motors.)

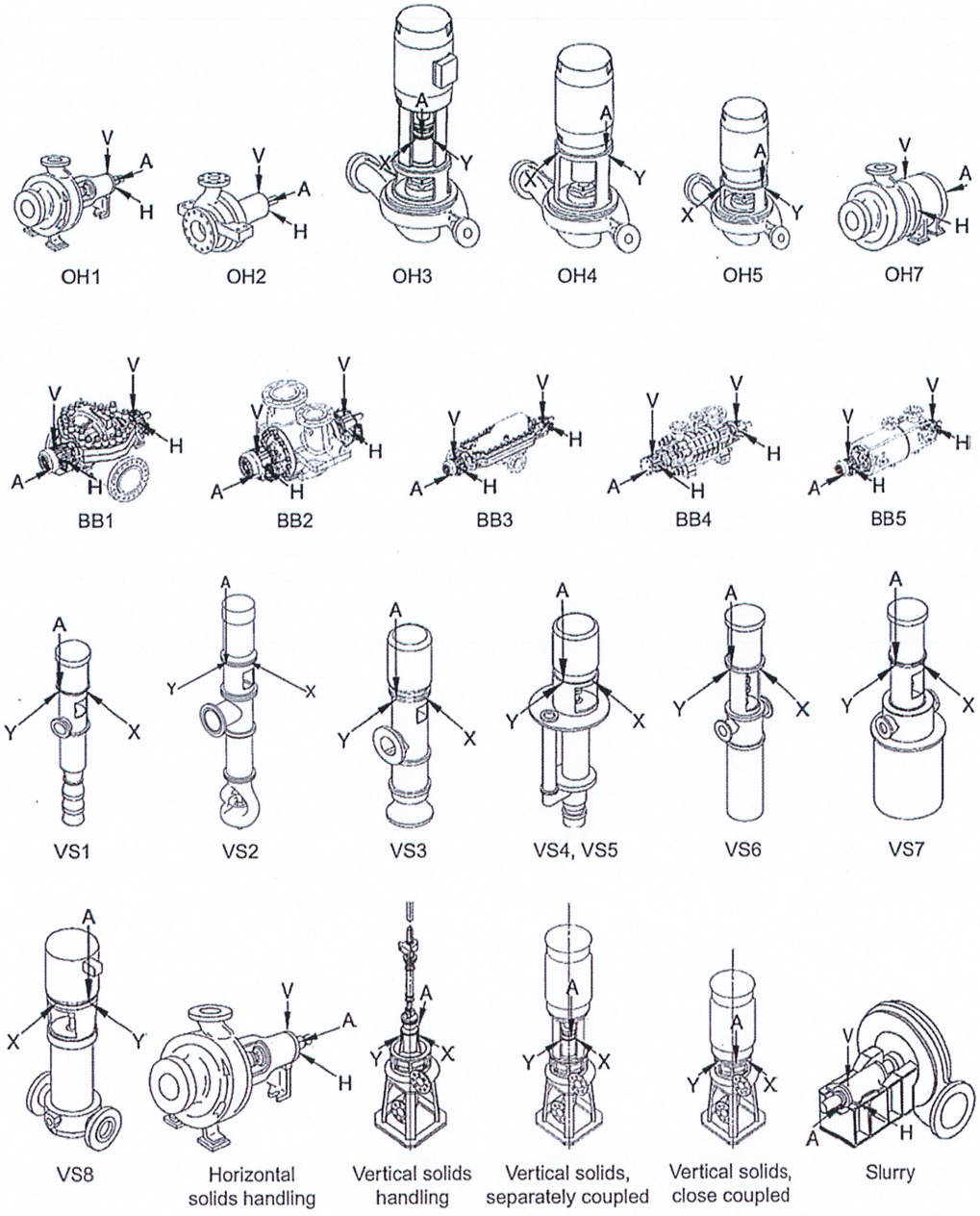


Figure 2 – Guideline for Motor Vibration for (Horizontal and) Vertical Motors per Appendix C ANSI/Hydraulic Institute 9.6.4-2016 Rotodynamic Pumps for Vibration Measurements and Allowable Values Both Inboard (IB) and Outboard (OB), Horizontal and Vertical Equipment (in-line with and 90° to discharge nozzle of Vertical Equipment)

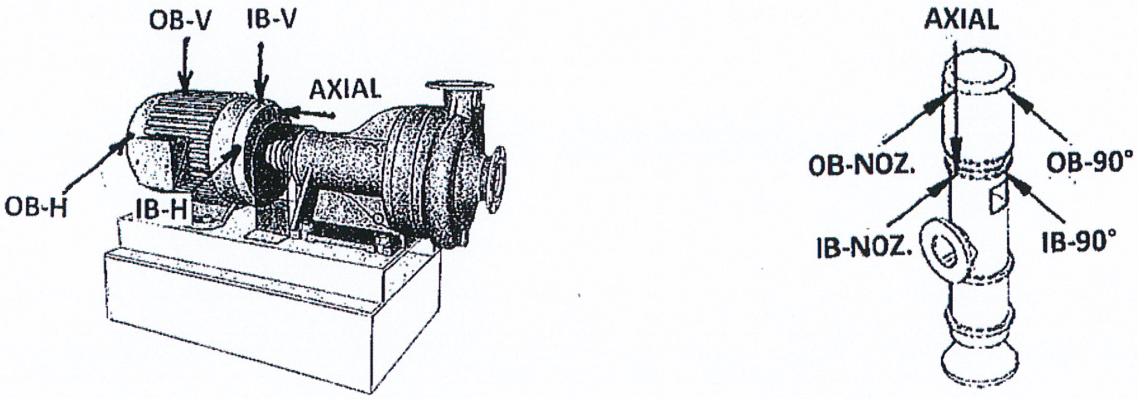
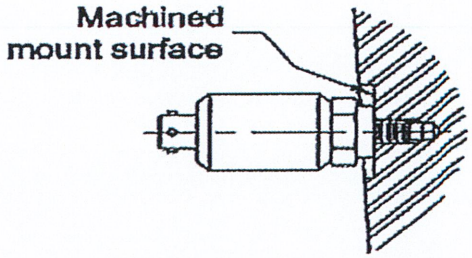
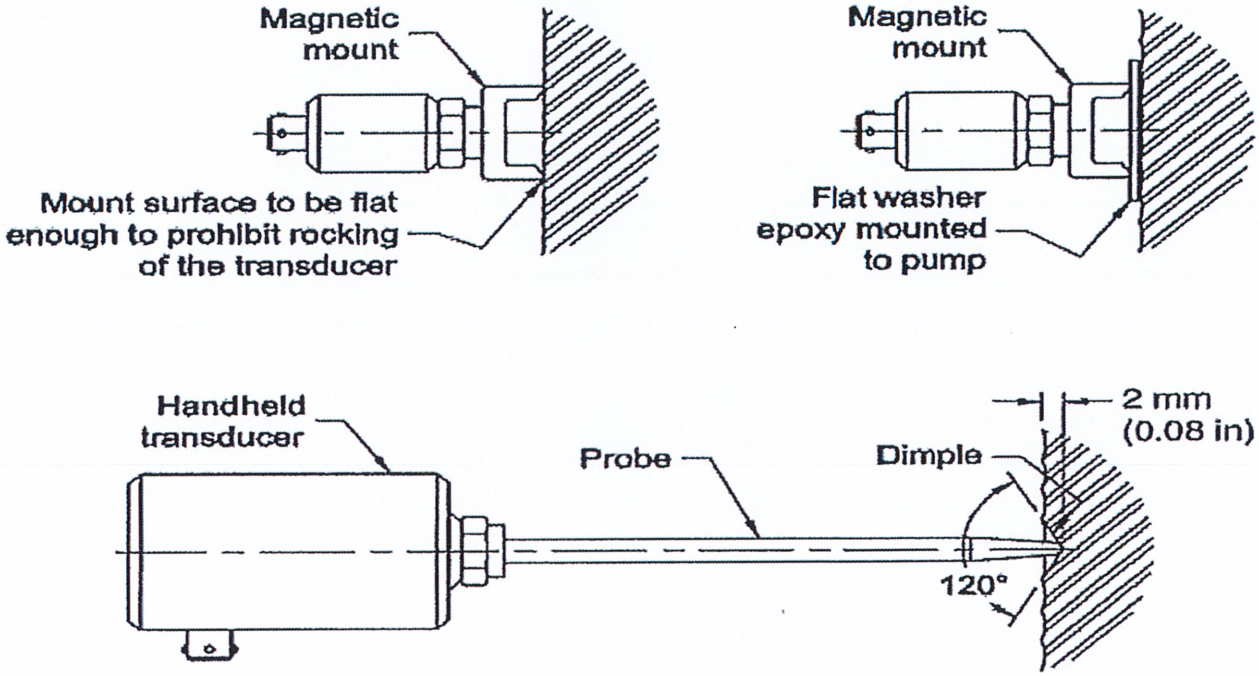


Figure 3 – Mounting Methods for Vibration Transducers per Figure 9.6.4.2.2.2 ANSI/Hydraulic Institute 9.6.4-2016 Rotodynamic Pumps for Vibration Measurements and Allowable Values

Permanent rigid mount of transducer



Temporary mount of transducer



705.7 Appendices
(none)

705.8 References
- Vibration Institute
- ISO 10816/20816
- Uptime Elements – Asset Condition Management

705.9 Reliability Acronym Reference
- PdM – Predictive Maintenance

705.10 Revision History
(Refer to title block.)

705.11 Approvals

(Refer to title block.)

705.12 Authors

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