OPERATOR'S MANUAL

655 VIBRATION METER, ANALYZER AND BALANCER KIT

TABLE OF CONTENTS

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412537-231 Rev "B"

1ST IMPORTANT NOTICE

Because of the high sensitivity of this unit over wide frequency range, the following is highly recommended for all displacement (mils) readings:

1. Use the 20 or 200 mils range. The 2 mil range should only be used on finely balanced equipment or in a laboratory environment.

2. Use the magnetic transducer clamp or the 1/4 in-28 UNF stud mount provision in bottom of transducer to mount the transducer on the machine being tested. Hand held transducer readings taken with a pencil probe may be erratic.

2ND IMPORTANT NOTICE

This instrument is equipped with a maintenance-free rechargeable lead acid battery. Unit should be charged every night or when not in use. Note:

1. You can use the instrument for approximately 2 hours after "LO BATT" appears on the display before readings become unacceptable.

2. If readings become unacceptable, the instrument can be used with battery charger connected.

3. Do not use any battery charger other than the one that is supplied with your instrument.

3RD IMPORTANT NOTICE

Many Operation and Application Notes are available in the "Quick Reference Guide" found in Appendix 1.

DETAILED TABLE OF CONTENTS

Table of Contents - continued

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
BNC	Bayonet Nut Coupling
CPM	Cycles Per Minute
F	Fahrenheit
Hz	Hertz (Cycles Per Second)
In/Sec	Inch/Second
LCD	Liquid Crystal Display
Mils	Vibration Units of Displacement
RPM	Revolutions Per Minute

1.0 PRODUCT DESCRIPTION

This section provides a general product description, as well as a description of the front and back panels and the transducer.

1.1 General

The Vitec 655 Vibration Meter, Analyzer and Balancer Kit is a compact, portable instrument intended for vibration measurement, analysis and machine balancing. The key elements are shown in Figure 1. The instrument is well suited for the more conventional applications, such as in-plant product testing and machinery start-up and checkout, and also the more specialized applications, such as potential fault diagnostic work (preventive maintenance, product safety), point of failure isolation, and dynamic balancing.

The 655 responds to vibration units of displacement in mils and velocity in inches/second (in/sec), both of which may be fed through the tunable filter portion of the instrument for analysis. The instrument, when used with the 4034 velocity transducer, is capable of making accurate vibration measurement over a frequency range of 12 Hz to 1,000 Hz at ±10% tolerance.

The 655 is powered by a maintenance-free, sealed, lead acid battery.

The 655's Quick Reference Guide of Operation and Application Notes is provided at Appendix 1.

The Specification is found in Appendix 2.

The 655 Kit Parts, Optional Accessories and Spare Part part numbers and descriptions are located in Appendix 3.

1.2 Front Panel Description

The controls necessary for operation of the 655 Vibration Meter, Analyzer and Balancer are front panel mounted.

1.2.1 Vibration Level Readout

The vibration level is read on the large Liquid Crystal Display (LCD) on the face of the meter. Refer to Figure 2. The meter will read out directly in mils or in/sec, depending upon the setting of the mode switch. The direct readout display eliminates the need for multiple scales or scale multipliers. Should the vibration level be higher than the range selected, the last three digits of the display will be blanked out to indicate an "over ranged" condition. The LCD display also provides a "LO BATT" display in the upper left hand corner of the display when the battery is low and should be recharged. Readings can, however, be taken for approximately two hours after the "LO BATT" indication first appears. Use of the unit beyond this period may result in faulty readings.

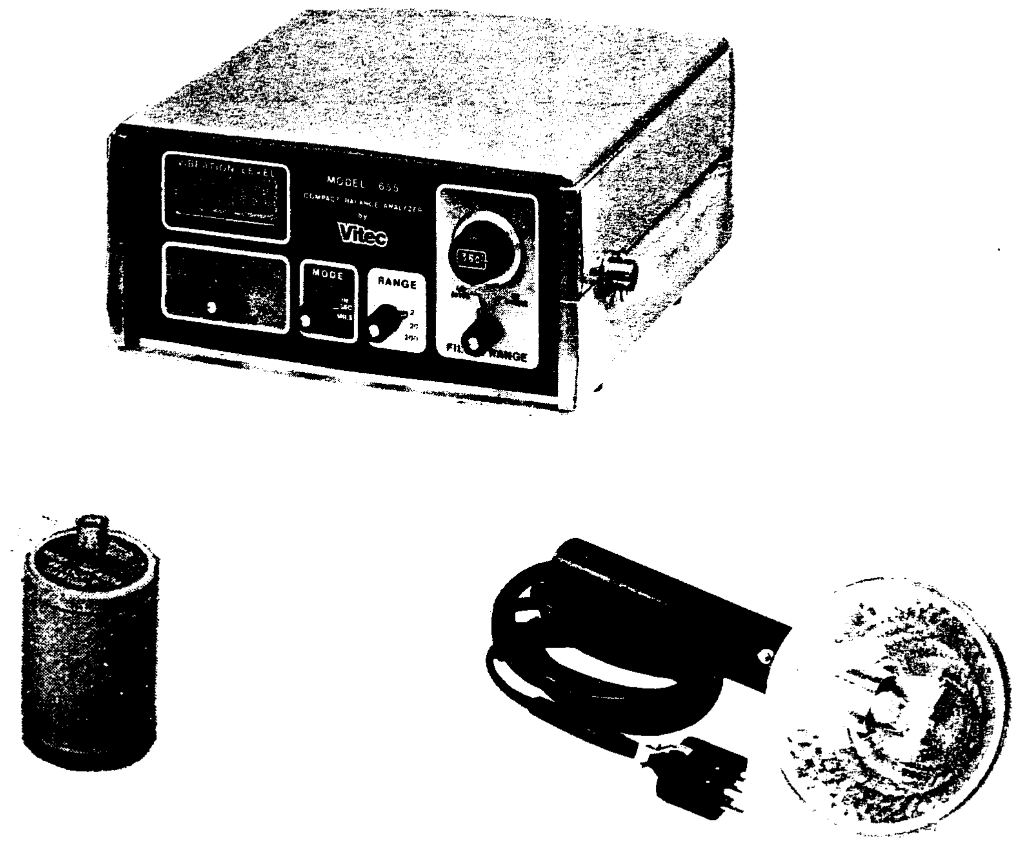


FIGURE 1 KEY ELEMENTS OF 655 VIBRATION METER, ANALYZER AND BALANCER KIT

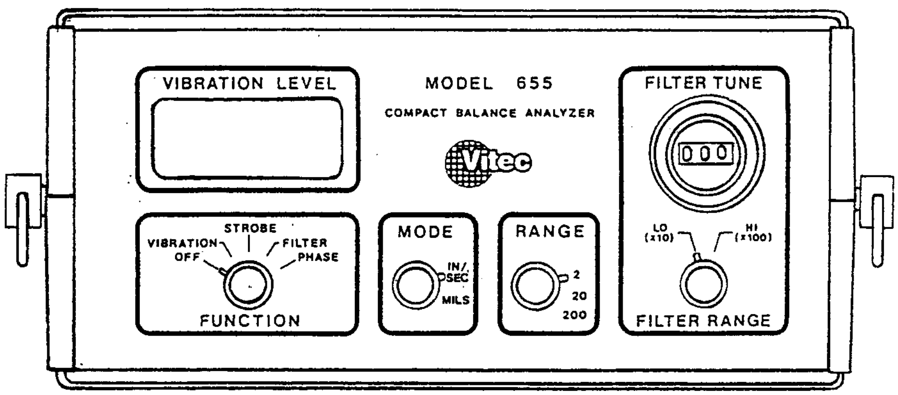


FIGURE 2 FRONT PANEL

NOTE: Do not attempt to use strobe after "LO BATT" indication as there is a possibility of misfire beyond that point.

1.2.2 Function Switch

The Function Switch on the 655 is located on the front panel in the lower left hand corner. This switch has five selectable positions.

Off: In this position all power to the 655 will be turned off. The switch should be turned to the OFF position when the unit is not in use.

Vibration: In this position the 655 will function as a wide band vibration meter. This position should be used to take overall vibration level readings. In this position, neither the filter nor the strobe light circuits are active.

Strobe: In the Strobe position, the strobe light will be controlled by the filter tuning knob. This position should be used to stop the motion of a shaft as the first step in a balancing procedure (to determine machine running speed).

NOTE: The vibration level display is "frozen" when in the Strobe mode.

Filter: The Filter position allows the operator to tune the 655 to the frequency desired for vibration analysis. When balancing, the filter tune knob should not be turned after the proper setting for stopping the shaft was obtained in the Strobe position. Note that the strobe is not functional in the Filter position.

Phase: The Phase position is used to take phase relationship readings for the balancing procedure. Note that the vibration level display is "frozen" when the 655 is switched to the phase position.

1.2.3 Mode Switch

The Mode Switch selects the mode of vibration to be measured. The vibration can be measured in velocity (in/sec) or displacement (mils) refer to application sections.

1.2.4 Range Switch

The Range Switch selects the full scale range for the vibration mode being measured, and causes the decimal point to be located on the display accordingly.

NOTE: If no prior readings or typical levels are available, it is advisable to start in the in/sec mode, 200 range, and select lower ranges as needed until the display reading is 020 or more. (For purposes of this step, ignore decimal placement.) Use of this procedure will help to eliminate over range errors.

1.2.5 Vibration Frequency Readout

The vibration frequency, in Cycles Per Minute (CPM), of the tunable filter is displayed on the mechanical display used to set the filter i.e., dial setting x 10 = frequency in "LO" filter position and dial setting x 100 = frequency in "Hi" filter position.

1.3 Back Panel

Figure 3 shows the Back Panel.

1.3.1 Input Signal Jacks

The Input Signal Jacks on the back panel receive 1/4 in phone plugs and are used to feed transducer Signals A or B into the system. The two transducers are switch selectable for use in Dual-Plane Balancing applications. An optional 655 Dual Plane Balancing Kit (including a second transducer, cable, and more) is available. It's Part No. is 53258-15.

1.3.2 AC Output Jack

The 655 has a Bayonet Nut Coupling (BNC) type connector on the back panel which provides an Alternating Current (AC) signal representative of the actual vibration signal, seen by the transducer.

NOTE: The signal output is affected by the setting of the tunable filter, when used, and the range/mode controls, i.e., in the in/sec mode the output is proportional to velocity and in the mils mode the output is proportional to displacement.

1.3.3 Strobe Jack

The Strobe Jack supplies the power and signal required to operate the Strobe. The Strobe can be used to determine equipment speed, conduct stop motion studies and perform dynamic balancing. Under the strobe light a rotating part will appear stationary when the flash rate is equal to the speed of rotation or any submultiple within a range of 0 to 7,200 RPM.

1.3.4 "X-Y" Output Jack

The "X-Y" Output Jack can be used with an X-Y recorder. The "X" axis should be 0 to 2 VDC proportional to frequency. The "Y" axis should be 0 to 2 VDC proportional to full scale vibration. The plot of vibration versus frequency or CPM is obtained by slowly turning the digital pot from 0 to 10,000 CPM.

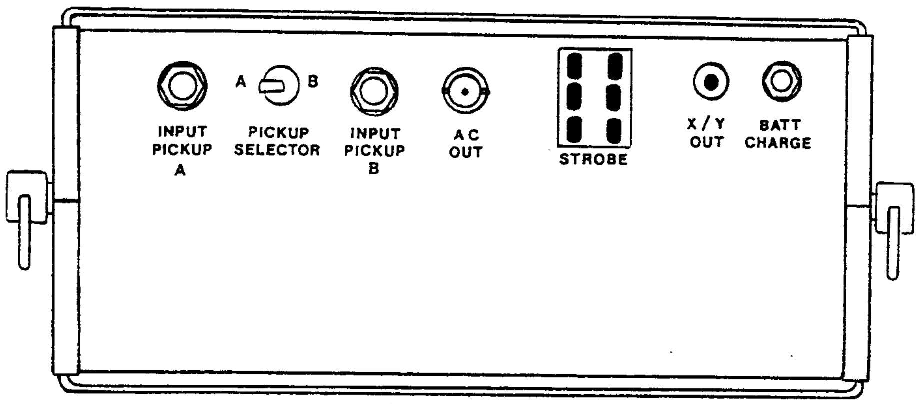


FIGURE 3 BACK PANEL

The result is a graph showing vibration amplitude at various frequencies. The graph can then be used as a standard for comparison with future reading and trend analysis.

1.3.5 Battery Charge Jack

The Battery Charge Jack is used to connect the Vitec 100-1 Battery Charger, Part No. 53260-1.

1.4 Vibration Transducer

The 4034 Velocity Transducer converts the mechanical vibration being measured into an electrical signal which is transmitted to the 655. The 655 provides accurate measurements over the wide frequency range of 600 to 60,000 CPM.

The 4034 is equipped with a 1/4 in-28 UNF mounting stud. By tapping a 1/4 in-28 UNF x 1/2 in deep hole in each monitoring point, the 4034 can be attached for vibration readings.

The 4034 is also supplied with a Transducer Magnetic Mounting (Mity Mag) which securely holds the Transducer to the equipment while measurements are being taken and eliminates the need for tapped holes in your equipment.

2.0 TYPICAL APPLICATIONS

Typical applications for the 655 Vibration Meter, Analyzer and Balancer Kit include:

1. Signature Analysis - One of the most useful capabilities of the instrument. Mapping of vibration signature data can aid not only in detecting potential mechanical failures, but also in isolating probable locations. See more in Appendix 4.

2. Diagnostic Survey - Useful for field service. Matchup with typical signature data can give information without the need for costly shutdowns. In plant, these same capabilities provide a quick and effective means of inspection for receiving or assembly line quality assurance.

3.0 OPERATIONAL DETAILS

This section provides operational details on nine topics: General, Vibration Tolerances, Taking Measurements, Measuring Displacement in Mils and in In/Sec, Tunable Filter Analysis, Balancing, Determining Slip of Belts and Pulleys, and Stop Motion Analysis.

3.1 General

One of the primary uses of the 655 Vibration Meter, Analyzer and Balancer Kit is to measure machinery vibration over a period of time. An increasing trend in the amount of vibration detected is an indication that the machine will soon need repairs because of bearing wear, loose or worn internal parts, or a general condition of unbalance. Early scheduling of such repairs will often result in avoiding costly, nonscheduled downtime caused by failure of a defective component.

In addition, the vibration analysis capabilities of the instrument can be helpful in potential problem isolation, which can reduce unnecessary downtime.

If vibration exceeds allowable limits, the machine should definitely be inspected to determine the cause.

The best point to measure vibration is on the bearing housings. If bearing housings are not readily accessible, place the transducer on nearby associated supports for structures.

3.2 Vibration Tolerances

The allowable limit of vibration which can be tolerated in a machine depends on many factors, including:

1. The function of the machine;

2. Stiffness of bearing supports and the base;

3. Alignment of the couplings and bearings;

4. Operating speed as related to resonance and critical speed; and

5. Transmitted vibration from other sources.

Machine products tested satisfactorily for allowable vibration limits during manufacture may produce different results when the same tests are performed under actual field installation and operating conditions. For this reason, it is sometimes difficult for a manufacturer to supply standard allowable limits of vibration for each item delivered. However, tentative guides can be set up for certain types of machinery listing vibration tolerances as standards for comparison.

Effective guidelines for your particular applications can best be established through correlation of vibration frequency/amplitude histories with available maintenance and inspection data.

3.3 Taking Measurements

Locate the Function Switch in the Vibration Position and hold the probe against the machine, preferably on a bearing housing. Take readings with the transducer in both vertical and horizontal planes with respect to the machine. An axial measurement is also recommended if obtainable. Record the data for future reference.

Be sure to apply enough pressure to the transducer to maintain solid contact with the machine and to prevent the probe from chattering. The transducer should be held perpendicular to the rotating shaft of the machine. Be careful to take successive or future readings for trending or comparison at the same exact location on the machine. Readings taken at different points on the machine are not comparable, and cannot be used for measuring changes in vibration levels.

> NOTE: Although the pencil probe is most useful for spot-checking and diagnostic survey applications it is generally more advisable to use a mounting stud or transducer magnetic mounting for purposes of long term history and analysis work.

3.4 Measuring Displacement in Mils

Measuring vibration in the displacement mode results in detection of actual physical displacement or movement of the surface to which the transducer is attached. The vibration is measured in mils peak to peak, 1 mil = 0.001 in.

3.5 Measuring Velocity in In/Sec

Measuring vibration in the velocity mode results in detection of the rate of change of displacement. This vibration is measured in terms of peak velocity or in/sec peak.

Velocity is a function of both displacement and frequency, and therefore will have additional sensitivity to higher frequency vibration. For example, a 1 mil displacement will have the same vibration meter reading at 1,000 CPM as at 10,000 CPM. The velocity for 1 mil at 100 CPM is 0.052 in/sec, while at 10,000 CPM, the velocity is 0.52 in/sec, or 10 times larger. The latter is a truer indication of force.

3.6 Tunable Filter Analysis

Any series of data taken should include measurements taken as indicated above, which are helpful in limiting the number of readings needed. In the filter "Out" position, total vibration level is read without regard for frequency.

The 655 may be set to the "HI" or "LO" filter position, and readings taken at the operating speed of the device under test (CPM=RPM). If these readings are essentially the same as the baseline, readings at other frequencies will not be appreciably higher. If there is a significant difference between the baseline data and the data taken at operating speed, then further data should be taken at twice operating speed, three times operating speed, etc., until the readings add up to approximately the level of the baseline data.

> NOTE: The magnitudes and frequency of each data set should be recorded; the frequency says more about where the problem is, the amplitude says more about how "bad" the problem is.

3.7 Balancing

This section provides a description of three aspects of balancing: How to set up the analyzer, confirming if problem is due to unbalance, and six steps to balancing.

3.7.1 Set Up Analyzer

There are basically two steps to setup the 655:

1. Attach transducer(s) on bearing cap, make sure that the transducer is firmly attached to the point of measurement; and do not move transducer(s) once balancing procedure has begun; and,

2. Connect cable(s) to left and/or right input jacks on back panel of the unit; the transducer selector switch, located between the two jacks, should be pointed to the selected transducer.

3.7.2 Confirming Problem Is One of Unbalance

Before attempting to balance a machine, it is recommended that the following check be made to confirm if the problem is caused by an unbalance condition.

High vibration levels can be caused by unbalance condition. High vibration levels can also be caused by misalignment, bent shafts, misaligned couplings, looseness, etc. Balancing will not correct these problems. The machine should be in good running order before a balancing procedure is attempted. To do so follow the following steps:

1. Set the Function Switch on Vibration, Mode Switch in the Mils, Position Range Switch to the lowest setting possible.

2. Record vibration level indicated.

3. Set the Function Switch on Strobe position, Filter Range Switch to the "LO" x 10 position.

4. Fire strobe and turn the Filter Tuning knob until the shaft appears to be stopped; read the digits on the knob and multiply by the Filter Range switch. This will be the shaft speed in RPM. Care should be used here, as the shaft could appear to be frozen when filter is tuned to multiples of the running speed.

   NOTE: Do not change the position of the Filter Tune knob for the remainder of the measurements taken during the balance procedure.

5. Set the Function Switch on the Filter position and record the vibration level displayed.

6. If the value recorded in Step 5 is significantly lower than the vibration level recorded in Step 2, then there is a good chance that there are other machine problems in addition to the unbalance. Remember: the machine should be put in good working order before balancing. If the reading in Step 5 is within 5% to 10% of the reading recorded in Step 2 proceed with the Balancing Steps (Section 3.7.3).

7. To help determine the probable cause of problems other than unbalance, use the FILTER position to determine the amount of vibration at the various multiples of running speed. This data can then be used to determine the probable cause of the vibration. Please refer to the "VIBRATION PRIMER" published by Vitec, Inc. for more detail on vibration analysis.

3.7.3 Balancing Steps

There are six steps to balancing as noted.

1. With the Function Switch in the Filter position, as in Step 5 above, record the vibration level. This will be the "Original" unbalance reading.

2. Turn the Function Switch to the Phase position. Record the position reference mark. This will be your "Original" phase reading. Note that the vibration reading will be "frozen" when the unit is switched to the phase position.

3. Stop the machine and add a trial weight.

4. Restart the machine, using care on variable speed equipment to ensure it is returned to the same speed it was at when the "Original" readings were taken. Then turn the Function Switch to the Filter setting and record the vibration level. This reading is referred to as the "Resultant" vibration.

5. Turn the Function Switch to the Phase position. Record the position of the phase mark as the "Resultant" phase reading.

6. Refer to the "VIBRATION PRIMER", Chapter 11, Section II, Pages 48 through 51 for the balancing calculations.

3.8 Determining the Relative Slip of Belts and Pulleys

This activity has three steps.

1. Turn the Function Switch to the Strobe position.

2. Tune the Filter Tune knob to the running speed of the pulley.

3. Fire the strobe light. If the belt(s) appear to be moving while the pulley(s) appear to be stationary, the belt(s) are slipping on the pulley(s). Note the setting of the Filter Tune knob when the pulley appears to be stationary. Turn the Filter Tune knob to the right or left until the belts appear to the stationary. The setting on the Filter Tune knob is an indication of the amount of slip between the belt and pulley.

3.9 Stop Motion Analysis

There are three steps to this analysis.

1. Turn the Function Switch to the Phase position.

2. Tune the Filter Tune knob to the frequency of the problem vibration.

3. Visually inspect the machine with the strobe light. The part of the machine that is vibrating at the tuned-in frequency will appear to be stationary when viewed with the strobe light.

APPENDIX 1

655'S QUICK REFERENCE GUIDE OF OPERATION AND APPLICATION NOTES

DESCRIPTION OF FRONT PANEL CONTROLS

The **VIBRATION** position of the function switch allows the unit to read the overall value of vibration. The filter tune knob and strobe light are not functional in this position. The meter will display the amount of vibration in the units of measure selected by the **MODE** switch. This position is a low battery drain position.

The **STROBE** position allows the operator to select the firing rate of the strobe light. This is done by turning the FILTER TUNE knob to the firing rate desired. This position is used to "freeze" the motion of a rotating shaft, or to determine the running speed of a particular machine. The vibration level meter is "frozen" in this switch position, and has no meaning. This position is a HIGH battery drain position! Do not leave the switch in this position unless the strobe is being used.

In the **FILTER** position, the 655 measures only the amount of vibration at the frequency set on the FILTER TUNE knob. This position is used to measure the amount of vibration at selected frequencies or for use in a balancing procedure. This position is a low battery drain position.

The **PHASE** mode allows the strobe light to be fired by the vibration signal. This allows the strobe light to indicate phase for balancing purposes. The vibration level meter is also "frozen" in this switch position. This is a HIGH battery drain switch position, do not leave the switch in this position.

The **MODE** switch selects the units of measure that will be displayed on the VIBRATION LEVEL meter.

The **RANGE** switch selects the full scale range of the VIBRATION LEVEL meter. In the mils mode, the 0 to 2 range is <u>very</u> sensitive, and should be used for very low level vibration readings only. For best results, select a range that is approximately two or three times the vibration level being measured.

The **FILTER TUNE** knob indicates the selected frequency of measurement in CPM (cycles per minute) when the unit is in the STROBE of FILTER position. The displayed numbers on the filter tune knob should be multiplied by the LO or HI multiplier as indicated. For example, a setting of 360 represents 3,600 CPM on the LO filter setting, and 36,000 CPM in the HI filter setting.

OPERATION AND APPLICATION NOTES

To Read Overall Vibration Levels

1. FUNCTION switch in the VIBRATION position.

2. MODE switch turned to the desired units of measurement, (mils, or in/sec).

3. RANGE switch set first at 0 to 20, change as required so vibration reading is greater than 10% of the full scale range.

To Read Vibration at Selected Frequencies

1. FUNCTION switch in the FILTER position

2. MODE and RANGE switch as desired.

3. Turn FILTER TUNE knob to selected frequency.

4. Vibration level meter will display the amount of vibration that exists at the selected frequency.

To Determine Running Speed of a Machine

1. FUNCTION switch in the STROBE position.

2. MODE switch, RANGE switch and VIBRATION LEVEL meter are nonfunctional.

3. Turn FILTER TUNE knob to approximate running speed of the machine.

4. Point strobe light at shaft of machine and fire strobe light by pressing button on the strobe light handle.

5. Turn FILTER TUNE knob slowly to the left or right until the machine shaft appears to be stationary.

6. Read running speed of machine on the FILTER TUNE knob.

   CAREFUL! The shaft of the machine will also appear to be stationary if the FILTER TUNE knob is set a ½, 2, 3, or 4 times running speed. If set at 1/2 of running speed the shaft will not appear to be as "sharp" or "clear" as when the FILTER TUNE is set at one times the running speed. If the FILTER TUNE knob is et at two or more times running speed, multiple images of reference marks or other obvious reference points on the shaft will appear. By turning the FILTER TUNE knob slightly to a setting slightly above or below the running speed of the machine, the shaft will appear to be turning slowly forward or backward. An ideal way to inspect couplings, belts or other machine elements while the machine is running.

To Determine The Relative Slip of Belts and Pulleys

1. FUNCTION switch in the STROBE position.

2. Tune FILTER TUNE knob to running speed of the pulley.

3. Fire the strobe light. If the belt(s) appear to be moving while the pulleys appear to be stationary, the belt(s) are slipping on the pulley. Note the setting of the FILTER TUNE knob when the pulley appears to be stationary. Turn the FILTER TUNE knob to the right or left until the belts appear to be stationary. The setting on the FILTER TUNE knob is an indication of the amount of slip between the belt and pulley.

To Determine Amount of Unbalance

1. Determine the overall vibration level.

2. Determine vibration level at one times running speed.

3. If the amount of vibration at one times running speed is close to the amount of overall vibration, it is likely that most of vibration problem is due to unbalance. If the vibration level at one times running speed is significantly less than the overall vibration level, then it is likely that there are one or more other problems with the machine in question.

4. To help determine the probable cause of problems other than just unbalance use the FILTER position to determine the amount of vibration at the various multiples of running speed. This data can then be used to determine the probable cause of the vibration. Please refer to the "VIBRATION PRIMER" published by Vitec, Inc. for more detail on vibration analysis.

Stop Motion Analysis

1. FUNCTION switch in the PHASE position.

2. Tune the FILTER TUNE knob to the frequency of the problem vibration.

3. Visually inspect the machine with the strobe light. The component of the machine that is vibrating at the tuned in frequency will appear to be stationary when viewed with the strobe light.

APPENDIX 2

655'S SPECIFICATION

Modes:	Displacement, mils and Velocity in/sec
Ranges:	Amplitude: 0 - 2, 0 - 20 and 0 - 200 Frequency: 10 - 10,000 CPM and 100 - 100,000 CPM
Filter:	Manual Tune and Bandpass
Bandwidth:	Q = 17
Accuracy:	±10% 12 Hz to 1,000 Hz
Display:	Amplitude: 3-1/2 Digit Liquid Crystal Display Frequency: 3 Digit Mechanical Display
Transducer:	4034 Velocity Transducer
Battery:	Rechargeable Lead Acid Battery
Dimensions:	4-1/2 in H x 9-3/4 in W x 12 in D
Weight:	10 lbs including accessories
AC Output:	A signal proportional to mode and range selected, modified by a tunable filter, from a BNC connector on the back panel
Operating Temperature:	33 to 150°F

APPENDIX 3

655 VIBRATION METER, ANALYZER AND BALANCER KIT

Part No.	Product Name and Description
53258-2	655 Vibration Meter, Analyzer and Balancer Kit
	Containing:[a] 655 Vibration Meter, Analyzer and Balancer 4034 Velocity Transducer 4034 to 655 Cable Assembly, 12 Feet Transducer Magnetic Mounting (Mity Mag) Strobe Light Assembly Rechargeable, Gel Cell 12V Lead Acid Battery Pencil Probe, 4 Inch Shoulder Strap 100-1 Battery Charger (110 VAC) 655 Vibration Meter, Analyzer and Balancer Operator's Manual Vibration Primer
53258-15	655 Dual Plane Balancing Kit
	Containing: 4034 Velocity Transducer 4034 to 655 Cable Assembly, 12 Feet Transducer Magnetic Mounting (Mity Mag) Briefcase Style Carrying Case

Optional Accessories

Part No.	Product Name
53267-1	Balance Buddy Computer Kit
412585-93A	Strobe Light to 655 Cable Assembly Extension, 25 Feet
412585-169A	Softpak Carrying Case

(a) Without a carrying case, see Option Part Number 53257-19, Hardpack Briefcase Style Carrying Case.

Part No.	Product Name and Description
602885-11RB	Vise Grip Transducer Mounting Clamp
602883-101A	Transducer to 655 Cable Assembly Extension, 15 Feet

Spare Parts Prices

Part No.	Product Name
53257-19	Hardpack Briefcase Style Carrying Case
53258-1	655 Vibration Meter, Analyzer and Balancer
53260-1	100-1 Battery Charger (110 VAC)
79985-87R	Strobe Light Assembly
412537-231	655 Vibration Meter, Analyzer and Balancer Operator's Manual
412560-21	Vibration Primer
412580-60B	Pencil Probe, 4 Inch
412585-143A	Transducer Magnetic Mounting (Mity Mag)
412585-159A	4034 Velocity Transducer
412707-15A	Shoulder Strap
412718-16A	Rechargeable 12V Lead Acid Battery, Gel Cell
412751-3A	Spare Strobe Lamp
602883-110C	4034 to 655 Cable Assembly, 12 Feet

APPENDIX 4

"VIBRATION PRIMER", CHAPTER 10, VIBRATION ANALYSIS

In Chapter 3, we stated that a vibration analyzer allows you to determine the cause of a vibration problem by supplying you with both amplitude and frequency data. Thus, vibration analysis breaks the overall vibration into its frequency components, and by knowing what frequencies are generated by various mechanical problems - the cause of vibration can be determined.

A very simple example will serve to illustrate this concept. An automobile is vibrating as a result of two problems: 1. The front tire has a "bubble" that causes a vibration very time it hits the pavement, and 2. the kids are jumping up and down in the back seat. A vibration meter would display the overall combined vibration of the two problems. The vibration analyzer, on the other hand, can separate the two problems into their frequency components. It could separate the kids jumping at 5 cycles per minute from the tire problem which may be happening at 50 cycles per minute. It could also tell you how much vibration is happening at each frequency, which obviously allows you to determine how much vibration is caused by each problem, and allow you to take corrective action. Figure 21 is a graphic representation of these two problems. As you can see, the vertical bars plotted on the axes represent both the amplitude and frequency of the vibrations that exist. In this example we have 2 mils vibration at 5 CPM and 3 mils of vibration at 50 CPM. This type of plot is commonly referred to as a "vibration signature" or "signature analysis".

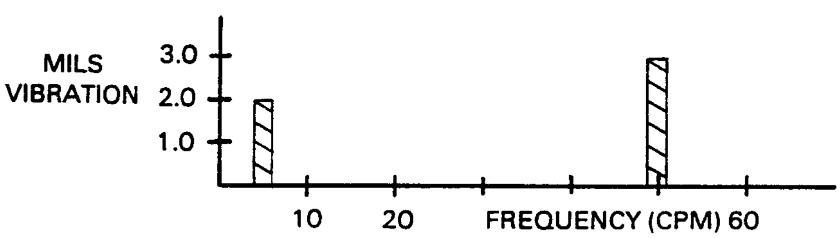


Figure 21
A simple vibration signature.

The same basic principles apply to machinery vibration analysis. Various mechanical problems will create different frequencies and amplitudes of vibration. An analysis of the vibration signature will allow you to determine the probable cause of vibration.

Again - none of the data listed is "magic" - all vibrations can be analyzed by determining "what mechanically in this particular machine can cause a vibration at this frequency and amplitude". A good understanding of the machine to be analyzed is essential to proper vibration analysis.

A strobe light should be used for visual examination of the machine to be analyzed. The number of reference marks that are revealed under strobe illumination should be recorded. These data may play an important role in correlating findings.

To avoid errors, all filter-in and filter-out readings should be taken consecutively at each key point and recorded.

The following pages contain a reference chart listing common vibration problems, followed by a descriptive section which explains why a particular vibration problem exhibits the vibration characteristics it does.

REFERENCE CHART - VIBRATION SOURCES

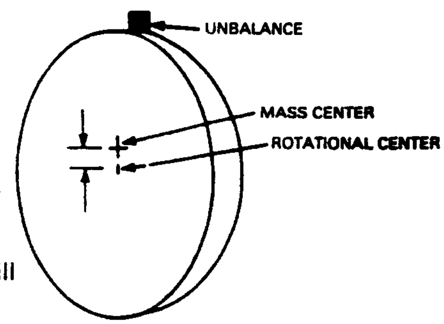
PROBABLE CAUSE	FREQUENCY relative to machine rpm	STROBE "PICTURE"	AMPLITUDE	NOTES
Unbalance	Rpm × 1	One - Steady	Radial - steady	Most common cause of vibration
Bent Shaft	Rpm × 1 (or × 2)	1, 2, or 3	Axial - high	Strobe picture depends on machine -usually unsteady
Anti-friction Bearings	Rpm × 20 to × 50 (or more)	Unstable	Radial - low	Use acceleration Mode
Sleeve Bearings	RPM × 1	One - Steady	Shaft = Bearing Rdgs.	Compare shaft to bearing readings
Faulty Belts	Rpm × 1 to Rpm × 5 (Belt Rpm × 2)	See "Notes" Column	Radial - Unsteady	Freeze belts with strobe and observe
Oil Whip	Less than machine rpm	Unstable	Radial - Unsteady sometimes severe	Frequency is near ½ rpm (commonly 42% to 48% × Rpm)
Gears	High (related to number of gear teeth)	--	Radial -- low	Use velocity or acceleration mode
Looseness	Rpm × 2	2	Proportional to looseness	Frequently coupled with misalignment
Foundation Failure	Unsteady	Unstable	Erratic	Shows up when balancing
Resonance	Specific "criticals"	1	High	Increased levels at critical speeds
Beat Frequency	Periodically varying	--	Pulsating	Caused by close rpm machines
<u>Misalignment</u>:				
Parallel	Rpm × 1, × 2	1, 2 or 3	Radial	
Angular	Rpm × 1, × 2	1, 2 or 3	Axial - high	Axial amplitude = .7 or higher of vertical or horizontal
Electrically <u>**Induced**</u>:	Note: All electrical problems can be confirmed by cutting power to machine - problems should disappear immediately.			
Loose Stator Laminations	High frequency (over 60K cpm)		Radial high - steady	
Stator Problems (shorts)	2 × line F		Radial	
Blade/Vane Pass	Number of blades/ vanes × Rpm		Radial - fluctuating	Look for radial vibration in direction of discharge piping
Cavitation	Random		Fluctuating	Can be up to 2000 Hz

CHARACTERISTICS OF COMMON VIBRATION CONDITIONS

(A Brief Description of Signature Origin)

UNBALANCE (1 × rpm)

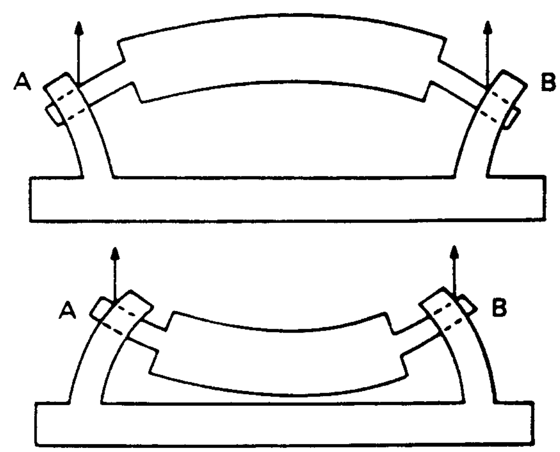
Unbalance is the most common cause of vibration. It occurs when the center of mass of an object is not also its center of rotation. The apparent presence of a "heavy spot" causes forces to be applied which result in vibration. Unbalance produces a vibration reading whose amplitude is directly proportional to the amount of the unbalance, and whose frequency is the same as the running speed of the machine being measured.



For example, an 1800 rpm motor which is unbalanced will have vibrations at 1800 cpm (30 cycles per second) and the amount of vibration will be proportional to the amount of unbalance.

BENT SHAFT (1 × rpm — sometimes 2 × rpm)

In case of a bent shaft, a high axial vibration level at a frequency of single and sometimes double shaft rpm will be noted. The figure shows the simultaneous and opposite axial deflection of the bearing housing. By observing the axial vibration at bearing A and bearing B, with the pickup held in the same direction on both bearings, the phase indication will be that of a static pair condition (reference mark at the same position for both bearings).



In the illustration, note that for every rotation of the shaft a vertical impulse on the out-board and in-board end of each bearing will occur. This results in two impulses of vibration for each rotation of the shaft. If the bent shaft condition occurs as deflection, or deformation, at operating speeds, it can in many cases be corrected by adding balance weights at the center of the shaft. This will tend to straighten the shaft and the mass center line will then coincide with the rotation center line. Normal two-plane balancing should be followed.

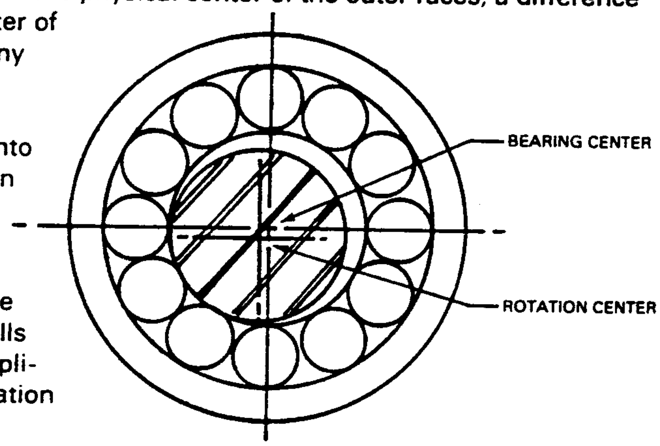
If shaft flutter, due to operating speed, is occurring and if the condition has been corrected by balancing, care must be taken to insure that changes in speed will not result in additional flutter of the rotor shaft.

If the bent shaft occurs due to actual physical deformation of the shaft, independent of rotation, the addition of balancing weight will have little effect.

The disproportionately large balance weight required to show any appreciable change in vibration level will show that a condition, other than mass displacement versus rotational centers, exists.

BEARINGS ANTI-FRICTION (Many × rpm)

In many cases, manufacturers balance the part by rotating it on the shaft, rather than in the bearing on which it will be finally assembled. If the rotational center of the anti-friction bearings in a race is not coincident with the physical center of the outer races, a difference in the mass center and rotational center of the shaft will occur. This obliterates any prior balance performed. If bearing replacement, after original machinery installation, does not take this factor into consideration, an unbalanced condition may occur.

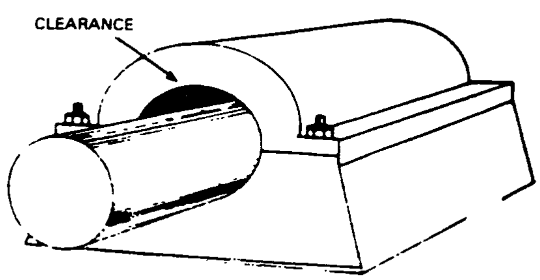


In the case of anti-friction bearings, the scoring or brinnelling of the balls or rolls will produce a high frequency, low amplitude vibration. It is best to use acceleration or velocity readings to detect bad anti-friction bearings. (A high frequency but low displacement signal has a high velocity, being a product of frequency and displacement, and higher acceleration being a product of the displacement times frequency signal squared.)

Verification of poor bearing performance is made by shutting off the machine and observing that the high bearing frequency remains as a unit reduces in speed. This high frequency signal will normally be retained until the machine comes to rest. The frequency indication is usually from 5 to 20 times the primary frequency of the part contained by the bearings.

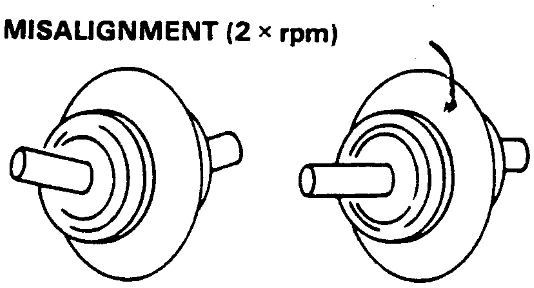
BEARINGS, SLEEVE (1 × rpm)

Excessive clearance in sleeve bearings can normally be determined by comparing the vibration level reading on the bearing housing using an accelerometer or velocity pickup, as close to the bearing as possible, and the vibration level of the shaft itself using a non-contact probe. Note: the pickups must be in the same plane and direction when taking both readings.



Sleeve bearings may also exhibit a condition known as "oil whip." This is discussed later.

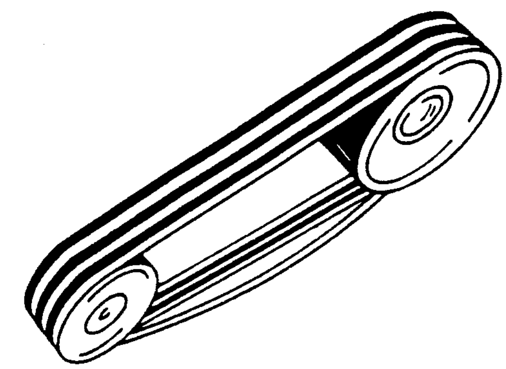
MISALIGNMENT (2 × rpm)



Misalignment of couplings and bearings results in a high axial vibration reading. This may be as much as 1.5 times the vertical or horizontal readings. This condition generally occurs at 2 times the running speed of the machine, although it may also occur at one (or even 3) times the running or primary frequency.

FAULTY V-BELTS (1—5 × rpm)

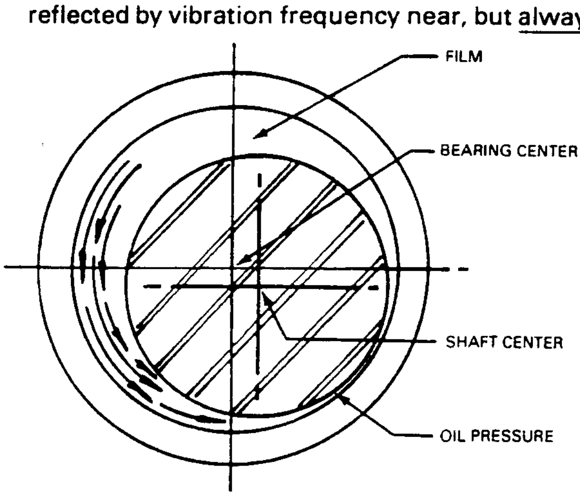
Faulty drive belts exhibit an unstable amplitude reading with a frequency of from one to five times the rotating speed of the machine. To determine if belts are bad, investigate under strobe light, freezing the belts for visual inspection. Relative slippage of one belt among several will usually be seen.



Vibration readings will be unsteady. This is caused by different sheave diameters, each with different unbalanced conditions, running at different speeds. Also, high and low points on each sheave will affect the running belt at varying times during rotation -- sometimes adding, sometimes subtracting. A vibration condition caused by faulty belts can best be corrected by installing perfectly matched sets of belts and assuring that high-quality sheaves are used.

OIL WHIP (lower than shaft rpm)

A condition known as "oil whip" may occur in lightly loaded sleeve bearings. This instability is reflected by vibration frequency near, but always lower than one half, the actual shaft speed.



Correction of "oil whip" can be made by changing the bearing clearances, changing the positions of the oil groove, increasing the shaft loading, or changing the oil characteristics, such as viscosity.

A word of warning! Increased vibrations caused by "oil whip" or apparent "oil whip" may indicate a problem so severe as to warrant immediate correction or machine shutdown. Such an example would be if the lubrication system has failed completely to deliver lubricant to the sleeve bearing.

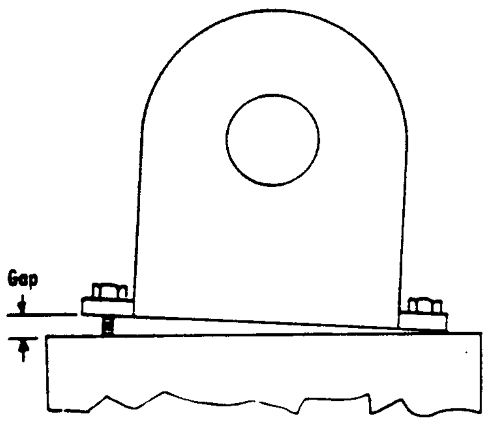
GEAR NOISE (Number of gear teeth × rpm)

Gear noise or faulty gears produce a low-displacement high-frequency signal which generally has some integral relationship to the number of gear teeth. As in the case of detecting bad anti-friction bearings, use the velocity or acceleration mode of measurement. These vibration measurements will provide a better indication than displacement of the gear condition, since displacement, particularly on the gear cases, is likely to be quite low.

In a multiple stage gear set, the pickup probe should be placed on the bearing housing holding the problem gear and shaft.

LOOSENESS (2 × rpm)

Mechanical looseness, coupled with misalignment of couplings or bearings, generally occurs at twice the machine rpm. Its amplitude is normally dependent on the amount of looseness and the design of the machine.



Unbalanced rotational forces (no system is in perfect balance) and changing torque loads, result in impacting of the base twice for each revolution. Excessive bearing clearance will produce the same results. Essentially, looseness allows more vibration to occur than what would otherwise be expected. This is particularly true in anti-friction bearings where small amounts of unbalance result in large vibrations at first and second harmonics of shaft speed. In most situations, this vibration will significantly reduce when the unbalanced force or misalignment is corrected.

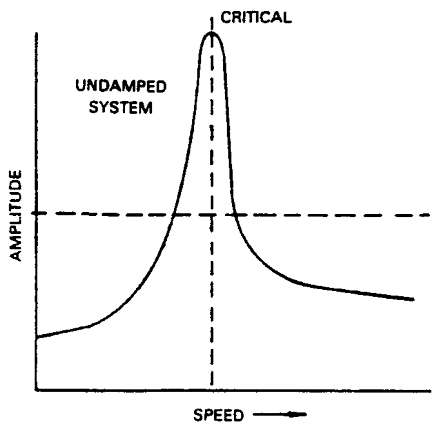
FOUNDATION FAILURE (unsteady)

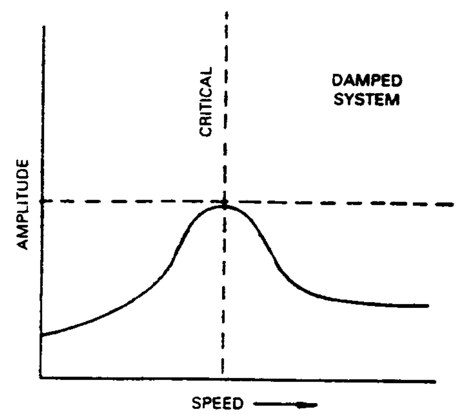
This condition can be determined by erratic changes in vibration amplitude and phase, occurring while conducting in-place balancing. This situation normally does not occur except in high-speed, heavy-mass equipment.

RESONANCE

Each part of a machine, as well as the machine itself, has a resonant frequency. Just as a tuning fork may be excited by a shock, small vibration or shock impulses may be synchronized with the resonant frequency of a machine, resulting in a high vibration level at critical machine operating speeds, tapering off if the speed is increased or decreased. The resonant frequency of a machine may be raised by increasing its stiffness, or lowered by increasing its mass.

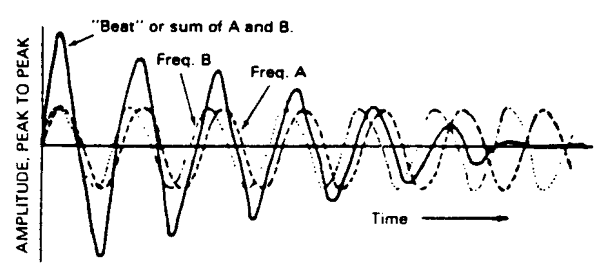
Under no conditions should a machine be operated in a resonant condition. When "criticals" are known to exist in the range of machine operating speeds, it is important that the machine pass through these points as quickly as possible.





BEAT FREQUENCY (periodic fluctuation)

A periodic rise and fall in the vibration level occurs when two frequencies are close to each other. This condition (beat frequency) is a result of the periodic "in phase" and "out of phase" condition of the vibrations. Beat frequencies are often found in multiple belt assemblies, as a result of the slippage in the belts. Also, when motors of nearly identical speed are mounted on a common base, a small difference in their speeds can cause vibrations to come in and out of step. A beat frequency condition can be eliminated by reducing the level of vibration of one of the sources to the point where it will not materially add or detract from the other source. The figure here shows high and low levels of vibration resulting when two vibrations of the same level are close to the same frequency.



The presence of a beat frequency indicates a need to locate the secondary vibration source and to keep it under surveillance. Increased vibration levels from the unknown source, even though small, may cause severe problems in the primary machine when vibrations are "additive." Strobe lamps are useful in detecting the unknown source.

Vitec, Inc.

4034 VELOCITY TRANSDUCER INSTALLATION AND SPECIFICATIONS

APPLICATION

The 4034 Velocity Transducer is a good quality transducer used for general purpose machine vibration measurement. It is self-powered device, capable of being used with cable runs of up to 1,000 ft.

INSTALLATION, ELECTRICAL

Cable Type: Use high quality, co-axial, or twisted, shielded cable between the transducer terminals and monitor terminals. Use of Vitec supplied cable assemblies is recommended.

Cable Length: Transducer to monitor cable length should not exceed 1,000 ft.

Cable Splicing: If cable splices are made, complete shielding must be maintained.

Cable Routing: Proper cable routing is required to avoid false signals being introduced into the measuring device (monitor). Avoid running transducer wires adjacent to, or parallel to, AC power lines. Where possible, provide a separate, grounded conduit to enclose the transducer cable. Route cable away from radio transmission equipment, motors, generators, and transformers. Avoid running cable through areas prone to ESD (Electro Static Discharge) or EMI (Electromagnetic Interference).

Cable Grounding: Connect the cable shield to a good, earth ground connection, at one end only (preferably at the monitor end of the cable). Vitec monitors provide this connection as a terminal block connection point.

INSTALLATION, MECHANICAL

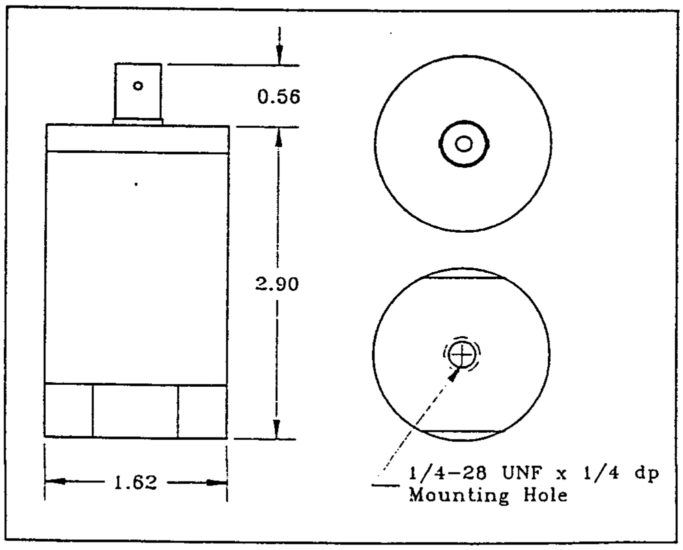
Location: Mount on, or as close as possible to, the bearing being monitored. Preferable mounting location is on the bearing cap.

Direction: The 4034 is only sensitive to vibrations that are occurring in the direction of the transducer's axis (the imaginary line running through the center of the connector and the mounting stud). Therefore, mount the transducer in a direction that will sense the vibrations to be measured.

Operating Position: The 4034 can be mounted in a position of +/- 180 degrees off of vertical, with vertical being defined as the connector in the "up", or 12:00 position.

Surface Preparation: The mounting surface must be flat and smooth. For best results, mounting surface should be flat to within 0.001 in TIR (Total Indicated Runout) over the full base dimension of the transducer, with a minimum 63 μin finish.

Stud Mounting: Drill and tap the mounting point for a 1/4-28 UNF stud, with a minimum thread depth of 3/8 in.



SPECIFICATIONS

Dynamic:	
Output, mV peak, +/- 10%, for 1.0 in/sec peak at 100 Hz	460
Frequency Response, %, 12 to 1,000 Hz	+/- 10
Natural Frequency, Hz, +/- 10%	10
Transverse Axis Sensitivity, %	10
Amplitude Range, inches, maximum: Horizontal Position Vertical and Inverted Position	 0.100 0.075
Operating G's, maximum	12.98
Damping	Shunt Resistor

Electrical:	
Power Requirements	None, Self Generating
Sensing Element Impedance, ohms, +/- 5%, at 77°F	215
Connections (Connector): Center Pin Shell	 Signal Signal Return

Environmental:	
Temperature Range, °F	30 to 160
Operating Position, degrees from vertical, connector up	+/- 180

Physical:	
Vitec Part No.:	412585-159A
Weight, oz.	14
Case Material	Aluminum, Anodized
Dimensions: Height, inches Body Diameter, inches Center Mounting Hole Wrench Flats, inches, at Bottom	 3.46 1.62 1/4-28 UNF x 1/4 in Deep 1-1/2
Mating Cable Assembly	Varies with application, contact factory

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