Accelerometer-Based Vibration Monitoring System

API STANDARD 678
FIRST EDITION, MAY 1981
REAFFIRMED, DECEMBER 1987

American Petroleum Institute
1220 L Street, Northwest
Washington, D C. 20005

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Refining Department

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FOREWORD

This standard is based on the accumulated knowledge and experience of manufacturers and users of monitoring systems. The objective of this publication is to provide a purchase specification for machinery monitoring systems using piezoelectric vibratory acceleration transducers.

This standard requires the purchaser to specify certain details and features. Also, it is recognized that the purchaser may wish to modify, delete, or amplify sections of the standard. It is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard rather than by rewriting or by incorporating sections into another complete standard.

Suggested revisions are invited and should be submitted to the director of the Refining Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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SECTION 1—GENERAL

1.1 Scope

This specification covers the minimum requirements for machinery monitoring systems using piezoelectric vibratory acceleration transducers It outlines a standardized system covering hardware (sensors and instruments) requirements, installation, and arrangement. This system may be used separately or in conjunction with noncontacting, eddy current proximity devices as described in API Standard 670 Accelerometer-based vibration monitoring systems are generally used for machinery having high shaft-to-bearing transmissibility, such as with rolling element bearings; for speed changers to monitor gear mesh condition; and for other turbomachinery to monitor such high frequency phenomena as blade rate, blade passing, and rubs, as well as such low frequency phenomena as cavitation and reciprocating compressor forces.

1.2 Alternative Designs

The vendor may offer alternative designs (see 6.1 for proposal requirements) Equivalent metric dimensions, fasteners, and flanges may be substituted as mutually agreed upon between purchaser and vendor.

1.3 Conflicting Requirements

In case of conflict between this standard and the inquiry or order, the information included in the order shall govern.

1.4 Definition of Terms

The terms used in this standard are defined as follows:

A *vibration transducer* is a device which converts mechanical vibration into an electrical signal proportional to that vibration.

A *piezoelectric accelerometer* is a transducer that translates vibratory acceleration to an electrical charge.

An *electrically isolated accelerometer* is one in which both signal leads are electrically separated from the accelerometer case.

The *charge amplifer cable* is the interconnection between the piezoelectric accelerometer and an external charge amplifier

The *extension cable* is the interconnection between an accelerometer having an integral impedance matching device and a junction box.

The *charge amplifier* is a conditioning device which converts the charge signal generated by the piezoelectric accelerometer and provides an output voltage signal proportional to the accelerometer's electrical charge (The charge amplifier must be powered by a direct current sufficient to provide the dynamic range required from the system.)

An *accelerometer with an integral impedance matching device* is a piezoelectric accelerometer with a built-in miniaturized charge amplifier (This design eliminates the need for an external charge amplifier.)

Linear frequency response range is the portion of the transducer's voltage output versus frequency curve, between the lower and upper frequency limits, where the response is within a specified tolerance.

Operating frequency range is the frequency range specified by the user for a particular type of machinery

A *channel* is a transducer and the hardware required to monitor its output signal

The term *field changeable* describes a required equipment feature the function of which may be changed after installation of the monitoring system. This change may be accomplished by (1) soldering jumper leads to terminal pins especially provided for this purpose, (2) employing circuit board-mounted switches or potentiometers, (3) using a shorting or diode pin-type matrix board, or (4) using prewired shorting plugs.

The term *field alterable* describes a required equipment feature the function of which may be altered after installation. This alteration may be accomplished by (1) making any changes in field changeable functions or (2) inserting or replacing plug-in modules or circuit boards in the monitor housing.

An *anticipatory alarm (alert)* is a device that indicates whether the transducer output signal has exceeded a pre-established value (first stage of alarm).

A *shutdown (danger)* is a device that indicates whether the transducer output signal has exceeded the anticipatory alarm value by a pre-established value (second or final stage of alarm).

A *filter* is an electrical device which suppresses signals outside the frequency range of interest

Signal suppression is a scheme for altering the vibration monitor's reading by subtracting (suppressing) mechanical runout, electrical noise, and so forth.

Root mean square (rms) is the square root of the mean of the square of the signal (voltage, acceleration, current) taken during a complete cycle.

The *machinery vendor* is the agency that designs, fabricates, and tests machines. The machinery vendor may purchase a monitoring system and may install transducers on machines.

The *instrument manufacturer* is the agency that designs, fabricates, and tests monitoring system components.

The *construction contractor* is the agency that installs the machinery train and installs monitors and connects them to transducers.

The *owner* is the final recipient of the machinery train; he may purchase the monitoring system.

G is a unit of acceleration equal to 386.4 inches per second squared (9.81 meters per second squared).

IPS is a unit of velocity equal to 1 inch per second (25.4 millimeters per second).

The *blade passing frequency* is calculated by multiplying the number of rotating blades times the rotational speed of the shaft.

The *blade rate frequency* is calculated by multiplying the blade passing frequency by the number of stationary blades, diffuser vanes, or volute tongues and dividing this number by the largest integer which is a common factor in the numbers of rotating blades and stationary blades, diffuser vanes, or volute tongues.

1.5 Referenced Publications

1.5.1 The latest edition of the following standards, codes, or specifications shall form to the extent specified herein a part of this standard.

IPCEA[1]	
S-61-402	*Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy*
ISO[2]	*Requirements for Instruments for Measuring Vibration Severity*
NFPA[3]	
Bulletin No. 70	*National Electrical Code*, Article 725, "Class 1, Class 2, and Class 3, Remote-Control, Signaling, and Power Limiting Circuits"
496	*Purged and Pressurized Enclosure for Electrical Equipment in Hazardous Locations*
NEMA[4]	
ICS 1-110	*Enclosures*
ANSI[5]	
Y-14.2	*Line Conventions and Lettering*

1.5.2 The applicability of any federal, state, or local codes, regulations, ordinances, or rules shall be mutually agreed upon by the purchaser and the vendor.

[1] Insulated Power Cable Engineers Association, 283 Valley Road, Montclair, New Jersey 07042.
[2] International Standards Organization, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.
[3] National Fire Protection Association, 470 Atlantic Avenue, Boston, Massachusetts 02210.
[4] National Electrical Manufacturer's Association, 2101 L Street, N.W., Washington, D.C. 20037.
[5] American National Standards Institute, 1430 Broadway, New York, New York 10018.

SECTION 2—GENERAL DESIGN SPECIFICATIONS

2.1 Linearity Requirements

The minimum linearity requirements of the system, including the transducer, the power supply, and the monitor, as calibrated on a bench test, shall be as described in 2.1.1 and 2.1.2 unless otherwise specified by the purchaser.

2.1.1 Accelerometer linearity shall be ±5 percent of 100 millivolts per *G* (or 10 pico coulombs per *G* for accelerometers without integral impedance matching devices) sensitivity over a minimum operating range of 0.1 to 75 *G* peak and over the frequency range of 5 hertz to 10 kilohertz.

2.1.2 Channel linearity shall be 10 percent of specified full scale acceleration display range over a frequency range of 5 hertz to 10 kilohertz.

2.2 Environmental Requirements

2.2.1 TEMPERATURE

The linearity requirements of 2.1 shall apply over the temperature ranges and temperature transients described in 2.2.1.1 through 2.2.1.6.

2.2.1.1 Piezolectric accelerometer without integral impedance matching device and charge amplifier cable: −65 to +450 F (−54 to +232 C) and a temperature transient of 5 F (2.8 C) per second.

2.2.1.2 External charge amplifier: −30 to +185 F (−34 to +85 C).

2.2.1.3 Accelerometer with an integral impedance matching device and extension cable: −65 to +250 F (−54 to +121 C) and a temperature transient of 5 F (2.8 C) per second.

2.2.1.4 Monitor and power supply: −20 to +150 F (−29 to +66 C).

• **2.2.1.5** When applications requiring operation of the charge amplifier outside the above temperature range are specified, military specification components suitable for −67 to +257 F (−55 to +125 C) shall be furnished.

NOTE: A bullet (•) in the margin indicates that a decision by the purchaser is required.

2.2.1.6 For certain special applications, such as gas turbine casings, components suitable for higher temperature ranges may be required. Details of such installations shall be mutually agreed upon by the purchaser and the vendor.

2.2.2 HUMIDITY

The linearity requirements of 2.1 shall apply at levels of relative humidity up to 95 percent noncondensing.

2.2.3 SHOCK

Accelerometers, both with and without integral impedance matching devices, shall be capable of surviving a mechanical shock of ±5000 *G*, peak, without affecting the linearity requirements specified in 2.1.

2.3 Interchangeability

All components covered by this standard shall be physically and electrically interchangeable without requiring recalibration of the channel to stay within the linearity requirements of 2.1. (This does not imply that interchangeability of components from different instrument manufacturers is required.)

2.4 System Responsibility

• **2.4.1** All monitoring equipment purchased under this standard and installed for a single machinery train shall be purchased from the same instrument manufacturer. The machinery vendor, instrument manufacturer, or construction contractor, as specified by the owner, shall assume responsibility for the design and installation of the monitoring system for the train.

2.4.2. The agency responsible for system design shall ensure that proper relay arc suppression is implemented throughout the system.

SECTION 3—CONVENTIONAL HARDWARE

3.1 Piezoelectric Accelerometers

3.1.1 The conventional electrically isolated accelerometer is an assembly consisting of a case, an electrically isolated piezoelectric crystal, an integral impedance matching device, and a connector. This accelerometer shall be used when the mounting environment temperature is less than 250 F (121 C).

3.1.2 The optional electrically isolated accelerometer is an assembly consisting of a case, an electrically isolated piezoelectric crystal, and a connector. This accelerometer requires an external charge amplifier and shall be used when the mounting environment temperature is equal to or greater than 250 F (121 C) and less than 450 F (232 C).

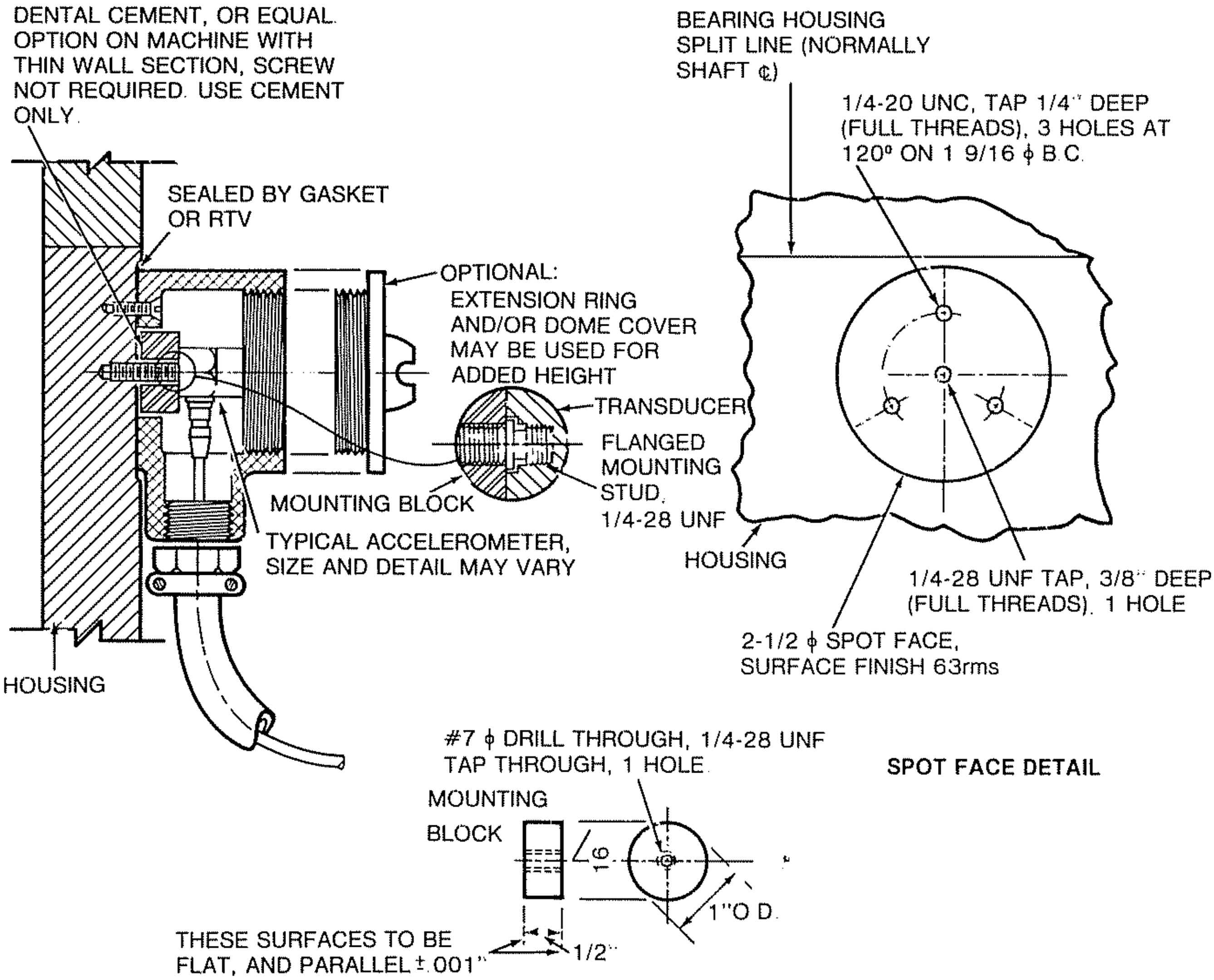
3.1.3 The accelerometer case shall be constructed from Type 316 stainless steel and shall be hermetically sealed. The case shall have a maximum outside diameter of 1 inch ±0.125 inch (25 millimeters ±3 millimeters). The overall case height shall not exceed 2.5 inches (65 millimeters) not including the connector. The accelerometer case base shall be fitted with standard wrench flats. The base shall have provision for safety lock wiring.

3.1.4 The accelerometer case mounting surface shall be finished to a maximum roughness of 16 microinches rms. The center of the mounting surface shall be drilled and finished tapped (perpendicular to the mounting surface ±5 minutes of an arc) with a ¼-28 UNF-2A threaded hole of ¼-inch minimum depth. The monitor vendor shall supply with each accelerometer a double-ended, flanged ¼-28 UNF-2A threaded, stainless steel mounting stud. The stud shall not prevent the base of the accelerometer from making flush contact with the mounting block (see Figure 1). (See Figure 2 for accelerometer housing details.)

3.1.5 The accelerometer transverse sensitivity shall not exceed 5 percent of the active axis sensitivity over the frequency range and operating range specified in 2.1.

3.2 Cables

• **3.2.1** Extension cables shall be shielded, twisted pair, or



NOTES:
1. Horizontal mount shown. A vertical mount would be similar but would be located on top of the bearing (90 degrees CCW).
2. Spot facing is shown on the existing housing but a raised boss with finish is preferred.

Figure 1—Accelerometer Case and Mounting Details

shielded twisted triad in accordance with Appendix A or coaxial as specified (see Figures 3 and 4). When specified, the conductors shall be tinned.

3.2.2 The charge amplifier cable shall be a low noise coaxial cable (see Figure 3).

3.2.3 The total physical length of the extension/charge amplifier cable shall be a minimum of 108 inches ±3 inches (274 centimeters ±7.5 centimeters) and a maximum of 180 inches ±6 inches (457 centimeters ±15 centimeters). This length is needed in order to provide physical compatibility with proximity probe systems.

3.2.4 The extension/charge amplifier cable and connector(s) assembly shall be designed to withstand a minimum tensile load of 50 pounds (222.5 Newton).

3.3 Connectors

The attached connector(s) shall meet or exceed mechanical, electrical, and environmental requirements specified in

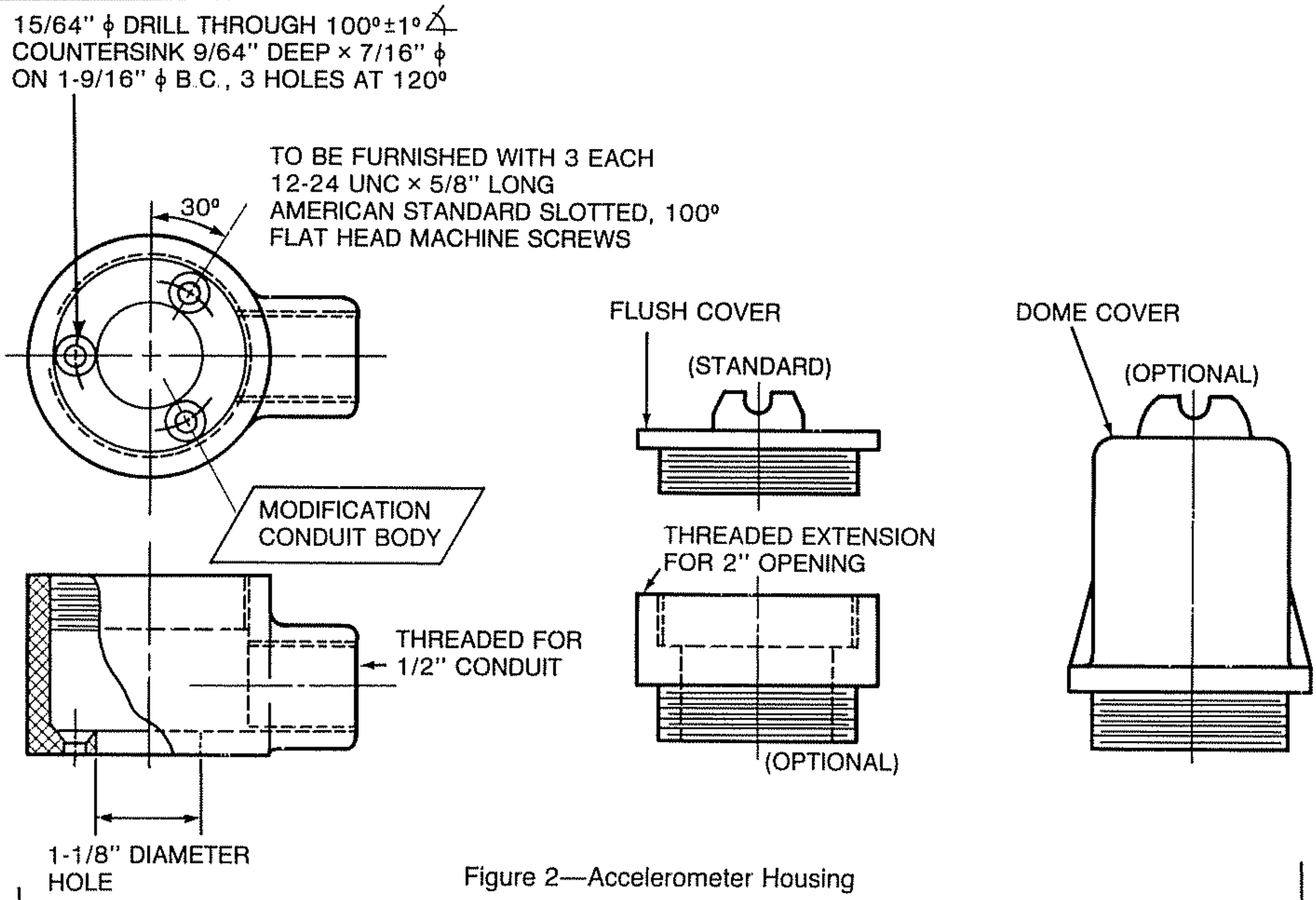
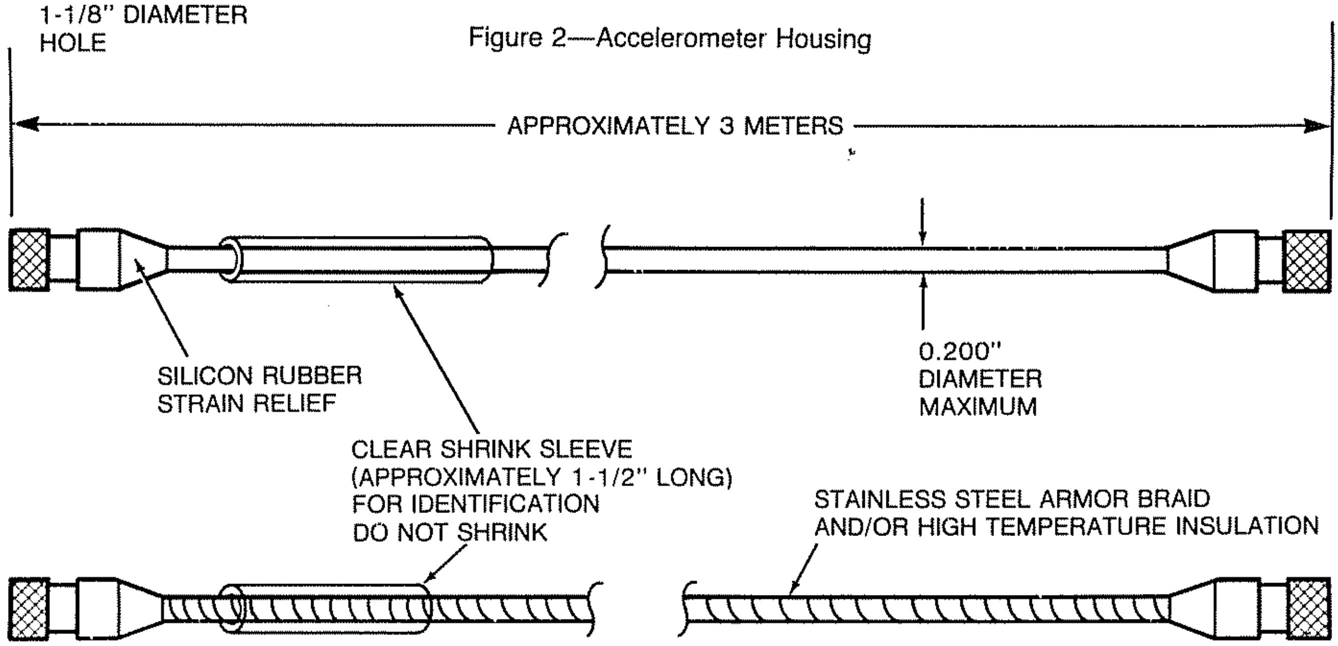


Figure 2—Accelerometer Housing



OPTIONAL CABLE FOR SEVERE DUTY SERVICE

Connectors: Type 316 stainless steel
Standard cable: #29 AWG
Fused teflon jacket
TFE insulation

30 pF/ft. capacitance
Low noise type, 1 5 pC, P P maximum
To withstand 95° humidity (noncondensing)
Temperature range: 450°F to 500°F

Figure 3—Charge Amplifier or Extension Cable

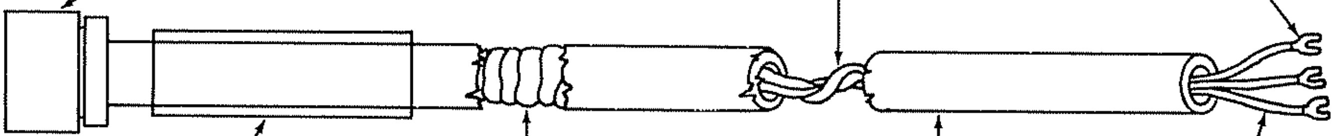


Figure 4—Extension Cable

2.2 and 3.2. Connector body material shall be Type 316 stainless steel. The connector shall be commercially available.

3.4 Charge Amplifiers

3.4.1 For installations where the accelerometer environment temperatures exceeds +250 F (+121 C), external charge amplifiers shall be used.

3.4.2 The charge amplifier shall be linear in accordance with the tolerances allowed in 2.1 with a standard supply voltage of minus 24 volts of direct current

3.4.3 The output, common, and power supply connections on the external charge amplifier shall be by means of a Type 316 stainless steel heavy duty, barrier-type terminal strip with size 6-32 screws of Type 316 stainless steel.

3.4.4 Means shall be provided for obtaining field data without disturbing the normal connections

3.4.5 The maximum outside physical dimensions for the external charge amplifier shall be 2.5 inches by 3.5 inches by 2.5 inches in height (6.35 centimeters by 8.9 centimeters by 6.35 centimeters) (see Figure 5).

3.5 Power Supply and Systems Output Relays

• **3.5.1** Monitoring hardware shall be capable of providing the readout linearity requirements specified in 2.1 with input voltage to the power supply of 117 volts alternating current rms ± 15 percent (50/60 hertz ± 10 percent). If an alternate power supply input is specified by the owner, the same accuracy and linearity requirements shall apply.

3.5.2 The output voltage from the power supply to the charge amplifier shall be minus 24 volts of direct current with sufficient regulation and ripple suppression to meet the linearity requirements specified in 2.1

3.5.3 The power supply shall be capable of sustaining a short circuit across the output for prolonged periods of time without damage. Output voltage shall return to normal upon removal of an overload or short circuit.

3.5.4 Channel isolation shall be provided to prevent a short circuit in one transducer from shorting or tripping any other transducer.

3.5.5 The monitor power shall be immune to an instantaneous transient input voltage equal to twice the normal rated peak input voltage for a period of 5 microseconds. Such a transient voltage shall not damage the power supply or affect normal monitor operations.

3.5.6 As a minimum for all instruments, the power supply transformer shall have separate isolated windings with grounded laminations or shall be shielded to eliminate the possibility of high voltage in the transformer secondary; in case of an insulation fault, the input voltage shall be shorted to ground

3.5.7 A minimum of three relays shall be provided: one anticipatory alarm (alert), one shutdown (danger), and one circuit fault relay. Anticipatory alarm and circuit fault relays shall be of the single-pole, double-throw type. Shutdown relays shall be of the double-pole, double-throw type with electrically isolated contacts.

3.5.8 All relays shall exhibit the following general specifications:

1. Relays shall be electromechanical or solid state.
2. Relays shall be hermetically sealed.
3. All contacts shall be wired to an accessible and clearly marked terminal board for field wiring attachment.
4. Relays shall have a contact rating of 5 amperes resistive load at 120 volts alternating current for a minumum of 10 000 operations.
5. Pole contacts on double-pole, double-throw relays shall be electrically isolated.
6. Alarm output relay contacts shall be completely isolated electrically from shutdown output relay contacts.

3.5.9 The minimum configuration for an anticipatory (alert) relay shall be single-pole, double-throw. Standard operational status shall be normally energized unless otherwise specified. Anticipatory alarm (alert) relays shall be of the latching (manual reset) type and shall be field changeable to nonlatching. Latching shall be electrical with at least one reset switch per power supply.

3.5.10 The minimum configuration for a shutdown (danger) relay shall be double-pole, double-throw. Operational status shall be normally deenergized unless otherwise specified. There shall be no false shutdown as a result of power interruption (line power or direct current output power) regardless of mode or duration except for the normally energized shutdown relay output. Shutdown (danger) alarms shall be field changeable to latching (manual reset) or nonlatching (automatic reset). Latching shall be standard. Latching shall be electrical with at least one reset switch per power supply.

3.5.11 The minimum configuration for a circuit fault relay shall be single-pole, double-throw. Operational status

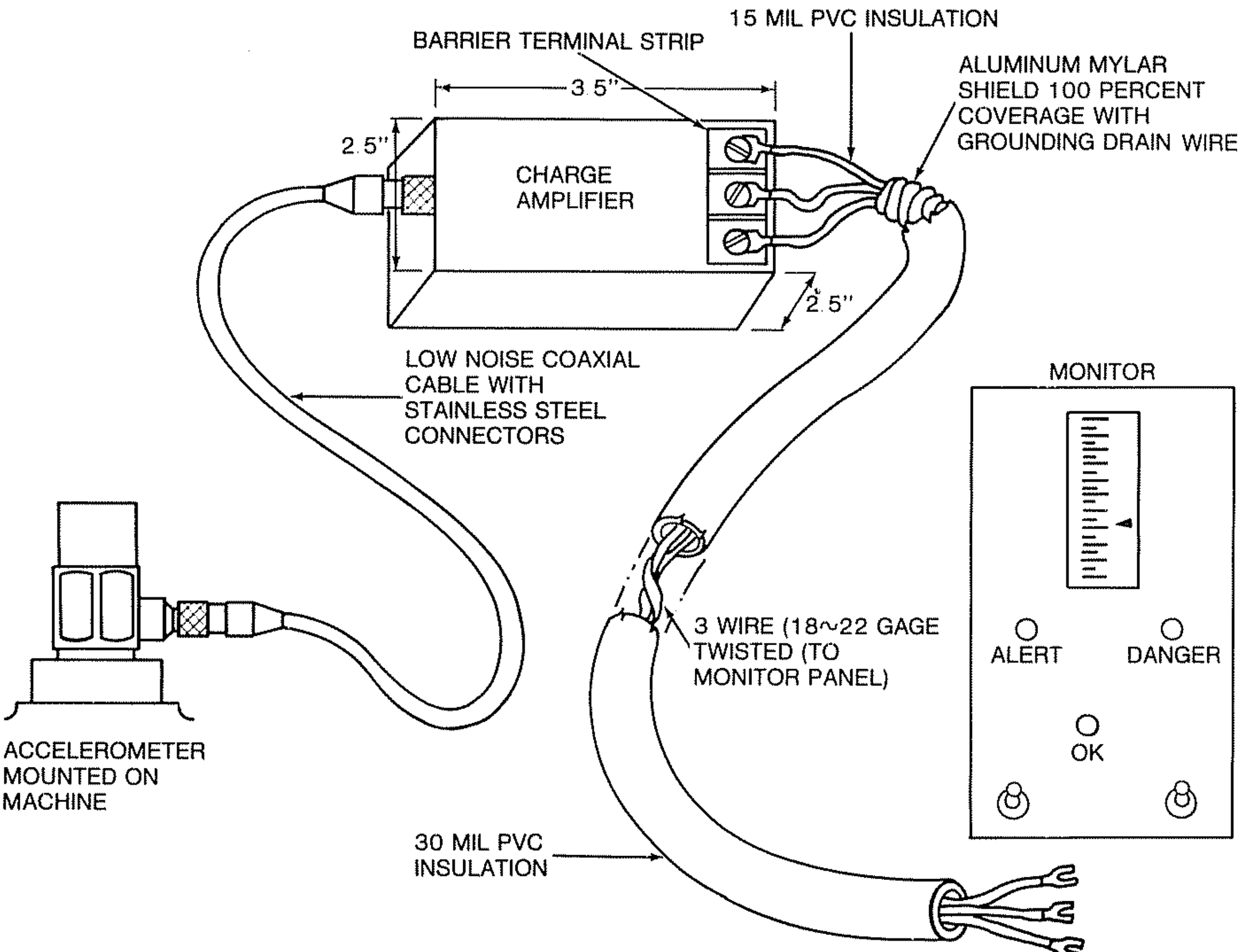


Figure 5—Accelerometer with External Charge Amplifier

shall be normally energized unless otherwise specified. A power supply failure shall activate the circuit fault relay.

3.5.12 The relay control circuit shall be field changeable to be either (1) de-energized to shutdown or alarm or (2) energized to shutdown or alarm.

3.6 Vibration Monitor

3.6.1 The front panel surface area, excluding mounting rack or bezel, shall not exceed 17 square inches (100 square centimeters) per monitor.

3.6.2 Each monitor shall be provided with the following features as a minimum unless otherwise specified:

• 1. Continuous indication (analog or digital) of vibration displayed in the units and range specified by the owner on the data sheet. Analog display, if used, shall have linearly spaced graduations with increments as specified in 3.6.10 and 3.8.
2. Anticipatory alarm (alert) output to alarm relay.
3. Shutdown (danger) output to shutdown relay with separate and isolated alarm contact.
4. Zero to ten volts of direct current signal (proportional to the displayed variable) available at a barrier strip connection located at the rear of the monitoring system.
5. Indicating, light-emitting diodes for anticipatory alarm, shutdown, and circuit fault.
6. Connections for monitoring the transducer output signal on the front of the panel and on a barrier strip located at the rear of the monitor. A short circuit of these outputs shall not affect monitor operation.
7. Front panel readout of anticipatory alarm and shutdown settings.
8. Front panel and remote reset of latching alarms and shutdowns.
9. A system to identify the first anticipatory alarm and the first shutdown. (The first-out indicators need not be located on the individual monitors.)

3.6.3 Internal circuit fault monitoring with a common alarm relay located in the rack or power supply and an indicating, light-emitting diode on each monitor shall be provided. A circuit fault alarm shall not initiate a shutdown. The circuit fault system shall be set to actuate when an open circuit or short circuit exists in the monitor-transducer-monitor loops (including the charge amplifier-transducer-charge amplifier loop).

3.6.4 The electrical and mechanical zeros, gain, alarm, and shutdown adjustments shall be tamperproof and not directly accessible on the front panel. The monitor shall continue to function normally during adjustment. Adjustments shall be accessible from the front side of the monitor system without the aid of special tools.

3.6.5 Fixed time delays for shutdown shall be field changeable to either 1 or 3 seconds. One second shall be standard.

3.6.6 A tamperproof means for disarming the shutdown and a visible indicating light-emitting diode shall be provided for each monitor channel. A common disarmed indicator relay located in the rack or power supply shall be furnished.

3.6.7 The anticipatory alarm (alert) and the shutdown (danger) set points shall be individually adjustable over the entire specified display range.

3.6.8 Signal suppression in the monitor shall not be allowed.

3.6.9 Printed circuit boards shall be coated for protection against moisture, fungus, and corrosion.

3.6.10 The conventional monitor shall have display, alarms, and direct current proportional to acceleration output over a range of 0 to 30 *G* true rms (not calculated from peak or average). Graduations for analog display (if used) shall have three major divisions. Each major division shall have ten minor divisions.

3.6.11 The conventional monitor shall be field alterable to accommodate any combination of options listed in 3.8.

•3.7 Filters

Filter architecture shall be Butterworth (or other design approved by the owner) with unity gain and no loss in the passband greater than 0.5 decibel referenced to the input signal level. The filter shall have a roll-off rate of 24 decibel per octave at the cutoff frequency (−3 decibel) specified by the owner.

•3.8 Monitor Options

When specified on the data sheet, the monitor shall be provided with the options described in 3.8.1 through 3.8.3.

3.8.1 A dual meter face graduated with three major divisions, each having ten minor divisions, and ten major divisions, each having 5 minor divisions shall be provided. The monitor shall have front panel indication of the readout mode (acceleration or velocity) and meter range selected. The monitor shall be provided with the following readout options:

1. Acceleration ranges of 0 to 3 *G* rms, 0 to 10 *G* rms, and 0 to 30 *G* rms (true rms, as above).
2. Single integration with scale ranges of 0 to 0.3 IPS peak (0 to 7.5 millimeters per second peak), 0 to 1.0 IPS peak (0 to 25 millimeters per second peak), and 0 to 3.0 IPS peak (0 to 75 millimeters per second peak) over a frequency range of 5 to 2500 hertz.

3.8.2 Monitor operation (including detection and display) shall use peak units rather than rms units.

3.8.3 Two filters in series shall be provided per monitor. Filters shall be any combination of high pass and/or low pass, as specified. Filtering shall occur prior to integration. These filters shall be in accordance with 3.7.

3.9 Wiring and Conduit (General)

Wiring and conduit shall be installed in accordance with the *National Electric Code*, Article 725, and good electrical installation practices as illustrated in Figures 1, 5, 6 and 7. All components (transducers, amplifiers, and so forth) and conduits shall be located in well ventilated areas away from hot spots, such as lines, machinery, and vessels. Components shall not be buried in insulation or obstructed by machinery covers, conduits, piping, or similar equipment. All components, conduit, and so forth, shall be located to allow disassembly and repair of equipment and machinery without removal of, or damage to, the conduit. Segregation of signal and power wiring shall be maintained according to good instrument installation practices. Signal wiring shall not be run in conduit or in trays with circuits above 30 volts of either alternating or direct current.

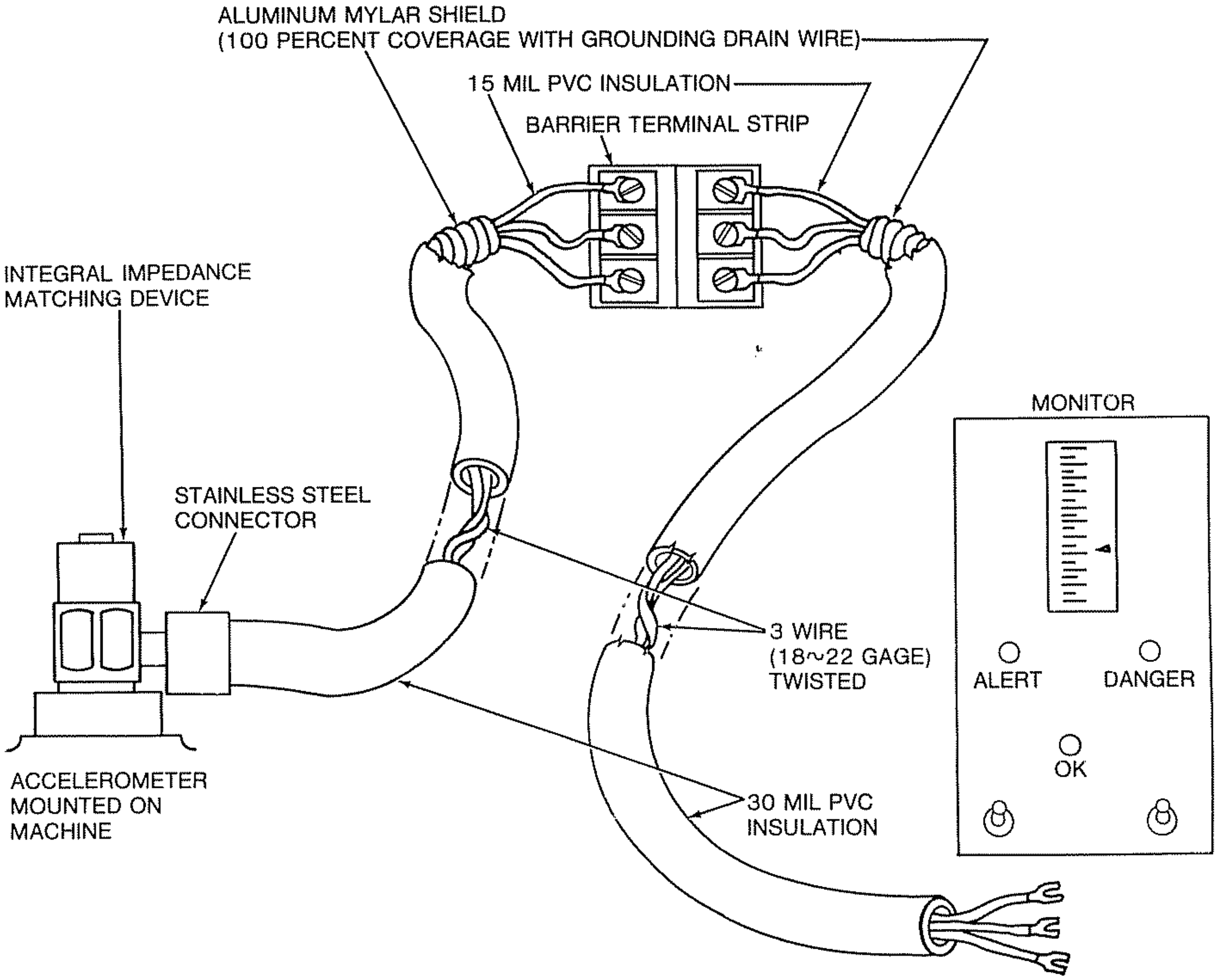


Figure 6—Accelerometer with an Integral Impedance Matching Device

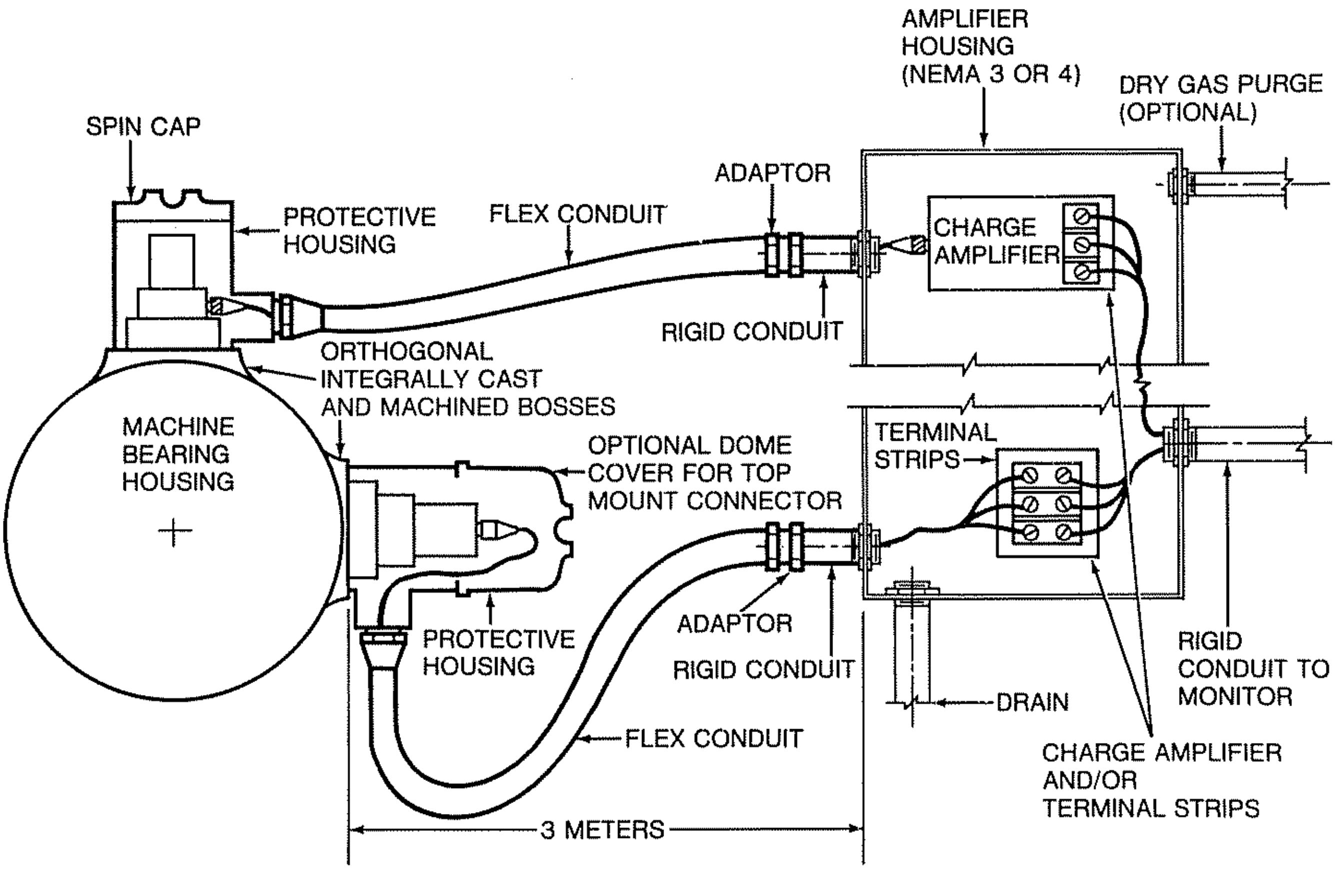


Figure 7—Transducer Orientation

•3.10 Conduit Run to Panel

Conduit of suitable size to accommodate the cables shall be installed with a drain at each low point. Underground conduit shall be adequately sealed to prevent the entrance of moisture. Three-wires twisted, shielded cables with No 18 to No. 20 gage stranded conductors shall be used. The cable shall be in accordance with the provisions of Appendixes A and B. When specified, the conductors shall be tinned. The physical length of the cable shall be limited to 500 feet (150 meters). The use of longer cable runs must be reviewed and approved in writing by the instrument manufacturer.

3.11 System Grounding

The construction contractor responsible for installation of the monitoring system shall ensure that good grounding practice is followed; cable shields shall be grounded only at one point.

•3.12 Location of Monitor

Monitors shall be located indoors or outdoors, as specified by the owner. (It should be recognized that outdoor installations must be designed and located to avoid adverse vibrational and environmental effects.)

3.13 Field-Installed Instruments

• **3.13.1** Field-installed vibration instrumentation systems shall be suitable for the electrical classification of the area in which they are installed. In hazardous areas systems shall be suitable for Class 1, Group B, C, or D, Division 2 (nonincendive) as specified by the owner. Housings shall be weatherproof (NEMA 3) or watertight (NEMA 4) if outdoors and/or subject to fire sprinklers.

Intrinsically safe systems are preferred; however, air purging of housings described in 3.13.2 is acceptable for meeting hazardous area requirements, if approved in writing by the owner.

• **3.13.2** When specified, air purging shall be used to avoid moisture problems even when weatherproof and watertight housings are used (see 3.13.1).

Purge air shall be clean and dry as in Type X or Y of NFPA 496, as required.

3.13.3 All charge amplifier junction boxes shall be arranged on the same side of the equipment train.

3.14 Calibration and Functional Test

3.14.1 Each transducer, amplifier, and charge amplifier cable (if any) shall be calibrated to meet the requirements of 2.1. This calibration shall be verified and documented by the agency that installs the transducer and monitoring system. A shaker, simultaneously exciting a separate calibration accelerometer, and a readout shall be used for calibration. Calibration of the transducer shall be performed at 2 *G*, rms, over a frequency range of 5 hertz to 10 kilohertz at a minimum of ten equally spaced frequencies and at 100 hertz over an amplitude range of 0 to 30 *G*, rms, at a minimum of five equally spaced amplitudes. These calibration tests shall be graphed, and the graphs shall be supplied to the owner.

3.14.2 All power supply functions and monitor features listed in 3.5, 3.6, and 3.7 shall be functionally tested and the calibration verified as being in accordance with the limits set in 2.1. These tests and calibrations shall be performed following the final field installation and documented by the agency that is responsible for the final installation of the monitoring system.

3.14.3 A system functional check shall be performed in the field on each monitor channel (except for the transducer) by injecting an electrical signal equivalent to 75 percent of the full scale meter reading at a fixed frequency which is within the range of the monitor.

SECTION 4—TRANSDUCER ARRANGEMENT

4.1 Location

Locations described in 4.1.1 through 4.1.4 are the minimum required for adequate machine protection. The owner shall have the option to review and approve the location of all transducers.

4.1.1 Transducers intended to monitor radial vibration shall be located on the radial bearing housing. If two transducers are located on one radial bearing housing, they shall be oriented such that one senses the vibration in the horizontal plane and the other senses the vibration in the vertical plane (on a vertical shaft machine, the transducers should sense the vibration in orthogonal planes). (See Figure 7.)

4.1.2 Transducers intended to monitor axial vibration shall be located on or as near as possible to the thrust bearing housing.

4.1.3 Location of transducers intended to monitor casing vibration created by sources such as blade passing must be jointly developed by the machinery manufacturer and the owner. In some applications, field determinations of the optimum mounting location may be required.

4.1.4 For gearboxes, one accelerometer shall be mounted radially on the coupling-end bearing housing of the high speed shaft and one accelerometer shall be mounted axially on the thrust bearing housing.

4.2 Transducer Mounting

4.2.1 The machinery vendor shall provide prepared transducer mounting points as shown in Figure 1. The boss or surface shall be cast integrally with the machine part.

4.2.2 The instrument manufacturer shall provide accelerometer mounting blocks as shown in Figure 1 for each transducer. These blocks shall be made of Type 316 stainless steel unless otherwise specified by the owner.

4.2.3 All cables shall be enclosed in conduit. The conduit shall not be attached to the accelerometer. It shall be attached to an enclosing box. Figures 1 and 2 show typical mounting and enclosing box arrangements.

4.3 Charge Amplifier Mounting

When an external charge amplifier is used, it shall be mounted in a junction box which provides a vibration-free environment. Where feasible, all externally mounted charge amplifiers for a machine shall be mounted in a common junction box (see Figure 7).

4.4 Transducer Identification

4.4.1 Each extension/charge amplifier cable and charge amplifier shall be plainly marked to indicate the transducer location and service.

4.4.2 For the owner's field identification, a piece of clear shrink-tubing (not to be shrunk at the factory) 1½ inches (38 millimeters) long shall be installed over the cable before the connector is installed.

SECTION 5—DOCUMENTATION AND DRAWINGS

5.1 Documentation

5.1.1 Machinery vendors shall furnish, at the time indicated in the following paragraphs, the specified numbers of copies of documentation on vibration monitoring system installation and calibration details and vibration limits as listed in 5.1.2 through 5.1.4.

Calibration and functional checkout of the entire monitoring system shall be performed by the appropriate construction agency prior to startup. The specified number of copies of documents shall be furnished to the owner.

5.1.2 At least 6 months prior to scheduled shipment, the machinery vendor shall supply:

1. Recommended vibration limits for anticipatory alarm and shutdown set points. Limits shall be stated in terms of monitor display (*G*s rms, IPS peak, and so forth).
2. A completed system arrangement plan for each machine in the train. The plan shall be in accordance with the description in Appendix C.
3. Wiring diagrams (including schematic, connection, and elementary diagrams) for installation and maintenance.
4. Supplementary proposal for spare parts other than those included in the original proposal. This supplementary proposal shall include recommended spare parts, cross-sectional or assembly-type drawings, parts numbers, materials, prices, and delivery. Parts numbers shall identify each part for interchangeability purposes. Standard purchased items shall be identified by the original manufacturer's numbers. This supplementary proposal shall be forwarded to the owner promptly after receipt of approved drawings and in time to permit ordering and delivery of parts prior to field startup.
5. Transducer serial numbers (manufacturer's) and transducer model numbers (manufacturer's)
6. Completed as-built API data sheets (see Appendix D).

5.1.3. Prior to performing the machinery vendor's factory mechanical tests, calibration curves for each transducer shall be supplied. Serial numbers and model numbers shall be included on each calibration curve.

5.1.4 Not later than 5 days after the scheduled shipping date, instruction manuals for the complete vibration monitoring system shall be supplied. The manuals shall include drawings and instructions covering installation; parts list; completed data sheets; final test calibrations; checks, start-up, and operating limits; operating procedures; and maintenance procedures.

5.2 Drawings

5.2.1 When necessary to meet the scheduled shipping date, the vendor shall proceed with manufacture without awaiting purchaser approval of drawings, unless otherwise specified.

5.2.2 Approval of drawings shall be made promptly after receipt by owner. However, such approval shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the drawings have been approved, certified copies shall be furnished in the quantity specified. All drawings must be clearly legible and in accordance with ANSI Y-14.2.

5.2.3 The following information shall be provided on the drawings:

1. The purchase order number (on every drawing).
2. The owner's equipment item number (on every drawing).
3. All principal dimensions including those required for panel arrangements, maintenance clearances, and dismantling clearance. Typical drawings are not acceptable.
4. Complete bills of material covering the entire scope of supply.
5. A list of reference drawings.
6. Special weather protection and climatization features, if any, supplied by the vendors and required by the owner.

SECTION 6—PROPOSALS AND SHIPMENT

6.1 Proposals

Proposals shall provide the following:

1. Complete descriptive information [including necessary drawings, diagrams, and API data sheets (see Appendix D)] covering any equipment that the machinery vendor, instrument manufacturer, or construction agency proposes to furnish. The machinery vendor, instrument manufacturer, or construction agency shall submit API data sheets completed to the greatest extent practicable.
2. A price list of spare parts
3. An outline for the owner showing all necessary special weather and winterizing protection required. The proposal shall list separately the proposed protective items
4. Either a specific statement that all equipment is in strict accordance with the owner specifications or a specific list

of deviations therefrom. All deviations shall be detailed and explained. Deviations may include alternative designs equivalent to those specified and guaranteed for the specified duties.

6.2 Shipment

The shipment date shall be specified in the vendor's proposal as a fixed number of weeks from the receipt of the order.

APPENDIX A
SINGLE CIRCUIT CABLE (NO MECHANICAL PROTECTION) WITH SHIELD FOR VIBRATION TRANSDUCER

This appendix covers the minimum requirements for a single circuit cable with a shield for a vibration transducer with a shield (The cable requires a conduit or a tray system for mechanical support and protection.) Insulation must conform to Article 725 of the *National Electrical Code* and must withstand with no shorts a 1-minute, 3000 volt, direct current test potential between conductor to conductor and conductor to shield.

	Description of Cable
Conductors	18 to 20 gage, 7 strand, Class B concentric lay copper per IPCEA S-61-402, Part 2, Table 1.
Primary insulation	15 mils (380 micrometers) minimum, 90 C polyvinyl-chloride (PVC). For environmental temperature higher than 90 C, special suitable insulation, such as tetra-fluoroethelene, shall be used.
Number of conductors	3 twisted.
Color code	Black, white, and red.
Lay of twist	1½ to 2½ inches (3.75 to 6.25 centimeters).
Shield	100 percent coverage. Aluminum/mylar shield with a minimum aluminum thickness of 0.35 mils (8.8 micro-meters) helically applied with a minimum of a 25 percent overlap. Aluminum side to be in continuous contact with a bare 22 American Wire Gage (AWG), 7 strand, Class B concentric lay drain wire.
Overall jacket	30 mils (750 micrometers) nominal, 80 C PVC.

APPENDIX B
MULTICIRCUIT CABLE (NO MECHANICAL PROTECTION) WITHOUT GROUP SHIELD FOR VIBRATION TRANSDUCER

This appendix covers the minimum requirements for a multicircuit cable without a group shield for a vibration transducer. (The cable requires a conduit or a tray system for mechanical support and protection.) Insulation must conform to Article 725 of the *National Electrical Code* and must withstand with no shorts a 1-minute, 3000 volt, direct current test potential between conductor to conductor and conductor to outer shield.

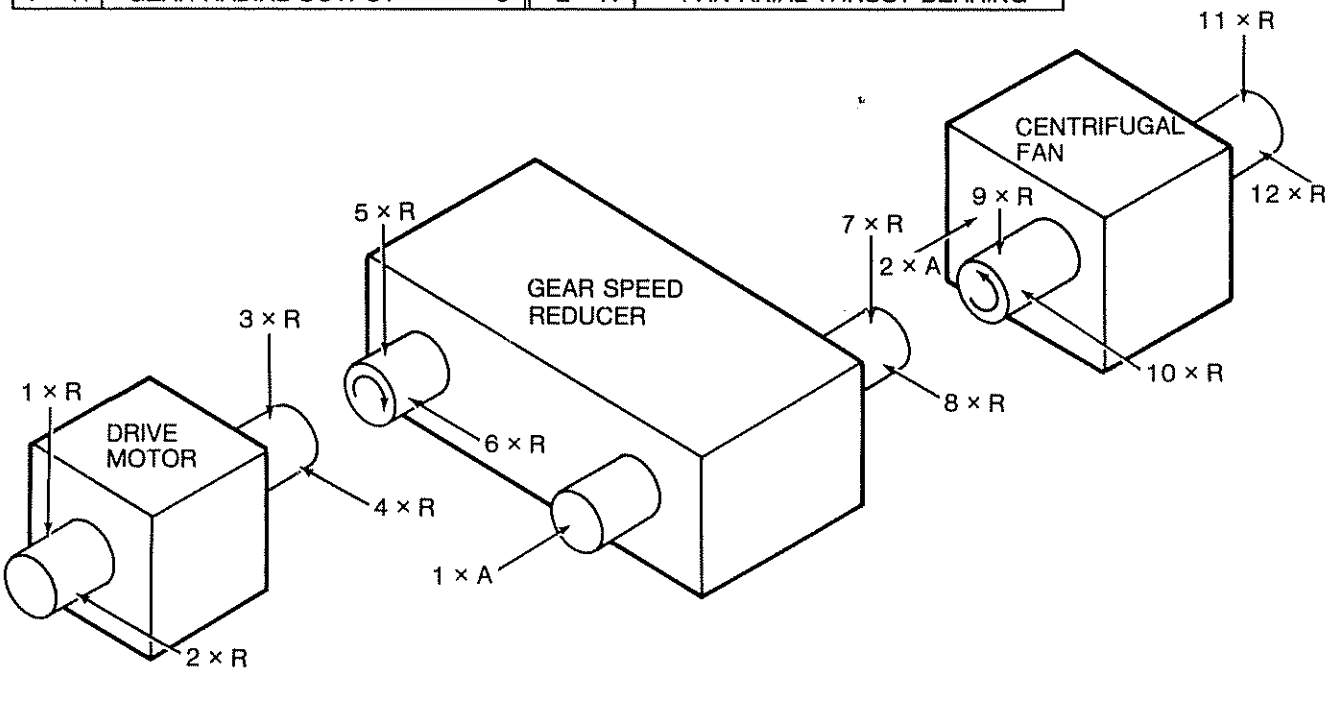
	Description of Cable
Conductors	18 to 20 gage, 7 strand, Class B concentric lay copper per IPCEA S-16-402, Part 2, Table 1
Primary insulation	15 mils (380 micrometers) minimum, 90 C PVC
Number of conductors per group	3 twisted
Color code	Black, white, and red.
Lay of twist	1½ to 2½ inches (3.75 to 6.25 centimeters).
Overall shield	2 to 3 mils (50 to 75 micrometers) of aluminum/mylar tape with a minimum aluminum thickness of 0.35 mils (8.8 micrometers) helically applied with a 25 percent overlap. Aluminum side to be a continuous contact with a bare copper 18 AWG, 7 strand, Class B concentric lay drain wire
Communication wire	22 gage, 7 strand, Class B concentric lay copper with 30 mils (750 micrometers) of insulation. Color code other than group color

APPENDIX C
TYPICAL SYSTEM ARRANGEMENT PLAN

This appendix presents a typical system arrangement for a motor, centrifugal fan, and double helical gear (see Figure C-1). The arrangement plan furnished for each machinery train (see 5.1.2 item 2) must illustrate as a minimum the following items:

1. The position of each transducer in relation to the machine's bearings.
2. The machine rotation showing a view of all drivers from the high pressure or outboard end and all driven machines from the driven end.
3. A complete system description, including any pertinent information applicable to the particular system layout and including:
   a. Transducer number, type, and positions.
   b. Bearing types.
   c. Radial transducer clock positions with degrees referenced to vertical top dead center (TDC) as zero.

ITEM	DESCRIPTION	ITEM	DESCRIPTION
1 × R	MOTOR RADIAL OUTBOARD 0°	8 × R	GEAR RADIAL OUTPUT 90°
2 × R	MOTOR RADIAL OUTBOARD 90°	9 × R	FAN RADIAL INBOARD 0°
3 × R	MOTOR RADIAL INBOARD 0°	10 × R	FAN RADIAL INBOARD 90°
4 × R	MOTOR RADIAL INBOARD 90°	11 × R	FAN RADIAL OUTBOARD 0°
5 × R	GEAR RADIAL PINION 0°	12 × R	FAN RADIAL OUTBOARD 90°
6 × R	GEAR RADIAL PINION 90°	1 × A	GEAR AXIAL THRUST BEARING
7 × R	GEAR RADIAL OUTPUT 0°	2 × A	FAN AXIAL THRUST BEARING



NOTE: Notation conforms to the Instrument Society of America standard references.
X vibration transducers
R radial transducer
A axial transducer

Figure C-1—Typical System Arrangement Plan for a Fan

APPENDIX D
TYPICAL ACCELEROMETER BASED VIBRATION MONITORING SYSTEM DATA SHEETS

ACCELEROMETER-BASED VIBRATION MONITORING SYSTEM DATA SHEET
Customary Units

JOB NO ____________ ITEM NO ____________
PURCHASE ORDER NO ____________
REQUISITION NO ____________
INQUIRY NO ____________
PAGE ______ OF ______ BY ____________

APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT DATE ____________ REVISION ____________

OWNER ____________ CONSTRUCTION AGENCY ____________

MACHINERY VENDOR ____________ INSTRUMENT MANUFACTURER ____________

SITE ____________ SERVICE ____________

NOTE: INFORMATION TO BE COMPLETED ○ BY PURCHASER ☐ BY MANUFACTURER

MACHINERY TRAIN COMPONENTS

○ **NUMBER OF:**

PUMPS ____________ STEAM TURBINES ____________

GAS TURBINES ____________ GEAR UNITS ____________

FANS AND BLOWERS ____________

COMPRESSORS

CENTRIFUGAL ____________ ROTARY ____________

○ **OPERATING FREQUENCY RANGE:**

____________ hertz TO ____________ kilohertz

SITE DATA

DESIGN TEMPERATURE: SUMMER (C) ______ WINTER (MIN) ______

○ **DESIGN WET BULB TEMPERATURE:** (C) ______ PERCENT HUMIDITY ______

○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQUIRED

○ UNUSUAL CONDITIONS: DUST ______ FUMES ______ OTHER ______

○ **ELECTRICAL HAZARD CLASS:** GR ____________ DIVISION ____________

○ DRY AIR PURGE: ☐ X OR ☐ Y

○ **OPERATING TEMPERATURE RANGE:**

ACCELEROMETER ______ F TO ______ F

EXTERNAL CHARGE AMPLIFIER ______ F TO ______ F

MONITOR AND POWER SUPPLY ______ F TO ______ F

ACCELEROMETER DATA

GENERAL:

☐ INSTRUMENT MANUFACTURER S MODEL NO ____________

○ EXTERNAL CHARGE AMPLIFIER ____________

○ SPECIAL BODY MATERIAL ____________

○ CONNECTOR LOCATION ______ TOP ______ SIDE

TRANSDUCER MOUNTING:

○ API ____________ OTHER ____________

○ NO OF TRANSDUCERS PER BEARING ____________

○ NO OF CHANNELS IN TRAIN ____________

CHARGE AMPLIFIER DATA:

☐ INSTRUMENT MANUFACTURER S MODEL NO ____________

☐ DIMENSIONS ______ inch X ______ inch X ______ inch

○ MILITARY SPECIFICATIONS COMPONENTS REQUIRED FOR OPERATION FROM −67 TO +257 F

MONITOR AND POWER SUPPLY:

☐ FRONT PANEL SURFACE ______ HEIGHT sq inches ______ WIDTH sq inches

○ SUPPLIED BY: VENDOR ______ OWNER ______

INPUT POWER:

○ 117 volt ALTERNATING CURRENT ○ 60 hertz ○ OTHER

MOUNTING LOCATION:

○ OUTDOOR ____________ INDOOR ____________

☐ LOCATION OF ALARM AND SHUTDOWN FIRST INDICATION (DETAILS) ____________

CABLE AND CONNECTOR DATA:

☐ TYPE OF CABLE ____________

○ SHIELDED TWISTED PAIR ○ CONDUCTOR ○ BARE ○ TINNED

○ SHIELDED TWISTED TRIAD ○ COAXIAL

○ APPROXIMATE PHYSICAL LENGTH OF CONDUIT FROM CHARGE AMPLIFIER OR FIELD JUNCTION BOX TO PANEL ______ feet

☐ CONNECTOR MANUFACTURER ______ MODEL ______

MONITOR DISPLAY DATA:

☐ ANALOG ____________ DIGITAL ____________

○ DUAL METER FACE ____________

	UNITS	RANGE
○ ACCELEROMETER Gs (rms)		○ 0-3 ○ 0-10 ○ 0-30
○ VELOCITY IPS (PEAK)		○ 0-0 3 ○ 0-1 0 ○ 0-3 0

MONITOR OPERATION (DETECTION AND DISPLAY):

○ PEAK UNITS

FILTER DATA:

○ LOW PASS CUT OFF FREQUENCY ____________

ONE ____________ TWO ____________

○ HIGH PASS CUT OFF FREQUENCY ____________

ONE ____________ TWO ____________

☐ FILTER PASSBAND LOSS ____________ decibels

DOCUMENTATION

DOCUMENT	COPIES

RESPONSIBILITY FOR DESIGN AND INSTALLATION OF MONITORINING SYSTEM ON MACHINERY TRAIN

○ MACHINERY VENDOR ____________

○ INSTRUMENT MANUFACTURER ____________

○ CONSTRUCTION CONTRACTOR ____________

ACCELEROMETER-BASED VIBRATION MONITORING SYSTEM DATA SHEET
Customary Units

JOB NO ______ ITEM NO ______
PURCHASE ORDER NO ______
REQUISITION NO ______
INQUIRY NO ______
PAGE ______ OF ______ BY ______

APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT DATE ______ REVISION ______
OWNER ______ CONSTRUCTION AGENCY ______
MACHINERY VENDOR ______ INSTRUMENT MANUFACTURER ______
SITE ______ SERVICE ______
NOTE: INFORMATION TO BE COMPLETED ○ BY PURCHASER □ BY MANUFACTURER

MACHINERY TRAIN COMPONENTS

○ **NUMBER OF:**
PUMPS ______ STEAM TURBINES ______
GAS TURBINES ______ GEAR UNITS ______
FANS AND BLOWERS ______
COMPRESSORS
CENTRIFUGAL ______ ROTARY ______
○ **OPERATING FREQUENCY RANGE:**
______ hertz TO ______ kilohertz

SITE DATA

DESIGN TEMPERATURE: SUMMER (C) ______ WINTER (MIN) ______
○ **DESIGN WET BULB TEMPERATURE:** (C) ______ PERCENT HUMIDITY ______
○ WINTERIZATION REQUIRED ○ TROPICALIZATION REQUIRED
○ UNUSUAL CONDITIONS: DUST ______ FUMES ______ OTHER ______
○ **ELECTRICAL HAZARD CLASS:** GR ______ DIVISION ______
○ DRY AIR PURGE: □ X OR □ Y
○ **OPERATING TEMPERATURE RANGE:**
ACCELEROMETER ______ F TO ______ F
EXTERNAL CHARGE AMPLIFIER ______ F TO ______ F
MONITOR AND POWER SUPPLY ______ F TO ______ F

ACCELEROMETER DATA

GENERAL:
□ INSTRUMENT MANUFACTURER S MODEL NO ______
○ EXTERNAL CHARGE AMPLIFIER ______
○ SPECIAL BODY MATERIAL ______
○ CONNECTOR LOCATION ______ TOP ______ SIDE

TRANSDUCER MOUNTING:
○ API ______ OTHER ______
○ NO OF TRANSDUCERS PER BEARING ______
○ NO OF CHANNELS IN TRAIN ______

CHARGE AMPLIFIER DATA:
□ INSTRUMENT MANUFACTURER S MODEL NO ______
□ DIMENSIONS ______ inch X ______ inch X ______ inch
○ MILITARY SPECIFICATIONS COMPONENTS REQUIRED FOR OPERATION FROM −67 TO +257 F

MONITOR AND POWER SUPPLY:
□ FRONT PANEL SURFACE ______ HEIGHT sq inches ______ WIDTH sq inches
○ SUPPLIED BY: VENDOR ______ OWNER ______

INPUT POWER:
○ 117 volt ALTERNATING CURRENT ○ 60 hertz ○ OTHER

MOUNTING LOCATION:
○ OUTDOOR ______ INDOOR ______

□ LOCATION OF ALARM AND SHUTDOWN FIRST INDICATION (DETAILS) ______

CABLE AND CONNECTOR DATA:
□ TYPE OF CABLE ______
○ SHIELDED TWISTED PAIR ○ CONDUCTOR ○ BARE ○ TINNED
○ SHIELDED TWISTED TRIAD ○ COAXIAL
○ APPROXIMATE PHYSICAL LENGTH OF CONDUIT FROM CHARGE AMPLIFIER OR FIELD JUNCTION BOX TO PANEL ______ feet
□ CONNECTOR MANUFACTURER ______ MODEL ______

MONITOR DISPLAY DATA:
□ ANALOG ______ DIGITAL ______
○ DUAL METER FACE ______

UNITS	RANGE		
○ ACCELEROMETER Gs (rms)	○ 0-3	○ 0-10	○ 0-30
○ VELOCITY IPS (PEAK)	○ 0-0 3	○ 0-1 0	○ 0-3 0

MONITOR OPERATION (DETECTION AND DISPLAY):
○ PEAK UNITS

FILTER DATA:
○ LOW PASS CUT OFF FREQUENCY ______
ONE ______ TWO ______
○ HIGH PASS CUT OFF FREQUENCY ______
ONE ______ TWO ______
□ FILTER PASSBAND LOSS ______ decibels

DOCUMENTATION

DOCUMENT	COPIES
______	______
______	______
______	______

RESPONSIBILITY FOR DESIGN AND INSTALLATION OF MONITORINING SYSTEM ON MACHINERY TRAIN
○ MACHINERY VENDOR ______
○ INSTRUMENT MANUFACTURER ______
○ CONSTRUCTION CONTRACTOR ______