

Vibration, Axial Position, and Bearing Temperature Monitoring Systems

API STANDARD 670
THIRD EDITION, NOVEMBER 1993

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Manufacturing, Distribution and Marketing Department

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**American
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Institute**



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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 the publication is to provide a purchase specification to facilitate the manufacture, procurement, installation, and testing of vibration, axial position, and bearing temperature monitoring systems for petroleum, chemical, and gas industry services.

The primary purpose of this standard is to establish minimum electromechanical requirements. This limitation in scope is one of charter as opposed to interest and concern. Energy conservation is of concern and has become increasingly important in all aspects of equipment design, application, and operation. Thus, innovative energy-conserving approaches should be aggressively pursued by the manufacturer and the user during these steps. Alternative approaches that may result in improved energy utilization should be thoroughly investigated and brought forth. This is especially true of new equipment proposals, since the evaluation of purchase options will be based increasingly on total life costs as opposed to acquisition cost alone. Equipment manufacturers, in particular, are encouraged to suggest alternatives to those specified when such approaches achieve improved energy effectiveness and reduced total life costs without sacrifice of safety or reliability.

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of this 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 thereof into another complete standard.

API standards are published as an aid to procurement of standardized equipment and materials. These standards are not intended to inhibit purchasers or producers from purchasing or producing products made to specifications other than those of API.

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

IMPORTANT INFORMATION CONCERNING USE OF ASBESTOS OR ALTERNATIVE MATERIALS

Asbestos is specified or referenced for certain components of the equipment described in some API standards. It has been of extreme usefulness in minimizing fire hazards associated with petroleum processing. It has also been a universal sealing material, compatible with most refining fluid services.

Certain serious adverse health effects are associated with asbestos, among them the serious and often fatal diseases of lung cancer, asbestosis, and mesothelioma (a cancer of the chest and abdominal linings). The degree of exposure to asbestos varies with the product and the work practices involved.

Consult the most recent edition of the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, Occupational Safety and Health Standard for Asbestos, Tremolite, Anthophyllite, and Actinolite, 29 *Code of Federal Regulations* Section 1910.1001; the U.S. Environmental Protection Agency, National Emission Standard for Asbestos, 40 *Code of Federal Regulations* 61.140 through 61.156; and the U.S. Environmental Protection Agency (EPA) rule on labeling requirements and phased banning of asbestos products, published at 54 *Federal Register* 29460 (July 12, 1989).

There are currently in use and under development a number of substitute materials to replace asbestos in certain applications. Manufacturers and users are encouraged to develop and use effective substitute materials that can meet the specifications for, and operating requirements of, the equipment to which they would apply.

SAFETY AND HEALTH INFORMATION WITH RESPECT TO PARTICULAR PRODUCTS OR MATERIALS CAN BE OBTAINED FROM THE EMPLOYER, THE MANUFACTURER OR SUPPLIER OF THAT PRODUCT OR MATERIAL, OR THE MATERIAL SAFETY DATA SHEET.

CONTENTS

	Page
SECTION 1—GENERAL	1
1.1 Scope	1
1.2 Alternative Designs	1
1.3 Conflicting Requirements	1
1.4 Definition of Terms	1
1.5 Referenced Publications	3
SECTION 2—GENERAL DESIGN SPECIFICATIONS	4
2.1 Accuracy	4
2.2 Monitoring System Environment	4
2.3 Interchangeability	6
2.4 Scope of Supply and Responsibility	6
SECTION 3—CONVENTIONAL HARDWARE	6
3.1 Radial Shaft Vibration and Axial Position Transducers	6
3.2 Casing Vibration	8
3.3 Thrust and Journal Bearing Temperature Channels	10
3.4 Power Supplies and System-Output Relays	12
3.5 Monitors	12
3.6 Wiring and Conduits	15
3.7 Grounding	15
3.8 Field-Installed Instruments	15
SECTION 4—TRANSDUCER AND SENSOR ARRANGEMENTS	19
4.1 Location and Orientation	19
4.2 Mounting	21
4.3 Identification of Transducers and Temperature Sensors	26
SECTION 5—INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT	26
5.1 General	26
5.2 Inspection	26
5.3 Testing	27
5.4 Preparation for Shipment	27
5.5 Mechanical Running Test	27
5.6 Field Testing	27
SECTION 6—VENDOR'S DATA	28
6.1 General	28
6.2 Proposals	28
6.3 Contract Data	35
APPENDIX A—VIBRATION, AXIAL POSITION, AND BEARING TEMPERATURE MONITORING SYSTEM DATA SHEETS	37
APPENDIX B—TYPICAL RESPONSIBILITY MATRIX WORKSHEET	43
APPENDIX C—ACCELEROMETER APPLICATION CONSIDERATIONS	45
APPENDIX D—SIGNAL CABLE	51
APPENDIX E—GEARBOX CASING VIBRATION CONSIDERATIONS	53
APPENDIX F—FIELD TESTING AND DOCUMENTATION REQUIREMENTS	55

	Page
APPENDIX G—VENDOR DRAWING AND DATA REQUIREMENTS	59
APPENDIX H—TYPICAL SYSTEM ARRANGEMENT PLANS	63
Figures	
1—Monitoring System Component Nomenclature	2
2—Accuracy of Radial Shaft Vibration and Axial Position Transducer Channels	5
3A—Standard Probe and Extension Cable	7
3B—Standard Options for Probes and Extension Cables	8
4—Typical Oscillator-Demodulator	9
5—Accelerometer Extension Cable Options	11
6A—Typical Standard Conduit Arrangement	16
6B—Typical Standard Option Armored Cable Arrangement	17
6C—Typical Transducer Installations for External Charge Amplifier	18
6D—Typical Transducer Installations for Integral Charge Amplifier	18
6E—Inverted Gooseneck Trap Conduit Arrangement	19
7—Standard Axial Position Probe Arrangement	21
8—Standard Option Axial Position Probe Arrangement With Integral Thrust Collar	22
9—Typical Installations of Radial Bearing Temperature Sensors	23
10—Typical Installation of Thrust Bearing Temperature Sensors	24
11—Typical Probe Mounting Arrangements	25
12—Nomenclature for Temperature Monitoring System	29
13—Calibration of Radial Monitor and Setpoints for Alarm and Shutdown	30
14—Calibration of Axial Position (Thrust) Monitor: Steam Turbine (SI Units)	31
15—Calibration of Axial Position (Thrust) Monitor: Compressor (Customary Units)	32
16—Typical Calibration Curve for Radial Vibration	33
17—Typical Calibration Curve for Axial Position	34
C-1—Typical Accelerometer Protective Cover and Stud-Mounting Details	46
C-2—Typical Mounting Arrangement for Integral-Stud Accelerometer and Cable	47
C-3—Typical Mounting Arrangement for Integral-Stud Accelerometer and Armored Extension Cable	48
C-4—Typical Accelerometer Three-Point Mounting Arrangement	49
H-1—Typical System Arrangement for a Turbine	64
H-2—Typical System Arrangement for a Double-Helical Gear	65
H-3—Typical System Arrangement for a Centrifugal Compressor or a Pump With Hydrodynamic Bearings	66
H-4—Typical System Arrangement for an Electric Motor With Sleeve Bearings	67
H-5—Typical System Arrangement for a Pump With Antifriction Bearings	68
Tables	
1—Minimum Separation Between Installed Signal and Power Cables	16
2A—Accelerometer Test Points (SI Units)	28
2B—Accelerometer Test Points (Customary Units)	28
D-1—Color Coding for Single-Circuit Thermocouple Signal Cable	52
F-1—Tools and Instruments Needed to Calibrate and Test Monitoring Systems	55
F-2—Typical Vendor Requirements	56
G-1—Typical Major Milestone Timeline	59

Vibration, Axial Position, and Bearing Temperature Monitoring Systems

SECTION 1—GENERAL

1.1 Scope

This standard covers the minimum requirements for monitoring radial shaft vibration, casing vibration, shaft axial position, and bearing temperatures. It outlines a standardized monitoring system and covers requirements for hardware (sensors and instruments), installation, testing, and arrangement.

Note: A bullet (●) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets (see Appendix A); otherwise it should be stated in the quotation request or in the order.

1.2 Alternative Designs

The vendor may offer alternative designs. Equivalent metric dimensions and fasteners may be substituted as mutually agreed upon by the purchaser and the 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

Terms used in this standard are defined as follows:

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

1.4.2 *Accuracy* is the degree of conformity of an indicated value to a recognized accepted standard value or ideal value.

1.4.3 The *active (normal) thrust direction* is the direction of a rotor axial thrust load expected by the vendor when the machinery is operating under normal running conditions.

1.4.4 *Alarm (alert) point* is a preset value of a parameter at which an alarm is activated to warn of a condition that requires corrective action.

1.4.5 A *bench test* is a factory acceptance test performed at any ambient temperature within the range of 0°C to 45°C (30°F to 110°F).

1.4.6 *Best fit straight line* is the line drawn through the actual calibration curve where the maximum plus or minus deviations are minimized and made equal.

1.4.7 A *buffered output* is designed to prevent a short circuit on the output side from affecting the input signal.

1.4.8 A *channel* consists of a transducer or sensor and hardware required to display its output signal.

1.4.9 A *channel pair* consists of two associated transducer outputs (such as the X and Y probes at a particular shaft location) that are processed in the same monitor unit.

1.4.10 The *charge amplifier* is a conditioning device that converts the charge signal generated by the piezoelectric accelerometer and provides an output voltage signal proportional to the accelerometer electrical charge.

1.4.11 A *circuit fault* is a monitoring system circuit failure that adversely affects the function of the system.

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

1.4.13 *Controlled access* refers to a feature of a monitoring system that restricts alteration of a parameter to specified individuals. Access may be limited by means such as the use of a key or coded password or other procedures requiring specialized knowledge.

1.4.14 *Dual voting logic* is a monitor feature whereby signals on two channels must both reach or violate a setpoint to initiate a shutdown signal (two out of two logic).

1.4.15 *Dynamic range* is the usable range of amplitude of a signal, usually expressed in decibels.

1.4.16 An *electrically isolated accelerometer* is one in which all signal connections are electrically insulated from the accelerometer case or base.

1.4.17 The *end user* is the final recipient who will operate the machinery train and monitoring system. The end user may purchase the monitoring system.

1.4.18 An *extension cable* is the interconnection between the sensor and a signal conditioning device.

1.4.19 *Field changeable* refers to a design feature of a monitoring system that permits alteration of a function after the system has been installed.

1.4.20 A *filter* is an electrical device that suppresses signals outside the frequency range of interest.

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

1.4.22 *Gauss level* is the magnetic field level of a component. It is usually measured with a Hall effect probe.

1.4.23 The *inactive (counter) thrust direction* is the direction opposite the active thrust direction.

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

1.4.25 *Inches per second* or *ips* is a unit of velocity equal to 25.4 millimeters per second (1 inch per second).

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

1.4.27 *Linear range* is the portion of a transducer's output where the output versus input relationship is linear within a specified tolerance.

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

1.4.29 A *monitoring system* consists of probes, accelerometers, or temperature sensors; signal conditioning devices (if required); interconnecting cables; monitors; and documentation (see Figure 1).

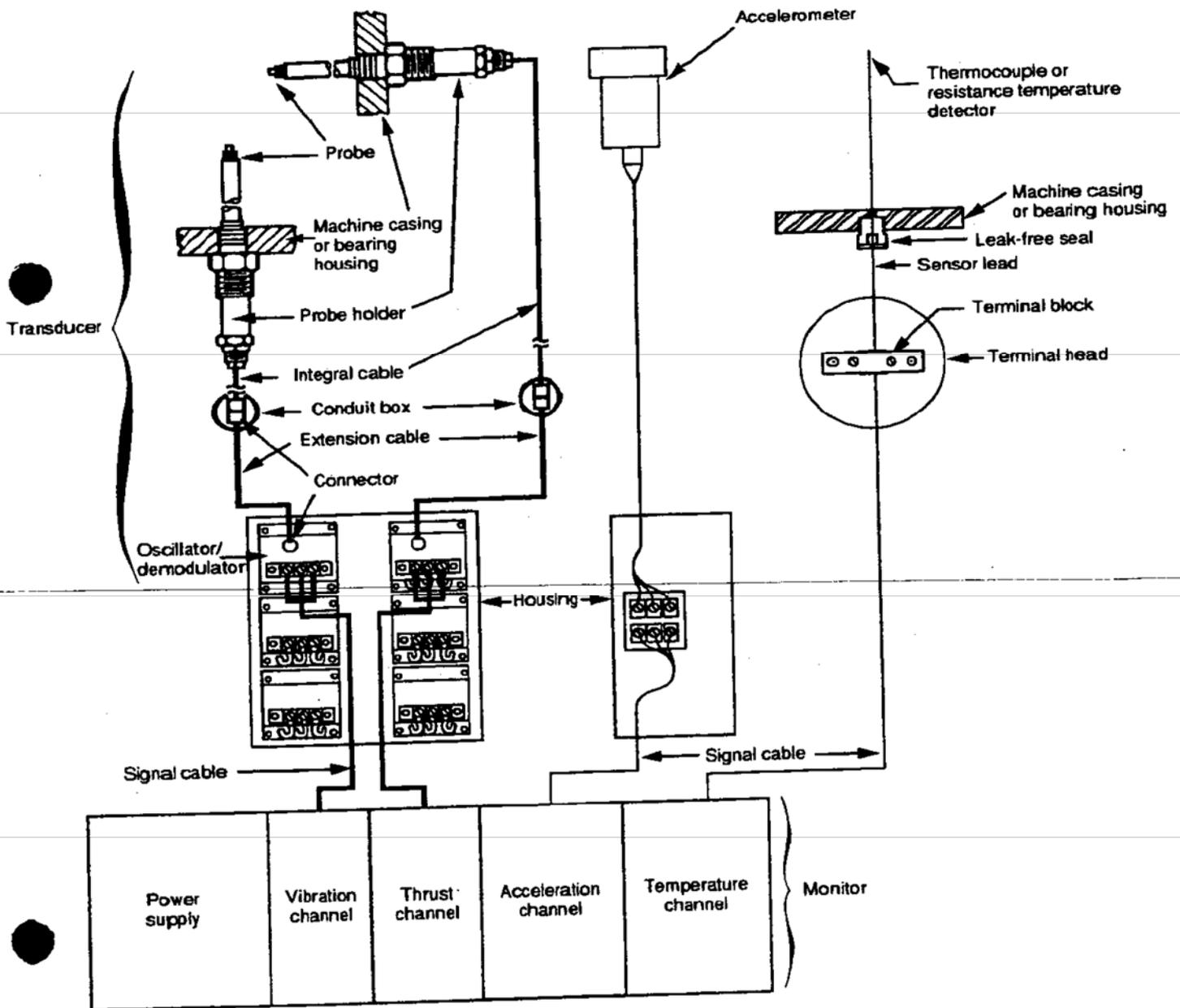


Figure 1—Monitoring System Component Nomenclature

1.4.30 An *oscillator-demodulator* is a signal conditioning device that sends a radio frequency signal to a probe, demodulates the probe output, and provides an output signal suitable for readout monitors, oscilloscopes, vibration analyzers, and other devices.

1.4.31 *Peak-to-peak value* is the difference between positive and negative extreme values of an electronic signal or dynamic motion.

1.4.32 A *phase reference transducer* is a gap-to-voltage device that consists of a probe, an extension cable, and an oscillator-demodulator and is used to sense a once-per-revolution mark.

1.4.33 A *piezoelectric accelerometer* is a sensor that generates an electrical charge proportional to vibratory acceleration.

1.4.34 A *probe* is a noncontacting sensor that consists of a tip, a probe body, an integral coaxial cable, and a connector and is used to translate distance (gap) to voltage.

1.4.35 *Probe gap* is the physical distance between the face of a proximity probe tip and the observed surface. The distance can be expressed in terms of displacement (mils, micrometers) or in term of voltage (volts).

1.4.36 The *purchaser* is the agency that buys the equipment.

1.4.37 *Radial shaft vibration* is the vibratory motion of the machine shaft in a direction perpendicular to the shaft centerline.

1.4.38 A *resistance temperature detector (RTD)* is a device that operates on the principle that a conductor's resistance to electrical current depends on the temperature of the conductor.

1.4.39 *Root mean square or rms* is the square root of the mean of the square of the sample values.

1.4.40 A *sensor* is a device (such as a proximity probe or an accelerometer) that detects the value of a physical quantity and converts the measurement into a useful input for another device.

1.4.41 A *shaft vibration or position transducer* is a gap-to-voltage device that consists of a probe, an extension cable, and an oscillator-demodulator.

1.4.42 The *shutdown (danger) point* is a preset value of a parameter at which automatic or manual shutdown of the system is required.

1.4.43 A *signal cable* is the interconnection between the transducer terminal block and the monitor.

1.4.44 A *signal conditioning device*, such as an oscillator-demodulator or a charge amplifier, modifies the sensor out-

put characteristics to match system requirements (such as impedance or amplitude).

1.4.45 *Signal-to-noise ratio* is the ratio of the power of signal conveying information to the power of the signal conveying information.

1.4.46 A *standard option* is a generally available alternative hardware configuration that may be specified in lieu of the standard configuration specified in this standard.

1.4.47 *Suppression* is a scheme by which a vibration meter reading is altered to subtract (suppress) mechanical and/or electrical runout or electrical noise.

1.4.48 *Tachometer* is a shaft rotational speed indicating device.

1.4.49 A *temperature sensor* consists of a thermocouple or resistance temperature detector and its integral sensing lead.

1.4.50 A *thermocouple* is two dissimilar thermoelements so joined as to produce a thermal electromotive force (emf) when the junctions are at different temperatures.

1.4.51 A *transducer* consists of a sensor, an extension cable, and a signal conditioning device. The transducer generates a signal that is proportional to the measured variable (shaft vibration, shaft position, acceleration, or temperature) (see Figure 1).

1.4.52 *Transverse sensitivity* is the accelerometer's response to dynamic loads applied in a direction perpendicular to the principal axis.

1.4.53 The *vendor* is the agency that manufactures, sells, and provides service support for the equipment.

1.5 Referenced Publications

1.5.1 The editions of the following standards, codes, and specifications that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this standard. The applicability of changes in standards, codes, and specifications that occur after the inquiry shall be mutually agreed upon by the purchaser and the vendor.

ANSI¹

MC96.1 *Temperature Measurement Thermocouples*

ASME²

Y14.2M *Line Conventions and Lettering*

¹American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

²American Society of Mechanical Engineers, 22 Law Drive, Box 2300, Fairfield, New Jersey 07007-2300.

IEC ³	584-1	<i>Thermocouples, Part 1: Reference Tables</i>
IPCEA ⁴	S-61-402	<i>Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy</i>
ISA ⁵	S12.1	<i>Definitions and Information Pertaining to Electrical Instruments in Hazardous (Classified) Locations</i>
	S12.4	<i>Instrument Purging for Reduction of Hazardous Area Classification</i>
Military Specifications ⁶	MIL-C-39012-C	<i>Connectors, Coaxial, Radio Frequency, General Specification for</i>
	MIL-C-39012/SF	<i>Connectors, Plug, Electrical, Coaxial, Radio Frequency, [Series N (Cabled) Right Angle, Pin Contact, Class 2]</i>
	MIL-STD-883B	<i>Tests, Methods, and Procedures for Micro-Electronics</i>

NEMA ⁷	250	<i>Enclosures for Electrical Equipment (1000 Volts Maximum)</i>
	WC 5	<i>Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy</i>
NFPA ⁸	70	<i>National Electrical Code</i>
	496	<i>Purged and Pressurized Enclosures for Electrical Equipment</i>
OSHA ⁹		<i>Form 20, Material Safety Data Sheet</i>
SAMA ¹⁰		Std PMC 33.1
	1.5.2	The standards, codes, and specifications of the American Iron and Steel Institute (AISI) ¹¹ also form part of this standard.
	1.5.3	The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any federal, state, or local codes, regulations, ordinances, or rules that are applicable to the equipment.

SECTION 2—GENERAL DESIGN SPECIFICATIONS

2.1 Accuracy

The minimum accuracy of the monitoring system, as calibrated during bench or field tests over an ambient temperature range of 0°C to 45°C (30°F to 110°F), shall be as specified in 2.1.1 through 2.1.3.

2.1.1 The channel accuracy for measuring radial shaft vibration and axial position shall be within ±5 percent of 8 millivolts per micrometer (200 millivolts per mil) and shall be within ±25 micrometers (±1 mil) of the best fit straight line at a slope of 8 millivolts per micrometer (200 millivolts per mil) over a minimum operating range of 2 millimeters (80 mils), as verified on the actual probe target area or on a target with the same electrical characteristics as those of the installed probe target area (see Figure 2).

2.1.2 The channel accuracy for measuring bearing temperature shall be within ±2°C (±4°F) over a measurement range from -20°C to 150°C (0°F to 300°F).

2.1.3 The channel accuracy for measuring casing vibration shall be within ±5 percent of 100 millivolts per G over a minimum range of 0.1 G to 75 G, peak, and over the frequency range of 10 hertz to 10 kilohertz (see note).

Note: Instrument manufacturers should be contacted for applications above 10 kilohertz and below 10 hertz.

2.2 Monitoring System Environment

2.2.1 TEMPERATURE RANGES

2.2.1.1 For components operating within the following temperature ranges, but excluding the range from 0°C to 45°C (30°F to 110°F), the channel accuracy for measuring radial shaft vibration and axial position shall not vary from that specified in 2.1.1 by more than an additional ±5 percent

³International Electrotechnical Commission, 1 Rue de Varembe, Geneva, Switzerland.

⁴Insulated Power Cable Engineers Association, 283 Valley Road, Montclair, New Jersey 07042.

⁵Instrument Society of America, P.O. Box 12277, Research Triangle Park, North Carolina 27709.

⁶Available from Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

⁷National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, D.C. 20037.

⁸National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, Massachusetts 02269.

⁹Occupational Safety and Health Administration, U.S. Department of Labor. The *Code of Federal Regulations* is available from the U.S. Government Printing Office, Washington, D.C. 20402.

¹⁰Scientific Apparatus Manufacturers Association, 370 Lexington Avenue, New York, New York 10017.

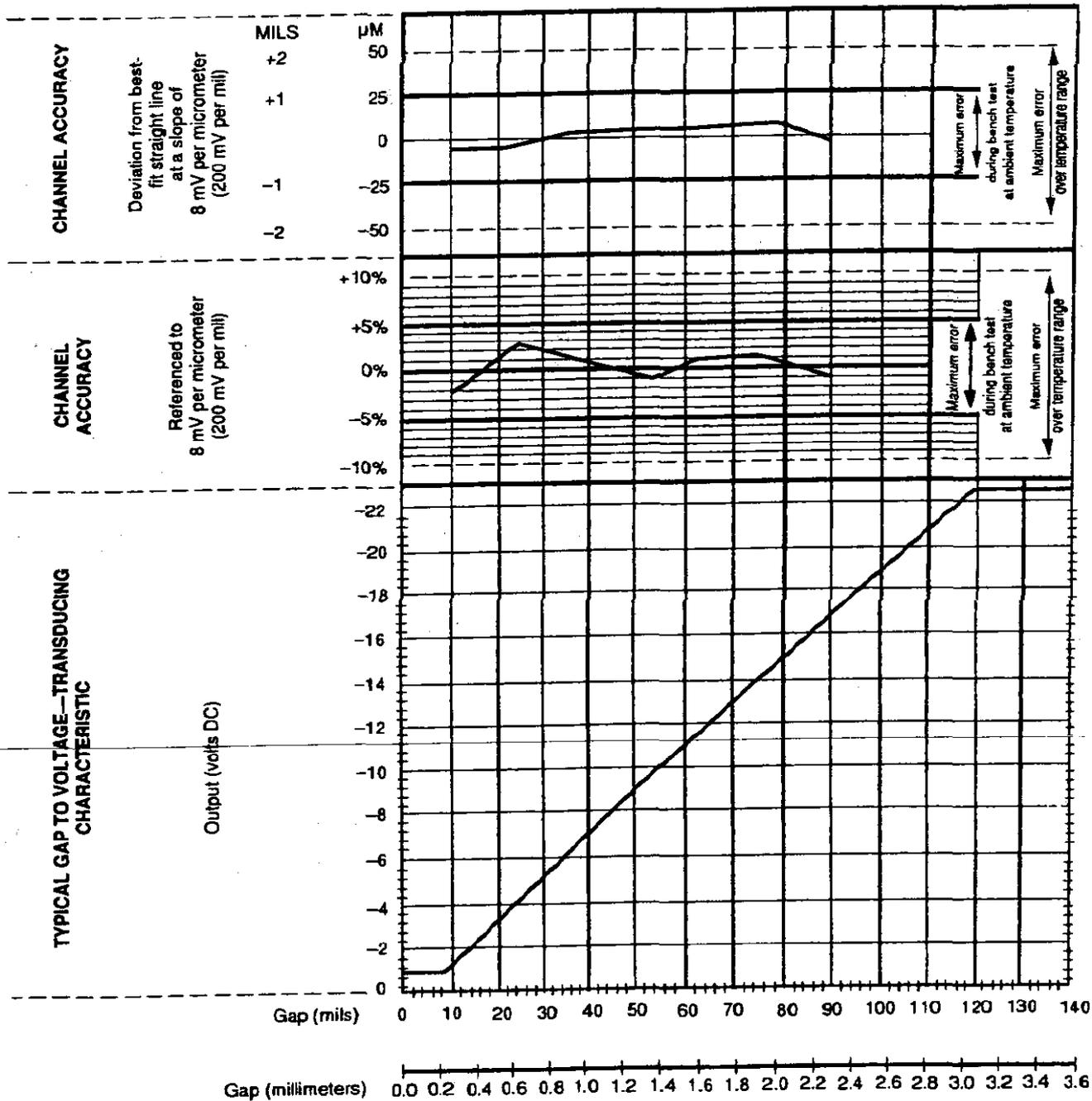
¹¹American Iron and Steel Institute, 1101 17th Street, N.W., Washington, D.C. 20036-4700.

up to a maximum of ± 50 micrometers (± 2 mils) from the best fit straight line:

- a. Probe and extension cable, a range from -35°C to 120°C (-30°F to 250°F).
- b. Oscillator-demodulators, a range from -35°C to 65°C (-30°F to 150°F).

c. Monitors and power supplies, a range from -30°C to 65°C (-20°F to 150°F).

2.2.1.2 For components operating within the following temperature ranges, but excluding the range from 0°C to 45°C (30°F to 110°F), the channel accuracy for measu



Note: Ambient temperature is 0°C to 45°C (30°F to 110°F).

Figure 2—Accuracy of Radial Shaft Vibration and Axial Position Transducer Channels

casing vibration shall not vary from that specified in 2.1.3 by more than an additional ± 5 percent:

- a. Accelerometer with an integral impedance matching device including extension cable, a range from -55°C to 120°C (-65°F to 250°F) and temperature transient of 3°C (5°F) per second.
- b. Piezoelectric accelerometer without integral impedance matching device including charge amplifier cable, a range from -55°C to 230°C (-65°F to 450°F) and a temperature transient of 3°C (5°F) per second.
- c. Monitors and power supplies, a range from -30°C to 65°C (-20°F to 150°F).
- d. External charge amplifiers, a range from -35°C to 85°C (-30°F to 185°F).

2.2.1.3 For components operating within the following temperature ranges, but excluding the range from 0°C to 45°C (30°F to 110°F), the channel accuracy for measuring bearing temperature shall not vary from that specified in 2.1.2 by more than an additional $\pm 1.7^{\circ}\text{C}$ ($\pm 3^{\circ}\text{F}$):

- a. Temperature sensors and leads, a range from -35°C to 175°C (-30°F to 350°F).
- b. Monitors and power supplies, a range from -30°C to 65°C (-20°F to 150°F).

- **2.2.1.4** When operation of the oscillator-demodulator or charge amplifier outside the temperature range in 2.2.1.1, Item b or 2.2.1.2, Item d is specified, components shall be furnished that meet the requirements of MIL-STD-883B, Method 1010.2, Condition B, for operation at temperatures from -55°C to 125°C (-67°F to 257°F).

2.2.1.5 The details of systems or components outside the scope of this standard shall be mutually agreed upon by the purchaser and vendor.

2.2.2 HUMIDITY

The accuracy 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 accuracy requirements specified in 2.1.

2.2.4 CHEMICAL RESISTANCE

2.2.4.1 Probes and probe extension cables shall be suitable for environments containing hydrogen sulfide and ammonia.

- **2.2.4.2** It shall be the joint responsibility of the purchaser and instrument manufacturer to ensure that all of the monitoring system components are compatible with other specified chemicals.

2.3 Interchangeability

All components covered by this standard shall be physically and electrically interchangeable within the accuracy specified in 2.1 and 2.2. This does not imply that interchangeability of components from different instrument manufacturers is required or that oscillator-demodulators calibrated for different shaft materials are electrically interchangeable.

• 2.4 Scope of Supply and Responsibility

For each train, the purchaser shall specify the agency or agencies responsible for each function of the design, scope of supply, installation, and performance of the monitoring system. If the purchaser is not the end user, then the end user shall approve the agency or agencies specified (see Appendix B).

SECTION 3—CONVENTIONAL HARDWARE

3.1 Radial Shaft Vibration and Axial Position Transducers

3.1.1 PROBES

3.1.1.1 A probe consists of a tip, a probe body, an integral coaxial cable, and a connector as specified in 3.1.3 and shall be chemically resistant as specified in 2.2.4. This assembly is illustrated in Figure 3A.

3.1.1.2 The standard probe shall have a tip diameter of 4.8 to 5.0 millimeters (0.190 to 0.200 inches), with approxi-

mately 25 millimeters (1 inch) body length and $\frac{1}{4}$ -28-UNF-2A threads.

- **3.1.1.3** When specified, the standard options may consist of one or more of the following (see Figure 3B):
 - a. A tip diameter of 7.6 to 7.9 millimeters (0.300 to 0.312 inches) and $\frac{3}{8}$ -24-UNF-2A threads.
 - b. A reverse mount, integral hex nut probe body.
 - c. A tip diameter of 7.6 to 7.9 millimeters (0.300 to 0.312 inches) and M10 metric threads.

- d. A tip diameter of 4.8 to 5.0 millimeters (0.190 to 0.200 inches) and M8 metric threads.
- e. Lengths other than approximately 25 millimeters (1 inch).
- f. Flexible stainless steel armoring attached to the probe body and extending to within 100 millimeters (4 inches) of the connector.

3.1.1.4 The overall physical length of the probe and integral cable assembly shall be approximately 1 meter (40 inches), measured from the probe tip to the end of the connector. The minimum overall physical length shall be 0.8 meters (33 inches); the maximum overall physical length shall be 1.1 meters (45 inches).

3.1.1.5 A piece of clear heat-shrink tubing (not to be shrunk at the factory) 40 millimeters (1.5 inches) long shall be installed over the coaxial cable before the connector is installed to assist the owner in tagging.

3.1.2 PROBE EXTENSION CABLES

Probe extension cables shall be coaxial, with connectors as specified in 3.1.3. The nominal physical length shall be 4

meters (160 inches) and shall be a minimum of 3.6 meters (140 inches) (see Figure 3A). Shrink tubing shall be provided at each end in accordance with 3.1.1.5.

3.1.3 CONNECTORS

The attached connectors shall meet or exceed the mechanical, electrical, and environmental requirements specified Section 2 and in MIL-C-39012-C and MIL-C-39012/5F. The body material shall be AISI Standard Type 300 stainless steel. The cable and connector assembly shall be designed withstand a minimum tensile load of 225 newtons (pounds).

3.1.4 OSCILLATOR-DEMODULATORS

3.1.4.1 The oscillator-demodulator shall be designed operate with the probe tip of the specified diameter and probe extension cable. The oscillator-demodulator output shall be 8 millivolts per micrometer (200 millivolts per mm) with a standard supply voltage of -24 volts DC. The oscillator-demodulator shall be calibrated for the standard length of the probe assembly and extension cable. The output, cc

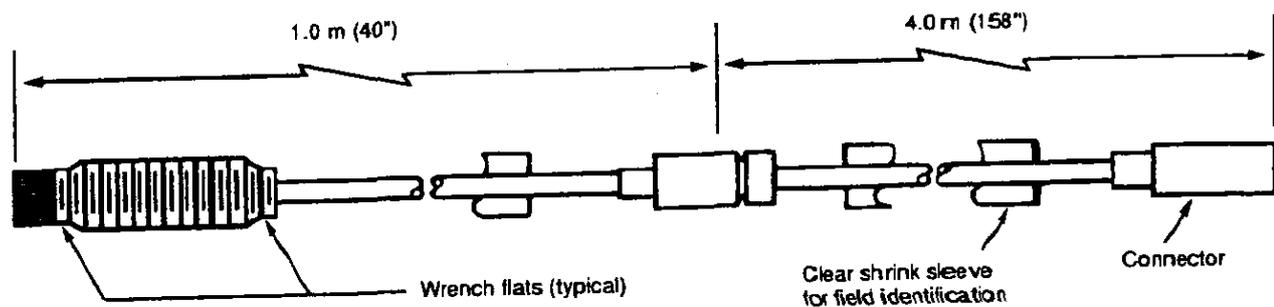
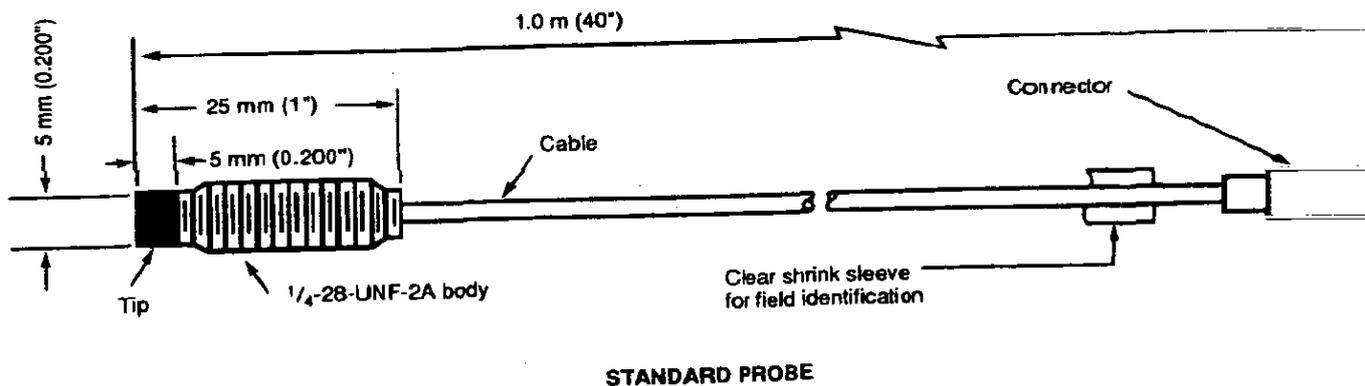


Figure 3A—Standard Probe and Extension Cable

mon, and power-supply connections shall be a heavy-duty, corrosion-resistant, screw-compression-type termination or barrier-type terminal strip suitable for at least 18 American Wire Gage (AWG) wire (1.0 square millimeters cross section). Oscillator-demodulators shall be mechanically interchangeable (see Figure 4). The oscillator-demodulator shall be electrically interchangeable in accordance with 2.3 for the same probe tip diameter. The interference or noise of the installed system (including oscillator-demodulator radio-frequency interference, line-frequency interference, and multiples thereof) on any channel shall not exceed 20 millivolts peak to peak, measured at the monitor inputs and outputs, regardless of the condition of the probe or the gap. The oscillator-demodulator common shall be isolated from ground.

3.1.4.2 The standard oscillator-demodulator shall be designed to operate with the standard probe as defined in 3.1.1.2 and the probe extension cable as defined in 3.1.2.

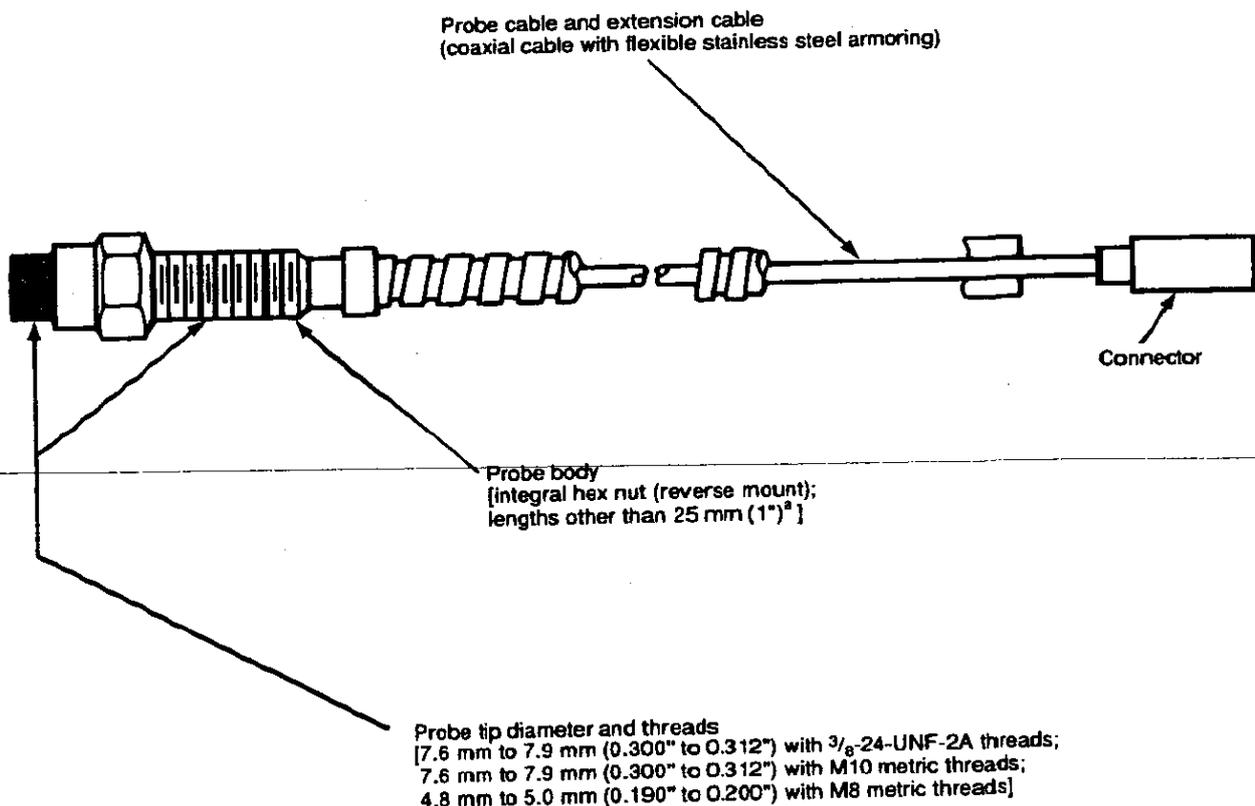
3.2 Casing Vibration

3.2.1 PIEZOELECTRIC ACCELEROMETERS

3.2.1.1 The standard accelerometer system shall be an electrically isolated transducer consisting of a case, a piezoelectric crystal, an integral amplifier, and a connector. This accelerometer shall be used when the mounting environment temperature is less than (120°C) 250°F.

- **3.2.1.2** When specified or when the mounting environment temperature is greater than 120°C (250°F), the standard option accelerometer transducer shall be used. The standard option accelerometer transducer shall be an electrically isolated sensor consisting of a case, a piezoelectric crystal and connector, an external charge amplifier, and a low-noise, high-temperature extension cable.

3.2.1.3 The accelerometer case shall be constructed from AISI Standard Type 316 or other equivalent corrosion resis-



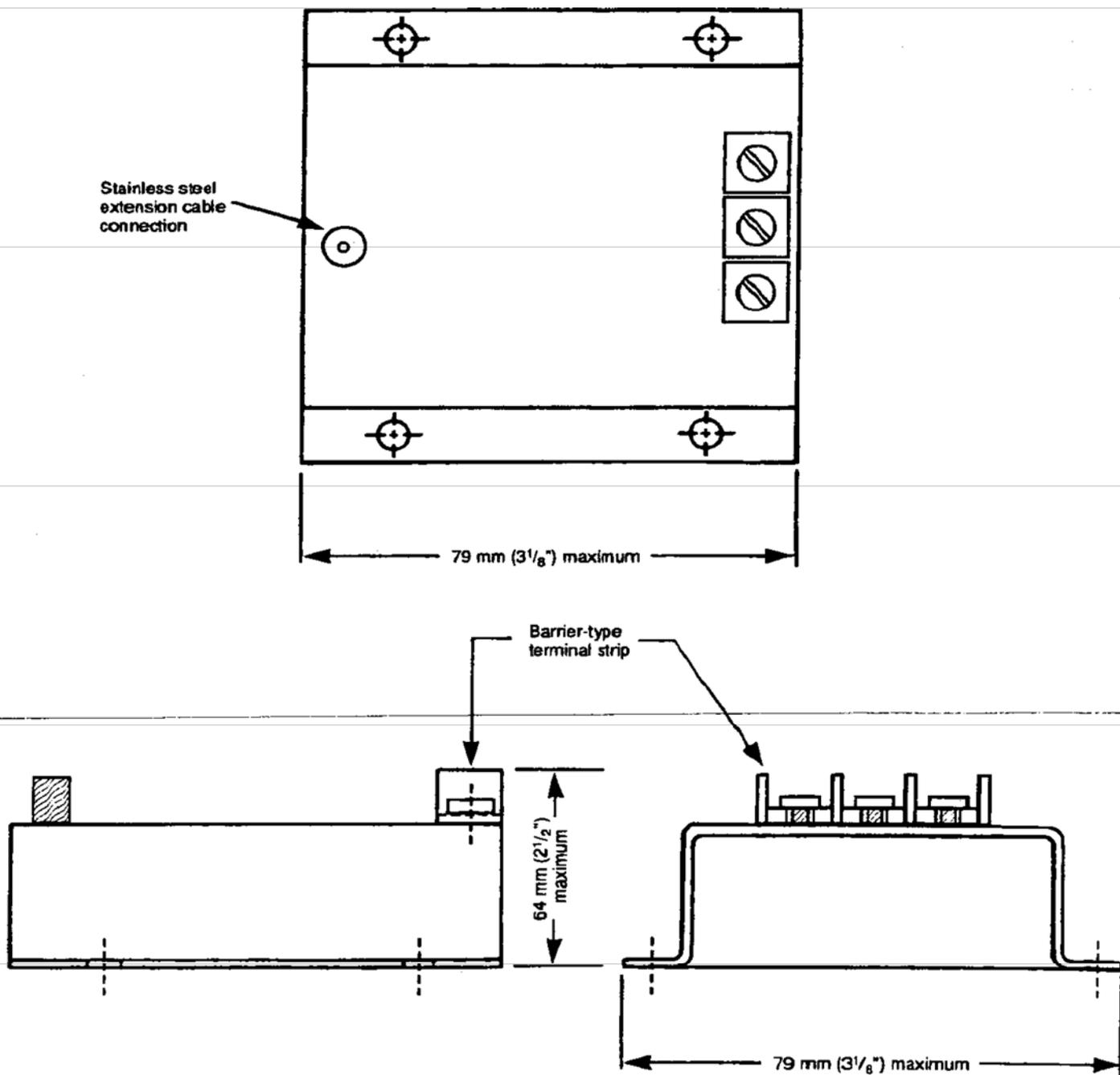
Note: The standard option probe may consist of one or more of the options discussed in 3.1.1.3 and can be used with the standard probe discussed in 3.1.1.2.

^aA 1/4"-28-UNF body more than 50 millimeters (2 inches) in length is undesirable from the standpoint of mechanical strength and availability.

Figure 3B—Standard Options for Probes and Extension Cables

tant stainless steel and shall be electrically isolated from the piezoelectric crystal and all internal circuitry. The case shall be hermetically sealed. The case shall have a maximum outside diameter of 25 millimeters (1 inch). The overall case height shall not exceed 65 millimeters (2.5 inches), not including the connector. The accelerometer case shall be fitted with standard wrench flats.

● 3.2.1.4 The mounting surface of the accelerometer shall be finished to a maximum roughness of 0.4 micrometers (16 microinches) R_a (arithmetic average roughness). The standard accelerometer shall have a top connector capable of withstanding the operating environment. The center of base mounting surface shall be drilled and tapped (perpendicular to the mounting surface ± 5 minutes of an arc) with



Note: The oscillator-demodulator common shall be isolated from ground.

Figure 4—Typical Oscillator-Demodulator

$\frac{1}{4}$ -28 UNF-2A threaded hole of 6 millimeters ($\frac{1}{4}$ inch) minimum depth. The vendor shall supply with each accelerometer a double-ended, flanged, $\frac{1}{4}$ -28 UNF-2A threaded, AISI Standard Type 300 stainless steel mounting stud. The stud shall not prevent the base of the accelerometer from making flush contact with its mounting. When specified, standard options may consist of one or more of the following (see Appendix C):

- a. Center post mounting: English threads other than $\frac{1}{4}$ -28 UNF.
- b. Center post mounting: metric threads.
- c. Three- or four-bolt flange mounting.
- d. Side connector.
- e. Integral extension cable.
- f. Accelerometer mounting block.
- g. Integral center post.

3.2.1.5 The accelerometer transverse sensitivity shall not exceed 5 percent of the principal axis sensitivity over the ranges specified in 2.1.3.

3.2.1.6 The accelerometer transducer signal-to-noise ratio shall be 60 decibels or greater.

3.2.2 ACCELEROMETER EXTENSION CABLES

3.2.2.1 Accelerometer extension cables shall be supplied by the instrument manufacturer. They shall be shielded coaxial, twisted pair, or triad and meet the temperature requirements of the accelerometer. Triad cables shall be in accordance with Appendix D. (See Figure 5 for an example.)

3.2.2.2 When an external charge amplifier is used, the accelerometer extension cable and connectors shall be low-noise, high-temperature type (see Figure 5).

3.2.2.3 Unless otherwise specified, the nominal physical length of the accelerometer extension cable shall be 5 meters (200 inches).

3.2.2.4 A piece of clear heat-shrink tubing (not to be shrunk at the factory) 40 millimeters (1.5 inches) long shall be installed over the accelerometer extension cable at each end to assist the owner in tagging.

3.2.3 CONNECTORS

The attached connector or connectors shall meet or exceed mechanical, electrical, and environmental requirements specified in Section 2 and in MIL-C-39012-C and MIL-C-39012/5F. The body material shall be AISI Standard Type 300 stainless steel. The accelerometer extension cable and connector assembly shall be designed to withstand a minimum tensile load of 225 newtons (50 pounds).

3.2.4 CHARGE AMPLIFIERS

3.2.4.1 The charge amplifier accuracy shall be in accordance with 2.1 with a standard supply of -24 volts DC.

3.2.4.2 The output, common, and power supply connections shall be a heavy-duty, corrosion-resistant, screw-compression-type termination or barrier-type terminal strip suitable for at least 18 AWG (1.0 square millimeter cross section) wire.

3.2.4.3 Mounting of charge amplifiers shall require space no larger than that of an oscillator-demodulator.

3.3 Thrust and Journal Bearing Temperature Channels

3.3.1 SENSORS

- **3.3.1.1** The standard temperature sensor shall be a grounded, Type J iron-copper-nickel (for example, Constantan) thermocouple manufactured in accordance with ANSI MC96.1 (IEC 584-1). When specified, the standard optional temperature sensor shall be a 100-ohm, platinum, three-lead resistance temperature detector with a temperature coefficient of resistance equal to 0.00385 ohm/ohm/°C from 0°C to 100°C (30°F to 210°F). Temperature sensors for electrically insulated bearings shall maintain the integrity of the bearing insulation (see 4.2.5.5 note).

- **3.3.1.2** Sensor leads shall be coated, both individually and overall, with insulation. When specified, flexible stainless steel overbraiding (see note) shall cover the leads and shall extend from within 25 millimeters (1 inch) of the tip to within 100 millimeters (4 inches) of the first connection.

Note: Stainless steel overbraiding may be difficult to seal in some installations.

- **3.3.1.3** A 40-millimeter (1.5-inch) piece of clear heat-shrink tubing (not to be shrunk at the factory) shall be installed at the connection end to assist in the tagging of the sensor.

3.3.2 WIRING

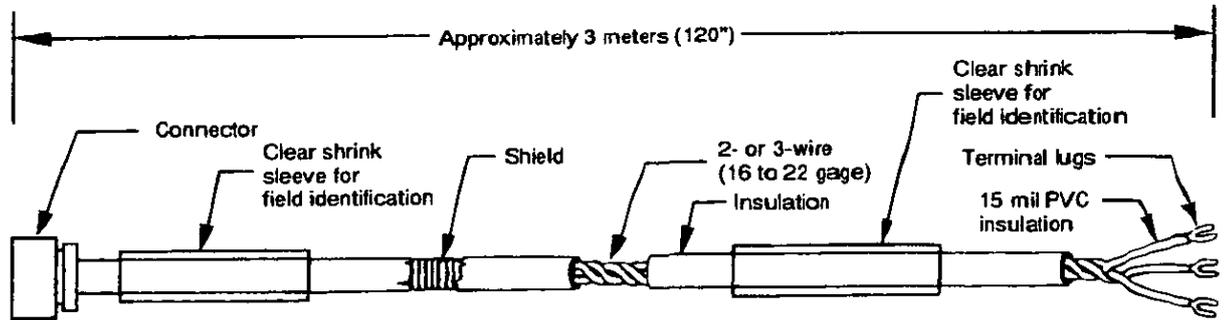
Wiring from the temperature sensor to the monitor shall be as follows:

- a. For thermocouples, use thermocouple extension wire of the same material as the thermocouple and in accordance with Appendix D.
- b. For resistance temperature detectors (RTDs), use three-conductor shielded wire in accordance with Appendix D.

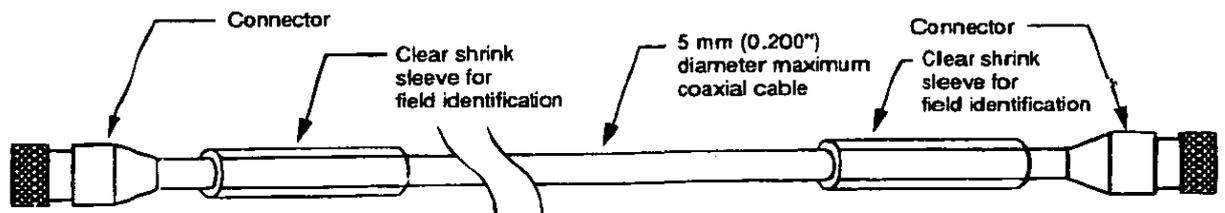
3.3.3 CONNECTORS

The standard installation shall employ a single compression-type, like-metal-to-like-metal connection technique between the sensor and the monitor. Unless otherwise specified, this connection shall be at a termination block external to the machine. Plug-and-jack, barrier-terminal-strip, or lug-type connectors shall not be used.

(A) TYPICAL TWISTED PAIR OR TRIAD EXTENSION CABLE



(B) TYPICAL LIGHT-DUTY COAXIAL CABLE



(C) TYPICAL CABLE FOR HEAVY-DUTY SERVICE

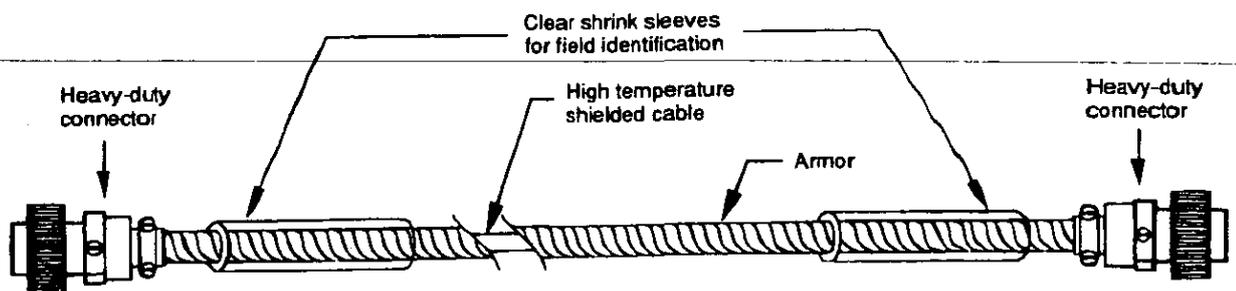


Figure 5—Accelerometer Extension Cable Options

3.4 Power Supplies and System-Output Relays

3.4.1 POWER SUPPLIES

3.4.1.1 The monitoring hardware shall be capable of meeting the accuracy requirements specified in 2.1 with input voltage to the power supply of 115 or 230 volts AC, ± 15 percent, 50 or 60 hertz. If an alternative power supply input is specified, the same accuracy requirements shall apply.

3.4.1.2 The output voltage to the oscillator-demodulator, charge amplifier, or other signal conditioning device shall be -24 volts DC with sufficient regulation and ripple suppression to meet the accuracy requirements specified in 2.1.

3.4.1.3 All power supplies shall be capable of sustaining a short circuit of indefinite duration across their outputs without damage. Output voltages shall return to normal when an overload or short circuit is removed.

3.4.1.4 The transducer power source shall be designed to prevent a fault condition in one transducer circuit from affecting any other channel.

3.4.1.5 All power supplies shall be immune to an instantaneous transient line input voltage equal to twice the normal peak input voltage for a period of 5 microseconds. Such a transient voltage shall not damage the power supplies or affect normal operation of the monitoring system.

3.4.1.6 All power supplies shall continue to provide sufficient power to allow normal operation of the monitoring system through the loss of AC power for a minimum duration of 50 milliseconds.

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

3.4.2 SYSTEM-OUTPUT RELAYS

3.4.2.1 As a minimum, one pair of relays, alarm (alert) and shutdown (danger), shall be provided for each of the following monitored variables: (a) axial position, (b) radial shaft vibration, (c) casing vibration, and (d) bearing temperature. In addition, one circuit fault relay shall be provided. Unless otherwise specified, the tachometer, if supplied, shall not be provided with relays.

3.4.2.2 Output relays shall be hermetically sealed electromechanical type. The relay control circuit shall be field changeable to be either normally deenergized or normally energized. Deenergize to alarm and energize to shutdown shall be standard. All relays shall be double-pole, double-

throw type with electrically isolated contacts. All contacts shall be available for wiring.

3.4.2.3 Alarm (alert) and circuit-fault relays shall be of the latching (manual-reset) type. Shutdown (danger) relays shall be field changeable to latching (manual reset) or non-latching (automatic reset). Latching shall be standard.

3.4.2.4 The circuit fault relay shall be normally energized. A power supply failure shall deenergize the circuit fault relay.

3.4.2.5 Contacts shall be rated at a resistive load of 5 amperes at 120 volts AC, or 3 amperes at 240 volts AC, or 5 amperes at 28 volts DC for a minimum of 10,000 operations. When inductive loads are connected, arc suppression shall be supplied at the load.

3.4.2.6 For normally deenergized shutdown (danger) output relays, an interruption of power (line power or DC output power) shall not transfer the shutdown (danger) relay contacts regardless of the mode or duration of the interruption.

3.5 Monitors

3.5.1 GENERAL

3.5.1.1 As a minimum, each monitoring system shall be provided with the following features:

- a. Indication capable of displaying measured variables, alarm (alert) and shutdown (danger) setpoints, and DC gap voltages (for radial shaft vibration and axial position channels). Unless otherwise specified, the system shall continuously display the higher radial shaft vibration of each bearing, all axial position measurements, the highest temperature, and the highest casing vibration. The indication may be an analog, digital, graphic, or other display specified by the purchaser.
- b. An alarm (alert) output from each channel to the corresponding alarm (alert) relay. Nonvoting (OR) logic is required.
- c. A shutdown (danger) output from each channel or channel pair to the corresponding shutdown (danger) relay, as discussed in 3.5.3.4, 3.5.5.4, and 3.5.6.4.
- d. For each channel, alarm (alert) and shutdown (danger) setpoints that are individually adjustable over the entire monitored range.
- e. Light-emitting diodes indicating circuit fault for each channel; alarm (alert) and shutdown (danger) for each channel or radial displacement and axial position channel pair.
- f. A continuous DC output proportional to the measured variable, available at a connector located at the rear of the monitoring system. The standard output shall be 4 to 20 milliamps. When specified by the end user, the output may be 0 to 10 volts DC or a digital output coded for computer-based systems, or both. When specified, the full-scale range of

these outputs shall be twice the full-scale range specified for monitoring (see 3.5.3.1). A short circuit of this output shall not affect the monitoring system.

g. Front-panel bayonet nut connector (BNC) connections to the output of all system transducers (except temperature) and rear-panel connections to channel transducer outputs (except temperature). All outputs shall be buffered so that a short circuit of the output shall not affect the operation of the monitoring system.

h. Front-panel switch and rear-panel connections for remote reset of latching alarms (alerts) and shutdown (danger) conditions.

i. A system to identify the first alarm (alert) and the first shutdown (danger).

j. A method of energizing all indicators for test purposes.

k. A means of indicating internal circuit faults, with a light-emitting diode for each individual channel, illuminated to indicate a no-fault condition. A common circuit fault relay shall be provided for each monitoring system. A circuit fault shall not initiate a shutdown or affect the shutdown logic in any way.

l. Isolation to prevent a failure in one transducer from affecting any other channel.

m. A design ensuring that a single circuit failure (power supply excepted) shall not affect more than two channels of radial shaft vibration, axial position and casing vibration, or six channels of temperatures on a single machine (see note).

Note: The intent of this requirement is to ensure comparable or higher reliability for digital, compared to analog, monitoring systems.

n. Electrical and mechanical adjustments for zeroes, gains, and alarm (alert) and shutdown (danger) setpoints that are field changeable and protected through controlled access. The monitoring system shall continue to function normally during adjustment. The adjustments shall be accessible from the front of the monitoring system without the aid of special tools.

o. Gain adjustment for each radial shaft vibration and axial position channel. Gain adjustment shall be factory calibrated for 8 millivolts per micrometer (200 millivolts per mil).

p. The time required to detect and initiate an alarm (alert) or a shutdown (danger) shall not exceed 100 milliseconds.

q. Fixed time delays for shutdown (danger) relay activation that are field changeable to require from 1 to 3 seconds sustained violation. A delay of 1 second shall be standard.

r. Coated printed circuit boards to provide protection from moisture, fungus, and corrosion.

- 3.5.1.2 When specified, any one or more of the following items shall be available for local display and as a digital output coded for a computer-based system:

- a. Channel status of alarm or no alarm.
- b. Armed/disarmed shutdown status for all machines.
- c. Alarm storage for storing the time, date, and value for a minimum of 64 alarms.

d. Channel value ± 0.5 percent full-scale range resolution.

e. Measured value as a percent of alarm (alert) and shutdown (danger) values to 1 percent resolution.

f. Transducer OK limits.

g. Hardware and software diagnostics.

h. Communication link status.

i. Alarm setpoints.

j. Gap voltage, when applicable.

k. Time stamp and date for all transmitted data.

l. System entry log to include date, time, individual access code, and record of changes.

- 3.5.1.3 When specified, a tachometer shall have the ability to record and store the highest measured rotational speed (rpm) above a setpoint. When specified, controlled access set capability for the tachometer shall be available both locally and remotely. A tachometer shall not be used for overspeed protection.

3.5.1.4 A single, tamperproof means of disarming the shutdown function shall be provided for each monitoring system, along with a corresponding indicating light (light when disarmed) and two sets of isolated external annunciator contacts. The system shutdown disarm may be internal or external to the monitoring system. Operation or maintenance of the monitoring system in the disarmed mode, including power supply replacements, shall not shut down the machine (see note).

Note: This feature is intended to be used as a shutdown bypass during monitoring system maintenance.

- 3.5.1.5 When specified, a tamperproof means for disarming the shutdown (danger) function and a visible indicating light-emitting diode (illuminated when disarmed) shall be provided for each monitored channel. Any disarmed condition shall activate a common relay located in the rack or power supply. This relay shall be in accordance with 3.4.4 and may be used for remote annunciation.

● 3.5.2 LOCATION OF MONITORS

The purchaser shall specify whether monitors are to be located indoors or outdoors (see note).

Note: Outdoor installations must be designed and located to avoid adverse vibrational and environmental effects. Area classification, orientation, prevailing lighting conditions, display brightness, and legibility must all be considered.

3.5.3 RADIAL SHAFT VIBRATION MONITORING

- 3.5.3.1 The full-scale range for radial shaft vibration monitoring shall be from 0 to 125 micrometers (0 to 5 mils) true peak-to-peak displacement with a minimum resolution of 2.0 micrometers (0.1 mil). When specified, the standard optional full-scale range shall be from 0 to 250 micrometers (0 to 10 mils) true peak-to-peak displacement with a minimum resolution of 5 micrometers (0.2 mil).

3.5.3.2 The radial shaft vibration circuit fault system shall be set to actuate at 125 micrometers (5 mils) less than the upper limit and 125 micrometers (5 mils) more than the lower limit of the transducer's linear range. The minimum allowable setting for the lower limit shall be 250 micrometers (10 mils) absolute gap.

3.5.3.3 Radial shaft vibration shall be monitored in paired channels from the two transducers mounted at each bearing. The system shall have the capability of displaying both values or automatically displaying the higher value with the ability to display either value.

3.5.3.4 The radial shaft vibration monitor's shutdown system shall be field changeable so that one or both transducer signals must reach or violate the setpoint to initiate a shutdown. Dual voting (two out of two) logic shall be standard (see note).

Note: In a dual voting logic system, although each channel may have reached or violated the shutdown (danger) setpoint at different times, both channels must jointly be at or above the shutdown (danger) setpoint before the shutdown (danger) relay activates. In the event of the failure of a single radial shaft vibration channel transducer or circuit, only the circuit-fault alarm will activate [that is, the shutdown (danger) relay will not activate].

3.5.3.5 Suppression shall not be allowed.

3.5.4 CASING VIBRATION MONITORING

3.5.4.1 Gear casing vibration shall be monitored in acceleration and velocity modes from a single accelerometer. Acceleration shall be monitored in a frequency range between 10 hertz and 10 kilohertz from 0 to 500 meters per second squared true peak with a minimum resolution of 10 meters per second squared (0 to 50 G's true peak with a minimum resolution of 1.0 G). Velocity shall be monitored in a frequency range between 10 hertz and 2500 hertz from 0 to 20 millimeters per second true peak with a minimum resolution of 0.4 millimeters per second (0 to 1.0 ips true peak with a minimum resolution of 0.02 ips) (see note).

Note: Acceleration should be used to indicate gear condition and not for machine protection. Velocity can be used for machine protection (see Appendix E).

3.5.4.2 When specified, a casing vibration monitoring system shall include one or more of the following options:

- a. Monitor and display of either acceleration or velocity.
- b. Monitor and display of two channels of acceleration or velocity.
- c. Alternate filter or frequency ranges.
- d. Monitor and display in true root mean square (rms).
- e. Alternate full-scale ranges.
- f. Dual voting logic.

3.5.4.3 The casing vibration circuit fault system shall activate when an open circuit or short circuit exists in the monitor-accelerometer-monitor loops or monitor-charge

amplifier-monitor loops. (The charge amplifier-accelerometer-charge amplifier loop is excepted.) The circuit fault system shall be latching and shall inhibit the operation of the affected channel until the fault is cleared and the channel reset.

3.5.4.4 Each casing vibration monitoring channel shall be equipped with two field-changeable filters, high and low pass, to set the monitored frequency range. Filters shall have the following characteristics:

- a. Unity gain and no loss in the passband greater than 0.5 decibels, referenced to the input signal level.
- b. A minimum roll-off rate of 24 decibels per octave at the high and low cutoff frequency (-3 decibels).
- c. Filtering prior to integration.

3.5.5 AXIAL POSITION MONITORING

3.5.5.1 The axial position monitoring range shall be from -1.0 to +1.0 millimeters (-40 to +40 mils) axial movement with a minimum of 50 micrometers (2 mils) resolution.

3.5.5.2 The axial position monitoring circuit-fault system shall be set to actuate at the end of the transducer's linear range but not closer than 250 micrometers (10 mils) of absolute probe gap.

3.5.5.3 The axial position shall be monitored in paired channels. The monitoring system shall be capable of displaying the deviation from zero for both channels. The two channels may share common alarm (alert) and shutdown (danger) setpoints but shall have separate zeroing and gain adjustments.

3.5.5.4 The axial position monitoring system shall be field changeable so that one or both transducer signals must reach or violate the shutdown (danger) setpoint to actuate the shutdown (danger) relay. Dual voting (two out of two) logic shall be standard (see note).

Note: In a dual voting logic system, although each channel may have reached or violated the preset shutdown (danger) setpoints at different times, both channels must jointly be at or above the shutdown (danger) setpoints before the shutdown (danger) relay activates. If each channel has its own separate setpoint, both channels need not be set at the same setpoint. In the event of the failure of a single axial position transducer or circuit, only the circuit-fault alarm and the alarm (alert) will activate [that is, the shutdown (danger) relay will not activate]. The shutdown (danger) relay will activate when any of the following conditions occur:

- a. Both axial position transducers or circuits fail.
- b. Either channel has failed, and the other channel has violated the shutdown (danger) setpoint.
- c. Both channels jointly violate the shutdown (danger) setpoint.

This logic is intended to address safety considerations.

3.5.5.5 Each axial position monitoring channel shall be field changeable so that the display will indicate either up-scale or downscale with increasing probe gap. Indicating up-scale with increasing probe gap shall be standard.

3.5.6 BEARING TEMPERATURE MONITORING

3.5.6.1 The full-scale range for bearing temperature monitoring shall be from 0°C to 150°C (0°F to 300°F) with a minimum resolution of 1°. When thermocouples are used, bearing temperature monitoring systems shall be designed to be suitable for grounded thermocouples.

3.5.6.2 A fault in the bearing temperature monitoring sensor circuit shall initiate the circuit-fault alarm. Downscale failure (that is, a failure in the zero direction) shall be standard.

3.5.6.3 Bearing temperature monitoring shall include the capability of displaying all monitored values. Unless otherwise specified, the display shall include automatic capability to display the highest temperature.

3.5.6.4 The bearing temperature monitor's shutdown (danger) function shall be field changeable to allow either of the following two possible configurations:

- a. Any individual sensor must reach or violate the shutdown (danger) setpoint.
- b. Dual voting logic between predetermined pairs of sensors must reach or violate the shutdown (danger) setpoint.

Dual voting logic shall be standard when two sensors are installed in the load zone of the bearing. Single violations (OR logic) shall be standard for all other sensor configurations.

3.6 Wiring and Conduits

3.6.1 GENERAL

Wiring and conduits shall be installed in accordance with electrical practices specified in NFPA 70. (See note and Figures 6A, 6B, 6C, 6D, and 6E and Figure C-3.) All conduit, signal and power cable, and monitoring system components shall be located in well-ventilated areas away from hot spots such as lines, machinery components, and vessels. Monitoring system components shall not be covered by insulation or obstructed by items such as machinery covers, conduits, and piping. All conduits, armored cable, and similar components shall be located to permit disassembly and repair of equipment without causing damage to the electrical installation. Signal and power wiring shall be segregated according to good instrument installation practices (see 3.6.2.3). Signal wiring shall not be run in conduits or trays containing circuits of more than 30 volts of either alternating or direct current.

Note: The selection of conduit, armored cable, and enclosures should comply with the option selected to meet the local area classification.

3.6.2 CONDUIT RUNS TO PANELS

3.6.2.1 Conduits shall be weatherproof and of suitable size to meet NFPA 70 requirements for the size and number

of signal cables to be installed. A drain shall be installed at each conduit low point except at underground conduits which shall be adequately sealed to prevent the entrance of moisture.

3.6.2.2 Signal cables shall be in accordance with the provisions of Appendix D. The physical length of signal cables shall be limited to a continuous run of 150 meters (500 feet). The use of longer cable runs must be reviewed and approved in writing by the instrument manufacturer. The use of noncontinuous runs must be approved by the end user.

3.6.2.3 The minimum separation between installed signal and power cables shall be as specified in Table 1.

3.7 Grounding

3.7.1 GROUNDING OF THE SYSTEM

The agency responsible for installing the monitoring system shall ensure that good grounding practice is followed. The construction agency shall obtain mutual agreement from the purchaser and the instrument manufacturer or manufacturers with respect to grounding, intrinsic safety, instrument performance, and elimination of ground loops. The transmitter common shall be isolated from the machine ground.

3.7.2 GROUNDING OF TRANSDUCER-TO-MONITOR SIGNAL CABLE SHIELDS

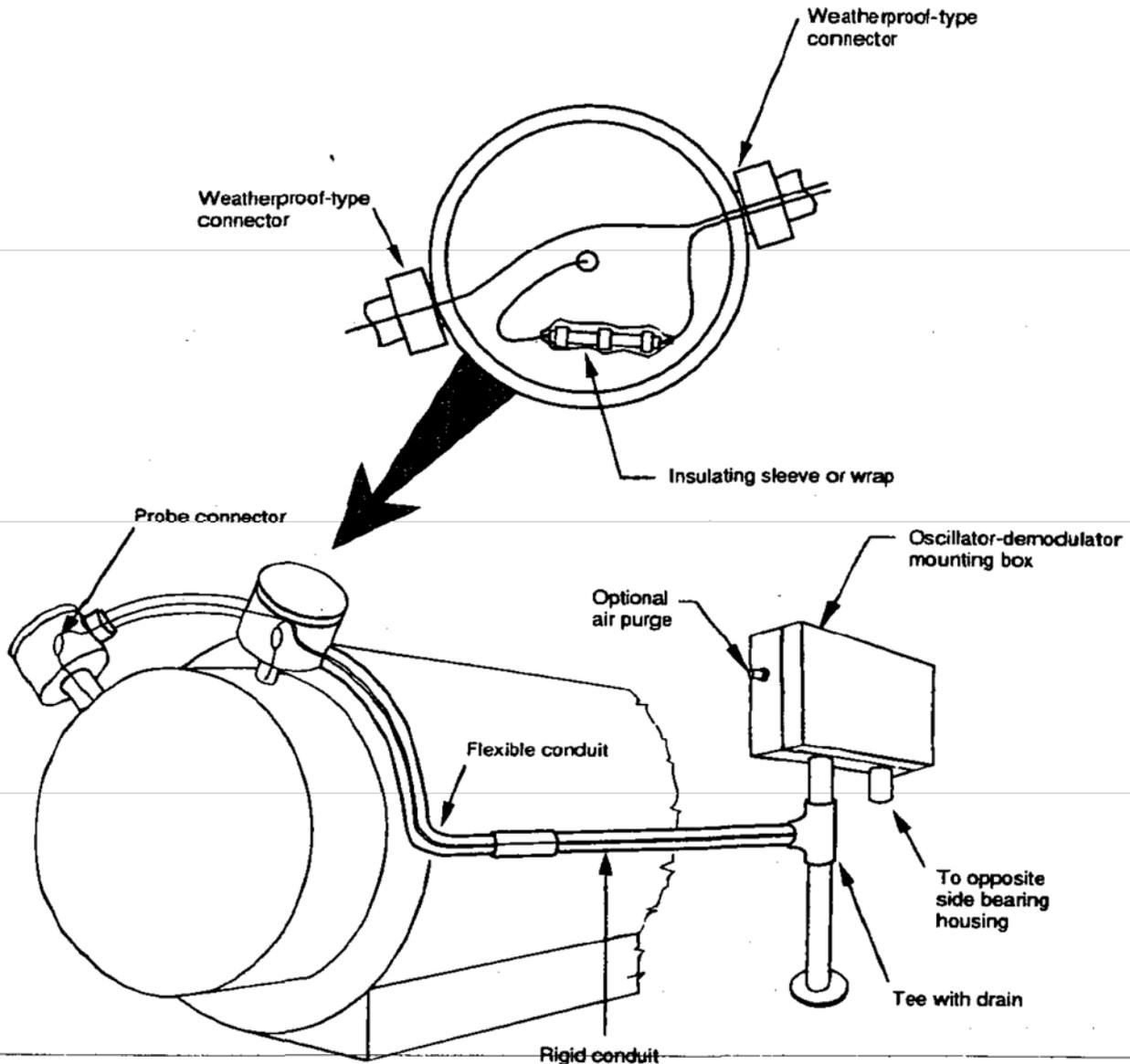
The signal cable shield shall only be grounded at the monitor. The shield shall not be used as the common return line.

3.8 Field-Installed Instruments

- **3.8.1** Field-installed vibration, axial position, and temperature instrumentation installed in hazardous (classified) locations shall be suitable for the area classification as defined in Article 500 of NFPA 70. The purchaser shall specify whether the atmosphere in such locations is Group B, C, or D (see NFPA 70). If instruments are located outdoors or are subject to fire sprinklers, their housings shall be weatherproof (NEMA Type 3) or watertight (NEMA Type 4), as specified in NEMA 250, in addition to any other enclosure requirements necessary for the area classification in which the instrument is installed. Intrinsically safe or nonincendiary instruments are preferred (see note); however, air purging c

Table 1—Minimum Separation Between Installed Signal and Power Cables

Voltage AC	Minimum Separation	
	Millimeters	Inches
120	300	12
240	450	18
440	600	24



Note: Probe extension cable connectors shall be insulated from ground.

Figure 6A—Typical Standard Conduit Arrangement

housings as described in 3.8.2 is acceptable for meeting area classification requirements.

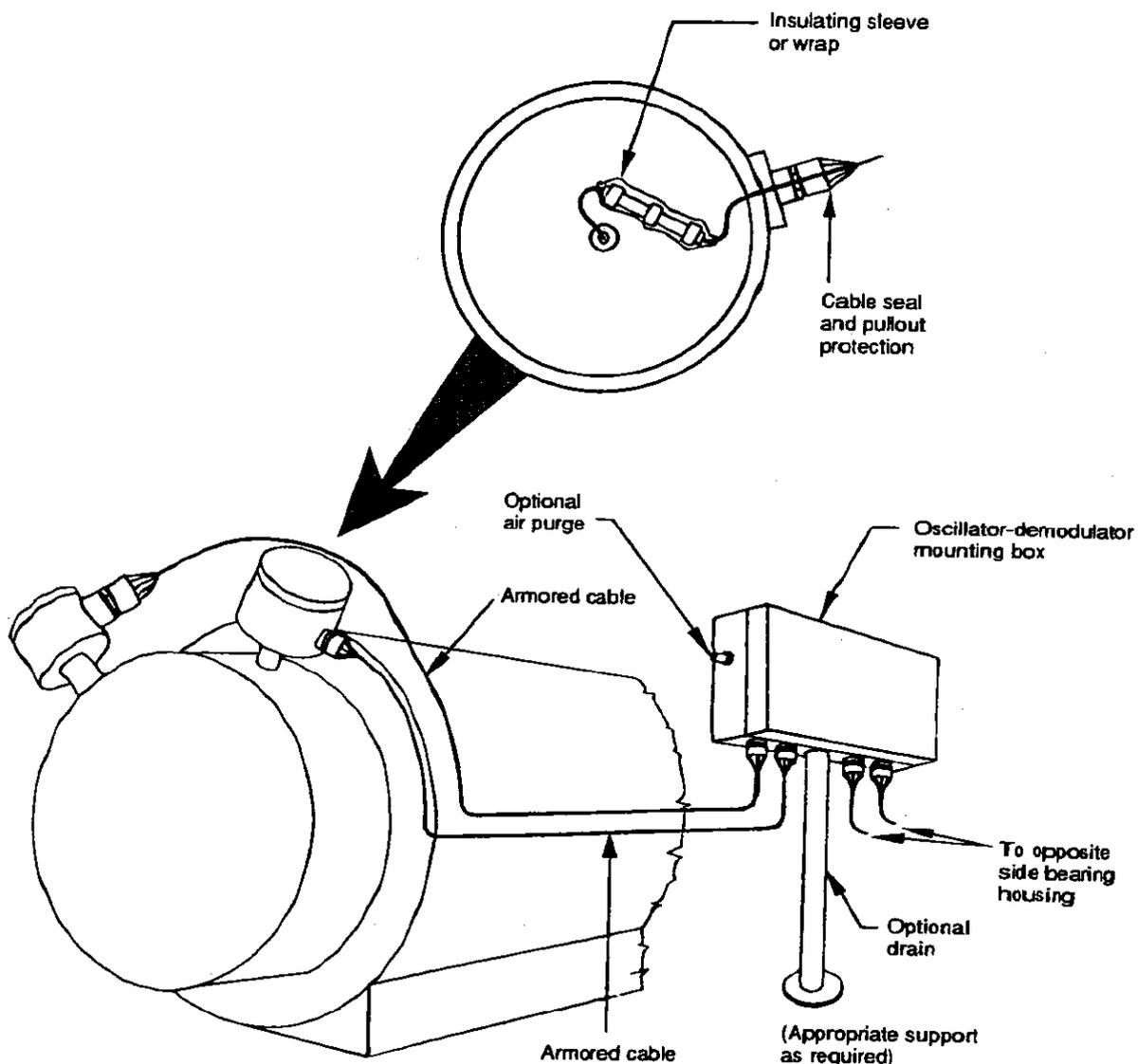
Note: Explosion-proof or intrinsically safe instrumentation shall be used for Class I, Division 1 and Division 2 hazardous (classified) locations; nonincendive instrumentation shall be suitable for Class I, Division 2 hazardous (classified) locations when installed in accordance with Article 501, NFPA 70.

3.8.2 When specified, air purging shall be used to avoid moisture problems, even when weatherproof or watertight housings are used (see 3.8.1). Purge air shall be clean and

dry. When air purging is specified to meet the area classification, it shall be in accordance with ISA S12.4, Type X or Y; or with NFPA 496, as required.

3.8.3 The construction agency shall comply with 3.5.1.4 regarding the installation of tamperproof means of bypassing the system's shutdown function.

3.8.4 The satisfactory operation of electronic instrumentation in the presence of radio-frequency interference requires



Note: Probe extension cable connectors shall be insulated from ground.

Figure 6B—Typical Standard Option Armored Cable Arrangement

that both the level and the form of the interference, as well as the required degree of immunity to it, be clearly defined by the end user. (One company may not allow the use of radios in a control room whereas another may allow their use behind instrument panels in the control room while the enclosures are open.) Once the requirement for immunity to radio-frequency interference is defined, the details of electronic design and hardware installation can be established (see note). Unless otherwise specified, monitoring systems shall be pro-

tected against electromagnetic radiation of Class 2 (10 volts per meter) at bands A, B, and C, 1 percent full-scale span susceptibility as defined by SAMA Standard PMC 33.1.

Note: In addition to sound practices in the areas of instrument design, grounding, and shielding, the use of metallic-conduit and radio-frequency interference gasketing is critical to a successful installation. To ensure a trouble-free installation, the detailed requirements of a particular system must be discussed during the procurement phase by the instrument manufacturer, the construction agency, and the end user. The instrument manufacturer does not usually have control over the installation of the monitoring system.

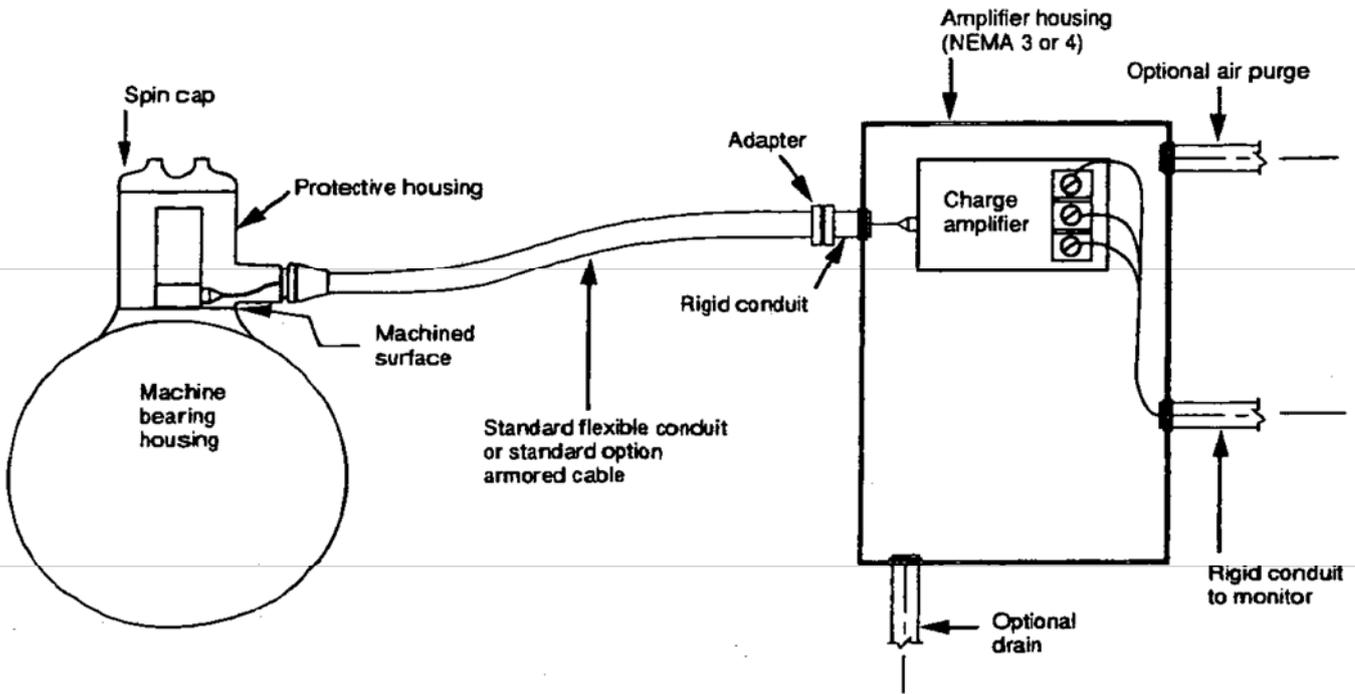


Figure 6C—Typical Transducer Installations for External Charge Amplifier

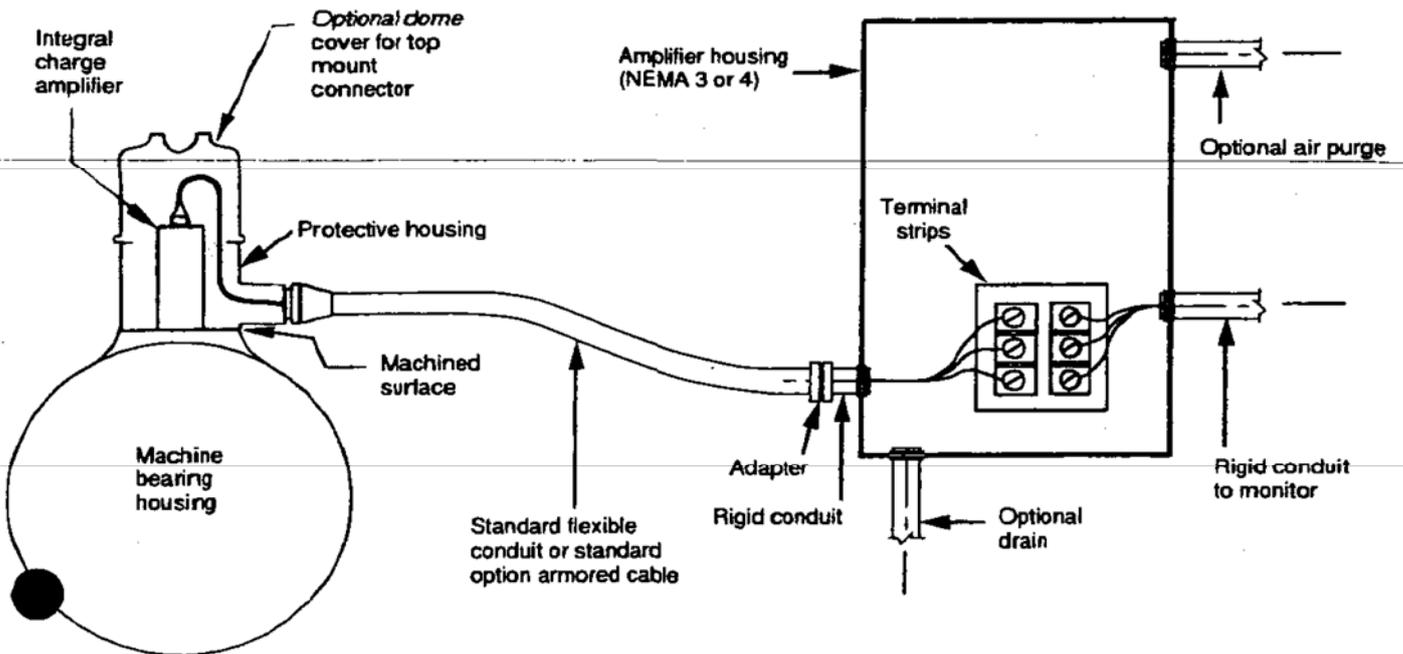


Figure 6D—Typical Transducer Installations for Integral Charge Amplifier

SECTION 4—TRANSDUCER AND SENSOR ARRANGEMENTS

4.1 Location and Orientation

4.1.1 RADIAL SHAFT VIBRATION PROBES

- 4.1.1.1 Two radially oriented probes shall be provided for each bearing. The two probes located at each bearing shall be coplanar, 90 degrees (± 5 degrees) apart and perpendicular to the shaft axis (± 5 degrees). The probes shall be located 45 degrees (± 5 degrees) from each side of the vertical center. Viewed from the driver end (or user defined reference) of the machine train, the Y (vertical) probe shall be on the left side of the vertical center, and the X (horizontal) probe shall be on the right side of the vertical center regardless of the direction of shaft rotation.

4.1.1.2 Probes shall be located within 75 millimeters (3 inches) of the bearing. The probe locations at each end of the machine shall be the same with respect to the nodal points of the shaft's lateral motion (for example, both sets of probes shall be either inside or outside the nodal points).

Probes shall not be located at a nodal point. The surface areas to be observed by the probes shall be concentric with the bearing journals and free from stencil and scribe marks or any other mechanical discontinuity, such as an oil hole or a keyway. These areas shall not be metallized or plated. The final surface finish shall be from 0.4 to 0.8 micrometer (16 to 32 microinches) root mean square, preferably obtained by honing or burnishing. These areas shall be properly demag-

netized or otherwise treated so that the combined total electrical and mechanical runout does not exceed 25 percent the maximum allowed peak-to-peak vibration amplitude in micrometers (0.25 mil), whichever is greater (see note).

Note: Diamond burnishing with a tool-post-held, spring-mounted diamond is common. Final finishing or light surface-removal finishing by grind will normally require follow-up demagnetization. The proximity probe track should be demagnetized. The gauss level of the proximity probe track should not exceed ± 2 gauss. The variation of gauss level around the circumference of the proximity probe track should not exceed 1 gauss.

4.1.1.3 For all conditions of rotor axial float and thermal expansion, a minimum side clearance of one-half the diameter of the probe tip is required. The probe shall not be affected by any metal other than that of the probe target area.

4.1.1.4 Unless otherwise specified, the probe gap shall be set at -10.0 volts DC (± 0.2 volts DC). Probes shall preferably be gapped while oil is circulated through the bearings at a stabilized temperature in the range of 40°C to 55°C (100 to 130°F). The standard gap voltage shall be consistent throughout the machinery train.

4.1.2 AXIAL POSITION PROBES

- 4.1.2.1 Two axially oriented probes shall be supplied for the thrust bearing end of each casing. Both probes shall sense the shaft itself or an integral axial surface installed within an axial distance of 300 millimeters (12 inches) from

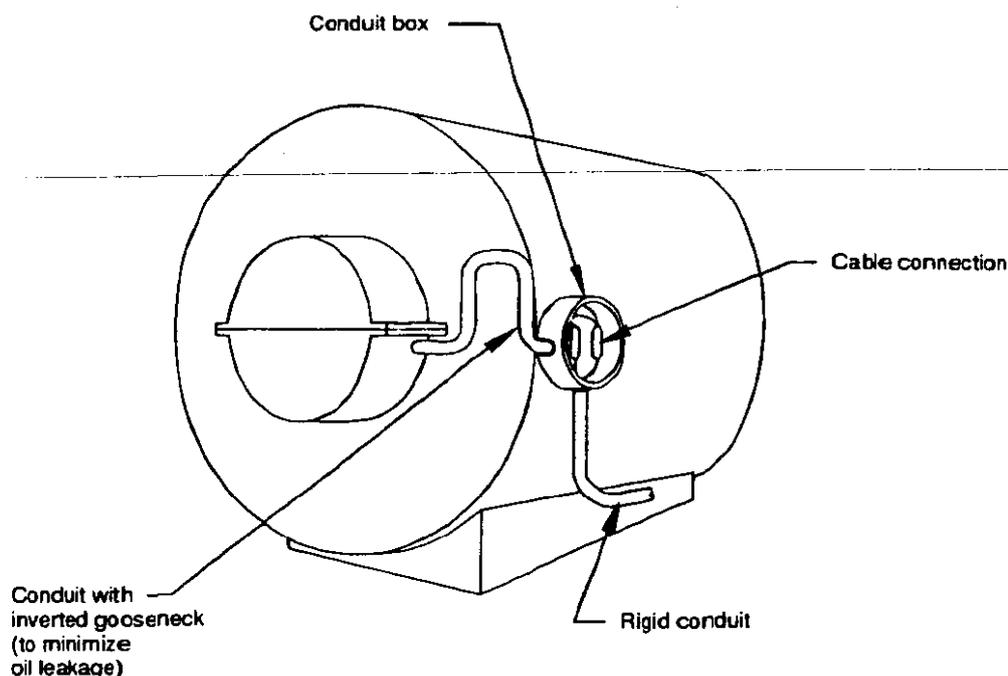


Figure 6E—Inverted Gooseneck Trap Conduit Arrangement

the thrust bearing or bearings (see Figure 7). When specified, the standard optional arrangement shall be one probe sensing the shaft end and one probe sensing an integral thrust collar (see Figure 8) (see note).

Note: Measurement on a loose nonintegral thrust collar will result in a false indication of shaft axial position.

4.1.2.2 It shall be possible to adjust the probe gap using commercially available wrenches. No special bent or split socket wrenches shall be required. The electrical box shall protect the axial probe assembly (see Figure 7) so that external loads (for example, those resulting from personnel stepping on the box) do not impose stress on the assembly and result in false shaft-position indication.

4.1.2.3 Externally removable probes shall include provisions to indicate that the gap adjustment has not been changed from the original setting. This may be accomplished by either tie wires or external markings.

4.1.2.4 Shaft and collar areas sensed by axial probes shall have a combined total electrical and mechanical runout of not more than 13 micrometers (0.5 mil) peak-to-peak. The provisions of 4.1.1.2 regarding surface finish and the requirement of 4.1.1.3 regarding minimum side clearance shall be observed.

4.1.2.5 The axial probe gap shall be set so that when the rotor is in the center of its thrust float, the transducer's output voltage is within ± 0.2 volts DC of the center of its linear range (nominally, -10 volts DC).

4.1.3 PHASE REFERENCE TRANSDUCERS

4.1.3.1 A one-event-per-revolution mark and a corresponding phase reference transducer shall be provided on the driver for each machinery train.

4.1.3.2 Where gearboxes are used, a one-event-per-revolution mark and a phase reference transducer shall be provided for each different rotational speed, as specified.

4.1.3.3 Phase reference probe mounting requirements and electrical conduit protection shall be identical to that of a radial or axial transducer (see 4.1.2.2 and 4.2.1.1).

4.1.3.4 The phase reference probe and its angular position shall be permanently marked with a metal tag on the outside of the machine casing. The angular position of the one-event-per-revolution mark on the rotor shall be marked on an accessible portion of the shaft.

4.1.3.5 A change in the transducer's output voltage of at least 7 volts shall be provided for triggering external analysis equipment and digital tachometers.

4.1.3.6 The minimum width of the marking groove shall be one and one-half times the diameter of the probe tip; the minimum length shall be one and one-half times the diame-

ter of the probe tip; and the minimum depth shall be 1.5 millimeters (0.06 inch). All edges shall be radiused to a minimum of 0.8 millimeter (0.03 inch). The one-event-per-revolution mark shall be long enough to allow for shaft thermal expansion and rotor float.

4.1.3.7 Phase reference probes shall be radially mounted to sense a one-event-per-revolution mark. The mark shall not be placed in the path of the normal radial-vibration probes.

4.1.4 ACCELEROMETERS

4.1.4.1 Accelerometers intended to monitor radial vibration shall be located on the radial-bearing housing. Location and number of accelerometers must be jointly developed by the machinery vendor and the end user. In some applications, field determination of the optimum mounting location may be required.

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

4.1.5 BEARING TEMPERATURE SENSORS

4.1.5.1 Radial Bearing Sensors

4.1.5.1.1 Unless otherwise specified, temperature sensors for sleeve-type journal bearings shall be arranged as specified in 4.1.5.1.2, 4.1.5.1.3, and 4.1.5.1.9.

4.1.5.1.2 Bearings whose length-to-diameter ratio is greater than 0.5 shall be provided with two axially collinear temperature sensors located in the lower half of the bearing, 30 degrees (± 10 degrees) from the vertical centerline in the normal direction of rotation.

4.1.5.1.3 Bearings whose length-to-diameter ratio is less than or equal to 0.5 shall be provided with a single sensor axially located in the center of the bearing, 30 degrees (± 10 degrees) from the vertical centerline in the normal direction of rotation.

4.1.5.1.4 Unless otherwise specified, temperature sensors for tilting-pad-type journal bearings shall be arranged as specified in 4.1.5.1.5 through 4.1.5.1.9.

4.1.5.1.5 Bearings whose length-to-diameter ratio is greater than 0.5 shall be provided with two axially collinear embedded temperature sensors located at the three-quarter arc length (75 percent of the pad length from the leading edge). For pads with self-aligning pivots, installation in accordance with 4.1.5.1.6 is acceptable.

4.1.5.1.6 Bearings whose length-to-diameter ratio is less than or equal to 0.5 shall be provided with a single sensor axially located in the center of the pad at the three-quarter arc length (75 percent of the pad length from the leading edge).

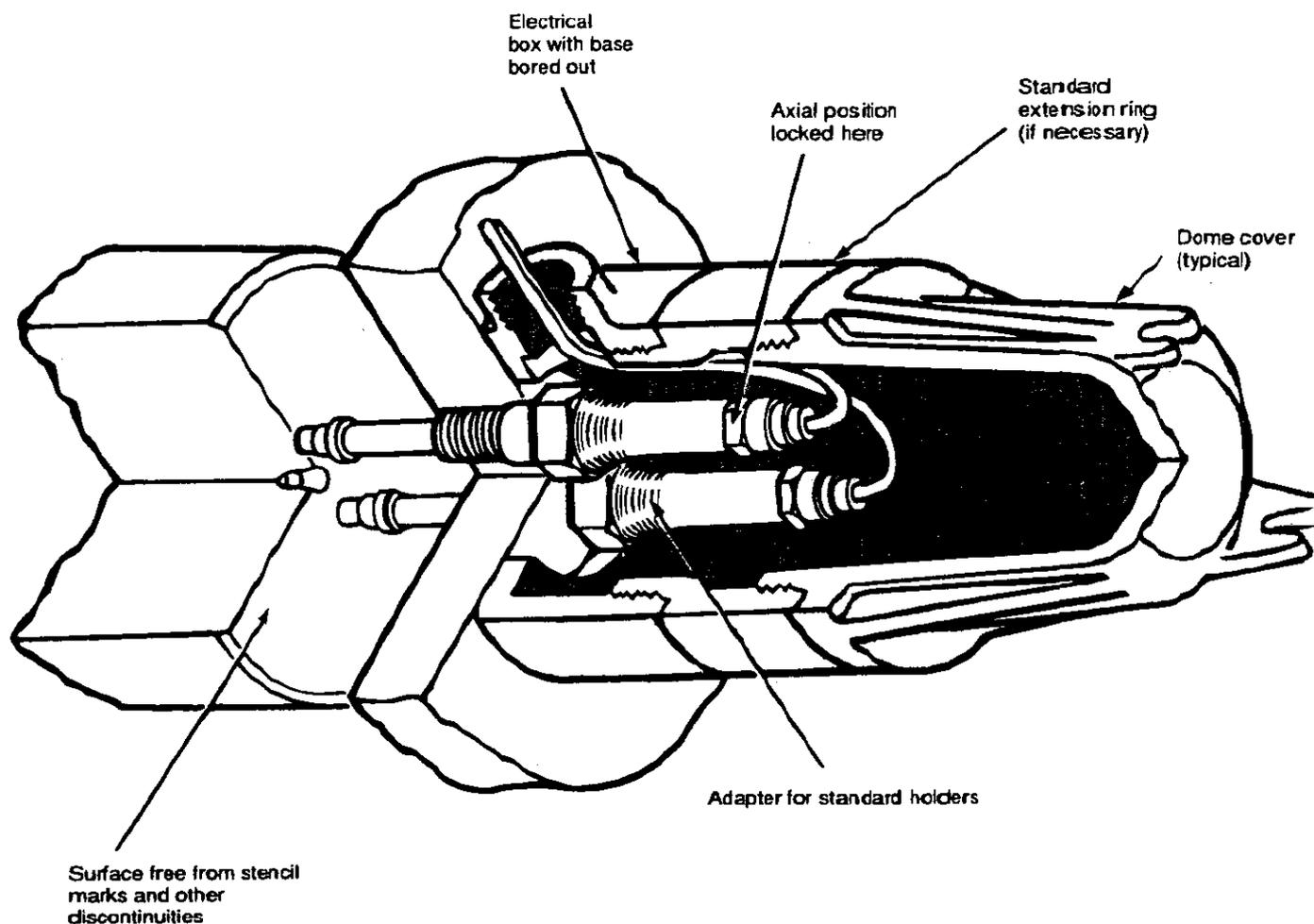


Figure 7—Standard Axial Position Probe Arrangement

4.1.5.1.7 For bearings with load-on-pad designs, the sensor or sensors shall be located in the loaded pad.

4.1.5.1.8 For bearings with load-between-pad designs, the sensor or sensors shall be located in the pad trailing the load (see Figure 9).

4.1.5.1.9 The machinery vendor shall notify the end user when the point of minimum lubrication film thickness does not coincide with the sensor locations specified in 4.1.5.1.1 and 4.1.5.1.4. The location of the temperature sensors shall then be mutually agreed upon by the end user and the machinery vendor (see Figure 9).

4.1.5.1.10 For machines such as gearboxes, the shaft operating attitude shall be considered in determining the exact location of the temperature sensors.

4.1.5.2 Thrust Bearing Sensors

4.1.5.2.1 A temperature sensor shall be located in each of two shoes in the normally active thrust bearing. These sen-

sors shall be at least 120 degrees apart. For maintenance purposes and also to identify the maximum pad temperature, the sensors preferably shall be located in the lower half of the thrust bearing assembly (see Figure 10).

4.1.5.2.2 Thrust bearing temperature sensors shall be placed at 75 percent of the pad width radially out from the inside bearing bore and at 75 percent of the pad length from the leading edge (see Figure 10).

4.1.5.2.3 Unless otherwise specified, at least two additional temperature sensors shall be provided in the normally inactive thrust bearing, arranged as specified in 4.1.5.2.1 and 4.1.5.2.2.

4.2 Mounting

4.2.1 PROBES

4.2.1.1 All probes, including phase reference probes, shall be mounted in holders that permit adjustment and are retractable or removable while the machine is running. Internal

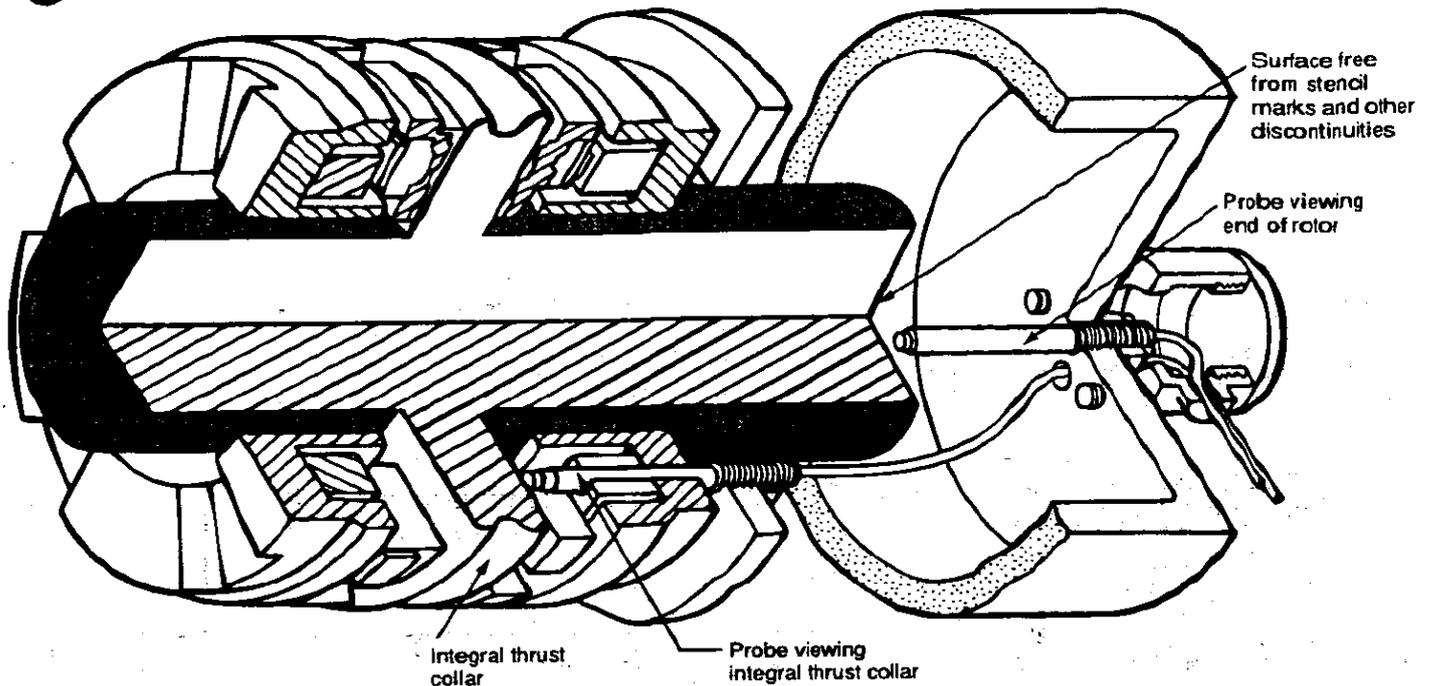


Figure 8—Standard Option Axial Position Probe Arrangement With Integral Thrust Collar

mounting of probes is acceptable only when approved by the end user. When internal probes are used, they shall be installed with complete spares, and the location shall be agreed to by the end user. The preferred location for the installed spare probes is 180 degrees radially from that of the installed contract probes.

4.2.1.2 Probe holders shall be free from natural frequencies that could be excited by machine-generated frequencies. The free cantilevered length of a probe holder shall not exceed 200 millimeters (8 inches). (See support guide shown in Figure 11.)

4.2.1.3 When a probe is internally mounted, armored probe leads are required. The probe holder shall be at least 10 millimeters ($\frac{3}{8}$ inch) thick. The probe lead shall be securely tied down to prevent cable whipping or chafing resulting from windage or oil. No cable connections shall be made inside the machine. To facilitate maintenance while the machine is running, all cable connections shall be made in conduit boxes located outside the machine.

4.2.1.4 In the standard configuration, all extension cables shall be protected in conduit as shown in Figure 6A. Extension

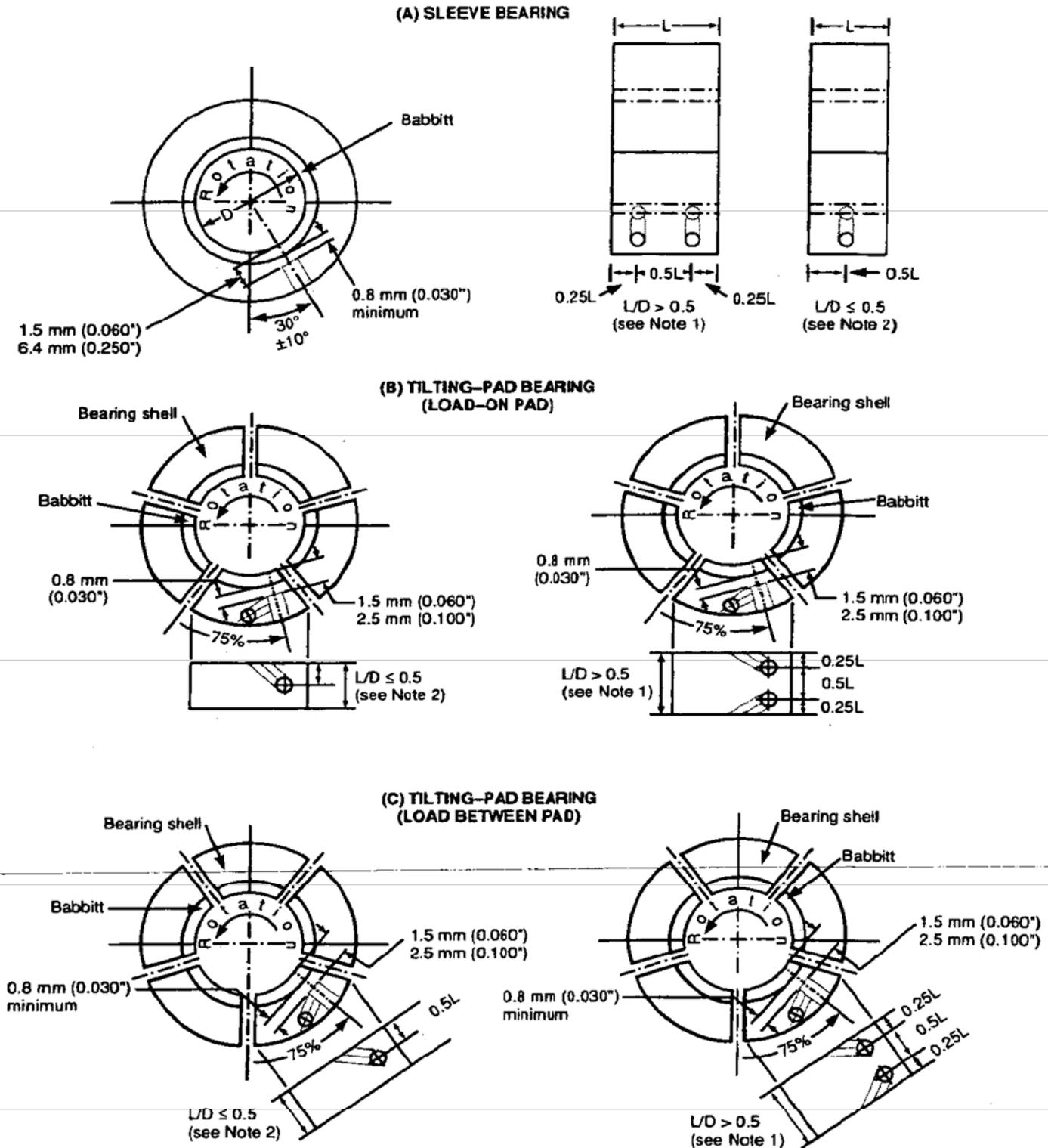
cable connectors shall be electrically isolated from conduit using an insulating sleeve or wrap. When specified, the standard option shall consist of armored extension cable as shown in Figure 6B.

4.2.2 OSCILLATOR-DEMODULATORS

The number, location, and installation of mounting boxes for oscillator-demodulators shall be mutually agreed upon by the end user and the construction agency. There shall not be less than one mounting box per machinery casing. All mounting boxes for oscillator-demodulators shall be located for ease of access and on the same side of the equipment train. These boxes shall not be mounted on the machine but shall be mounted to provide a vibration-free environment at ambient temperatures.

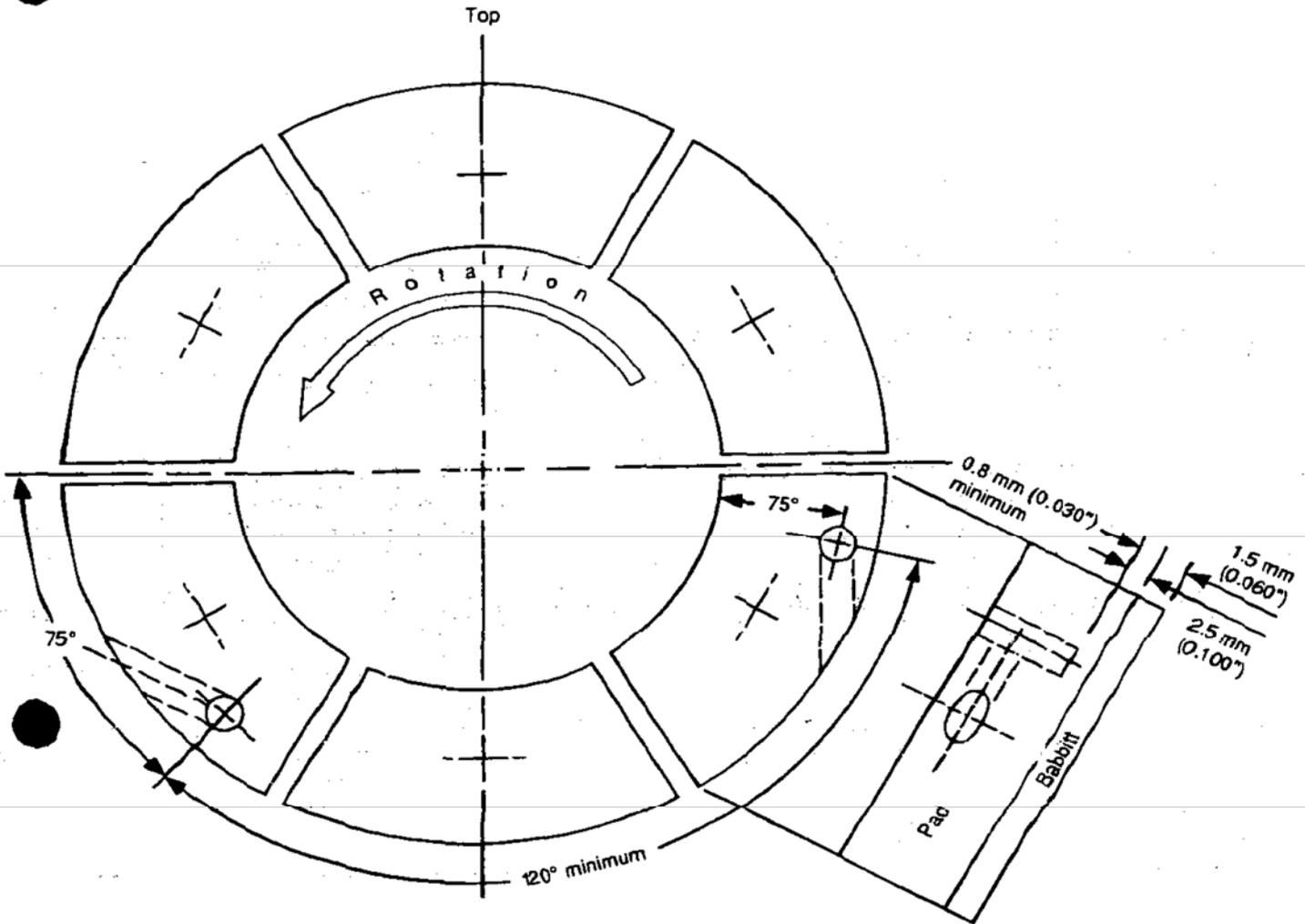
4.2.3 ACCELEROMETERS

4.2.3.1 The machinery vendor shall provide machined and finished accelerometer mounting points as shown in Appendix C. The boss or surface shall be an integral part of the machine casing.



- Notes:
1. If the length-to-diameter (L/D) ratio is greater than 0.5, two sensors shall be installed, each located at a distance of 0.25L from the end of the bearing's running face.
 2. If the L/D ratio is less than or equal to 0.5, a single sensor shall be axially located in the center of the bearing.

Figure 9—Typical Installations of Radial Bearing Temperature Sensors



Notes:

1. The temperature sensor shall be located 1.5 to 2.5 millimeters (0.060 to 0.100 inch) from the bearing running face and not less than 0.8 millimeter (0.030 inch) from the (white metal) babbitt/pad interface. The holes shall be finished with a bottoming drill, and all corners shall be broken.

2. The sensor lead shall be routed from the bearing to the outside of the machine through a penetration fitting. The sensor lead shall be properly secured, with no internal connections, to prevent damage as a result of whipping, chafing, windage, and oil. The sensor lead shall not restrain pivoting thrust shoes.

Figure 10—Typical Installation of Thrust Bearing Temperature Sensors

4.2.3.2 Unless otherwise specified, the machinery vendor shall provide the standard accelerometer mounting configuration as shown in Appendix C for each accelerometer.

4.2.3.3 All cables shall be enclosed in conduit. The conduit shall be attached to an enclosure, not to the accelerometer. (See Figures 6C and 6D and Appendix C for typical mounting and enclosure arrangements.)

4.2.3.4 When specified, the standard option accelerometer extension cable shall be protected by a weatherproof, flexi-
cable (see note). (See Figures 6C and 6D and Appendix C for details.)

Note: This permits mounting the accelerometer with mechanical protection without using conduit.

4.2.4 CHARGE AMPLIFIERS

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

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

4.2.5 BEARING TEMPERATURE SENSORS

4.2.5.1 Embedded temperature sensors shall not contact the babbitt (white metal) but shall be located in the bearing

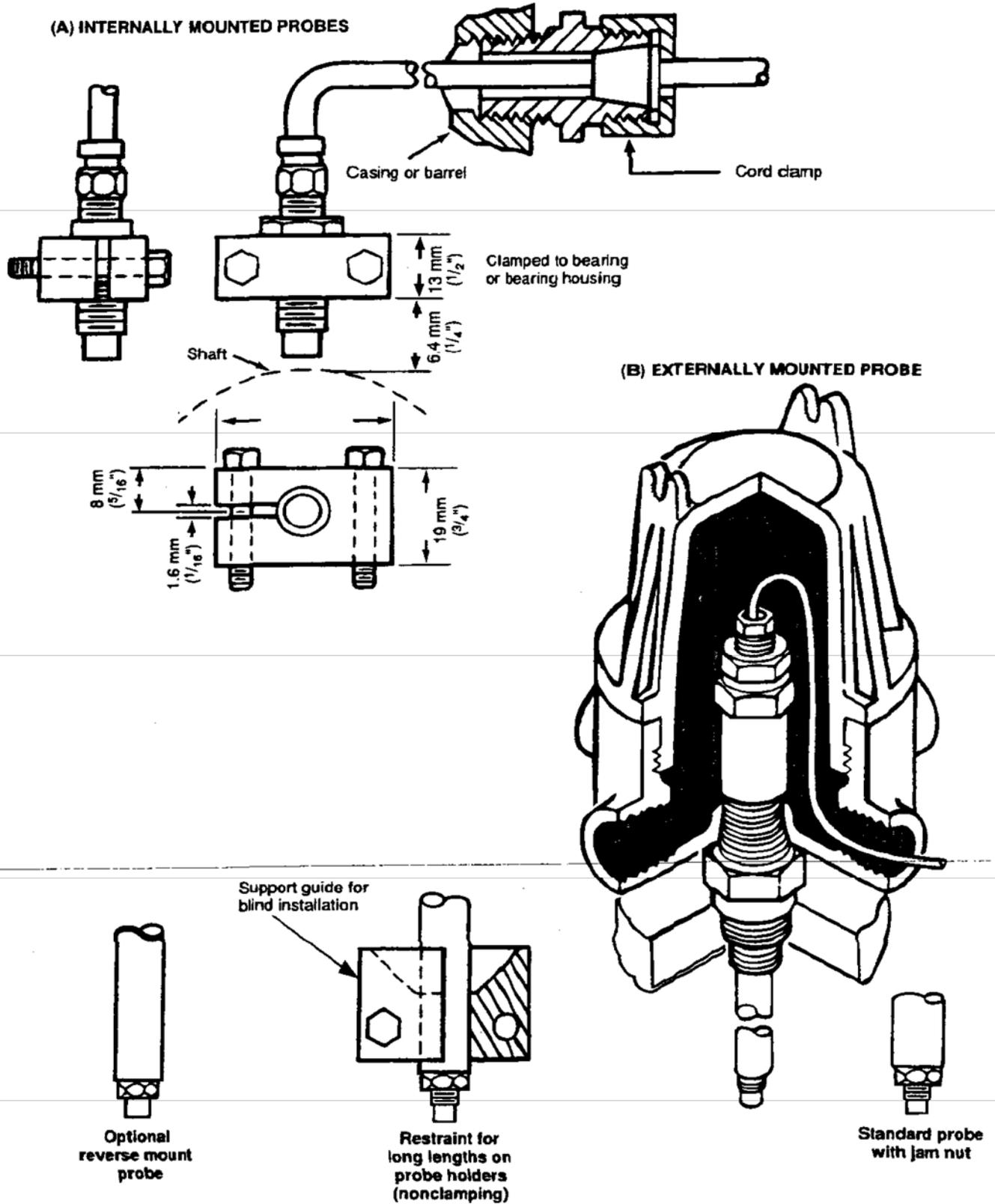


Figure 11—Typical Probe Mounting Arrangements

backing metal (see Figure 9). Through-drilling and puddling of the babbitt is not permitted.

4.2.5.2 The heat-sensing surface of the temperature sensor shall be in positive contact with the bearing backing metal and not less than 0.75 millimeter (30 mils) from the babbitt bond line. The recommended distances from the babbitt running face are as follows (see Figure 9):

- a. For tilting-pad-type bearings, from 1.5 to 2.5 millimeters (60 to 100 mils).
- b. For sleeve-type bearings, from 1.5 to 6.4 millimeters (60 to 250 mils).

4.2.5.3 When specified, spring-loaded (bayonet type) temperature sensors that contact the outer shell of the bearing metal are permitted without bonding or embedment.

4.2.5.4 The leads from all temperature sensors shall be oriented to minimize bending or movement during operation and maintenance. The sensor leads shall be secured to prevent cable whipping and chafing resulting from windage or oil without restricting pad movement. Unless otherwise specified, no sensor lead connections shall be made inside the machine. To facilitate maintenance while the machine is running, a terminal head for all cable connections shall be provided outside the machine. The sensor leads shall be free from splices (see Figure 12).

4.2.5.5 When specified, the temperature sensor tip shall be electrically insulated from the bearing (see note).

Note: Many machines, notably electric motors and generators, require electrically insulated bearings to prevent circulating shaft currents. Bearing temperature sensors must not violate this insulation requirement (see 3.3.1.1 and 3.7.1).

4.2.5.6 The temperature sensor signal cables shall not leak out of the point where they penetrate the bearing housing.

Acceptable arrangements include the following:

- a. Potted, encased sleeves that are sealed with compression-type seals.
- b. Molded signal leads within an elastomeric material that is sealed with a tapered compression fitting.
- c. Hermetic seals.
- d. Inverted gooseneck trap arrangement in conduit (see Figure 6E).

4.3 Identification of Transducers and Temperature Sensors

Each probe lead, extension cable, oscillator-demodulator, and temperature sensor lead shall be plainly marked to indicate the location and service of its associated probe or sensor.

SECTION 5—INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

5.1 General

5.1.1 After advance notification of the vendor by the purchaser, the purchaser's representative shall have entry to all vendor and subvendor plants where manufacturing, testing, or inspection of the equipment is in progress.

5.1.2 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

5.1.3 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed.

5.1.4 The purchaser will specify the extent of his participation in the inspection and testing and the amount of advance notification he requires.

5.1.4.1 When shop inspection and testing have been specified by the purchaser, the purchaser and the vendor shall meet to coordinate hold points and inspectors' visits.

Witnessed means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or his representative in attendance. For mechanical running or performance tests,

this requires written notification of a successful preliminary test.

5.1.4.3 Observed means that the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test.)

5.1.5 Equipment for the specified inspection and tests shall be provided by the vendor.

5.1.6 The purchaser's representative shall have access to the vendor's quality-control program for review.

5.2 Inspection

The vendor shall keep the following data available for at least 5 years for examination by the purchaser or his representative upon request:

- a. Purchase specifications for all major items on bills of materials.
- b. Test and calibration data to verify that the requirements of the specification have been met.

5.3 Testing

5.3.1 GENERAL

5.3.1.1 Equipment shall be tested in accordance with 5.3.2.

5.3.1.2 The vendor shall notify the purchaser not less than 5 working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than 5 working days before the new test date.

5.3.2 INSTRUMENT MANUFACTURER TESTING

5.3.2.1 As a minimum, the instrument manufacturer shall individually bench test each component of the monitoring system at an ambient temperature within the range of 0°C to 45°C (30°F to 110°F) to ensure compliance with 2.1.

5.3.2.2 The instrument manufacturer shall have test documentation and certification available for inspection by the purchaser.

5.4 Preparation for Shipment

5.4.1 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

5.4.2 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser.

5.4.3 The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists, one on the inside and one on the outside of the shipping container.

5.4.4 One copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

● 5.4.5 The purchaser shall specify to the vendor any specialized requirements for packing, sealing, marking, or storage of the equipment.

5.5 Mechanical Running Test

Radial shaft vibration and axial position probes, extensometers, cables, oscillator-demodulators, piezoelectric accelerometer amplifiers, charge amplifiers (if any), and temperature sensors purchased for the installation shall be in use during factory mechanical running test of monitored equipment.

5.6 Field Testing

5.6.1 All features of the power supply and monitoring system specified in 3.4 and 3.5 shall be functionally tested by the construction agency (see Appendix F). Results shall be documented in accordance with 6.3. The construction agency shall verify that the alarm (alert) and shutdown (danger) setpoints are adjusted to the values agreed upon with the end user.

5.6.2 Each monitoring system shall be tested in the field to verify calibration at ambient conditions (see 2.1). The tests shall be conducted in accordance with 5.6.2.1, 5.6.2.2, and 5.6.2.3 by the construction agency using the actual monitoring system components to be installed on the machine. Results shall be documented in accordance with 6.3 (see note).

Note: Figures 13, 14, and 15 illustrate typical overall system functions.

● 5.6.2.1 For radial shaft vibration and axial position transducers, a graph of the gap (a minimum of 10 points) versus the transducer's output voltage shall be provided by the construction agency and supplied to the end user (see Figures 16 and 17). This procedure shall be performed in accordance with the requirements of the instrument manufacturer (see 6.3.3.2). When specified, calibration to the installed probe target area shall be performed.

5.6.2.2 Temperature monitors shall be tested by substitution of the job temperature sensor with an appropriate sensor simulator. A minimum of three points (20 percent, 50 percent, and 80 percent of span) shall be simulated and the monitor readings recorded.

5.6.2.3 For casing vibration systems, a shaker simultaneously exciting the job accelerometer and a calibrated reference accelerometer shall be used for testing. The accelerometer shall be tested over the frequency and amplitude ranges listed in Table 2A and 2B. The monitoring system shall be tested to full-scale amplitude by electronic simulation.

Table 2A—Accelerometer Test Points
(SI Units)

Frequency (Hz)	Acceleration		Velocity	
	m/sec ² rms	m/sec ² peak	mm/sec rms	mm/sec peak
10 ^a	1	1.41	15.92	22.51
20	7	9.90	55.70	78.78
50	7	9.90	22.28	31.51
100 ^a	7	9.90	11.14	15.76
159.15 ^b	7	9.90	7.00	9.90
200	7	9.90	5.57	7.88
500	7	9.90	2.23	3.15
1000 ^a	7	9.90	1.11	1.58
1000	15	21.12	2.39	3.38
2000	30	42.43	2.39	3.38
5000 ^a	30	42.43	0.95	1.35
10000	30	42.43	0.48	0.68

Note: All values are based on sinusoidal waveforms.

^aThese values are required test points.

^bAt 159.15 Hz, 1.0 m/sec² equals 1.0 mm/sec (crossover frequency).

Table 2B—Accelerometer Test Points
(Customary Units)

Frequency (Hz)	Acceleration		Velocity	
	G peak	G rms	ips peak	ips rms
10 ^a	0.15	0.11	0.92	0.65
20	1	0.71	3.08	2.17
50	1	0.71	1.23	0.87
61.44 ^b	1	0.71	1.00	0.71
100 ^a	1	0.71	0.62	0.43
200	1	0.71	0.31	0.22
500	1	0.71	0.12	0.09
1000 ^a	1	0.71	0.06	0.04
1000	2	1.41	0.12	0.09
2000	4	2.83	0.12	0.09
5000 ^a	4	2.83	0.05	0.03
10000	4	2.83	0.02	0.02

Note: All values are based on sinusoidal waveforms.

^aThese values are required test points.

^bAt 66.14 Hz, 1.0 G equals 1.0 ips (crossover frequency).

SECTION 6—VENDOR'S DATA

6.1 General

6.1.1 The information required in 6.2 and 6.3 shall be provided by the vendor or responsible agency specified in Appendix B. The vendor shall complete and forward the Vendor Drawing and Data Requirements form (see Appendix G) to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

6.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information:

- The purchaser/end user's corporate name.
- The job/project number.
- The equipment item number and service name.
- The inquiry or purchase order number.
- Any other identification specified in the inquiry or purchase order.
- The vendor's identifying proposal number, shop order number, serial number, or other reference required to identify return correspondence completely.

6.2 Proposals

6.2.1 GENERAL

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 6.2.2 and 6.2.3, as well as a

specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 6.1.2.

6.2.2 DRAWINGS

The drawings indicated on the Vendor Drawings and Data Requirements form (see Appendix G) shall be included in the proposal. As a minimum, the following data shall be furnished:

- A general arrangement or outline drawing for each monitoring system, including overall dimensions, installation details, and maintenance clearance dimensions.
- Typical installation wiring diagrams.

6.2.3 TECHNICAL DATA

The following data shall be included in the proposal:

- The purchaser's data sheets, with complete vendor's information entered thereon and literature to fully describe details of the offering.
- A scope of supply and equipment list.
- The Vendor Drawing and Data Requirements form (see Appendix G), indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.

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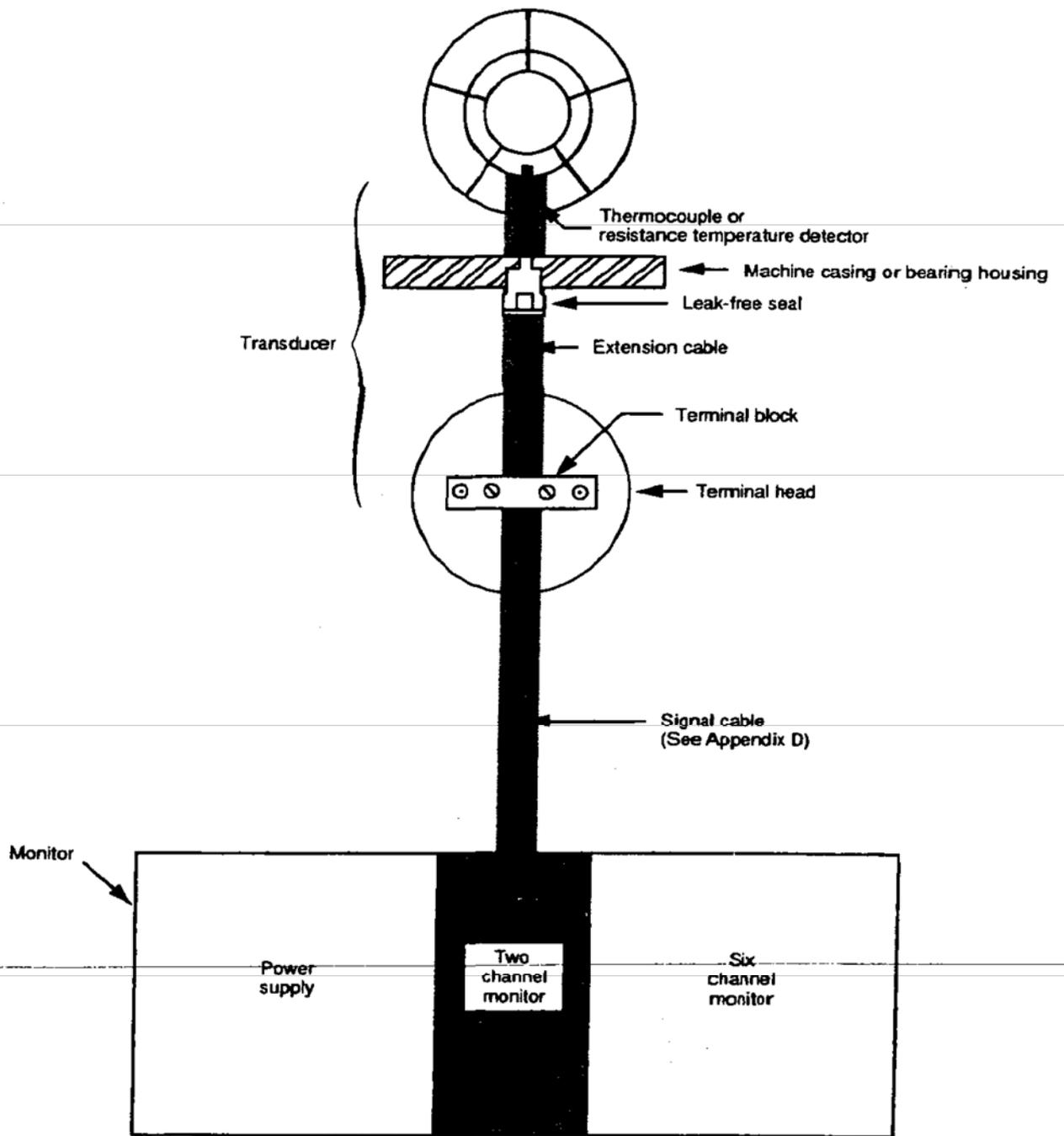
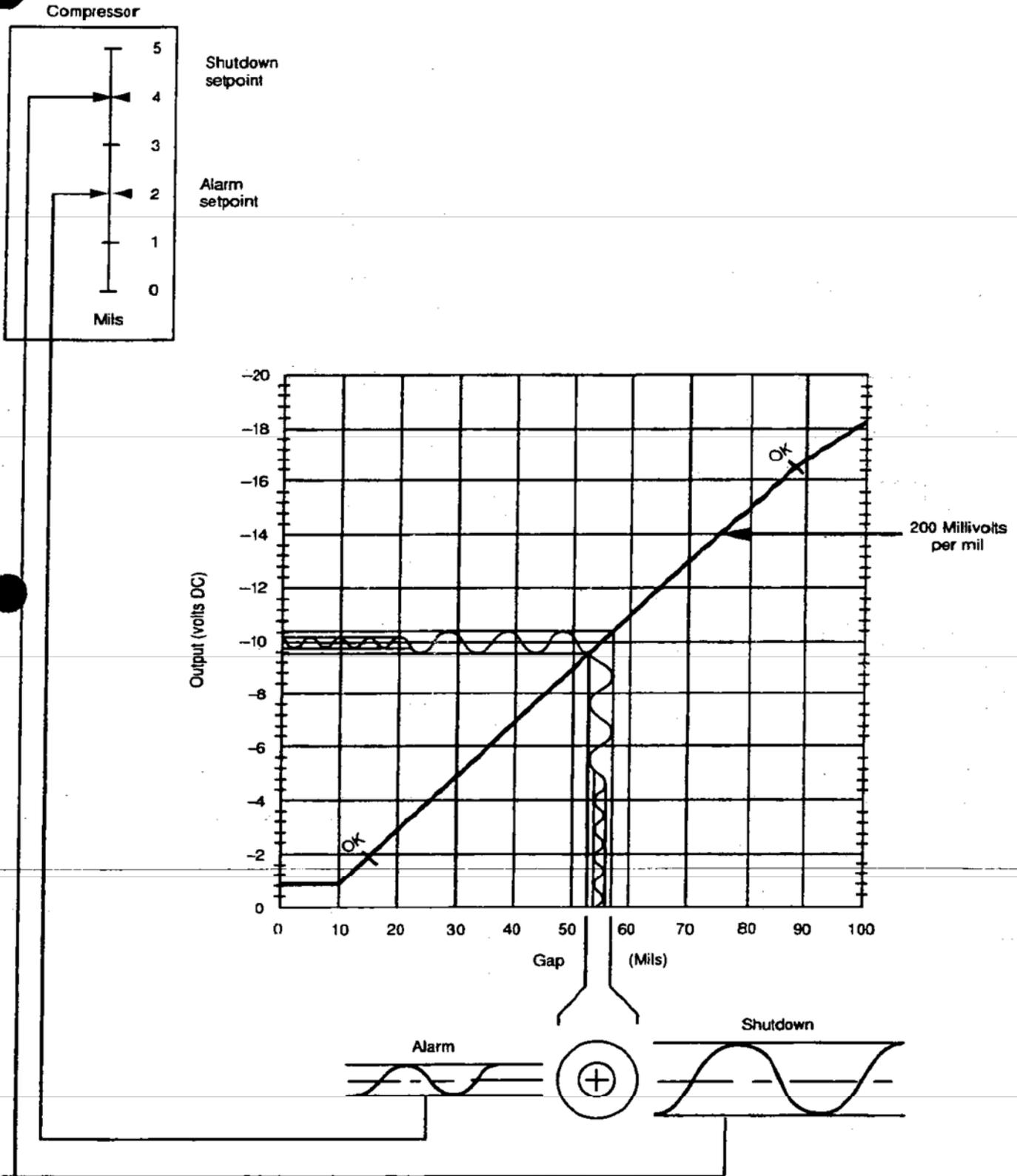
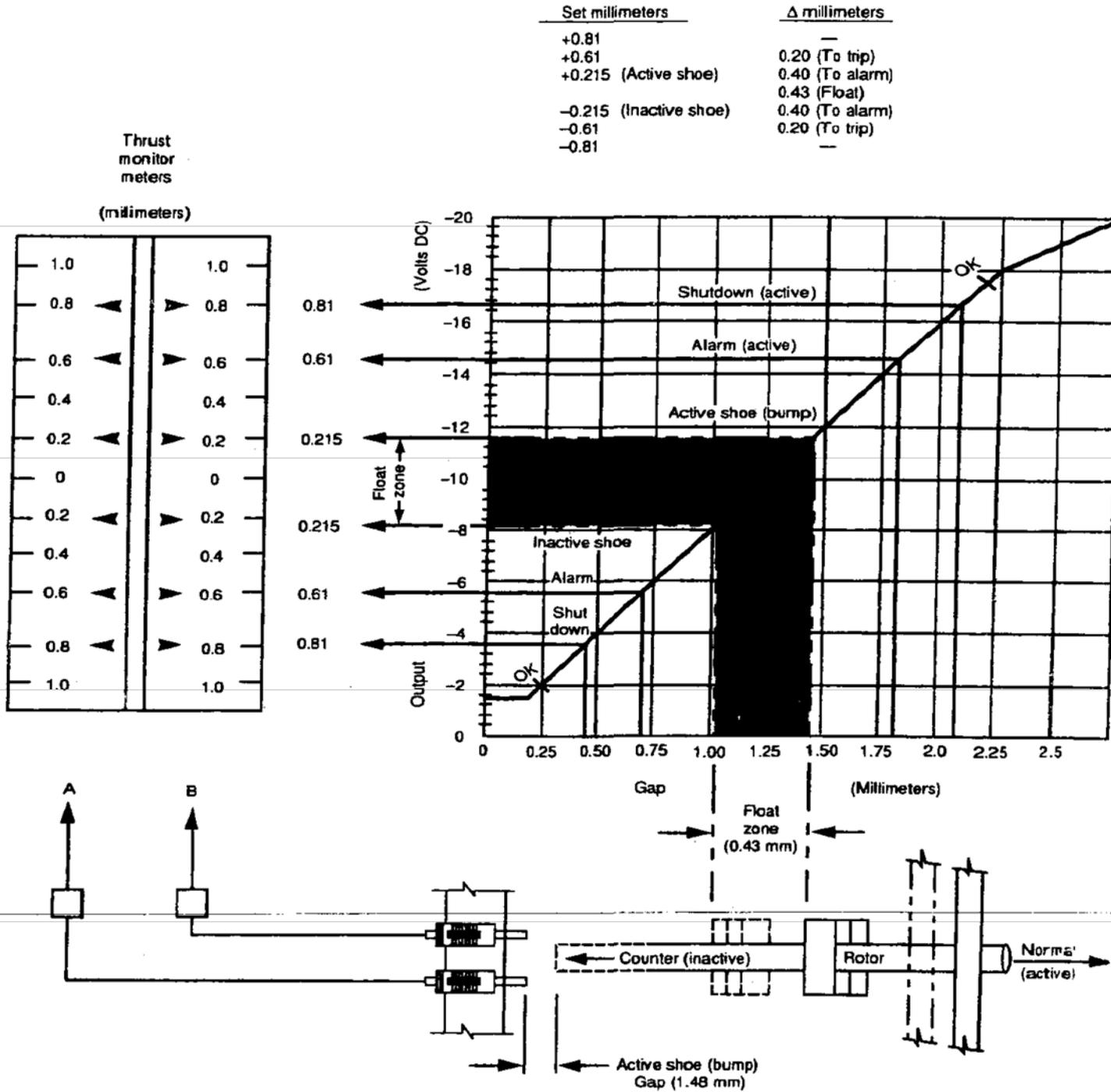


Figure 12--Nomenclature for Temperature Monitoring System



Note: The example shown is for illustration purposes only and does not necessarily represent any actual condition or machine.

Figure 13— Calibration of Radial Monitor and Setpoints for Alarm and Shutdown



Notes:

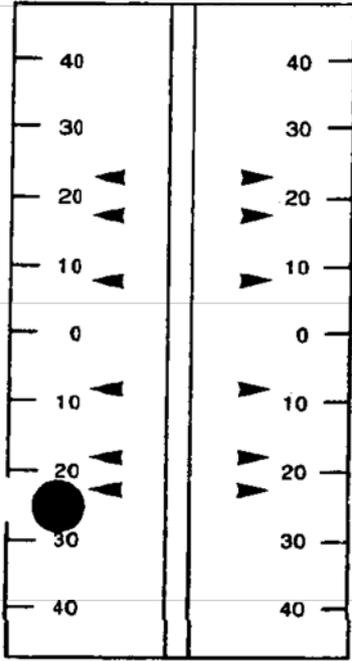
1. The monitor is calibrated for 8 millivolts per micrometer (200 millivolts per mil) and has a cold float zone of 0.43 millimeters (17 mils). The monitor's range is from +1 millimeter to -1 millimeter (+39.4 mils to -39.4 mils). The calibration procedure consists of the following steps: (1) assuring the calibration curve, (2) bumping the shaft to the active shoe, (3) adjusting

the probe for a meter indication of 0.2 millimeters (a transducer output of approximately 11.7 volts DC), (4) bumping the float to confirm the thrust, and (5) setting the alarm and shutdown points.

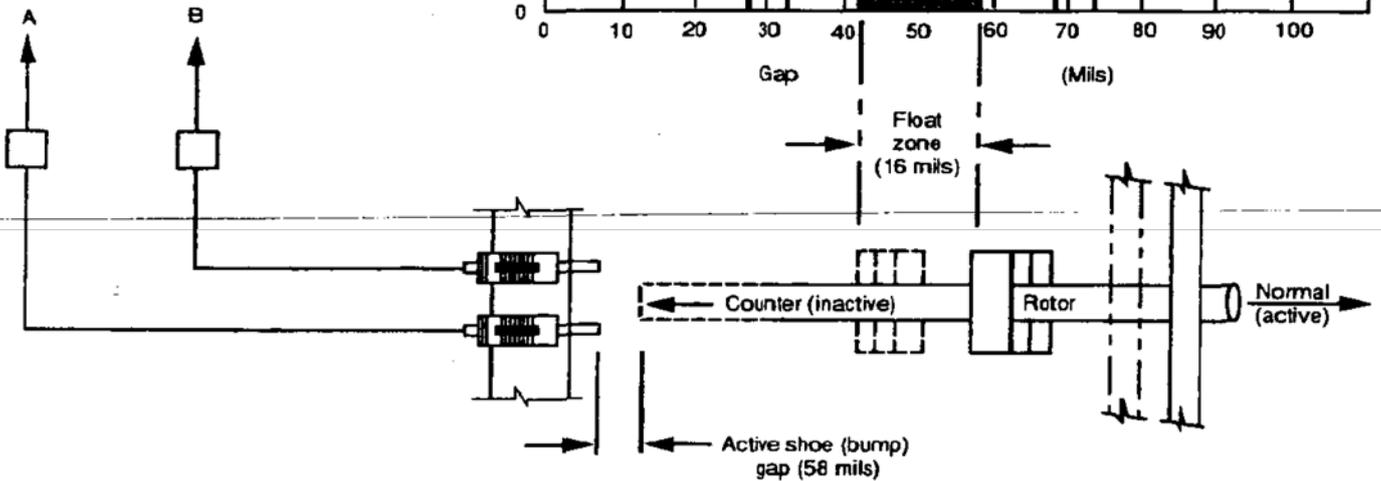
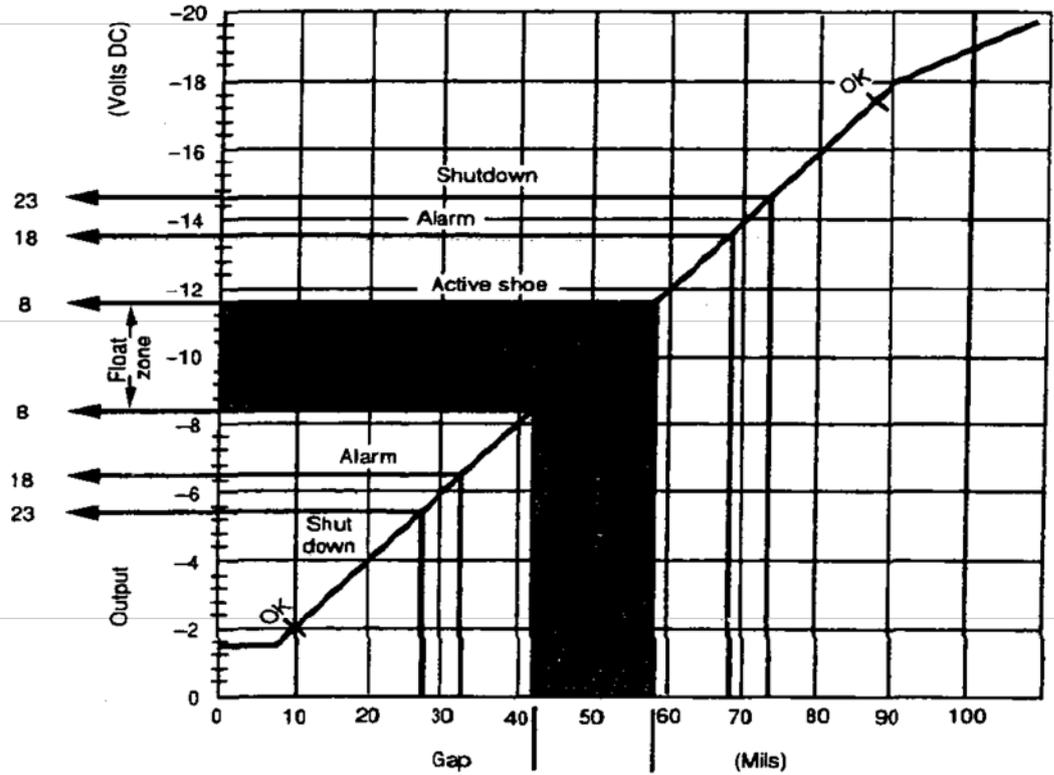
2. The example shown is for illustration purposes only and does not necessarily represent any actual condition or machine.

Figure 14— Calibration of Axial Position (Thrust) Monitor: Steam Turbine (SI Units)

Thrust monitor meters (mils)



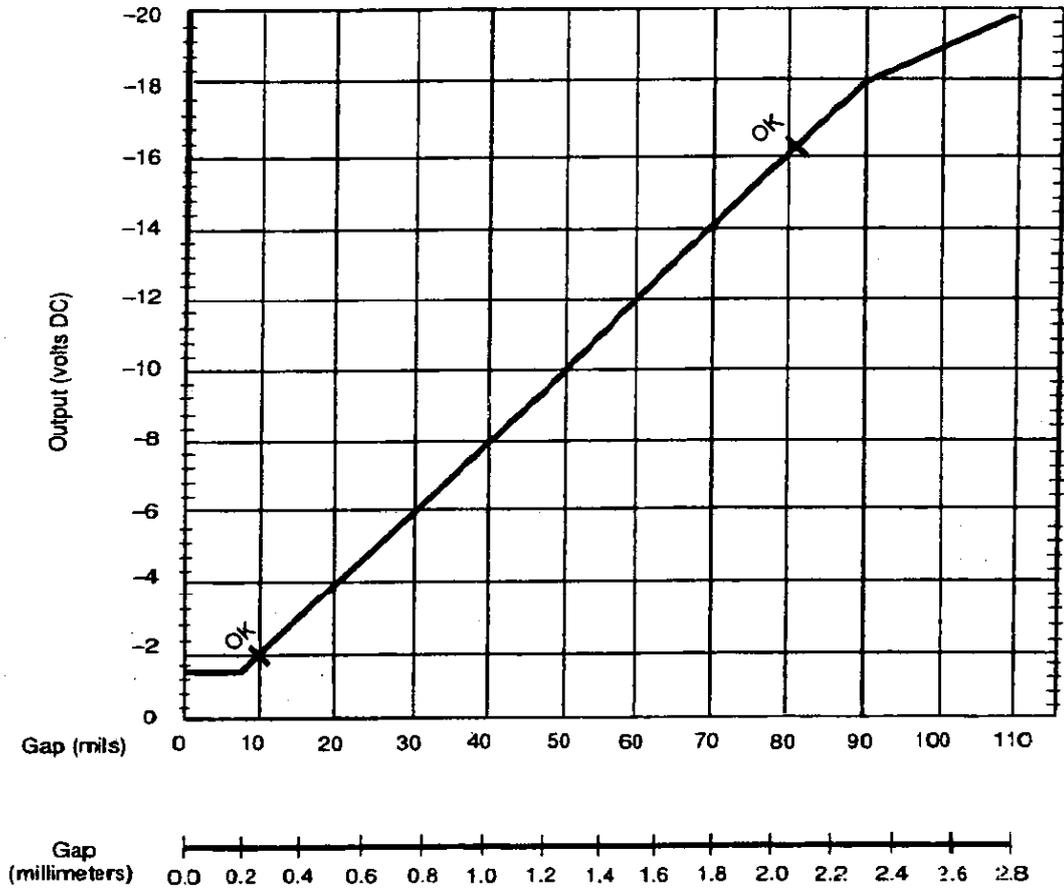
Set mils	Δ mils
+23.00	—
+18.00	5 mils (To trip)
+ 8.00	10 mils (To alarm)
	16 mils (Float)
- 8.00	10 mils (To alarm)
-18.00	5 mils (To trip)
-23.00	—



Notes:
 1. The monitor is calibrated for 200 millivolts per mil and has a cold float zone of 16 mils. The monitor's range is from +40 mils to -40 mils. The calibration procedure consists of the following steps: (1) assuring the calibration, (2) bumping the shaft to the active shoe, (3) adjusting the probe

for a meter indication of 8 mils (a transducer output of approximately 11.6 volts DC), (4) bumping the float to confirm the thrust, and (5) setting the alarm and shutdown points.
 2. The example shown is for illustration purposes only and does not necessarily represent any actual condition or machine.

Figure 15—Calibration of Axial Position (Thrust) Monitor: Compressor (Customary Units)

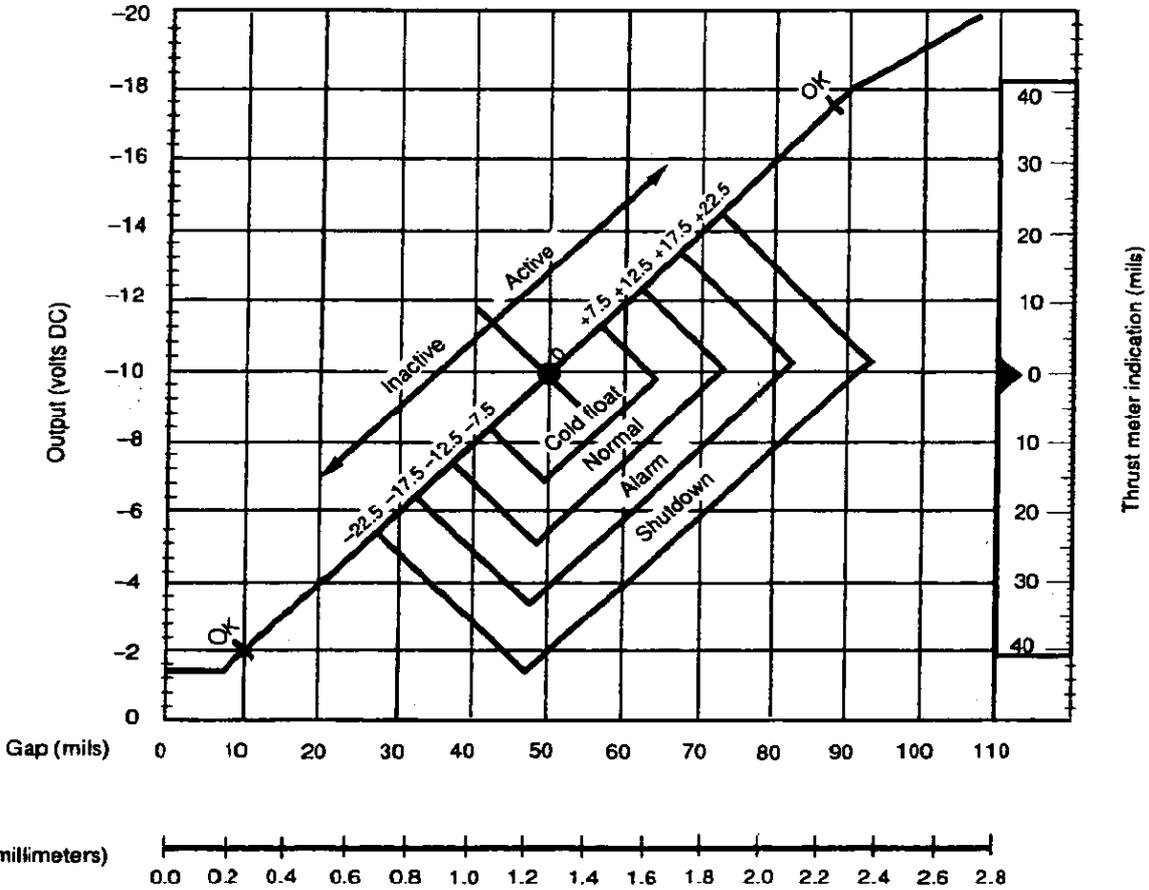


Calibration Gap (Mils)	Output (Volts DC)
10	-2.0
20	-4.0
30	-6.0
40	-8.0
50	-10.0
60	-12.0
70	-14.0
80	-16.0
90	-18.0

Machine Number _____
 Probe Number _____
 Probe Serial Number _____
 Model _____ Length _____
 Extension Cable Number _____
 Resistance Probe _____
 Resistance Probe and Cable _____
 Oscillator-Demodulator: _____
 Type/Serial Number _____
 Supply Voltage _____
 Cold Gap Set _____
 Alarm Set _____
 Shutdown Set _____
 Date _____

Note: Referenced to 200 millivolts per mil.

Figure 16—Typical Calibration Curve for Radial Vibration



Output (Volts DC)	Meter Indication
-2.0	-40
-4.0	-30
-6.0	-20
-8.0	-10
-10.0	0
-12.0	+10
-14.0	+20
-16.0	+30
-18.0	+40

Meter Indication	Output (Volts DC)
-40	-2.0
-30	-4.0
-20	-6.0
-10	-8.0
0	-10.0
+10	-12.0
+20	-14.0
+30	-16.0
+40	-18.0

Machine Number _____
 Probe Number _____
 Probe Serial Number _____
 Model _____ Length _____
 Extension Cable Number _____
 Resistance Probe _____
 Resistance Probe and Cable _____
 Oscillator-Demodulator:
 Type/Serial Number _____
 Supply Voltage _____
 Thrust Clearance _____
 Active Volts DC _____
 Inactive Volts DC _____
 Zero Gap Volts _____
 Date _____

Note: Referenced to 200 millivolts per mil.

Figure 17—Typical Calibration Curve for Axial Position

- d. A schedule for shipment of the equipment, in weeks after receipt of the order.
- e. A list of recommended start-up and other spares, including any items that the vendor's experience indicates are likely to be required.
- f. A list of the special tools for maintenance.
- g. A list of any special protection required for start-up, operation, and periods of idleness under the site conditions specified. The list shall show the protection to be furnished in the vendor's scope of supply.
- h. A description of any special requirements specified in the purchaser's inquiry and as outlined in 3.5.1.2, 3.5.1.3, 3.5.1.4, 3.5.2, 3.5.4.2, 3.8.4, and 5.4.5.
- i. A description of how the system meets specified area classification requirements, as discussed in 3.8.1.

6.3 Contract Data

6.3.1 GENERAL

6.3.1.1 The contract data to be furnished by the vendor or construction agency is specified in Appendix G. Each drawing, bill of material, and data sheet shall have a title block in its lower right-hand corner that shows the date of certification, a reference to all identification data specified in 6.1.2, the revision number and date, and the title.

6.3.1.2 The purchaser will promptly review the vendor's data when he receives them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data have been reviewed, the vendor shall furnish certified copies in the quantity specified.

6.3.1.3 All contract data obtained by the purchaser shall be supplied to the end user no later than 4 weeks before field testing.

6.3.1.4 A complete list of vendor data shall be included with the first issue of the major drawings. The list shall contain titles, drawing numbers, and a schedule for transmission of all the data the vendor will furnish (see Appendix G).

6.3.2 DRAWINGS

6.3.2.1 The drawings furnished shall contain sufficient information so that with the drawings and the manuals specified in 6.3.6, the construction agency or end user can properly install, operate, and maintain the ordered equipment. Drawings shall be clearly legible, shall be identified in accordance with 6.3.1.1, and shall be in accordance with ASME Y14.2M. As a minimum, the drawings shall include the details listed in Appendix G.

6.3.2.2 Drawings showing principal dimensions, including those required for panel arrangements and main-

tenance and dismantling clearances, shall be provided. Typical drawings are not acceptable.

6.3.2.3 The following information shall be provided the drawings:

- a. Complete bills of materials covering the entire scope supply.
- b. A list of reference drawings.

6.3.3 TECHNICAL DATA

6.3.3.1 The data shall be submitted in accordance with Appendix G and identified in accordance with 6.3.1.1. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor (see note).

Note: These notations will result in the purchaser's issue of complete corrected data sheets as part of the order specifications.

- **6.3.3.2** At the specified time, the construction agency shall furnish the specified number of copies of documentation of the monitoring system's installation and calibration details, curves and data, rotor runouts, and recommended setpoints, as listed in 6.3.3.3, 6.3.3.4, 6.3.3.5, 6.3.5, and 6.3.6. The construction agency shall perform the field testing of the entire monitoring system in accordance with 5.4 before start-up and shall furnish the specified number of copies of documentation to the end user.

6.3.3.3 Promptly after completion of the design and analysis of the shaft and rotor and at least 2 months before the start of machining, the purchaser shall obtain from the machinery vendor and supply to the end user the location of the rotor's predicted nodal points relative to the bearing centerlines and the radial shaft vibration probes.

6.3.3.4 Within 6 weeks after order placement, the purchaser shall obtain and supply to the end user the following items:

- a. The radial shaft vibration, bearing housing vibration, axial position, and bearing temperature limits for alarm (alert) and shutdown (danger) setpoints as recommended by the machinery vendor. The limits shall be stated in terms of the monitor display (for example, unfiltered mils peak-to-peak, G's peak, or ips peak).
- b. The completed system arrangement plan for each machine in the train.
- c. The wiring and connection diagrams required for installation and maintenance.
- d. The number and location of sensors and mounting boxes for signal conditioning devices.
- e. Completed data sheets (see Appendix A).
- f. The instrument manufacturer's sensor and signal conditioning device model number.

6.3.3.5 Before the machinery vendor performs any factory mechanical tests, the vendor shall supply the following items to the purchaser:

- a. Documentation of the waveform of mechanical and electrical runout for each probe area of each shaft. The waveform plot shall be phase-related to the permanent or temporary once-per-revolution marker.
- b. Calibration data for each transducer or sensor in accordance with 6.3.4.

6.3.3.6 When a factory mechanical test is not performed, the items listed in 6.3.3.5 shall be provided to the end user in accordance with Appendix G. These items shall be provided prior to field testing.

6.3.3.7 The construction agency shall supply a grounding plan for the system (see 3.7.1).

6.3.3.8 The end user shall supply the construction agency with job-specific channel identification and hardware component tagging requirements including content, location, material, and method of attachment. The construction agency shall transmit tagging requirements to the instrument manufacturer at least 4 weeks prior to instrument shipment.

6.3.3.9 Unless otherwise specified, the end user shall supply to the agency responsible for field installation and calibration all radial shaft vibration, bearing housing vibration, axial position, and bearing temperature limits for alarm (alert) and shutdown (danger) setpoints.

6.3.4 CURVES

6.3.4.1 Calibration data shall be provided for each radial shaft vibration and axial position transducer, accelerometer transducer, and temperature sensor. The instrument manufacturer's transducer or sensor serial number and the model number shall be included on the calibration data.

6.3.4.2 Calibration data for radial shaft vibration and axial position transducers shall be presented in a format similar to that shown in Figure 16 or Figure 17.

6.3.4.3 Calibration data for each radial shaft vibration and axial position transducer shall include the target material used.

6.3.5 RECOMMENDED SPARES

The vendor shall submit a complete list of spare parts, including those shown in the original proposal. The list shall

include spare parts for all equipment and accessories supplied, with cross-sectional or assembly-type drawings for identification, part numbers, and delivery times. Part numbers shall identify each part for purposes of interchangeability. Standard purchased items shall be identified by the original manufacturer's numbers. The vendor shall forward the list to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified in 6.1.2.

6.3.6 INSTALLATION, OPERATION, MAINTENANCE, AND TECHNICAL DATA MANUALS

6.3.6.1 General

The vendor shall provide sufficient written instructions and a cross-referenced list of all drawings to enable the purchaser and the end user to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference-identifying data specified in 6.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation; a typical manual is not acceptable.

6.3.6.2 Installation, Operation, and Maintenance Manual

No more than 5 days after the scheduled shipping date, the instrument manufacturer shall furnish installation, operation, and maintenance manuals for the complete monitoring system. The manuals shall include legible drawings of the equipment, parts lists, and installation, operation and maintenance information.

6.3.6.3 Technical Data Manual

The construction agency shall provide the purchaser with a technical data manual within 4 weeks after field testing. This manual shall contain completed as-built data sheets, tagging information, instrument manufacturer's monitoring system serial numbers, calibration data, and other installation-specific data. (See Appendix G for detail requirements.)

**APPENDIX A—VIBRATION, AXIAL POSITION, AND BEARING
TEMPERATURE MONITORING SYSTEM DATA SHEETS**

MONITORING SYSTEM DATA SHEET

PAGE _____ OF _____

JOB NO. _____ ITEM NO. _____
 PURCH. ORDER NO. _____ DATE _____
 INQUIRY NO. _____ BY _____
 REVISION _____ DATE _____

1	APPLICABLE TO: <input type="radio"/> PROPOSAL <input type="radio"/> PURCHASE <input type="radio"/> AS BUILT	DATE _____	REVISION _____
2	FOR _____	UNIT _____	
3	SITE _____		
4	SERVICE _____		
5	INSTRUMENT MANUFACTURER _____		
6	NOTE: <input type="radio"/> INDICATES INFORMATION TO BE COMPLETED BY PURCHASER <input type="checkbox"/> BY MACHINERY VENDOR		
7	<input checked="" type="checkbox"/> BY PURCHASER OR MACHINERY VENDOR		
8	MACHINERY TRAIN COMPONENTS	OPERATING ENVIRONMENT	
9	NUMBER OF:	<input type="radio"/> STANDARD COMPONENTS (2.2.4.1)	
10	____ PUMPS _____ ROTARY COMPRESSORS	<input type="radio"/> SPECIFIED CHEMICALS (2.2.4.2) _____	
11	____ STEAM TURBINES _____ GEAR UNITS		
12	____ GAS TURBINES _____ ELECTRIC MOTORS	PROBE DATA (3.1.1)	
13	____ CENTRIFUGAL COMPRESSORS _____ OTHER (DESCRIBE) _____	<input type="radio"/> STD. 4.8 TO 5 mm TIP DIA. WITH 1.0 METER INTEGRAL CABLE (3.1.1.2)	
14		<input type="radio"/> OPTIONAL PROBES WITH THE FOLLOWING STANDARD	
15	SCOPE OF RESPONSIBILITIES	OPTIONS: (3.1.1.3)	
16	<input type="radio"/> APPENDIX B _____	<input type="radio"/> 7.6 TO 7.9 mm (0.300 TO 0.312 INCHES)	
17	<input type="radio"/> FINAL INSTALLATION _____	PROBE TIP WITH 3/8-24-UNF-2A PROBE THREADS (3.1.1.3a)	
18	<input type="radio"/> MONITORS _____	<input type="radio"/> REVERSE MOUNT, INTEGRAL HEX NUT PROBE BODY (3.1.1.3b)	
19	<input type="radio"/> SIGNAL CABLES _____	<input type="radio"/> TIP DIAMETER OF 7.6 TO 7.9 mm WITH M10 METRIC THREADS	
20	<input type="radio"/> TRANSDUCERS & SENSORS _____	(3.1.1.3c)	
21	<input type="radio"/> APPENDIX F REQUIREMENTS _____	<input type="radio"/> TIP DIAMETER OF 4.8 TO 5.0 mm AND M8 METRIC THREADS	
22		(3.1.1.3d)	
23	SCOPE OF SUPPLY	<input type="radio"/> LENGTHS OTHER THAN APPROXIMATELY 25 mm (1 INCH)	
24	<input type="radio"/> TRANSDUCERS _____	(3.1.1.3e)	
25	<input type="radio"/> SENSORS _____	<input type="radio"/> FLEXIBLE STAINLESS STEEL ARMORING ATTACHED TO THE	
26	<input type="radio"/> MONITORS _____	PROBE BODY AND EXTENDING TO APPROXIMATELY 100 mm	
27		(4 INCHES) OF THE CONNECTOR (3.1.1.3f)	
28	SITE DATA	<input type="radio"/> OTHER (DESCRIBE) _____	
29	DESIGN TEMP. °C OR °F _____ SUMMER MAX. _____ WINTER MIN. _____		
30	DESIGN WET BULB TEMP. °C OR °F _____		
31	<input type="radio"/> WINTERIZATION REQUIRED		
32	<input type="radio"/> TROPICALIZATION REQUIRED		
33	<input type="radio"/> UNUSUAL CONDITIONS		
34	<input type="radio"/> DUST		
35	<input type="radio"/> FUMES		
36	<input type="radio"/> OTHER (DESCRIBE) _____		
37			
38	ELECTRICAL EQUIPMENT HAZARD CLASS	NUMBER OF PROBES IN TRAIN	
39	CLASS _____ GROUP _____ DIVISION _____	<input type="radio"/> STANDARD COMPLEMENT (APPENDIX H)	
40	<input type="radio"/> RADIO FREQUENCY INTERFERENCE (3.8.4) _____	<input type="radio"/> NONSTANDARD COMPLEMENT REQUIRED	
41		PRIMARY RADIAL _____	
42	OPERATING TEMPERATURE RANGE	SPARE RADIAL _____	
43	<input type="radio"/> STANDARD, ALL COMPONENTS (2.2)	PRIMARY AXIAL _____	
44	<input type="radio"/> NONSTANDARD REQUIREMENTS	SPARE AXIAL _____	
45	<input type="radio"/> PROBE & EXTENSION CABLE °C OR °F FROM _____ TO _____	PHASE REFERENCE _____	
46	<input type="radio"/> OSCILLATOR-DEMULATOR °C OR °F FROM _____ TO _____		
47	<input type="radio"/> TEMP. SENSOR & LEAD °C OR °F FROM _____ TO _____	PROBE ARRANGEMENT (APPENDIX H)	
48	<input type="radio"/> MONITOR AND POWER SUPPLY °C OR °F FROM _____ TO _____	RADIAL TRANSDUCERS	
49	<input type="radio"/> ACCELEROMETER °C OR °F FROM _____ TO _____	<input type="radio"/> STANDARD ARRANGEMENT (4.1.1)	
50	<input type="radio"/> CHARGE AMPLIFIER °C OR °F FROM _____ TO _____	<input type="radio"/> DEVIATION FROM STANDARD RADIAL PROBE ARRANGEMENT	
51		REQUIRED: (DESCRIBE) _____	

MONITORING SYSTEM DATA SHEET

PAGE _____ OF _____
 JOB NO. _____ ITEM NO. _____
 REVISION _____ DATE _____
 BY _____

<p>1 PROBE ARRANGEMENT (APPENDIX H) (CON'T)</p> <p>2 AXIAL TRANSDUCERS</p> <p>3 <input type="radio"/> STANDARD SHAFT END OR INTEGRAL AXIAL SURFACE</p> <p>4 <input type="radio"/> OPTIONAL ONE PROBE ON SHAFT & ONE PROBE ON INTEGRAL THRUST COLLAR</p> <p>5 OTHER (DESCRIBE) _____</p> <p>6 _____</p> <p>7 _____</p> <p>8 <input checked="" type="checkbox"/> PROBES MOUNTED TO MEASURE INCREASING GAP FOR NORMAL OPERATION (3.5.5.5)</p> <p>9 <input checked="" type="checkbox"/> PROBES MOUNTED TO MEASURE DECREASING GAP FOR NORMAL OPERATION (3.5.5.5)</p> <p>10 PHASE REFERENCE TRANSDUCERS ONE EVENT PER REVOLUTION</p> <p>11 <input type="radio"/> DRIVER</p> <p>12 <input type="radio"/> GEARBOX</p> <p>13 <input type="radio"/> INPUT SHAFT</p> <p>14 <input type="radio"/> OUTPUT SHAFT</p> <p>15 <input type="radio"/> DRIVEN EQUIPMENT</p> <p>16 <input type="radio"/> OTHER (DESCRIBE) _____</p> <p>17 _____</p> <p>18 _____</p> <p>19 _____</p> <p>20 EXTENSION CABLE DATA (3.1.2)</p> <p>21 <input type="radio"/> STANDARD 4.0 METER (160 INCHES) LENGTH, NONARMORED</p> <p>22 <input type="radio"/> 4.0 METER (160 INCHES) LENGTH, ARMORED (4.2.1.4)</p> <p>23 <input checked="" type="checkbox"/> CABLE CONNECTOR ELECTRICAL ISOLATION (4.2.1.4)</p> <p>24 <input type="radio"/> INSULATING SLEEVE _____</p> <p>25 <input type="radio"/> INSULATING WRAP (DESCRIBE) _____</p> <p>26 _____</p> <p>27 <input type="radio"/> OTHER (DESCRIBE) _____</p> <p>28 _____</p> <p>29 PIEZO ELECTRIC ACCELEROMETER DATA (3.2)</p> <p>30 GENERAL:</p> <p>31 <input checked="" type="checkbox"/> INSTRUMENT MANUFACTURER'S MODEL NO. _____</p> <p>32 <input checked="" type="checkbox"/> ACCELEROMETER POWER REQMT _____ 24VDC _____ (mA)</p> <p>33 <input type="radio"/> EXTERNAL CHARGE AMPLIFIER</p> <p>34 <input type="radio"/> SPECIAL BODY MATERIAL _____</p> <p>35 MOUNTING ENVIRONMENT TEMPERATURE °C OR °F _____</p> <p>36 TRANSDUCER MOUNTING:</p> <p>37 <input type="radio"/> API APPENDIX FIGURE: <input type="radio"/> C1 <input type="radio"/> C2 <input type="radio"/> C3 <input type="radio"/> C4</p> <p>38 <input type="radio"/> OTHER _____</p> <p>39 <input type="radio"/> STANDARD MOUNTING/STANDARD ACCELEROMETER (3.2.1)</p> <p>40 <input type="radio"/> ACCELEROMETER WITH THE FOLLOWING OPTIONS: (3.2.1.4)</p> <p>41 <input type="radio"/> CENTER-POST MOUNTING - ENGLISH THREADS OTHER THAN 1/4-28 UNF (3.2.1.4a)</p> <p>42 SPECIFY THREADS _____</p> <p>43 <input type="radio"/> CENTER-POST MOUNTING - METRIC THREADS (3.2.1.4b)</p> <p>44 SPECIFY THREADS _____</p> <p>45 <input type="radio"/> THREE-OR FOUR-BOLT FLANGE MOUNTING (3.2.1.4c)</p> <p>46 <input type="radio"/> SIDE CONNECTOR (3.2.1.4d)</p> <p>47 <input type="radio"/> INTEGRAL EXTENSION CABLE (3.2.1.4e)</p> <p>48 <input type="radio"/> ACCELEROMETER MOUNTING BLOCK (3.2.1.4f)</p> <p>49 <input type="radio"/> INTEGRAL CENTER POST (3.2.1.4g)</p> <p>50 _____</p> <p>51 _____</p>	<p>PIEZOELECTRIC ACCELEROMETER DATA (3.2) (CON'T)</p> <p><input type="radio"/> STANDARD 5 METER (200 INCH) ACCELEROMETER EXTENSION CABLE (3.2.2.3)</p> <p><input type="radio"/> OTHER (DESCRIBE) (m) (INCHES) _____</p> <p><input type="radio"/> EXTENSION CABLE PROTECTION (4.2.3.4)</p> <p><input type="radio"/> STANDARD CONDUIT _____</p> <p><input type="radio"/> OPTIONAL WEATHERPROOF FLEXIBLE ARMOR</p> <p><input type="radio"/> NUMBER OF ACCELEROMETERS PER BEARING _____</p> <p><input type="radio"/> NUMBER OF CHANNELS IN TRAIN _____</p> <p>CHARGE AMPLIFIER DATA:</p> <p><input type="checkbox"/> INSTRUMENT MANUFACTURER'S MODEL NO. _____</p> <p><input checked="" type="checkbox"/> DIMENSIONS (mm) (INCHES) _____ X _____ X _____</p> <p>TEMPERATURE SENSOR DATA (3.3.1)</p> <p><input type="radio"/> SENSORS NOT REQUIRED</p> <p><input type="radio"/> STANDARD GROUNDED, TYPE J IRON/COPPER-NICKEL (CONSTANTAN) THERMOCOUPLE</p> <p><input type="radio"/> OPTIONAL 100 OHM, PLATINUM, THREE-LEAD RTD'S, WITH A TEMPERATURE COEFFICIENT OF RESISTANCE EQUAL TO 0.00385 OHM/OHM/°C _____</p> <p><input type="radio"/> OTHER (DESCRIBE) _____</p> <p><input type="radio"/> FLEXIBLE STAINLESS STEEL OVERBRAIDING ON LEADS (3.3.1.2)</p> <p>TEMPERATURE SENSOR MOUNTING</p> <p><input type="radio"/> EMBEDDED SENSORS</p> <p><input type="radio"/> SPRING-LOADED SENSORS (BAYONET TYPE) (4.2.5.3)</p> <p><input type="radio"/> OTHER (DESCRIBE) _____</p> <p><input type="radio"/> ELECTRICALLY INSULATED FROM BEARING (4.2.5.5)</p> <p>RADIAL BEARING TEMPERATURE SENSOR ARRANGEMENT</p> <p><input type="radio"/> SENSORS REQUIRED</p> <p><input type="radio"/> SENSORS NOT REQUIRED</p> <p><input type="checkbox"/> SLEEVE TYPE, L/D RATIO > 0.5 (4.1.5.1.2)</p> <p><input type="checkbox"/> SLEEVE TYPE, L/D RATIO ≤ 0.5 (4.1.5.1.3)</p> <p><input type="checkbox"/> TILT-PAD TYPE, L/D RATIO > 0.5 (4.1.5.1.5)</p> <p><input checked="" type="checkbox"/> TILT-PAD TYPE, L/D RATIO ≤ 0.5 (4.1.5.1.6)</p> <p><input type="checkbox"/> LOAD-ON PAD (4.1.5.1.7)</p> <p><input type="checkbox"/> LOAD-BETWEEN-PADS (4.1.5.1.8)</p> <p><input type="checkbox"/> OTHER (DESCRIBE) _____</p> <p>THRUST BEARING TEMPERATURE SENSOR ARRANGEMENT</p> <p><input type="radio"/> SENSORS REQUIRED</p> <p><input type="radio"/> SENSORS NOT REQUIRED</p> <p><input type="radio"/> STANDARD TWO SENSORS IN ACTIVE BEARING</p> <p><input type="checkbox"/> SENSORS _____ DEGREES APART</p> <p><input type="radio"/> STANDARD TWO SENSORS IN INACTIVE BEARING</p> <p><input type="checkbox"/> SENSORS _____ DEGREES APART</p> <p><input type="radio"/> OTHER (DESCRIBE) _____</p> <p>_____</p> <p>_____</p>
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MONITORING SYSTEM DATA SHEET

PAGE _____ OF _____

JOB NO. _____ ITEM NO. _____

REVISION _____ DATE _____

BY _____

<p>1 MONITOR & POWER SUPPLY DATA</p> <p>2 <input type="checkbox"/> MONITOR MOUNTING DIMENSIONS (mm) (INCHES)</p> <p>3 HEIGHT _____ WIDTH _____ DEPTH _____</p> <p>4 LOCATION <input type="radio"/> INDOOR <input type="radio"/> OUTDOOR</p> <p>5 INPUT <input type="radio"/> _____ VAC _____ Hz</p> <p>6 <input type="radio"/> _____ VDC</p> <p>7 OUTPUTS</p> <p>8 <input type="radio"/> STANDARD 4 TO 20 mA <input type="radio"/> ZERO TO TEN VOLTS DC</p> <p>9 <input type="radio"/> ANALOG <input type="radio"/> DIGITAL OUTPUT <input type="radio"/> GRAPHIC</p> <p>10 <input type="radio"/> OTHER (DESCRIBE) _____</p> <p>11 <input type="radio"/> TAMPERPROOF SHUTDOWN DISARM WITH LIGHT EMITTING</p> <p>12 DIODE (3.5.1.5)</p> <p>13 RELAYS</p> <p>14 <input type="radio"/> ALARM (ALERT)</p> <p>15 <input type="radio"/> STANDARD NORMALLY ENERGIZED</p> <p>16 <input type="radio"/> OPTIONAL NORMALLY DEENERGIZED</p> <p>17 <input type="radio"/> SHUTDOWN (DANGER)</p> <p>18 <input type="radio"/> STANDARD NORMALLY DEENERGIZED</p> <p>19 <input type="radio"/> OPTIONAL NORMALLY ENERGIZED</p>	<p>RADIAL SHAFT VIBRATION AND AXIAL POSITION CHANNEL (CON'T)</p> <table style="width: 100%; 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APPENDIX B—TYPICAL RESPONSIBILITY MATRIX WORKSHEET^a

JOB NO. _____ ITEM NO. _____
 PURCHASE ORDER NO. _____ DATE _____
 REQUISITION NO. _____ DATE _____
 INQUIRY NO. _____ DATE _____
 PAGE _____ OF _____ BY _____
 REVISION _____
 UNIT _____
 NO. REQUIRED _____

FOR _____
 SITE _____
 SERVICE _____

Function	Instrument Manufacturer	Machinery Vendor ^b	Construction Agency	End User	Other (Specify: _____)
Project coordination					
System design					
Instrument purchase					
Panel design and assembly					
Grounding plan (see 3.7.1)					
Supply of drawings and data per Appendix G					
Installation on machinery train					
Mechanical running test with contract instrumentation (see 5.5)					
Field tests (see 5.6)					

^aTo be completed by the purchaser and the end user by placing an "X" in the appropriate boxes to indicate responsibility for each function (see 2.4).

^bResponsibility would normally be placed with the prime machinery vendor having unit responsibility for the entire machinery train. If responsibilities are divided among individual machinery vendors, appropriate statements should be noted above or on an attached sheet.

APPENDIX C—ACCELEROMETER APPLICATION CONSIDERATIONS

C.1 General

The accelerometer is a contact-type sensor (as opposed to a noncontact-type proximity probe) that measures the motion of the surface to which it is attached. Its many benefits include *linearity over a wide frequency and dynamic range*. Accelerometers have typically been used in higher frequency applications (over 1 kilohertz) for machinery monitoring and diagnostics. In order to apply the accelerometer and get reliable measurements, proper attention must be paid to the following areas:

- a. Sensor mounting configurations.
- b. Frequency range of interest.
- c. Amplitude range of interest.
- d. Use for machine protection or for diagnostics.
- e. Characteristics of the particular accelerometer under consideration.
- f. Cabling and signal conditioning.
- g. Environmental considerations.

There are many good reference sources discussing these considerations. The manufacturer of the particular accelerometer can also be consulted for answers to application questions. The primary focus of this appendix is to address sensor mounting, cabling, and signal conditioning considerations for use with machine protection systems. Typically, accelerometers are recommended for use up to about one third to one half of their mounted resonant frequency. Therefore, mounting techniques can limit the useful frequency range of the accelerometer. Knowing these limitations and applying the proper technique are necessary to meet the requirements of the monitoring application. Cabling and signal conditioning can affect the accelerometer output signal and therefore are also important considerations in the overall design of the measurement system.

C.2 Accelerometer Mounts and Mounting Considerations

Since the accelerometer is a contact device, care in mounting is of particular importance since improper installation can affect the performance of the device and give unreliable and unexpected output signals.

C.2.1 STUD-MOUNTING

Figure C-1 shows a typical stud-mounting application. Following proper stud-mounting techniques generally will not degrade the frequency response of the accelerometer, therefore allowing the use of the accelerometer to provide response data over the frequency range recommended by the manufacturer. The following are offered as guidelines for proper stud-mounting:

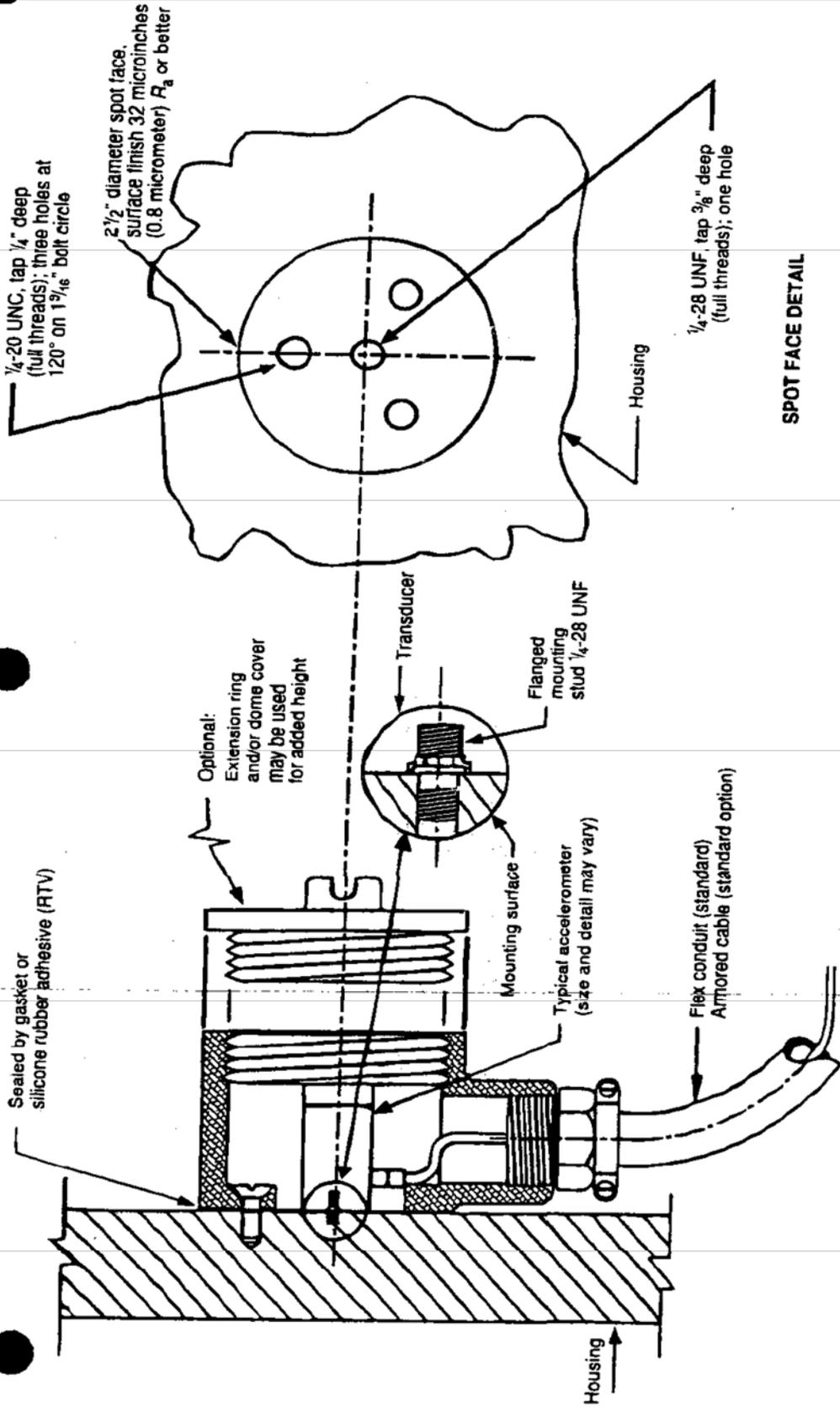
- a. Published criteria vary for surface finish and flatness, but most sources agree that surface finish should be 0.001 micrometer (32 microinches) R_a or better and surface flatness should be well below 25 micrometers (1 mil).
- b. The accelerometer must be held snugly over its entire base to prevent mounting-post resonance, which occurs when the accelerometer base is not flush against the mounting surface. In this case, the mounting stud becomes a structural element and lowers the mounted resonance frequency. To prevent this from occurring, the stud axis must be perpendicular to the mounting surface and the tapped hole must be deep enough to prevent the stud from bottoming. The mounting hole must be perpendicular to the surface within 5 degrees of arc or less.
- c. Excessive mounting torque might distort the accelerometer case, thus affecting the accelerometer response characteristics. Too little torque will result in a loose accelerometer that can lead to large errors at higher frequencies. Torque requirements vary with stud size, but published values range from 0.6 to 2.7 newton-meters (5 to 24 pound-inches). Manufacturer recommendations should be followed.
- d. The mounting interface should be clear of any particles or debris that could prevent the accelerometer from coming down flat on the mounting surface. A thin layer of silicone grease may be applied between the accelerometer and the mounting surface to fill minute voids and improve the stiffness of the mounting.

C.2.2 INTEGRAL STUD-MOUNT ACCELEROMETERS

Figures C-2 and C-3 show a typical built-in stud-mount accelerometer application. The advantage of this type of mounting configuration is that it only requires a drilled and tapped hole to be made at the measurement location for proper mounting. The accelerometer is already built onto the stud and sealed in its case. This type of accelerometer mount would be acceptable for permanent installations where machine protection is the primary objective. This design is often used for accelerometers with a built-in acceleration-to-velocity integrator.

The following should be considered when using this type of accelerometer configuration for monitoring:

- a. The machine point at which the accelerometer is to be mounted should be massive enough to accommodate the mass of the accelerometer without altering the response of the structure. The machines considered for permanent monitoring in this specification will typically be suitable for this method of mounting.
- b. The drilled and tapped mounting hole should be perpendicular to the measurement surface within 5 degrees of arc or less.



Notes:

1. Horizontal mount shown. Vertical would be similar but on top of bearing.
2. Spot face is shown on existing housing but a raised boss with proper surface finish is preferred.

Figure C-1—Typical Accelerometer Protective Cover and Stud-Mounting Details

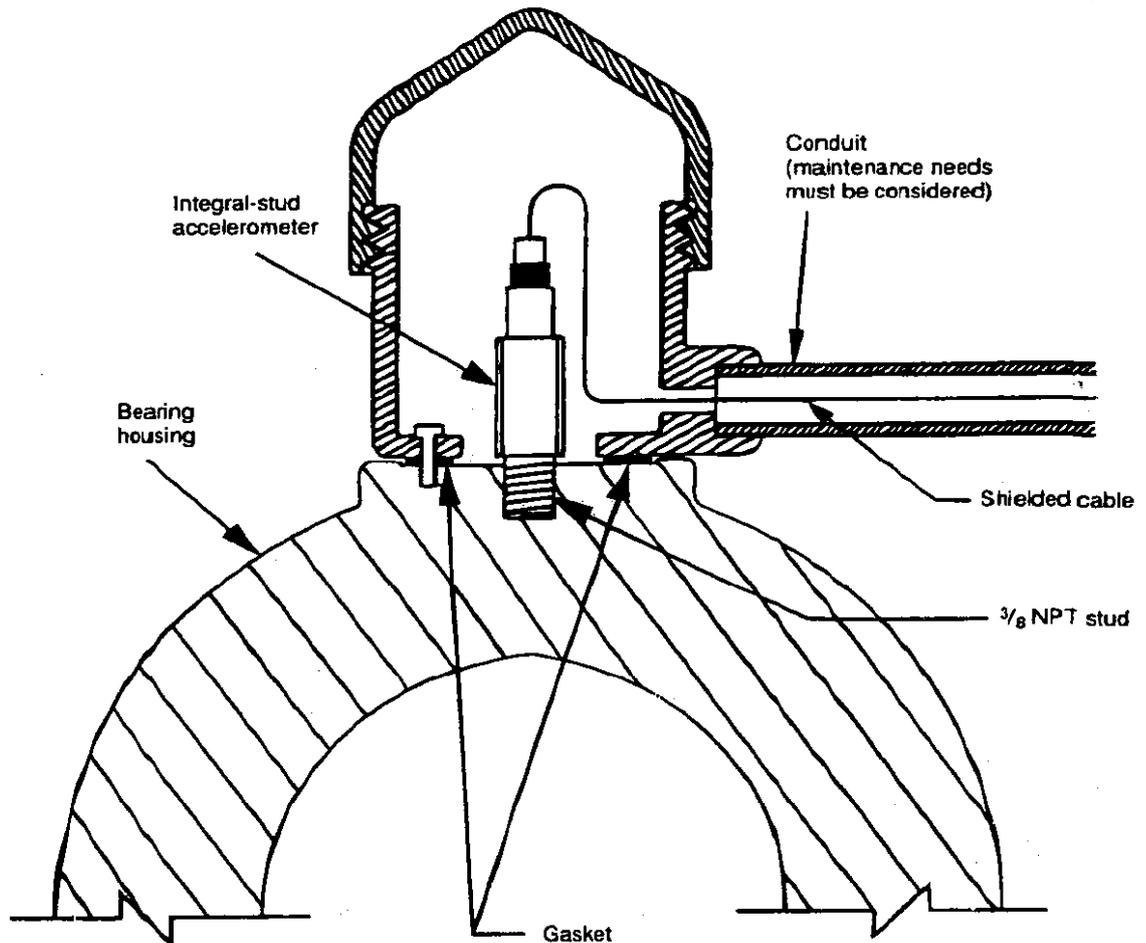


Figure C-2—Typical Mounting Arrangement for Integral-Stud Accelerometer and Cable

c. The manufacturer's torque specifications should be followed to avoid damaging the case by overtightening or affecting the frequency response through looseness. A thread-locking compound may be used.

C.2.3 THREE- AND FOUR-POINT FLANGE-MOUNTED ACCELEROMETERS

Multiple screw mounts are commonly used for engine monitoring and are a viable alternative to single stud mounting. This type of accelerometer has a triangular or square base. It is provided with a rugged side connector and can be installed without a protective enclosure. Even though the bolt circle diameter is a little larger than the diameter of most stud-mounted accelerometers, the accelerometer footprint is smaller than that of the protective box required by other types of accelerometers. This consideration becomes important when space is limited. See Figure C-4 for details of a three-point mount.

C.2.4 USE OF ADHESIVES AND BONDING AGENTS

The use of bonding agents (such as bee's wax, dental cement, epoxy cement, and methyl cyanoacrylate cement) is not discussed here since these agents are not considered suitable for permanent installations.

C.2.5 BOTTOMLESS PROTECTIVE BOXES VERSUS UNPROTECTED MOUNTING

A common method of protecting the accelerometer and its connector from the elements and from damage at the hands of mechanics and operating personnel is to mount it within a box. Installation kits available from various sources consist of a modified electric junction or explosion-proof box. The box must be separated from the accelerometer (to prevent affecting the accelerometer frequency response), normally by cutting a hole in the bottom of the

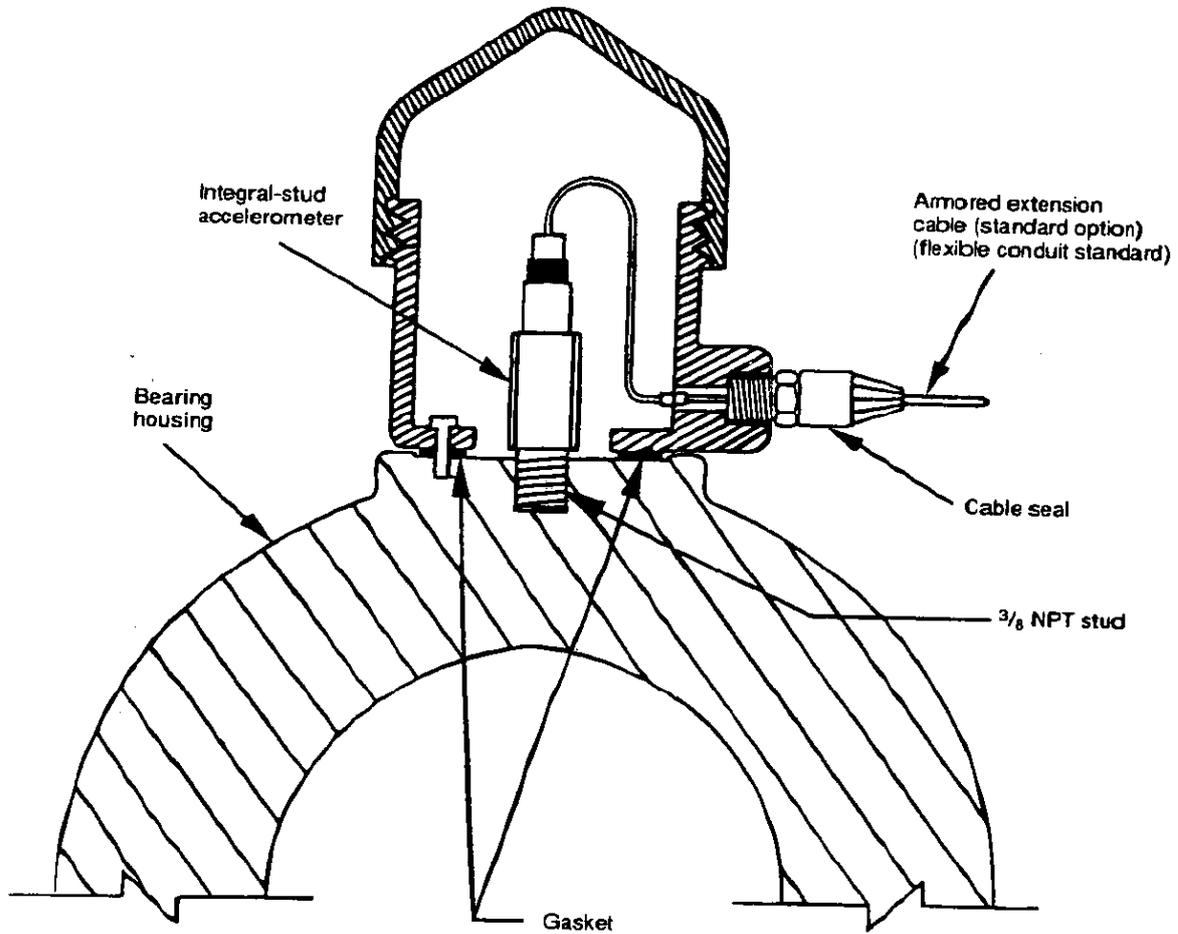


Figure C-3—Typical Mounting Arrangement for Integral-Stud Accelerometer and Armored Extension Cable

electrical box (see note). Installation requires care to prevent the box from making contact with the accelerometer case and from excessively bending the accelerometer cable. The box must also be mounted on a relatively wide and flat surface to permit proper sealing of the base and to prevent water intrusion. These considerations must be weighed against the cost of multiple screw-mount accelerometers. See Figures C-1 and C-2 for examples of bottomless protective boxes.

Note: Cutting the bottom of an explosion-proof box renders it non-explosion-proof. Other means must be used to meet area classification requirements.

C.3 Installation and Protection of Cables

Mechanical protection of the cable can be achieved by running the cable in rigid conduit. However, maintenance requirements dictate easy removal and reinstallation of the

conduit section closest to the machinery. The use of flexible conduit is not necessarily the best solution because it is not easy to remove, does not always stay in place, and often results in cable damage caused by the sharp edges of the internal reinforcing coil. Consider using armored or hardline cables. This type of cable is relatively flexible and can be routed next to the machinery below guards or flanges and out of harm's way. Installation or removal of this type of cable does not require an electrician, and if properly routed and securely clamped, it cannot be used as a footstep by maintenance personnel. The same considerations apply to proximity probe extension cables. The following precautions apply:

- a. If the accelerometer is left unprotected, water intrusion in the connector can be alleviated by filling the connector with a silicon-type grease. A commercially available silicon sealing compound or a specially designed protective boot can be used to seal the connector entry to the accelerometer.

- b. The conduit or junction box must be sealed at the cable entry point. Rubber grommets or removable, nonadhesive sealants should be used.
- c. The cable must be routed to avoid excessive temperatures. Cable material limits must be considered. As an

example, PTFE insulated cables cannot normally be used above 200°C (400°F).

- d. An accelerometer with an integral hardline cable provides a rugged construction that should be considered in extreme environments, such as high ambient temperature

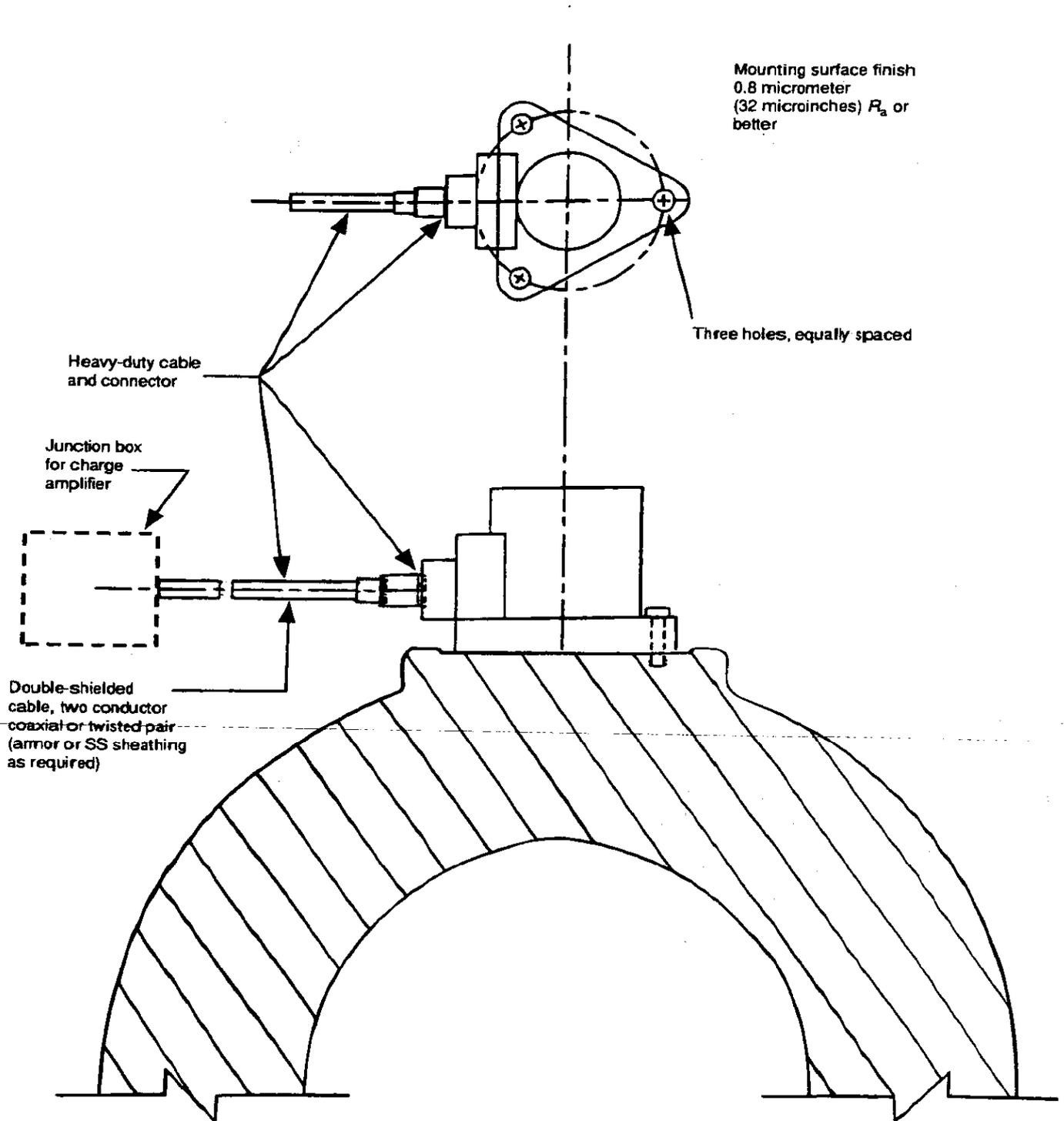


Figure C-4—Typical Accelerometer Three-Point Mounting Arrangement

high humidity conditions. Typically, the cable consists of stainless steel tubing filled with a high temperature insulating material, such as aluminum oxide that surrounds the conductors.

e. Where the hazardous area classification requires it, consideration should be given to the use of zener-type barriers located as close as possible to the power source. Intrinsically safe designs can be achieved by installing this type of energy limiting device. However, the instrument manufacturer should be consulted for overall system design considerations.

C.4 Noise Considerations

Accelerometer extension cables used with unamplified accelerometers must be carefully installed to prevent cable movement (cable whip), because electrical noise (due to tribo-electric effects) can be generated by internal cable

capacitance changes, and the spurious signal generated adds to the vibration signal. Consider the following guidelines:

- a. Use only high-quality, low-noise cables. Low-noise cables are designed to minimize the effect of cable movement by reducing cable capacitance. Manufacturers can achieve this by controlling the braided shield weave tightness or by filling the shield with graphite to reduce voids between shield and cable insulation.
- b. Clamp the cable to avoid relative movement, but leave enough wire slack to allow free movement of the accelerometer. Provide generous cable bend radius; a rule of thumb is to provide a bend radius greater than ten times the cable diameter.
- c. For accelerometers with integral preamplifiers, the considerations in Items a and b do not apply.
- d. In all cases, avoid running the cable near sources of electromagnetic interference (EMI) such as large motors or high-voltage wiring.

APPENDIX D—SIGNAL CABLE

D.1 General

This appendix covers the minimum requirements for single- and multiple-circuit signal cable for vibration, axial position, and RTD transducers and single- and multiple-circuit signal cable for thermocouples. (All of these cables require a conduit or a tray system for mechanical support and protection.) The insulation shall conform to Article 725 of NFPA 70 (*National Electrical Code*), Class 2P, and shall withstand, with no shorts, a 1-minute test potential of 1000 volts DC plus two times the rated voltage between conductor-to-conductor and conductor-to-shield.

D.2 Shielded Single-Circuit Signal Cable for Vibration, Axial Position, or RTD Transducers

D.2.1 CONDUCTORS

Shielded single-circuit cable for vibration or axial position transducers shall contain three twisted conductors. The conductors shall be 16 to 22 American Wire Gage (AWG), or 0.336 to 1.374 square millimeters, seven-strand (minimum), Class B, concentric-lay, tinned or silver-coated copper wire as specified in NEMA WC 5, Part 2 (IPCEA S-61-402). The lay of the conductor's twist shall be from 38 to 64 millimeters (1.5 to 2.5 inches). The conductors shall be color coded black, white, and red. The drain wire attached to the cable shield shall have the same specification as the three twisted conductors. Prior to installation of the cable, a green or green and yellow stripe sleeving shall be installed over the drain wire.

D.2.2 PRIMARY INSULATION

The conductors' primary insulation shall be rated for 300 volts, 100°C (200°F) and pass the Underwriters' Laboratories (UL) VW-1 flame test. The standard primary insulation shall be polyvinyl-chloride (PVC) with a thickness of 0.38 millimeter (15 mils). When specified, fluorinated ethylene propylene (FEP) with a thickness of 0.25 millimeter (10 mils) will be the standard option for severe environment use.

D.2.3 SHIELD

The cable shield shall be polyester/aluminum film tape with 100 percent coverage and drain wire, or tinned or silver-coated copper wire braid with 90 percent coverage. The tape shall be helically applied with a minimum of a 25 percent overlap. The aluminum-coated side of the film shall be at least 0.9 micrometer (0.35 mil) thick and shall be in continuous contact with the drain wire, which shall be the same wire gage as the inner conductors of the cable and meet the

other requirements of D.2.1. A braided shield shall have a single conductor attached to it. The single conductor shall have the same wire gage as in the inner conductors of the cable and meet the other requirements of D.2.1.

D.2.4 OVERALL JACKET

The cable's standard jacket shall be PVC with a nominal thickness of 0.75 millimeter (30 mils) and meet the other requirements of D.2.2. When specified, FEP with a thickness of 0.25 millimeter (10 mils) will be the standard option for severe environment use.

D.3 Multiple-Circuit Signal Cable (with Group Shields) for Vibration, Axial Position, or RTD Transducers

D.3.1 CONDUCTORS

Multiple-circuit cable with group shields is recommended (see note). Multiple-circuit cable with group shields for vibration or axial position transducers shall contain three twisted conductors per group. The conductors shall be 16 to 22 AWG, seven-strand, Class B, concentric-lay, tinned or silver-coated copper wire as specified in NEMA WC 5, Part 2 (IPCEA S-61-402). The lay of the conductors' twist shall be from 38 to 64 millimeters (1.5 to 2.5 inches). The conductors in each group shall be color-coded black, white, and red, and each group of three shall be identifiable by using colors or numbers.

Note: Group shields are recommended to minimize cross-talk between monitoring channels.

D.3.2 PRIMARY INSULATION

The conductors' primary insulation shall be the same as stated in D.2.2.

D.3.3 OVERALL SHIELD

The shield of each three-conductor group and the overall shield (see note) of the multiple-circuit cable shall be polyester/aluminum-coated film or braided tinned or silver-coated copper. The shield specifications shall be the same as stated in D.2.3.

Note: Overall shields are recommended to provide isolation from external noise.

D.3.4 COMMUNICATIONS WIRE

The cable shall contain a 16 to 22 AWG, seven-strand Class B, concentric-lay, copper communication wire whose insulation is 1.9 millimeters (75 mils) thick. The commu-

ication wire shall be coded with a color other than the group color.

D.4 Signal Cable for Thermocouples

D.4.1 CONDUCTORS

Single-circuit signal cable for thermocouples shall consist of a twisted pair of conductors. Single- or multiple-circuit cables are acceptable. The conductors shall be 16 to 22 AWG solid (stranded can be used) wire, matched and calibrated as specified in ANSI MC96.1. The lay of the conductors' twist shall be a maximum of 51 millimeters (2 inches). The conductors shall be color coded as specified in Table D-1.

D.4.2 PRIMARY INSULATION

The conductors' primary insulation shall be the same as stated in D.2.2.

D.4.3 SHIELD

The cable shield shall be the same as stated in D.2.3.

D.4.4 PAIR JACKET

The cable's pair jacket shall have a nominal thickness of 0.9 millimeter (35 mils), be of the color specified in Table D-1, and meet the other requirements stated in D.2.2.

Table D-1—Color Coding for Single-Circuit Thermocouple Signal Cable

Type ^a	Conductor		
	Pair Jacket	Positive	Negative
TX	Blue	Blue	Red
JX	Black	White	Red
EX	Purple	Purple	Red
KX	Yellow	Yellow	Red
SX	Green	Black	Red
BX	Gray	Gray	Red

^aType designations are from ANSI MC96.1, Table VI.

APPENDIX E—GEARBOX CASING VIBRATION CONSIDERATIONS

E.1 General

The requirements for a casing vibration monitor for gear units are specified in 3.5.4. The monitor is a dual-path design. It receives its input signal from an accelerometer mounted on a gear bearing housing. This signal is divided into two separate paths in the monitor. The first path is high pass filtered and read out directly in acceleration units (G's or meters per second squared). This path observes the frequencies associated with gear mesh and provides information on mesh condition. The second path is integrated to velocity units (inches per second or millimeters per second). This signal is low pass filtered to observe frequencies associated with the vibration of the rotating elements. It provides additional machine condition information to supplement a shaft vibration monitor.

E.2 Signal Detection Schemes

Two signal detection schemes are available in this monitor. They are true peak or true rms.

E.2.1 A true peak detector responds (within certain limitations of the amplifier) to excursions of the signal from zero to a maximum (or minimum). This technique is equally sensitive to both periodic and short duration (low duty cycle) vibration events in the waveform. Because gears tend to generate the short duration (spike) vibration events when malfunctioning, peak detection is the standard.

E.2.2 A true rms detector responds to the total area within the vibration waveform. It is less sensitive to short duration vibration events and tends to average them out as a form of filter. (Details of the actual mathematics of rms detection are available in many texts.)

E.2.3 Use of one technique over the other is usually determined by geographical and historical preferences. Advocates of a peak measurement prefer it because it is easy to understand and it responds to the short duration events

described in E.2.1. Advocates of an rms measurement prefer its smoothing effect and the lower values it yields. RMS detection is offered as a standard option.

E.2.4 Several important additional factors must also be considered:

- a. The detection circuitry in the monitor must be consistent with the displayed units. If peak is displayed, a peak circuit detector must be used in the monitor circuitry. Confusion occurs when an rms detector is used in the monitor and its output is scaled by 1.414 to display as peak units. This conversion is only valid for purely sinusoidal signals, which is rarely the situation except during calibration. An instrument displaying peak as $1.414 \times \text{rms}$ may yield significantly lower values than one with a true peak detector when observing the same vibration signal. Many portable instruments use this approach, which can create confusion when comparing readings.
- b. Use the same units for both acceptance testing and permanent monitoring. This allows direct comparison and reduces confusion.
- c. An AC voltmeter is commonly used for instrument calibration. Voltmeter calibration traceability is most common in rms terms. Calibration of a peak detecting instrument using $\text{rms} \times 1.414$ may be utilized but is only valid for a pure sine wave signal.
- d. Alarm limits must reflect the units used. Use of empirically determined peak limits with an instrument using rms detection may result in machine damage. The reverse may provide unwanted alarms.

Selection of a scheme depends on experience. Companies with a database of machinery measurements and vibration limits in peak terms may not be comfortable using rms, and vice-versa. Each scheme can be made to work by knowledgeable people. Care and understanding must be applied to each application to ensure that adequate machine protection is provided.

APPENDIX F—FIELD TESTING AND DOCUMENTATION REQUIREMENTS

F.1 General

This appendix outlines minimum field testing and documentation requirements for monitoring system components. It is intended as a convenience to the purchaser and the end user in clearly specifying the total job requirements.

Verification and documentation shall be submitted to the end user as follows:

- a. Machinery vendors shall submit documentation at least 2 weeks prior to any factory mechanical testing.
- b. Construction agencies shall submit documentation at least 4 weeks prior to machine start-up.

F.2 Tools and Instrumentation

The codes in Table F-1 are used to designate tools and instruments needed to calibrate and test various portions of the monitoring system.

F.3 Vendor Requirements

The purchaser shall use the form in Table F-2 to indicate the required activities and the responsible agency or vendor required to perform each specified activity.

Table F-1—Tools and Instruments Needed to Calibrate and Test Monitoring Systems

Code	Tool or Instrument	Typical Application
A	DC voltage nulling circuit	Shaft runout checks
B	Analog X-Y plotter	Runout plots
C	Probe calibration test kit	Runout, calibration, functional, and accuracy testing
D	Digital multimeter and frequency measuring device	Calibration, functional, and accuracy testing
E	Variable frequency waveform generator with DC offset	Simulation testing
F	Variable frequency calibration shaker with calibrated reference accelerometer and frequency readout	Accelerometer testing
G	Dual channel oscilloscope with optional camera	Runout testing
H	Temperature sensor simulator	Temperature simulation

Table F-2—Typical Vendor Requirements

Directions:

I — Activity item number

R — An X in this box indicates a required activity

M — An X in this box indicates the required activity to be performed by the machinery vendor

C — An X in this box indicates the required activity to be performed by the construction agency

O — An X in this box indicates the required activity to be performed by other agency; specify agency:

I	R	M	C	O	Activity	Tool and Instrument Codes* and (Paragraph Reference)
1					Location of rotor nodal points	(6.3.3.3)
2					Electrical/mechanical runout plots	A, B, C, D (6.3.3.5)
3					Calibration curve for each transducer	C, D (5.6.2.1)
4					Acceleration or velocity shaker test	D, F, G (5.6.2.3)
5					System arrangement plan	(6.3.3.4 Item b, 6.3.6.2)
6					Monitor calibration check	C, D, E, F, G, H (2.1, 5.6.2)
7					Recommended alarm and shutdown setpoints	(6.3.3.4 Item a)
7.1					Shaft vibration	(6.3.3.4 Item a)
7.2					Shaft axial position	(6.3.3.4 Item a)
7.3					Radial bearing temperature	(6.3.3.4 Item a)
7.4					Thrust bearing temperature	(6.3.3.4 Item a)
7.5					Casing acceleration	(6.3.3.4 Item a)
7.6					Casing velocity	(6.3.3.4 Item a)
8					Operation for hazardous area compliance testing	(3.8.1)
9					Channel accuracy test	(2.1)
9.1					Radial shaft vibration	C, D, E, G (2.1.1, 5.6.2.1)
9.2					Axial position	C, D (2.1.1, 5.6.2.1)
9.3					Casing vibration	D, F, G (2.1.3, 5.6.2.3)
9.4					Bearing temperature	D, H (2.1.2, 5.6.2.2)
10					Buffered output versus input accuracy	C, D, E, G (2.1, 3.5.1.1 Item g, 5.6.2)
11					Power supply short-circuit test	D (3.4.1.3, 5.6.1)
12					Output relay test	(5.6.1)
12.1					Circuit fault	C, D (3.5.1.1 Item m, 3.5.3.2, 3.5.4.3, 3.5.5.2, 5.6.1)
12.2					Shaft axial position alarm	C, D (3.5.1.1 Item d, 3.5.5.3, 5.6.1)

*Tool and instrument codes are listed in Table F-1.

Table F-2—Typical Vendor Requirements—Continued

I	R	M	C	O	Activity	Tool and Instrument Codes ^a and (Paragraph Reference)
12.3					Shaft axial position shutdown	C, D (3.5.1.1 Item d, 3.5.5.4, 5.6.1)
12.4					Radial shaft vibration alarm	D, E (3.5.1.1 Item d, 3.5.3.3, 5.6.1)
12.5					Radial shaft vibration shutdown	D, E (3.5.1.1 Item d, 3.5.3.4, 5.6.1)
12.6					Casing vibration alarm	D, E (2.1, 3.5.1.1 Item d, 3.5.4.1, 5.6.1)
12.7					Casing vibration shutdown	D, E (2.1, 3.5.1.1 Item d, 3.5.4.1, 5.6.1)
12.8					Bearing temperature alarm	D, H (2.1, 3.5.1.1 Item d, 3.5.6.3, 5.6.1)
12.9					Bearing temperature shutdown	D, H (2.1, 3.5.1.1 Item d, 3.5.6.4, 5.6.1)
13					System shutdown disarm test	C, D, E (3.5.1.4, 5.6.1)
14					Recorder output accuracy test	C, D, E, G, H (3.5.1.1 Item f, 5.6.1)
15					First out alarm and shutdown test	C, E (3.5.1.1 Item i, 5.6.1)
16					Circuit fault functional test	C, D (3.5.1.1 Item k, 5.6.1)
17					Shutdown system functional test	E, G (5.6.1)
18					Individual channel shutdown disarm test	C, D, E (3.5.1.5, 5.6.1)
19					Dual voting logic tests	(5.6.1)
19.1					Shaft axial position	C, D (3.5.5.4; 5.6.1)
19.2					Radial shaft vibration	D, E (3.5.3.4, 5.6.1)
19.3					Casing vibration	D, E (5.6.1)
19.4					Bearing temperature	E, H (3.5.6.4, 5.6.1)
20					Casing vibration filter cutoff frequency	D, E, G (3.5.4.4, 5.6.1)
21					Temperature sensor downscale failure verification test	(3.5.6.2, 5.6.1)
22					System wiring signal loss test	D, E, G (5.6.1)
23					Wiring connection verification test	(5.6.1)
24					Radio transmission RFI verification test	(3.8.4)
25					Final system arrangement plan	(6.3.6.2)

^aTool and instrument codes are listed in Table F-1.

APPENDIX G—VENDOR DRAWING AND DATA REQUIREMENTS

This appendix contains a sample distribution record (schedule). It is intended for the purpose of organization and is not meant to be duplicated for use since different manufacturers will use different names for the same drawing. The items in the description column should be modified in the early stages of the order using the drawing names supplied by the manufacturer. For purposes of illustration, Table G-1 includes a typical major milestone timeline.

Table G-1—Typical Major Milestone Timeline

Milestone	Paragraph Reference	Typical Schedule	Activity
T1			Initial specification and request for quotation
T2			Proposal
T3			Contract
A	6.3.3.4	6 weeks after T3	Purchaser obtains and supplies to end user: setpoints, wiring, diagrams, sensor list, data sheets, and model numbers
B	6.3.3.8	4 weeks prior to T4	Channel tagging requirements given to construction agency and forwarded to instrument manufacturer
T4			Instrument manufacturer shipping date
A	6.3.6.2	5 days after T4	Instrument manufacturer supplies standard manuals
B	6.3.3.3	Before machining	Analysis of rotor nodal points
C	Appendix F	2 weeks prior to T5	Machinery vendor supplies verification and documentation data
D	6.3.3.5	Before T5	Machinery vendor supplies run-out data and calibration data on each transducer
T5			Machine shop test date
T6			Machine shipping date
A	6.3.1.3	4 weeks prior to T7	Purchaser forwards contract data to end user
B	6.3.3.6	4 weeks prior to T7	Purchaser forwards run-out and calibration data on each transducer to end user
T7			Functional test
A	6.3.6.3	4 weeks after T7	Construction agency provides purchaser technical data manual
B	6.3.5	Before T8	Reviewed spare parts list given to purchaser with time enough to purchase and receive spares for field start-up
C	Appendix F	4 weeks prior to T8	Construction agency supplies verification and documentation data
T8			Field start-up

VENDOR DRAWING AND DATA REQUIREMENTS

FOR _____
 SITE _____
 SERVICE _____

JOB NO. _____ ITEM NO. _____
 PURCHASE ORDER NO. _____ DATE _____
 REQUISITION NO. _____ DATE _____
 INQUIRY NO. _____ DATE _____
 PAGE _____ OF _____ BY _____
 REVISION _____
 UNIT _____
 NO. REQUIRED _____

Responsible Agency^a (Appendix B)

Proposal^b Bidder shall furnish _____ copies of data for all items indicated by an X.

Review^c Vendor shall furnish _____ copies and _____ transparencies of drawings and data indicated.

Final^c Vendor shall furnish _____ copies and _____ transparencies of drawings and data indicated.
 Vendor shall furnish _____ operating and maintenance manuals.

DISTRIBUTION RECORD

Final—Received from vendor _____
 Final—Due from vendor^d _____
 Review—Returned to vendor _____
 Review—Received from vendor _____
 Review—Due from vendor^d _____

DESCRIPTION

		DESCRIPTION							
		1. Certified general arrangement or outline drawing and list of connections (6.2.2).							
		2. Cross-sectional drawing and bill of materials (6.2.3, 6.3.2).							
		3. Electrical and instrumentation wiring diagrams and bills of materials (6.2.2).							
		4. Electrical and instrumentation assembly drawings and lists of connections (6.3.3.4).							
		5. Calibration curves (5.3, 5.6).							
		6. As-built data sheets (6.3.1.4, 6.3.3).							
		7. As-built dimensions and data (6.2.2).							
		8. Installation, operation, and maintenance manual (6.3.6).							
		9. Spare parts recommendations (6.2.3).							
		10. Engineering, fabrication, and delivery schedule (progress reports) (6.2.3).							
		11. List of drawings (6.3.1, 6.3.2).							
		12. Shipping list (6.2.3).							
		13. List of special tools furnished for maintenance (6.2.3).							
		14. Technical data manual (6.3.6.3).							
		15. Material Safety Data Sheets.							

^a1. Instrument manufacturer; 2. Machinery vendor; 3. Construction agency; 4. End user; 5. Other (_____).
^bProposal drawings and data do not have to be certified or as-built.
^cPurchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.
^dBidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

Notes:

1. Send all drawings and data to _____
2. All drawings and data must show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation must be forwarded with the shipment.

Nomenclature:

- _____ S-number of weeks prior to shipment.
- _____ F-number of weeks after firm order.
- _____ D-number of weeks after receipt of approved drawings.

Vendor _____
 Date _____ Vendor Reference _____
 Signature _____

(Signature acknowledges receipt of all instructions)

DESCRIPTION

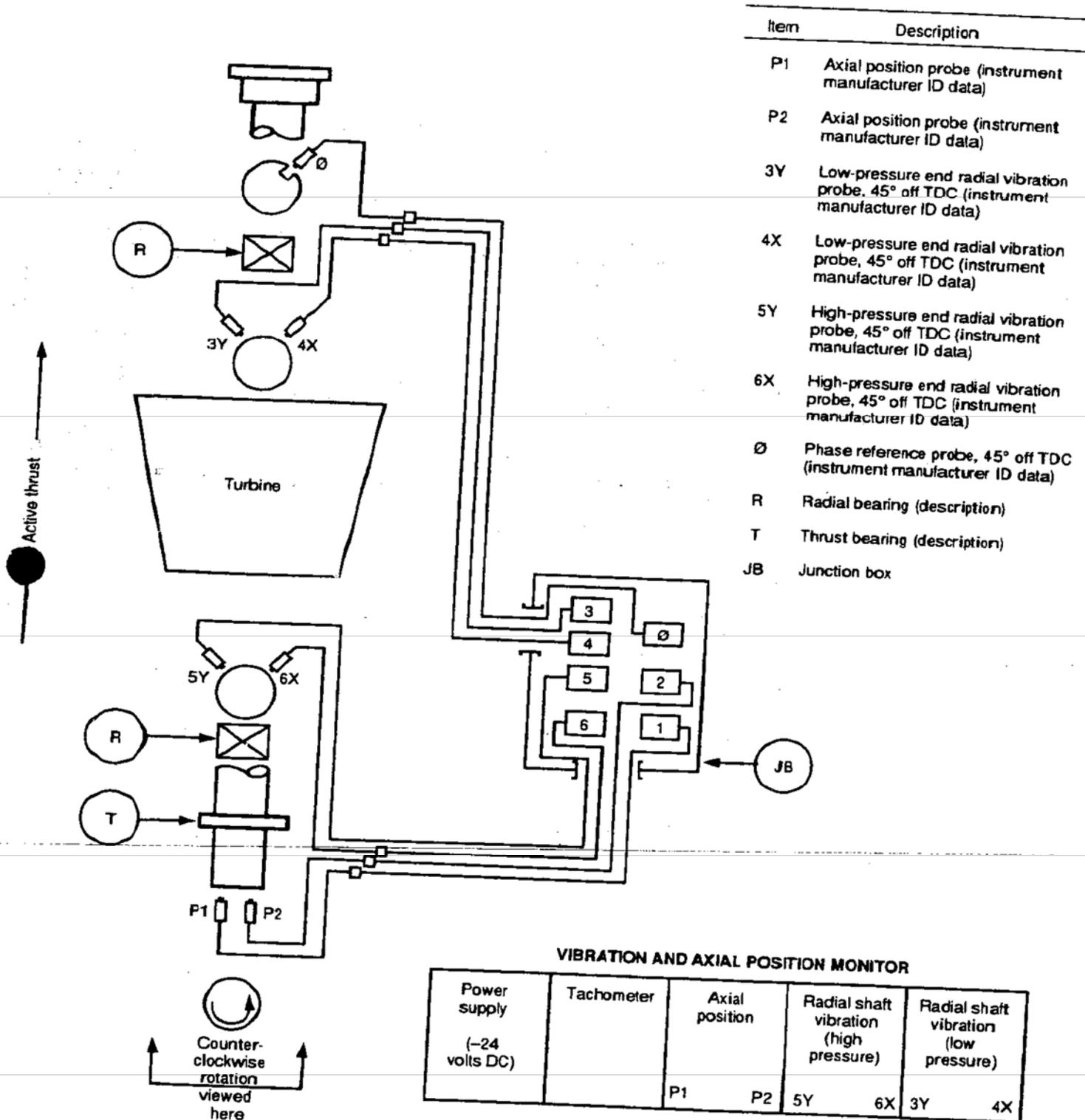
1. Certified general arrangement outline drawing and list of connections, including the following:
 - a. Size, rating, and location of all customer connections.
 - b. Approximate overall handling weights.
 - c. Overall dimensions.
 - d. Dimensions of mounting plates and locations of bolt holes for hardware installation.
 - e. Maintenance and disassembly clearances.
2. Cross-sectional drawing and bill of materials, including the following:
 - a. Machine-mounted sensors and probe holders.
 - b. Vendor-supplied extension cables and connectors.
 - c. Monitor rack assemblies.
3. Electrical and instrumentation schematics and wiring diagrams and bills of materials for all systems. The schematics shall show all adjustment points for alarm and shutdown limits (setpoints).
4. Electrical and instrumentation arrangement drawings and lists of connections.
5. Calibration curves showing sensor linearity within specified tolerances, and sensor test data showing electrical and mechanical runout at sensor mounting locations (see 6.3.3.5).
6. As-built data sheets.
7. As-built dimensions (including nominal dimensions with design tolerances) and data for the following parts:
 - a. Special transducers.
 - b. Special mounting fixtures.
8. Installation, operation, and maintenance manual describing the following (see 6.3.6.2):
 - a. Storage procedures.
 - b. Mounting details.
 - c. Wiring connections.
 - d. Installation and calibration instructions.
 - e. Board level troubleshooting instructions.
 - f. Basic operation details.
 - g. Alarm (alert) and shutdown (danger) setpoint adjustment.
 - h. System bypass operation.
9. Spare parts list with stocking level recommendations, in accordance with 6.3.5.
10. Progress reports and delivery schedule, including vendor buy-outs and milestones.
11. Drawing list, including latest revision numbers and dates.
12. Shipping list, including all major components that will ship separately.
13. List of special tools furnished for maintenance.
14. Technical data manual, including the following:
 - a. Storage procedures.
 - b. Calibration data, per Item 5 above.
 - c. Drawings, in accordance with 6.3.2.
 - d. Tagging information.
 - e. Spare parts list, in accordance with Item 9 above.
 - f. Utility data (power source and purge requirements).
 - g. Field test documentation, per 6.3.3.2.
 - h. Rotor nodal points, per 6.3.3.3.
 - i. As-built data sheets, per item 6 above.
15. Material Safety Data Sheet (OSHA Form 20), as applicable.

APPENDIX H—TYPICAL SYSTEM ARRANGEMENT PLANS

This appendix presents typical system arrangements for a turbine (Figure H-1), a double-helical gear (Figure H-2), a centrifugal compressor (Figure H-3), an electric motor with sleeve bearings (Figure H-4), and a centrifugal pump with antifriction bearings (Figure H-5). As a minimum, the arrangement plan furnished for each machinery train (see 6.3.3.4, Item b) shall illustrate the following items on the typical system arrangements:

- a. The position of each probe in relation to the machine bearings (see note).
- b. The machine direction of active thrust.
- c. The machine direction of rotation. This shall be accomplished by means of a view of all drivers from the high-pressure or outboard end and of all driven machines from the driven end.
- d. A complete description of the system, including the following items, as well as any other information applicable to the layout of the particular system:
 1. The number, type, and position of probes.
 2. The type of bearings.
 3. The radial clock position of probes, with degrees referenced to the vertical top dead center (TDC) as zero.
 4. The clock position of phase reference probes, with degrees referenced to the vertical TDC as zero.
 5. The location of axial position probes.
 6. The arrangement of the machine/oscillator-demodulator box.
- e. The layout of the radial shaft vibration, axial position, casing vibration, and bearing temperature monitors and all machine signal locations on the monitor.
- f. The type of machine.
- g. The end user machine identification number.

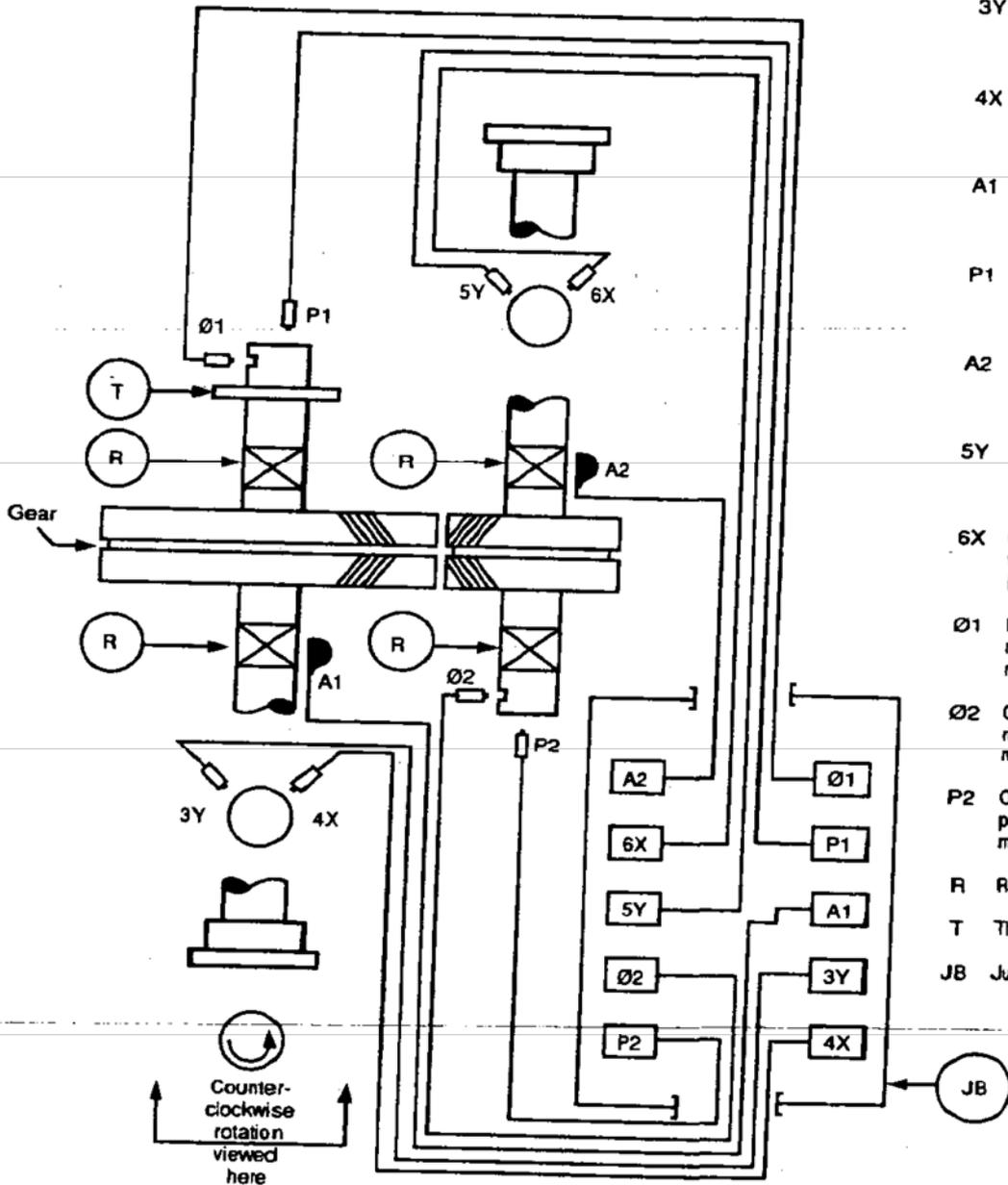
Note: The direction of rotation does not affect the X and Y probe location. The X and Y probes are always located as defined in 4.1.1.1.



Notes:

1. The numbering system shown is based on the higher pressure end equaling a higher device number.
2. TDC = top dead center.

Figure H-1—Typical System Arrangement for a Turbine



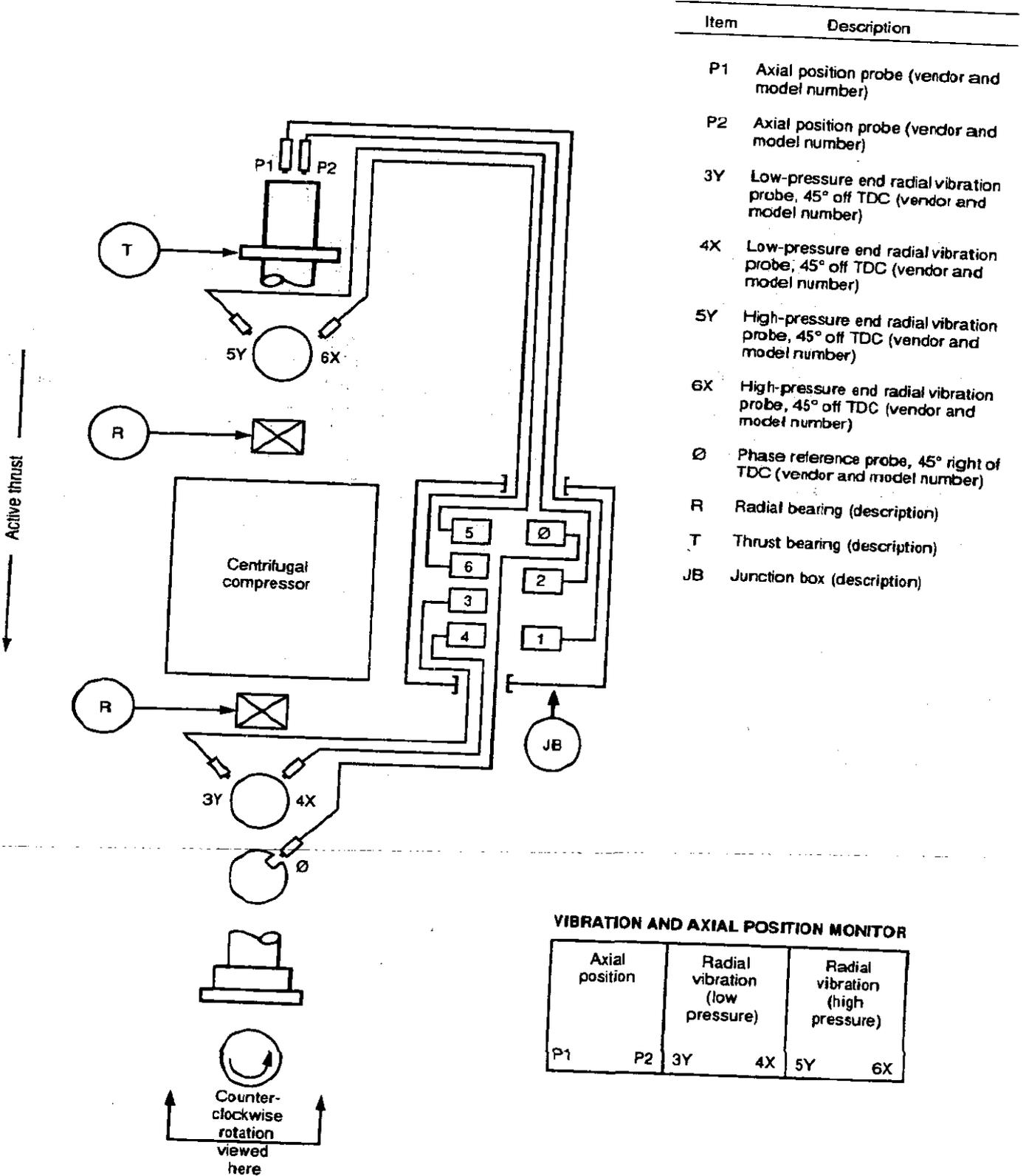
Item	Description
3Y	Input shaft coupling end Y radial vibration probe, 45° off TDC (instrument manufacturer ID data)
4X	Input shaft coupling end X radial vibration probe, 45° off TDC (instrument manufacturer ID data)
A1	Input shaft coupling end horizontal radial accelerometer, 90° off TDC (instrument manufacturer ID data)
P1	Input shaft thrust bearing end axial position probe #1 (instrument manufacturer ID data)
A2	Output shaft coupling end horizontal radial accelerometer, 90° off TDC (instrument manufacturer ID data)
5Y	Output shaft coupling end Y radial vibration probe, 45° off TDC (instrument manufacturer ID data)
6X	Output shaft coupling end X radial vibration probe, 45° off TDC (instrument manufacturer ID data)
Ø1	Input shaft noncoupling end phase reference probe at TDC (instrument manufacturer ID data)
Ø2	Output shaft noncoupling end phase reference probe at TDC (instrument manufacturer ID data)
P2	Output shaft thrust bearing end axial position probe #2 (instrument manufacturer ID data)
R	Radial bearing (description)
T	Thrust bearing (description)
JB	Junction box

VIBRATION AND AXIAL POSITION MONITOR

Radial shaft vibration (input shaft)	Bearing cap vibration (input shaft)	Axial shaft position	Radial shaft vibration (output shaft)	Bearing cap vibration (output shaft)
3Y 4X	A1	P1 P2	5Y 6X	A2

- Notes:
1. TDC = top dead center.
 2. Oscillator-demodulators and accelerometer signal conditioners should be located in separate junction boxes.
 3. For a single-helical gear, a pair of axial probes should be installed at each thrust bearing end.

Figure H-2—Typical System Arrangement for a Double-Helical Gear



Item	Description
P1	Axial position probe (vendor and model number)
P2	Axial position probe (vendor and model number)
3Y	Low-pressure end radial vibration probe, 45° off TDC (vendor and model number)
4X	Low-pressure end radial vibration probe, 45° off TDC (vendor and model number)
5Y	High-pressure end radial vibration probe, 45° off TDC (vendor and model number)
6X	High-pressure end radial vibration probe, 45° off TDC (vendor and model number)
Ø	Phase reference probe, 45° right of TDC (vendor and model number)
R	Radial bearing (description)
T	Thrust bearing (description)
JB	Junction box (description)

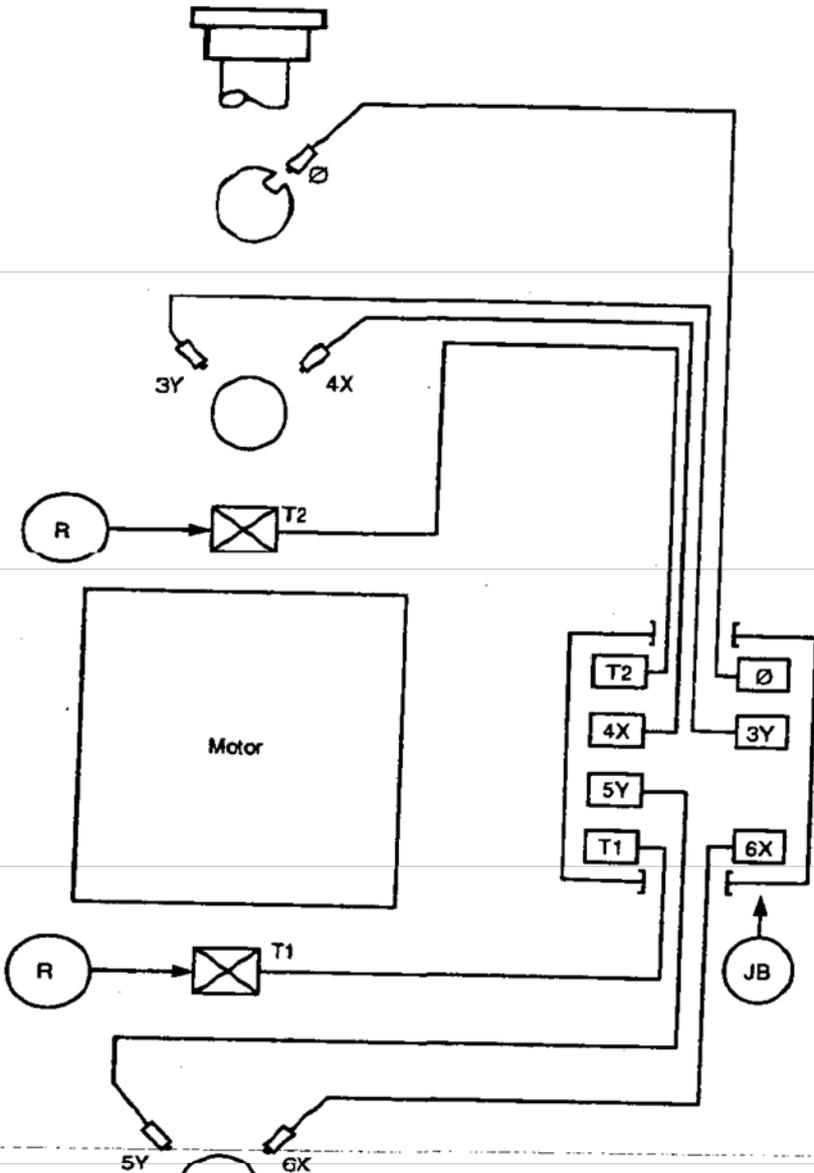
VIBRATION AND AXIAL POSITION MONITOR

Axial position		Radial vibration (low pressure)		Radial vibration (high pressure)	
P1	P2	3Y	4X	5Y	6X

Note: TDC = top dead center.

Figure H-3—Typical System Arrangement for a Centrifugal Compressor or a Pump With Hydrodynamic Bearings

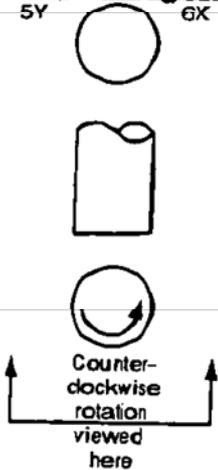
VIBRATION, AXIAL POSITION, AND BEARING TEMPERATURE MONITORING SYSTEMS



Item	Description
5Y	Outboard end Y radial vibration probe, 45° off TDC (instrument manufacturer ID data)
6X	Outboard end X radial vibration probe, 45° off TDC (instrument manufacturer ID data)
3Y	Coupling end Y radial vibration probe, 45° off TDC (instrument manufacturer ID data)
4X	Coupling end X radial vibration probe, 45° off TDC (instrument manufacturer ID data)
Ø	Phase reference probe, 45° off (instrument manufacturer ID data)
T1	Outboard end bearing temperature
T2	Coupling end bearing temperature
R	Radial bearing (description)
JB	Junction box

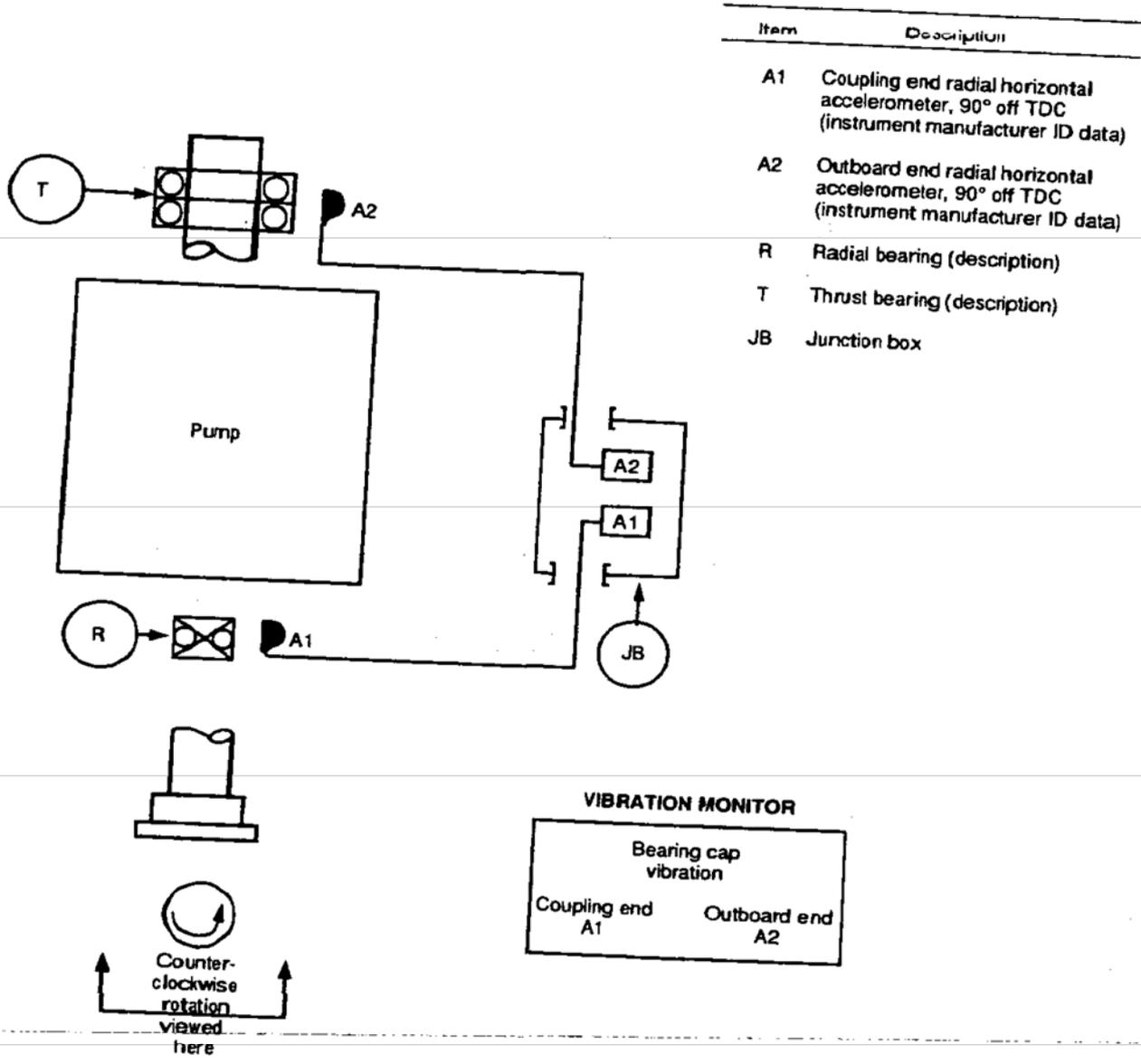
VIBRATION AND BEARING TEMPERATURE MONITOR

Radial shaft vibration (outboard)		Radial shaft vibration (coupling end)		Bearing temperature	
5Y	6X	3Y	4X	T1	T2



Note: TDC = top dead center.

Figure H-4—Typical System Arrangement for an Electric Motor With Sleeve Bearings



Note: TDC = top dead center.

Figure H-5—Typical System Arrangement for a Pump With Antifriction Bearings

Order No. 822-67000

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

