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MILITARY STANDARDIZATION HANDBOOK

SELECTION OF ACOUSTIC EMISSION SENSORS

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DEPARTMENT OF DEFENSE
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SELECTION OF ACOUSTIC EMISSION SENSORS

1. This standard handbook was developed by the Department of Defense with the assistance of the U.S. Army Materials Technology Laboratory and under a contract with Physical Acoustics Corporation. It is approved for use by all departments and agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, US Army Laboratory Command, Materials Technology Laboratory, ATTN: SLCMT-MEE, Watertown, MA 02172-0001 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

The use of acoustic emission testing and monitoring is growing rapidly. Each class of applications places its own demands on the acoustic emission (AE) instrumentation, and, in particular, on the choice of sensors. Many types of sensors are commercially available and each has been designed to optimize certain attributes. This handbook has been developed to assist Department of Defense Personnel in selecting sensors for a particular application. Sensor attributes are defined, discussed and related to typical characteristics of applications.

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1. SCOPE

1.1 Purpose. This handbook provides guidelines for selecting sensors for a particular application.

1.2 Method. Because applications are too numerous to treat in detail, characteristics of applications are defined and relevant sensor attributes are discussed for each application characteristic. Use of the handbook requires reviewing sensor attributes and application characteristics relative to a planned application and noting the corresponding recommendations for choosing appropriate sensor. A list of some basic guidelines is also given.

1.3 Terminology. Definitions are contained in MIL-STD-1945 for many terms used in this handbook.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

MILITARY

MIL-STD-1945 - Glossary of Terms and Definitions for Acoustic Emission Testing Procedures

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-Government publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E650 - Mounting Piezoelectric Acoustic Emission Contact Sensors
ASTM E750 - Standard Practice For Measuring The Operating Characteristics of Acoustic Emission Instrumentation
ASTM E976 - Guide for Determining the Reproducibility of Acoustic Emission Sensor Response
ASTM E1067 - Standard Practice for Acoustic Emission Examination of Fiberglass Reinforced Plastic Resin (FRP) Tanks/Vessels
ASTM E1106 - Primary Calibration of Acoustic Emission Sensors

(Application for copies should be addressed to the ASTM, 1916 Race Street, Philadelphia, PA 19103.)

GENERAL

"Acoustic Emission Transducer Calibration Using Transient Surface Waves and Signal Analysis," C. Feng and R.M. Whittier, in Advances in Acoustic Emission. eds. H.L. Dunegan and W.F. Hartman, Dunhart Publishers, 1981, Knoxville, Tennessee, pp 350-366.

3. SENSORS

3.1 Sensor definition. An acoustic emission sensor is a detection device that transforms the particle action produced by an elastic wave into an electrical signal.

3.1.1 Types of sensors. Acoustic emission sensors have been designed using various transducing devices, including acoustoelectric, piezoresistive, eddycurrent, electromagnetic, magnetostrictive, photoacoustic, capacitive and piezoelectric.

3.1.1.1 Capacitive sensor. Because it has an excellent, flat, broadband response to normal surface displacements, the capacitive type sensor is used in laboratory measurements that determine reference standards for AE sensor response. However, use of this type of sensor in field applications is uncommon.

3.1.1.2 Piezoelectric sensor. The most frequently used sensor is the piezoelectric type. This type has been commercially available since the mid 1960's. None of the other types have experienced extensive use; nor are they readily available in designs suitable for a broad range of applications. Although this document only treats selection of piezoelectric sensors, most of the sensor attributes could apply to the other types of sensors.

3.2 Attributes of a sensor. Manufacturers routinely supply information on some sensor attributes, such as sensitivity, frequency range, operating temperature range, size and weight. Information on other attributes is not always provided and should be requested if sensor selection requires such information. Sensor attributes are listed below in the order of decreasing relevance to most applications. However, for some applications, normally insignificant attributes may be of prime relevance. This is especially true for certain environmental conditions. A sketch of a basic AE sensor is given in figure 1.

3.2.1 Sensitivity/frequency response. These characteristics form one attribute that is generally the most fundamental attribute in selecting a sensor. Based on frequency response, there are two general types of sensors; resonance type and broadband type.

3.2.1.1 Resonance type. This is the most common type of AE sensor. It is intended to be used in a narrow band width that contains its resonant frequency. The sensitivity is very high at the resonant frequency, making this type of sensor appropriate for most of those applications where maximum sensitivity is of primary importance. An AE wave excites the resonance to a peak voltage, resulting in a ring-down whose duration depends on the peak value. Sensors having resonant requencies in the range 100-200 kHz are most often used. For such sensors, a high amplitude emission can produce ring-down durations of several milliseconds.

3.2.1.1.1 Dual-resonance type. A variant of the resonance type is the dual-resonance type. The sensitivity at the two resonances are normally lower than that of a single resonance type; but the usable frequency band is extended. Sensors are not normally classified by the manufacturers as being single resonance or dual resonance; but a careful look at their frequency-response plots can reveal this. Figures 2A and 2B show examples of frequency-response plots for these types.

3.2.1.2 Broadband type. This type of sensor, also known as a "wideband" type, may be designed as a multiple-resonance type, resulting in good sensitivity in several narrow regions of the specified broad operating bandwidth. Other designs produce broadband sensors without resonances within the specified operating bandwidth. These are known as "flat" response broadband sensors. Broadband sensors are typically more damped and have little "ringing". They have better fidelity for frequency analysis than the multiple-resonance type. A typical frequency response plot for a "flat" broadband sensor is shown in figure 2C.

3.2.2 Sensor's sensitivity. A sensor's sensitivity as a function of frequency is usually determined in one of two ways: surface-wave calibration method or face-to-face ultrasonic calibration method. Although other methods are sometimes used, they are not widely practiced.

3.2.2.1 Determination by surface-wave method. The surface-wave (Rayleigh wave) method uses a transient surface wave and a digital signal analysis technique to obtain an absolute calibration of the sensor's response to normal displacements. This technique is traceable to methods developed by the National Institute of Standards & Technology (formerly NBS). The method is described in the reference by Feng and Whittier. The sensor's sensitivity is expressed in dB referenced to one volt per meter per second (1 V/M/S). Examples of the resulting frequency-response plots are shown in figure 2.

3.2.2.2 Determination by face-to-face ultrasonic calibration method. The face-to-face ultrasonic calibration method uses a white noise ultrasonic source, applied through a broadband driving transducer to the face of the sensor. The sensor's response is then recorded from the output of a spectrum analyzer. This method, although very reproducible and easy to perform, does not provide a calibration that can be directly related to the surface-wave type or transferred to an absolute calibration. The sensor's sensitivity is compared to a reference sensor's response and is then expressed in dB referenced to one volt per microbar (1 V/μbar). An example of a typical frequency-response plot, obtained this way, is shown in figure 3. A variant of this method, using a "nonresonant" metal block between the driving transducer and the sensor, is described in ASTM E976.

3.2.2.3 Common feature to both calibration methods. A feature common to both calibration methods is the fact that the sensor is liquid-coupled to the other medium. This means that sensor excitation caused by normal displacements is predominant. Excitation caused by transverse displacements exists only to the extent that shear stress is supported by the viscosity of the couplant. Therefore, the calibration does not reflect the frequency response of the sensor to transverse displacements when bonded (glued) to the test part.

3.2.2.4 Similarity of results. For resonance-type sensors, having resonant frequencies less than 300 kHz, the peak sensitivities obtained by each of the two calibration methods are similar numbers; that is, even though the units are different, the dB values are nearly the same, although one is positive and the other negative. Typically, the surface wave method results in peak sensitivities that are 3 to 6 dB less than the absolute value of the peak sensitivity obtained by the face-to-face method. This results in confusion when comparing sensitivities of sensors calibrated by different methods. For example, a sensor having a peak sensitivity (ultrasonic method) of -70 dB re 1V/μbar may have a peak sensitivity (Rayleigh wave method) of 65 dB re 1 V/M/S. These correspond to 3.16x10-4 V/ubar and 1778 V/M/S, respectively. There is no simple relationship between these numbers. Furthermore, when comparing the frequency-response plots obtained by the two methods, significant differences appear in the shape of the plots at higher frequencies and for broadband sensors, in general. This is due to the fact that the sensor's response is directly related to the instantaneous average of the particle displacements over the surface of the sensor. For waves travelling perpendicular to the sensor surface this averaging effect does not change with frequency. However, for waves travelling parallel to the sensor face (Rayleigh waves) the averaging effect produces decreasing sensitivity as the acoustic wavelength gets smaller than the diameter of the sensor. This means, as the frequency increases, the sensor's response to the surface wave method will probably produce a frequency-response plot that is shaped differently than that produced by the face-to-face ultrasonic calibration method. It is therefore advisable to compare broadband frequency responses only for equivalent calibration methods.

3.2.2.5 Temperature range. The operating temperature range of a piezoelectric sensor is determined primarily by the thermal properties of the piezoelectric element, and those of the wearplate and the substance used to bond the sensor to the wearplate. It is not necessary to know the details of the design because the manufacturer specifies the operating temperature range. Sensors are available that operate at near cryogenic temperatures as well as up to temperatures of 550°C.

3.2.2.6 Wearplate. The wearplate, also known as "contact shoe", "coupling shoe", "protective shoe" and "face material", is typically fabricated of ceramic or epoxy. Other materials occasionally used are anodized aluminum, stainless steel, high nickel-chromium alloys and brass. A ceramic wearplate has an acoustic impedance very similar to that of the most common piezoelectric material, lead-zirconate-titanate (PZT). It is a better impedance match to metals than epoxy. Sensors having epoxy wearplates can be used with better sensitivity on non-metallic surfaces, such as fiberglass reinforced plastics. Although the sensor's frequency-response plot is obtained with the wearplate affixed, only in the surface wave method of calibration is the wearplate necessarily coupled to a metal surface.

3.2.2.7 Differential design. This special design reduces the sensor's susceptibility to RFI/EMI, especially to radiated or induced electrical spikes. A differential sensor must be used with a differential preamplifier. It should be noted that some differential sensors exhibit directionality variations as great as ± 4 dB.

3.2.2.8 Size and shape. The common shape of a sensor is a right-circular cylinder whose diameter is comparable to the width of the piezoelectric element and whose height is generally similar to its diameter. Sensor diameters range from a few millimeters to over 50 millimeters. (The very low frequency sensors used in geologic applications may be much larger.) A popular size has a diameter of 20 mm and a height of 16 mm.

3.2.2.9 Weight. Sensor weights range from less than a gram to over 500 grams, with 15 gm being very common.

3.2.2.10 Housing material. The housing material, also known as the "case material", is most often stainless steel or aluminum. Other materials that are used include carbon steel, brass, and high nickel-chromium alloys.

3.2.2.11 Connector. The connector is top or side mounted. Common connector types are BNC and microdot; but other types are used on special sensors. Some sensors have integral cables, usually less than 2 m in length, usually terminated with BNC connectors.

3.2.2.12 Grounding features. Most sensors have housings that are grounded and electrically isolated from the test part by a non-conducting wearplate. If the wearplate is metallic and the test part an electrical conductor, ground loops can be created unless an intermediate non-conductor is used between the sensor and test part. Note that it would also be important to use a non-conductor between the sensor and any metallic mounting fixture, as well.

3.2.2.13 Directionality. Most sensors have omnidirectional sensitivity in the plane of contact with variations not exceeding $\pm$ 2 dB. Exceptions to this are some differential sensors and sensors having designed directional features.

3.2.2.14 Seal type. Housings are usually epoxy sealed or hermetically sealed. The latter is preferred for hostile environments.

3.2.2.15 Shock resistance. Sensors having integral preamplifiers and some special broadband sensors usually are rated to withstand shocks up to 500 peak g in any direction. Most other sensors typically have shock limits of 10,000 g.

3.2.2.16 Radiation resistance. Sensors can be designed to withstand, without degradation, both neutron and gamma radiation. The maximum integrated dose is specified by manufacturers for some sensors. Sensors containing integral preamplifiers are least suited for use in radiation environments.

3.2.2.17 Curie temperature. This is the temperature beyond which the piezoelectric material loses its transducing properties. The specified operating temperature range for a sensor is always less than the Curie temperature. However, it must be realized that exceeding this temperature will cause permanent damage to most AE sensors.

3.2.2.18 Capacitance. It is often helpful to know the sensor capacitance when deciding on cable lengths between the sensor and preamplifier. The signal loss due to the cable capacitance is given by:

$$\text{Signal loss} = Cc/Cs + Cc,$$

where Cc is cable capacitance and Cs is the sensor capacitance. A meter length of coaxial cable has a capacitance of approximately 100 pF. Therefore, sensors having capacitance values less than 100 pF would experience signal losses greater than 50%. Sensor capacitance values typically fall in the range 100 pf to 1000 pF.

3.2.2.19 Piezoelectric material. The type of piezoelectric material is not always specified by the manufacturer of sensors. The most common material is lead-zirconate-titanate (PZT) and its variants. Other materials used are barium titanate, lithium niobate and lead metaniobate. Knowledge of the piezoelectric material can be used to infer the acoustic impedance and the Curie temperature.

3.3 Integral-preamplifier sensors. Sensors with preamplifiers built into their housings provide high sensitivity and the elimination of the sensor to preamp connection. When considering selection of such a sensor, additional attributes are investigated. These relate to typical specifications of the preamplifier and include gain, dynamic range and noise.

4. APPLICATION/SENSOR RELATIONSHIP

4.1 General. AE applications are too numerous and various to be easily placed into classes. If done with detail sufficient to enable prescription of appropriate sensor specifications for each class, the resulting number of classes would be great and overlapping. Therefore, in order to provide guidelines for sensor selection, it is more efficient to describe general "Application Characteristics" and to discuss how these relate to certain sensor attributes. Some sensor attributes are easily selected, while others can provide a puzzling choice. The most fundamental choice, and often the most important, is the choice of sensitivity/frequency response. This is the essential feature of the sensor and many application characteristics may influence its choice. Often, some measurements must be performed in order to make a confident choice. In discussing the application characteristics, emphasis is placed on selection of sensitivity/frequency response. As discussed in 3.2.1, the two types of calibration methods produce different frequency response plots, especially at high frequencies. In discussing application characteristics, consideration will be given to whether a particular calibration method is more appropriate in selecting a sensor based on its sensitivity/frequency response.

4.2 Frequency range. Although AE phenomenon are known to occur over the frequency range 100 Hz to 10 MHz, the most frequently used bandwidth is 100 to 400 kHz. It is highly probable that well over half of all AE measurements to date were made using a resonant sensor having a resonance near 150 kHz. One of the reasons for this is the desire to keep the resonance frequency high enough to be insensitive to most mechanical background noise, but low enough so that detection of AE at a distance from the source is not significantly reduced by attenuation. AE detection is influenced by attenuation whenever the sensor is not in the immediate proximity of the AE source, that is, it is "remote" from the source. The term "remote detection" will be used below to signify that the sensor is not to be placed immediately next to or on top of the source of AE to be detected.

4.3 Application characteristics. The application characteristics discussed here are not mutually exclusive and sometimes one characteristic will suggest a sensor attribute that is in conflict with that suggested by another characteristic. Nevertheless, some basic guidelines can be succinctly stated and, following discussion here, are summarized in 5.

4.3.1 Material. Solids and fluids produce and transmit AE. Hard metallic solids have higher amplitude emissions and less attenuation than soft metallics and non-metallics. High frequency (150-800 kHz) sensors may be used for remote detection in hard metallics. Remote detection in most non-metallics (concrete, rubber, plastics, ceramics, rock, wood, etc.) often requires lower frequency (25 kHz - 150 kHz) sensors.

Material characteristics of solids associated with higher amplitude emissions are:

High Strength
Anisotropy
Non Homogeneity
Flawed Material

Cast Metal or Alloy
Large Grain Size
Fiber Reinforced

When several of these characteristics apply to an application high sensitivity does not need to be a priority in selecting a sensor type. (See also 4.3.4)

4.3.1.1 Solids. Solids having low shear wave speeds, such as Polymethylmethacrylate, present an interesting guideline with respect to sensor diameter. Recall that in 3.2.1 it was pointed out that the averaging of the particle displacements over the sensor produces decreasing sensitivity as the acoustic wavelength gets smaller than the diameter of the sensor. Because the sensor calibration is performed on steel, comparable response will be obtained for low wave-speed solids according to frequency scaled by the ratio Cl/Cs, where Cl is the low shear wave speed and Cs is the shear wave speed of steel. For the case of polymethylmethacrylate, the response at 250 kHz would shift to 100 kHz. If higher frequency response is required, either smaller diameter sensors should be used or a small-diameter wave guide may be used with larger sensors. (See 4.3.8)

4.3.1.2 Fluids. AE in fluids includes cavitation, degassing and turbulence in liquids and turbulence in gases. Selection of a sensor for detecting AE in water or other liquids requires a non-corrosive, hermetically sealed housing having a watertight connector or integral cable. Because only pressure waves propagate in water, it is preferred to compare sensors calibrated by the face-to-face ultrasonic method.

4.3.1.3 Air. The detection of leak noise through air is best accomplished using a low frequency (less than 50 kHz) sensor, preferably one designed for airborne detection, i.e., one whose wearplate is specially thinned.

4.3.2 Size and design of structure or part. Solid test objects range from tiny electronic chips to huge tanks and vessels. The size and design features of the test structure or part have influence on sensor selection. In the testing of a very small part, the part is attached to the sensor. In this case it is best to choose face-to-face calibrated sensors. On the other hand, large structures usually require remote detection and this means surface wave detection and so the corresponding type of calibration is preferred.

4.3.2.1 Surface having high curvature. In choosing a sensor that is to be mounted on a surface having high curvature, preference should be given to smaller diameter sensors, because the mounting forces could damage a large diameter sensor which is in contact only along a line.

4.3.2.2 Thick and thin - walled structures. Emissions from thick-walled structures have higher amplitudes and higher frequency content than emissions from thin-walled structures. Because thin-walled structures support flexural waves, lower frequency sensors should be used.

4.3.2.3 Attenuation factors. The greater the attenuation produced by structural features, the less high frequency acoustic energy can be remotely detected. Structural design features contributing to attenuation are:

transitions in wall thickness
appurtenances (legs, braces, manholes, pipes)
surface coatings (paint, oxides)
insulation

In order to know the extent of attenuation, so as to better select a sensor, it is often necessary to perform some attenuation measurements. It is best to do this using a broadband sensor, so that the attenuation as a function of frequency can be gauged.

4.3.3 Background noise. Sources of background noise are: mechanical noise, such as friction of moving parts, pump noise and vibration, all typically less than 100 kHz; flow noise, such as cavitation and turbulence, typically 100-400 kHz; and EMI, typically greater than 1 MHz.

4.3.3.1 Measurement. Background noise, which cannot be eliminated from the test object, must be accommodated. This means that the sensor's frequency range should be chosen to minimize the detection of background noise. Selecting the sensor without knowledge of the background noise is not recommended. Therefore, it is often necessary to measure background noise before specifying the sensor for the application. This should be done using a flat broadband sensor that has been calibrated by the appropriate method. If the background noise cannot be determined or confidently estimated before beginning a test or monitoring period, and sensor selection must be finalized without this information, a broadband sensor should be selected. (Filtering techniques may then be used to reduce the effects of the background noise.) When airborne EMI/RFI is severe, a sensor of differential design or a sensor with integral preamplifier will be less sensitive to the EMI/RFI.

4.3.4 AE source type. Often a choice must be made between maximum sensitivity and optimizing frequency range or other sensor attributes. When the anticipated AE source is a strong emitter, maximum sensitivity may be sacrificed. Some examples of strong and weak sources are:

Strong Sources	Weak Sources
Cleavage Fracture	Ductile Tearing
Oxide Fracture	Plastic Deformation
Intergranular Cracking	Twin Deformation
Fiber Breaking	Matrix Crazing
High Pressure Gas Breaks	Low Pressure Liquid Leaks

4.3.5 Environmental factors. For very high temperature applications, a stand-off device (waveguide) may be used with sensors having lower temperature range. (See 4.3.8) The effective sensitivity of a mid-temperature sensor on a waveguide is often greater than mounting a high-temperature sensor directly on the hot surface. This is especially true if couplant cannot be used on the high temperature surface. In general, dry mounting of a sensor reduces the effective sensitivity by 20-30 dB.

4.3.5.1 Vibration. When the test object is vibrating or experiencing shock, it is advisable to select sensors that have integral cables and do not have integral preamplifiers.

4.3.5.2 Pressure variations. Ambient pressure variations can affect some sensors. Before finalizing selection, seek manufacturer's opinion.

4.3.5.3 Chemically contaminated surfaces. For chemically contaminated surfaces, select sensors having appropriate housing material, seal and wearplate.

4.3.5.4 Explosive environments. For explosive environments, select intrinsically safe sensors with integral preamplifiers.

4.3.6 Fidelity requirements. If the application calls for waveform analysis, such as fast Fourier transformation, it is best to use a broadband, preferably flat-response, sensor. Resonant type sensors do not provide reliable information on the frequency content of the AE wave. However, a dual resonance sensor can give good information on the relative partitioning of the acoustic energy into two narrow bandwidths, if appropriate filters are used.

4.3.7 Special measurement requirements. Some special measurement requirements relating to sensor characteristics are:

4.3.7.1 High event rate. High event rate is better detected using a damped (broadband) sensor, because the ring-down time is minimized, thus making closely-occurring events discernible.

4.3.7.2 Amplitude distribution analysis. Amplitude Distribution Analysis is best performed with high dynamic range. The dynamic range depends on the voltage measured due to the background noise level and this increases with increasing sensitivity of the sensor. Therefore if amplitude distribution is a high priority, high sensitivity sensors may not be appropriate, depending on background noise.

4.3.7.3 Source location accuracy. Source location accuracy is improved by using sensors having the lowest directionality characteristics (± 1 dB).

4.3.7.4 Known defect. AE from a known defect can be monitored with good noise discrimination by using a high frequency (greater than 500 kHz) resonant sensor mounted immediately adjacent to the known defect.

4.3.8 Use of waveguide. Waveguides are commonly used to couple a sensor to a test part which is in a hostile environment or simply unaccommodating of the sensor's size. Waveguides may be used to apply large diameter sensors to small contact areas. When a sensor is attached to a waveguide, the overall sensitivity of the sensor to the AE in the test medium is dependent upon the design of the waveguide, the technique of its attachment to the test medium and the technique of mounting the sensor to the waveguide. Guidelines for sensor selection in these cases are limited to knowledge of successful techniques. As an example, the sensor/waveguide assembly shown in figure 4 is often used for AE monitoring of pressure vessels at elevated temperatures. It consists of an aluminum or steel rod (5 mm diameter) having one end terminated in a cone. The sensor is a resonance type (140 kHz), having an epoxy wearplate, and is bonded to the cone using epoxy cement. The other end of the waveguide is held in contact with the test object using the magnet/spring assembly. The length of the waveguide is about 40 cm. Because the thin waveguide channels rod waves to normal incidence on the sensor, sensors calibrated by the face-to-face method are appropriate for consideration. If a waveguide is to be used in a new application, it is suggested that preliminary feasibility measurements be made using one or more sensor-waveguide designs.

5. SUMMARY: SOME BASIC GUIDELINES

1. Use frequency response plots from surface wave calibration for selecting sensors for surface wave applications.

2. Use frequency response plots from face-to-face ultrasonic calibration for selecting sensors for:

   ... detection in fluids,
   ... detecting AE from small parts attached to sensor,
   ... sensor to be mounted on waveguide.

3. When selecting a resonant type sensor, choose a resonance frequency that minimizes sensitivity to background noise while retaining sensitivity to source strength, compatible with attenuation.

4. Survey background noise with broadband sensor.

5. Lower frequency sensors should be used for remote detection when attenuation is high.

6. High frequency sensors (150-800 kHz) may be used for remote detection in hard metallic solids.

7. Low frequency sensors (25-150 kHz) should be used for remote detection of AE in most non-metallic solids.

8. High peak sensitivity sensors are not necessary for detecting strong emission sources.

9. Low frequency sensors should be used for thin-walled structures.

10. High frequency sensors may be used for thick-walled structures.

11. Use a flat broadband sensor for frequency analysis.

12. Use low frequency (less than 50 kHz) sensors for detection of airborne AE.

13. Use smaller diameter sensors for:

    ... mounting on surfaces of high curvature,
    ... increased sensitivity to surface waves at higher frequencies,
    ... broadband detection of surface waves in materials having low shear wave speeds.

14. Choose a sensor having high capacitance when long cable lengths are required between sensor and preamplifier.

15. Choose sensor connector type and location that are compatible with method of mounting sensor.

Custodians:
Army - MR
Navy - AS
Air Force - 11

Review activities:
Army - AR, EA, MI
Navy - SH
Air Force - 99, 70, 80, 82, 24, 84

User activities:
Army - AT, AL, ME, TE, AR
Navy - OS
Air Force - 71

Preparing activity:
Army - MR

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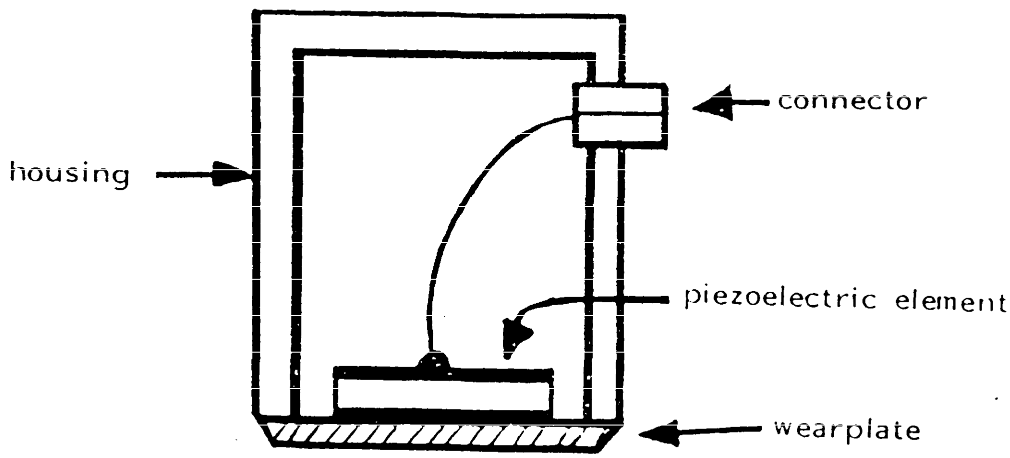
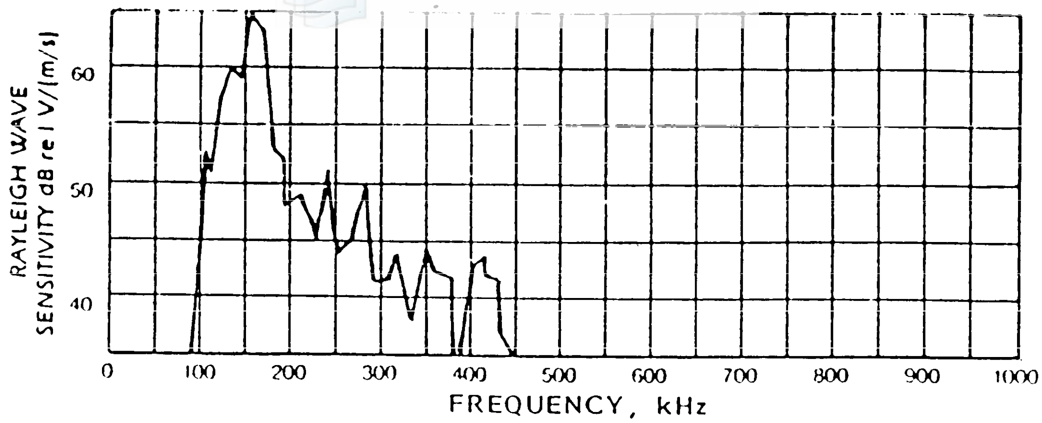


FIGURE 1. Typical construction of a resonance type AE sensor.

A



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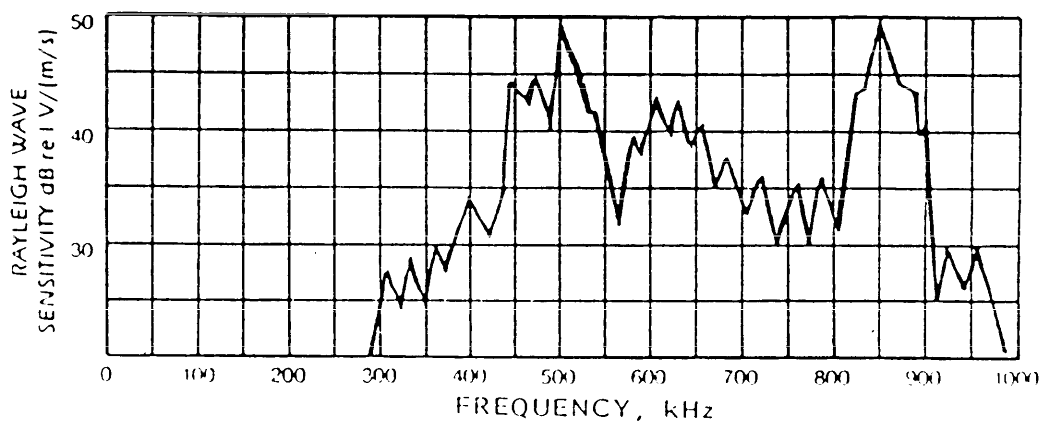

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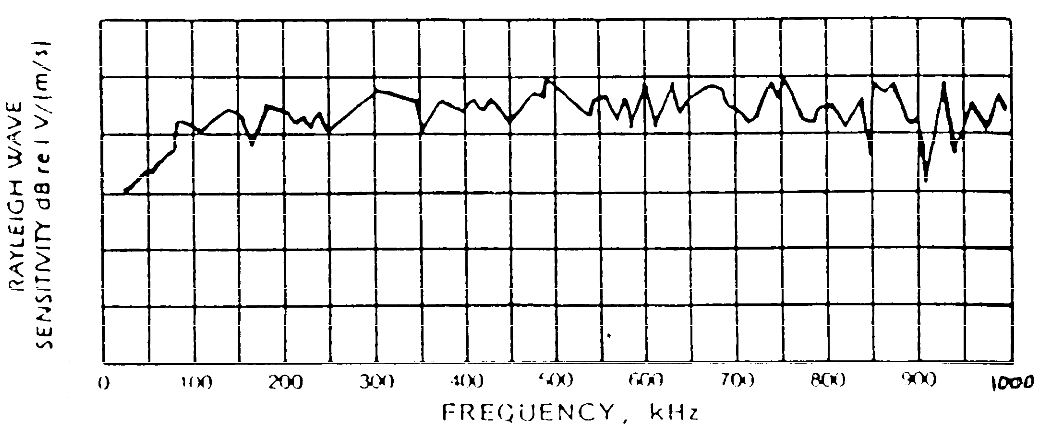

FIGURE 2. Typical surface-wave calibration plots for
(A) single-resonance sensor
(B) dual-resonance sensor
(C) flat-broadband sensor

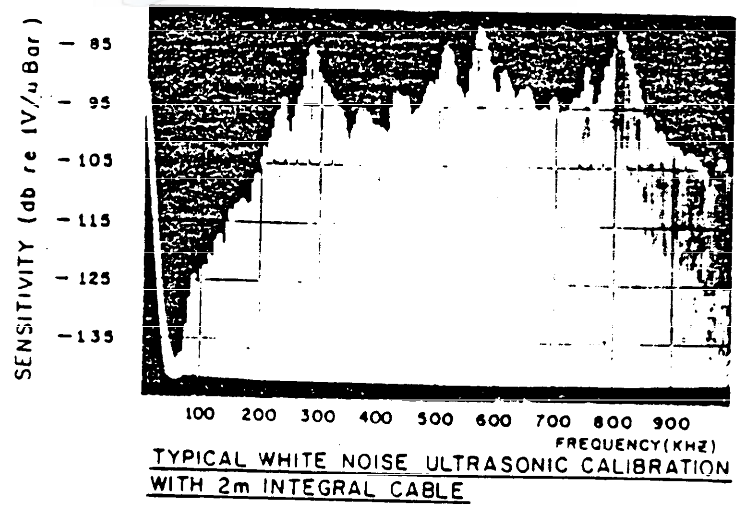

FIGURE 3. Typical face-to-face calibration plot for a broadband sensor.

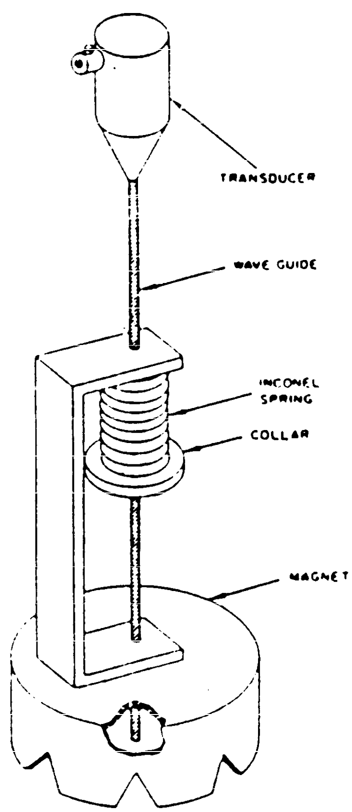

FIGURE 4. A sensor-waveguide assembly.

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

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- ☐ USER
- ☐ MANUFACTURER
- ☐ OTHER *(Specify)*: ______

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

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