HAZARDOUS PARTICULATES AND NOISE

NOISE

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NOISE INSTRUMENTATION SYSTEMS

Many types of instrumentation systems can be utilized for the measurement of sound depending on the characteristics of sound involved; extent of information that is desired about the sound; and the amount of time available.

The various elements of an instrumentation system are:

A. transducer (microphone or vibration pickup);
B. electronic amplifier and calibration attenuator (gain control);
C. data storage system;
D. frequency analyzer, and
E. read out (meter, chart, tape)

Not all elements are used in every instrumentation system. The microphone is connected either to a sound level meter or to a magnetic-tape recorder. The sound level meter is used if the sound pressure level is to be measured directly, and magnetic tape recorder if the sound signal is to be stored for future measurement or reference.

Although these components of a measuring system are shown as separate units, a number of their functions may be combined into one instrument. Even in these combined instruments, provision is commonly made for the use of different types of microphones, and input and output terminals are often included so that other instrumentation can be connected to yield complementary information about a sound.

There are two basic functions of an instrumentation system.

a. to obtain sound or vibration data in the field, and
b. to reduce measured data to a meaningful form, e.g. to weighted values of a sound pressure level, or jerk.

Much of the reliability of a measurement depends on how the instruments are used and set up. One must be thoroughly familiar with an instrument to make full use of its capabilities. The material covered here will help the reader become familiar with the capabilities of various instruments but a thorough study of the handbook supplied by the manufacturer of a particular instrument is also essential.

A. Transducers. A transducer is any device capable of converting power of one kind into power of another kind. In acoustics, transducers are used to convert sound power into electrical power.

Transducers used to convert changes in pressure variations of a sound wave to an electrical signal are called pressure transducers or microphones. Transducers used to convert the acceleration of a vibrating body into an electrical signal are called vibration transducers or accelerometers.

The measurement of the transducer movement can be in terms of displacement, velocity, acceleration and jerk. With pressure transducers the resultant electrical power relates to the rms square of the sound pressure. By using a log circuit a sound pressure level can be determined directly. Vibration transducers are similar but the initial electrical power relates to the acceleration and is passed into an integrator circuit which integrates (summation) for velocity and displacement but differentiates (gradient) for jerk.

a. Pressure Transducer (Microphone). To convert sound fluctuations into electrical variations one commonly uses one of three major types, the piezoelectric (ceramic), condenser and the dynamic.

Desirable microphone characteristics are:

reliability,
smooth frequency response,
minimum phase distortion,
high sensitivity,
small size (to minimize disturbance of the sound field),
simplicity,
minimal effects to environmental changes, and
reasonable price.

b. Piezoelectric Transducer (ceramic microphone). The piezoelectric (ceramic) principle is a ceramic (leadtitonate, lead zirconate) which has the property of producing electrical charges on the surface when the material is strained. These microphones are regularly supplied with sound level meters and are available for use with other measuring instruments. They can be mounted directly on the instrument or separately with cable connections.

c. Condenser Transducer (microphone). A condenser microphone is essentially an electrical capacitor formed by a thin metallic diaphragm which is exposed to sound waves by a back plate or perforated electrode. Condenser microphones are more stable with time and temperature than either the ceramic or the dynamic microphones, have excellent responses for various frequencies. Condenser microphones generate more self-noise than other types from air eddies within the microphone head.

d. Vibration Transducer (accelerometer).

i. Piezoelectric vibration transducer (accelerometer). In the simplest form, a mass is mounted on one side of a piezoelectric material, and the other side is cemented to the accelerometer base. The accelerometer base is then rigidly affixed to the sample whose vibration is under study. Movement of the accelerometer base generates an inertial force in the dynamic mass, which then strains the crystal, generating voltage.

ii. Electrodynamic vibration transducer (accelerometer). A transducer similar in principle to the dynamic microphone provides an output proportional to velocity. A dynamic mass as a permanent magnet, is mounted so as to form a spring mass system with a damp resonance at a frequency below the operating range of frequencies. A stationary coil is mounted near the moving mass to detect its relative motion.

B. Sound Level Meter. The most common instrument to measure sound levels in air is the sound-level meter, a sensitive electronic voltmeter used to measure the electrical signal from a transducer, which is usually mounted on the instrument for portability.

The electrical signal from the transducer is fed to the pre-amplifier where the cables may be long. The input is then amplified. The amplified signal is weighted according to the ABCD or flat scales and filtered (or not filtered) over a specific range of frequencies. Further amplification prepares the signal as an output to other instruments or for rectification and direct reading on a meter.

The needle of the indicating meter has two speeds of indication: "fast" and "slow". On the fast setting, the needle gives true indication of the level within 200 to 250 milliseconds after a 1,000 hz tone has been fed into the preamplifier. The overshoot before that time is not greater than 1 dB. The slow setting averages the level for a greater time period.

a. Weighting network criterion. The sensitivity of a sound level meter for any range of frequencies is controlled by the electrical weighting networks according to response curves. A, B, C, weightings have been standardized in the United States in ANSI S1.4-1971 for the sound level meter. Measurement results are designated as dBA, dBB, dBC.

Originally these networks were designed to simulate the loudness level sensitivity of the human ear when listening to pure tones. Today the B weighting network is rarely used. D and E scales have been proposed in connection with noisiness problems. The C weighting (or flat response) is generally used when the problem is of a physical nature such as recording sounds or analyzing data. The A weighting selectively discriminates against low frequency sound and filters out as much as 20 to 40 dB. It is used to estimate hearing damage in industry in the OSHA regulations for measurement of sound levels. A semantic difficulty arises in the literature where unweighted measures are "sound pressure levels" and weighted are "sound levels". To avoid ambiguity the term should state if the measure is weighted. Most commercially available sound level meters meet the ANSI 1.4-1971 specification for precision, general purpose, survey and special purpose sound level meters.

b. Precision Sound Level Meter. Precision Sound Level Meter provides greater accuracy and meets stringent requirements. They provide lower internal noise level and higher gain for measurements of lower sound levels; wider dynamic range, better frequency response characteristics and a low distortion output for driving analyzers or tape recorder. Certain precision sound level meters also impulse (impact) sounds.

C. Vibration Meter. For measurements of displacement, velocity acceleration and jerk a vibration meter is used. A typical unit consists of a vibration transducer (accelerometer), integrator, adjustable attenuator, an amplifier, rectifier, and a direct reading meter. Connections are provided for earphones, sound and vibration analyzer, impact sound analyzer or an oscilloscope. Generally the meter is calibrated directly in terms of peak, peak-to-peak and average displacement, velocity, acceleration and jerk; these are indicated in mils, inches/sec, inches/ sec^2, and inches/ sec^3 respectively.

D. Frequency Analyzer. Broad band measurements are often inadequate. Full understanding can be gained only when distribution of energy over the frequency spectrum is known. The process of determining this distribution is called "analysis" or "spectrum analysis", and the instruments used are called "spectrum analyzers" or "frequency analyzers". These analyzers vary in cost, complexity and ease of operation. Choice between them is generally determined by their availability and the amount of detailed information needed to solve a particular problem.

a. Octave Band Analyzer. Octave band analyzers make it possible to perform a simple and rapid analysis of sound spectra. The battery operated analyzer consists of a set of band pass filters, attenuator and an amplifier which drives both an indicating meter and a monitoring instrument. Octave band analyzers generally use octave bands centered on the following preferred frequencies, 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16000 Hz. (ANSI S1.6, 1967). The actual nominal frequency range of any one of these bands is 2 - to - 1. Octave band analyzers operate directly from the output of a microphone, a sound level meter, vibration transducer, or a vibration meter.

i. One-third & one-tenth octave Bandwidth Analyzer. When an octave band analysis of sound is not sufficient, a third or a one-tenth octave band analyzer is used. This yields an instrument especially useful in complex sound and vibration problems where machinery diagnosis is important.

E. Impulse (impact) Sound Analyzer. The impact sound analyzer helps evaluate impulsive or impact sounds such as those of pile drivers and punch presses which cannot be properly evaluated by a sound level meter, a vibration meter, or a spectrum analyzer because of rapidity of the sound level changes.

In the measurement of impulsive sounds the criteria are the unfiltered peak pressure value, the pulse rise time, the duration of the pressure wave and the frequency spectrum of the pulse. The indicating meter must have a rise time not greater than 50 sec. for a response within 1dB of the peak value.

F. Graphic Level Recorder. Frequently the sound in an industrial environment varies so much so quickly that it is difficult to measure. Under such conditions a graphic recorder can be used to obtain a permanent record of the sound level.

The graphic level recorder is essentially a recording voltmeter with a logarithmic scale. The input signal voltage connects to a potentiometer, and the voltage from it is amplified and converted to a DC voltage which is amplified and used to drive a movable coil in a strong magnetic field. The coil is mechanically coupled to the movable arm on the potentiometer and also to a pointer which traces a record on paper, divided for levels in decibels. This continuous recording conveys more information about a varying sound than a few selected readings.

G. Magnetic Tape Recorder. The magnetic tape recorder is an instrument which amplifies the signals from a microphone, sound level meter or analyzer and records them on a continuously moving magnetic tape. The modulation of a signal by the recording amplifier can be in terms of the amplitude (AM) or the frequency (FM). Most recording are AM or a particular recording tape speed. However, FM recording has decided frequency analysis advantages. Loop recorders are also available for repeating a portion of the tape continuously.

Calibration and setting the recorder gain are vital issues in tape recording. Tape recording is ideal for documenting the nature of the sound sequence but does not replace the sound level meter measurements.

H. Calibrator. All measuring instruments require calibration and this is normally accomplished by placing a standard source, the calibrator, over the transducer head.

a. Pressure transducer (microphone) calibrator. Two forms are available, a pistonphone which is a motor driven piston and an oscillator calibrator which is an oscillator driven transducer. A piston phone calibrator has the disadvantage of being limited to a 250Hz narrow band signal and needs a correction added for the barometric pressure. An oscillator calibrator often has calibrator points for four octave intervals from 125 Hz. 500 Hz is an important frequency.

b. Vibration Transducer (accelerometer) calibrator. Basically the calibrator is a shaking system of specified narrow band frequency, acceleration, loading and displacement. The vibratory movement is perpendicular to the transducer head which is applied to the vibrating surface.

I. Sound Exposure Monitor. The legislation for work environment requires that we know the duration of sound levels in dBa above prescribed values. Doing this manually can be tedious and thus the sound exposure meter does this automatically.

Various manufacturers have now developed exposure monitoring instruments with measuring circuits which meet OSHA criteria and ANSI Standard S1.4-1971 for a weighted slow response circuit. The General Radio Unit accepts sound information from a microphone or sound level meter, samples, categorizes and weighs it and displays digitally percent of sound exposure or percent of test time as selected. A pocket size battery operated sound exposure monitor is also now available from General Radio.

J. Oscilloscope. A sound level meter shows one characteristic of a sound wave - the rms sound pressure level, but it gives no information about the sound wave form. For this purpose a cathode ray oscilloscope is used. The electron beam in the tube is ordinarily deflected by a sweeping signal so that the trace on the screen moves at a uniform rate horizontally along the x axis, quickly returns it to the beginning, and the pattern is repeated. The combined motion results in a display of the instantaneous amplitude of the wave as a function of time. This display can be photographed to yield permanent records.

Oscilloscopes are particularly helpful in analysis of impact (impulse) sounds.

K. Real Time Analyzer. A real time analyzer displays the spectral distribution of sound pressure levels for an instance in time, by a very rapid electronic switching arrangement which sweeps across the filters in rapid succession. The values appear on a cathode ray tube as a storage display or digitized for computer analysis and storage.

L. Audiometer. The Audiometer is an instrument used in determining the hearing threshold level of an individual in comparison with a chosen standard reference threshold level, primarily for the purpose of identification of hearing deficiencies. Audiometric measurements may be made by pure tone or speech audiometers. Performance requirements for each are specified in ANSI S3.6-1969. Therefore generally for determining the hearing threshold level of an individual a pure tone manual or automatic (self recorder) audiometer is used.

Essential components of such an audiometer include:

1. An electronic sine wave oscillator - which produces "pure" tones of 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. At each test frequency an audiometer zero (standard reference threshold) has been established. The oscillator output is adjusted at the factory so that at any frequency, when the attenuator dial reads "0 dB" the acoustic output of the earphone corresponds to the ANSI Specification for the standard reference sound pressure levels.

2. Attenuator, or the hearing threshold level dial - which permits dial readings of hearing threshold level from minimum of 0 dB, to a maximum of 100 dB depending upon frequency, by intervals of 5 dB or less.

3. Tone switch - which permits an audiometer operator to initiate or terminate the tone at will.

4. Earphone - which is necessary for tests by air conduction. Ear audiometer is usually calibrated at the factory to a particular earphone. If a different earphone is substituted, the acoustic output may no longer meet the specification. Each earphone is equipped with an air cushion for contact with the head of the subject and is provided with a spring headband.

The results of hearing threshold measurements made with pure tone audiometer can be recorded as a numerical tabulation or in the graphical form of an audiogram.

Commercial audiometers present serious calibration problems. The ANSI specification provides guidelines for audiometer manufacturers regarding frequencies to include, intensity ranges, test tone purity, attenuator and so forth which must be met. The audiometric technician must insure that this equipment is in good working order before testing. Each time the equipment is turned on the technician, after giving the equipment several minutes to warm up, (as recommended by the manufacturer) puts the earphones on his head and rotates the attenuator through its range for each frequency in each phone.

An acoustic output check on an audiometer, with its associated earphone, is another important test, with the use of a sound level meter and earphone coupler. An independent check should be made on the microphone sensitivity and stability using the sound level calibrator.

In addition, periodic exhaustive calibrations of the equipment are generally recommended every 6 to 12 months, done at the manufacturers service facility or an independent laboratory. Calibration checks and audiometric testing must be performed by trained technicians who are thoroughly familiar with the test procedures and methods. Knowledge of test procedures and methods may be gained by reading individual instruction manuals and by attending training programs offered at universities, colleges, hospitals and certain learning centers and associations.

TYPES OF FIELD NOISE MEASUREMENTS

The previous discussions have dealt with measurements to simulate human responses and measurement to predict the distribution of sound in an environment. In the field, the primary interest is monitoring sound in a space to determine if it is compatible with the activity involved and if it is distributed according to the predicted design.

Several types of field measurement surveys are listed below:

1. General sound survey. Record the weighted sound pressure levels using a general survey sound level meter manually. dBA relates to many loudness problems and dbD to noisiness problems and a difference between dBC and dBA indicates low frequency components. Most surveys will be of this nature in order to identify problems. If sound pressure levels continuously exceed 90dBA, it is certain that the legislated sound exposure criterion would not be met.

2. Sound exposure survey. A continuous storage of dBA weighted sound level exposure is made to check for compliance with legislative acts. Either a personally worn or fixed station sound exposure monitoring instrument may be used. This type of survey is necessary, especially with fluctuating and intermittent sounds in order to simplify their measurement and analysis.

3. Sound survey. Record weighted sound pressure level in octave bands using a precision sound level meter and octave band analyzer manually. In case of impulse sounds record peak and time averaged values in octave bands using a sound impulse (impact noise) analyzer as an accessory to the precision sound level meter. The objective of this type of survey is to establish the nature and sources of the problems. Vibration measurements should be made on problem surfaces to define the nature and scope of the sound problem.

4. Recorded sound survey. Record accurately the actual sounds and vibrations in a space for later measurement and analysis. It could be of a typical sound for the activity, sampled in a particular pattern over a period of time, or continually recorded. Frequency modulation (FM) is often used for frequency analysis but amplitude modulation (AM) is the common method of recording.

5. Recorded interview survey. Record accurately the actual sounds people experience in order to relate these sounds to their assessments during an interview or psychophysical experiment for later analysis.

6. Measurement for reverberation time. Record the sound level decay with a graphical sound level recorder either directly or from a recorded sound. Relate to reverberation response problems and the mean sound absorption efficiency.

7. Survey for transmission loss determination. Measure the sound pressure levels between the spaces in question. Flanking sound and leakage are problems to account for.

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