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ASA

American Standard

Acoustical Terminology

Z24.1-1951

CORRECTION SHEET

In subsections 1.325 and 1.365, the following changes should be made:

1.325 Sound Pressure Level

Page 11

Change Note 2 to read:

Note 2: It is to be noted that in many sound fields the sound pressure ratios are not the square roots of the corresponding power ratios and hence cannot be expressed in decibels in the strict sense; however, it is common practice to extend the use of the decibel to these cases. (See 1.280 and 1.285)

1.365 Velocity Level

Page 12

Change Note to read:

Note: It is to be noted that in many sound fields the particle velocity ratios are not the square roots of corresponding power ratios and hence cannot be expressed in decibels in the strict sense; however, it is common practice to extend the use of the decibel to these cases. (See 1.280 and 1.285)

July 31, 1952

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Z24.1-1951

Revision of Z24.1-1942

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American Standard

Acoustical Terminology

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Foreword

(This Foreword is not a part of the American Standard Acoustical Terminology, Z24.1-1951.)

This standard comprises a part of a group of definitions, standards, and specifications for use in acoustical work.

In May, 1932, the American Standards Association initiated a standardization project on Acoustical Measurements and Terminology under the sponsorship of the Acoustical Society of America. The scope of this project is as follows:

Preparation of standards of terminology, units, scales, and methods of measurement in the fields of acoustics and mechanical vibration.

A committee was organized to take charge of this work, and this committee, in turn, appointed subcommittees to carry out the program. Among the standards issued was one on Acoustical Terminology, Z24.1-1942. Following the Second World War, with its impact on acoustical work, both the American Standards Association and the Institute of Radio Engineers decided to revise their standards on acoustical and electroacoustical terminology. The American Institute of Electrical Engineers, as sponsor of Sectional Committee C42, also undertook a revision of American Standard Definitions of Electrical Terms.

After several years of independent effort the ASA and IRE committees were combined. This larger group worked in close cooperation with various subcommittees of C42 concerned with the Definitions of Electrical Terms. When the work of the combined committee was completed the IRE, on the recommendation of its Electroacoustics Committee, published a major part as "Standards on Electroacoustics, Definitions of Terms, 1951."* All terms therein are included in American Standard Acoustical Terminology, but not all terms in this standard are included in the IRE publication.

Sectional Committee Z24, responsible for this and other acoustical standards, has at this time the following personnel:

LEO L. BERANEK, *Chairman*

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**Proceedings*, Institute of Radio Engineers, 509, 39, 1951. Reprints of standard known as 51 IRE 651.

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American Standard Acoustical Terminology

SECTION 1

General

1.005 Sound

(a) Sound is an alteration in pressure, stress, particle displacement, particle velocity, etc, which is propagated in an elastic material, or the superposition of such propagated alterations.

(b) Sound is also auditory sensation which is usually evoked by the alterations described above.

NOTE: In case of possible confusion, the term "sound wave" or "elastic wave" may be used for concept (a), and the term "sound sensation" for concept (b).

1.010 Acoustics. Acoustics is the science of sound including its production, transmission, and effects.

1.015 Acoustic.* The word "acoustic," when used as a qualifying term, means containing, producing, arising from, actuated by, or carrying sound, or designed to carry sound and capable of doing so.

EXAMPLES: Acoustic horn, transducer, energy, wave, impedance.

1.020 Acoustical.* The word "acoustical," when used as a qualifying term, means related to, pertaining to, or associated with sound, but not having its properties or characteristics.

EXAMPLES: Acoustical engineer, school, glossary, unit.

1.025 Wave. A wave is a disturbance which is propagated in a medium in such a manner that at any point in the medium the displacement is a function of the time, while at any instant the displacement at a point is a function of the position of the point.

Any physical quantity which has the same relationship to some independent variable (usually time) that a propagated disturbance has, at a particular instant, with respect to space, may be called a wave.

NOTE: In this definition, displacement is used as a general term, indicating not only mechanical displacement, but also electric displacement, etc.

1.030 Noise. Noise is any undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in any transmission channel or device.

1.035 Distortion. Distortion is a change in wave form. Noise and certain desired changes in wave form,

*This usage of "acoustic" and "acoustical" as modifiers agrees with the commonly accepted usage of "electric" and "electrical." In the science of mechanics, however, the term "mechanical" is the only modifier in common use.

such as those resulting from modulation or detection, are not usually classed as distortion.

1.040 Oscillation (Vibration). Oscillation is the variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the reference.

1.045 Periodic Quantity. A periodic quantity is an oscillating quantity the values of which recur for equal increments of the independent variable. If a periodic quantity, y , is a function of x , then y has the property that

$$y = f(x) = f(x + k)$$

where k , a constant, is a period of y .

The smallest positive value of k is the primitive period of y , generally called simply the period of y .

NOTE: In general, a periodic function can be expanded into a series of the form

$$y = f(x) = A_0 + A_1 \sin(\omega x + a_1) + A_2 \sin(2\omega x + a_2) + \dots,$$

where

ω , a positive constant, equals 2π divided by the period k , and the A 's and a 's are constants which may be positive, negative, or zero.

1.050 Period (Primitive Period). The period of a periodic quantity is the smallest value of the increment of the independent variable for which the function repeats itself.

1.055 Cycle. A cycle is the complete sequence of values of a periodic quantity which occur during a period.

1.060 Frequency of a Periodic Quantity. The frequency of a periodic quantity, in which time is the independent variable, is the number of periods occurring in unit time. If a periodic quantity, y , is a function of the time, t , such that

$$y = f(t) = A_0 + A_1 \sin(\omega t + a_1) + A_2 \sin(2\omega t + a_2) + \dots,$$

then the frequency is $\omega/2\pi$.

NOTE 1: Unless otherwise specified, the unit is the cycle per second.

NOTE 2: It is recommended that the following terms be discontinued: double vibrations, dv, periods per second, pps, and hertz, all of which are equivalent to cycles per second, and vibrations per second, vs, which has sometimes been used as the equivalent of half-cycles per second.

1.065 Amplitude of a Generalized Sinusoidal Quantity. The amplitude of a generalized sinusoidal

quantity for any value of the independent variable is the value of the modifying function for that particular value of the independent variable. If

$$y = f_0(x) \sin(\omega x + a)$$

the amplitude of y for $x = x_1$ is $f_0(x_1)$.

1.070 Amplitude of a Simple Sinusoidal Quantity. The amplitude of a simple sinusoidal quantity is the largest value that the quantity attains. If

$$y = A \sin(\omega x + a)$$

A is the amplitude.

1.075 Peak-to-Peak Amplitude (Double Amplitude). The peak-to-peak amplitude of an oscillating quantity is the difference between extremes of the quantity.

1.080 Phase of a Periodic Quantity. The phase of a periodic quantity, for a particular value of the independent variable, is the fractional part of a period through which the independent variable has advanced, measured from an arbitrary origin.

NOTE: In the case of a simple sinusoidal quantity, the origin is usually taken as the last previous passage through zero from the negative to positive direction. The origin is generally so chosen that the fraction is less than unity.

1.085 Wave Front

(a) The wave front of a progressive wave in space is a continuous surface which is a locus of points having the same phase at a given instant.

(b) The wave front of a progressive surface wave is a continuous line which is a locus of points having the same phase at a given instant.

1.090 Wavelength. The wavelength of a periodic wave in an isotropic medium is the perpendicular distance between two wave fronts in which the displacements have a difference in phase of one complete period.

1.095 Fundamental Frequency. The fundamental frequency of a periodic quantity is the frequency of a sinusoidal quantity which has the same period as the periodic quantity.

1.100 Basic Frequency. The basic frequency of an oscillatory quantity having sinusoidal components with different frequencies is the frequency of the component considered to be the most important.

NOTE: In a driven system, the basic frequency would in general be the driving frequency, and in a periodic oscillatory system, it would be the fundamental frequency.

1.105 Harmonic. A harmonic is a sinusoidal quantity having a frequency which is an integral multiple of the fundamental frequency of a periodic quantity

to which it is related. For example, a wave, the frequency of which is twice the fundamental frequency, is called the second harmonic.

NOTE: This definition is in physical terms. For the definition in musical terms see 6.035.

1.110 Subharmonic. A subharmonic is a sinusoidal quantity having a frequency which is an integral submultiple of the fundamental frequency of a periodic quantity to which it is related. For example, a wave, the frequency of which is half the fundamental frequency of another wave, is called the second subharmonic of that wave.

1.115 Spectrum. The spectrum of a wave is the distribution in frequency of the magnitudes (and sometimes phases) of the components of the wave. Spectrum also is used to signify a continuous range of frequencies, usually wide in extent, within which waves have some specified common characteristic, e.g., audio frequency spectrum, radio frequency spectrum, etc.

1.120 Line Spectrum. A line spectrum is the spectrum of a wave the components of which are confined to a number of discrete frequencies.

1.125 Continuous Spectrum. A continuous spectrum is the spectrum of a wave the components of which are continuously distributed over a frequency region.

1.130 Compressional Wave. A compressional wave is a wave in an elastic medium which causes an element of the medium to change its volume without undergoing rotation.

NOTE 1: Mathematically, a compressional wave is one whose velocity field has zero curl.

NOTE 2: A compressional plane wave is a longitudinal wave.

1.135 Longitudinal Wave. A longitudinal wave is a wave in which the direction of displacement at each point of the medium is normal to the wave front.

1.140 Shear Wave (Rotational Wave). A shear wave is a wave in an elastic medium which causes an element of the medium to change its shape without a change of volume.

NOTE 1: Mathematically, a shear wave is one whose velocity field has zero divergence.

NOTE 2: A shear plane wave in an isotropic medium is a transverse wave.

1.145 Transverse Wave. A transverse wave is a wave in which the direction of displacement at each point of the medium is parallel to the wave front.

1.150 Plane Wave. A plane wave is a wave in which the wave fronts are everywhere parallel planes normal to the direction of propagation.

GENERAL

1.155 Spherical Wave. A spherical wave is a wave in which the wave fronts are concentric spheres.

1.160 Cylindrical Wave. A cylindrical wave is a wave in which the wave fronts are coaxial cylinders.

1.165 Plane Polarized Sound Wave (Linearly Polarized Sound Wave). At a point in an elastic medium, a plane polarized sound wave is a transverse wave in which the displacements at all times lie in a fixed plane which is parallel to the direction of propagation.

NOTE: The above definition is equivalent to stating that, in a plane polarized sound wave, the displacement vector at any point lies in a fixed straight line passing through the point.

1.170 Elliptically Polarized Sound Wave. An elliptically polarized sound wave is a transverse wave in an elastic medium in which the displacement vector at any point rotates about the point and has a magnitude which varies as the radius vector of an ellipse.

NOTE: An elliptically polarized wave is equivalent to two superimposed plane polarized waves of simple sinusoidal form in which the displacements lie in perpendicular planes and are in quadrature.

1.175 Circularly Polarized Sound Wave. A circularly polarized sound wave is an elliptically polarized sound wave in which the displacement vector at any point rotates about the point with constant angular velocity and has a constant magnitude.

A circularly polarized wave is equivalent to two superposed plane polarized waves of sinusoidal form in which the displacements have the same amplitude, lie in perpendicular planes, and are in quadrature.

1.180 Sound Field. A sound field is a region containing sound waves.

1.185 Free Field. A free field is a field (wave or potential) in a homogeneous, isotropic medium free from boundaries. In practice it is a field in which the effects of the boundaries are negligible over the region of interest.

NOTE: The actual pressure impinging on an object (e.g., electroacoustic transducer) placed in an otherwise free sound field will differ from the pressure which would exist at that point with the object removed, unless the acoustic impedance of the object matches the acoustic impedance of the medium.

1.190 Free Progressive Wave (Free Wave). A free progressive wave is a wave in a medium free from boundary effects. A free wave in a steady state can only be approximated in practice.

1.195 Diffuse Sound. Diffuse sound in a given region is sound which has uniform energy density and is such that all directions of energy flux at all parts of the region are equally probable.

1.200 Audio Frequency. An audio frequency is any frequency corresponding to a normally audible sound wave.

NOTE 1: Audio frequencies range roughly from 15 to 20,000 cycles per second.

NOTE 2: The word "audio" may be used as a modifier to indicate a device or system intended to operate at audio frequencies, e.g., "audio amplifier."

1.205 Infrasonic Frequency (Subsonic Frequency*). An infrasonic frequency is a frequency lying below the audio frequency range.

NOTE: The word "infrasonic" may be used as a modifier to indicate a device or system intended to operate at infrasonic frequencies.

1.210 Ultrasonic Frequency (Supersonic Frequency†). An ultrasonic frequency is a frequency lying above the audio frequency range. The term is commonly applied to elastic waves propagated in gases, liquids, or solids.

NOTE: The word "ultrasonic" may be used as a modifier to indicate a device or system intended to operate at ultrasonic frequencies.

1.215 Beats. Beats are periodic variations that result from the superposition of waves having different frequencies.

1.220 Wave Interference. Wave interference is the phenomenon which results when waves of the same or nearly the same frequency are superposed and is characterized by a spatial or temporal distribution of amplitude of some specified characteristic differing from that of the individual superposed waves.

1.225 Standing Waves. Standing waves are periodic waves having a fixed distribution in space which is the result of interference of progressive waves of the same frequency and kind. Such waves are characterized by the existence of nodes or partial nodes and antinodes that are fixed in space.

1.230 Stationary Waves. Stationary waves are standing waves in which the energy flux is zero at all points.

NOTE: Stationary waves can only be approximated in practice.

1.235 Nodes. Nodes are the points, lines, or surfaces in a standing wave system where some characteristic of the wave field has essentially zero amplitude.

NOTE: The appropriate modifier should be used with the word "node" to signify the type that is intended (pressure node, velocity node, etc).

1.240 Antinodes (Loops). Antinodes are the points, lines, or surfaces in a standing wave system

*Deprecated
†Obsolete. See 4.010.



where some characteristic of the wave field has maximum amplitude.

NOTE: The appropriate modifier should be used with the word "antinode" to signify the type that is intended (pressure antinode, velocity antinode, etc).

1.245 Partial Nodes. Partial nodes are the points, lines, or surfaces in a standing wave system where some characteristic of the wave field has a minimum amplitude differing from zero.

NOTE: The appropriate modifier should be used with the words "partial node" to signify the type that is intended (pressure partial node, velocity partial node, etc).

1.250 Modulation. Modulation is the process or the result of the process whereby some characteristic of one wave is varied in accordance with some characteristic of another wave.

1.255 Echo. An echo is a wave which has been reflected or otherwise returned with sufficient magnitude and delay to be perceived in some manner as a wave distinct from that directly transmitted.

1.260 Flutter Echo. A flutter echo is a rapid succession of reflected pulses resulting from a single initial pulse.

1.265 Musical Echo. A musical echo is a flutter echo that is periodic and has a flutter the frequency of which is in the audible range.

1.270 Rate of Decay. The rate of decay is the time rate at which the sound pressure level (or velocity level, or sound-energy density level) is decreasing at a given point and at a given time. The practical unit is the decibel per second.

1.275 Reverberation. Reverberation is the persistence of sound at a given point after direct reception from the source has stopped.

NOTE: This may be due (a) (as in the case of rooms) to repeated reflections from a small number of boundaries or to the free decay of the normal modes of vibration that were excited by the sound source, (b) (as in the case of underwater sound in the ocean) to scattering from a large number of inhomogeneities in the medium or reflection from bounding surfaces.

1.280 Bel. The bel is a dimensionless unit for expressing the ratio of two values of power, the number of bels being the logarithm to the base 10 of the power ratio.

NOTE: With P_1 and P_2 designating two amounts of power and N the number of bels corresponding to the ratio P_1/P_2

$$N = \log_{10} (P_1/P_2)$$

1.285 Decibel (db). The decibel is one-tenth of a bel. The abbreviation "db" is commonly used for the term decibel.

NOTE: With P_1 and P_2 designating two amounts of power and n the number of decibels corresponding to their ratio

$$n = 10 \log_{10} (P_1/P_2)$$

When the conditions are such that scalar ratios of currents or of voltages (or analogous quantities in other fields such as pressures, amplitudes, particle velocities in sound) are the square roots of the corresponding power ratios, the number of decibels by which the corresponding powers differ is expressed by the following formulae:

$$n = 20 \log_{10} (I_1/I_2)$$

$$n = 20 \log_{10} (V_1/V_2)$$

where I_1/I_2 and V_1/V_2 are the given current and voltage ratios, respectively.

By extension, these relations between numbers of decibels and scalar ratios of currents or voltages are sometimes applied where these ratios are not the square roots of the corresponding power ratios; to avoid confusion, such usage should be accompanied by a specific statement of this application.

1.290 Neper (Napier*). The neper is a unit used to express the scalar ratio of two currents or two voltages, the number of nepers being the natural logarithm of such ratio.

NOTE 1: With I_1 and I_2 designating the scalar value of two currents, and n the number of nepers denoting their scalar ratio

$$n = \log_e (I_1/I_2)$$

When the conditions are such that the power ratio is the square of the corresponding current or voltage ratio, the number of nepers by which the corresponding voltages or currents differ may be expressed by the following formula:

$$n = 1/2 \log_e (P_1/P_2)$$

where P_1/P_2 is the given power ratio.

By extension, this relation between number of nepers and power ratio is sometimes applied where this ratio is not the square of the corresponding current or voltage ratio; to avoid confusion, such usage should be accompanied by a specific statement of this application.

NOTE 2: One neper is equal to 8.686 db.

NOTE 3: The neper is used in mechanics and acoustics by extending the above definition to include all scalar ratios of like quantities which are analogous to current or voltage.

1.295 Static Pressure (Hydrostatic Pressure). The static pressure at a point in a medium is the pressure that would exist at that point with no sound waves present. In acoustics, the commonly used unit is the microbar.

1.300 Microbar, Dyne Per Square Centimeter (Barye*) (Bar*). A microbar is a unit of pressure commonly used in acoustics. One microbar is equal to 1 dyne per square centimeter.

NOTE: The term "bar" properly denotes a pressure of 10^6 dynes per square centimeter. Unfortunately, in acoustics the bar was used to mean 1 dyne per square centimeter. It is recommended, therefore, in respect to sound pressures that the less ambiguous terms "microbar" or "dyne per square centimeter" be used.

1.305 Instantaneous Sound Pressure. The instantaneous sound pressure at a point is the total instantaneous pressure at that point minus the static pressure at that point. The commonly used unit is the microbar.

*Deprecated



GENERAL

1.310 Maximum Sound Pressure. The maximum sound pressure for any given cycle of a periodic wave is the maximum absolute value of the instantaneous sound pressure occurring during that cycle. The commonly used unit is the microbar.

NOTE: In the case of a sinusoidal sound wave this maximum sound pressure is also called the pressure amplitude.

1.315 Peak Sound Pressure. The peak sound pressure for any specified time interval is the maximum absolute value of the instantaneous sound pressure in that interval. The commonly used unit is the microbar.

NOTE: In the case of a periodic wave, if the time interval considered is a complete period, the peak sound pressure becomes identical with the maximum sound pressure.

1.320 Effective Sound Pressure (Root-Mean-Square Sound Pressure). The effective sound pressure at a point is the root-mean-square value of the instantaneous sound pressures, over a time interval at the point under consideration. In the case of periodic sound pressures, the interval must be an integral number of periods or an interval long compared to a period. In the case of nonperiodic sound pressures, the interval should be long enough to make the value obtained essentially independent of small changes in the length of the interval.

NOTE: The term "effective sound pressure" is frequently shortened to "sound pressure."

1.325 Sound Pressure Level.* The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. The reference pressure shall be explicitly stated.

NOTE 1: The following reference pressures are in common use:

- (a) 2×10^{-4} microbar
- (b) 1 microbar

Reference pressure (a) has been in general use for measurements dealing with hearing and sound-level measurements in air and liquids, while (b) has gained widespread use for calibrations and many types of sound-level measurements in liquids.

NOTE 2: It is to be noted that in many sound fields the sound pressure ratios are not proportional to the square root of corresponding power ratios and hence cannot be expressed in decibels in the strict sense; however, it is common practice to extend the use of the decibel to these cases. (See 1.280 and 1.285.)

1.330 Band Pressure Level. The band pressure level of a sound for a specified frequency band is the effective sound pressure level for the sound energy contained within the band. The width of the band and the reference pressure must be specified.

NOTE: When measuring thermal noise, the standard deviation of the sound pressure readings will not exceed about 10 percent if the product of the band width in cycles per second and the integration time in seconds exceeds 20.

1.335 Octave-Band Pressure Level (Octave

Pressure Level). The octave-band pressure level of a sound is the band pressure level for a frequency band corresponding to a specified octave.

NOTE: The location of the octave-band pressure level on a frequency scale is usually specified as the geometric mean of the upper and lower frequencies of the octave.

1.340 Pressure Spectrum Level. The pressure spectrum level of a sound at a specified frequency is the effective sound pressure level for the sound energy contained within a band 1 cycle per second wide, centered at the specified frequency. Ordinarily this has significance only for sound having a continuous distribution of energy within the frequency range under consideration. The reference pressure should be explicitly stated. (See 1.325.)

NOTE: Since in practice it is necessary to employ filters having an effective band width greater than 1 cycle per second, the pressure spectrum level is in general a computed quantity. For a sound having a uniform distribution of energy, the computation can be made as follows: Let L_{ps} be the desired pressure spectrum level, p be the effective pressure measured through the filter system, p_0 be reference sound pressure, Δf be the effective band width of the filter system (see 3.220), and Δf_0 be the reference band width (1 cycle per second), then

$$L_{ps} = 10 \log_{10} \left[\frac{p^2 / \Delta f}{p_0^2 / \Delta f_0} \right]$$

For computational purposes, if L_p is the band pressure level observed through the filter, the above relation reduces to

$$L_{ps} = L_p - 10 \log_{10} \frac{\Delta f}{\Delta f_0}$$

1.345 Velocity. The velocity of a point is the time rate of change of a position vector of that point with respect to an inertial frame.

NOTE: In most cases the approximation is made that axes fixed to the earth constitute an inertial frame.

1.350 Relative Velocity. The relative velocity of a point with respect to a reference frame is the time rate of change of a position vector of that point with respect to the reference frame.

1.355 Acceleration. The acceleration of a point is the time rate of change of the velocity of the point.

1.360 Particle Velocity. In a sound wave the particle velocity is the velocity of a given infinitesimal part of the medium, with reference to the medium as a whole, due to the sound wave. The commonly used unit is the centimeter per second.

NOTE: The terms "instantaneous particle velocity," "effective particle velocity," "maximum particle velocity," and "peak particle velocity" have meanings which correspond with those of the related terms used for sound pressure.

1.365 Velocity Level.* The velocity level, in decibels, of a sound is 20 times the logarithm to the base

*See note under Intensity Level, 1.375.

10 of the ratio of the particle velocity of the sound to the reference particle velocity. The reference particle velocity shall be stated explicitly.

NOTE: It is to be noted that in many sound fields the particle velocity ratios are not proportional to the square root of corresponding power ratios and hence cannot be expressed in decibels in the strict sense; however, it is common practice to extend the use of the decibel to these cases. (See 1.280 and 1.285.)

1.370 Sound Intensity* (Specific Sound-Energy Flux) (Sound-Energy Flux Density). The sound intensity in a specified direction at a point is the average rate of sound energy transmitted in the specified direction through a unit area normal to this direction at the point considered. The commonly used unit is the erg per second per square centimeter, but sound intensity may also be expressed in watts per square centimeter.

NOTE 1: The sound intensity in any specified direction, a , of a sound field is the sound-energy flux through a unit area normal to that direction. This is given by the expression

$$I_a = \frac{1}{T} \int_0^T p v_a dt$$

where

T = an integral number of periods or a time long compared to a period

p = the instantaneous sound pressure

v_a = the component of the instantaneous particle velocity in the direction a

NOTE 2: In the case of a free plane or spherical wave having the effective sound pressure, p , the velocity of propagation, c , in a medium of density, ρ , the intensity in the direction of propagation is given by:

$$I = \frac{p^2}{\rho c}$$

1.375 Intensity Level (Specific Sound-Energy Flux Level) (Sound-Energy Flux Density Level). The intensity level, in decibels, of a sound is 10 times the logarithm to the base 10 of the ratio of the intensity of this sound to the reference intensity. The reference intensity shall be stated explicitly.

NOTE: In discussing sound measurements made with pressure or velocity microphones, especially in enclosures involving normal modes of vibration or in sound fields containing standing waves, caution must be observed in using the terms "intensity" and "intensity level." Under such conditions it is more desirable to use the terms "pressure level" or "velocity level," since the relationship between the intensity and the pressure or velocity is generally unknown.

1.380 Sound Level. The sound level, at a point in a sound field, is the weighted sound pressure level determined in the manner specified in the American Standard Sound Level Meters for Measurement of Noise and Other Sounds, Z24.3-1944, or the latest revision thereof approved by the American Standards Association, Incorporated. (See 10.360.)

NOTE: The meter reading (in decibels) corresponds to a value of the sound pressure integrated over the audible frequency range with a specified frequency weighting and integration time.

1.385 Noise Level. Noise level is the value of noise integrated over a specified frequency range with a specified frequency weighting and integration time. It is expressed in decibels relative to a specified reference.

NOTE: In air the acoustical noise level is usually measured with a sound-level meter (see American Standard Sound Level Meters for Measurement of Noise and Other Sounds, Z24.3-1944, or the latest revision thereof approved by the American Standards Association, Incorporated), and hence is the same as the sound level of the noise. For special purposes other measuring techniques are used and must be specified.

1.390 Overload Level. The overload level of a system, component, etc., is that level at which operation ceases to be satisfactory as a result of signal distortion, overheating, damage, etc.

NOTE: In electroacoustics the overload level is most frequently set by signal distortion.

1.395 Volume. The volume in an electric circuit is the magnitude, as measured on a standard volume indicator, of a complex voice frequency wave. The volume is expressed in vu. (See 1.405.) In addition, the term "volume" is used loosely to signify either the intensity of a sound or the magnitude of an audio frequency wave.

1.400 Reference Volume. Reference volume is that magnitude of a complex electric wave, such as that corresponding to speech or music, which gives a reading of zero vu on a standard volume indicator. The sensitivity of the volume indicator is adjusted so that reference volume or zero vu is read when the instrument is connected across a 600-ohm resistance to which there is delivered a power of 1 milliwatt at 1,000 cycles per second.

1.405 Volume Unit (vu). The volume unit (vu) is a unit for expressing the magnitude of a complex electric wave, such as that corresponding to speech or music. The volume in vu is equal to the number of decibels by which the wave differs from reference volume.

1.410 Doppler Effect. The Doppler effect is the phenomenon evidenced by the change in the observed frequency of a wave in a transmission system caused by a time rate of change in the effective length of the path of travel between the source and the point of observation.

*See note under Intensity Level, 1.375.

1.415 Doppler Shift. The Doppler shift is the magnitude of the change in the observed frequency of a wave due to the Doppler effect. The unit is the cycle per second.

1.420 Sound Energy. The sound energy of a given part of a medium is the total energy in this part of the medium minus the energy which would exist in the same part of the medium with no sound waves present.

1.425 Sound-Energy Density. The sound-energy density at a point in a sound field is the sound energy contained in a given infinitesimal part of the medium divided by the volume of that part of the medium. The commonly used unit is the erg per cubic centimeter.

NOTE 1: The terms "instantaneous energy density," "maximum energy density," and "peak energy density" have meanings analogous to the related terms used for sound pressure.

NOTE 2: In speaking of average energy density in general, it is necessary to distinguish between the space average (at a given instant) and the time average (at a given point).

1.430 Sound-Energy Flux. The sound-energy flux is the average rate of flow of sound energy for one period through any specified area. The commonly used unit is the erg per second. Expressed mathematically, the sound-energy flux, J , is

$$J = \frac{1}{T} \int_0^T p S v_a dt$$

where

T = an integral number of periods or a time long compared to a period

p = the instantaneous sound pressure over the area S

v_a = the component of the instantaneous particle velocity in the direction a , normal to the area S

NOTE: In a medium of density, ρ , for a plane or spherical free wave having a velocity of propagation, c , the sound-energy flux through the area, S , corresponding to an effective sound pressure, p , is

$$J = \frac{p^2 S}{\rho c} \cos \theta$$

where

θ = the angle between the direction of propagation of the sound and the normal to the area S .

1.435 Volume Velocity. Volume velocity is the rate of flow of the medium through a specified area due to a sound wave.

NOTE: The terms "instantaneous volume velocity," "effective volume velocity," "maximum volume velocity," and "peak volume velocity" have meanings which correspond with those of the related terms used for sound pressure.

1.440 Sound Power of a Source. The sound power of a source is the total sound energy radiated by the source per unit of time. The commonly used unit is

the erg per second, but the power may also be expressed in watts.

1.445 Strength of a Sound Source (Strength of a Simple Source). The strength of a sound source is the maximum instantaneous rate of volume displacement produced by the source when emitting a wave with sinusoidal time variation.

1.450 Simple Sound Source. A simple sound source is a source which radiates sound uniformly in all directions under free-field conditions.

1.455 Efficiency. The efficiency of a device with respect to a physical quantity which may be stored, transferred, or transformed by the device is the ratio of the useful output of the quantity to its total input.

NOTE: Unless specifically stated otherwise, the term "efficiency" means efficiency with respect to power.

SECTION 2

Sound Transmission and Propagation

2.005 Impedance. An impedance is the complex ratio of a force-like quantity (force, pressure, voltage, temperature, or electric field strength) to a related velocity-like quantity (velocity, volume velocity, current, heat flow, or magnetic field strength).

NOTE: The terms and definitions to which this note is appended pertain to single-frequency quantities in the steady state, and to systems whose properties are independent of the magnitudes of these quantities. These quantities can be represented mathematically by complex exponential functions of time. Under these conditions the factors involving time cancel out in the ratios called for, leaving complex numbers independent of time. Solutions based on complex exponential functions under these conditions give the solution for real sinusoidal oscillations.

Because of the similarity of electrical, mechanical, and acoustical transmission theory, the same terminology is used in the three cases. Where confusion is likely to occur, the proper term should be prefixed to the general term, *e.g.*, acoustic transfer impedance, but unless otherwise specified the definitions apply not only in acoustics but in mechanics as well. While acoustics is a branch of mechanics, it is found convenient to distinguish an acoustic system from a mechanical one whenever elastic wave motion is an essential feature.

While a strict application of the impedance concept implies the restrictions given above, it is common practice to extend the term "impedance" to situations involving nonsinusoidal quantities or nonlinear systems. Such extensions should be accompanied by an explanatory statement.

2.010 Acoustic Impedance.* The acoustic impedance of a sound medium on a given surface lying in a wave front is the complex quotient of the sound pressure (force per unit area) on that surface by the flux (volume velocity, or linear velocity multiplied by

*See note under 2.005.



the area), through the surface. When concentrated rather than distributed impedances are considered, the impedance of a portion of the medium is defined by the complex quotient of the pressure difference effective in driving that portion, by the flux (volume velocity). The acoustic impedance may be expressed in terms of mechanical impedance, acoustic impedance being equal to the mechanical impedance divided by the square of the area of the surface considered. The commonly used unit is the acoustical ohm.

NOTE: Velocities in the direction along which the impedance is to be specified are considered positive.

2.015 Specific Acoustic Impedance (Unit Area Acoustic Impedance).* The specific acoustic impedance at a point in the medium is the complex ratio of sound pressure to particle velocity.

2.020 Acoustic Resistance.* Acoustic resistance is the real component of the acoustic impedance. The commonly used unit is the acoustical ohm.

2.025 Specific Acoustic Resistance.* Specific acoustic resistance is the real component of the specific acoustic impedance.

2.030 Acoustic Reactance.* Acoustic reactance is the imaginary component of the acoustic impedance. The commonly used unit is the acoustical ohm.

2.035 Specific Acoustic Reactance.* Specific acoustic reactance is the imaginary component of the specific acoustic impedance.

2.040 Acoustical Ohm.* An acoustic resistance, reactance, or impedance has a magnitude of one acoustical ohm when a sound pressure of 1 microbar produces a volume velocity of 1 cubic centimeter per second.

2.045 Acoustic Mass (Acoustic Inertance).* Acoustic mass is the quantity which, when multiplied by 2π times the frequency, gives the acoustic reactance associated with the kinetic energy of the medium. The commonly used unit is the gram per centimeter to the fourth power. Its dimensions are ML^{-4} .

2.050 Acoustic Stiffness.* Acoustic stiffness is the quantity which, when divided by 2π times the frequency, gives the acoustic reactance associated with the potential energy of the medium or its boundaries. The commonly used unit is the dyne per centimeter to the fifth power. Its dimensions are $ML^{-4}T^{-2}$.

2.055 Acoustic Compliance.* Acoustic compliance is the reciprocal of acoustic stiffness. Its dimensions are $M^{-1}L^4T^2$.

2.060 Driving-Point Impedance.* The driving-point impedance at a driving point of a transducer is the complex ratio of the applied sinusoidal potential difference, force, or pressure to the resultant current, velocity, or volume velocity, respectively, at this point, all inputs and outputs being terminated in any specified manner.

2.065 Transfer Impedance.* The transfer impedance between two points of a transducer is the complex ratio of the applied sinusoidal potential difference, force, or pressure at one point to the resultant current, velocity, or volume velocity at the other point, all inputs and outputs being terminated in any specified manner.

2.070 Conjugate Impedances.* Conjugate impedances are impedances having resistance components which are equal and reactance components which are equal in magnitude but opposite in sign.

NOTE: Conjugate impedances are expressible by conjugate complex quantities.

2.075 Transmission Loss. In communication, transmission loss (frequently abbreviated "loss") is a general term used to denote a decrease in power in transmission from one point to another. Transmission loss is usually expressed in decibels.

2.080 Insertion Loss. The insertion loss resulting from the insertion of a transducer in a transmission system is the ratio of the power delivered to that part of the system which will follow the transducer, before insertion of the transducer, to the power delivered to that same part of the system after insertion of the transducer.

NOTE 1: If the input power, or the output power, or both consist of more than one component, the particular components used must be specified.

NOTE 2: This ratio is usually expressed in decibels.

2.085 Transducer Loss. Transducer loss is the ratio of the available power of the specified source to the power that the transducer delivers to the specified load under specified operating conditions.

NOTE 1: If the input power, or the output power, or both consist of more than one component, the particular components used must be specified.

NOTE 2: This ratio is usually expressed in decibels.

NOTE 3: The transducer loss is made up of a transition loss between the source and the transducer, a transition loss between the transducer and the load, and a dissipation loss within the transducer.

2.090 Transducer Dissipation Loss. The transducer dissipation loss of a transducer operating between specified source and load is the ratio of the power delivered by the specified source when the transducer is connected to the specified load, to the power available from the transducer when connected to the specified source.

*See note under 2.005.

NOTE 1: If the input power, or the output power, or both consist of more than one component, the particular components used must be specified.

NOTE 2: This ratio is usually expressed in decibels.

NOTE 3: See note 3 under 2.085.

2.095 Transition Loss. The transition loss at a discontinuity in a transmission system is the ratio of the signal power delivered to that part of the system following the discontinuity after the insertion of an ideal transducer, to the signal power delivered to that same part before the insertion. This ratio is usually expressed in decibels.

2.100 Velocity Resonance (Resonance) (Phase Resonance). Velocity resonance exists between a body, or system, and an applied sinusoidal force if any small change in the frequency of the applied force causes a decrease in velocity at the driving point; or if the frequency of the applied force is such that the absolute value of the driving-point impedance is a minimum.*

2.105 Displacement Resonance. Displacement resonance exists between a body, or system, and an applied sinusoidal force if any small change in frequency of the applied force causes a decrease in the amplitude of displacement.*

2.110 Resonant Frequency. A resonant frequency is a frequency at which resonance exists. The commonly used unit is the cycle per second.

NOTE: In cases where there is a possibility of confusion, it is necessary to specify the type of resonant frequency, e.g., displacement resonant frequency or velocity resonant frequency.

2.115 Velocity Antiresonance. Velocity antiresonance exists between a body, or system, and an ap-

plied sinusoidal force if any small change in the frequency of the applied force causes an increase in velocity at the driving point, or if the frequency of an applied force is such that the absolute value of the driving-point impedance is a maximum.*

2.120 Displacement Antiresonance. Displacement antiresonance exists between a body, or system, and an applied sinusoidal force if any small change in the frequency of the applied force causes an increase in the amplitude of displacement at the driving point.*

2.125 Antiresonant Frequency. An antiresonant frequency is a frequency at which antiresonance exists.* The commonly used unit is the cycle per second.

NOTE: In cases where there is a possibility of confusion it is necessary to specify the type of antiresonant frequency, e.g., displacement antiresonant frequency or velocity antiresonant frequency.

2.130 Forced Oscillation (Forced Vibration). The forced oscillation of a system is the oscillation of some physical quantity of the system when external periodic forces outside the body or system determine the period of the oscillations.

2.135 Free Oscillation (Free Vibration). The free oscillation of a system is the oscillation of some physical quantity of the system when the externally applied forces consist either of those which do no work, or of those which are derivable from a potential that is invariant during the time under consideration, or both.

2.140 Natural Frequency. A natural frequency of a body or system is a frequency of free oscillation.

*DISCUSSION: In the case of a system whose motion can be described by the equation:

$$M \frac{d^2x}{dt^2} + R \frac{dx}{dt} + Sx = A \cos \omega t$$

the characteristics of the different kinds of resonance in terms of the constants of the above equation are given in the table:

	At velocity resonance	At displacement resonance	At the natural frequency
Frequency	$\frac{1}{2\pi} \sqrt{\frac{S}{M}}$	$\frac{1}{2\pi} \sqrt{\frac{S}{M} - \frac{R^2}{2M^2}}$	$\frac{1}{2\pi} \sqrt{\frac{S}{M} - \frac{R^2}{4M^2}}$
Amplitude of displacement	$\frac{A}{R \sqrt{\frac{S}{M}}}$	$\frac{A}{R \sqrt{\frac{S}{M} - \frac{R^2}{4M^2}}}$	$\frac{A}{R \sqrt{\frac{S}{M} - \frac{3R^2}{16M^2}}}$
Amplitude of velocity	$\frac{A}{R}$	$\frac{A}{R \sqrt{1 + \frac{R^2}{4MS - 2R^2}}}$	$\frac{A}{R \sqrt{1 + \frac{R^2}{16MS - 4R^2}}}$
Phase of displacement with reference to applied force	$\frac{\pi}{2}$	$\tan^{-1} \sqrt{\frac{4MS}{R^2} - 2}$	$\tan^{-1} \sqrt{\frac{16MS}{R^2} - 4}$

For values of R , small compared to $\sqrt{SM}$, there is little difference between the three cases discussed above.