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Standard Practice for Measurement of Equipment-Generated Continuous Noise for Assessment of Health Hazards[1]

This standard is issued under the fixed designation E2202; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard defines noise measurement procedures for estimating the risk of hearing loss among users of noise producing equipment. It is applicable to ground vehicles, aircraft, watercraft, and other mobile, transportable, or stationary equipment.

1.2 This standard does not recommend noise exposure limit levels or criteria for any application discussed.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C634 Terminology Relating to Building and Environmental Acoustics

2.2 *ANSI Standards:*[3]

ANSI S 1.1 Acoustical Terminology

ANSI S 1.4 Specification for Sound Level Meters

ANSI S 1.11 Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters

ANSI S1.25 Specification for Personal Noise Dosimeters

ANSI S 1.40 Specification for Acoustical Calibrators

3. Terminology

3.1 Except as noted in Appendix X1, the terms and symbols used in this practice are defined in Terminology C634.

3.2 The terms specific to nonmandatory Appendix X1 are in X1.2.

4. Summary of Practice

4.1 For most equipment generating steady noise, the A-weighted and octave band levels are measured at locations normally occupied by personnel. The hazard contours around the equipment are also determined in terms of A-weighted sound levels in decibels. In some cases, duty cycle testing is used to determine time-weighted average sound levels.

4.2 The operating conditions for specific equipment types are in sections as follows:

4.2.1 Ground vehicles in 8.2 and 9.2.

4.2.2 Construction and material handling equipment in 9.3.

4.2.3 Watercraft in 9.4.

4.2.4 Stationary equipment in 9.5.

4.2.5 Helicopters in 9.6.

5. Significance and Use

5.1 This standard defines measurement procedures for estimating the risk of noise-induced hearing loss among users of noise producing equipment. It is applicable to ground vehicles, aircraft, watercraft, and mobile, transportable, and stationary equipment. The primary approach is to separately measure the sound level at operator ear locations for each normal operating condition. These levels can be combined with operational use scenarios and exposure criteria to define noise exposure severity. The data can also be used to define hearing protection requirements or administrative controls to preclude hearing hazard.

5.2 The practice has the following limitations:

5.2.1 The practice uses field portable measurement equipment.

5.2.2 The practice produces data which may be compared with applicable criteria or limits if the limits are in terms of the quantities measured in this standard or which can be calculated from the measured data.

6. Instrumentation

6.1 *Requirements:*

6.1.1 Sound level meters and microphones shall conform to requirements for type 1, as specified by ANSI S1.4.

[1] This practice is under the jurisdiction of ASTM Committee E33 on Building and Environmental Acoustics and is the direct responsibility of Subcommittee E33.08 on Mechanical and Electrical System Noise.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

6.1.2 Band filter sets shall meet the requirements for Order 3, Type 3-D, Extended Range, as specified by ANSI S1.11.

6.1.3 Acoustic calibrators shall meet ANSI S1.40.

6.1.4 Noise dosimeters shall meet ANSI S1.25.

6.2 *Calibration:*

6.2.1 All noise measurement instrumentation shall have undergone a complete electro-acoustical calibration in accordance with manufacturer's instruction no more than 1 year prior to the noise measurement.

6.2.2 The noise measurement instrumentation, including microphones and filter sets, shall undergo an end to end calibration check with an acoustical calibrator prior to the start of the measurement, and after completion, on the day of the measurement. If the sensitivity after the measurements differs from the sensitivity before the measurement by more than 0.5 dB, the data shall be discarded.

7. Test Environment

7.1 *Test Site*—Equipment shall be tested in its exact operating location if the location is known and such testing is feasible. When this is not possible, the test site shall be a uniform flat paved surface or hemi-anechoic chamber. It shall be free of reflecting surfaces such as buildings, trees, or hillsides within 30 m. A grass surface, free of ice, snow, or vegetation over 15 cm tall may be substituted if the equipment is not normally operated on a paved surface.

7.2 *Background Noise*—When practical, background noise, including wind noise, shall be at least 10 dB below that of the equipment noise being measured; however, background noise shall always be at least 10 dB below the criteria. A windscreen shall be used at wind velocities of 10 km/h or more. Measurements shall not be made at wind velocities of 20 km/h or more.

7.3 *Surface and Grade for Vehicle Testing*—Vehicles shall be driven along a dry, smooth, paved, and level road (<1 % grade), free from gravel or other loose material. Vehicles having nonrubber-padded tracks shall be driven on level, compact earth. Measurements shall not be made when the road surface is wet, covered with snow or ice, or during precipitation.

8. Measurement Location and Orientation

8.1 If possible, measure at the probable head position of the occupant of interest with the occupant absent. If an operator must be present to operate the equipment under test, measure the operator position by placing the microphone 15 cm from the more exposed ear. If there is a wall or reflective surface less than 30 cm from that ear, measure midway between the ear and the surface.

8.2 For ground equipment or watercraft, sound measurements shall be made at:

8.2.1 Each operator or crew position.

8.2.2 Representative positions where one or more individuals (for example, passengers) will be located, and

8.2.3 Occasionally occupied positions during typical operation or maintenance of the item or system.

8.3 For aircraft sound measurements shall be made at or near the head positions of all crew stations and at a representative number of passenger stations. Whenever possible, measurements should be made with the crew member or passenger absent. The measurement shall be at the elevation of the center of the head (80 cm above the seat reference point or, if standing, at 160 cm above the floor). If practical during each measurement, the microphone shall be rotated in a 15 to 30 cm diameter horizontal circle with the microphone sensing element facing up.

8.4 *Noise Contours*—Where the steady-state sound level around stationary equipment is 85 dB(A) or greater, the distances and directions from the noise source at which the sound level equals 85 dB(A) shall be determined. The 85 dB(A) contours shall also be determined for mobile equipment which could, at times, be stationary. The 85 dB(A) contour shall be determined from measurements made around the noise source at angular increments not greater than 45 degrees, and also at the noisiest angle.

NOTE 1—The 85 dB(A) contour is the most commonly used. Certain jurisdictions use other values such as 84 dB(A) or 90 dB(A). For equipment capable of generating very high noise levels additional contours may be specified such as a 103 dB(A) contour within which double hearing protection may be required by certain jurisdictions. For these cases, the appropriate contour level shall be measured.

9. Equipment Configuration and Operating Conditions

9.1 *General*—Systems shall be operated as required to accomplish their intended missions or functions. The operating conditions listed are preferred but other conditions may be added if they are judged to result in more accurate noise exposure estimates.

9.2 *Ground Vehicles:*

9.2.1 *Equipment Openings*—All windows, vents, and access openings shall be in the normal operation position. If it is possible to operate with these in either the open or closed positions, both configurations shall be tested.

9.2.2 *Vehicle Speed and Gear*—The vehicle speed shall be measured by a calibrated speedometer or other velocity measuring device. Measurements shall be made at either 8 or 16 km/h increments up to the maximum vehicle speed. If 16 km/h increments are selected, measurements shall start at 16 km/h rather than 8 km/h.

9.2.3 *Load-Carrying Equipment*—All load-carrying equipment shall be operated at the maximum payload including any towed trailers at maximum payload.

9.2.4 All subsystems and auxiliary equipment normally in use shall be operating. Where heaters and air conditioners may be used at the same time (such as humidity control) both shall be operated. Where both heaters and air conditioners are present, the one producing the higher sound level shall be operated.

9.3 *Construction and Materials-Handling Equipment:*

9.3.1 Duty cycle testing may be used. Define a duty cycle typical of the anticipated use of the equipment. If more than one type of duty cycle is applicable, specify the most frequently used and the noisiest duty cycles.

9.3.2 Duty cycles shall be as short as practical and the noise exposure of sufficient cycles shall be measured for a minimum duration of 1 h at rated capacity.

9.3.3 The equipment shall be operated at a test site typical of the environment in which the equipment is to be used.

9.3.4 Measure the time-averaged A-weighted sound level $L_{avg}(r)$ at the operator ear position where r is the applicable exchange rate (see Appendix X1).

NOTE 2—The exchange rate must be specified if the measurements are for a jurisdiction which uses exchange rates other than 5 dB per doubling of time.

9.3.5 If the operator is in a enclosed cab, measure $L_{avg}(r)$ for cab doors and windows closed and cab doors and windows open. When the cab doors and windows are closed measure with all heater, air conditioners and other noise-producing cab auxiliary equipment operating.

9.4 *Watercraft*—Watercraft noise shall be measured under normal cruise/calm water conditions.

9.5 *Stationary Equipment:*

9.5.1 *Speed*—All equipment shall be operated at maximum-rated continuous duty speed and other speeds at which normally operated.

9.5.2 *Load*—All equipment shall be operated at normal maximum rated load. The exception is that variable-speed equipment, which is normally operated at less than maximum, shall be operated at two-thirds maximum-rated load.

9.5.3 *Auxiliary Equipment*—All auxiliary equipment normally in use shall be operating.

9.6 *Helicopters:*

9.6.1 *Flight Conditions*—Flight conditions shall include the following:

9.6.1.1 Hover in ground effect (IGE). The helicopter shall be flown at a height determined by a *Z/D* ratio of 0.4 ± 300 mm,

where:

Z = height of the rotor above the ground, and
D = main rotor diameter.

9.6.1.2 *Level Flight*—At lower forward airspeed of either $0.9V_H$ or 0.9VNE,

where:

V_H = maximum horizontal velocity at maximum continuous power, and
VNE = velocity never exceeded.

9.6.2 *Gross Weight and Rotor Speed Conditions*—Noise measurements shall be made while the helicopter is in flight at maximum design gross weight and at normal ±5 % of rated rotor speed.

9.6.3 *Helicopter Subsystems and Equipment*—The subsystem and equipment which are normally operated continuously for more than five (5) min/h in flight shall be operating during flight noise data acquisition. The heater shall be operated unless an air conditioner is present and generates a higher sound level; then the air conditioner shall be operated. Where heaters and air conditioners may be operated at the same time (such as for humidity control) both shall be operated.

9.6.4 *Helicopter Configuration*—The helicopter shall be operated in the following configurations:

9.6.4.1 With doors, windows, and vents closed, and acoustical/thermal insulation treatment (hereafter referred to only as acoustical treatment) intact and in place.

9.6.4.2 Doors and windows open, removable acoustic treatment in place.

NOTE 3—The maximum allowable forward airspeed for this condition may he less than that specified in 9.6.1.2.

9.6.4.3 Doors and windows closed, removable acoustic treatment out.

9.6.5 *Helicopter Ground Measurements:*

9.6.5.1 *Positions*—Measurements shall be made at the head position of a representative number of normal maintenance locations. These measurements shall be made with the aircraft on the ground. All subsystems which are normally operated during ground maintenance (for example, generators, hydraulics, environmental control unit) shall be operating. Doors and windows shall be open. All acoustic treatments and access panels normally removed for maintenance shall be removed.

9.6.5.2 *Conditions:*

(1) Engines off, auxiliary power unit (APU) operating (if so equipped).

(2) All engines operating with rotors turning at flight-idle rpm (minimum collective pitch), and the APU operating (if so equipped).

9.6.5.3 *Measurement Time*—The recording time of each noise data sample shall be sufficient to produce a continuous 30-s or longer record of analyzed data.

10. Data Analysis and Display

10.1 Octave band and A-weighted data shall be displayed in tabular format representing the measured level as dB, slow meter response.

10.2 Contours shall be displayed on a sketch, either dimensioned or drawn to scale with the scale reference included.

11. Report

11.1 Report the following information:

11.1.1 *Measured Data*—Per Section 10.

11.1.2 *Measurement Instrumentation*—Complete list of calibrated instrumentation (for example, microphone, preamplifier, sound level meter, calibrator, tape recorder, power supply, oscilloscope, frequency analyzer) used for measurements, including nomenclature, model, serial number, manufacturer, date of calibration, and period of calibration.

11.1.3 *Equipment Being Measured*—Complete identification of the equipment whose noise is being measured, including nomenclature, type, serial number, mileage (if appropriate), and any modifications to the equipment.

11.1.4 *Operational Conditions*—Complete description of the operational conditions under which the test was conducted, such as speed (for example, ⅔ maximum posted speed), rpm (for example, rated engine rpm ⅔ rated engine rpm).

11.1.5 *Time and Place*—Date, time of day, and location of test.

11.1.6 *Test Site*—Physical description of the area, including ground surface and reflecting surfaces (if appropriate), a sketch of contributing noise sources, normal personnel operating

positions, microphone locations, and the location of personnel present during the tests.

11.1.7 *Atmospheric Conditions*—Air temperature, relative humidity, wind direction and speed, barometric pressure, cloud cover, and other atmospheric conditions.

11.1.8 *Background Noise*—Background level, using the same bandwidths employed for the measurements of the noise source.

11.1.9 *Calibration*—Method and time of calibration.

11.1.10 *Frequency Analyzer Bandwidth*—Bandwidth of frequency analyzer (for example, octave, one-third octave).

11.1.11 *Time Response*—Time response of the measuring system (that is, "slow" or "fast" or other appropriate description).

11.1.12 *Microphone Angles*—Orientation angles of the microphones.

11.1.13 *Tape Recorder Characteristics*—Frequency control settings including pre-emphasis, equalization, or other applicable equipment mode, and tape speed of tape recorder.

11.1.14 *Test Personnel*—Name, address, and phone number of personnel making the noise measurements, and of personnel such as official witnesses and equipment operator(s).

12. Precision and Bias

12.1 *Precision*—The precision of the measured levels is unknown. The precision is in process of being developed.

12.2 *Bias*—The standard has no bias because noise data are defined only in terms of this practice and the particular environment evaluated.

13. Keywords

13.1 aircraft; equipment; ground vehicles; noise contours; steady noise; watercraft

APPENDIX

(Nonmandatory Information)

X1. HEARING CONSERVATION NOISE EXPOSURE CRITERIA

X1.1 Introduction

X1.1.1 This appendix describes the more common criteria for limiting personnel exposure to steady-state noise. Hearing conservation criteria are usually quantified in terms of an 8-h time-weighted average normalized sound level *(TWA)*. The time-averaging is not always based on the energy-equivalent (approximately 3 dB) exchange rate.

X1.2 Definitions

X1.2.1 *action level, TWA_{act}*—the *TWA* in dB at which hearing conservation measures are implemented.

X1.2.2 *criterion level, TWA_{crit}*—the *TWA* in dB at which corresponds to 100 % noise dose.

X1.2.3 *exchange rate, time-intensity exchange rate, r*—the decibel change in the *TWA* required to double the damage potential of the sound during a fixed time period of exposure.

X1.2.4 *noise dose, D*—the ratio, expressed as a percentage, of the damage potential of a noise environment to the damage potential of exposure to the criterion level for 8 h. Implicit in the noise dose concept is a specified time-intensity exchange rate.

$$D = 100 \cdot 2^{((TWA_r - TWA_{crit})/r)} \quad \text{(X1.1)}$$

where:

D = percent dose,
TWA_r = 8-h time weighted average sound level with exchange rate r,
TWA_{crit} = criterion level, and
r = exchange rate in dB.

X1.2.5 *eight-hour time-weighted average normalized sound level, TWA_r*—a measure of the noise exposure normalized on 8 h. It is that constant sound level, measured in A-weighted decibels, slow meter response, which would produce the same hearing damage over an 8-h period as produced by the actual workday noise exposure. Implicit in the *TWA* is a specified time-intensity exchange rate *r*. The noise dose and *TWA* are different ways of expressing the same physical quantity.

$$TWA_r = \frac{r}{log(2)} \cdot log\left[\frac{1}{8}\int_0^T 2^{(L_{AS}(t)/r)}dt\right] \quad \text{(X1.2)}$$

where:

TWA_r = 8-h time weighted average sound level for the entire time of exposure with exchange rate r,
r = exchange rate in dB,
T = entire time of exposure in hours, and
$L_{AS}(t)$ = instantaneous A-weighted, slow meter response sound level.

X1.2.6 *time-averaged sound level, sound level, $L_{avg}(r)$*—sound level, measured in A-weighted decibels, slow meter response and using a specified time-intensity exchange rate of r dB.

X1.3 Criteria Usage

X1.3.1 Regulatory bodies define the limit on noise exposure of persons under their jurisdictions. Typically, daily exposures are allowed up to the action level. Control measures are required if the exposures exceed the action level. Table X1.1 lists the levels and exchange rates for some of the major bodies.

X1.4 Contours

X1.4.1 Contours representing the locus of points at which the sound level is at a certain value are often defined for noisy equipment. The value is usually a dB(A) level equal to the action level. These contours are used to define the zone within

TABLE X1.1 Hearing Conservation Criteria

Regulatory Body or Promulgating Authority	Criterion Level, TWA in dB(A)	Action Level, TWA in dB(A)	Exchange Rate, dB
U.S. Department of Labor Occupational Safety and Health Administration (OSHA)	90	85	5
U.S. Navy	84	84	4
U.S. Air Force, U.S. Army, European Community, most of the rest of the world	85	85	3

which personnel are required to wear hearing protectors. For mobile equipment, the contours are defined in operator manuals or on warning decals affixed to the equipment. For stationary equipment, the contours are marked on the ground.