Determining OSHA-Compliant Maximum Permissible Ambient Noise Levels (MPANLs) for the Kuduwave Audiometer (Utilizing Foam Eartips)

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Abstract:
This white paper investigates the determination of OSHA-compliant Maximum Permissible Ambient Noise Levels (MPANLs) for the Kuduwave audiometer when used with foam eartips. It reviews OSHA's baseline MPANLs (29 CFR 1910.95 Appendix D, Table D-1) and the more current ANSI S3.1-1999 (R2018) standard, which OSHA permits for use with insert earphones via a Letter of Interpretation dated October 11, 2022.1 The paper details the Kuduwave's specific attenuation characteristics with foam eartips and discusses core OSHA audiometric testing parameters, including the minimum threshold for testing (0 dB HL), mandated test frequencies, and the definition of a Standard Threshold Shift (STS). Several MPANL options are analyzed: OSHA Table D-1, ANSI S3.1-1999 for generic insert earphones, Kuduwave's operational MPANLs (insert eartip + cup), a "Noisiest Permissible" Hybrid (combining OSHA and ANSI S3.1 insert values), and a theoretically derived maximum permissible Kuduwave MPANL with specific adjustments for low frequencies. The paper concludes by recommending the "Noisiest Permissible" Hybrid MPANL as a practical approach for the Kuduwave with foam eartips, aligning with OSHA's allowance for ANSI S3.1 for insert earphones while maximizing permissible ambient noise.

1. Executive Summary: Key MPANL Determinations for Kuduwave (Foam Eartips) in OSHA Programs

The Occupational Safety and Health Administration (OSHA) mandates audiometric testing within hearing conservation programs, requiring specific Maximum Permissible Ambient Noise Levels (MPANLs) in test environments to ensure valid results. Historically, OSHA's MPANLs, as detailed in 29 CFR 1910.95 Appendix D, Table D-1, were established based on conventional audiometry using supra-aural earphones (like the Telephonics TDH-39) with limited inherent noise attenuation.[2] Modern audiometric devices, such as the Kuduwave audiometer, particularly when used with its foam eartips, incorporate advanced transducer technology and significant passive noise attenuation, often allowing for accurate testing in environments that would not meet the traditional

Table D-1 criteria.

OSHA has acknowledged these technological advancements through Letters of Interpretation, notably one issued on October 11, 2022, which permits the use of the American National Standards Institute (ANSI) S3.1-1999 (Reaffirmed 2018) standard for determining MPANLs when using insert or circumaural earphones.[1] This is particularly relevant for the Kuduwave, which utilizes insert-style transducers with foam eartips within a circumaural earcup design. This paper focuses exclusively on the Kuduwave configuration using foam eartips due to their superior attenuation characteristics.

This white paper provides a definitive guide to establishing OSHA-compliant MPANLs for the Kuduwave audiometer (foam eartips). It will present and analyze several MPANL options, culminating in a consolidated table:

1. **OSHA Table D-1:** The baseline OSHA standard.
2. **ANSI S3.1-1999 for Insert Earphones:** Standard ANSI values for generic insert earphones.
3. **Kuduwave Operational MPANLs (insert eartip + cup):** Manufacturer-specified limits, aligned with ANSI S3.1 principles for the Kuduwave's specific attenuation.
4. **"Noisiest Permissible" Hybrid:** A combination of the least stringent values from OSHA Table D-1 and ANSI S3.1 (Insert). **This is the recommended option.**
5. **Theoretically Derived "Maximum Permissible" Kuduwave MPANLs:** A technical calculation based on combined offsets and Kuduwave-specific attenuation advantages, with specific low-frequency adjustments as requested (presented for informational purposes, but not recommended for practical application).

By understanding these frameworks and the Kuduwave's specific characteristics with foam eartips, occupational health professionals can confidently implement compliant and accurate hearing testing programs.

2. Foundations: OSHA and ANSI MPANL Frameworks

2.1. OSHA's Baseline: 29 CFR 1910.95 Appendix D (Table D-1)

The foundational OSHA requirement for ambient noise in audiometric test rooms is specified in 29 CFR 1910.95, Appendix D.[4] This appendix includes Table D-1, which lists the Maximum Allowable Octave-Band Sound Pressure Levels (SPLs) for audiometric test rooms.[4]

Table 1: OSHA 29 CFR 1910.95 Appendix D, Table D-1 - Maximum Allowable Octave-Band Sound Pressure Levels for Audiometric Test Rooms

Octave-band center frequency (Hz)	Sound pressure level (dB)
500	40

1000	40
2000	47
4000	57
8000	62

Source: [4]

These levels were historically developed considering the use of supra-aural earphones, such as the Telephonics TDH-39, which provide minimal attenuation of ambient noise beyond that offered by the earphone cushion itself.[2] Consequently, Table D-1 represents the minimum compliance levels if no other standard or interpretation is applied. It assumes a test environment where the earphones themselves do not significantly shield the ear from external noise. For modern audiometers with substantial built-in attenuation, these levels may not accurately reflect the achievable quiet at the eardrum, leading OSHA to provide interpretations that allow for alternative, more suitable standards.

2.2. The ANSI S3.1-1999 (R2018) Standard: A Comprehensive Approach

The ANSI S3.1-1999 (Reaffirmed 2018), "Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms," offers a more detailed and psychoacoustically robust framework for determining MPANLs.[6] This Standard is designed to ensure that ambient noise in the test room results in negligible masking (≤2 dB) of test signals presented at reference equivalent threshold levels (i.e., 0 dB Hearing Level (HL)).[6]

A key feature of ANSI S3.1 is its provision of different MPANLs based on the type of earphone used (e.g., supra-aural vs. insert) and the specific frequency range being tested.[6] This differentiation acknowledges the varying sound attenuation characteristics of different transducers. For instance, insert earphones generally provide greater attenuation of external noise compared to supra-aural earphones, particularly at lower frequencies.[6] The Kuduwave audiometer employs insert-style transducers with foam eartips within its earcups, making the ANSI S3.1 values for insert earphones a relevant reference.

Table 2: ANSI S3.1-1999 Octave Band MPANLs for Insert Earphones (Test Frequency Range 500-8000 Hz)

Octave Band Center Frequency (Hz)	MPANL (dB re: 20 µPa)
125	78.0

250	64.0
500	50.0
1000	47.0
2000	49.0
4000	50.0
8000	56.0

Source: Adapted from ANSI S3.1-1999, Table 1 (Ears Covered, Insert Earphone, 500 to 8000 Hz test range).[6] *Note: This table includes values for 125 Hz and 250 Hz which are derived based on the upward spread of masking from the 500 Hz MPANL, as per Annex A.4 of the standard.*[6]

For comparative purposes, the ANSI S3.1-1999 MPANLs for supra-aural earphones are also presented:

Table 3: ANSI S3.1-1999 Octave Band MPANLs for Supra-aural Earphones (Test Frequency Range 500-8000 Hz)

Octave Band Center Frequency (Hz)	MPANL (dB re: 20 µPa)
125	39.0
250	25.0
500	21.0
1000	26.0
2000	34.0
4000	37.0
8000	37.0

Source: Adapted from ANSI S3.1-1999, Table 1 (Ears Covered, Supra-aural Earphone, 500 to 8000 Hz test range).[6]

The methodology used in ANSI S3.1-1999 to derive these MPANLs involves a computational approach based on sound field thresholds, principles of masking for a given threshold shift, power-law summation of masking, and average earphone attenuation values.[6] This makes it a more precise tool for ensuring audiometric accuracy compared to the older, more generalized OSHA Table D-1.

2.3. Bridging the Standards: OSHA's Acceptance of ANSI S3.1

Recognizing the advancements in audiometric technology and standards, OSHA has issued Letters of Interpretation (LOIs) that provide guidance on the applicability of ANSI S3.1. A pivotal LOI, dated October 11, 2022, explicitly states that "OSHA will allow the use of ANSI MPANLs in lieu of the MPANLs in the occupational noise exposure standard when insert earphones or other types of earphones (e.g., circular) are used".[1] This interpretation is critical because it officially permits employers to use the MPANLs specified in ANSI S3.1-1999 (R2018) for devices like the Kuduwave, which features a circumaural design with insert components (foam eartips).

This acceptance is significant. It moves beyond simply acknowledging that ANSI S3.1 is more stringent or current; it makes it an *officially permissible and applicable* alternative to OSHA's Table D-1.[1] Earlier LOIs also acknowledged that ANSI standards are generally more stringent and that octave-band measurements (as used in both Table D-1 and ANSI S3.1 tables) are sufficient for demonstrating compliance with OSHA's ambient noise requirements.[7] OSHA's pragmatic approach allows for the use of standards that better reflect the capabilities of modern audiometric equipment, ultimately supporting the primary goal of effective hearing conservation programs.[8]

3. The Kuduwave Audiometer: Specifics for MPANL Application (Foam Eartips Focus)

This white paper specifically addresses the Kuduwave audiometer when used with **foam eartips**, as these provide superior sound attenuation compared to silicone eartip alternatives. All Kuduwave-specific attenuation data and derived MPANLs herein assume the use of foam eartips combined with the circumaural cup.

3.1. Transducer Design and Integrated Attenuation (Foam Eartips)

The Kuduwave audiometer is distinguished by its integrated design, which combines insert-style transducers housed within circumaural earcups, featuring what the manufacturer terms Ambi-dome™ technology. When using foam eartips, this system provides significant passive attenuation of ambient noise, effectively creating a controlled acoustic environment at the user's ear.[9]

The manufacturer publishes sound attenuation characteristics for the Kuduwave system with foam eartips.

Table 4: Kuduwave Air Conduction System Sound Attenuation Characteristics (Combined Ear-cup and Foam Ear-insert)

Frequency (Hz)	Attenuation (dB)
125	31.0
250	37.7
500	43.8
1000	40.8
2000	38.1
4000	52.3
8000	45.8

Source: [9]

This built-in attenuation is fundamental to the Kuduwave's capability as a "boothless" audiometer. It allows for valid hearing tests in environments where ambient noise levels might exceed those permissible for unattenuated earphones. The Kuduwave system's attenuation with foam eartips is a result of its specific design, and therefore, its operational MPANLs are based on *its* measured attenuation performance rather than generic values for standalone insert or supra-aural earphones. While the ANSI S3.1 *methodology* for deriving MPANLs from attenuation data is applicable, the Kuduwave's unique attenuation profile justifies its specific MPANL values.

3.2. Reference Equivalent Threshold Sound Pressure Levels (RETSPLs) and "Reference Shift"

For any audiometer, accurate calibration is essential. This is achieved using Reference Equivalent Threshold Sound Pressure Levels (RETSPLs). RETSPLs are specific sound pressure levels, measured in a standardized acoustic coupler or ear simulator, that correspond to 0 dB HL for a given type of transducer at each audiometric frequency.[11] In essence, RETSPLs "normalize" the acoustic output of different transducers so that 0 dB HL consistently represents the average hearing threshold of a normally hearing young adult population.[11]

The term "Reference Shift" in the context of the Kuduwave (or any audiometer with unique transducers) refers to the establishment and application of these specific RETSPLs for its built-in transducers.[9] It is crucial to distinguish this calibration reference from a Standard Threshold Shift (STS), which indicates a change in an individual's hearing over time.[13] The Kuduwave, having its own integrated transducers, requires its own set of RETSPLs to ensure that when the audiometer dial reads 0 dB HL, the sound presented to the ear accurately corresponds to the standardized normal hearing threshold.[9] Without correct, device-specific RETSPLs, all hearing level measurements would be inaccurate, and the application of any MPANL standard would be compromised because the fundamental target of testing (0 dB HL) would not be correctly established. The Kuduwave's technical specifications indicate its RETSPLs are established as per ISO 389-2.[9]

4. Core OSHA Audiometric Testing Parameters

To correctly apply MPANLs, it is essential to understand the core parameters of audiometric testing under OSHA's hearing conservation program.

4.1. Targeting 0 dB HL: The Minimum Threshold for Testing

OSHA's regulations implicitly require that audiometric tests be capable of measuring hearing thresholds down to 0 dB HL.[14] This is the reference level for normal hearing, and the ability to test accurately at this level is crucial for establishing valid baseline audiograms and detecting early changes in hearing. MPANLs are specifically designed to prevent ambient noise from masking these faint 0 dB HL signals, ensuring that the quietest sounds an individual should hear are indeed audible during the test.[14] The Kuduwave's specifications explicitly state its operational background sound pressure levels are designed to allow testing down to 0 dB HL.[9] If ambient noise elevates or masks the 0 dB HL signal, true hearing thresholds cannot be determined, potentially missing early signs of noise-induced hearing loss and undermining the effectiveness of the hearing conservation program.

4.2. Mandated Test Frequencies for OSHA

OSHA's Occupational Noise Exposure standard (29 CFR 1910.95(h)(1)) mandates that pure tone, air conduction hearing threshold examinations include, as a minimum, the following frequencies: 500, 1000, 2000, 3000, 4000, and 6000 Hz.[7] Tests at each frequency shall be taken separately for each ear.[7] While not mandated for the hearing conservation program audiogram, testing at 8000 Hz is often included as good practice and is part of the Kuduwave's standard test frequencies.[9] These frequencies are selected because of their importance for speech understanding and their susceptibility to noise-induced damage. The validity of measurements at these specific frequencies, particularly those used for STS calculation, is paramount.

4.3. Standard Threshold Shift (STS): The Critical Metric

A Standard Threshold Shift (STS) is a key indicator used in OSHA's hearing conservation programs to identify changes in hearing that may be work-related. An STS is defined as a change in hearing threshold, relative to the employee's baseline audiogram, of an average of 10 dB or more at 2000, 3000, and 4000 Hz in one or both ears.

The accurate detection of an STS is a primary objective of the audiometric testing program. Therefore, ensuring that ambient noise does not interfere with measurements at 2000, 3000, and 4000 Hz is critically important. Any interpretation or application of MPANLs, especially those allowing for more relaxed low-frequency noise limits, must rigorously protect the integrity of measurements at these STS-critical frequencies. If ambient noise were to cause an apparent shift at these frequencies, it could lead to a false positive STS. Conversely, if noise masks a true, early-stage STS, the opportunity for intervention would be missed. This focus on protecting the STS frequencies underpins the pragmatic approach to MPANL interpretation.

5. Exploring Different MPANL Options for Kuduwave (OSHA Compliance)

Several approaches can be considered for determining MPANLs when using the Kuduwave audiometer with foam eartips under OSHA's hearing conservation program.

5.1. Option 1: Standard OSHA MPANLs (29 CFR 1910.95 Appendix D, Table D-1)

This is the baseline OSHA requirement, historically based on supra-aural earphones like the TDH-39. These values are presented in **Table 1** (see Section 2.1). While permissible, these MPANLs do not account for the superior attenuation provided by modern devices like the Kuduwave with foam eartips.

5.2. Option 2: ANSI S3.1-1999 MPANLs for Insert Earphones (Generic)

As per OSHA's 2022 Letter of Interpretation [1], the MPANLs from ANSI S3.1-1999 for insert earphones can be used. The values for the 500-8000 Hz test frequency range are presented in **Table 2** (see Section 2.2). This table already incorporates the upward spread of masking principle for the 125 Hz and 250 Hz bands, deriving them from the 500 Hz MPANL for insert earphones.[6] These represent a more modern standard for generic insert earphones.

5.3. Option 3: Kuduwave Operational MPANLs (insert eartip + cup)

This option utilizes the Kuduwave's manufacturer-specified "Operational background sound pressure levels to test down to 0dBHL (ANSI S3.1...)".[9] These values inherently account for the Kuduwave's specific transducer and combined foam eartip/earcup attenuation. They represent the ambient noise conditions under which the manufacturer states the device can accurately test to 0 dB HL in accordance with ANSI S3.1 principles.

Table 5: Kuduwave Operational MPANLs (Foam Eartips) for OSHA Testing

Octave Band Center Frequency (Hz)	Kuduwave Operational MPANL (dB SPL)
125	< 70
250	< 69
500	< 58
1000	< 53

2000	< 50
4000	< 59
8000	< 59

Source:.[9] *Note: These are the maximum levels; actual ambient noise should be at or below these values. The Kuduwave tests at 3000 Hz and 6000 Hz; the MPANL for the octave band encompassing these frequencies (e.g., 4000 Hz octave band for 3000 Hz tone, 8000 Hz octave band for 6000 Hz tone) should be met.*

It's noteworthy that the Kuduwave's stated operational MPANLs for 125 Hz (<70 dB) and 250 Hz (<69 dB) are more stringent than what would be derived by applying the 14 dB/octave upward spread of masking rule to its own 500 Hz MPANL (<58 dB + 28 dB = <86 dB for 125 Hz; <58 dB + 14 dB = <72 dB for 250 Hz). This indicates the manufacturer's values are conservative and already account for low-frequency noise effects appropriately.

5.4. The "Upward Spread of Masking" Principle and its Application

5.4.1. Explanation of the Principle
A critical psychoacoustic phenomenon relevant to MPANLs is the "upward spread of masking." This refers to the ability of intense low-frequency sounds to elevate the hearing thresholds for higher-frequency sounds.6 In other words, a loud hum or rumble can make it harder to hear higher-pitched tones. However, the effectiveness of this masking diminishes as the frequency separation between the masker (low-frequency noise) and the signal (higher-frequency tone) increases.

ANSI S3.1-1999, Annex A.4, provides a quantitative guideline: "the slope for the upward spread of masking function is 14 dB per octave below the lowest test frequency".[6] This means that for frequencies below the lowest *critical* test frequency being evaluated (e.g., 500 Hz for OSHA), the MPANL can be increased by 14 dB for each octave of separation from that critical frequency, without causing more than negligible masking (≤2 dB threshold shift) at that critical frequency.

- MPANL at one octave below (e.g., 250 Hz if 500 Hz is lowest critical) = MPANL at critical frequency + 14 dB.
- MPANL at two octaves below (e.g., 125 Hz if 500 Hz is lowest critical) = MPANL at critical frequency + 28 dB.

5.5. Combining OSHA and ANSI S3.1 for a "Noisiest Permissible" Scenario

5.5.1. Rationale and Discrepancies
An interesting observation is that for some frequencies, the older OSHA Table D-1 (designed for

supra-aural earphones) allows for more ambient noise than the more modern ANSI S3.1-1999 standard for supra-aural earphones. This is due to different derivation methodologies and underlying assumptions.[6]

Table 6: Comparison of Octave Band MPANLs: OSHA Table D-1 vs. ANSI S3.1-1999 (Supra-aural, 500-8000 Hz Test Range)

Octave Band Center Freq. (Hz)	OSHA Table D-1 (dB SPL)	ANSI S3.1-1999 Supra-aural (dB SPL)	Difference (OSHA - ANSI Supra)
500	40	21.0	+19.0
1000	40	26.0	+14.0
2000	47	34.0	+13.0
4000	57	37.0	+20.0
8000	62	37.0	+25.0

Note: Positive values indicate OSHA Table D-1 allows more noise than ANSI S3.1 for supra-aural earphones at that frequency.

5.5.2. Option 4: "Noisiest Permissible" Hybrid MPANL (Recommended)
This theoretical option constructs a hybrid MPANL set by selecting the least stringent (highest dB value, i.e., allowing more noise) MPANL for each octave band from either the standard OSHA Table D-1 (Table 1) or the ANSI S3.1-1999 values for insert earphones (Table 2). This approach seeks the maximum allowable noise under any permissible standard for the respective earphone type consideration. OSHA's allowance for ANSI S3.1 for insert earphones 1, combined with the existing OSHA Table D-1, provides the basis for this hybrid approach.

Table 7: "Noisiest Permissible" Hybrid MPANL (Maximum of OSHA Table D-1 and ANSI S3.1-1999 Insert Earphone Values) - RECOMMENDED

Octave Band Center Freq. (Hz)	OSHA Table D-1 (dB SPL)	ANSI S3.1 Insert (500-8k Hz range) (dB SPL)	"Noisiest Permissible" Hybrid MPANL (dB SPL)	Source of Hybrid Value
125	N/A	78.0	78.0	ANSI S3.1 Insert
250	N/A	64.0	64.0	ANSI S3.1 Insert

500	40	50.0	50.0	ANSI S3.1 Insert
1000	40	47.0	47.0	ANSI S3.1 Insert
2000	47	49.0	49.0	ANSI S3.1 Insert
4000	57	50.0	57.0	OSHA Table D-1
8000	62	56.0	62.0	OSHA Table D-1

5.6. A Theoretical "Maximum Permissible" Calculation for Kuduwave (Not Recommended for Use)

5.6.1. Derivation Logic

This section explores a theoretical calculation to derive a highly permissive MPANL set for the Kuduwave with foam eartips. This approach is presented for technical discussion only and is NOT recommended for practical application due to the compounded allowances which may not fully preserve the integrity of threshold testing at 0 dB HL under all conditions.

The logic attempts to combine several allowances:

1. For frequencies 500 Hz and above: Start with ANSI S3.1-1999 MPANLs for *insert earphones* (Table 2). Add the "OSHA supra-aural advantage" (difference where OSHA Table D-1 is more lenient than ANSI S3.1 for *supra-aural* earphones, from Table 6). Add the "Kuduwave attenuation advantage" (additional attenuation from Kuduwave with foam eartip + cup (Table 4) compared to generic insert earphone attenuation values from ANSI S3.1-1999, Annex A, Table A.1 [6]).
    - Generic ANSI Insert Attenuation (EA-IE from Table A.1 [6]): 125Hz: 29.9dB, 250Hz: 31.4dB, 500Hz: 33.7dB, 1kHz: 34.0dB, 2kHz: 34.1dB, 4kHz: 38.6dB, 8kHz: 42.7dB.
    - Kuduwave Atten. Advantage = Kuduwave Atten (Table 4) - ANSI Generic Insert Atten (EA-IE).
        - 125 Hz: 31.0 - 29.9 = 1.1 dB
        - 250 Hz: 37.7 - 31.4 = 6.3 dB
        - 500Hz: 43.8 - 33.7 = 10.1 dB
        - 1000Hz: 40.8 - 34.0 = 6.8 dB
        - 2000Hz: 38.1 - 34.1 = 4.0 dB
        - 4000Hz: 52.3 - 38.6 = 13.7 dB
        - 8000Hz: 45.8 - 42.7 = 3.1 dB
2. For 250 Hz: Take the Kuduwave Operational MPANL at 250 Hz (from Table 5) and add 14 dB (upward spread of masking allowance).
3. For 125 Hz: Take the Kuduwave Operational MPANL at 125 Hz (from Table 5) and add 28 dB (upward spread of masking allowance, 14 dB * 2 octaves).

5.6.2. Option 5: Theoretically Derived Kuduwave MPANLs (Not Recommended)

Table 8: Theoretically Derived "Maximum Permissible" Kuduwave MPANLs (Foam Eartips) - Not Recommended for Use

Freq (Hz)	ANSI S3.1 Insert (Table 2) (A)	OSHA Supra Advantage (Table 6 Diff.) (B)	Kuduwave Atten. Advantage over Generic Insert (C)	Option 5 MPANL (dB SPL) (Calculation)
125	78.0	N/A	1.1	70.0 (Kudu Op. MPANL @125Hz from Table 5) + 28.0 (Upward Spread) = **98.0**
250	64.0	N/A	6.3	69.0 (Kudu Op. MPANL @250Hz from Table 5) + 14.0 (Upward Spread) = **83.0**
500	50.0	19.0	10.1	50.0 (A) + 19.0 (B) + 10.1 (C) = **79.1**
1000	47.0	14.0	6.8	47.0 (A) + 14.0 (B) + 6.8 (C) = **67.8**
2000	49.0	13.0	4.0	49.0 (A) + 13.0 (B) + 4.0 (C) = **66.0**
4000	50.0	20.0	13.7	50.0 (A) + 20.0 (B) + 13.7 (C) = **83.7**
8000	56.0	25.0	3.1	56.0 (A) + 25.0 (B) + 3.1 (C) = **84.1**

Disclaimer: These values are high and derived from compounding multiple theoretical allowances, with specific adjustments for low frequencies as requested. Their use is not recommended as they may compromise the accuracy of threshold audiometry, especially for detecting early hearing changes.

6. Summary of MPANL Options for Kuduwave with Foam Eartips

The following table consolidates the various MPANL options discussed for use with the Kuduwave audiometer (foam eartips) in OSHA hearing conservation programs.

Table 9: Consolidated MPANL Options for Kuduwave (Foam Eartips) under OSHA Guidelines (dB SPL)

Octave Band Center Freq. (Hz)	Option 1: OSHA Table D-1 (Supra-aural	Option 2: ANSI S3.1 Insert Earphones (Generic,	Option 3: Kuduwave Operational MPANLs (insert	Option 4: "Noisiest Permissible" Hybrid (Max of Opt 1 & Opt 2 values for 500Hz+) -	Option 5: Theoretical Max Kuduwave (NOT RECOMMENDED)

	Baseline)	500-8kHz range)	eartip + cup)	RECOMMENDED	
125	N/A	78.0	70	**78.0**	98.0
250	N/A	64.0	69	**64.0**	83.0
500	40	50.0	58	**50.0**	79.1
1000	40	47.0	53	**47.0**	67.8
2000	47	49.0	50	**49.0**	66.0
4000	57	50.0	59	**57.0**	83.7
8000	62	56.0	59	**62.0**	84.1

Guidance on Selecting and Applying the Appropriate MPANL Table:

- **Option 4 ("Noisiest Permissible" Hybrid)** is the **recommended** choice. This approach utilizes the maximum permissible noise levels by combining OSHA's baseline Table D-1 with the ANSI S3.1 values for insert earphones (which OSHA explicitly allows via LOI [1]). This hybrid caters to a "best-case" scenario from existing permissible standards when considering insert earphones, as OSHA's LOI primarily addresses insert earphones rather than explicitly detailing allowances for combined cup-and-insert attenuation like that of the Kuduwave.
- **Option 3 (Kuduwave Operational MPANLs - insert eartip + cup)** directly aligns with the Kuduwave's specified operational limits for ensuring test validity down to 0 dB HL and is based on its specific attenuation with foam eartips. While these values reflect the device's capabilities, Option 4 is recommended here as it more directly aligns with the letter of OSHA's interpretations regarding insert earphones.
- Option 5 presents a theoretical exercise with specific low-frequency adjustments as requested and is not advised for use.

Regardless of the table chosen, accurate octave-band sound level measurements of the test environment are essential prior to and periodically during testing to ensure and document compliance.

7. OSHA's Position on Boothless Audiometry

OSHA does not have specific regulations that explicitly define or govern "boothless audiometry." Instead, OSHA's compliance requirements focus on the performance of the audiometric test environment, specifically that it must meet the applicable MPANL requirements at the time of the test. Whether these MPANLs are achieved within a traditional sound-attenuating booth or via a device with high passive attenuation like the Kuduwave (with foam eartips) is secondary to the outcome of a valid, unmasked audiogram.

The OSHA Letter of Interpretation of October 11, 2022, allowing the use of ANSI S3.1 MPANLs, is key for boothless devices because these devices often rely on their own attenuation characteristics to meet the more nuanced ANSI criteria at the ear.[1] Devices such as the Kuduwave, which integrate significant sound attenuation (especially with foam eartips), can create an acoustic environment at the eardrum that is equivalent to being inside a traditional booth, even when used in moderately noisy surroundings.[15] The critical factor is that the test environment (i.e., the acoustic conditions at the listener's ear) meets the chosen MPANL standard (either OSHA Table D-1, or ANSI S3.1 as per the LOI) *every time an audiometric test is performed*. Some portable systems incorporate real-time ambient noise monitoring to help ensure compliance during testing.[7] The advancement in boothless audiometry supports compliance with OSHA regulations by making testing more accessible while maintaining accuracy, provided MPANLs are met.

8. Conclusion and Recommendation

The Kuduwave audiometer, when used with its **foam eartips**, offers a robust and flexible solution for conducting OSHA-compliant hearing tests due to its significant integrated sound attenuation. By leveraging OSHA's Letter of Interpretation dated October 11, 2022 [1], which permits the use of ANSI S3.1-1999 MPANLs for insert earphones, users can confidently apply standards that reflect the Kuduwave's capabilities within the framework of OSHA's allowances.

Among the various MPANL options explored:

- **Option 4: "Noisiest Permissible" Hybrid MPANL** (see Table 7 and Table 9) is the **recommended MPANL set**. This approach combines the least stringent values from OSHA's traditional Table D-1 and the ANSI S3.1-1999 standard for insert earphones. Given that OSHA's Letter of Interpretation [1] specifically allows the use of ANSI S3.1 for insert earphones, this hybrid option provides a practical interpretation that maximizes allowable ambient noise while adhering to permissible standards. It acknowledges that OSHA's direct guidance focuses on insert earphone performance rather than explicitly detailing the combined attenuation benefits of devices like the Kuduwave (cup + insert).

While Option 3 (Kuduwave Operational MPANLs) reflects the Kuduwave's full attenuation capabilities and is scientifically sound for the device itself, Option 4 is recommended as a pragmatic approach based on current OSHA interpretations. The theoretically derived Option 5, with its specific low-frequency calculation method, is not recommended for practical use. This theoretical option is however in line with the OSHA supra-aural MPANLs. It demonstrates that the current OSAH MPANLs should rather be replaced by the ANSI S3.1 standard for all headsets used, including supra-aural headsets.

Successful implementation requires a clear understanding of the Kuduwave's specific attenuation capabilities with foam eartips, ensuring correct RETSPL calibration for its transducers, accurate measurement and documentation of ambient noise levels in the test environment, and selection of the recommended MPANL table (Option 4). By adhering to these principles, practitioners can ensure that audiometric testing with the Kuduwave is both accurate and fully compliant with OSHA regulations, contributing effectively to hearing conservation efforts.

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