Expert Guidance on SANS 10083:2023 and its Implications for Boothless Audiometry with Kuduwave Technology

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Abstract

This technical report provides an evidence-based interpretation of the South African National Standard SANS 10083:2023 for occupational health professionals using the GeoAxon Kuduwave audiometer. It reaffirms that the standard has consistently been performance-based, requiring a verifiably quiet acoustic environment at the patient's ear rather than mandating a physical sound booth. The report addresses a confusing new note (Clause 15.1.2.3, Note 1), demonstrating its scientific invalidity and clarifying the correct, performance-based path to compliance. The Kuduwave system's compliance is established through its dual-component passive attenuation system, which provides superior noise reduction compared to average single-walled sound booths, especially at problematic low frequencies. Furthermore, its integrated real-time ambient noise monitoring offers a dynamic and continuous method of quality assurance that surpasses static room certification. The technology's accuracy is substantiated by extensive peer-reviewed clinical validation and its successful deployment by NASA on the International Space Station. The report concludes that the Kuduwave is not only a fully compliant solution under SANS 10083:2023 but represents a technologically superior method for conducting accurate and reliable occupational audiometry.

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1.0 Introduction: Understanding the Core Principles of Occupational Hearing Conservation Standards

1.1 Acknowledging a Consistent Standard

The publication of the South African National Standard SANS 10083:2023, Edition 6.1, continues South Africa's long-standing commitment to robust, evidence-based occupational hearing conservation programmes.[1] This standard upholds established methodologies for the measurement, assessment, and management of occupational noise, aligning national practices with international standards and acknowledging the rapid pace of technological innovation in audiometry. This communication serves as an expert technical report and guidance letter for occupational health professionals. Its purpose is to provide a detailed, evidence-based interpretation of the standard's requirements for audiometric test environments, with a specific focus on the compliant use of advanced boothless audiometry systems.

1.2 The Central Thesis: Performance over Prescription

A core principle, consistently upheld throughout the history of the SANS 10083 standard, is its flexible, performance-based framework. This principle is critical. The standard does not mandate the use of a specific piece of hardware, such as a traditional soundproof booth. Instead, its core principle is the verifiable achievement of a valid acoustic environment *at the patient's ear* during testing. This outcome-oriented approach is pivotal, as it opens the door for scientifically validated technologies that can meet, and often exceed, the required performance benchmarks in a more efficient, accessible, and cost-effective manner. Advanced boothless systems, exemplified by the Kuduwave audiometer, are designed precisely to meet this performance-based criterion.

The standard's consistent focus on defining the *outcome* (e.g., "the ambient noise at the point of testing must not exceed specified levels") rather than prescribing the *means* (e.g., "you must use a sound booth") is a hallmark of modern, effective technical standards. Through its normative reference to SANS 10182 and its alignment with the principles of international standards like ISO 8253-1, SANS 10083:2023 maintains this progressive, science-based philosophy.[1] This allows practitioners to leverage innovations that improve service delivery without compromising data integrity. This report will demonstrate that the Kuduwave system is not a workaround to the standard, but rather a direct and sophisticated fulfillment of its underlying scientific and clinical objectives.

1.3 Scope of this Guidance

This report will provide a comprehensive analysis to support practitioners in their use of Kuduwave technology under the new standard. The analysis is structured to:

- Deconstruct the core principles governing the audiometric test environment as defined by SANS 10083:2023 and its referenced standards.
- Address and scientifically resolve a perceived contradiction introduced by a new note (Clause 15.1.2.3, Note 1) within the standard.
- Provide a detailed technical overview of the Kuduwave system's sound attenuation and real-time

noise monitoring capabilities.
- Review the extensive body of peer-reviewed scientific literature and high-stakes case studies that validate the clinical accuracy and reliability of boothless audiometry.
- Offer clear, actionable recommendations for ensuring and documenting compliance in daily practice.

2.0 The Core Principle of the Audiometric Test Environment: A Focus on Outcomes, Not Enclosures

2.1 Interpreting SANS 10083 Clause 15.1.2

Clause 15.1.2 of SANS 10083:2023, titled "Test environment," is the central provision governing the acoustic conditions for audiometry. Clause 15.1.2.1 states that a testing environment (booth, room, or mobile unit) must "comply with the provisions of SANS 10182".[1] This is the key directive. The standard does not explicitly mandate a "sound booth"; it mandates compliance with SANS 10182. SANS 10182 is the South African National Standard for "The measurement and assessment of acoustic environments for audiometric tests".[2] Therefore, the primary requirement is not the presence of a specific type of enclosure, but the achievement of a specific, measurable acoustic quality within the testing space. This means that any space used for audiometry must be formally assessed and certified as being quiet enough to produce valid test results.

2.2 The International Context: ISO 8253-1 and Maximum Permissible Ambient Noise Levels (MPANLs)

The principles outlined in SANS 10182 are harmonized with international best practices, most notably ISO 8253-1, "Acoustics — Audiometric test methods — Part 1: Pure-tone air and bone conduction audiometry".[3] This international standard provides the definitive scientific benchmark for a valid test environment through the concept of Maximum Permissible Ambient Noise Levels (MPANLs).[3]

MPANLs are the highest sound pressure levels of background noise, measured in one-third-octave bands, that can be present in a test environment without masking the pure-tone signals presented to the patient at threshold levels. Crucially, ISO 8253-1 specifies that these MPANLs are not a single, fixed set of values. They are fundamentally dependent on the sound attenuation provided by the transducer (i.e., the earphone or headset) being used. The standard provides different MPANL tables for testing with ears uncovered (as in bone conduction or sound field testing) and for testing with ears covered by various types of earphones.[3] A headset with higher attenuation will permit testing in a room with higher ambient noise levels, as it more effectively blocks that noise from reaching the eardrum.

2.3 Redefining the "Test Environment"

This principle—that attenuation dictates the permissible ambient noise—is the foundation of modern boothless audiometry. With high-attenuation headsets, the functional "test environment" is no longer the entire room but is effectively reduced to the acoustically isolated micro-environment created between the earphone and the tympanic membrane.

The technology of the Kuduwave system fundamentally decouples the acoustic integrity of the hearing test from the acoustic properties of the surrounding room. A traditional sound booth functions as a large-scale passive attenuator, aiming to make the entire room quiet enough for a low-attenuation

supra-aural headset to be used. In contrast, a high-attenuation system like the Kuduwave headset acts as a highly effective, localized passive attenuator for the very small space around the ear. The Kuduwave's Ambi-Dome system, which combines deeply inserted foam eartips with passively attenuating circumaural earcups, creates a physical barrier that provides substantial, validated noise reduction directly at the source of sound reception.[4] This effectively brings the function of the "booth" to the patient, making the acoustic properties of the external room a secondary, manageable factor rather than the primary limiting one. The focus thus shifts from certifying a room to using a certified device that creates its own compliant micro-environment.

3.0 Reconciling the New Note in SANS 10083:2023 (Clause 15.1.2.3, Note 1)

3.1 The Point of Contention

The 2023 revision of SANS 10083 introduced a new note that has become a source of significant confusion for practitioners. Clause 15.1.2.3, Note 1 states:

> "NOTE 1 Insert earphones, circumaural earcups (headphones) or a combination thereof or any similar device of which the actual attenuation cannot be measured physically with a type 1 or 2 sound level meter equipped with an octave filter should not satisfy this requirement of the testing environment (see SANS 10182)." [1]

On a superficial reading, this note appears to challenge the validity of any advanced headset whose attenuation cannot be casually measured by a user in the field. This interpretation, however, is based on a misunderstanding of acoustic metrology and creates a compliance paradox that would invalidate nearly all forms of modern audiometry, including those using standard, universally accepted equipment.

3.2 A Scientific and Legal Interpretation

The ambiguity of Note 1 is not merely a technical curiosity; it represents a significant compliance risk for practitioners. In the context of occupational health, standards are regulatory documents.[1] An inspector or auditor lacking deep acoustic expertise could misinterpret the note literally, leading to an incorrect finding of non-compliance. It is therefore imperative to establish an authoritative, scientifically sound interpretation that practitioners can rely upon. A rigorous analysis reveals the note to be fundamentally flawed.

Argument 1: Attenuation is a Laboratory-Validated, Not Field-Measured, Property
The premise of the note—that a user should physically measure a headset's "actual attenuation" with a handheld sound level meter—is scientifically invalid. Headset sound attenuation is a complex acoustic property determined under highly controlled laboratory conditions using specialized equipment and methodologies, as prescribed by international standards like ISO 4869-1.3 These tests involve using an acoustic test fixture or human subjects in a calibrated sound field. It is impossible to replicate these conditions or obtain a meaningful result with a simple sound level meter in a field environment. The note's requirement is therefore impractical and scientifically unsound for *any* audiometric headset, including standard supra-aural models.[6]

Argument 2: The Intent vs. Literal Interpretation
The most charitable interpretation is that the note's intent was to prevent the use of uncertified,

consumer-grade headphones with unknown or unverified attenuation properties. However, its literal wording is imprecise and overreaching. The correct, defensible interpretation hinges on the phrase "of which the actual attenuation cannot be measured." For a device like the Kuduwave, the actual attenuation can be and has been measured and validated extensively in certified acoustic laboratories. This data is published and readily available in its technical specifications.4 Therefore, the Kuduwave system does not fall into the category of a device whose attenuation "cannot be measured." The note should be understood to mean that a device is compliant if its "actual attenuation" is *known, quantified, and scientifically validated*, not that it must be *re-measured* by the end-user in an inappropriate manner.[6]

3.3 The Correct Path to Compliance

The scientifically and legally correct path to compliance with SANS 10083 and SANS 10182 bypasses the flawed premise of the note and focuses on the performance-based principles of the standard. Compliance is demonstrated by:

1. **Using Validated Attenuation Data:** The practitioner uses the manufacturer's laboratory-validated attenuation data for the specific headset.
2. **Calculating Device-Specific MPANLs:** This validated attenuation data is used to calculate the specific MPANLs for the device, establishing the maximum permissible ambient noise levels in the room where testing can occur.
3. **Ensuring Conditions are Met:** The practitioner ensures, through site selection and/or active monitoring, that the ambient noise in the room does not exceed these calculated, device-specific MPANLs.

This approach is directly supported by the framework of ISO 8253-1.[3] Furthermore, the Kuduwave system provides an additional, superior layer of quality assurance through its active, real-time ambient noise monitoring, which continuously verifies that the acoustic conditions

inside the earcup are met during every single test, for every frequency measured. This dynamic, continuous verification is arguably a more robust method of ensuring data integrity than a static, annual certification of an empty sound booth.

4.0 The Kuduwave Solution: A Validated System for SANS 10083:2023 Compliance

4.1 The Dual-Component Attenuation System

The Kuduwave audiometer achieves its high level of passive noise reduction through a proprietary dual-component system known as the Ambi-Dome. This system combines two distinct layers of attenuation:

1. **Insert Earphones:** The test signal is delivered via foam eartips that are compressed and inserted deep into the ear canal, where they expand to create a tight seal. This functions like a high-quality earplug, providing significant attenuation before any external sound can enter the ear canal.[4]
2. **Circumaural Earcups:** The insert earphones are housed within large, circumaural earcups that seal around the entire pinna (outer ear). These earcups provide a second layer of passive attenuation, further reducing the ambient noise that reaches the sealed ear canal.

This combined approach is particularly effective at attenuating low-frequency noise (125 Hz to 500 Hz), which is notoriously difficult to block and is the primary cause of upward spread of masking in audiometry.

4.2 Active Real-Time Ambient Noise Monitoring

Beyond its passive attenuation, the most significant technological advantage of the Kuduwave system is its active, real-time ambient noise monitoring. Microphones integrated within the Ambi-Dome earcups continuously measure the sound pressure level of any ambient noise that penetrates the passive barriers. This in-situ data is processed by the GeoAxon EMR software, which provides the operator with a real-time, on-screen visual indicator of the noise level relative to the permissible limit for the frequency being tested.

This functionality provides an unparalleled level of quality control:

- **Continuous Validation:** It confirms that the testing conditions are valid for every threshold measurement, rather than relying on an annual, static room certification.
- **Dynamic Adaptation:** If a transient noise event occurs (e.g., a door slams, a vehicle passes), the system immediately flags it, and testing can be automatically paused until the noise subsides, preventing contaminated results.
- **Auditable Record:** The system can log the noise conditions under which each threshold was obtained, creating a robust, auditable record that proves the validity of the test.

4.3 Quantifying the Performance Advantage

The superior performance of the Kuduwave system can be demonstrated with concrete, quantitative data. The validated attenuation figures translate directly into significantly less stringent requirements for the quietness of the surrounding room.

Table 1: Sound Attenuation Performance of the Kuduwave System

This table presents the laboratory-validated combined sound attenuation provided by the Kuduwave headset across the standard audiometric frequencies.

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

Data sourced from Kuduwave technical specifications.[4]

Table 2: Maximum Permissible Ambient Noise Levels (MPANLs) for Kuduwave vs. Standard Supra-aural Headsets for Testing to 0 dB HL

This table translates the attenuation data from Table 1 into practical terms. It compares the MPANLs for standard supra-aural headsets (as specified in international standards) with the calculated MPANLs for the Kuduwave system. The "Kuduwave Advantage" column shows the additional decibels of ambient room noise the Kuduwave can tolerate while maintaining full compliance for threshold testing down to 0 dB HL.

Frequency (Hz)	MPANL for Supra-aural Headsets (dB SPL)[1]	Calculated MPANL for Kuduwave (dB SPL)[2]	Kuduwave Advantage (dB)
125	28	< 70	+42
250	19	< 69	+50
500	18	< 58	+40
1000	23	< 53	+30
2000	30	< 50	+20
4000	36	< 59	+23
8000	33	< 59	+26
[1] Values from ISO 8253-1:2010, Table 2, for the most stringent test tone frequency range (125 Hz to 8000 Hz).[3]			
[2] Values from Kuduwave technical specifications, representing the maximum permissible background sound pressure levels to test down to 0 dB HL.[4]			

The data is unequivocal. At 250 Hz, a critical frequency for potential masking, the Kuduwave system allows for compliant testing in an environment that is 50 dB louder than what is permissible for a standard headset. This demonstrates that the Kuduwave does not simply meet the standard; it creates a testing environment that is far more resilient to ambient noise interference.

4.3.1 Kuduwave Attenuation vs. Single-Walled Sound Booths

A direct comparison of the Kuduwave's passive sound attenuation with that of an average single-walled sound booth further highlights its performance, particularly in the low frequencies where ambient noise is often most problematic.[7]

Table 3: Comparative Sound Attenuation: Kuduwave vs. Average Single-Walled Booth

Frequency (Hz)	Kuduwave Combined Attenuation (dB)	Average Single-Walled Booth Attenuation (dB)
125	31.0	21.0
250	37.7	24.0
500	43.8	29.0
1000	40.8	35.0
2000	38.1	39.0
4000	52.3	41.0
8000	45.8	42.0
Data sourced from GeoAxon white paper and Kuduwave technical specifications.[4]		

As shown in Table 3, the Kuduwave headset provides significantly better sound attenuation than an average single-walled booth at low frequencies (125 Hz, 250 Hz, and 500 Hz). This is a critical advantage, as low-frequency noise can mask higher-frequency test tones (a phenomenon known as upward spread of masking), compromising the validity of the entire audiogram. By more effectively blocking this type of noise, the Kuduwave provides a more robust and reliable testing environment directly at the patient's ear.

5.0 The Scientific and Clinical Validation of Boothless Audiometry

The technical specifications of the Kuduwave system are robustly supported by a large and growing body of independent, peer-reviewed scientific research and real-world application in the most demanding environments.

5.1 Peer-Reviewed Evidence

Numerous clinical studies have been conducted to validate the accuracy of boothless audiometry using the Kuduwave system against the gold standard of conventional audiometry performed inside a soundproof booth. These studies consistently conclude that there is no clinically significant difference between the two methods.

- A study by Maclennan-Smith et al. (2013) found that audiometric thresholds obtained outside the test booth were similar to those obtained inside for ≥95% of participants.[5]
- A study by Storey et al. (2021) demonstrated clinical validity to within ±10 dB of standard audiometry for 94.5% of all thresholds measured with a boothless approach.[8]
- A 2022 study on patients with multidrug-resistant tuberculosis found that automated audiometry with the Kuduwave Prime in a 60 dB open space was a valid method for hearing examination, with sensitivity ranging from 80-97% and positive predictive value from 74-98% compared to conventional audiometry in a 28 dB soundproof chamber.[9]

- Multiple other validation studies have confirmed the accuracy of Kuduwave audiometry in diverse settings, including schools, rural communities, and for older adults, consistently demonstrating its reliability outside of a sound-treated environment.[10]

5.2 The Ultimate Case Study: NASA and the International Space Station (ISS)

The most compelling validation of the Kuduwave's capability comes from its selection and deployment by the U.S. National Aeronautics and Space Administration (NASA) for use aboard the International Space Station (ISS). The ISS is an extremely challenging acoustic environment, with constant background noise from fans, pumps, and life support systems reaching levels of 60-70 dB. In this environment, a traditional sound booth is an impossibility.

NASA selected a modified Kuduwave Pro-TMP specifically because its "unique noise attenuation and noise monitoring features are well suited for the challenge of assessing hearing in ambient noise levels created by multiple fans and hardware systems". Astronauts now use the device to conduct self-administered hearing assessments in orbit. The successful deployment and ongoing use of the Kuduwave on the ISS provides definitive proof of concept: if the technology can produce valid audiograms in the high-noise, zero-gravity environment of space, it is more than capable of performing accurately in a quiet room on Earth.[12]

5.3 Broader Acceptance and Application

The move towards boothless audiometry is not a niche trend but a global shift in hearing healthcare delivery. In the United States, the Department of Veterans Affairs (VA) has successfully implemented boothless audiometry clinics to improve access to care for veterans, reducing travel and wait times while achieving high patient satisfaction ratings (94.9% for quality, 96.4% for satisfaction).[13] The technology is also being used to bring hearing testing into schools, remote and underserved communities, and industrial sites, demonstrating its versatility and effectiveness in breaking down the traditional barriers of cost and location associated with sound booths.[10]

6.0 Practical Guidance and Recommendations for Occupational Health Professionals

To ensure full and demonstrable compliance with SANS 10083:2023 when using Kuduwave audiometers, practitioners should adopt the following best-practice protocol. This protocol not only meets the requirements of the standard but also establishes a robust quality assurance framework.

6.1 A Protocol for Ensuring and Documenting Compliance

1. **Maintain Calibration Certificates:** As per SANS 10083:2023, Clause 16.3, ensure that stationary Kuduwave audiometer undergoes an annual calibration by an accredited laboratory. The resulting calibration certificate is a primary compliance document. (Mobile audiometry requires quarterly calibrations).[1]
2. **Utilize Real-Time Noise Monitoring:** Make the on-screen ambient noise monitor an active part of every test. Before initiating a test, observe the indicator to confirm a "pass" condition. If the indicator shows a "fail" or "warning" during a test due to transient noise, pause the test and only resume when the indicator returns to "pass." Document in the patient's record or test report that "All thresholds were obtained while real-time in-ear noise monitoring confirmed ambient noise levels

were within permissible limits as per SANS 10182 / ISO 8253-1." This creates an auditable, per-test record of compliance that is superior to a static annual room certificate.
3. **Reported Ambient Noise Levels:** The Kuduwave report on the test reports the ambient noise levels for each frequency tested. These values must be taken into consideration when interpreting the Hearing level results.
4. **Conduct Preliminary Site Surveys:** When setting up at a new or unfamiliar mobile testing location, use the Kuduwave's integrated sound level meter ("Noise-Check" feature) to perform a brief survey of the room's general ambient noise level. This allows for optimal placement of the testing station away from noise sources like air conditioners or high-traffic areas.[4]

6.2 Responding to Audits and Inquiries

Should the use of a boothless methodology be questioned during an audit or inquiry, practitioners can confidently defend their practice by presenting the following logical arguments, supported by the evidence in this report:

- **The Standard is Performance-Based:** The primary requirement of SANS 10083:2023 is compliance with SANS 10182, which defines a required acoustic outcome (meeting MPANLs), not a prescribed piece of equipment. The environment must be certified to be quiet enough for the transducers in use.
- **The Kuduwave Creates a Compliant Environment:** The device's validated high-attenuation headset creates a compliant micro-environment at the ear, meeting the standard's performance requirement.
- **Note 1 is Scientifically Reconciled:** Explain that the device's "actual attenuation" is known and laboratory-validated, thereby satisfying a correct interpretation of the note. The premise of field measurement is scientifically unsound.
- **Continuous Monitoring Provides Superior QA:** Present the real-time noise monitoring feature as a dynamic quality assurance system that provides a higher level of data integrity than a static, annual booth certification.
- **The Method is Clinically and Scientifically Validated:** Reference the extensive peer-reviewed literature and the ultimate validation by NASA to demonstrate that the methodology is not experimental but is an established and accepted standard of care.

7.0 Conclusion: Advancing Hearing Conservation with Modern Technology

7.1 SANS 10083:2023 as a Forward-Looking Standard

SANS 10083:2023, when interpreted through the lens of its core scientific principles, continues to be a forward-looking standard that supports technological advancement in the service of better hearing conservation. While the ambiguity of Clause 15.1.2.3, Note 1, is an unfortunate addition and warrants future revision, it does not invalidate the standard's long-standing, fundamentally performance-based approach. By consistently focusing on the required acoustic outcome rather than the physical means, the standard empowers professionals to adopt the most effective and efficient tools available.

7.2 Kuduwave as a Compliant and Superior Solution

The Kuduwave boothless audiometry system represents more than just a compliant alternative to the traditional booth-based model; it is a technological advancement that enhances the quality and integrity of occupational hearing testing. The system's combination of high passive sound attenuation and, most importantly, active real-time ambient noise monitoring, provides a level of dynamic quality assurance that is impossible to achieve with a passive sound booth alone. The extensive clinical validation, culminating in its use by NASA on the International Space Station, confirms its accuracy and reliability beyond any reasonable doubt.

7.3 Final Endorsement

Occupational health professionals in South Africa can proceed with confidence in using Kuduwave audiometers for SANS 10083:2023 compliant testing. By adhering to the practical protocols outlined in this report and understanding the scientific principles that underpin boothless audiometry, practitioners can leverage this technology to expand access to care, improve operational efficiency, and elevate the standard of their hearing conservation programmes. This modern approach aligns perfectly with the ultimate goal of SANS 10083: to protect the hearing health of the South African workforce through accurate, reliable, and accessible medical surveillance.

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