Comparative Electro-Acoustic Analysis of Cerumen Protection Systems (HF3, HF4, Cerustop) in the Phonak Sound Delivery System 6.0 (SDS 6.0) Platform: Implications for Optimal Fidelity and Reliability

I. Executive Summary: Performance Synthesis and Primary Recommendations

The determination of which wax filter—HF3, HF4, or Cerustop—provides superior acoustic performance in the Phonak Sound Delivery System 6.0 (SDS 6.0) architecture is not a matter of subjective preference but one governed by mandatory mechanical compatibility and quantifiable physical dimensions. The critical distinction lies in the coupling system utilized: standard dome fittings mandate the use of Cerustop, while custom earpieces require either HF3 or HF4. Direct comparison is therefore limited to the HF series when used with custom products.

For custom applications where a choice exists, the HF3 filter is conclusively superior to the HF4. The HF3 possesses a larger physical diameter (3.0–3.3 mm versus 2.2–2.4 mm, respectively). This increased aperture translates directly into two principal acoustic advantages: first, a measurable reduction in acoustic mass impedance, which yields "Better acoustic reliability" and a more accurate frequency response ; and second, a significantly larger internal volume for cerumen collection, ensuring "longer filter change intervals" and greater resistance to sudden acoustic degradation via blockage.

The goal of "hearing better" is therefore realized through selecting the filter that offers the most consistent acoustic output over time. For the SDS 6.0 custom line, this unequivocally points to the HF3, provided the physical anatomy of the ear canal accommodates its fitting. The Cerustop filter, mandated for standard dome fittings, serves as the acoustically optimized baseline for that particular coupling system.

Filter System	Coupling System	Primary Fit Factor	Nominal Diameter (mm)	Acoustic Reliability (Clean)	Cerumen Capacity	Long-Term Performance
Cerustop	Standard Receiver + Dome	Universal RIC Standard	N/A (Smallest aperture)	Optimized Baseline Transparency	Standard	Highly Reliable (requires timely maintenance)
HF4	Custom Earpiece	Narrow Canals Only	2.2 – 2.4	Less Accurate	Small Cavity	Prone to Quick

Filter System	Coupling System	Primary Fit Factor	Nominal Diameter (mm)	Acoustic Reliability (Clean)	Cerumen Capacity	Long-Term Performance
	(SlimTip/cShell)			Acoustic Performance		Blockage
HF3	Custom Earpiece (SlimTip/cShell)	Wide Canals / High Power	3.0 – 3.3	Better Acoustic Reliability	Large Cavity	Best Longevity and Fidelity

II. Introduction to SDS 6.0 Architecture and the Imperative of Cerumen Management

2.1 The Phonak SDS 6.0 Platform and Acoustic Goals

The Phonak Sound Delivery System 6.0 (SDS 6.0) represents the latest generation of receiver technology, launched in 2024 for the Audéo Infinio and Audéo Sphere hearing aid lines. This architecture is designed to deliver enhanced sound clarity, improved speech understanding, and superior overall performance compared to previous generations (e.g., SDS 4.0/5.0). Preliminary technical descriptions suggest that the receiver architecture aims to provide an expanded frequency response, notably by adding higher frequencies to the output, a crucial element for maximizing speech discrimination.

2.2 The Wax Guard as an Acoustic Component

Wax guards, alternatively known as wax filters or cerumen traps, are miniature protective barriers located at the sound outlet of the receiver-in-canal (RIC) or in-the-ear (ITE) hearing instrument. Their primary mandate is to prevent earwax (cerumen), moisture, and environmental debris from infiltrating the delicate, miniature loudspeaker (receiver). Failure to utilize or maintain these components is the most common cause of hearing aid malfunction, resulting in compromised sound transmission, reduced amplification quality, and potentially necessitating costly lab repair.

The essentiality of the wax guard positions it at a critical point in the electro-acoustic path. Due to its physical presence—comprising a mesh filter and the minute air cavity created between the receiver diaphragm and the filter—it introduces acoustic variables, specifically impedance, that can modify the programmed frequency response of the hearing aid. Therefore, the choice of filter is not merely about maintenance; it is intrinsically linked to the hearing aid’s output fidelity.

2.3 Defining Optimal Performance

Optimal hearing aid performance is achieved through a synergy of two factors: initial acoustic transparency and long-term acoustic reliability. Initial acoustic transparency refers to the filter’s ability to allow the full frequency bandwidth programmed by the hearing care professional to pass through with minimal insertion loss (attenuation) when the filter is clean. Long-term acoustic reliability, however, relates to the filter's structural resistance to performance degradation caused by earwax or moisture buildup over the typical wear cycle. The filter that balances minimal impedance with maximum cerumen capacity will, in practice, deliver the most

consistent and superior sound quality to the user, providing the practical definition of "hearing better."

III. Mechanical Constraints: Filter Compatibility and Mandatory Selection

A fundamental finding of the analysis is that the user’s ability to choose among Cerustop, HF3, and HF4 is severely constrained by the physical coupling system used with the SDS 6.0 receiver. Mechanical compatibility is a first-order constraint that dictates selection, limiting direct acoustic comparison primarily to the HF series.

3.1 Cerustop: The Default for Standard RIC Fittings

For Phonak’s latest SDS 6.0 receivers, such as those compatible with the Audéo Infinio and Audéo Sphere hearing aids, the receiver wire, when used with standard Phonak 4.0 Domes, is engineered to utilize **Cerustop Filters**. Cerustop is a well-established, proprietary system designed for standard RIC and ITE products across several manufacturers, including Phonak and Unitron. This selection is functionally mandatory for users relying on non-custom dome tips for coupling.

3.2 HF Series: The Requirement for Custom Earpieces

In contrast, the HF3 and HF4 filters are explicitly designated for use exclusively with **custom earpieces**, specifically cShells and SlimTips, on the SDS 6.0 platform. Custom molds are often required for higher degrees of hearing loss, complicated canal anatomy, or when greater retention and feedback reduction are necessary.
A critical barrier exists because the mechanical seating mechanisms for HF filters and Cerustop filters are physically different. Consequently, a Cerustop filter cannot be substituted for an HF3 or HF4 filter in a custom mold fitting, nor can an HF filter be used in a dome-based system. This mechanical design requirement establishes that Cerustop operates in a distinct and incompatible acoustic coupling system compared to the HF series. The most relevant performance comparison for the end user is therefore the direct acoustic trade-off between HF3 and HF4 in the context of custom molds.

3.3 Dimensional Differentiation of HF3 and HF4

The functional difference between the HF3 and HF4 filters is entirely based on their physical diameters. The HF3 is defined as the larger filter, measuring 3.0 mm or 3.3 mm in diameter. The HF4 is the smaller variant, measuring 2.4 mm or 2.2 mm in diameter. Both types use a fine mesh filter to prevent cerumen ingress.
This dimensional differentiation is necessitated by ear canal anatomy. The smaller HF4 is required when the physical constraints of a narrow ear canal dictate the use of a custom earpiece with a reduced diameter, thereby requiring a smaller filter aperture. Conversely, the HF3 is used when the ear canal provides sufficient space, allowing the use of the larger filter housing. This demonstrates that the initial filter choice for custom products is dictated not by acoustic preference, but by the physical limits of the user's anatomy.

IV. Advanced Electro-Acoustic Theory and Filter-Induced Impedance

The physical difference in diameter between the HF3 and HF4 filters creates predictable and quantifiable variations in their electro-acoustic performance, directly addressing the question of which option allows the user to "hear better."

4.1 Acoustic Loading and Impedance Modeling

A wax guard is modeled in acoustic engineering as a non-ideal component that contributes acoustic mass and resistance to the sound delivery pathway. The miniature air volume contained within the receiver output cavity, coupled with the resistive nature of the fine mesh filter, introduces acoustic impedance into the system.
In the confined space of a hearing aid coupler, the presence of this structure can result in high-frequency damping. Acoustic theory confirms that the dimensions of the sound outlet, including the filter and any associated vent, significantly influence the frequency response. Specifically, the acoustic mass effect tends to permit low frequencies to pass relatively unobstructed, while providing greater obstruction or damping to high-frequency acoustic energy. Any increase in acoustic impedance will typically result in insertion loss, particularly in the critical high-frequency regions required for speech clarity.

4.2 The Acoustic Advantage of HF3's Larger Diameter

The larger diameter of the HF3 (3.0–3.3 mm) provides a wider acoustic aperture compared to the HF4 (2.2–2.4 mm). In acoustic physics, increasing the diameter of an aperture reduces the resultant acoustic mass impedance that the aperture imposes on the sound path.
This reduction in impedance is crucial for maintaining the fidelity of the SDS 6.0 system, which is explicitly engineered to enhance high-frequency output. By minimizing high-frequency damping, the larger HF3 filter ensures that the user receives the full clarity and bandwidth intended by the advanced sound processing features of the hearing aid. Manufacturer documentation supports this theoretical premise by explicitly correlating the HF3 filter with "Better acoustic reliability". This confirms that the HF3 configuration minimally perturbs the intended acoustic transfer function. Furthermore, the larger internal cavity volume of the HF3 minimizes perturbation to the natural resonance characteristics of the coupled air volume, contributing to stable, predictable acoustic output that is crucial for the sophisticated processing of the AutoSense 6.0 platform.

4.3 The Detriment of HF4 and the Role of Compromise

The inverse relationship holds true for the smaller HF4 filter. Its reduced aperture creates a comparatively greater acoustic load on the receiver. This increased impedance results in more pronounced high-frequency roll-off, a form of insertion loss that compromises the accuracy of the acoustic output. Phonak notes this detriment directly, stating that the HF4 results in "Less accurate on the acoustic performances".
This acoustic compromise is an inevitable consequence when the user's anatomy dictates a smaller custom earpiece. The mechanical constraint—a narrow ear canal—mandates the

smaller mold, which in turn necessitates the smaller HF4 filter. While the HF4 is functionally crucial for protection in narrow canals, the user must accept a trade-off in peak acoustic fidelity. For the hearing professional, this implies that the HF4 is a necessary engineering compromise, while the HF3 represents the acoustically optimal choice.

4.4 Cerustop Acoustic Performance (Baseline Transparency)

Cerustop filters are typically designed to be highly transparent acoustically when clean. While proprietary data specifically comparing Cerustop's clean filter frequency response against HF3 is not publicly detailed in clinical literature, similar advanced protective systems have been shown to introduce a negligible difference, often less than 1 dB, across the frequency range when new. Cerustop is considered the optimized baseline for the standard dome-based SDS 6.0 system, achieving the highest possible fidelity within its non-custom mechanical constraints.

V. Comparative Reliability and Longevity: The Dominance of Maintenance

While the difference in acoustic performance between a clean HF3 and a clean HF4 might be subtle, the practical reality of "hearing better" in a real-world scenario is overwhelmingly influenced by the filter's resistance to blockage. A filter's longevity and reliability are critical determinants of consistent acoustic output.

5.1 Longevity by Design: Cerumen Capacity

The principal functional advantage of the HF3 filter relates directly to its physical size: its large diameter is specifically designed for "longer filter change intervals". The increased dimensions allow for a larger internal cavity or surface area dedicated to trapping cerumen and debris before the sound pathway is compromised. This extended reliability profile ensures the integrity of the acoustic signal is preserved for a longer period between maintenance cycles.
In direct contrast, the smaller HF4 filter is explicitly categorized as having a "Small cavity for trapping cerumen can block quickly". This means that in users with moderate to high cerumen production, the HF4's acoustic performance degrades rapidly. The potential for immediate performance reduction is higher with HF4 than with HF3, making the acoustic stability of the HF4 configuration markedly inferior over the course of a typical replacement period.

5.2 Acoustic Degradation due to Blockage

The most common failure mode in hearing aids is wax obstruction of the sound outlet. When a filter clogs, the acoustic output rapidly deteriorates from slight muffling or distortion to a complete loss of sound. This catastrophic failure mode is far more detrimental to the user's communication ability than any minor difference in the clean-filter frequency response between HF3 and HF4.
Therefore, the functional superiority of the HF3 filter lies not only in its initial fidelity but in its ability to resist this rapid performance degradation. Because the HF3 maintains clear acoustic transfer for a longer duration than the HF4, it offers a statistically superior average acoustic performance throughout the required maintenance cycle (which is typically four weeks, but can vary from weekly to monthly). This consistent, uninterrupted sound delivery is the ultimate

criterion for ensuring a user truly "hears better."

5.3 Maintenance and Filter Replacement Protocol

Regardless of the wax guard type—Cerustop, HF3, or HF4—regular maintenance is non-negotiable for preserving optimal hearing aid function. Phonak recommends that earwax protection systems should be inspected regularly and exchanged approximately every four weeks, or immediately if any reduction in volume or sound quality is detected.
Users must employ the correct, designated exchange tool and procedure for their specific filter type to prevent structural damage to the receiver or the custom earpiece. It is crucial for users of custom molds to verify with their hearing care professional whether they require HF3 or HF4, as attempting to seat an HF4 into the aperture designed for an HF3 may lead to improper retention and potential loss of the filter element within the ear canal. Furthermore, moisture accumulation is a significant accelerant of receiver failure and filter blockage, emphasizing the importance of utilizing active drying solutions, such as the Phonak D-Dry system, to maximize component life and acoustic consistency.

VI. Detailed Recommendations and Clinical Application

6.1 Clinical Guidance for Ultra Power (UP) Receivers

The dimensional and acoustic advantages of the HF3 filter gain particular significance when paired with high-power systems. The analysis notes that the HF3 is specifically recommended for custom cShells utilized with Ultra Power (UP) receivers on the SDS 6.0 platform.
UP receivers are necessary for users with severe to profound hearing losses and require maximum stable acoustic gain. These fittings are highly sensitive to feedback and acoustic degradation. Any loss of clarity or attenuation caused by a restrictive or blocked filter, such as the HF4, disproportionately impacts the user’s ability to discriminate speech and benefit from the amplification. The HF3, by minimizing acoustic load and resisting blockage, is functionally necessary to ensure the high-power fitting maintains its intended clinical efficacy, thereby providing a robust and reliable listening experience.

6.2 Filter Selection and the Role of the Hearing Care Professional

Because filter selection is dictated by mechanical constraints rather than simple acoustic choice, the hearing care professional (HCP) plays a central role in fitting.
For the vast majority of users fitted with the SDS 6.0 receiver utilizing a standard dome, the mandated filter is Cerustop. This is the engineered solution for that coupling architecture.
For users requiring custom earpieces (cShell or SlimTip), the HCP determines whether the ear canal dimensions permit the use of the acoustically superior HF3 (3.0–3.3 mm). If the canal is too narrow, the smaller HF4 (2.2–2.4 mm) becomes the obligatory choice, accepting the trade-off of "Less accurate on the acoustic performances" and shorter functional longevity.
The realization that the filter choice reflects the required power level and anatomical constraint underscores the complexity of optimizing fidelity in custom fittings. While the HF3 is clearly acoustically superior, it is not universally applicable.

VII. Conclusion: Synthesis of Acoustic Performance and User Experience

The question of whether HF3, HF4, or Cerustop is acoustically superior for Phonak SDS 6.0 receivers is answered by a synthesis of mechanical compatibility, acoustic impedance theory, and practical reliability data.
The Cerustop filter is the mandatory, acoustically optimized solution for standard dome-based SDS 6.0 fittings.
For custom earpieces, the HF3 filter provides superior acoustic performance and reliability compared to the HF4. The HF3's larger diameter minimizes acoustic impedance, resulting in a more accurate frequency response and reduced high-frequency damping. Furthermore, the increased size provides a larger cerumen reservoir, granting significantly extended functional life and mitigating the primary cause of sudden acoustic failure. This advantage in reliability means the HF3 delivers more consistent and predictable sound quality over time, making it the preferred option for users seeking maximal fidelity and stable performance. This superiority is amplified in high-gain fittings, where the HF3 is recommended for Ultra Power receivers to preserve crucial acoustic stability and gain.
In conclusion, to maximize the benefit and "hear better" through a Phonak SDS 6.0 hearing aid, users must adhere strictly to the coupling system's mechanical requirements. Where custom fittings allow a choice, the selection of the larger HF3 yields tangible acoustic and reliability benefits. Above all, maintaining the integrity of the chosen filter through rigorous and timely replacement remains the single most critical factor in ensuring the hearing aid operates at its maximum potential performance.

Cytowane prace

1. HF3 & HF4 Wax Filters – Cerustop, https://www.cerustop.co.uk/product/hf3-hf4-wax-filters/ 2. HF wax filters - Phonak - Claso Audiología, https://claso.net/en/hf-wax-filters 3. Custom Product Reference Guide (New!) - Phonak, https://www.phonakpro.com/content/dam/phonakpro/gc_hq/en/campaigns/ite-excellence/documents/PH_ReferenceGuide_CustomProducts_210x297_EN_027-0670-02.pdf 4. Phonak 6.0 Receivers for Phonak Infinio and Sphere Hearing Aids, https://www.hearingaidaccessory.com/phonak-receiver/phonak-6-0-receivers-for-phonak-infinio-and-sphere-hearing-aids/ 5. Phonak Hearing Aids Review: A Comprehensive Guide - National Council on Aging, https://www.ncoa.org/product-resources/hearing-aids/phonak-review/ 6. Not using filters - On Phonak Sphere cShell Molds - Page 2 - Hearing Aid Forum, https://forum.hearingtracker.com/t/not-using-filters-on-phonak-sphere-cshell-molds/100787?page=2 7. The Importance of Wax Guards in Hearing Aid Care, https://lacanadahearing.com/blog/the-importance-of-wax-guards-in-hearing-aid-care 8. Cerustop Wax Guards - Hearing Aid Filters, https://www.hearinggroup.com/product/cerustop-hearing-aid-wax-guards/ 9. Understanding the Importance of Regular Wax Filter Replacement in Hearing Aids, https://aanviihearing.com/blogs-on-hearing-health/understanding-the-importance-of-regular-wax-filter-replacement-in-hearing-aids 10. Signia miniReceiver / HF4 PRO / C-Grid / Nanocare wax guards - Spectrum Hearing, https://spectrum-hearing.co.za/blog/signia-minireceiver-wax-guards/ 11. Using Transfer-Matrix Computation to Analyze Wax Guard Acoustics | COMSOL Blog, https://www.comsol.com/blogs/using-transfer-matrix-computation-to-analyze-wax-guard-acoustic

s 12. Wax Traps - the weak link of a hearing aid - HearingUp, https://hearingup.com/videos/wax-traps 13. Phonak S Receiver 6.0 | Enhanced Compatibility - Japebo.com, https://japebo.com/phonak-s-receiver-6-0/ 14. SDS 6.0 Tips and Tricks - Hearing Aid Forum, https://forum.hearingtracker.com/uploads/short-url/w5mhBOnVNKfNAHlLzewQ3ShnfCy.pdf 15. Phonak wax guard problem - Hearing Aid Forum, https://forum.hearingtracker.com/t/phonak-wax-guard-problem/105189 16. UNIVERSITY OF SOUTHAMPTON INSTITUTE OF SOUND AND VIBRATION RESEARCH A STUDY OF EARMOULD MODIFICATION EFFECTS ON THE FREQUENCY RE, https://eprints.soton.ac.uk/422842/1/92019511.pdf 17. The acoustical effect of various factors on the frequency response of a hearing aid receiver, https://www.researchgate.net/publication/287646778_The_acoustical_effect_of_various_factors_on_the_frequency_response_of_a_hearing_aid_receiver 18. Phonak Hearing Aids Review by Testers & Audiologists (2025), https://audiologists.org/brand-reviews/phonak-hearing-aids-review 19. A New System to Protect Hearing Aids from Cerumen and Moisture, https://hearingreview.com/hearing-products/hearing-aids/a-new-system-to-protect-hearing-aids-from-cerumen-and-moisture 20. HF3 / HF4 Wax Filters - Shop Omni Hearing Inc., https://shop.omnihearing.ca/products/hf3-hf4-filters-black 21. How to change the wax filter with CeruStop on Phonak hearing aids, https://www.phonak.com/en-us/support/knowledge-base/articles/how-to-change-the-wax-filter-with-cerustop-on-phonak-hearing-aids