REFURBISHMENT OF THE ANECHOIC CHAMBER AT THE UNIVERSITY OF SOUTHAMPTON

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1 INTRODUCTION

Anechoic chambers consist of rooms with sound absorbing material on all surfaces (walls, floor and ceiling) to eliminate sound reflections or echoes and thereby room effects, so that measurements can be made in an ideal, repeatable and standardised ‘free-field’ environment. In addition, many specialist measurements or hearing research studies require very low background noise levels which must be accommodated.

The principal performance requirements of an anechoic room are low internal background noise and the provision of a free-field environment, for example, as required when using precision methods to measure sound power levels in accordance with BS EN ISO 3745:2012[1]. The free-field conditions are verified using the procedure described in BS EN ISO 26101-1:2022[2]. A sound source is placed at the position which would be occupied by a device being tested and sound pressure levels are measured along ‘chords’ away from the source to the corners and walls of the room. Sound pressure levels should attenuate with distance at 6 dB per doubling of distance in accordance with the inverse square law. BS EN ISO 3745 allows deviations from the ideal inverse square law of ± 1 dB in frequency bands from 800 Hz to 5000 Hz, and ± 1.5 dB at frequencies above and below this range.

The anechoic chamber at the University of Southampton was one of the first and largest facilities of its type in the UK and is now around 45 years old. With substantial use and general wear and tear over the years, refurbishment and replacement of the sound absorbing wedges has been required from time to time, roughly at 25 year intervals. Due to the specialist nature of these facilities and stringent acoustic requirements, any modifications must be managed carefully, with consideration of acoustic conditions, noise and vibration levels, ventilation, health and safety, and usability aspects.

This paper outlines the background and challenges of the latest anechoic chamber refurbishment, and gives acoustic results, alongside discussion of accommodating modern measurement and work practices in the design.

2 BACKGROUND

The large anechoic chamber at ISVR, was originally constructed in 1968, it consists of a 0.305 m (actually 1 ft) thick reinforced concrete structure, with the interior measuring 9.2 × 9.2 × 7.3 m (l × w × h). The anechoic chamber is isolated from the surrounding building structure and reverberation chamber by means of rubber bearings and airgaps which ensures that noise and vibration from elsewhere in the building and from the outside world is kept to a minimum. A schematic of the anechoic chamber and adjacent facilities is shown in Figure 1.

The original configuration of the chamber is shown in Figure 2. Reflections from the chamber’s surfaces were suppressed by means of over 8000 acoustically absorbent, open-cell polyurethane foam wedges which can be seen in the figure. There are limits to the effectiveness of any acoustic treatment, and the amount of acoustic absorption at low frequencies is determined by the length and material composition of the wedges. Longer wedges result in a free-field environment being achieved at lower frequencies, but this comes at the expense of reduced usable space in the interior of the chamber. Generally wedges are highly effective absorbers of sound at frequencies above a nominal 'cut-off' frequency that corresponds to a wedge length of a quarter wavelength, although there is a gentle roll-off for absorption at lower frequencies. The original foam wedges had a length of 91 cm (3 ft) corresponding to a quarter wavelength of about 93 Hz, and the chamber was recorded[3] as having a free-field response down to 70 Hz.

The chamber floor was made up of removable steel grid panels, approximately 60 cm square, supported above the floor wedges by removable steel posts at each corner. These posts were located in sockets permanently bolted to the concrete floor. The sockets and posts were spaced approximately 60 cm (2 ft) apart. Floor panels and posts could be installed or removed as required, and can be seen in Figure 2. The floor was capable of supporting a load of several tons, and allowed level access from the adjacent corridor and control room.

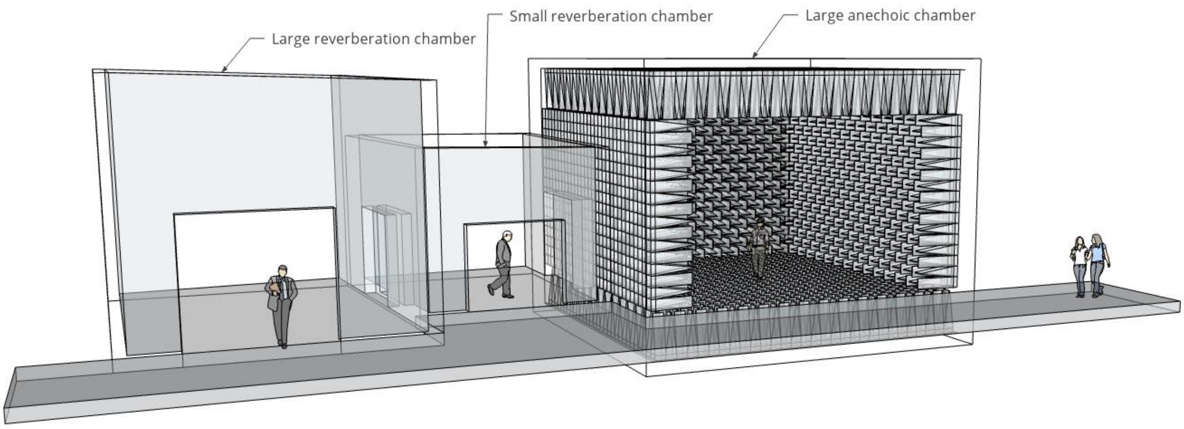

Figure 1. Schematic of chamber layout

Figure 2. Sound level measurements in the original anechoic chamber, circa 1975

The anechoic chamber underwent a refurbishment in 1995. The main modification was the replacement of the original wedges by mineral fibre wedges in a lightly woven retaining jacket. The new wedges were the same length as the original ones at 91 cm. The free-field conditions were recorded[4] as extending down to roughly 80 Hz. The original floor was retained.

Since 1995, the anechoic chamber has seen heavy use, by scores of undergraduates, postgraduates and external consultancy customers. Over the years some of the glass-fibre wedges had sagged particularly around the side doors of the chamber, where wedges had been removed, for access to install large items of equipment, and then poorly replaced. While the acoustic performance had not suffered unduly, aesthetics and other limitations, particularly with the flooring, made another refurbishment desirable, if not essential.

3 REFURBISHMENT: DESIGN

The latest refurbishment, completed in 2022, presented the opportunity to make some changes to the anechoic chamber design, mainly to improve usability and ensure longevity of the facility.

3.1 Chamber floor

One of the major, long-standing concerns was the floor of the anechoic chamber. The steel gratings that had been used since the chamber was built could be installed or removed to suit the test or measurement requirements. When in place they provided a load bearing capacity of several tons but could be removed during tests to reduce any impact on the acoustic characteristics of the chamber. However, these gratings were considerably heavy and cumbersome. Installing or removing them required a good deal of time and effort and could take two people two or three hours to install or remove the full floor. The weight of the panels and posts was also a health and safety problem with manual handling considerations.

Many discussions were held between facility users on the subject of flooring. The anechoic chamber has a wide range of uses from original academic research in the ISVR to product development and commercial testing by ISVR Consulting. Some potential users wanted a permanent wire-mesh floor held in tension with wall anchors. Other potential users wanted a rigid load-bearing grid floor similar to the original, but much lighter in weight. A wire-mesh floor is often used in anechoic chambers and has the advantage of having negligible impact on the acoustic free-field environment. It has the disadvantages of a much-reduced load-bearing capacity and of inherently reduced stability or ‘trampoline’ effect. The trampoline effect can make it difficult to quickly and accurately position microphones on stands because the mesh floor sags slightly when walked on and the microphone stands will sway. Based on existing experience in the room, a lighter weight grid floor would affect the free field only slightly at higher frequencies, but would enable tests of heavy machinery and experimental rigs and the accurate positioning of microphones. The grid floor could also be covered with substantial solid boards to convert the room to a hemi-anechoic chamber to allow tests requiring a ‘free field over a reflecting plane’.

Ultimately it was decided, despite cost implications, to provide the best of both worlds: a permanently-installed wire-mesh floor with a removable grating system above.

The wire mesh can hold up to 8 persons, distributed across the floor, and has the advantage of being able to catch some dropped items that might otherwise have been difficult to retrieve from the depths of the floor wedges. The new rigid floor system was made of 60 cm square GRP (glass-reinforced plastic) gratings, which are much lighter and thinner than the previous steel gratings, but still able to support several tons whilst having minimal impact on the acoustic environment. The new gratings can easily be carried and fitted by one person and are supported on new posts which fit into the original floor sockets from 1988.

An image of the flooring systems is shown in Figure 3, in which operators are shown standing on the wire-mesh floor, and an item of equipment under test is mounted on a section of rigid flooring.

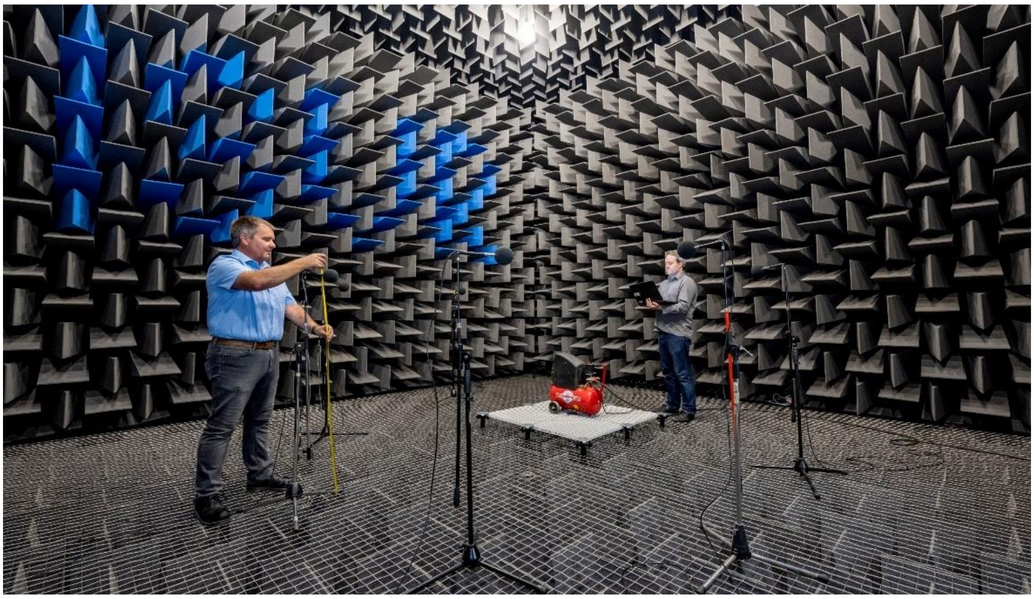

Figure 3. The refurbished anechoic chamber, 2022

3.2 Acoustic wedges

The mineral fibre wedges used in the 1995 refurbishment had provided many years of good use, but were sagging and had the disadvantages that their handling required PPE to be worn to avoid skin irritation. In addition, after extended periods of time in the chamber, some users had complained of a dry throat, which had been attributed to fibres from the wedges if disturbed.

The consideration of new wedges included aspects of acoustic performance, fire safety, PPE requirements and aesthetics. The decision was to use 3209 non-flammable, open-cell polyurethane wedges, with an overall length of 1.20 m, with a taper of 1.075 m to meet the design criterion of an 80 Hz cut-off frequency. As such, the usable space between wedge tips was slightly reduced compared to the previous 91 cm wedges, but with an improved low-frequency performance. The qualification tests of the newly refurbished chamber show that the free-field conditions now extend down to 63 Hz.

The refurbishment of the anechoic chamber, from the removal of the old wedges to the installation of the new wedges and floor systems, is illustrated in three articles on LinkedIn[5–7].

3.3 Other changes

When undertaking sound insulation tests between the adjacent reverberation chamber and the anechoic chamber, it is necessary to remove a section of wedges to reveal the test aperture. This was previously a laborious task. Therefore the recent refurbishment included the addition of a pivoting door mechanism to allow easier access. An additional pivoting door has been added for the aperture for the 'DARP' wind tunnel system[8], which allows aero-acoustic tests to be conducted for wind speeds up to 120 m/s.

The requirement for power supply during tests has increased over the years, and in response to this, additional power sockets have been installed. The lighting has also been improved, doubling the number of lights installed in the ceiling, with modern, brighter LED lights to offset the reduction in lighting attributed to the darker colour of the foam wedges. Remote monitoring for safety has been improved with the installation of unobtrusive webcams linked to a display screen in the control room and the main laboratory across the corridor.

Technical details of the refurbished room are available online on the ISVR Consulting[9] and the University of Southampton[10] websites.

4 ACOUSTIC RESULTS

Following the refurbishment, the acoustic environment has been verified. The free-field conditions were evaluated by traversing a measurement microphone along ‘chords’ from an omnidirectional sound source, using the method described in BS EN ISO 26101-1:2022[2]. The presence of the grating floor was shown to influence the free-field characteristics slightly at high frequencies for the downwards-oriented chords, as illustrated at 4000 Hz in Figure 4, but was still within the tolerance required by BS EN ISO 3745. The chamber meets the requirement of the standard at all test frequencies, and free-field conditions extend to a radius of at least 3 m from the centre of the room at all frequencies tested.

BS EN ISO 3745 also provides criteria for maximum background noise levels. The background noise levels were measured during the qualification testing with the ventilation off and are presented in Figure 5. The overall measured A-weighted background noise level was -0.5 dB(A), and the background noise levels meet the requirements of BS EN ISO 3745.

The refurbishment of the anechoic chamber has been considered a success, and remains in nearly constant use by academics, researchers and many external clients.

5 CONCLUSIONS

Anechoic chambers are important facilities for acoustic measurement for research, for product verification to international standards and for product development. The large anechoic chamber at the University of Southampton was originally constructed in 1968 and has been used extensively since. Although refurbished in 1995, another refurbishment was needed and overdue, and this was completed in 2022.

As part of the refurbishment, a new wire-mesh floor was installed, with a new light-weight removable rigid floor grating system above it. The rigid floor was shown to have a minor impact on the free-field response at high frequencies for some chord directions but was within the tolerance limits given by BS EN ISO 3745.

The acoustic wedges were replaced with longer polyurethane foam wedges, and improvements were also made to access, usability, and provision of lighting and power.

The refurbished large anechoic chamber has an improved low frequency response (down to 63 Hz) and has maintained its low background noise level of -0.5 dB(A), which also complies with the requirements of BS EN ISO 3745.

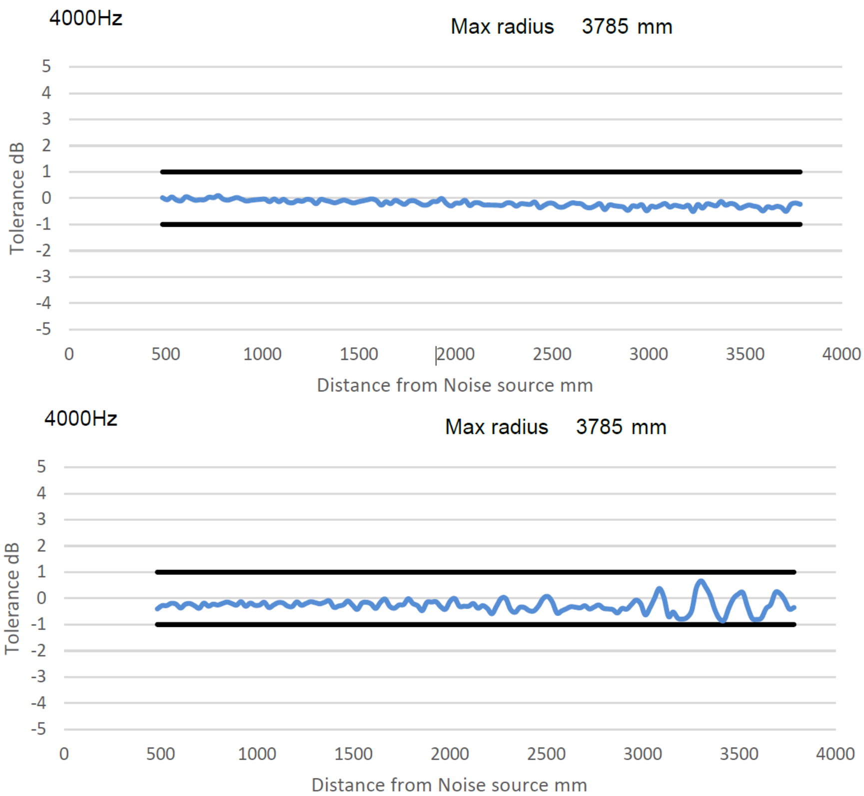

Figure 4. Sound pressure level deviation from inverse square law, downward facing chord, 4000 Hz, without grating (upper) and with grating (lower), from [11].

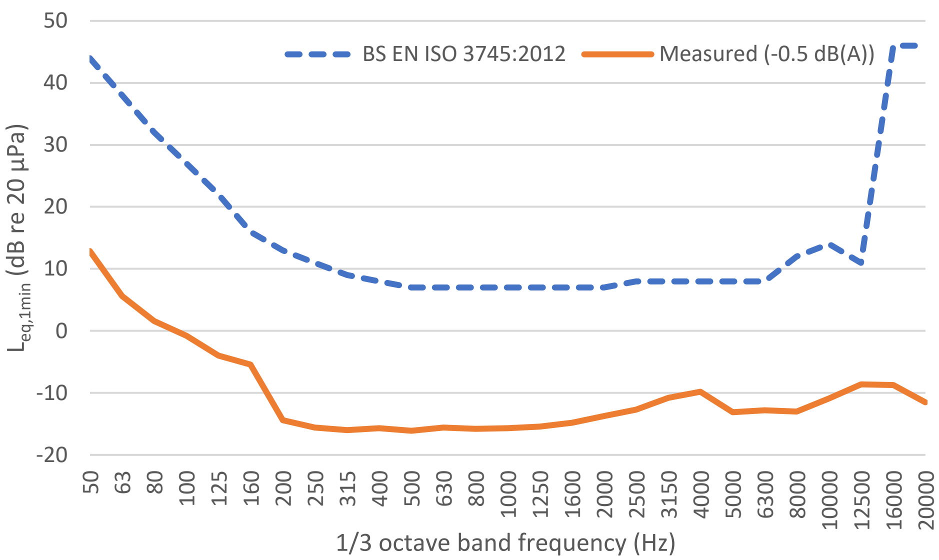

Figure 5. Measured background noise levels, including electronic noise from the instrumentation

6 ACKNOWLEDGEMENTS

The 2022 refurbishment of the anechoic chamber was made possible by a generous donation to the University of Southampton from the estate of John Gozzard (1932-2018), a British inventor and engineer. Working as a sound recordist for television in the 1970's, he was unhappy with the weight, robustness and performance of the existing microphone windshields. He therefore set about designing the cylindrical or Zeppelin shaped windshields which became the precursor to those often found in modern broadcasting and film environments. He went on to found Rycote in 1969, which remains the foremost brand in the design and production of microphone windshields. Figure 6 shows a selection of modern versions of these types of windshields.

The decision to invest a significant part of the donation into refurbishing the anechoic chamber was made on the basis of the chamber's importance to both research and commercial activity at the University of Southampton.

Figure 6. Windshields designed by John Gozzard and Rycote *(source: CineD)*

The 2022 refurbishment, and indeed the earlier 1995 refurbishment of the anechoic chamber were undertaken by IAC Acoustic Company UK Ltd, who also verified the performance of the room.

7 REFERENCES

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