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REPORT AS 2516/ACT

UNIVERSITY OF AALBORG: DENMARK

Anechoic Chamber & Listening Room Commissioning:

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For: Industrial Acoustics Ltd
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CONTENTS

1.0 INTRODUCTION

A new fully anechoic chamber has recently been built in the new Acoustics Laboratory at the University of Aalborg, Denmark. The chamber shell is constructed from IAC Noiselock (2) panels with an IAC panel floor, and internally lined with IAC foam absorptive wedges.

The anechoic performance of the chamber is required to comply with the qualification requirements of ISO 3745 between 200 Hz and 10 kHz over a specified measurement range in order to enable the University to carry out acoustic testing. The internal ambient noise level with the ventilation system operating is also required to achieve a performance specification set by the University in their document '*Arrangement works in the acoustic room:* November 2000'. The acoustic specification proposed by IAC Ltd is contained in their quotation and specification for the project.

In addition to the test chamber, a large Listening Room and two Listening Cabins have been constructed in the new Acoustics Laboratory. The are rooms isolated from the main building structure and are constructed from high performance Noise Lock (2) IAC acoustic panels with an outer plasterboard builderswork structure.

The internal ambient noise level with the ventilation system operating is required to achieve a performance specification set by the University in their November 2000 document with minor amendments agreed with IAC Ltd subsequently. The reverberation time in the Listening Room and permissible tolerances are also specified by the University.

2.0 BRIEF

To assess the free-field conditions within the anechoic chamber, by testing the inverse square law relationship along a number of different axes of the chamber, in accordance with the procedures described in ISO 3745 Sound Power Levels of Noise Sources: Part 5: '*Precision Methods for determination of Sound Power Levels for sources in anechoic and semi-anechoic rooms*'.

To measure background noise levels within the Anechoic Chamber, the Listening Room, and the Listening Cabins, with the ventilation system operating to ensure the chamber meets contractual specifications.

To measure the reverberation time in the Listening Room to ensure this meets contractual specifications. For completeness, the reverberation time in the Listening Cabins was also measured, although there is no specification for this.

To measure the available sound insulation provided by the Listening Room and the Listening Cabins, and identify any acoustic leakage.

3.0 INSTRUMENTATION

The following equipment was used during the course of the commissioning tests:

Norsonic precision integrating real time analyser	Type SA110
Rion precision Real Time Analyser	Type NA27E
Rion sound level calibrator	Type NC 73
Norsonic Sound Level Calibrator	Type 1253
Dell laptop computer	Type Inspiron 7000
C Audio: Power Amplifier	Type 600i
Custom Pink Noise Source	
Soundcraft Folio Powerpad Mixer	
Specialist acoustical software	
Bruel & Kjaer omni-directional loudspeaker system	Type 4295
Turbosound High Power Loudspeakers	Type Impact 120

All instrumentation was calibrated prior to commencement of the measurements, and operated in accordance with the manufacturers instructions.

4.0 TEST DESCRIPTION AND DISCUSSION

The layout of the rooms is shown in the IAC drawings AO-03082-1, Sheets 1 & 2.

4.1 ANECHOIC CHAMBER: INVERSE SQUARE LAW

The acoustic performance of an anechoic chamber is determined by comparing the behaviour of sound generated inside the chamber to a theoretical model of the behaviour of sound in a three dimensional free field. In free-field conditions, sound pressure levels of a point source will decrease at a rate of six decibels with doubling of distance from the source, in accordance with the inverse square law. For a chamber to be considered anechoic therefore, sound generated within must behave in a similar manner.

In order to accomplish this in a chamber which is a completely bounded space, its walls and ceilings must be treated with anechoic wedges which provide extremely high sound absorption characteristics. Sound waves which 'strike' any of these treated surfaces are almost fully absorbed thereby simulating continued propagation into free space.

If sound waves are not sufficiently absorbed by the boundary surfaces they will be reflected back into the space. The reflected waves will then combine with the direct sound waves causing unpredictable interference, resulting in the possibility of serious performance inaccuracies during acoustic testing in the chamber.

In practice, a chamber can provide satisfactory performance when the normal incidence absorption of its wedges is no less than 99% throughout the frequency range of interest. The cut-off frequency of the wedges is the lowest frequency within the range of frequencies for which the absorption coefficient is 99% or higher. In this case, the frequency range of concern is 200 Hz to 10 kHz.

In order for an anechoic chamber to qualify as providing an actual free-field environment for accurate sound level measurements, deviations from the inverse square law caused by reflections from surfaces within the chamber must lie within a well defined tolerance range, as laid down in ISO 3745. The effectiveness of an anechoic chamber, therefore, is usually determined by making sound pressure level measurements as a function of distance from a small omnidirectional source and comparing these results with corresponding values predicted by the inverse square law.

4.2 AMBIENT SOUND PRESSURE LEVELS

The required background noise level criteria for the chamber are shown in the Table 2516/TB1 in Appendix D of this Report. These are in terms of one third octave band levels. The background noise levels in terms of L_{eq} as specified in the contract documents were measured with the ventilation operating and with it switched off.

4.3 REVERBERATION TIME MEASUREMENTS

The required reverberation times are specified in the University document '*Arrangement works in the acoustic room:* November 2000'.

4.4 SOUND INSULATION MEASUREMENTS

The available sound insulation between the Listening Room and the Listening Cabins and the surrounding area was measured in accordance with procedure set out in BS EN ISO 140 - 4: 1998: '*Field measurement of sound insulation between rooms*'. Single number ratings were calculated in accordance with the procedure set out in BS EN ISO 717 - 1.

5.0 TESTING PROCEDURES

5.1 ANECHOIC CHAMBER: INVERSE SQUARE LAW

The sound measuring system was set up in the chamber, with instrumentation in the adjacent room, and the entire system was calibrated.

Inverse square law tests were conducted by generating a test signal from the loudspeaker system set up inside the chamber and taking the sound pressure level measurements at incremental distances from the sound source, on a wire line or chord transcribing the path for acceptable microphone locations as described in the ISO standard. The speaker was very close to the exact centre of the chamber and measurements were made radially outward in eight directions. The omni-directional source was placed on a support from the base chamber floor tubes and slightly above the cable floor close to the centre of the chamber.

The test frequency range was 63 Hz to 20kHz in bandwidth increments of one third octave, where the low frequency design cut-off is 200 Hz.

The distance from the centre of the sound source was measured along each chord to the microphone diaphragm. Sound pressure levels at constant amplification were then measured along the chord for several distances from the loudspeaker. Prior to testing, the chamber door was closed, making sure all un-necessary equipment was cleared from within. This was repeated for the other 7 chords (see figure 2516/SK1).

The test procedures used are in accordance with the applicable portions of ISO 3745-1977.

5.2 AMBIENT NOISE LEVELS

Measurements were taken in the centre of the anechoic chamber; the Listening Room; and the Listening Cabins, to determine the chamber noise level. Measurements were made in one third octave bandwidths at centre frequencies from 20 Hz to 20 kHz. Background noise measurements were taken with the lights off and with the ventilation fan operating and with it switched off.

Finally, after all the measurements had been completed, the noise measurement system was calibrated again to ensure no drift had occurred during the commissioning process.

5.3 REVERBERATION TIME MEASUREMENTS

The reverberation times were measured using a 0.38 calibre starting pistol as the source. Up to four locations were used in the various rooms tested and the average reverberation time recorded using the Rion NA27 Real Time Analyser set to its reverberation mode. This enables reverberation times at least as low as 0.15 seconds to be measured and gives a visual representation of the decay to enable spurious measurements to be discarded. A frequency range in one third octave bands between 63Hz and 8kHz was used.

5.4 SOUND INSULATION MEASUREMENTS

The available sound insulation was measured between the Listening Room and the adjacent rooms, and to the corridor. These measurements were carried out in one third octave bands between 100Hz and 3150Hz as specified in the Standard.

A sound source was set up in the Listening Rooms and Cabins as *'source'* rooms and fed with high levels of pink noise. The mean noise level inside the chamber and in the external (*'receive'*) areas was determined with the loudspeakers in the specified number of locations in each room.

The reverberation time in the *'receive'* areas was measured in a number of locations using the Rion NA27 analyser set to reverberation time, but using a loudspeaker pink noise source.

6.0 RESULTS AND DISCUSSIONS

6.1 INVERSE SQUARE LAW

The inverse square law test results are included in Appendix B, sections one to eight over the frequency range 200Hz - 10kHz. They show the results for each of the eight main chords, graphically and numerically in third octave bandwidths at the centre frequencies defined in ISO 3745. The variables shown are: chord radius; sound pressure level; deviation from the theoretical decay and the mean tolerance.

The average deviations stated graphically and numerically are based on a slope through an average of the first three points. Additional "diagnostic" plots showing all deviations along each chord at once are shown in Appendix C for more immediate reference. These plots show an extended frequency range of 100Hz - 20kHz for each of the eight chords. In the 20kHz one third octave band, the signal level was very close to the background noise level. The measurements have been corrected for background, but are probably better than indicated because of the difficulties in making these corrections when the signal to noise ratio is so small.

These results show that compliant anechoic performance has been achieved along all of the chords tested down to the design cut-off frequency of 200Hz, over the range of measurement positions up to 2.2 metres from the source, with the exception of Chord C which is +0.3dB in the 250Hz one third octave band at 2 metres from the source. At all other frequencies and distances, Chord C complies with the requirements of the Standard. This minor deviation is considered to result from the gap (greater than 100mm) between the wedge door and the adjacent wedges in the corner, and the presence of the extract duct outlet close to this measurement position. This range of commissioning measurement positions is used to define the range of measurement positions which can be used by the client in tests within the chamber in compliance with the International Standard. The introduction of some acoustically absorbent foam down the side of the wedge door should resolve this minor deviation.

6.2 AMBIENT NOISE LEVELS

The typical mean ambient 1/3 octave band noise levels recorded within the anechoic chamber are shown in Appendix D in Figures 2516/NS1 - 4 plotted against the specified levels. These levels were measured during normal working hours. These levels are also plotted in octave band levels in the Figures 2516/NSO1 - 4 in Appendix D.

At these very low levels, even with a Type 0 analyser such as the Norsonic 110 used for the measurements, there is an underlying level of electronic noise from the instrument.

Two pre-amplifiers were used with the Norsonic 110 system and the 'quieter' of the two was used for the ambient measurements. In the Figure for the anechoic chamber 2516/NS4 the measured levels with the ventilation system switched off have been taken as the 'noise floor' for the measuring system and plotted on the Figures for the Listening Room and Cabins.

For the Listening cabins, the Figures 2516/NS1 & NS2 show the levels with the ventilation on and off to be virtually identical, although the underlying ambient is above the specified levels from extraneous noise. This could be related to noise from the ventilation plant, etc., to other areas, and should be investigated.

For the Listening Room the mean measured ambient noise levels is below (better than) the design specification at all frequencies and is controlled by the noise floor of the equipment at the 2kHz one third octave band and above. It is considered that the actual level in the chamber in these upper frequencies if measured with the most sensitive measuring equipment available, with a lower noise floor, would also be below the specified levels.

Equally the levels in the anechoic chamber are below the specified levels, being controlled at 2kHz one third octave band and above by the equipment noise floor. It is considered also that the actual level in the chamber in these upper frequencies if measured with the most sensitive measuring equipment available, with a lower noise floor, would also be below the specified levels.

6.3 REVERBERATION TIME MEASUREMENTS

The mean reverberation times in the Listening Room and the Listening Cabins are shown in the Figures 2516/RT1 & RT2 in Appendix E to this Report.

The mean reverberation time in the Listening Room over the frequency range 63Hz - 8kHz in one third octave bands is shown in the Figure 2516/RT1, plotted against the specified tolerance limits. The plot shows that the measured reverberation characteristics achieve the specified values.

There is no specification of reverberation time for the Listening cabins, but these were measured for completeness and are shown in Figure 2516/RT2 in Appendix E of this Report.

6.4 SOUND INSULATION MEASUREMENTS

The measured levels of sound insulation between the Listening Rooms and Cabins and the surrounding areas are shown in Figures 2516/RW1 - 4 in Appendix F of this Report. These show the measured values over the one third octave frequency bands 100Hz - 3150Hz plotted against the achieved R'_w values.

Between the two Listening Cabins (Figure 2516/RW1) the value achieved of R'_w: 73 is a very good level of sound insulation. For the Listening Cabins to the adjacent corridor (Figures 2516/RW2 & RW3) the measured values were R'_w: 56 for the right hand Cabin (1) and R'_w: 52 for the left hand Cabin (2). The slightly lower value for the Cabin (2) reflects the door sealing of the inner door. When the outer door was closed, this pressurised the door void, pushing the inner door slightly off its seals. There should be provision in the door reveals to allow for some air leakage to control this effect.

For the Listening Room, a value of R'_w: 61 was measured (Figure 2516/RW4). This was compromised by acoustic leakage at the access door to the corridor. Inspection with the noise source on indicated that whilst the inner IAC chamber door was sealing adequately, the outer door had a leak at the threshold. It appears that the threshold plate has not been set onto mastic, and the noise is leaking underneath it. When this has been rectified a further listening test should be carried out, to ensure that the outer threshold seal is working satisfactorily.

7.0 CONCLUSIONS

The anechoic chamber at the University of Aalborg: Denmark has been tested in accordance with ISO 3745 for free-field conditions. The chamber meets all the contractual specifications in terms of low frequency cut-off requirements.

The free field performance within the chamber has been shown to comply with the requirements of ISO 3745, subject to the remedial measures to the wedge door proposed in this Report.

Background noise measurements taken within the anechoic chamber and the Listening Rooms with the mechanical and electrical systems operating have shown general compliance with the specified noise levels. For the Listening Cabins, the measured levels with the ventilation on and off showed no significant difference. The levels were slightly above the specification in the mid frequencies and its is considered this could be related to extraneous noise from building services or other plant operating within the building such as the plant areas below. This should be investigated.

The reverberation time within the Listening Room is within the specified tolerances across the indicated frequency range in one third octave bands. Whilst not part of the specification, the reverberation times in the two Listening Cabins were also measured and have been reported.

The available sound insulation between the Listening Rooms and Cabins and the surrounding areas has been measured in one third octave bands and the R'_w values reported. These generally show good levels of sound insulation, but have highlighted some remedial measures required to the access doors in some instances.

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1/3 Octave Frequency Hz	Anechoic Background Noise Specification: dB	Listening Room Background Noise Specification: dB	Anechoic Background Noise Specification: dB	Listening Room Reverberation Time Specification: Seconds
31.5	54	54	52	+0.30
40	48	48	44	+0.25
50	42	42	38	0.3 sec - 0.05 +0.20
63	37	37	32	0.3 sec - 0.05 +0.15
80	32	32	27	0.3 sec - 0.05 +0.10
100	28	28	22	0.3 sec - 0.05 +0.05
125	25	25	17	0.3 sec - 0.05 +0.05
160	22	22	14	0.3 sec - 0.05 +0.05
200	19	19	12	0.3 sec - 0.05 +0.05
250	16	16	10	0.3 sec - 0.05 +0.05
315	14	14	8	0.3 sec - 0.05 +0.05
400	12	12	6	0.3 sec - 0.05 +0.05
500	10	10	5	0.3 sec - 0.05 +0.05
630	8	8	5	0.3 sec - 0.05 +0.05
800	7	7	4	0.3 sec - 0.05 +0.05
1000	6	6	4	0.3 sec - 0.05 +0.05
1250	5	5	4	0.3 sec - 0.05 +0.05
1600	4	4	5	0.3 sec - 0.05 +0.05
2000	2	2	5	0.3 sec - 0.05 +0.05
2500	1	1	3	0.3 sec - 0.05 +0.05
3150	0	0	1	0.3 sec - 0.05 +0.05
4000	-1	-1	-1	0.3 sec - 0.05 +0.05
5000	-2	-2	1	0.3 sec - 0.05 +0.05
6300	-3	-3	6	0.3 sec - 0.10 +0.10
8000	-3	-3	12	0.3 sec - 0.10 +0.10
10000	-	-	-	-
12500	-	-	-	-

TABLE 2516/TB1 Specifications for Acoustic Facilities
University of Aalborg