A REPORT ON THE ACOUSTIC CONDITIONS OF IEQ LABORATORY USING ISO 3382-3

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Abstract: Recently, many facilities have completed new laboratories that may be used to assess various measures of Indoor Environment Quality (IEQ) in office spaces. Also recently, a new standard, ISO 3382-3, was released for assessing the effects of speech on IEQ in open plan offices. The aim of this report is to assess one room of the IEQ lab using the ISO 3382-3 standard. It is expected that the data gained will be of help to researchers using the facility in the future.

Keywords: ISO 3382-3, Indoor Environment Quality, Acoustics

Introduction

In the field of acoustics, speech has always been one of the subjects that has interested researchers, particularly speech privacy and speech intelligibility. From time to time new ideas are raised and regulation changes affect the way that speech descriptors and requirements can be evaluated. The current descriptors for speech privacy and speech intelligibility are stated in AS 2822, but recently they have been specified for open plan offices in ISO 3382-3. Modern open plan offices require reasonable levels of speech privacy between workstations, particularly if the speech is of a confidential nature. ISO 3382-3 specifies methods for the measurement of room acoustic properties in open plan offices with furnishing [1].

The objective of this report is to identify the Speech Transmission Index (STI) properties of the Indoor Environment Quality laboratory (IEQ lab) and to begin development of a spreadsheet that provides the report data required by ISO 3382-3. All the parameters and data used to assess the STI such as background noise, A-weighted Sound Pressure Level (SPL) of speech, and SPL in octave bands of pink noise, will be discussed further in this report.

Measurement Room (IEQ Lab)

The lab used for this purpose of experiment has three rooms and a corridor (see figure 1). The test room was furnished with chairs and desks, which are essentials for the measurements according to the ISO 3382-3, 5.2.1, Measurement conditions. For this measurement, Environmental chamber 1 will be used.

The Environmental Chamber 1 has the following dimensions:

Length (L) = 5.42m

Width (W) = 4.19m

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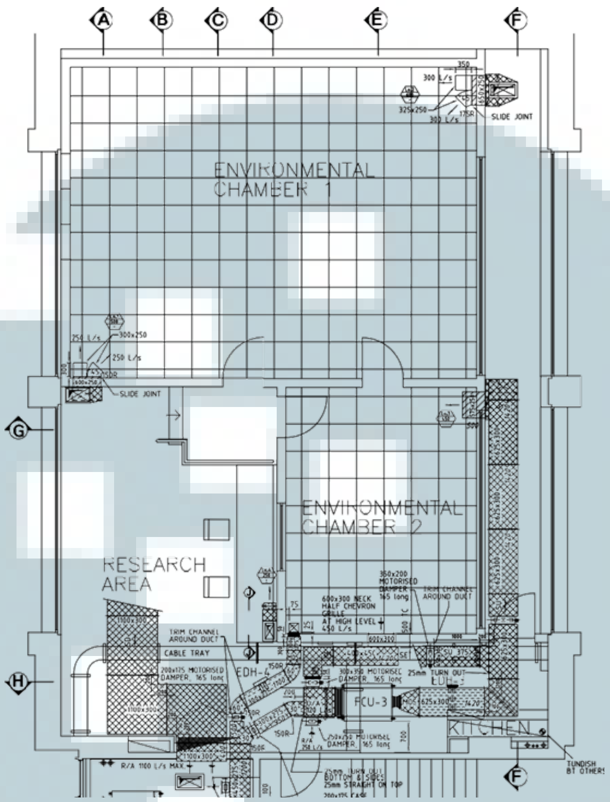

Figure 1. IEQ Lab Schematic

Height (H) = 2.59m

Volume (V) = 58.82m

Test Standards and References

Test Standards applicable for the measurements and determination of acoustic parameters such as Speech Transmission Index value, Background noise, and A- weighted SPL of speech are as follows:

a. AS ISO 3382-3: 2011 Acoustics – Measurement of room acoustic parameters, Part 3: Open Plan Offices

b. AS/NZS 2822: 1985 Acoustics – Methods of assessing and predicting speech privacy and speech intelligibilit

Definition of parameters as per ISO 3382-3

The terms and definitions below are essential for the measurements procedure.

a. Spatial sound distribution of the A-weighted sound pressure level of speech.

Curve which shows how the A-weighted sound pressure level decreases as a function of the distance from the sound source emitting noise with the sound power spectrum of normal speech

b. Spatial decay rate of speech, $D_{2,S}$

Rate of spatial decay of A-weighted sound pressure level of speech per distance doubling

NOTE This definition in an application of DL_2 defined in ISO 14257, but the spectrum of normal speech and A-weighting over the whole frequency range. The spatial decay is not determined for individual octave bands.

c. Wweighted sound pressure level of speech at a distance of 4 m

Nominal A-weighted sound pressure level of normal speech at a distance of 4,0 m from the sound source

NOTE: The measurement position does not need to be located at this distance from the sound source. $L_{p,A,S,4\,m}$ is obtained using a linear regression line from the spatial sound distribution of the A-weighted sound pressure level (SPL) of speech.

d. Speech transmission index, STI

Physical quantity representing the transmission quality of speech with respect to intelligibility

[IEC 60268 – 16:2011]

e. Spatial sound distribution of the speech transmission index

Curve which shows how the speech transmission index decreases from a reference sound source when distance increases

f. Distraction distance, r_D

Distance from speaker where the speech transmission index falls below 0,50

NOTE 1 Distraction distance is expressed in metres.

NOTE 2 Above the distraction distance, concentration and privacy start to improve rapidly.

g. Privacy distance, r_P

Distance from speaker where the speech transmission index falls below 0,20

NOTE 1 Privacy distance is expressed in metres.

NOTE 2 Above the privacy distance, concentration and privacy are experienced very much the same as between separate office rooms. STI values less than 0,20 are difficult to achieve in offices with poor speech privacy or small volume.

h. Background noise level, $L_{p,B}$

Sound pressure level in octave bands present at the workstation during working hours with people absent

NOTE 1 Background noise here means all such continuous sounds, which are not caused by people, e.g. heating, ventilation, and air conditioning (HVAC) devices, environmental traffic noise, office equipment or a sound-masking system.

Measurements quantities

The room parameters must be calculated and measured. To determine the parameters of speech intelligibility and speech privacy, some measurements are essential as per AS ISO 3382-3. The measurements are:

a. Sound pressure level in octave bands of pink noise, $L_{p,Ls}$;

b. STI;

c. Background noise in octave bands, Lp,B;

d. Distance to the sound source, r

Measurement equipment

The following equipment was used for the measurement:

a. Sound source

NTI Talkbox

The NTI Talk box is a directional sound source, which can be used to generate different types of signals, such as pink. It also has a line input for connecting external sound sources.

b. Sound Level Meter

Brüel & Kjær Type 2250 Sound Level Meter

The sound level meter was used to measure the background noise level and the sound pressure level of pink noise. This sound level meter is capable of providing data in one-third-octave and octave bands.

c. Computer Analyzer

Dell Laptop with EASERA

The computer was used with EASERA to generate sin wave sweep. The Edirol USB audio interface was connected to the NTI Talk box line input.

d. Omnidirectional Microphone

Earthworks M30

This measurement microphone has a reasonably flat frequency response. It was connected directly to the Edirol USB audio interface

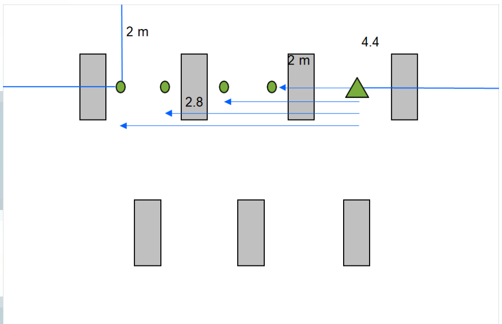

Figure 2. Equipment position and distance

Test Procedure

General Measurement conditions

Measurements in accordance with ISO 3382 shall be made in furnished rooms, but without the presence of people, except the persons needed to carry out the measurements. The HVAC devices and other noise source shall operate on the same power as during typical working hours. If the

HVAC cannot be operated during the measurements, adjustments must be made to compensate it.

Frequency range of measurement

The measurement of room acoustic parameters for open plan offices (especially SPL and STI) was measured in octave bands from 125 Hz to 8,000 Hz. For this measurement, third-octave bands shall be used for the purpose of gaining more data and the frequency range of 125 Hz to 10,000 Hz were used. STI shall be determined in accordance with the full method specified in IEC 60268-16.

Generating sound source

According to AS ISO 3382-3, an omnidirectional sound source producing pink noise shall be used since people in open plan office do not continuously speak in any fixed direction. This measurement used a directional sound source (NTI Talk box). The sound source was positioned at the height of 1.2 m, the average head height of a seated person.

Background noise measurement

Background noise level, $L_{p,B}$, is measured at each measurement position in octave bands. The average background noise level of all the measurement positions is determined. The background noise is measured for one minute at each measurement position.

Sound Pressure Level measurement

The Sound Pressure Level shall be measured using a sound level meter in each octave band and each microphone position with integration time should be at least 10 s. The microphone shall be omnidirectional.

Microphone and sound level meter position

"It is recommended that the measurements be carried out along a line, which crosses over workstations. The preferred number of successive measurement positions in the line is 6 to 10; the minimum number is 4" – et al ISO 3382-3. Only the positions within the range of 2 m to 16 m are used for the determination of spatial decay rate of speech (D2, S). For this measurement, the first position of the microphone and the sound level meter is 2.11 m from the sound source

Sound source position

The positions of loudspeaker and microphone shall be at least 0.5 m from the tables and at least 2 m from the walls and other reflecting surfaces. At least two sound source positions shall be used. As stated on 8.1.3, the sound source shall be placed at the height of 1.2 m above the floor.

Measurement

Sound pressure level measurement was undertaken in accordance to ISO 3382-3. A directional loudspeaker with pink noise output was used in the measurement. The sound power level of the pink noise must be sufficiently high for the sound pressure level to exceeds the background noise level by 6 dB at the most distant measurement point. Measurements were undertaken in one-third octave band frequencies at 4 different positions.

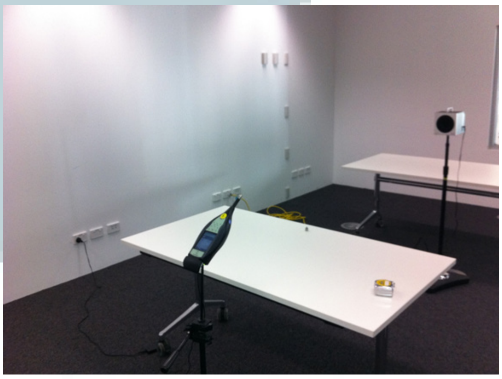

Figure 3. Measurement of background noise and pink noise

STI Measurement

The STI measurement was performed using the EASERA program. EASERA is able to generate a sine wave sweep that is used to calculate STI value. The omnidirectional microphone was connected to the input of the EDIROL audio interface. The output of the audio interface was connected to the line input of the NTI Talkbox. For each measurement position the signal was played four times. The duration of each sweep was 43 seconds. By doing this, any artifacts that might occur during the measurement can be ignored.

Table 1. Summary of results

STI in the nearest workstation	0.77
Distraction distance rD in m (predicted)	17.9
Privacy distance rp in m (predicted)	35.3
Spatial decay rate of A-weighted speech D2,s in dB	1.7
A weighted SPL of speech at 4m, Lp,a,s,4m in dB	54.8
Average A weighted background noise Lp,a,b in dB	42.5

Measurement procedure

The NTI Talkbox was positioned two metres from the two nearest walls. The sound level meter (SLM) was placed at the first workstation, 2.11 m from the NTI. It should be noted that each position of the microphone and the sound level meter must be at least 2 m apart from the wall. Figure 2 shoes the room layout and the location of the source and receiver positions.

The background noise was measured at each of the positions for one minute by using the sound level meter in one-third octave band mode. The ceiling HVAC was running during all measurements.

The measurement of the Sound Pressure Level of pink noise is identical to the procedure used when measuring background noise. The NTI Talk box, is used to generate pink noise pink noise. This is measured using the SLM giving us data in 1/3 octave bands.

STI measurements were taken at teach receiver position using the method stated in 8.4.

It should be noted that the procedure we used does not fully comply with ISO 3382-3. We used a directional sound source instead of an omnidirectional sound source. We had limited time in the lab to take the measurements and as a result we were only able to take on line of measurements instead of the two lines required.

We attempted to take another set of measurements using a compact omnidirectional sound source and a swept sin wave signal. However, due to major ongoing issues with the computer and software system we were unable to get any usable results.

Results and calculations of parameters

The results were calculated in Excel using the formulas provided by the ISO 3382-2 standard. Table 1 shows a summary of the results as required by the standard.

$_{rD}$ and $_{rP}$ were calculated using a lin-

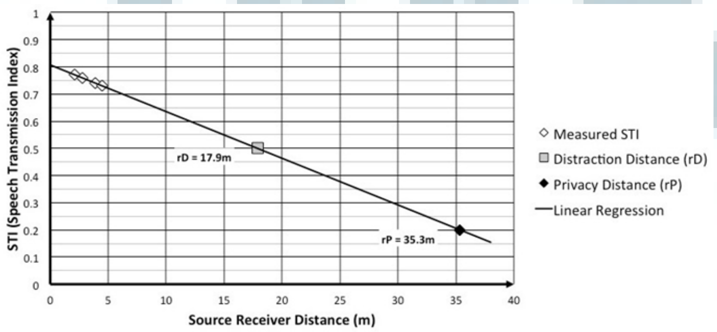

Figure 4. STI, $_{rD}$ and $_{rP}$

ear regression line determined from the measured STI values graphed in Excel (See figure 4). The formulas used to determine rD and rP are;

$_{rD}$ = (0.5 – Intercept)/Slope $_{rP}$ = (0.2 – Intercept)/Slope

Where 0.5 is the STI value at rD and 0,2 is the STI value at $_{rP}$. Slope and Intercept values were calculated in Excel using the appropriate functions.

D2, S and Lp,A,S,4 m

The sound power level of the NTI Talkbox in octave bands was calculated using SPL measurements taken in the anechoic chamber. This allowed us to calculate

Lp, Ls, 1m for each octave. The formulas provided by the standard in section 6.2 were used to calculate the A-weighted sound pressure level of speech (Lp, A, S, n) at each measurement location. The levels and distances were used to plot a graph in Excel and linear regression was used to determine D2, S and Lp,A,S,4 m (see Figure 5).

Average background noise

The average background noise was determined from the noise measurements at each position. (See Figure 5 and Table 1)

Discussion

As suggested by Haka, M., Haapakangas, A., Keränen, J., Hakala, J., Keskinen, E. and Hongisto, V. (2009), STI values of open plan offices can be qualified as;

- a private office (STI = 0.10),
- an acoustically excellent open office (STI = 0.35)
- an acoustically poor open office (STI = 0.65) [4].

When the results that we obtained are compared to the ratings from Haka, M., et al, it can be seen that the IEQ lab Chamber 1 is a rather poor office environment.

The high STI levels mean that rD and rP are outside the room's boundaries. ISO 3382 includes a diagram that shows the effect of high STI values on worker productivity. (figure 6) The task performance of anyone working in this room would be very poor and they would not have any speech privacy. Chamber 1 requires significant improvement to be an effective workspace while maintaining the same number of workstations.

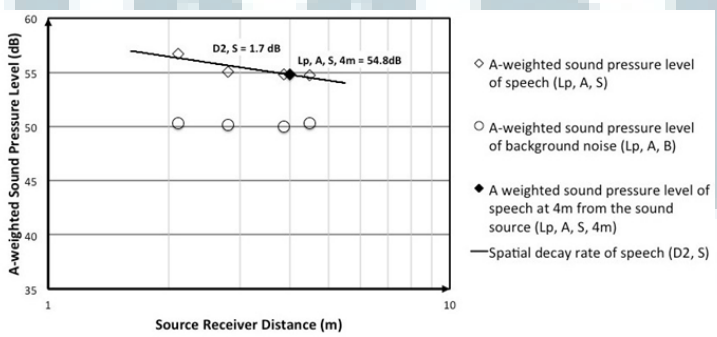

Figure 5: $_{D2, S}$ and $_{Lp,A,S,4 m}$

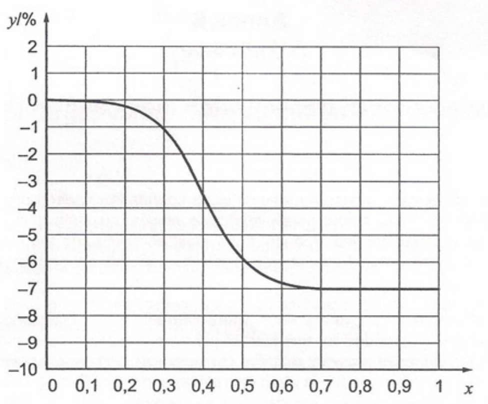

Figure 6. STI (x-axis) versus minimum change in task performance (y-axis)

It should be noted that this room was only just large enough to allow the minimum number of four measurement positions required by ISO 3382-3 with a minimum distance of 2 m from any wall. In fact the dimensions of the room only allowed us to measure along one axis. It is possible that Chamber 1 will not be suitable for measurement using ISO 3382-3 in some configurations.

We have tried to find the reason for the high STI values and have concluded that the walls and the ceilings are the major contributors. The walls are quite reflective, as you'd expect. The ceiling tiles, although not as hard as the walls seem to be hard enough to provide significant reflection. There are other considerations. The room is relatively unfurnished, being without chairs or partitions between workstations and a realistic open plan layout has yet to be implemented. Alternative wall and ceiling materials should also be considered (Bradley.J.S., 2008).

We would suggest that the conditions in the room might be improved by some or all the following;

a. Replace the ceiling tiles with acoustic ceiling tiles

b. Adding acoustic panels to the walls to increase absorption

c. Use of acoustic partitions to separate workstations

d. Use of an active sound masking system

Conclusions

The results tabled in this report give an unsurprising assessment of the IEQ lab. The STI between workstations is high and significant work will have to be undertaken to improve this if a higher level of privacy is required. Our test method didn't comply fully with ISO 3382-3. Another assessment meets the requirements of the standard should be undertaken when the room is fully furnished.

References

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