Interlaboratory and proficiency tests for building's sound insulation field measurements in Brazil - 4th Edition 2020

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ABSTRACT

Since 2013 Brazil has implemented the ABNT NBR 15575:2013, a national technical standard that establishes acoustic requirements for dwellings that can be verified by means of field measurements procedures performed according to specific ISO standards. These demands have fostered the acoustic field measurement market, and the number of field measurements acoustic laboratories has quickly increased around the country. ProAcústica - Brazilian Association for Acoustical Quality, a non-profit entity, aiming to improve the quality of the acoustics sector in Brazil has organized in 2020 the fourth edition of the "Interlaboratory and proficiency program of field measurements for building acoustics laboratories – INTERLAB Program". This consists of a fundamental tool for acoustic field laboratories to evaluate and verify the quality of their measurement results. In the 2020 edition a total number of 25 laboratories participated (32% more participants than last edition in 2017) for different types of tests: airborne sound insulation, airborne facade sound insulation, impact sound level, sound pressure level from service equipment in buildings, and reverberation time). The main objectives were the evaluation of the precision of the field test methods in the Brazilian market, the analysis of the performance of the participating laboratories as a quality control tool. This paper presents the methodologies, procedures and results of the ProAcustica's interlaboratory and proficiency program 2020, carried out in São Paulo (Brazil), as well a comparison between the three last editions results.

1. INTRODUCTION

An interlaboratory test is a collaborative test in which all the participant laboratories measure the same item, with their own methods, instrumentation, and staff. It aims to evaluate the acoustic measurement tests service quality provided by the acoustic laboratories through an instrument that allows evaluating the measurement procedure of the participating laboratories.

The main objectives of interlaboratory tests are:

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- Assess the precision and equivalence between different test methods.
- Assess the technical compliance of laboratories to carry on acoustic tests (proficiency tests) in a continuous follow-up of the performance.
- Detection of problems during the measuring process and developing corrective solutions.
- Provide confidence to the market.

The proficiency test is a specific case of interlaboratory test, that aims to assess the performance of the different participant laboratories. Regular participation in proficiency tests is a fundamental tool for the quality control of measurement services offered in each laboratory portfolio, as it is the most effective way of assessing if the tests are being carried out properly.

2. BACKGROUND

2.1. General

In Brazil, ProAcustica Association is the first institution to develop a program of interlaboratory and proficiency field tests for building acoustics. All the tests were carried out in the city of São Paulo joining laboratories from all over the country. The first edition, 2012 joined five laboratories, for the second edition (2014) the number of participants increased up to seven, in the third edition in 2017, nineteen laboratories participated and in the last one, 2020, the number raised to twenty-five participants.

The first two interlaboratory programs took place in residential buildings provided by the construction company Tecnisa, the third edition the building under evaluation was lent by the company EZTec. For the last edition, the building under evaluation was lent by the company OWA Sonex.

2.2. Fourth Edition (2020)

The 4th INTERLAB ProAcústica Edition was scheduled for 2019, however, due to the Covid-19 Pandemic, it extended throughout 2020. The measurements were carried out from January to August by the 25 participant laboratories, listed in Table 1.

Table 1: Participant laboratories of the INTERLAB Program 4th Edition (2020)

PARTICIPANT LABORATORIES	
Acoem Brasil Comércio de Equipamentos Ltda.	Modal Acústica e Engenharia Ltda.
Acústica Engenharia SS	Nepomuceno & Trindade Arquitetos Associados S/S
Anima Acústica Tecnologia e Conhecimento Ltda.	Pedrosa e Nascimento Engenharia e Consultoria SS Ltda.
Associação Antônio Vieira (ASAV - UNISINOS)	Scala Acústica Ltda.
Atenua Som Indústria e Comércio Ltda.	SENAI Criciúma
Bracústica Consultoria Ltda.	SENAI Minas Gerais
CM2 Engenharia e Tecnologia Ltda.	SENAI Ponta Grossa PR
Echo Projetos Acústicos Ltda.	SENAI Três Rios RJ
Environmental Solutions Consultoria Ltda.	Silentium Engenharia Acústica Ltda.
Harmonia Acústica Ltda.	Síntese Arquitetura e Construção Ltda.
Inovatech Engenharia Ltda.	Tecomat Engenharia Ltda.
Lacrose Engenharia e Consultoria Eireli	Trional Ensaios, Tecnologia e Inovações Ltda.
MMC Lab Controle Tecnológico Ltda.	

Table 2 shows the number of participants that had attended each available test of the INTERLAB program, as not all laboratories participated in all tests, totalizing 146 measurements.

Table 2: Tests of the INTERLAB program and number of participant laboratories

Nº	TEST	NUMBER OF LABORATORIES
1	ISO 16283-1:2014 – Acoustics -- Field measurement of sound insulation in buildings and of building elements -- Part 1: Airborne sound insulation	24
2	ISO 10052:2004 – Acoustics -- Field measurements of airborne and impact sound insulation and of service equipment sound -- Survey method: airborne sound insulation between rooms	12
3	ISO 16283-3:2016 – Acoustics -- Field measurement of sound insulation in buildings and of building elements -- Part 3: Façade sound insulation	24
4	ISO 10052:2004 – Acoustics -- Field measurements of airborne and impact sound insulation and of service equipment sound -- Survey method: airborne sound insulation of facades	12
5	ISO 16283-2:2020 – Acoustics -- Field measurement of sound insulation in buildings and of building elements -- Part 2: Impact sound insulation	24
6	ISO 10052:2014 – Acoustics -- Field measurements of airborne and impact sound insulation and of service equipment sound -- Survey method: impact sound insulation of floors	12
7	ISO 3382-2:2008 – Acoustics -- Measurement of room acoustic parameters -- Part 2: Reverberation time in ordinary rooms	23
8	ISO 16032:2004 – Acoustics -- Measurement of sound pressure level from service equipment in buildings -- Engineering method	15

For each test, the participants carried out five complete repetitions of the measurement, with procedures that should comply with the corresponding ISO measurement standard. It is important to highlight that each participant laboratory was allowed to decide some aspects like the number of measurement points, the location of source/microphone, and measurement time.

3. RESULTS

3.1. Presented quantities

The results of the performed field measurements of each laboratory were assessed accordingly to ISO 17043:2014 [2], with the following indicators as output data:

a) True value (X) and proficiency standard deviation (σp), obtained respectively from the robust mean value (x*) and robust standard deviation (s*), regarding annex C of the standard ISO 13528:2015 [3].

b) Z'-Score, for assessment of the performance of the participant laboratories, calculated with the following equation:

$$Z' = (x - X)/\sqrt{{\sigma_p}^2 + {u_x}^2}\ , \qquad (1)$$

Where x is the result obtained by each laboratory, X is the true value of the result and σp is the proficiency test standard deviation.

- For $|Z'| \leq 2$, the result of the individual participant is regarded as acceptable (satisfactory performance).
- For $2 < |Z'| \leq 3$, the result of the individual participant is regarded questionable, being recommended to carry out an assessment of the possible causes and special caution in that values when testing.
- For $|Z'| > 3$, the result of the individual participant is regarded as non-acceptable (unsatisfactory performance).

c) The standard uncertainty of interlaboratory test (u) calculated regarding ISO 5725-1 [4] 5725-2 [5],
d) Repeatability and reproducibility of the interlaboratory test calculated regarding ISO 5725-2 [5].

3.2. Airborne sound insulation between dwellings - $D_{nT,w}$

In this section, the results of the airborne sound insulation between dwellings - $D_{nT,w}$ are presented for the engineering method and survey method.

ISO 16283-1:2014 - engineering method (24 laboratories)

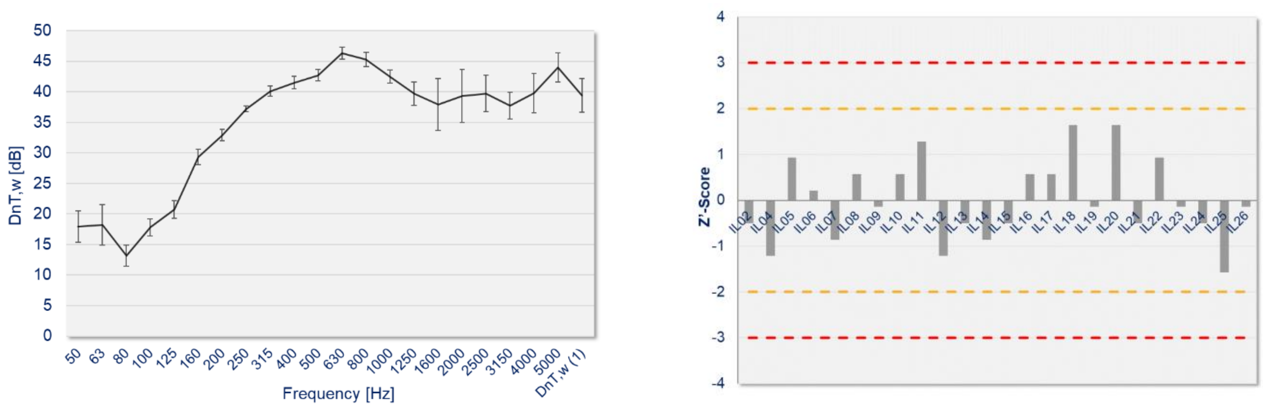


Figure 1. True value (X) and standard deviation (σp) (left),
Z'-Score $D_{nT,w}$ for each laboratory (IL) (right)

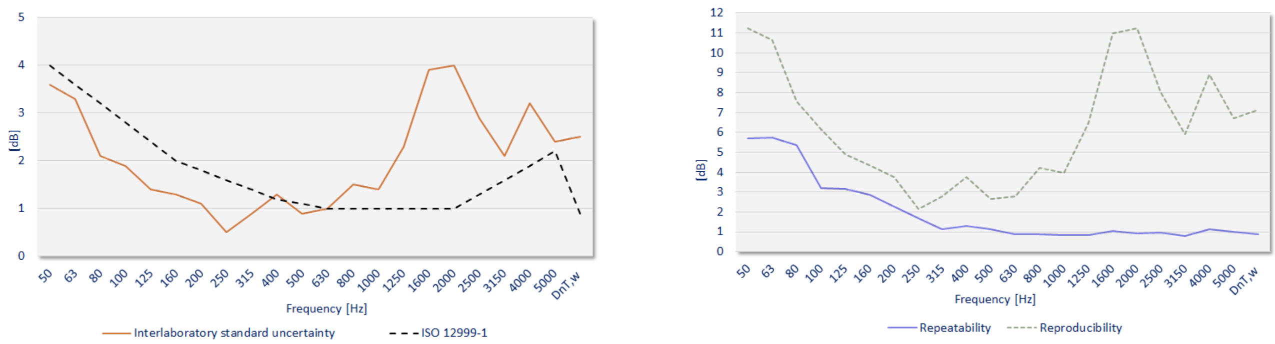


Figure 2. Comparison between standard uncertainty (u) and ISO 12999-1(left),
repeatability and reproducibility (right)

ISO 10052:2004 – Survey method (12 laboratories)

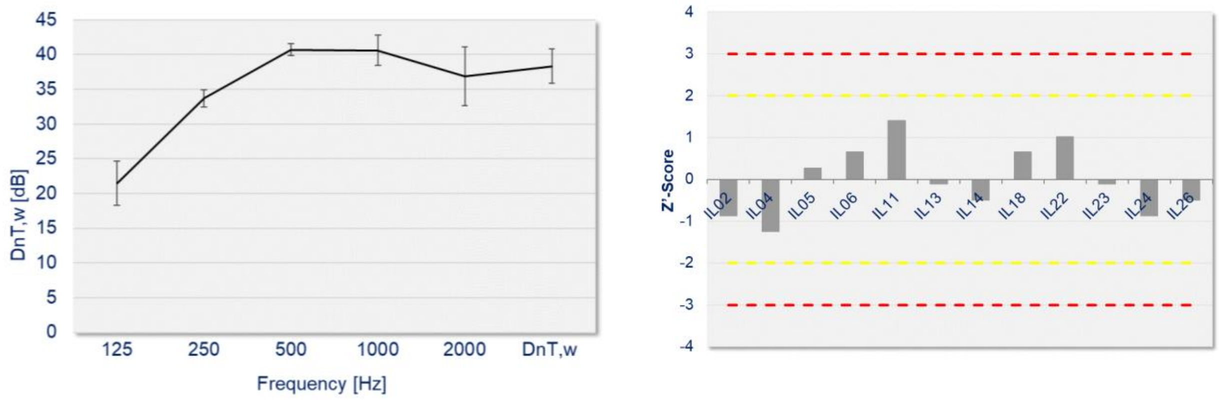


Figure 3. True value (X) and standard deviation (σp) (left),
Z-Score $D_{\mathrm{nT,w}}$ for each laboratory (IL) (right)

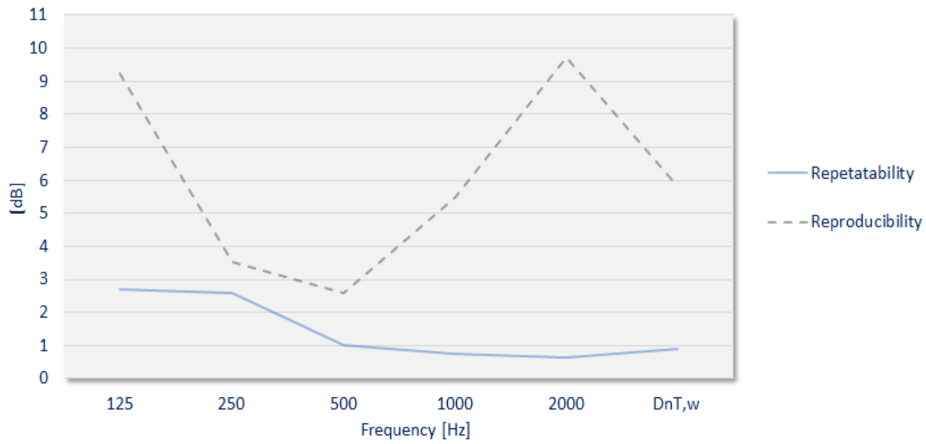


Figure 4. Repeatability and reproducibility

3.3. Impact sound insulation between dwellings – $L'_{nT,w}$

In this section, the results of the impact sound insulation between dwellings – $L'_{nT,\mathrm{w}}$ are presented for the engineering method and survey method.

ISO 16283-2:2015 - Engineering method (24 laboratories)

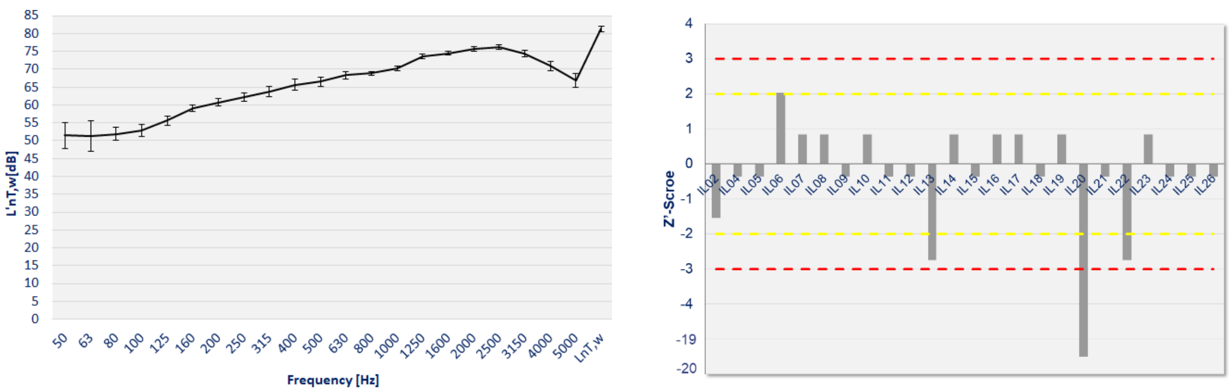


Figure 5. True value (X) and standard deviation (σp) (left),

Z'-Score $L'_{nT,w}$ for each laboratory (IL) (right)

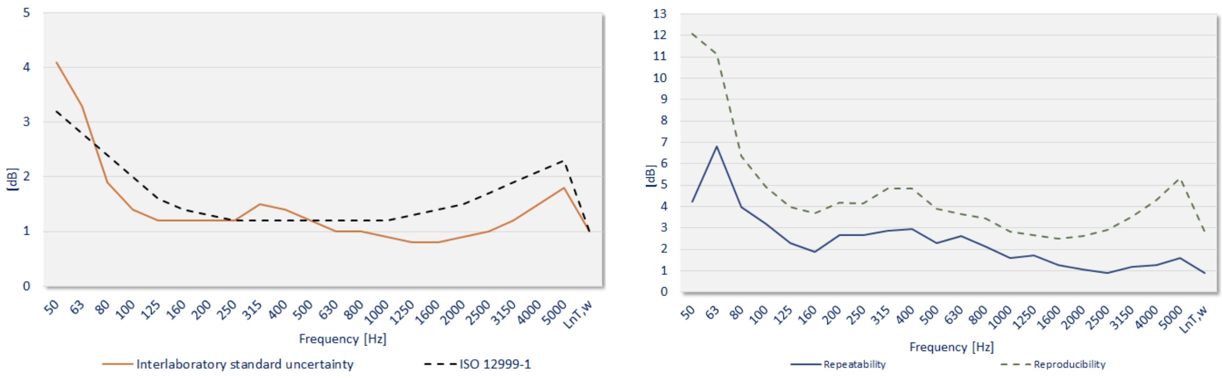


Figure 6. Comparison between standard uncertainty (u) and ISO 12999-1(left), repeatability and reproducibility (right)

ISO 10152:2004 – Survey method (12 participant laboratories)

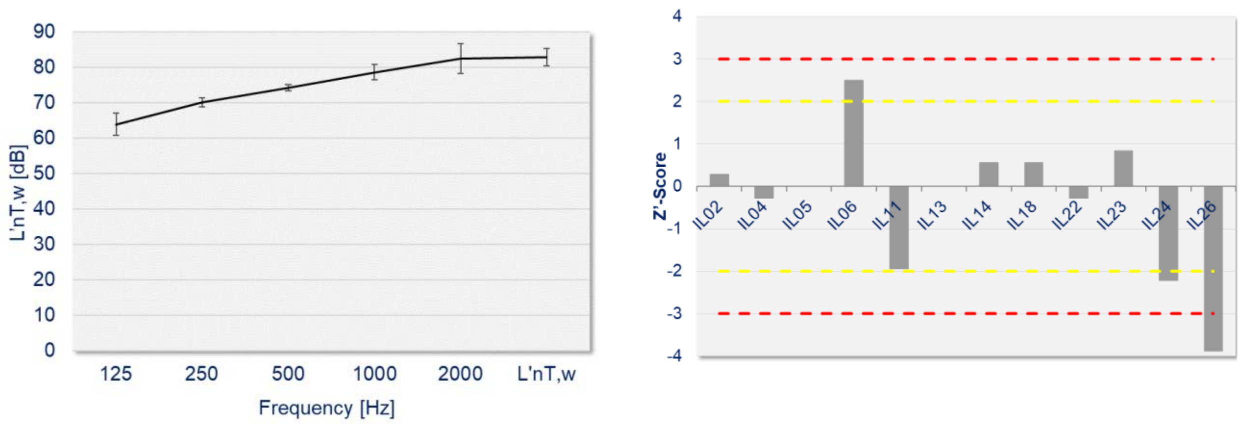
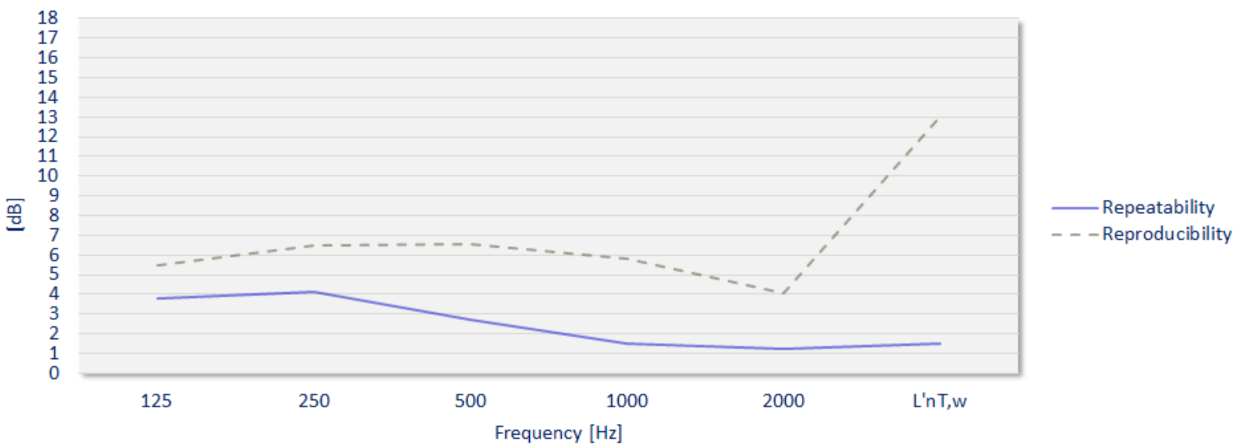


Figure 7. True value (X) and standard deviation (σp) (left),



Z'-Score $L'_{nT,w}$ for each laboratory (IL) (right)

Figure 8. Repeatability and reproducibility

3.4 Airborne façade sound insulation - $D_{2m,nT,w}$

In this section, the results of the airborne façade sound insulation - $D_{2m,nT,w}$ are presented for the engineering method and survey method.

ISO 16283-3:2016 - Engineering method (24 laboratories)

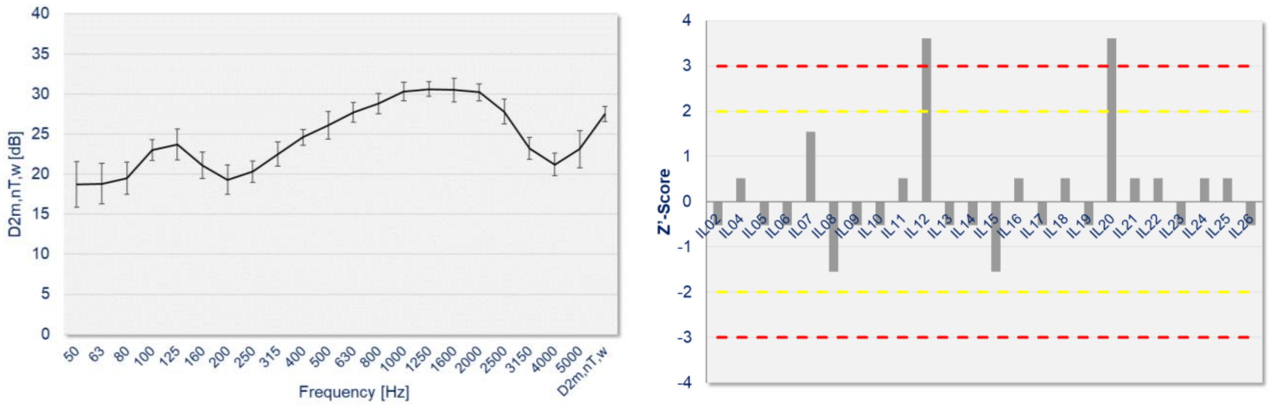


Figure 9. True value (X) and standard deviation (σp) (left),
Z'-Score $D_{2m,nT,w}$ for each laboratory (IL) (right)

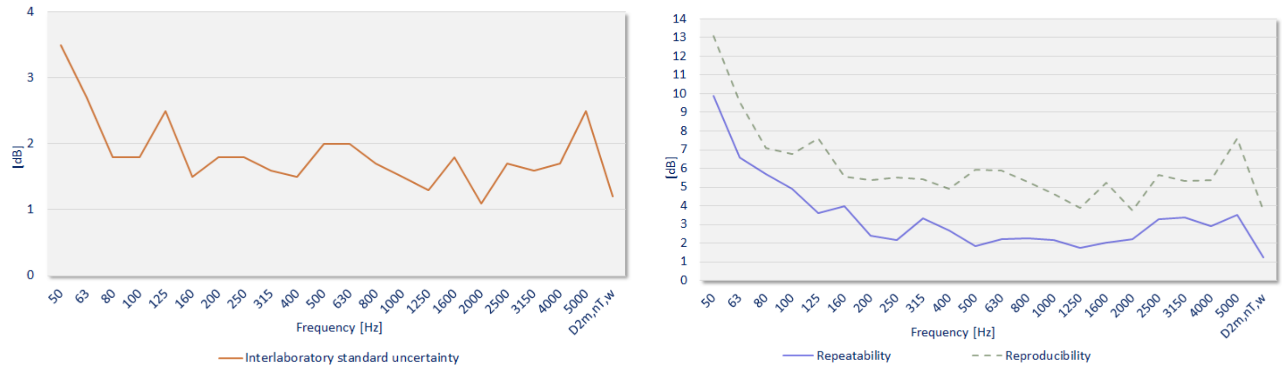


Figure 10. Standard uncertainty (u) (left), repeatability and reproducibility (right)

<u>ISO 10052:2004 – Survey method (12 laboratories)</u>

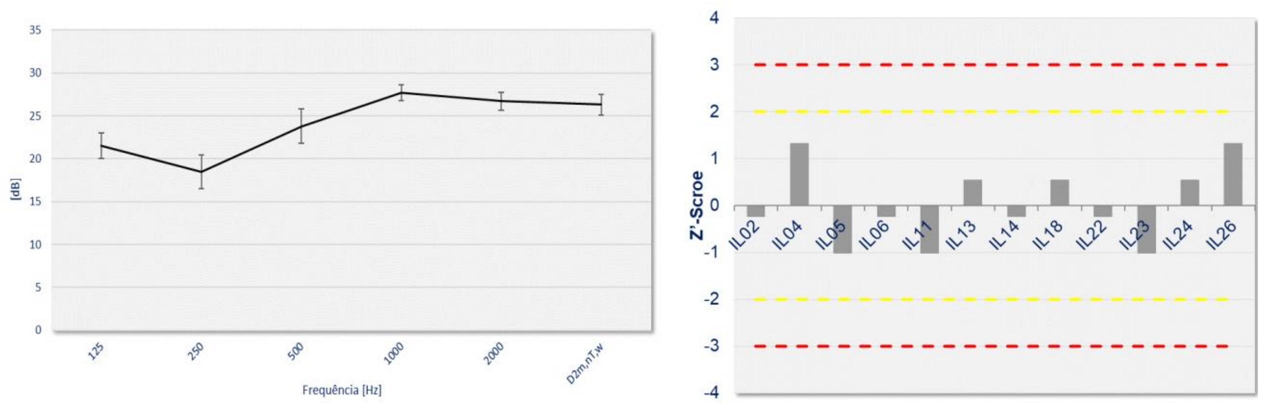


Figure 11. True value (X) and standard deviation (σp) (left),
Z-Score $D_{2m,nT,w}$ for each laboratory (IL) (right)

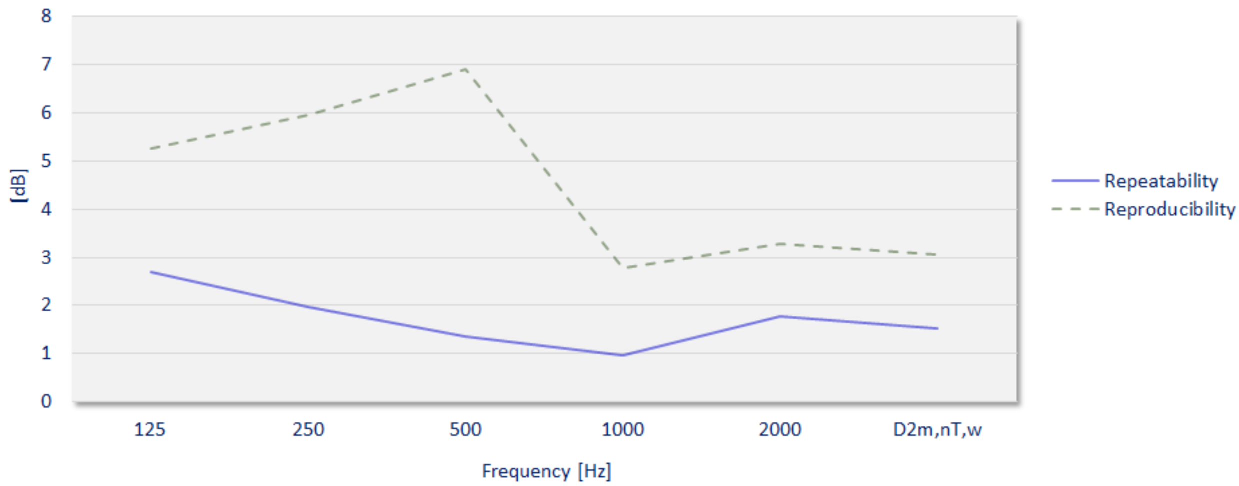


Figure 12. Repeatability and reproducibility

3.5 Noise level from service equipment - $L_{Aeq,nT}$, $L_{ASmasx,nT}$

ISO 16032:2004 (15 laboratories)

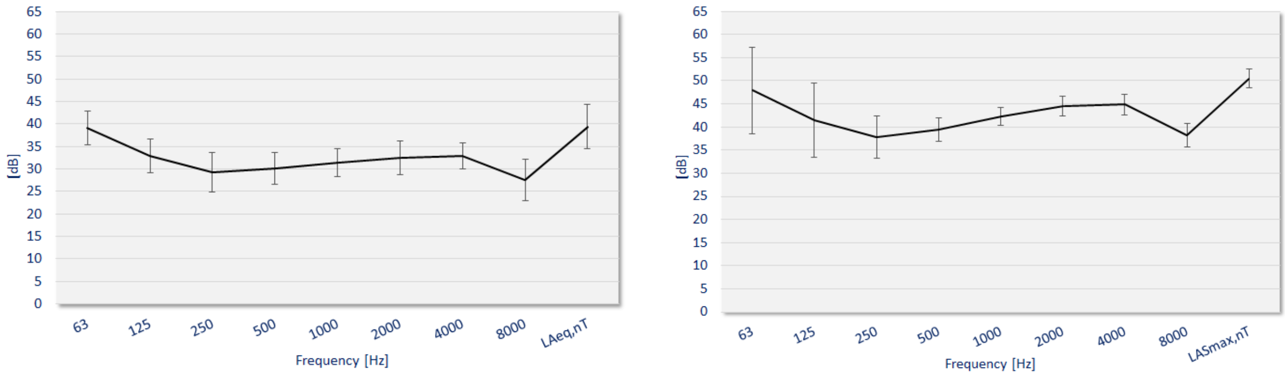


Figure 13. True value (X) and standard deviation (σ_p) $L_{Aeq,nT}$ (left) and $L_{ASmax,nT}$ (right)

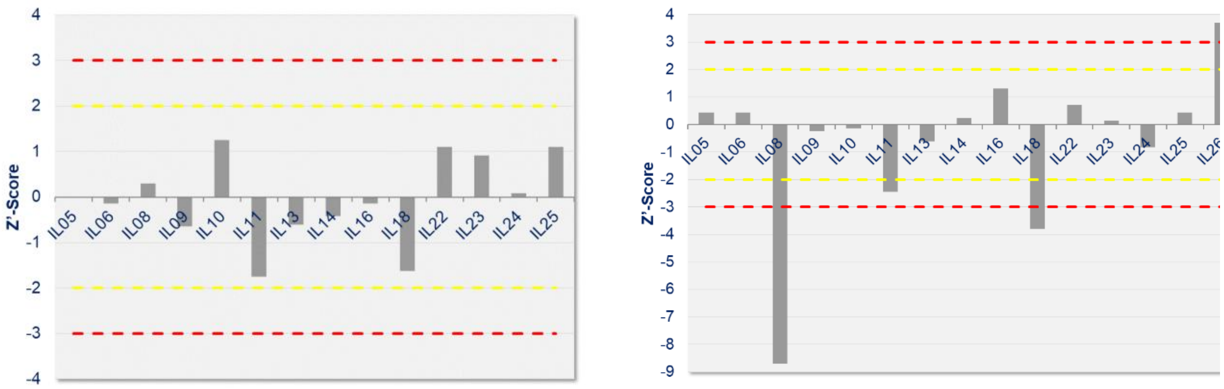


Figure 14. Z-Score $L_{Aeq,nT}$ (left) and $L_{ASmax,nT}$ for each laboratory (IL) (right)

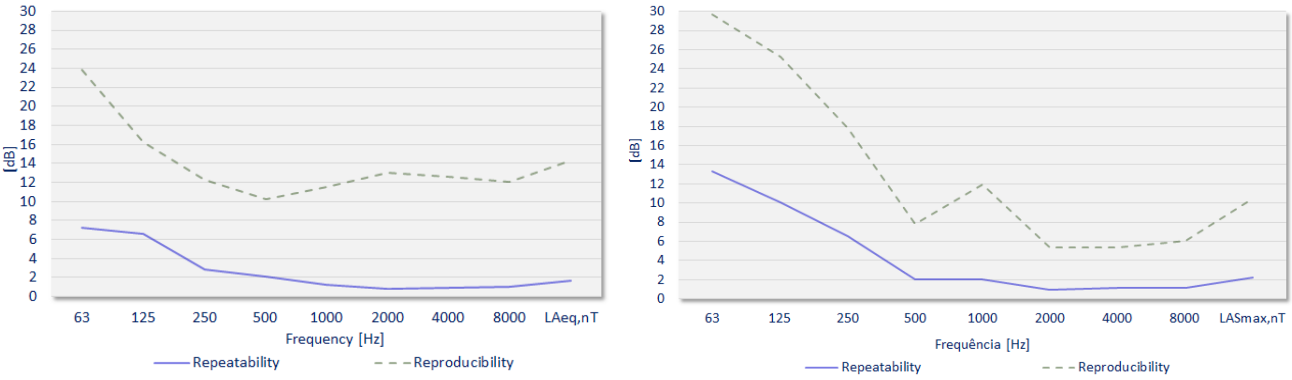


Figure 15. Repeatability and reproducibility $L_{\mathrm{Aeq,n}T}$ (left) and $L_{\mathrm{ASmax,n}T}$ (right)

3.6 Reverberation Time - TR

ISO 3382-2:2008 (23 laboratories)

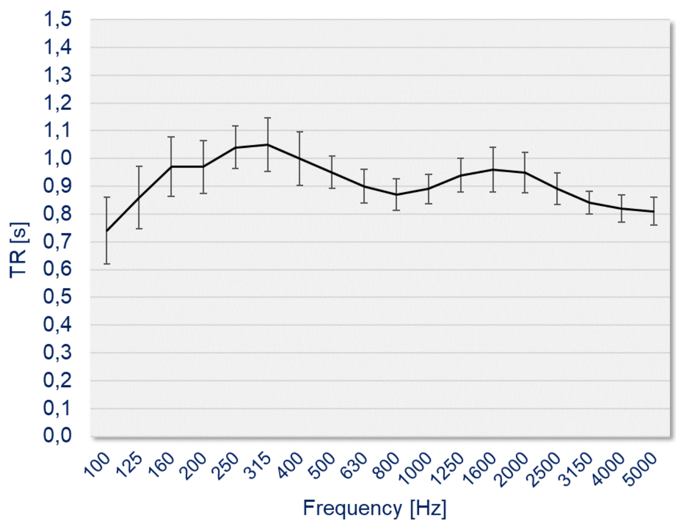


Figure 16. True value (X) and standard deviation (σp)

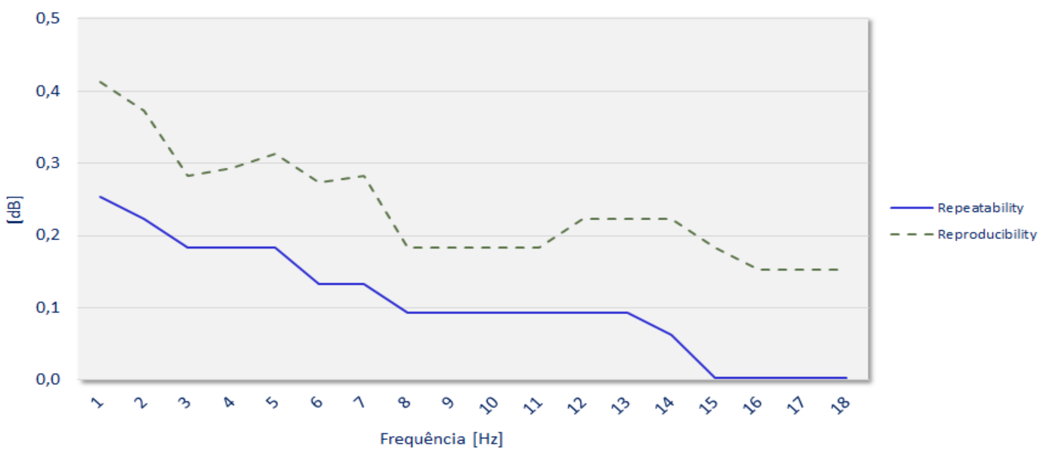


Figure 17. Repeatability and reproducibility

4. COMPARISON BETWEEN EDITIONS (2014 VS. 2017 VS. 2020)

This section presents the comparison of the results obtained in the 2014 edition with the former standard ISO series 140, in 2017 and 2020 with the new standard ISO series 16283.

4.1 Airborne sound insulation between dwellings ($D_{nt,w}$) comparison: 2014 (7 laboratories), 2017 (19 laboratories), 2020 (25 laboratories)

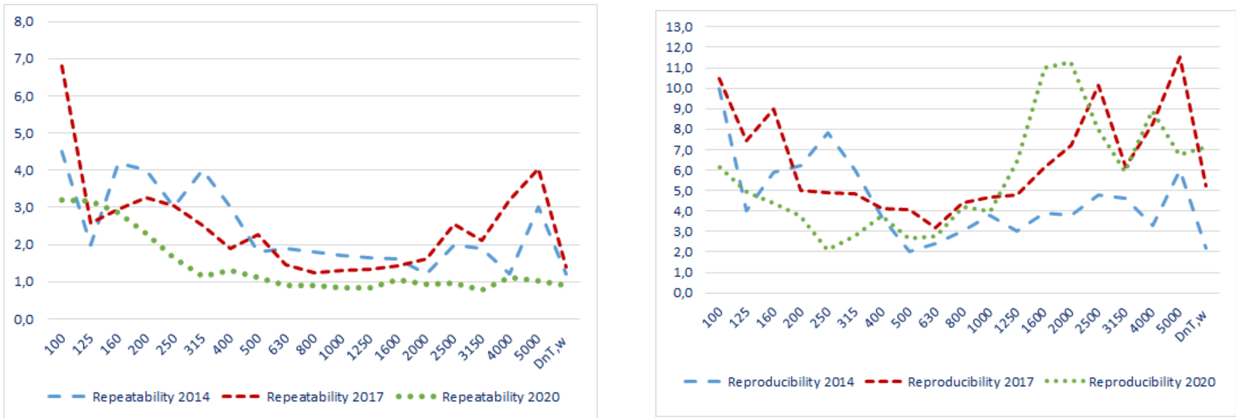


Figure 18. Comparison of $D_{nt,w}$ repeatability and reproducibility 2014, 2017 and 2020

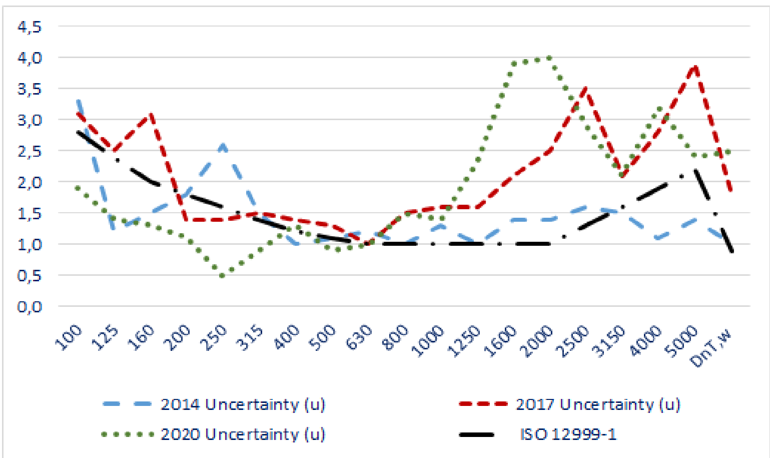


Figure 19. Comparison of uncertainty 2014, 2017 and 2020

4.2 Impact sound insulation between dwellings ($L'_{nt,w}$) comparison: 2014 (7 laboratories), 2017 (19 laboratories), 2020 (25 laboratories)

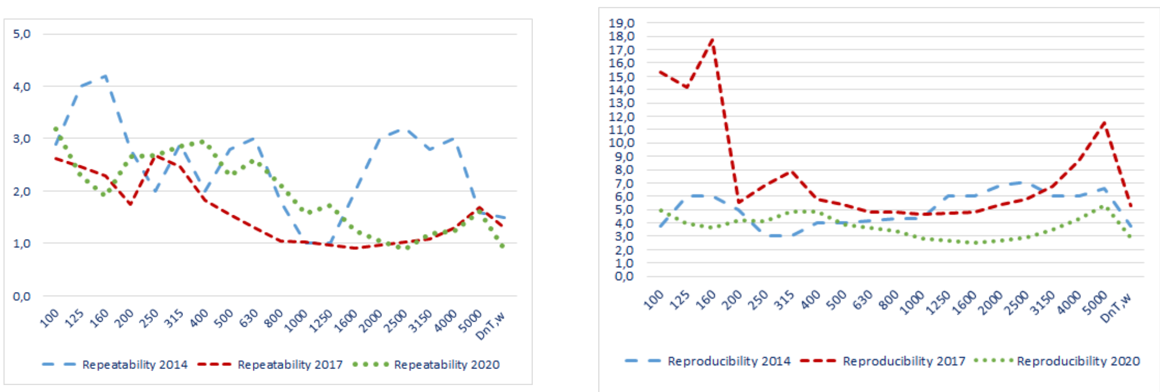


Figure 20. Comparison of repeatability and reproducibility 2014, 2017 and 2020

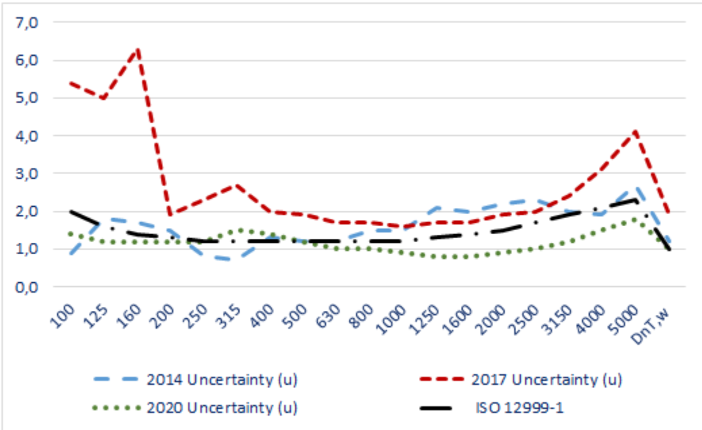


Figure 21. Comparison of uncertainty 2014, 2017 and 2020

4.3 Façade sound insulation ($D_{2m,nt,w}$) comparison: 2017 (19 laboratories) and 2020 (25 laboratories)

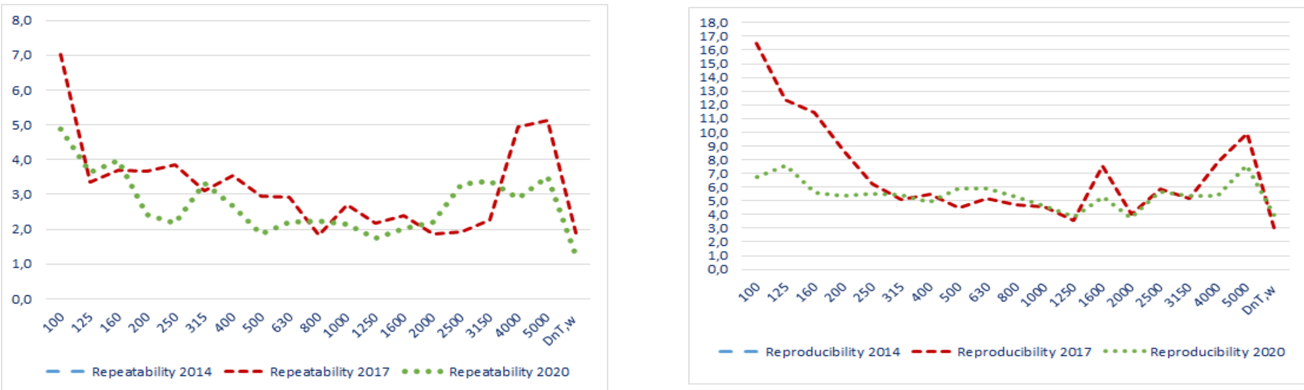


Figure 22. Comparison of repeatability and reproducibility 2014, 2017 and 2020

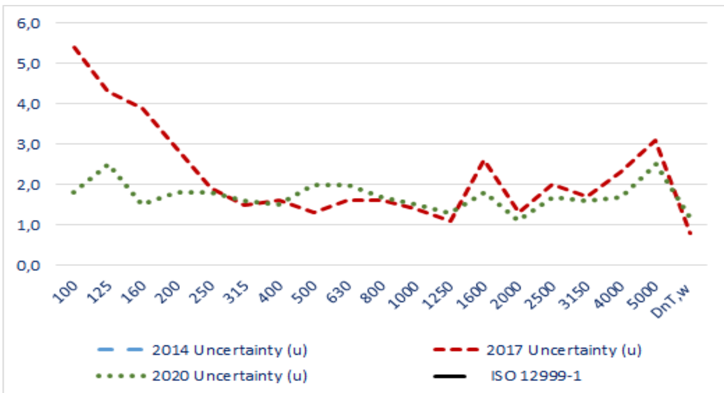


Figure 23. Comparison of uncertainty 2014, 2017 and 2020

6. CONCLUSIONS

• Considering the number of participants, it was observed an increasing interest in participating in proficiency tests, revealing a growing market of acoustics field measurements during the years.

• The uncertainties of the results of airborne sound insulation and impact sound insulation obtained by the engineering method fit better with the reference curve from ISO 12999-1 when compared with the previous edition results.

• The highest uncertainties values were obtained for the service equipment noise test results, probably due to the fact that the procedure consists of absolute measurement, the noise source is not standardized, and the SNR ratio was low during the tests due to high background noise.

• In the current interlaboratory program, unlike the 2014 and 2017 editions, the receiving room was furnished. As expected, that has affected positively the reverberation time measurement uncertainty, that has decreased if compared with the previous edition results. This is reflected on the method repeatability and reproducibility showed in the comparison between editions in section 4. The conclusions are summarized below:

- the airborne sound insulation ($D_{nT,w}$) repeatability, reproducibility and uncertainty values of edition 2020 are much lower compared to the last editions, except for reproducibility and uncertainty in higher frequencies. This increase in high frequencies might have happened because this region was close to the gypsum board partition critical frequency, which might have generated a more unstable acoustic field.
- in the impact sound insulation ($L'_{nT,w}$) reproducibility it is noticed a huge improvement in the results of the 2020 edition compared to the past editions. This is a very good result considering the number of 25 participants. Also considering the 2020 L'nT,w uncertainty curve, it is the only one that practically meets the ISO 12999-1 reference values. Further analysis must be done to identify the reason that the same improvement effect has not occurred in the repeatability results.
- the façade sound insulation ($D_{2m,nT,w}$) uncertainty, repeatability and reproducibility presented better results in the 2020 edition than 2017 edition, especially in lower frequencies. This outcome might be due to the better outdoor noise conditions. The building had less influence from a heavy road traffic noise in the 2020 edition. Therefore the measurements were probably less influenced by lower frequency components, where the common measurement sound sources (omnidirectional loudspeaker) do not reproduce well.

7. ACKNOWLEDGEMENTS

We would like to thank the company OWA Sonex, for lending the building for the Interlaboratory Program for the last edition, 2020.

8. REFERENCES

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4. ISO 5725-1:1994 Accuracy (trueness and precision) of measurement methods and results - - Part 1: General principles and definitions.
5. ISO 5725-2:1994 Accuracy (trueness and precision) of measurement methods and results - - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.
6. ISO 12999-1:2014 Acoustics - Determination and application of measurement uncertainties in building acoustics - Part 1: Sound insulation