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LABORATORY MEASUREMENTS OF SOUND REDUCTION INDEX - CONFIDENCE OF TEST RESULTS

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INTRODUCTION

The quality or performance of a product is often assessed or documented by means of tests carried out according to test methods, which are standardized.

Test results have different applications:

- Documentation for performance – in general or for a specific purpose
- Comparison with test results for other products
- Classification

Unfortunately, it is a fact, that tests performed on presumably "identical products" do not, in general, yield identical results. Regarding the above mentioned applications it is obvious that when a product is tested twice by the same laboratory (or organization) or by different laboratories, the difference between the results should be within certain limits. So, some specifications are necessary concerning the test facility, and the precision of the test procedure. To a certain degree differences between test results must be accepted, because it is impossible to specify completely all factors that influence a test result.

The concepts repeatability (r) and reproducibility (R) are used as confidence measures for test results, within a laboratory and between different laboratories, respectively. Both give a value, below which the absolute difference between two single test results may be expected to lie with a specified probability. Normally a confidence level corresponding to 95% probability is used. Determination of repeatability and reproducibility is described in ISO 5725 [1], which is not related to a specific test property or a specific type of products, but is intended to be applied to standardized test methods in general.

The present paper deals with some Nordic Round Robin experiments comprising measurements of sound reduction index for the same type of building component in five laboratories. The aim of the experiments was to provide repeatability and reproducibility values for sound reduction index measurements carried out according to the test method outlined in ISO 140 [2]. The present version of the standard includes requirements to the repeatability values, but reproducibility requirements have been postponed due to the lack of experimental data.

ROUND ROBIN EXPERIMENTS

The experiments were carried out within two Nordtest-projects NT 235–80 and NT 360–82. The test series are described in detail in the project reports [3] and [4].

The main aim of the project NT 235-80 was to achieve repeatability and reproducibility data for measurements of sound reduction index. The measurement programme was set up, so it was possible to estimate some sources of errors and their relative contributions to the total variance of a measurement result. For economical reasons the number of test objects had to be limited to one even if more than one type of test specimen and one level of the test property were desirable, since the repeatability and reproducibility can be expected to depend on both factors. A glazing was chosen as test specimen because the largest discrepancies in measurement results were found for windows. The test specimen for the project NT 235-80 was a glazing mounted in a flat test opening, and 4 test series were planned within this project.

Before the accomplishment of the experiments, a proposal for a supplementary test series was brought about. Due to an international discussion on the shape of test openings for windows, it was decided to carry out - within a new project NT 360-82 - measurements for the same type of glazing mounted in a simulated staggered test opening. The aim was to find out, whether the reproducibility is considerably influenced by the type of test opening.

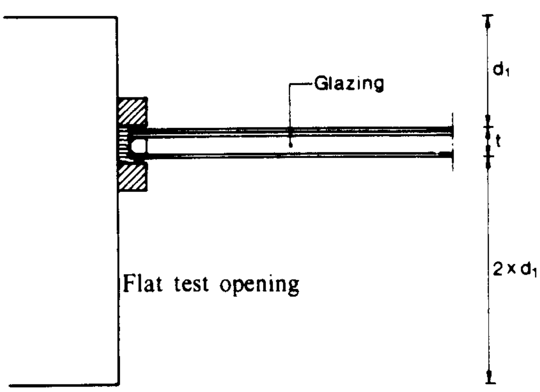

Fig. 1. Mounting of glazing in a flat test opening 1,21 m × 1,21 m

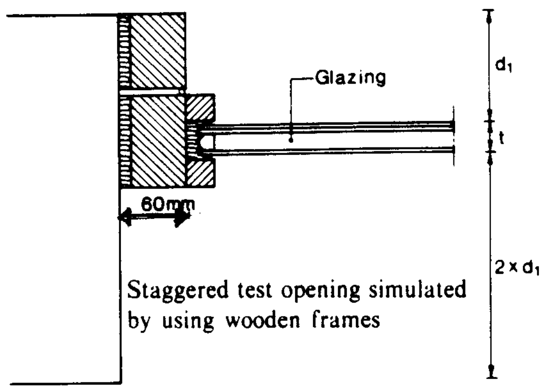

Fig. 2. Mounting of glazing in a staggered test opening, 1,09 m × 1,09 m

The total measurement programme for the projects included 5 series of measurements. Series 1-4 belong to NT 235-80 (glazing in a flat test opening), and series 5 belongs to NT 360-82 (glazing in a staggered test opening):

Measurement series	Number of measurements in each laboratory
Series 1: Influence of stochastic noise signal	5
Series 2: Remounting of glazing	1
Series 3: Repeatability/reproducibility	6
Series 4: Reproducibility within laboratories (long-time variations within a laboratory simulated by changing test procedure and/or conditions)	5
Series 5: Repeatability/reproducibility for measurements of a glazing in a staggered test opening	6

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STATISTICAL ANALYSIS

The statistical analysis is carried out according to the guidelines in ISO 5725 [1]. A single test result obtained with a standardized test method is described as a sum of three components: $y = m + B + e$, where y is a single test result for the tested material, m is the average of several test results for the material tested in many laboratories, B is a term representing the deviation for the actual laboratory from m, and e represents a random error occurring in every test.

When the repeatability r or the reproducibility R is used to check whether a difference between two measurement results is significant, a bias of m will have no influence and can be ignored, and the calculations of r and R are based on the variances of B and e. For further analysis of sources of errors (test series 1-4) the terms B and e are subdivided into some individual components:

$B = B_o + B_s + P$ and $e = u + d + k$, see Fig. 3. A more detailed description of the statistical analysis is found in [3].

TEST RESULTS

The significance of the various error components is illustrated in Fig. 3. It is seen that the important factors are the laboratory components B_o and B_s.

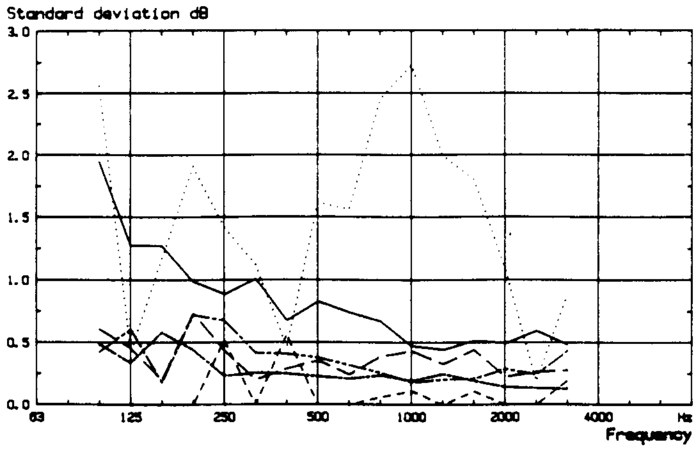


Fig. 3. Standard deviations for the various error components calculated from test series 1 – 4 (NT 235–80)

———— THE TERM B_0 (LONG-TIME VARIATIONS WITHIN A SINGLE LABORATORY)
············ THE TERM B_s (PERMANENT, SYSTEMATIC DIFFERENCES BETWEEN LABORATORIES)
– – – – – – THE TERM P (DIFFERENCE BETWEEN SAMPLES)
———— THE TERM u (STOCHASTIC NOISE SIGNAL)
–·–·–·– THE TERM d (RANDOM ERROR EXCEPT U RELATED TO THE NORMAL TEST PROCEDURE)
— — — THE TERM k (MOUNTING OF TEST SPECIMEN)

In short, the repeatability depends on the terms u, d and k and the reproducibility depends on all the terms shown in Fig. 3. Consequently, the repeatability values are, as expected, small compared to the reproducibility values. The repeatability values fulfill the requirements in both the present and proposed ISO 140/2. The term B_S has a very pronounced peak around 1000 Hz, which implies poor reproducibility values, and the proposed reference values for ISO 140/2 are exceeded considerably in this frequency range. This is illustrated in Fig. 4, which also shows the reproducibility for a glazing in a simulated staggered test opening.

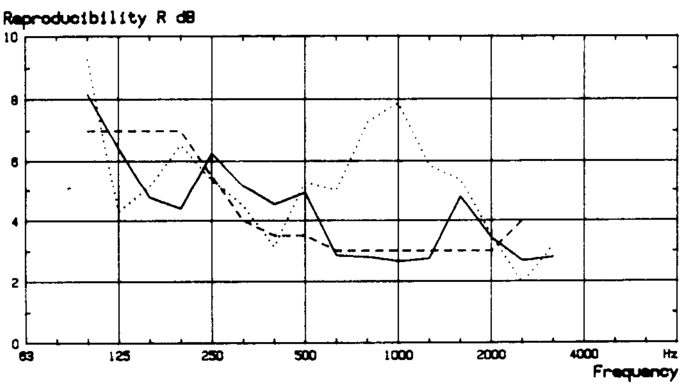
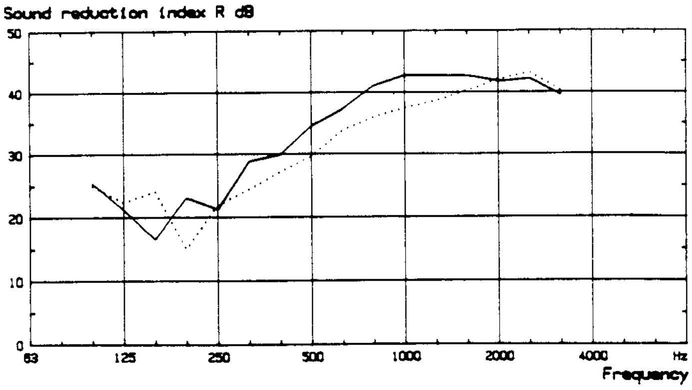


Fig. 4. Reproducibility values for measurements of sound reduction index for a glazing mounted in two different types of test openings (see Figs. 1 – 2). The stretched curve indicates proposed values for a revised ISO 140/2

———— CALCULATED REPRODUCIBILITY NORDTEST 360–82 : STAGGERED TEST OPENING
············ CALCULATED REPRODUCIBILITY NORDTEST 235–80 : FLAT TEST OPENING
– – – – – – PROPOSED REFERENCE CURVE ISO/TC 43/SC 2/WG 8 N34

In the frequency range 630–1250 Hz the reproducibility values are considerably better with the test specimen mounted in a staggered test opening. Possibly, the main reason is not the shape of the test openings, but the improved uniformity due to identical materials in the test openings. However, the test values of reproducibility do still not strictly fulfill the proposed reference values at all frequencies, even if the character of the two curves are rather similar.

Besides different reproducibility values for the two types of test openings, it is found that the measured sound reduction index is systematically influenced by the type of test opening. This might be caused by different lateral modes in the airspace within the glazing. The measurement results (mean of five laboratories) are shown in Fig. 5. The best sound insulation is obtained with the staggered test opening. It should be noted that both the systematic difference and the reproducibility are frequency-dependent and are further expected to depend on the type of test specimen. It is obvious that a systematic difference added to other reproducibility variations complicates a comparison between measurement results from different laboratories.



——— STAGGERED TEST OPENING
············ FLAT TEST OPENING

Fig. 5. Measured sound reduction index for a glazing mounted in two different types of openings. Mean values of five laboratories

CONCLUSIONS

The variances for the various components contributing to the total variance of sound reduction index measurements have been estimated. The results show that variances due to other factors than differences between laboratories are relatively small.

As indicated in ISO 5725 [1], pronounced differences between test results reported by different laboratories may indicate that the standard is not yet sufficiently detailed and can possibly be improved. As regards the specific problems of glazings this is also realized internationally, and an ISO working group is revising ISO 140/3, (test method). Another working group is revising ISO 140/2 (precision). However, the problem of glazings is somewhat complicated, as the choice of a standardized method should be based on considerations taking into account both the systematic influence due to the type of test opening, the practical aspects concerning mounting and the applications of the test results.

The inter-laboratory test described deals specifically with precision problems related to laboratory measurements of sound reduction index according to the test method ISO 140 [2]. However, problems are likely to exist for several test methods. The results illustrate that the precision of test results to a high degree are related to the experimental details specified in a test method.

REFERENCES

[1] ISO 5725 – 1981 (E): "*Precision of test methods – Determination of repeatability and reproducibility by inter-laboratory tests*".

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[3] SØREN DAMGAARD KRISTENSEN & BIRGIT RASMUSSEN: "*Repeatability and Reproducibility of Sound Insulation Measurements*". (Nordtest-project NT 235-80). Danish Acoustical Institute. Report No. 118, 1984.

[4] BIRGIT RASMUSSEN: "*Measurement of Sound Reduction Index for Glazings in a Staggered Test Opening*", (Nordtest-project NT 360–82). Danish Acoustical Institute. Report No. 119, 1984.