Problems of measurement and evaluation of low-frequency noise in residential buildings in the light of recommendations and the new European standards

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The paper covers the methods of measurement of noise from building equipment included in the drafts of the new European standards: pr EN ISO 10052 – survey method and pr EN ISO 16032 – engineering method. The results of acoustic surveys performed in several apartments are the basis for discussing the problems of measurement and evaluation of low frequency noise, in the light of the binding and the proposed measuring methods. The proposed assessment method for the noise spectrum is given.

1. Introduction

According to the recommendations of the WHO [1] concerning community noise, noise at levels up to 30 dB (A) should be regarded acceptable even in bedrooms during night hours. However, the practice shows that noise at levels below 25 dB (A) can be stress level, and the acceptable noise levels applied in many European countries, equal to 25 dB (A) – at night and 35 dB (A) – during daytime do not guarantee comfortable acoustic conditions. Noise measurements and evaluation which use the single-number indicator; A-weighted sound level – are also not adequate, especially in the case of low frequency noise, at low levels, which slightly exceeds background noise levels. It has, therefore, been expected that the new ISO and EN standards concerning the measurement of noise within buildings, shall also recommend measuring low-frequency noise. In the further part of the elaboration, there is a discussion on the methods of the noise measurement methods proposed in the drafts of 2 new European standards – with regard to low-frequency noise.

2. Recommendations for and the procedure of performing noise measurement according to the drafts of the new European standards

Currently, the workgroup CEN/TC 126/WG 1, linked to the Technical Committee ISO/TC 43/SC 2 "Building Acoustics", is in the final stage of preparation of two new European standards concerning the methods of measuring noise from service equipment in buildings:

1. pr EN ISO 10052 – survey method [2]
2. pr EN ISO 16032 – engineering method [3].

The **survey method,** according to pr EN ISO 10052, consists in measuring the sound level for two microphone positions within the compartment – including one corner position – for 3 operating cycles of the equipment. The measurements are carried out with the use of a sound level meter, and the measurement result is the average A- or C-weighted sound level from 3 readouts (equivalent and/or maximum) – standardized or normalized, without correction for background noise. If the difference between the noise level of the equipment and the background noise level is lower than 6 dB, it should be noted in the report, adding that this accounts for inaccuracy of the result. Measurements using the survey method should be carried out for control purposes and in order to qualify the building for the appropriate acoustic class.

In special instances, when we want to more precisely determine the noise level of the equipment, we should use the engineering method in accordance with pr EN ISO 16032.

The basic measurement parameter in the engineering method is the sound pressure level (SPL), specified in octave bands within the range 31.5 Hz to 8000 Hz, which can be measured as:

– maximum L_{Smax}, (slow) or L_{Fmax} (fast)
– equivalent - (L_{eq}).

The measurements should be carried out with the use of real time analyzer, with an octave filter, which allows for the measurement and storage of sound pressure levels from a longer time interval, equivalent to the operational cycles of the equipment whose noise will be measured, by analogue methods in the survey method.

The draft of the standard specifies the conditions and cycles of work for which the equivalent and/or maximum SPL of typical equipment installed in the building should be specified. For instance, the cycle for the elevator contains the elevator's start from the level closest to the machine room, its course stopping on every floor and opening and closing of door, then returning to the starting point, opening and closing its door. For constant noises, such as that made by a ventilator, the time during which the maximum and/or equivalent sound pressure level is specified is approx. 30 seconds.

According to the measuring procedure recommended in pr EN ISO 16032, one should:

1. Determine 3 microphone positions (one in the corner and two in the reverberant field) and determine the number of measurements in the selected positions. Using the sound level meter, find the corner of the room in which for the entire operational cycle of the equipment there is the highest level L_C (max and/or eq), then determine level differences L_A (max and/or eq) in that corner for two consecutive cycles. this requires a minimum of 6 operational cycles.
2. Measure the SPL in the selected positions in octave bands during the operation of the noise source under investigation and calculate the average energy level from all the data at the measuring points - L_{eq} and/or L_{Fmax} or L_{Smax}).
3. At the same positions, measure the SPL of the background noise in octave bands (equivalent to approx. 30 s) and calculate the average levels.
4. Possibly measure reverberation time in octave bands.
5. Calculate the SPL in octave bands corrected by adjustment for background noise and, possibly, the compartment's absorption properties (normalized or standardized).
6. Determine the A-weighted sound level calculated from the octave-band levels in the frequency range 63 Hz–8000 Hz, from the corrected sound pressure levels.
7. Determine the C-weighted sound level calculated for the range 31.5 Hz–8000 Hz, from the corrected sound pressure levels.

If the noise contains an audible tonal component, it should be noted in the report.

On the basis of the recommendations of this standard, testing measurements were performed in residential buildings. On the basis of the measurement results obtained, attempts were made to determining whether the engineering method recommended in pr EN ISO 16032 is actually more accurate and whether it allows for determining low-frequency noise as well. The results of these measurements are discussed below.

3. Problems of low frequency noise measurement

Polish Local Health Authorities (SAN-EPID) advise of the growing number of complaints about noise whose levels do not exceed the allowed A-weighted sound levels. In such cases, even though evidence of noise has been found, there is no legal basis for ordering the elimination of noise and the complaint is found to be unsubstantiated.

In Table 1 below we present a statement of the information gathered on complaints about noise made to the SAN-EPID which were found to be unsubstantiated in the light of the relevant laws.

Many of these complaints were transferred to the Acoustics Department of the Building Research Institute with a request for noise spectrum measurements and for determining whether the reason for the significance of that noise was not infrasound components.

In several buildings, noise was measured and evaluated by the following methods:

a) measurement using the method recommended in the Building Research Institute Instructions no. 358/98 (measurements in 1/3-octave bands of the range of 8–8000 Hz and spectrum evaluation with the use of A10 characteristics) [4],

b) measurement with the use of the engineering method in accordance with pr EN ISO 16032 - measurements in octave bands for the frequency of 31.5–8000 Hz and spectrum evaluation with the use of A15 characteristics (the equivalent of A10 characteristics for octave bands),

c) measurement with the survey method in accordance with pr EN ISO 16032.

The measurements carried out have confirmed the existence of noise in nearly all cases of residential complaints, also the unsubstantiated ones. Comparing the equipment noise spectrum, background noise spectrum and A10 and A15 characteristics, limiting non-significant levels, we can point out the components which are decisive for the significance of the noise. Often, despite subjective impressions, these are not infrasound components nor even low-frequency components. It has been observed that the noise within the audible range but at very low level, close to the detection level threshold, does not produce an impression of a high tone and is perceived as infrasound noise.

The occurrence of infrasound components of significant levels (i.e. above the threshold detection levels and above A10 or A15 characteristics) in the noise spectrum was not found in any of the examined compartments.

Selected measurement results are presented below.

4. Results of test measurements according to the old and the new methods

The measurements were performed using a mobile frequency analyser SVAN 912 or B&K 2231. For the recommended operating cycles A- and C-weighted sound levels – for equipment noise and background noise, were registered in selected measurement points (by means of the "plot" function). In order to assign the maximum and equivalent SPL in octave bands the whole spectrum was

Table 1 Statement of noise sources which were the reasons for complaints founds unsubstantiated by the local SAN-EPIDs

No.	Noise source – reason for complaints	Total number of complaints	Unsubstantiated complaints
1	Pumps and heating equipment	246	39 (16%)
2	Industrial and servicing plants	101	34 (34%)
3	Fans and air conditioners	87	24 (28%)
4	Refrigerators and cooling equipment	84	5 (6%)
5	Production in adjacent apartment	15	10 (67%)
6	Transformer stations	15	7 (47%)

recorded for a whole operating cycle.

Analysis of measurement results permits to state, what follows:

1. At low levels of noise (20–30 dB(A)), which mostly occur in habitable rooms, the measurement results are affected by instruments own noise, and in particular, accidental levels registered at the moment the instrument is switched on (Figure 1). It is necessary to average levels from a section of time in order to define a level accurately. When such an averaged level is obtained much lower levels are recorded which determine the final estimate of the noise level (see Figure 2).

2. For continuous noises at steady levels it was possible to register spectrums for some work sections of 30 seconds each. In the case of transient noise it was never possible to perform measurements for more than 3 operating cycles. It was too time-consuming and arduous both for the inhabitants of the building, in which noise was measured and for the measuring team. For measurements of noise of levels up to 30 dB(A), it is in practice very difficult to make longer term measurements without accidental acoustic disturbances. The operating cycles are in many cases comparatively long e.g., driving with a lift up and down with stops and opening the door on every floor, or filling a bathtub to half of its capacity.

3. Comparing the results of measurements of noise level, executed simultaneously for the same equipment according to pr EN ISO 10052 and according to pr EN ISO 16032 one can notice, that in most cases, A-weighted sound levels defined according to pr EN ISO 16032 are lower than those defined according to pr EN ISO 10052. The differences may result both from the influence of acoustic background, and from the different approach to A-weighting i.e., frequency weighting of the whole band of acoustic frequency, as it is carried out in the case of direct measurement, or only for the middle frequencies of the octave bands, as it takes place in the methodology proposed in pr

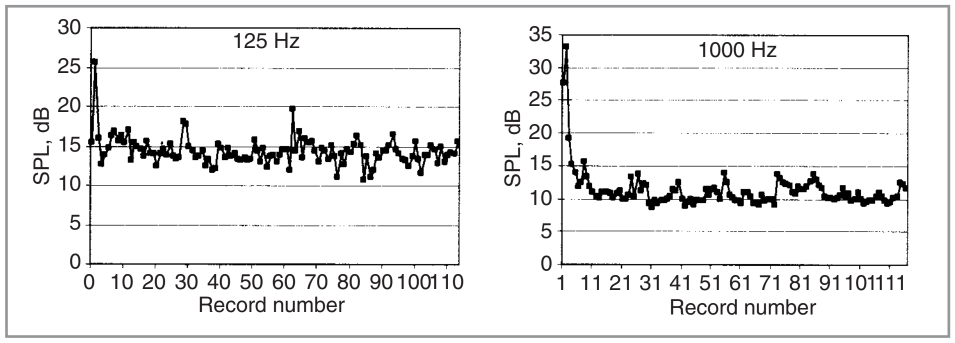

Figure 1 Octave-band SPL is registered during measurements of background noise in a room

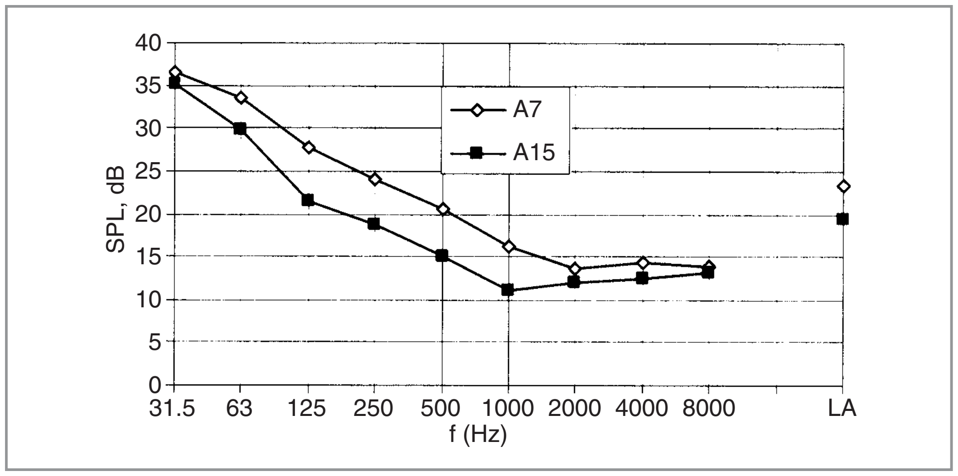

Figure 2 *Equivalent sound pressure levels for background noise in a room, averaged for the whole section of observation time (A7) and for restricted section (A15).*

EN ISO 16032.

4. Having analysed measurement results obtained by the engineering method for more than ten sources a statement has been made that in all cases it should be recorded in report, that the result is influenced by background noise. Even in cases, when difference between noise and background amounted to 10 dB A, for spectrum of the noise shower frequencies at which the difference between SPL of noise and background was smaller than 4 dB (Figure 3).

5. The use of energy and spectral average is controversial in the case of environmental and background noise. If measurements are made in order to estimate exposure to noise, a spectrum of noise from the measurement point with the highest levels should be taken, and not the average over the room.

It is unclear which component can be acknowledged as tonal.

5. Assessment of measurement methods proposed in new EN standards

Verification measurements of noise penetrating into rooms from equipment installed in buildings showed, that measurements according to the engineering method were not exact and they did not ensure a more reliable estimate of noise than measurements

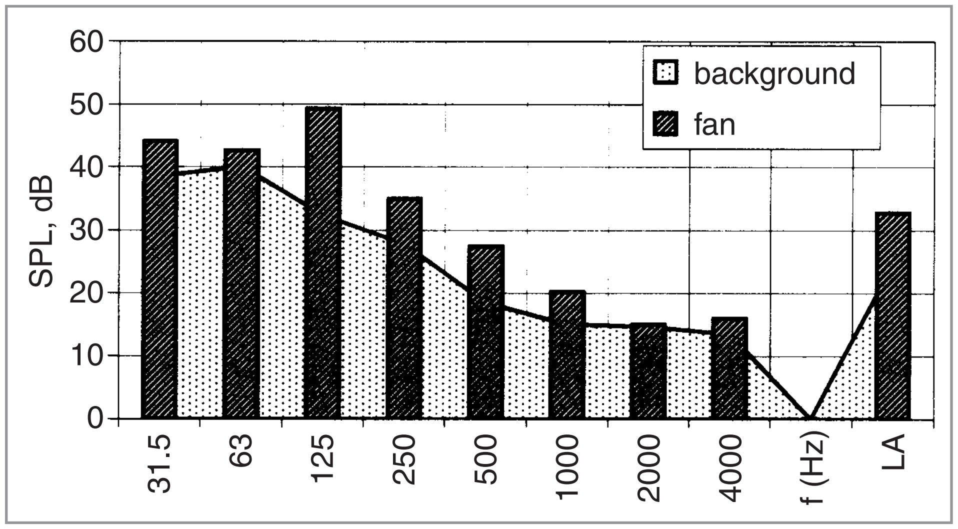

Figure 3 *Noise spectrum of fan and background in dwelling.*

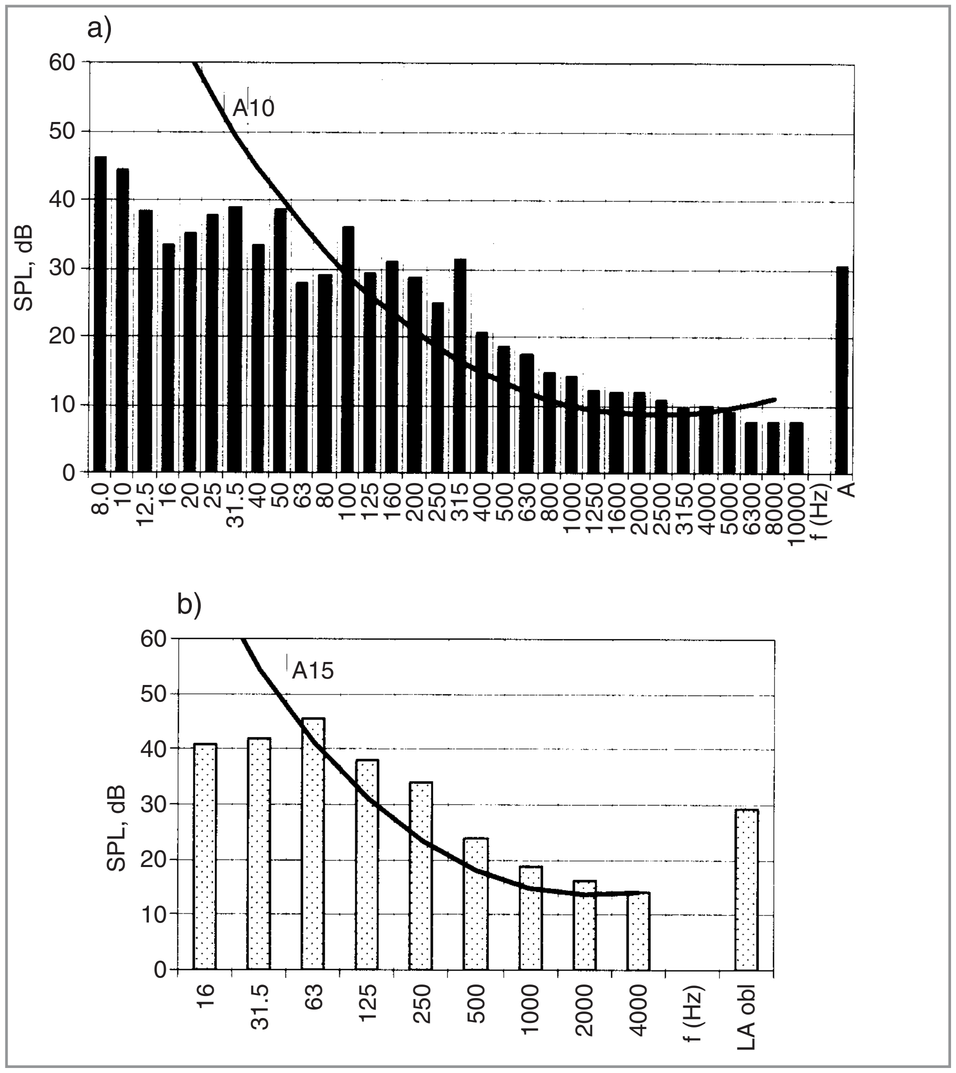

Figure 4 *Assessment of noise spectrum of ventilation equipment measured in livingroom of apartment situated over the Telepizza: a) for 1/3 octave bands, b) for octave bands.*

according to EN ISO 10052. Instead, they are more difficult, more labour-consuming and they require the use of analysers in real time of low levels of their own noise with a large "buffer" of memory. It would not be difficult, if with the use of the same analysers, measurements were carried out in one third octave bands over a wide range of frequencies, including the range of low frequency noise from 8 Hz, and the results would surely be more exact.

For control purposes it could be considered sufficient to make a measurement of the noise spectrum from one of the loudest positions, a situation occupied by the residents or users and to obtained background spectrum without accidental noises. For comparison with noise limits A- and C-weighted levels over the full frequency range (e.g., 8–10000 Hz) could be used and eventually normalized or standardized.

In controversial cases an evaluation of noise could be made by comparison of the measured spectrum of noise and the spectrum of background (without any correction). Our experiments prove that if in spectrum of noise components appear with SPL is 5 dB larger than the level of background - then a noise can be audible and annoying.

To estimate the noise spectrum the characteristic $L_{A10} = 10 - k_A$ can also be used – for spectrum in 1/3 octave bands, or L_{A15} = 15 – k_A – for octave bands (see Figure 4) - corresponding with the level LA = 25 dB, thus corresponding with relatively comfortable acoustic conditions [5].

6. Conclusions

1. In consequence of the introduction of the new European standards as the binding standards concerning the measurement of noise from equipment installed in buildings, low-frequency noise shall not be taken into account in the evaluation of acoustic conditions and in the acoustic classification of buildings.
2. It would be reasonable to suggest to the workgroup CEN/TC126/ WGl that it should make changes in the draft of the EN ISO 16032 standard that would include the measurement of the noise spectrum within the low frequency range, or to work on a new standard concerning low frequency noise measurements.

References

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noise notes

Highway speed limits

The speed limit on Interstate 70 through Vail is 65 mph. Vail police are patrolling the highway, searching out speeders. The enforcement effort – which will begin with warnings for all but egregious offenders – is part of a plan to attempt to muffle the highway's noise through town. In addition to speed enforcement, town officials will look at other ways to dull the near-constant roar of traffic. The town recently authorized a $90,000 consulting contract with Hankard Environmental of Fort Collins to monitor noise levels on the interstate and develop a noise mitigation plan for the highway. Part of that plan may involve setting up a type of temporary noise wall along the interstate. That wall might consist of empty semi-trailers parked along either the interstate or the frontage roads. The trailers would be provided with the cooperation of the Colorado Motor Carriers Association, a trucking industry group now involved in ways to try to cut the noise. if brought to Vail, the trailers would be parked in various locations around town for a few weeks at a time. If noise walls are proven effective, the town will seek funding for more permanent structures. The combination of reduced speed and strategically placed noise walls could net a two- to three-decibel reduction in the thrum from the highway, Vail Town Councilman Greg Moffet said. Either measure alone might drop highway noise perhaps one dB, which would be barely noticeable, Moffet said. However, a two- or three-dB drop would be significant, given the way sound pressure is measured. Surveys of summer tourists indicate highway noise is becoming an increasing problem. And Vail residents near the highway – which is most of them – are becoming more and more frustrated. “It's becoming an issue about our economic viability,” Moffet said of the noise issue. “I-70 is a blessing and a curse. It makes us different than other resorts. We have to figure out how to live with it.”