6 Practical aspects of making sound measurements

6.1 General

The requirements set out in IEEE C57.12.90 are the minimum required to gain an acceptable determination of the sound power level of a test object. However, many years of practical experience have demonstrated that these basic requirements can be expanded upon, and improved if a more accurate result is required. This clause provides further practical advice on making sound pressure and sound intensity measurements.

6.2 Orientation of the test object

In a test room, the emitted acoustic pressure waves produce both direct and reflected sound waves. The reflected waves can constructively interfere with the emitted waves to produce standing waves. Under such conditions, sound pressure measurements made in the region of standing waves will give over-estimates of sound power. It is therefore advisable to orient the test object as illustrated in figure 8, clause 5.2.

6.3 Number of measurement points on a measuring surface

IEEE C57.12.90 and C57.12.91 states that the microphone positions shall be on the prescribed contour(s), approximately equally spaced and not more than 1 meter apart.
It also requires a minimum of six microphone positions for any test object. However, due to the location of the active part in the tank, the location of cooling elements and the overall design of the tank, the sound field can be inhomogeneous, in other words, one side of the tank may emit more sound than the others. Practical experience has therefore indicated that the basic requirement for the number of measurement points can be improved upon. For example, if ΔL is found to exceed 8 dB when using the sound intensity technique, the accuracy of the test may be improved by measuring at one-third and two-thirds of the test object height when, according to IEEE C57.12.90 or C57.12.91, only measurements at half the height are required. Further refinements are described below.

6.3.1 Power transformers

The basic constraint of having microphone positions with a spacing of not more than 1 meter apart results in an acceptable sound determination because power transformers are large, and consequently significantly more than six positions are required. Averaging of the sound levels measured at each point reduces the influence of local highs or lows in the sound field.

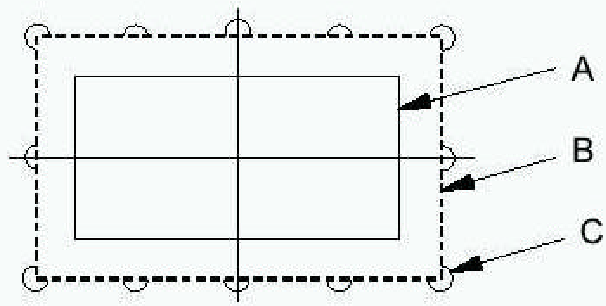
6.3.2 Distribution transformers

Although the minimum requirement of six measuring positions may be acceptable from the point of view of having the microphone positions not more than 1 meter apart, eight measuring positions per contour may be preferable. These should be distributed half way along each side of the tank and one at each corner.

For a more accurate measurement, twenty points equally spaced on the prescribed contour may be used. However, experiments have shown that the difference between a sound determination based on eight measurement points and one based on twenty measurement points is less than 1 dB(A).

6.3.3 Dry-type transformers

In most cases, due to the strong differences in the sound field radiating from the three coils, experience has shown that twelve points are required. These should be distributed with one at the middle of each coil, and one at each corner of the enclosure, see figure 10.



Legend
A indicates the transformer
B indicates the prescribed contour
C indicates the microphone positions

Figure 10 - Sketch of dry-type showing measurement points

For a more accurate measurement, twenty points equally spaced on the prescribed contour can be used. Experiments have shown that the difference between a determination based on twelve measurement points and a determination made with twenty measurement points is less than 1 dB(A).

6.4 Choice of microphone spacer for sound intensity measurements

When using the two-microphone technique, it is necessary to choose a spacer (see figure 7) that is appropriate for the frequencies being measured. The assumptions made in the theory of sound intensity measurements impose an upper frequency limit that can be measured accurately – the smaller the spacer, the higher the frequency that can be measured. Phase mismatch in the analysing system causes a low frequency limit – the larger the spacer, the lower the frequency that can be measured accurately.

Persons making sound intensity measurements should refer to the measurement equipment manufacturer's handbook in order to determine the appropriate spacer length for each test object. As a guide, a spacer of length 50 mm is typically used for low-frequency (approximately 63 to 1,250 Hz) sound from transformers, while a 12 mm spacer is required for higher-frequency (approximately 250 to 5,000 Hz) sound from cooling equipment.

6.5 Impact of background noise on sound intensity measurements.

As described before, the sound intensity method measures the propagating part of the sound field only and therefore its results do not require a correction for background noise. However, there are still limits regarding the level of background noise which is acceptable for a valid measurement, and these limits depend on the measurement equipment. As indicated by equation 5, the sound intensity at each point is computed from the average of the sound pressure measured at two closely spaced microphones and the difference between the two sound pressures at the same microphone pair.

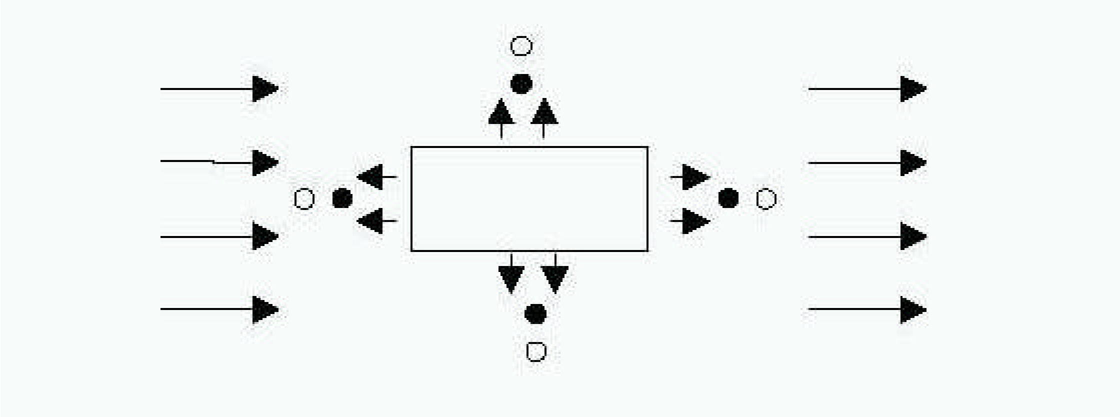


Figure 11 - Illustration of background sound passing through test area and sound radiated from the test object. Microphone pair positions indicated by open (microphone A) and full (microphone B) circles.

At each point, the sound intensity radiated from the test object is related to a small pressure difference between the two microphones.

At the measurement positions near the long sides of the test object in figure 11, the contribution of the background noise field to the measured pressures p_A and p_B should be equal. In high background noise levels, the measurement system has to detect a small difference between two large pressure signals. Usually the measurement error for each microphone is a certain percentage of the full range. If the background noise pressure is so high that the full range error is of the same order of magnitude as the pressure difference caused by the sound from the test object, the measurement of sound intensity at each point becomes uncertain. The local difference ΔL (= $L_p - L_I$) will indicate this type of problem. Therefore ΔL should be examined for each measurement point, as well as for the averages of the sound pressure and sound intensity values, in order to indicate the acceptability of the test environment. The same effect occurs with large contributions from reflected sound.

At the measurement positions near the short sides of the test object in figure 11, there will be a significant difference between p_A and p_B, the magnitude of which will primarily be determined by the background noise. For each measurement position on these sides, ΔL (the log of $(p_A + p_B)/2/(p_A - p_B)$) will give no warning of an invalid measurement. However the system can only detect the sound intensity at each position with limited precision, which again is given by a certain percentage of the full range. The sound power radiating from the short sides of the test object is determined from the small difference in intensities on the left and right sides of the test object. If this difference is in the range of the measurement error for the individual readings, the measurement becomes uncertain in spite of an acceptable value of ΔL locally. In this case, only ΔL determined from the measured sound pressure and sound intensity levels averaged over the entire measurement surface indicates that there is uncertainty.

The above discussion demonstrates that the validity of sound intensity measurements can only be judged on the basis of ΔL determined from the measured sound pressure and sound intensity levels averaged over the entire - closed - measurement surface.

The limit of ΔL = 8 dB stated in IEEE C57.12.90 is a consequence of the precision of the measurement equipment available at the time of the experimental work.

6.6 Measurements in the presence of sound-proofing screens

In cases where transformers are provided with a soundproofing screen that leaves the top of the transformer uncovered, the measurement distance should be at least 2 m. This is because at 0.3 m distance sound energy can not be assumed to radiate equally in all directions, and consequently the approximation $S = 1,25hl_m$ will no longer be valid.

The possibility of making measurements at a greater distance should be investigated.